Africa Research in Sustainable Intensification for the Next Generation in Ethiopian Highlands project

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 US 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. http://africa-rising.net/

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Acronyms

2-WT	Two-wheel tractor
ADF	Acid Detergent Fibre
ADL	Acid Detergent Lignin
Africa RISING	Africa Research in Sustainable Intensification for the Next Generation
ANOVA	Analysis of Variance
BoA	Bureau of Agriculture
CP	Crude Protein
CSA	Climate-smart agriculture
DAP	Di-ammonium Phosphate
DM	Dry matter
DST	Decision Support Tool
EthioSIS	Ethiopian Soil Information System
FDG	Focus group discussion
FTC	Farmers training centre
GIS	Geographic Information System
ha	hectare
hh	Household
ILSSI	Innovation Lab for Small-Scale Irrigation
ISFM	Integrated Soil Fertility Management
KCL	Potassium Chloride
KII	Key informant interview
LULC	Land Use Land Cover
ME	Metabolizable Energy
NDF	Neutral Detergent Fibre
NDVI	Normalized Difference Vegetation Index
NPS	Nitrogen, Phosphorus, Sulfur
NPSK	Nitrogen, Phosphorous, Sulfur and Potassium
NRM	Natural resource management
R4D	Research for development
R&W	Rope and Washer
RCBD	Randomized Complete Block Design
SI	Sustainable intensification
SLM	Sustainable land management
SLMP	Sustainable Land Management Program

SNNPR	Southern Nations, Nationalities, and People’s Region
SWC	soil and water conservation
t	ton
TIVOMD	True In vitro Organic Matter Digestibility
USAID	United States Agency for International Development
WP	Wettable Powder

Summary

This summary briefly highlights the 2021 main cropping season crop, livestock and natural resource management (NRM)-related research results conducted in the Ethiopian highlands.

Research for development (R4D) trials of the livestock feed and forage work focused more on Desho grass and vetch intercropping at different seed proportions, oat variety and cutting management trials, as well as tree lucerne management trials. Desho-vetch intercropping proved to be highly promising and resulted in more than 60% yield advantage, considerably improving forage quality and addressing soil fertility issues related to sole Desho grass establishments.

The crop research in the 2021 cropping main rainy season considered early community seed production, demonstration of different crop varieties and scaling of validated crop varieties. The average productivity of faba bean, bread wheat and malt barley varieties from the community seed production scheme were 2, 4 and 3 t/ha, respectively. The seeds from the different crop varieties will get to farmers through unions and farmer-to-farmer exchanges.

A crowdsourcing approach has been implemented to support the improved crop varieties seeds for needs program in Sinana, Lemo and Basona Africa RISING sites of the Ethiopian highlands. Durum wheat and faba bean were the crops considered for the study. Twenty durum wheat varieties were delivered to 200 farmers in Bale Zone and 13 faba bean varieties to 400 farmers in North Shewa and Hadiya zones. Each farmer received a combination of three randomly selected varieties and was advised to rank them based on their disease resistance, earliness, plant height, tillering capacity, spike quality, biomass and grain yield. Data for all are under analysis using different software programs.

A landscape position fertilizer and Integrated Soil Fertility Management (ISFM) validation trials conducted in Africa RISING and other areas. Six farmers engaged in landscape position-related fertilizer trials and nine farmers in ISFM validation trials. The landscape by fertilizer treatment interaction resulted in higher wheat grain yields of 4.8 and 4.3 t/ha from the application of NPSK (Nitrogen, Phosphorous, Sulfur and Potassium) at the foot slope position and NPS at the mid-slope position, respectively. Similarly, the highest grain (3.7 t/ha) and total biomass (7.3 t/ha) yields of wheat were recorded from the incorporation of green manure and the application of inorganic fertilizer. Wheat grain yield advantages due to the integrated application of green manure and inorganic fertilizer were 23% and 10%, respectively, compared to the combined application of compost and inorganic fertilizer and the recommended inorganic fertilizer yields.

Different mechanization technologies have also been introduced and tested on smallholder farms. The mechanization technologies were value chain focused, covering crop production, irrigation, harvesting,

post-harvest processing (threshing and shelling) as well as transportation services. Research findings from the current work show that households using mechanization services for ploughing and planting reduced their time spent on those activities by 19.45 hours for men and 21.43 hours for women. Similarly, wheat and teff yield obtained from the threshing service were higher than in the non-mechanized fields. For instance, the average wheat yield obtained from fields that used the threshing service was 2,847 kg/ha^{-1}, compared to 2,153 kg/ha^{-1}, a significant difference, and an increase of 32% (or a reduction in losses).

Research work has been carried out in Africa RISING sites and other locations to evaluate adoption and impacts of different climate-smart agriculture (CSA) practices in model watersheds. The preliminary findings show that the adoption rate of individual CSA practices widely varies among smallholder farmers. The most CSA practices adopted by smallholder farmers are soil and water conservation (SWC) practices (60.1%) followed by ISFM (56.6%) and agroforestry (44.2%). It was also found that a significant yield increase of four major crops (maize, wheat, teff, and finger millet) occurred because of implementation of integrated land and water management interventions. The increase in yield varied from crop to crop, the highest being for maize (120%) while the lowest was for wheat (9%). An increase in the overall and average carbon stored in Mg per pixel for all watersheds that had CSA interventions was also found.

The Africa RISING project in the Ethiopian highlands managed to conduct different capacity development programs including training, field visits, field days, workshops and meetings. In this regard, the program engaged with over 3,063 beneficiaries during the current reporting period. The project has also benefited 14 MSc and PhD (new and continuing) students through its research attachment schemes.

Introduction

The Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research for development projects supported by the United States Agency for International Development (USAID) as part of the US government's Feed the Future initiative.

In its second phase, the Africa RISING project in the Ethiopian highlands is seeking to elaborate the generic research questions presented in the program umbrella document for issues identified largely during phase I (2011–2016). The research questions addressed by our five (see below) specific activities will contribute insights from specific sustainable intensification-related activities and geographic areas within the country.

Trade-offs and synergies

Umbrella research question: What are the environmental, economic, human and social impacts of productivity-enhancing interventions?

Adaptation and adoptability

Umbrella research question: How are these interventions aiming at increasing productivity and improving environmental conditions to benefit diverse farmer typologies in the target areas?

Livelihoods

Umbrella research question: How do changes in the management of specific activities or a combination of activities within a farm (e.g. a field or a livestock unit) affect overall livelihood conditions for different farmer typologies?

Enabling environments

Umbrella research question: How do enabling conditions affect the nature (variety, agro-inputs, complexity and diversity) of promising interventions moving towards sustainable intensification (SI)?

Equity

Umbrella research question: How does social capital affect community productivity, cooperation and well-being along with the scaling up of SI innovations?

Africa RISING in Ethiopia Highlands project is led by scientists from the International Livestock Research Institute (ILRI) in partnership with scientists from other CGIAR centres, the Ethiopian national agricultural research system and local communities.

In its second phase (2016–2021), the project has been targeting 0.7 million households with sustainable intensification (SI) technologies. So far, after five cropping seasons, the project has managed to reach and benefit more than 412,026 households (hhs) with its validated technologies and 35,000 beneficiaries through capacity building initiatives. The geographical and administrative coverage of the project has also increased from four to more than 36 woredas and from four to 11 zones. In the remaining one year of the project, we will seek to generate wider evidence for the benefits of the novel R4D techniques adopted in the project, synthesize the lessons learned and deliver the tools required to support wider employment of these approaches.

Highlights from the current reporting period

Feed and forage innovations

Introduction

During the reporting period, on-farm experiments and capacity building activities have been implemented with the aim of generating multi-year evidence on selected forage technologies that need additional data and continue to support national partners in promoting suitable animal feed technologies. The R4D work included Desho grass and vetch intercropping at different seed proportions, oat variety and cutting management trials, as well as tree lucerne management trials. The support to development partners has mainly focused on strengthening the local forage seed system and ensuring continuity of technology sharing and transfer. Thus, summaries of research results and capacity building activities are included in this report.

Brief methodology

The research methods followed for the R4D trials were the same as the previous year. Briefly the Desho grass vetch intercropping trials were implemented at three seed rates for the vetch forage: 12 kg/ha; 9 kg/ha; and 6 kg/ha. The Desho grass was established using root splits and the vetch was planted between rows of the Desho grass according to the seed rate. Sole Desho grass and vetch forage plots were included as well, to compare the yield advantages of the intercropping practice.

The effect of different cutting management on the yield and quality of forage oat and food oat varieties was investigated. The oat varieties were harvested at the vegetative and maturity stages to explore if this practice can result in a yield and quality advantage over one-time cutting at maturity. For the forage oat one-time cutting at hay stage was compared with two-time cutting at vegetative and maturity stages. The tree lucerne cutting management trial plots had been established in the 2021 planting season to generate additional evidence on the optimal cutting height and frequency under field conditions.

Key results/findings

Desho grass and vetch intercropping

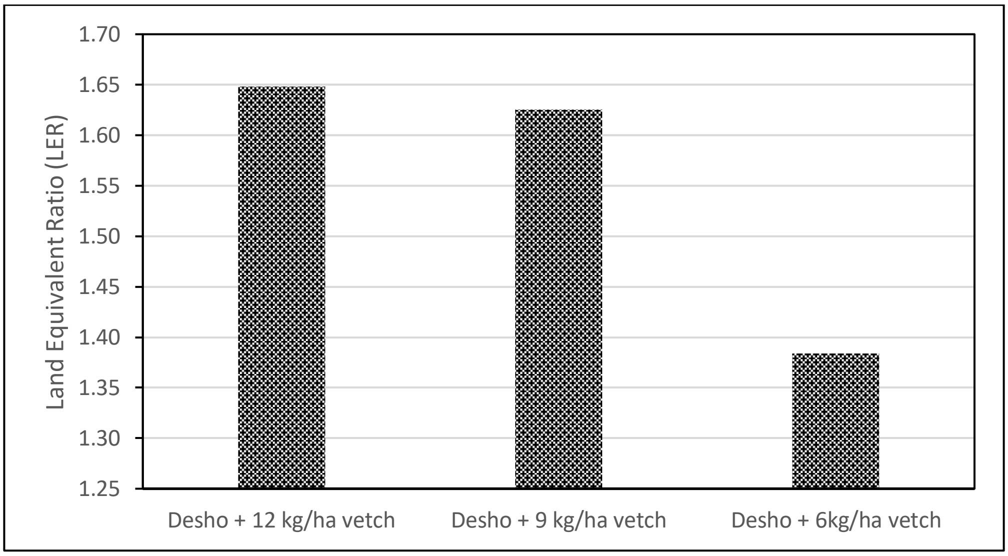
The yield advantages of intercropping Desho grass with vetch is indicated in Table 1. The results of this trial revealed a considerable yield advantage of the intercropping option over the sole production practice. Desho grass grown with vetch at 12 kg/ha and 9 kg/ha vetch seed rate clearly showed a better yield advantage over the sole cropping (32 vs 27 ton dry matter [DM]/ha, respectively). The increase in yield performance of Desho grass when grown with vetch suggests the biological compatibility of the two forages for intercropping and the benefit that can be obtained from nitrogen fixation by the vetch. The result confirms the initial hypothesis that the nutrient mining problem on Desho grass plots and the declining biomass productivity could be addressed through intercropping with legumes. When the vetch seed rate was 6kg/ha, there was low yield advantage, suggesting a higher seed rate (9-12kg/ha) is required to benefit from the practice.

Table 1. The effect of Desho grass vetch intercropping on yield performance of the forage mixtures

Treatment	Desho DM (t/ha)	Vetch DM (t/ha)	Total DM (t/ha)
Desho + 12 kg/ha vetch	31.6	1.98	33.6
Desho + 9 kg/ha vetch	32.4	1.77	32.4
Desho + 6kg/ha vetch	27.1	1.58	28.7
Sole desho	27.3	-	27.3
Sole vetch	-	4.04	4.0

The land equivalent ration calculated based on the biomass yield from the different seed rates is shown in Figure 1. The results indicate that the yield advantage of the intercropping option ranges from 38 to 65%, the highest being Desho + 12kg/ha vetch.

Figure 1. Land equivalent ratio calculated for desho-vetch forage biomass grown with different seeding rate for vetch.



The chemical composition of Desho grass and vetch grown either intercropped or solely is presented in Table 2. The chemical composition of both forages appears to be unaffected by the seed rate applied for the intercropping. Sole Desho and sole vetch forages showed slightly better quality than the intercropped counterparts. However, these differences are minimal compared to the yield advantage observed for the intercropping practice. The crude protein contents of both Desho (14%) and vetch (29%) on dry matter basis were higher. True in vitro organic matter digestibility of 59% for Desho and 71% for vetch provides a very good combination of quality to use as a supplemental feed for ruminant livestock. Generally, these results suggest that in terms of both yield and quality, the Desho-vetch mixture is a good technology to promote in the smallholder system.

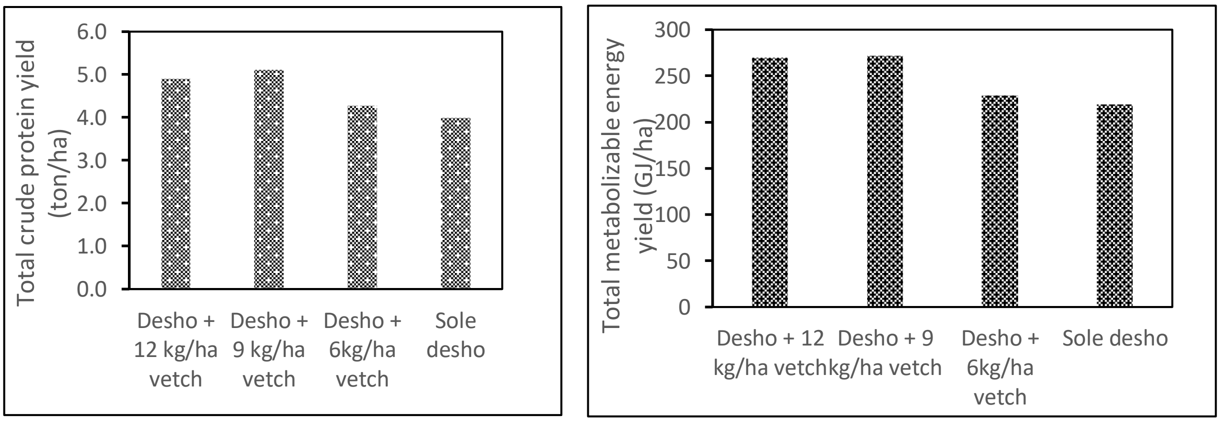
Table 2. Chemical composition and energy content of Desho and vetch forages grown differently

Forage	Vetch seed rate	CP (%)	NDF (%)	ADF (%)	ADL (%)	TIVOMD (%)	ME(MJ/Kg)
Desho	12 kg/ha	13.7	62.0	37.0	3.20	59.0	7.95
	9 kg/ha	14.2	62.0	37.0	3.20	58.5	7.87
	6 kg/ha	14.1	62.0	37.0	3.10	58.7	7.92
	Sole Desho	14.6	61.5	36.6	3.10	59.3	8.01
Vetch	12 kg/ha	29.2	35.6	29.5	5.02	71.4	9.59
	9 kg/ha	29.0	35.5	29.7	4.99	70.1	9.50
	6 kg/ha	29.0	35.8	29.6	5.00	70.1	9.48
	Sole Vetch	31.4	33.3	27.3	4.40	73.0	9.76

Note: CP- Crude Protein, NDF- Neutral Detergent Fibre, ADF- Acid Detergent Fibre, ADL- Acid Detergent Lignin, TIVOMD- True In vitro Organic Matter Digestibility, ME- Metabolizable Energy

The nutrient yield in terms of crude protein (CP) and metabolizable energy (ME) was calculated by multiplying biomass yield by the respective forage nutrient concentration. Such a procedure is important to consider the trade-offs between biomass yield and nutritional quality of forages, which is frequently observed in forage production practices. As shown in Figure 2, the total CP and ME yields of Desho-vetch intercropping were much higher at 12kg and 9 kg/ha than the 6 kg/ha and sole Desho cropping, following the same trend as the biomass yield. This is because the difference in DM yield is significant while that of the chemical composition is minimal with little influence on the trend of nutrient yield.

Figure 2. Total crude protein and metabolizable energy yield from Desho and vetch mixture forage and sole Desho grass plots.



Oat variety cutting management trial

When the food oat and forage oat varieties were subjected to different cutting management practices (vegetative, hay and maturity stages), the yield performance varied considerably. Forage, straw and gain yield components and the combined monetary values are shown in Table 3. Forage oat appeared to give the maximum yield when harvested once at hay stage (milky stage). Twice cutting of forage oat at the vegetative and either the hay or maturity stages gave lower yield performance than one-time cutting at the hay stage. Similarly, the straw and grain yields of food oats were better when harvested once at maturity than twice at vegetative and maturity stages. Generally, prices of forage and grain vary

depending on location and time of the year. Taking average values, one time cutting at hay stage and maturity seems to give higher income than the other alternatives (Table 3). However, it is important to note that during the main growing season farmers face feed shortages and the multiple cutting options could offer an alternative source of feed for farmers at critical times, despite the low yield potentials.

Table 3. Forage, straw, and grain yields and estimated monetary values of yield components for oat variety trials

		Yield components (ton DM/ha)				**Estimated monetary (000, ETB/ha)***
Oat variety	**Cutting treatment**	**Vegetative**	**Hay**	**Straw**	**Grain**	
Forage oat	Once: hay stage	-	16.24	-	-	114
	Once: maturity	-	-	10.33	5.22	109
	Twice: vegetative and hay stage	3.46	5.27	-	-	61
	Twice: vegetative and maturity	3.46	-	6.62	1.94	73
Food oat 1	Once: maturity	-	-	12.5	6.22	143
	Twice: vegetative and maturity	2.45	-	6.65	3.83	102
Food oat 2	Once: maturity	-	-	10.6	5.11	119
	Twice: vegetative and maturity	3.63	-	5.97	2.89	92

*For this calculation the following average prices were considered: hay, 7 ETB/kg; straw, 3 ETB/kg; grain; 17 ETB/kg

There is always a trade-off between yield and nutritional quality as the growth of forages advances. In the present experiment, the quality of the forage at the vegetative stage was much higher than that of maturity and hay stage. The CP content at the vegetative stages ranged between 12-14%, while that at maturity ranged between 4-5%. Similarly, the true in vitro organic matter digestibility was high at the vegetative stages (61-63%) but declined to 49% at maturity (Table 4). These results indicate that although the twice-cutting management does not have yield advantage, it would provide high-quality forage that can be used as a supplement to poor-quality local feed resources. Therefore, the decision on which cutting management to apply would depend on the local context and need.

Table 4. Chemical composition of oats forage harvested at early vegetative, hay and maturity stages

Forage type	**Stage of growth at sampling**	**Ash (%)**	**CP (%)**	**NDF (%)**	**ADF (%)**	**ADL (%)**	**TIVOMD (%)**	**ME (MJ/Kg)**
Food oats 1	Vegetative	17.06	14.0	62.30	38.80	4.72	63.70	8.79
	Maturity	8.33	4.5	81.40	52.60	8.98	49.17	7.50
Food oats 2	Vegetative	15.45	12.0	68.80	43.10	4.98	61.00	8.51
	Maturity	9.12	4.8	80.40	54.40	9.74	49.47	7.51
Forage oats	Vegetative	16.51	13.1	65.50	40.00	4.68	62.30	8.68
	Hay stage	10.11	7.8	65.90	41.40	6.16	54.30	8.02
	Maturity	8.80	4.1	83.70	55.70	9,65	48.60	7.42

Tree lucerne cutting management

The majority of tree lucerne seedings, planted at the end of July 2021 to collect additional data on cutting management practices, have reached an average plant height of 193 cm and a root collar

diameter of 2.9 cm after 8 months of growth. The first cutting treatment has been applied. The trees in each plot have been assigned randomly to cutting heights of 1 m and 1.5 m cutting and the first round of data collection completed. The regular yield and nutritional quality measurement will continue through the next growing season.

Capacity development

In collaboration with the Innovation Lab for Small-Scale Irrigation (ILSSI) project and local partners, two dairy cooperatives, one in Lemo (Habebo Cooperative) and another in Kedida Gamela woreda (Mishgida Eta Cooperative) have been supported to start forage seed multiplication (Photo 1). The support included on-site training programs for selected cooperative management members, and basic forage seeds of oats and vetch enough to multiply the seeds on 1.5 hectares of land per cooperative. Other logistical support involved establishing a seed store and sales shop in the premises of each of the cooperatives. These capacity building support has enabled the cooperatives to start the forage seed business and diversify their income sources. The support is expected to help improve local capacity.

Photo 1. Habebo Dairy Cooperative forage seed and milk sales shop constructed through technical support from Africa RISING and financial support from ILSSI.

Moreover, two MSc graduate fellows from Wachemo and Debre Birhan universities have been supported to conduct their thesis research. The student from Wachemo University has completed data collection and is currently writing his thesis. The student from Debre Birhan University continues to collect data on the performance of tree lucerne subjected to different cutting management treatments. Short-term training, field days, workshops and visits are included in the overall Africa RISING project capacity development of the current six months report.

Key messages including challenges and lessons

- Results of the R4D trials provided valuable information to improve feed resource availability and quality at household level.
- Desho-vetch intercropping proved to be highly promising resulting in more than 60% yield advantage, considerably improving forage quality and addressing soil fertility issues related to sole Desho grass establishments. As vetch can be easily over sown on established Desho grass plots, this

practice has a high potential for adoption, especially in southern Ethiopia where the grass is widely planted for feed and soil and water conservation purposes.

- The yield and quality of feed obtained from food oat and forage oats varieties were affected by the cutting management applied. While one-time cutting at hay/milky stage or maturity provided higher yield, vegetative cutting and the regrowth provided better-quality fodder and alternative feed during the main growing season. Therefore, the choice of management to apply should depend on the local condition of farmers and interests.
- The support provided to cooperatives to strengthen their capacity in terms of basic infrastructure and technical skills to multiply and market forage seeds has provided encouraging results. It is important that the local administration and the extension system continue to support these cooperatives for a better market linkage for their produce including forage seeds.

Crop varieties and management

Introduction

Wheat (bread and durum wheat), barley (food and malt barley) and food legumes (faba bean, field pea, chickpea, lentil and grass pea) are major food and crops that occupy large acreages of arable land in the Ethiopian highlands. Food legumes are important as a rotation crop for sustainability of the wheat-based cropping system. High yield gaps exist in wheat, barley and food legumes that lead the country to import wheat and malt barley to meet local demands for food, and raw materials to agro-industries. Major factors that contribute to high yield gaps are poor access to high-quality seeds of improved cultivars, weak extension system, mono-cropping of wheat, diseases, and expansion of acid soil in the highlands of Ethiopia. The objectives of the study are to:

- Strengthen seed growers through provision of early generation seeds to ensure future access to quality seeds of farmer preferred varieties.
- Facilitate scaling through effective linkages with bureaus of agriculture (BoA) and unions.
- Identify adapted and high-yielding lentil and teff cultivars for north Shewa mid-altitude areas.
- Supports graduate student theses research.

Brief methodology

Community-based seed production and scaling of validated crop technologies:

The Africa RISING project provided early generation seeds under a revolving seed scheme to farmers in four intervention zones. Community-based seed multiplication helps to produce enough seeds to scale up crop technologies. A total of 34.5 tons of basic and certified seeds of bread wheat (two cultivars), durum wheat (one cultivar) and faba bean (three cultivars) were purchased from three seed producing farmer unions (Zereta-SNNPR, Tuka Katar-Oromia and Tegulet Union-Amhara) and public seed enterprises. In north Shewa Zone, farmers used Noble 25% WP fungicide sprays at seedling and vegetative stages of the crop to protect against faba bean gall disease. In most intervention sites, the seed production followed a cluster approach (Photo 2) for better management and experience sharing

among farmers. Scaling of crop technologies were done together with partners mainly with BoA in different districts. Yield data was collected by contact persons from each district/woreda and zone.

Photo 2*:* Cluster seed production bread wheat and faba bean varieties in Bale Zone in the 2021/22 cropping season.

Demonstration:

Siyadebirna Wayu District in north Shewa (Amhara Region) requested Africa RISING to provide released teff and lentil varieties to demonstrate in their farmer training centres (FTCs) using their own resources. Four teff varieties (*Dega-teff, Dagm, Nigus* and *Bishoftu*) and three lentil varieties (*Beredu, Derash* and *Alemaya*) were demonstrated in six FTCs on 25 m^2 plot per variety and farmers were involved in ranking based on tillering/branching, biomass, maturity and seed yield of the varieties**.**

Key results/findings

Early generation community seed production:

In North Shewa Zone early generation seed production, farmers produced 148 ton of seeds of three farmer preferred faba bean, bread wheat and malt barley varieties on 52 ha of land (Table 5). The numbers of direct beneficiaries of the intervention were 129 households (14 female households). The average productivity of faba bean, bread wheat and malt barley varieties were 2, 4 and 3 t/ha, respectively. The seeds will be used in the coming growing season through unions and farmer-t- farmer exchanges.

Table 5. Multiplication of certified seeds of bread wheat, malt barley and faba bean varieties in the 2021/22 cropping season, North Shewa Zone

District	Crop	Variety	Household beneficiary		Total	Area (ha)	Total seed yield (t)	Average productivity (t/ha)	Seed class
			Male	Female					
Hageremariam	Faba bean	Numan	8		8	5	12	2	C2
Siyadebirna Wayu			17		17	5	10	2	C2
Basona Worena			37	2	39	12	21	2	C2
Moretinajiru			12	3	15	5	10	2	C2
Hageremariam	Bread wheat	Wane	11	2	13	7	22	3	C1
Basona Worena			14	6	20	10	39	4	C1
Moretinajiru			15	1	16	8	32	4	C1
Basona Worena	Malt barley	HB1964	1		1	1	2	3	C2
Total	3	3	115	14	129	52	148		

In Bale Zone, 246 t seeds of nine varieties of five crops were produced by 132 farmers (13 female farmers) on 104.9 ha of land (Table 6). Although the average productivity of the crops varied from place to place depending on crop management practices, some cultivars showed productivity of ≥3 t/ha. Still farmers and unions are interested to grow durum wheat, faba bean and malt barley as parts of a diversification strategy to their bread wheat dominated cropping system.

Table 6. Early generation seed multiplication of bread and durum wheat, malt barley and faba bean in the 2021/22 cropping season in Bale Zone

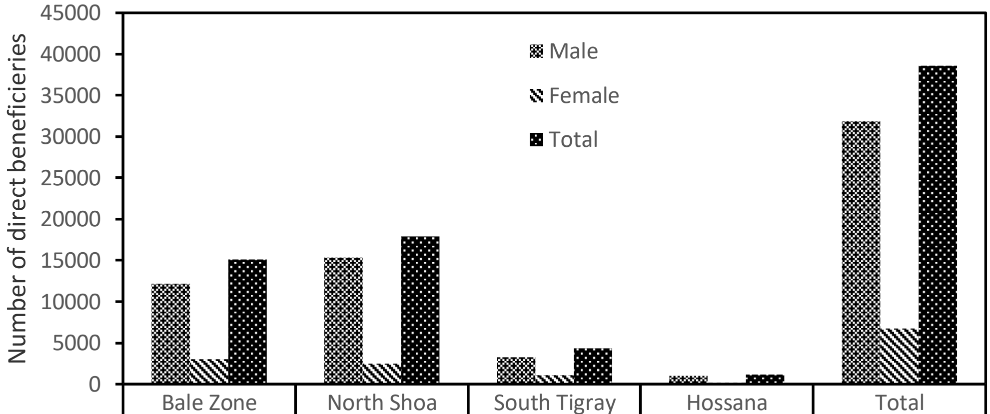
Districts	Crop	Variety	Household beneficiary		Total	Area (ha)	Total seed yield (t)	Average productivity (t/ha)
			Male	Female				
Dinsho	Faba bean	Numan	10	3	13	5	8.5	1.7
Dinsho		Gora	7		7	3.25	5.3	1.6
Goba	Bread wheat	Wane	19		19	16.17	30.7	1.9
Goba	Food barley	Adoshee	5		5	3.33	15	4.5
Goba	Malt barley	HB1964	32		32	29.69	57.5	1.9
Goba	Faba bean	Numan	8		8	5	16.9	3.4
Goba	Durum wheat*	Bulala	-	-		10	19.2	1.9
Agarfa	Faba bean	Numan	10		10	5	10.5	2.1
Goro		Gora	12	4	16	3.07	5.9	1.9
Sinana	Bread wheat	Lemu	3	1	4	3.96	13.3	3.4
Sinana		Deka	4	1	5	3.64	15.6	4.3
Sinana		Wane	6	2	8	9.9	29.7	3.0
Sinana	Durum wheat	Bulala	1	1	2	2.6	7.9	3.0
Sinana		Utuba	2	1	3	4.3	10.1	2.3
Total	5	9	119	13	132	104.91	246.1	

*Seeds were produced by seed producing union

Partner scaling:

In 2021/22 cropping season, 38,571 (17% female hhs) hosted scaling of cereals and food legume varieties included in the extension packages in the four intervention zones (Figure 3). Most of the households hosted farmer preferred varieties of bread wheat (32,259 hhs) followed by durum wheat (2,951hhs), faba bean (1,867), malt barley (785 hhs) and field pea (445 hhs). Field pea has been adopted only by farmers in the south Tigray Zone.

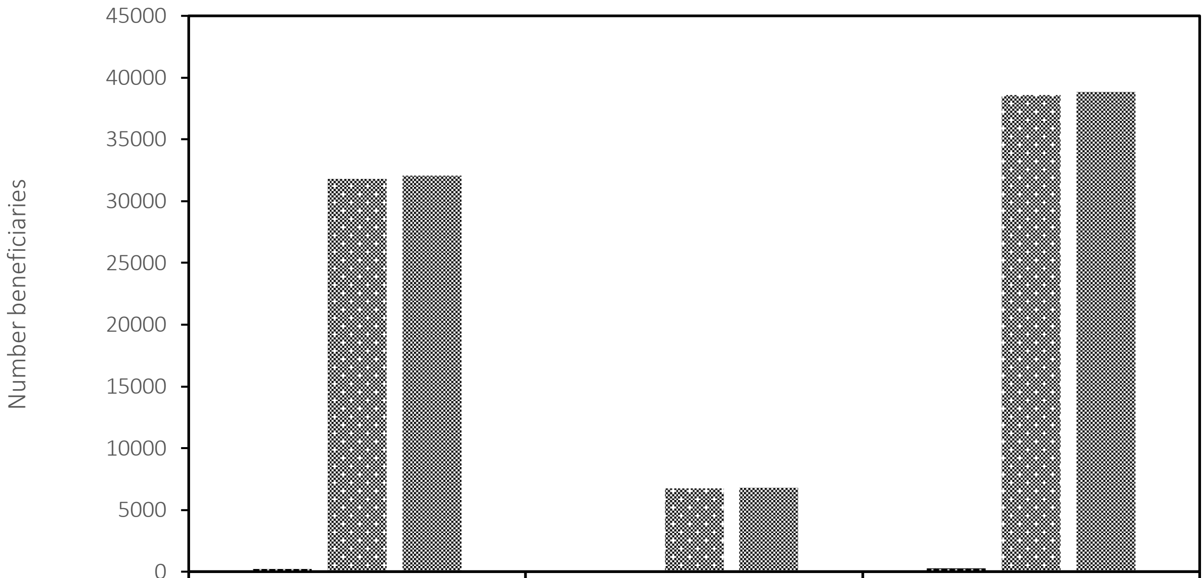
Figure 3. Summary of direct beneficiaries from partner scaling in four intervention zones.



	Bale Zone	North Shoa	South Tigray	Hossana	Total
Male	12138	15381	3258	1040	31817
Female	2995	2506	1121	132	6754
Total	15133	17887	4379	1172	38571

The total beneficiaries from project and partner scaling are 38,822 (17% female hhs) in the four intervention areas (Figure 4). The seeds produced by these farmers will help to contribute to improving access to quality seeds of farmers preferred varieties of cereals and food legumes.

Figure 4. Number of direct beneficiaries from project and partner scaling in the four intervention zones.



	Male	Female	Total
Project scaling	234	17	251
Partner scaling	31817	6754	38571
Total	32051	6771	38822

Demonstration of teff varieties at FTCs:

Based on mean ranking of farmers in six FTCs, two varieties (Dega-teff and Dagm) were selected (Table 7) for next season production (Photo 3). The average productivity of the varieties across locations was very low and but the selected varieties recorded a yield of 2 t/ha in some locations. The Debre Zeit Agricultural Research Centre has shown interest to further scale the selected cultivars in the coming cropping season by using their own resources.

Table 7. Ranking and yield of four teff varieties demonstrated at six FTCs in North Shoa Zone.

Varieties	**Ejersa Kubeti**	**Gash Amba**	**Dawo**	**Romie**	**Esat Amba**	**Siyadebir**	**Mean ranking**	**Location means of seed yield (t/ha)**	**Seed yield (range t/ha)**
Dega-Teff	4	1	3	2	2	1	2.2	1.2	0.2-2
Dagm	3	2	1	1	3	2	2.0	1.3	0.2-2
Nigus	2	3	2	4	1	3	2.5	1.1	0.1-1.7
Bishoftu	1	4	4	3	4	4	3.3	0.7	0.1-1.4

Photo 3. Performance of Dega-teff variety in North Shewa Zone.

Demonstration of lentil varieties at FTCs:

Based on selection criteria used by farmers (tillering, maturity, biomass and yield), the most popular lentil variety, Alemaya (Photo 4). was selected and the yield of the three varieties was very low due to a water logging problem (Table 8). The result was shared with Debre Zeit Agricultural Research Centre which wants to validate more recently released varieties to address the needs of farmers in the zone.

Photo 4. Performance of lentil (variety Alemaya) in some FTCs in North Shewa Zone.

Table 8. Ranking and yield of three lentil varieties demonstrated at six FTCs in North Shewa Zone

Varieties	Siyadebir	Esat Amba	Romie	Dawo	Gahs Amba	Ejersa Kubeti	Mean ranking	Location means seed yield (t/ha)	Seed yield (range t/ha)
Alemaya	1	2	2	1	1	3	1.7	0.5	0.2-0.9
Derash	3	1	3	2	3	1	2.2	0.4	0.1-1
Beredu	2	3	1	3	2	2	2.2	0.4	0.1-0.8

Capacity development

Three PhD students who are working on key food legume diseases were partially supported by Africa RISING project. One of the PhD students will defend his work in May 2022 and a copy of his thesis will be provided to Africa RISING for documentation. Short-term training, field days, workshops and visits are included in the overall Africa RISING project capacity development of the current six months report.

Key messages, challenges and lessons

- The approach of selecting released crop varieties encouraged the BoA in North Shewa to follow the same approach and validate available technologies like teff and lentil for their farming communities. This is an indication of substantivity of technology scaling after the project is phased-out.
- Key seed producing unions included cereals and food legume varieties in their seed production plans.
- Use of zonal and district level project focal persons was critical in implementing the project and getting data during COVID-19 pandemic and security problems.
- There is still difficulty of getting early generation seeds of cereals and food legumes from research centres (pre-basic and basic seeds).
- Because of insecurity reasons, it was not possible to get data from farmers in South Tigray and there were few regular trips to interact with key partners and farmers.
- Uses of a cluster approach for seed production helps farmers to get experience sharing and in organizing field days.
- We managed to provide fungicide to control faba bean gall diseases and farmers and the union were interested to produce faba bean seeds in North Shewa.
- High experts turnover at zonal and district levels.

Crowdsourcing (cultivar diversity of durum wheat and faba bean)

Introduction

The challenges of future food production are related to climate change coupled with the status of local agricultural production. A sustained effort is thus required to generate crops with higher and more stable yields across diverse and changing environments. Bioversity International has successful experience in the Seeds for Needs Initiative which uses existing genetic diversity of durum wheat and faba bean to identify traits for adaptation to climate change. Since 2010, Bioversity International has conducted research under the initiative together with Ethiopian and international partners to understand and study the potential of these varieties in marginal areas and to increase the resilience of communities where these varieties are cultivated. The main goal was to offer variety that allowed farmers to adapt to climate change. Seeds for Needs is a participatory approach which works with farmers, in particular women farmers, to identify a set of crops and varieties to be further tested under their farming conditions through crowdsourcing approach.

Brief methodology

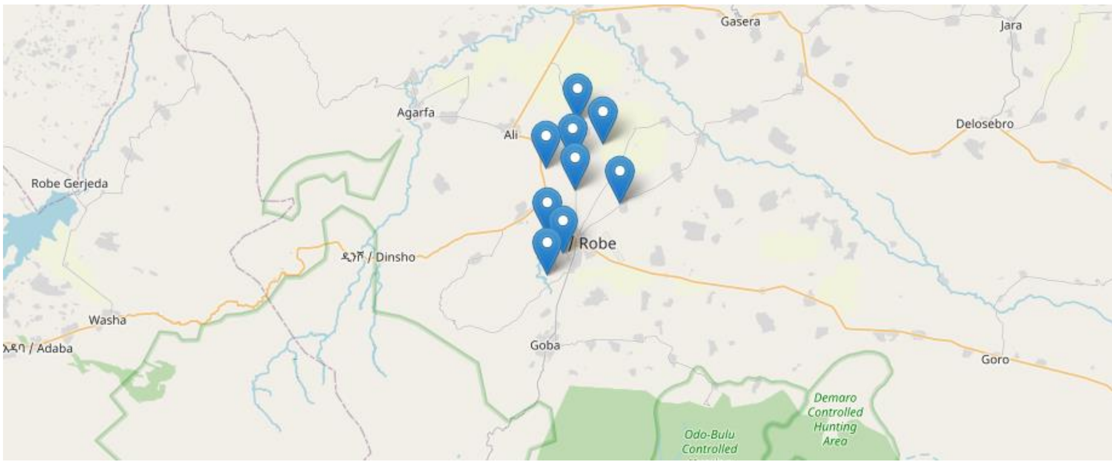
Durum wheat and Faba bean were the crops tested in Africa RISING intervention areas. Twenty Durum wheat varieties were delivered to 200 farmers in Bale Zone and 13 Faba bean varieties to 400 farmers in North Shewa and Hadiya zones. Each farmer received a combination of three random varieties. All the necessary farm inputs and site selection were left to the farmer's decision. Parameters for the evaluations of each variety were set after consulting key informants of the local community. Based on that all farmers evaluated the varieties using the best and worst ranking method. Once the farmers provide the rank, the enumerators encoded the data using Open Data Kit (ODK) through ClimMob platform, which collects data centrally.

Key results/findings

Durum wheat varieties evaluation:

Overall, 200 participants registered to this research work (Figure 5). Ultimately, over 130 farmers were able to provide the full data until the end of the research. Each participant assessed three different varieties and ranked them in order of its 'overall ranking'. In addition, they provided rankings for seven additional traits.

Figure 5. Distribution of the villages where the 200 farmers are located.



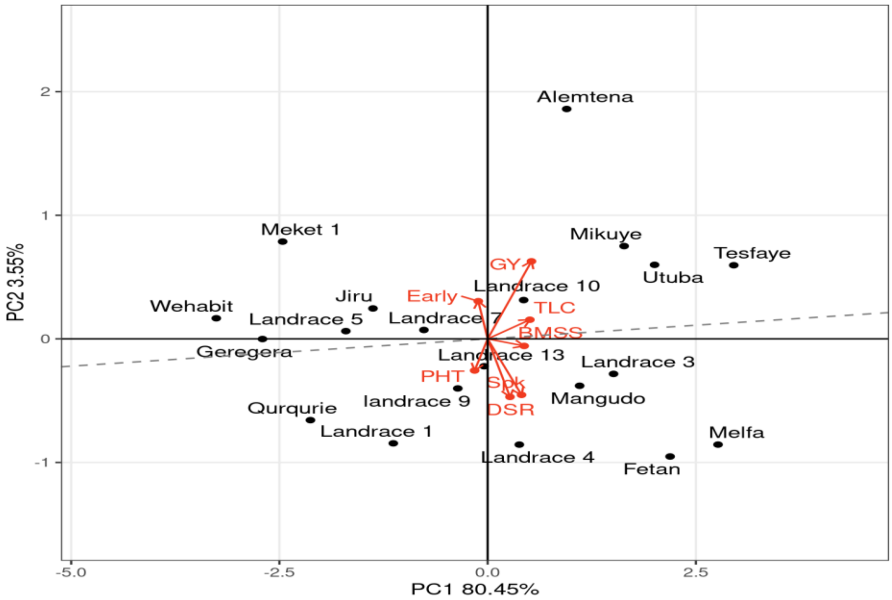
Data were collected based on eight parameters. Based on the overall performance parameter, farmers selected Mikuye, Alemtena, and Melfa among the others (Table 9). The first two are improved varieties, while 'Melfa' is a landrace collected from Tigray region that performed very well in high potential areas of Bale Zone (Landrace 10). This showed that in our selection trials we should include all options as much as we can, regardless of the recommendation area and the category of the varieties.

Table 9. Summary of Durum wheat varieties ranked best and worst based on farmers evaluation in Bale Zone.

Trait	**Data collection moment**	**Best ranked**	**Worst ranked**	**p.value**	
Disease resistance	First data collection	Mangudo, Landrace 1, Fetan	Alemtena, Landrace 5, Meket 1	1.23e-01	
Earliness	Second data collection	Wehabit, Meket 1, Landrace 7	Melfa, Landrace 1, Mangudo	6.11e-02	.
Plant Height	Second data collection	Landrace 4, Meket 1, Landrace 10	Mikuye, Mangudo, Utuba	1.09e-01	
Tillering capacity	Second data collection	Melfa, Tesfaye, Utuba	Wehabit, Qurqurie, Geregera	1.20e-01	
Spike quality	Second data collection	Tesfaye, Fetan, Landrace 3	Geregera, Meket 1, Wehabit	8.61e-04	***
Biomass Yield	Second data collection	Melfa, Tesfaye, Fetan	Landrace 1, Jiru, Geregera	4.29e-02	*
Grain yield	Second data collection	Tesfaye, Alemtena, Landrace 10	Wehabit, Geregera, Qurqurie	2.38e-02	*
Overall ranking	Final data collection	Mikuye, Alemtena, Melfa	Wehabit, Geregera, Landrace 1	6.37e-04	***

The principal component analysis also shows which varieties performed well based on different parameters (Figure 6).

Figure 6. Partial least squares biplot of relationship between Durum wheat varieties and the parameters evaluated.

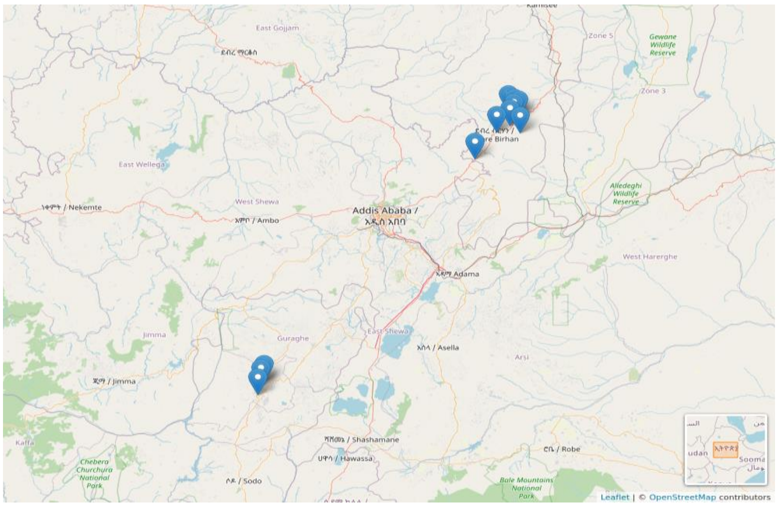


The dashed line represents the ‘overall ranking’ with an increase in performance as the x and y increase.

Faba bean varieties evaluation:

Four hundred farmers participated in the Faba bean varieties evaluation. Among these, 349 farmers were able to provide data for the pre-selected parameters. The farmers who participated in the research were from different villages (Figure 7). The data collected from North Shewa was reliable but the one from Hadiya was found unreliable because of the enumerators negligence to record all the data the farmers provided. For these reasons we have rejected all the parameters except diseases data, which is presented below.

Figure 7. Distribution of the villages where the 200 farmers are located.



Among the tested varieties of faba bean, Tumisa, Numan and Hachalu were found to be resistant to diseases, while Jamma local and Dagim were the most susceptible. Currently, faba bean production is challenged by disease. The area coverage has also reduced year-on-year. For this reason, finding a disease resistance variety is an important milestone to continue its production.

During our data analysis, no split was found for the Plackett-Luce tree based on the tested locations. This means, the model for the rankings provided in this project showed that none of the tested locations had a clear influence on the rankings of 'disease resistance' with an alpha = 0.5. So, the resistance level of the varieties was consistent over the tested locations and was ranked consistently by the farmers.

Capacity development

Short-term training sessions on the concept of crowdsourcing and selection of farmers for the field trial, field days and visits are included in the overall Africa RISING project capacity development of the current six months report.

Key messages, challenges and lessons

Due to security-related travel restrictions, it was not possible to go to all locations for evaluation from Addis Ababa. But the experiments were handled by Africa RISING focal persons in the localities. This strategy allowed us to collect the data remotely without much impact on the quality of the data. But in one of the sites, Hadiya, the enumerators provided incorrect data. This was discussed with Africa RISING focal person, and the project is working on a solution to the problem.

Soil fertility management

Introduction

Soil fertility depletion and nutrient mining are critical challenges for Ethiopian agriculture and sustainable crop production. Low crop response to fertilizers is a major concern despite there being consistent increase in fertilizer supply and usage in the country. The effectiveness of matching fertilizer types to soil fertility problems depends on the ability to identify limiting factors, characterize sites, and develop appropriate recommendations. Identification of nutrient management zones requires the collection and interpretation of spatial data, such as yield, elevation, soil nutrient maps, and farmers' classification criteria. In Ethiopia, a great effort is being done to test and recommend balanced fertilizers for increased crop yield and quality. Fertilizer trials are in progress using balanced blended fertilizers containing multiple nutrients, such as NP and S (sulfur) and/or zinc (Zn) and boron (B). The basis for the formulation of these fertilizers was an analysis of data collected under the EthioSIS project, which identified S, Zn, and B as deficient nutrients in Ethiopian soils. Wheat yields significantly responded to landscape positions where wheat yield was higher by 50-300% in foot slopes than in hillslopes, depending on location and input level. Significant variations were observed in crop fertilizer response with topo-sequence due to a significant decrease in soil organic carbon, clay content, and soil water content.

Integrated soil fertility management (ISFM) is an approach to improving yields of crops while preserving sustainable and long-term soil health and fertility through the combined application of fertilizers, recycling of organic resources, use of responsive crop varieties, and improved agronomic practices, which minimize nutrient losses and improve the nutrient-use efficiency of crops. Yield benefits were more apparent when fertilizer application was accompanied by crop rotation, green manuring, or crop residue management. For example, the combined application of organic and inorganic fertilizers increased wheat yields by 50–100%, whereas crop rotation with grain legumes increased cereal grain yields by up to 200%. Although organic residues are key inputs for soil fertility management, about 85% are used for livestock feed and energy sources. The main incentive for farmers to adopt ISFM practices is economic benefits. Therefore, the objectives of this research were to:

- validate landscape-based site-specific fertilizer recommendations for wheat in selected wheat-producing areas of central and south Ethiopia,
- generate information on fertilizers that will help develop fertilizer decision support tool (DST) in the country, and
- validate best-bet ISFM practices for wheat production and generate information on ISFM that could help develop fertilizer DST in the country.

Brief methodology

The validation trial was conducted on farmers' fields of Lemo District/Woreda in Hadiya Zone of the South region and Basona Worena District in North Shewa Zone of the Amhara Region. Six farmers were selected per landscape position (four at hillslope, four at mid-slope, and four at foot slope position) for the fertilizer and nine farmers for ISFM validation trials. To characterize each landscape position, slope percentage was used as a key criterion. Accordingly, landscape positions with < 5°, 5-15°, and 15-30° are characterized as foot slope, mid-slope, and hillslope positions, respectively. The three treatments were landscape-based site-specific fertilizer recommendations, model-generated rate and the current blanket or extension fertilizer rate applied for wheat across all landscape positions at each implementing woreda (Table 10). The improved wheat variety (*var*. *Danfe*) was sown in rows following the planting date of the crop and based on the onset of the main rainy season.

Table 10. Summary of treatments based on landscape position for wheat

Woreda		**Foot slope**	**Mid-slope**	**Hillslope**
Lemo	Site-specific fertilizer rate (kg/ha)			
	Urea	125	75	75
	NPS	180	60	60
	KCl	65	65	35
	Model generated rate (kg/ha)			
	Urea	225	133	75
	NPS	182	195	61
	Current extension rate as a control (kg/ha)			
	Urea	150	150	150
	NPSB	100	100	100
Basona Worena	Site-specific fertilizer rate (kg/ha)			
	Urea	243	203	150
	NPS	182	158	121
	KCl	0	0	0
	Model generated rate (kg/ha)			
	Urea	225	225	133

	NPS	182	182	195
	Current extension rate as a control (kg/ha)			
Vertisol	Urea	150	150	150
	NPSB	100	100	100
Nitisol	Urea	100	100	100
	NPSB	150	150	150

For the ISFM validation trial on wheat in Lemo Woreda, the sites were selected based on severity of soil fertility depletion, soil acidity and landscape position in collaboration with the Woreda Agriculture Office. Vetch (*Vicia sativa* L.) was grown as a short-term green manure crop during the short rainy season and the shoot and root biomass of the green manure was incorporated into the field. The amount of lime applied ha^{-1} was determined based on the exchangeable acidity of the soil. Lupin was grown as a green manure crop. The treatments included:

i. Green manure + 65% of the recommended N fertilizer rate + the recommended rate of other nutrients (P, S, and micronutrients).
ii. 50% of the recommended N fertilizer rate (N) + 50% of the recommended organic fertilizer. (compost) as N equivalent + the recommended rate of other nutrients (P, S and micronutrients).
iii. The recommended rate of inorganic fertilizer alone.

The treatments were arranged in a randomized complete block randomized design and replicated four times at each landscape (hill, mid-and foot slope) position on four farmers' fields on a plot size of 10 m by 10 m (100 m^2). The appropriate wheat variety for each area was sown for both validation trials. Other recommended agronomic practices for wheat production were uniformly applied to all plots. The validation trials were evaluated by farmers, extension agents and experts during the grain filling stage of the wheat crop. The required agronomic data such as total biomass of the and grain yield of wheat will be collected.

Key results/findings

Wheat yield response to different fertilizer treatments:

Although statistically significant differences were not observed among landscape positions in the growth and yield of wheat, numerical variations were observed in wheat yield. The highest grain (4,200 kg/ha) and total biomass (11,551 kg/ha) yields of wheat were recorded at the foot slope position in Lemo District. Grain yield increments at the foot slope position were 3.0 and 9.6% compared to the yields at mid-and hillslope positions, respectively, with the general trend in yield increase down to the topo-sequence and vice versa (Table 11). The soil pH at Lemo Woreda is moderately acidic thereby the effect of soil acidity was not a limiting factor for the growth and yield of wheat.

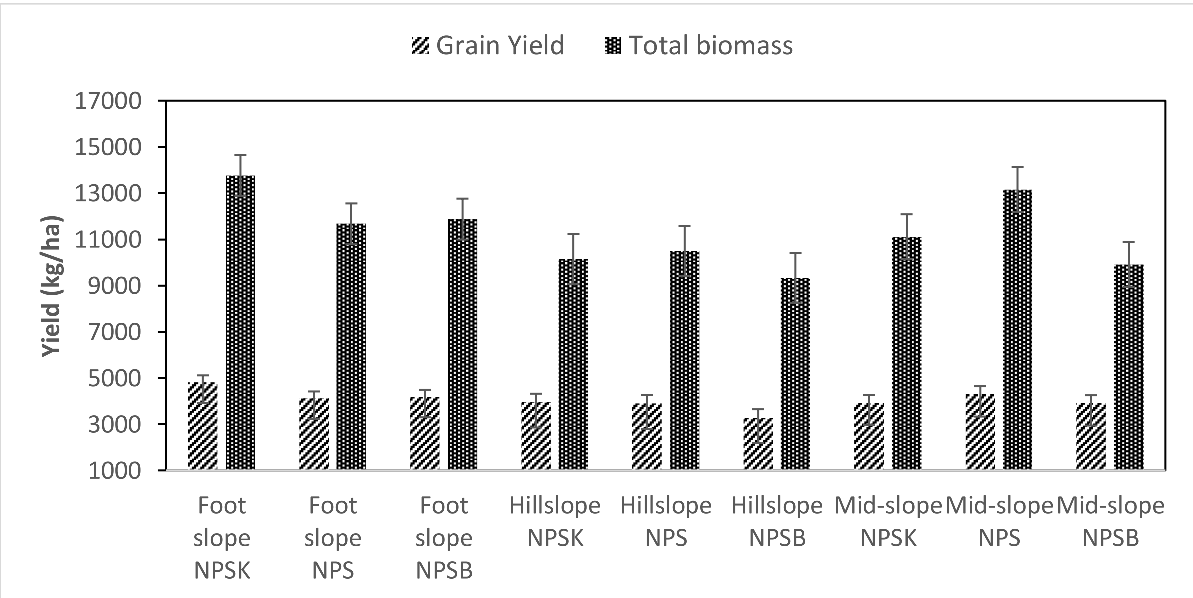
The research recommendation treatment (NPSK + urea) resulted in significantly the highest grain (4,200 kg/ha) and total biomass (11,600 kg/ha) yields of wheat, with grain yield increments of 3.1 and 11.6%, compared to the site-specific and extension fertilizer rates, respectively (Table 11). However, statistically significant differences were not observed among the three fertilizer treatments for both grain and total biomass yields of wheat implying that yield differences were mainly attributed to differences in N and P rates. The addition of K did not bring a significant yield difference, compared to the treatments without K application (Table 11).

Table 11. The main effect of landscape position and fertilizer on yield and some yield components of wheat in Lemo District of Hadiya Zone in the 2021/22 cropping season.

Landscape	**Grain yield (kg/ha)**	**Biomass (kg/ha)**	**Tillers per plant**	**Plant height (cm)**	**Spike length (cm)**
Foot slope	4,200	11,551	2.13	91.2	8.40
Mid-slope	4,077	11,472	1.70	92.9	8.17
Hillslope	3,832	10,800	1.87	94.9	7.82
SE	178	511	0.13	1.74	0.23
Treatments					
Research rate (NPSK + urea)	4,224	11,600	1.88	92.1	8.08
DST site-specific rate (NPS + urea)	4,098	11,772	1.96	93.4	8.37
Extension rate (NPSB + urea)	3,786	10,451	1.86	93.4	7.94
SE	198	567	0.12	1.77	0.24

The landscape by fertilizer treatment interaction resulted in higher wheat grain yields of 4,802 and 4,302 kg/ha from the application of NPSK at the foot slope position and NPS at the mid-slope position, respectively, with respective yield increases of 47% and 31.7%, compared to the application of the extension fertilizer recommendation (NPSB) at hillslope position (Figure 8). The economic feasibility of the fertilizer treatments will be determined through partial budget analysis and other methods.

Figure 8. Landscape by fertilizer interaction effect on grain yield and total biomass of wheat in Lemo District of Hadiya Zone in 2021/22 cropping season.

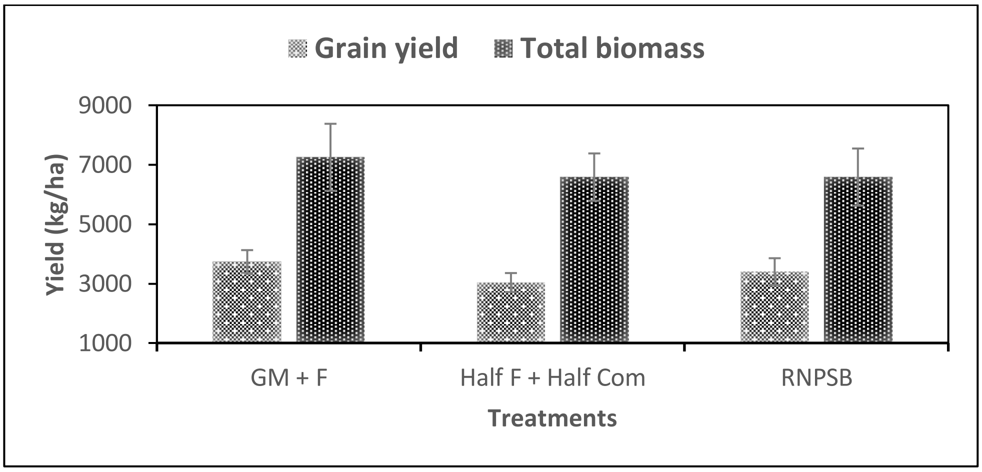


Validation of best-bet ISFM practices for wheat production:

The effects of organic amendments on wheat yield were evaluated in nine farmers' fields in comparison with the fertilizer treatments only in Lemo District in 2021 cropping season. The highest grain (3,742 kg/ha) and total biomass (7,250 kg/ha) yields of wheat were recorded from the incorporation of green

manure and the application of inorganic fertilizer (Figure 9). Wheat grain yield advantages due to the integrated application of green manure and inorganic fertilizer were 23 and 10%, compared to the combined application of compost and inorganic fertilizer and the recommended inorganic fertilizer only, respectively. The yield response from the application of compost as organic nutrient source may be influenced by the quality and amount of compost applied. However, the contribution of organic amendments in terms of soil health and crop yield is long-term and its effect needs to be evaluated over 3-5 years.

Figure 9. Wheat yield response to application of organic and inorganic nutrient sources in Lemo District of Hadiya Zone in 2021/22 cropping season.



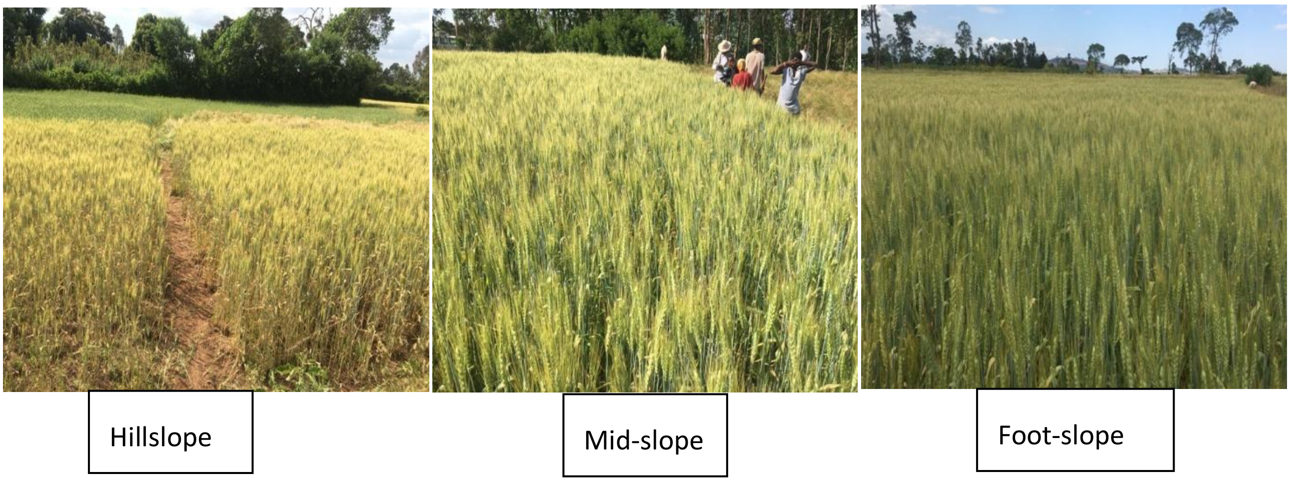


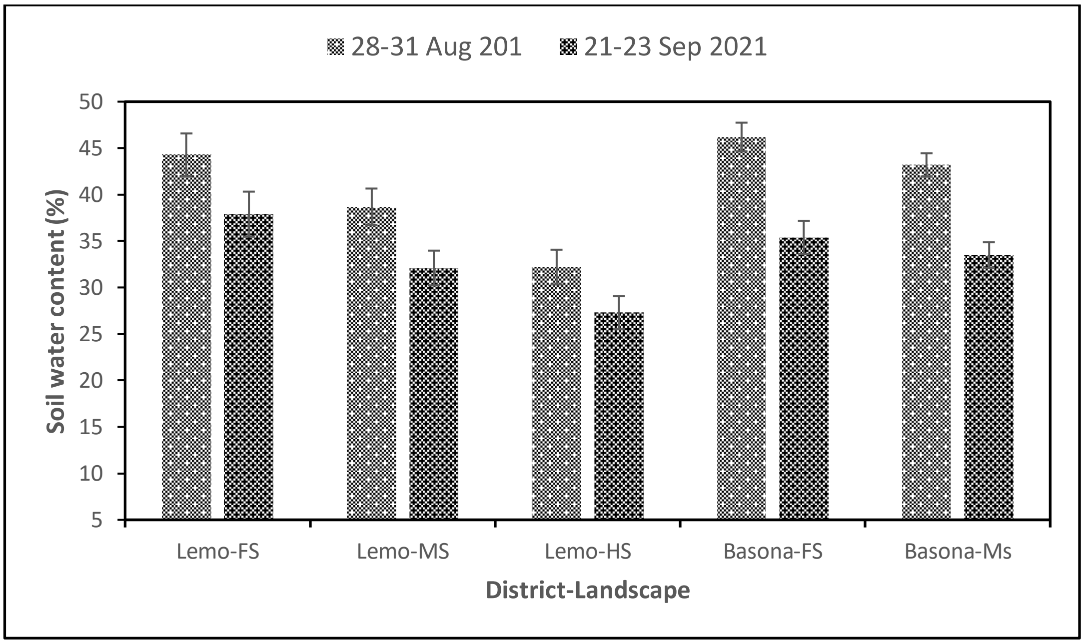
Photo 5. Wheat growth performance under different fertilizer treatments and landscape positions in Lemo Woreda of Hadiya Zone, 2021.

Soil moisture content:

The aim of the measurement of volumetric soil water content was mainly to verify whether soil moisture content varies across landscape positions. Measurements of soil water content were taken twice from wheat trial fields at foot, mid-slope and hillslope positions in Lemo and Basona Worena districts. TDR 300 portable soil moisture probe was used to measure soil moisture content at the field level. As shown in Figure 10, distinct variations were observed in soil water content along with the

landscape positions. Soil moisture content increased down to the topo-sequence. The growth and yield of wheat were positively correlated with the soil water content, where wheat yield increased from hillslope to foot slope position. Higher soil water contents (about 44% in Lemo and 46% in Basona District) were recorded in August than in September because of the peak rainy season. The relatively higher soil water content recorded in Basona District is an indicator of the higher water holding capacity of Vertisol compared to the water contents measured in Lemo on Nitisol and Cambisol soil types.

Figure 10. Volumetric soil water content at foot slope (FS), mid-slope (MS) and hillslope (HS) positions in Lemo and Basona districts using TDR in August and September in 2021 cropping season.



Capacity development

Farmers who have hosted the validation trials, development agents working in the trial sites and experts in Lemo and Basona districts were trained before the implementation of the validation trials. We had discussions with researchers and technical assistants of Debre Berhan and Areka agricultural research centres on how to select sites, design, apply the treatments under field conditions and collect the necessary data during the crop growth period. We have also organized training for 94 men and women farmers, 25 extension agents and supervisors which could assist them in the implementation of the validation trials. About 75-100 farmers have made field visits during different growth stages of the crop. Field days were also organized in both woredas in October 2021 to evaluate the trials under field conditions with farmers, development agents, agricultural officers, and other relevant stakeholders in collaboration with the research centers and district agricultural offices. In total 297 men and 53 women participated in training, meetings, and field visits. In the long-term, the direct and indirect beneficiaries of this project are estimated to be over 30,000 farmers in the two woredas.

Key messages including challenges and lessons

- Institutional linkage and partnership: The partnerships that have been created with regional research and development institutions enabled us to implement the project and deliver project

outputs in the difficult time of 2021. The progress made so far has been possible through the joint efforts of our project partners.
- Security problem: The conflicts and security risks in the country have been fundamental problems to plan field trips and execute activities. The validation trials in Endamehoni were canceled due to the continuous conflicts in Tigray and neighbouring regions. The fertilizer validation trial planned in Sinana Woreda was not implemented because most farmers are not willing to rent their farmlands and manage such trial plots as mechanized farming is the dominant farm operation in the area.
- COVID-19: the constant spread of this pandemic has been the major threat in the country, hindering the movement and follow-up of activities under field conditions.

Way forward

- The agronomic data of Basona Worena collected in collaboration with Debre Birhan Research Center will be compiled and included in the next report.
- Conducting economic analysis will be an additional tool to identify the best and economically feasible treatments for each location, crop, and soil type.
- Developing the decision support tool (DST) and fertilizer recommendations based on the crop and soil data generated.
- Further work will be necessary on crop quality analysis that will help determine the critical micronutrient concentrations in grains.
- Work with partners to disseminate the DST for fertilizer recommendation.

Agricultural mechanization

Introduction

Maize and wheat production systems in the Ethiopian smallholder farming sector are characterized by high drudgery. Farming operations on the farms are predominantly performed by human muscle power leading to high drudgery. Low horsepower two-wheel or walking tractor (2-WT) is an alternative technology that reduces drudgery and can increase crop productivity on smallholder farms. Appropriate mechanization technologies adapted to the smallholder farming conditions are being promoted in different parts of the Ethiopian highlands. The mechanization technologies are value chain focused, covering crop production, irrigation, harvesting, post-harvest processing (threshing and shelling) as well as transportation services on smallholder farms. The 2-WT powered technologies that are being promoted in Ethiopia increase opportunities to free up available farm labour to pursue other on-farm and off-farm income generating activities within and outside the rural communities. Activities were implemented in all project sites during the October 2021 to March 2022 period. Planned activities during this period included conducting mechanization adoption survey, analysing survey data and developing a survey report, soil sampling and analysis, monitoring service provision, collecting and analysing agronomy and gross margins data from on-farm trials, and developing a technical project report.

Brief methodology

Adoption survey conducted in November 2021:

A multi-stage sampling procedure was used to select study districts, sample kebeles and households. Gimbichu and Tiyo districts were purposely selected in the project areas as the main study areas because the security situation could allow the survey team to perform its duties. The security situation in Gudeya-Billa Woreda and the Amhara and Tigray regions could not permit the survey team to travel to those project areas. As the main purpose was to compare adopting and non-adopting farmers, Ada'a and Diglunatijo districts, with similar farming systems, were also purposely selected from non-project sites to serve as control districts for Gimbichu and Tiyo districts, respectively. Out of the total kebeles where mechanization services were provided 10 kebeles were randomly selected from both districts (five from Gimbichu and five from Tiyo) using simple random sampling. To proceed with the overall sample selection, a list of farmers engaged in agriculture in each kebele was collected, and then identified as beneficiaries and non-beneficiaries of mechanization technologies. At the third stage of sampling, in every selected kebele, proportional sampling method was used to select sample respondents. Accordingly, a total of 150 sample respondents (100 mechanization service users and 50 non-users) were selected from the Gimbichu and Tiyo. Moreover, simple random sampling was used to select both study kebeles and sample respondents from control woredas, with 5 kebeles randomly selected from each of the two districts. Then 50 respondents were randomly selected from the two districts (25 from Ada'a and 25 from Diglunatijo) using simple random sampling technique (Table 12).

The data from the household interviews were collected during the one-to-one interviews using a structured survey questionnaire by well trained and experienced enumerators who had prior knowledge of the farming system and spoke the local languages (i.e. Oromifa). The survey questionnaire development was done during the period of August to October 2021. The questionnaire was programmed using CSPro prior to enumerator training, which was based on both paper and electronic versions. Enumerators went through an intensive three-days training to familiarize them with the questionnaire and the data collection process using electronic devices. The enumerators were trained by the International Wheat and Maize Improvement Center (CIMMYT) staff for three days. A pre-test survey was also conducted outside the sample areas to assess the ability of each enumerator to administer the questionnaire and to customize the questionnaire more to the study purpose. The overall data collection process was supervised by CIMMYT staff and well-trained recruited supervisors. All data analyses were done by CIMMYT during the December 2021-January 2022 period. More details and findings of the mechanization adoption survey will be presented in a separate survey report.

Table 12. Zones and districts selected from Oromia region for conducting the adoption survey during November 2021.

Region	**Zone**	**Districts**	**Location type**	**No of sample farmers selected**		
				Service users	***Non-users***	***Total***
Oromia	East Shewa	Gimbichu	Project area	50	25	75
		Ada'a	Non project / control area	-	25	25
	Arsi	Tiyo	Project area	50	23	73
		Digeluna Tijo	Non project / control area	-	25	25
Total				*100*	*98*	*198*

On-farm demonstrations:

Eight on-farm demonstrations on 2-WT direct seeding were established during the May-June 2021 and yield data was collected from all of them between November and December 2021. Maize trials were established in Gudeya-Billa District while wheat trials were only established in Machakel District. Both grain yields and gross margins from the conventional and 2-WT direct seeded treatments were determined and are presented in this report.

Soil analyses from conventional and 2-WT treatments:

Soil samples were collected from the on-farm sites that have been in use for four years. The purpose of soil analyses was to determine differences in soil quality indicators between conventionally ploughed plots and those plots that were direct seeded using a 2-WT without any tillage for four years. Soil samples were collected from the 0-15 cm depth in each treatment. Soil samples were analysed by the Horticoop Laboratory in Debre Zeit.

Technical backstopping of service provision:

Technical backstopping of service provision activities was mainly achieved through telephone calls to service providers and woreda agriculture experts. Travelling to project sites in Amhara, southern part of Oromia and Southern Nations, Nationalities, and Peoples' Region (SNNPR) is scheduled for April 2022.

Key results/findings

Preliminary results of the adoption survey of mechanization technologies:

In terms of mechanization services, farmers used different type of machines (Table 13) and most fields (81%) were ploughed by four-wheel tractors (4-WTs) with only 19% being ploughed by 2-WT in the surveyed areas. However, in terms of threshing, 2-WT (66%) was used more than the combine harvester (32%). Generally, this result may confirm that 4-WT and combine harvester were more widely used machines for ploughing and harvesting, while 2-WT was widely used in threshing services, and to some extent, for transport services as well. Analysis of the mechanization services by crops showed that wheat is the crop on which most services were used, followed by barley and teff in the surveyed areas (Table 14). Threshing is clearly the most mechanization service used, followed by harvesting and transport.

Table 13: The different types of mechanized farm operations and the source of power used to provide the services in the surveyed areas.

Farming operation	**Type of machines used**	**%**
Ploughing	2-WT	19
	4-WT	81
		100
Planting	2 BFG/blue coloured seeder	100
		100
Irrigation	Water pump mounted on 2-WT	75
	Conventional water pump	25
		100

Harvesting	harvester or reaper attached to 2-WT	8.6
	Combine harvester	91
		100
Threshing	2-WT attached thresher/sheller	66
	Small engine thresher/sheller	1.86
	Combiner	32
		100
Transport	2-WT attached trailer	26
	Truck	78
	Other	1.4
		100

Table 14: Use of mechanization services on different crops (% of plots) in the surveyed areas.

Service	**Wheat**	**Barley**	**Teff**
Threshing	49.8	33.8	40.6
Harvesting	25.5	21.1	1.0
Transport	13.8	16.9	1.6
Ploughing	8.6	5.6	1.0
Planting	0.7	1.4	0.0
Total	98.4	78.9	44.3

Mechanization services reduced labour demand for both men and women, and its effects were most visible (Table 15). Households using mechanization services for ploughing and planting reduced their time spent on those activities by 19.45 hours for men and 21.43 hours for women. Though labour reduction is visible for all mechanized farming operations, the time saved due to the use of mechanization services is significant for harvesting and threshing. As shown in Table 15, men saved 31 and 48.85 hours per season as the result of using mechanization service for harvesting and threshing, respectively, whereas the time saved by women due to the use of mechanization services for harvesting and threshing was estimated to be 30.27 and 31.65 hours per season.

Using mechanization services for farming operations, especially for threshing and shelling, might lead to reduced harvest and post-harvest losses and improve the productivity of crop if holistically addressed from field to market level. The result showed that wheat and teff yield obtained from the threshing service were higher than the non-mechanized fields (Table 16). For instance, the average wheat yield obtained from fields that used the threshing service was 2,847 kg ha^{-1}, compared to 2,153 kg ha^{-1}, a significant difference, and an increase of 32% (or a reduction in losses). When only analysing the wheat yield from fields that used harvesting and threshing services, and those using harvesting, threshing and transport, there were no significant differences with non-mechanized fields.

Table 15: Impact of mechanization services on labour saving in the surveyed areas.

Mechanized farming operation	*Average hours saved per season*	
	Male	*Female*
Threshing	48.85	31.65
Harvesting	31	30.27
Ploughing and planting	19.45	21.43
Transport	14.62	17.29

Table 16: Impact of mechanization services on crop productivity in the surveyed areas.

Crop	**Productivity (kg ha^{-1})**										
	Non-mechanized plot		**Threshing service**			**Harvesting and threshing service**			**Harvesting, threshing and transport**		
	Obs.	**Mean**	**Obs.**	**Mean**	**t-test**	**Obs.**	**Mean**	**t-test**	**Obs.**	**Mean**	**t-test**
Wheat	126	2,153	71	2847	-694***	24	3139	-293	36	3251	-111
Teff	111	1,599	71	1981	-381***	-	-	-	-	-	-
Barley	36	2,178	12	2544	-367	-	-	-	-	-	-

Agronomy and gross margin results from on-farm trials:

Wheat productivity, reflected by grain yield, was similar in conventional and 2-WT seeded systems across farms (Figure 11). The conventional practice had 7 kg/ha^{-1} more grain than the direct seeded 2-WT treatment though this difference was not statistically significant. Similarly, gross margins were not statistically different but direct seeded wheat generated more (USD1,417) compared with conventional practice (USD1,196) from a hectare (Figure 12). In the maize systems, maize yield was higher in the 2-WT by 602 kg/ha^{-1} compared with the conventional practice (Figure 13). The 2-WT treatment generated more gross margins (US$425 ha^{-1}) than the conventional practice (USD302 ha^{-1}) (Figure 14).

Figure 11. Wheat grain and straw yields from conventional practice and 2 WT direct seeding system across farms in 2021 season. Vertical bars represent standard deviation for each treatment.

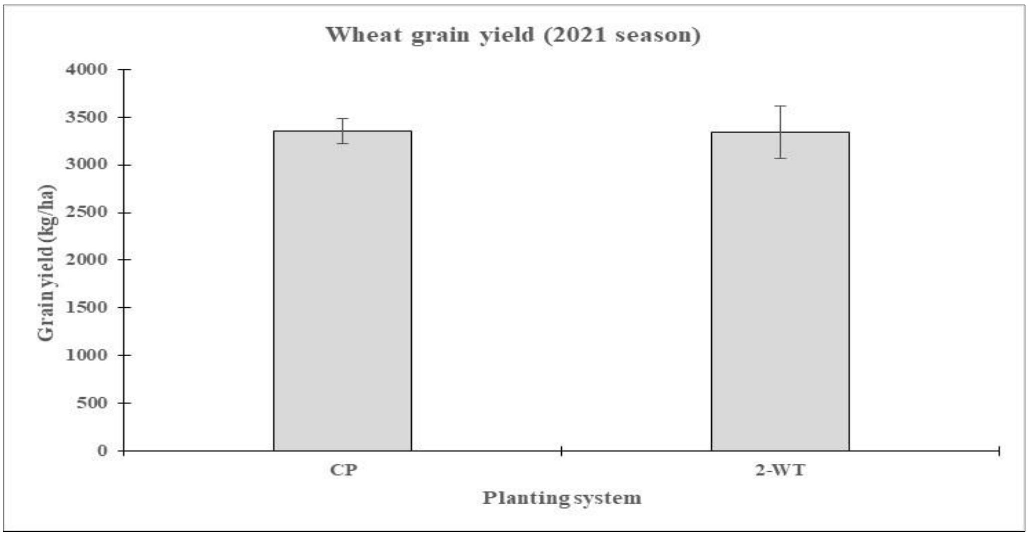


Figure 12: Gross margins from conventional practice and 2 WT direct planting systems across farms in 2021 season. Vertical bars represent standard deviation for each treatment.

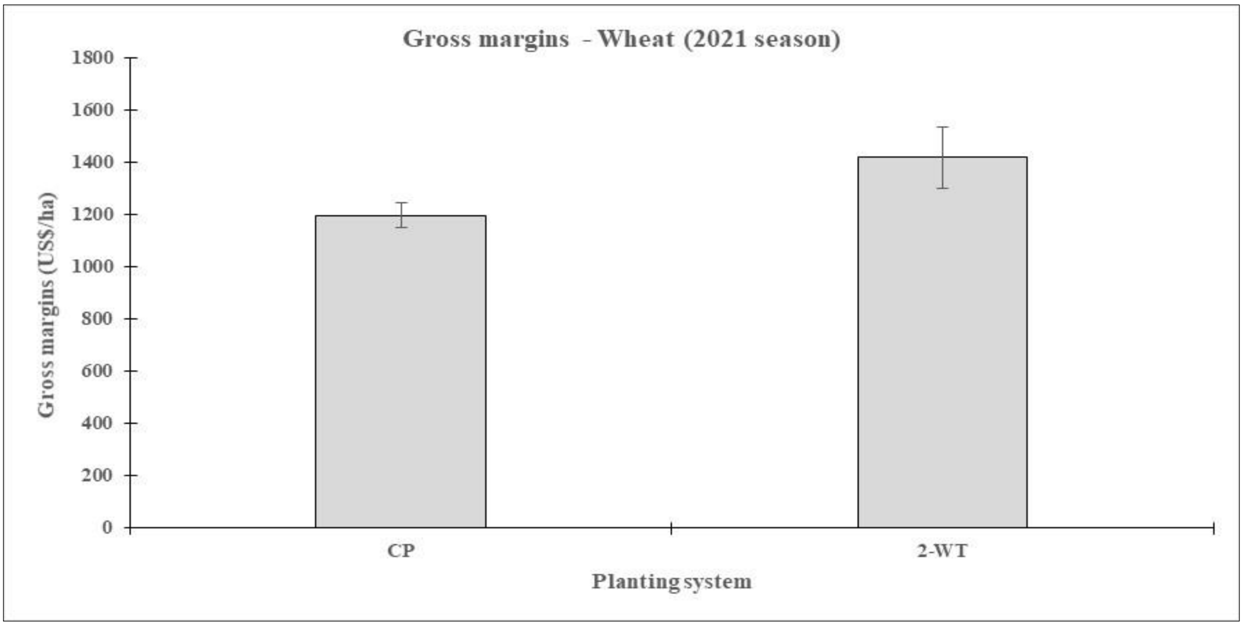


Figure 13. Maize grain yields from conventional practice and 2 WT direct seeding system across farms in 2021 season. Vertical bars represent standard deviation for each treatment.

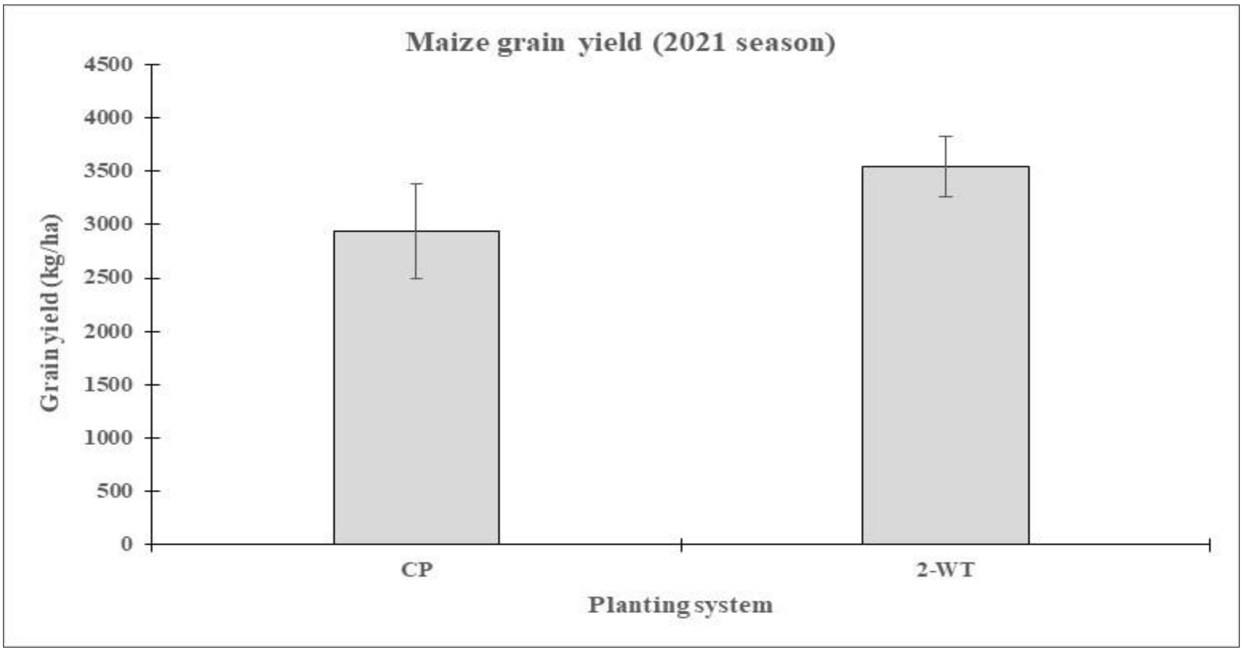
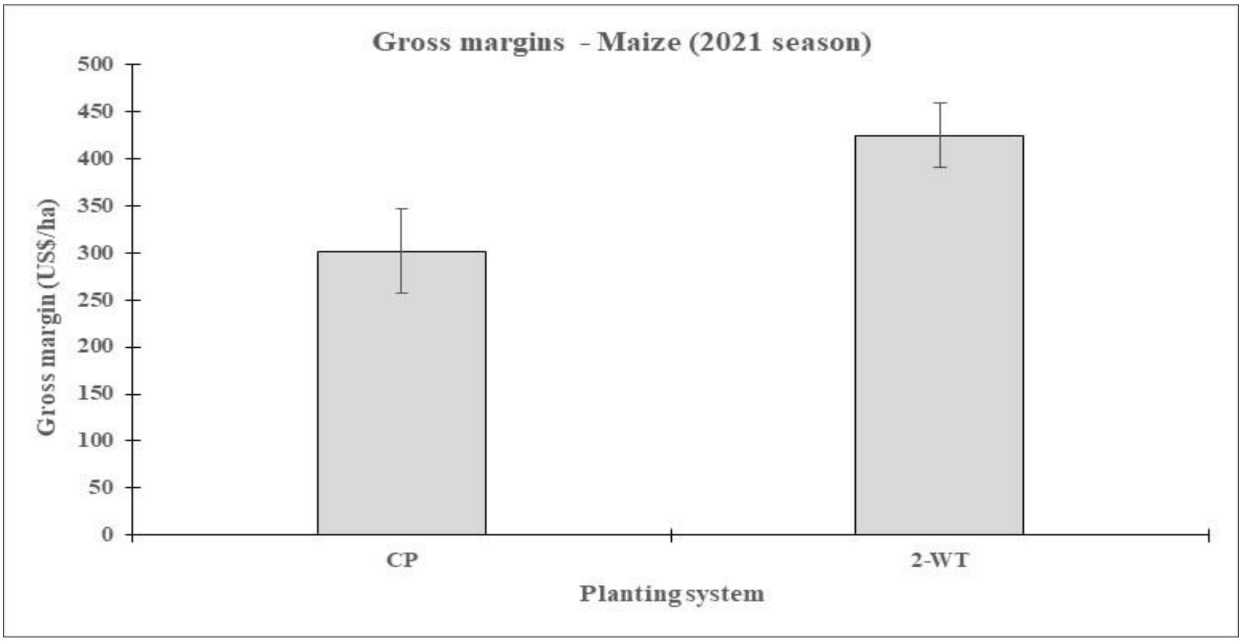


Figure 14. Gross margins from conventional practice and 2 WT direct planting systems across farms in 2021 season. Vertical bars represent standard deviation for each treatment.



Soil analyses from conventional and 2-WT treatments:

Soil conditions improved when tillage was stopped, and maize seeding achieved through direct planting using a 2-WT (Table 17). All measured soil parameters except total nitrogen were higher in the 2-WT treatment compared with the conventional ploughing. The increase in soil pH over time with direct planting is important for reducing soil acidity which is prevalent in western Ethiopia and other similar environments in the country. Similarly, the increase in soil organic carbon over time will improve physical, chemical and biological conditions of the soil, leading to increased crop productivity on the farms. The results also indicated an increase in zinc, one of the major micro-nutrients required for human nutrition.

Table 17. Soil properties measured 4 years after introducing 2-WT direct planting in maize systems of Gudeya-Billa District. (Figures in brackets are standard deviation of each mean).

Soil property	Conventional practice	2-WT direct planting
pH	5.6 (0.44)	5.7 (0.92)
Organic carbon (%)	3.4 (0.07)	3.8 (0.45)
Phosphorus (ppm)	4.7 (0.68)	5.2 (0.09)
Total nitrogen (%)	0.3 (0.04)	0.3 (0.03)
Sulphur (ppm)	8.5 (2.74)	10.7 (3.27)
Zinc (ppm)	2.6 (0.29)	3.5 (0.74)
Cation Exchange Capacity (ppm)	26.2 (0.57)	26.9 (0.81)

Capacity development

For the quality of data collection, the selected 15 enumerators (1 female) were trained by CIMMYT staff. A total of 198 farmers were engaged in mechanization adoption survey that helped to interact farmers

with enumerators and learn each other. In general, the project was not able to conduct farmers' 'capacity development through field days, exchange visits, and demonstration of reaper harvester, threshing/shelling machines and irrigation of high value crops due to travel restriction within the reporting period, which coincided with harvesting, post harvesting and irrigated vegetables' activities.

Key messages, challenges and lessons

Travel restrictions due to security concerns in some of the project areas. Project partners and service providers spearheaded the implementation of field activities.

Water lifting and delivery

Introduction

During Africa RISING phase I, the International Water Management Institute (IWMI) evaluated the feasibility of various water-lifting technologies which enabled smallholder farmers to overcome dry spells or increase their land productivity outside of the rainfed season. A number of water-lifting technologies, irrigation applications, and agronomic practices have been validated as the best-fitted packages for scaling irrigation technologies, practices, and services. These packages include different water-lifting technologies coupled with agronomic practices for irrigated fodder, avocado, and vegetable value production. Research findings in the first phase showed promise of using hand-and motorized pumps (solar, tractor driven, diesel pumps) to support off-season vegetable and irrigated fodder production

Under the Innovation Laboratory for Small Scale Irrigation (ILSSI), IWMI works together with its partners to develop sustainable scaling pathways for small-scale irrigation through the public and private sectors. During 2019-2020, the IWMI team, together with farmers and actors of the irrigated agricultural value chains in the various woredas, carried out research on the co-identification of value chain scaling pathways for these best-fitted packages. In Lemo, the private-led pathway was co-identified to further facilitate the scaling of these packages along with the irrigated vegetable and fruit value chains by leveraging ongoing ILSSI efforts and the various agricultural value chains being developed under Africa RISING.

Accordingly, IWMI has identified three components that can be used to construct the private-led scaling of water lifting technologies, namely building an irrigation equipment supply chain, farmers as business partners, and a scaling platform. The building irrigation equipment supply chain is a core component by which local equipment manufacturers develop their business with suppliers from big cities and manufacturing companies to enhance the availability of irrigation equipment stock. On the other hand, the manufacturers can establish their distribution and technician networks in the farming community by partnering with the local trader systems and farmer/community-based organizations. These networks help to provide technical support and maintenance services to irrigators. The technologies will be part of the ILSSI scaling initiative with the public and private sectors. The aim is that technologies demonstrated in the communities are in demand, available in surrounding markets, affordable, and economically feasible whilst the agricultural products find their way to the market. Hence, IWMI under Africa RISING will use a farm-to-market approach for the irrigated value chains of the Lemo District.

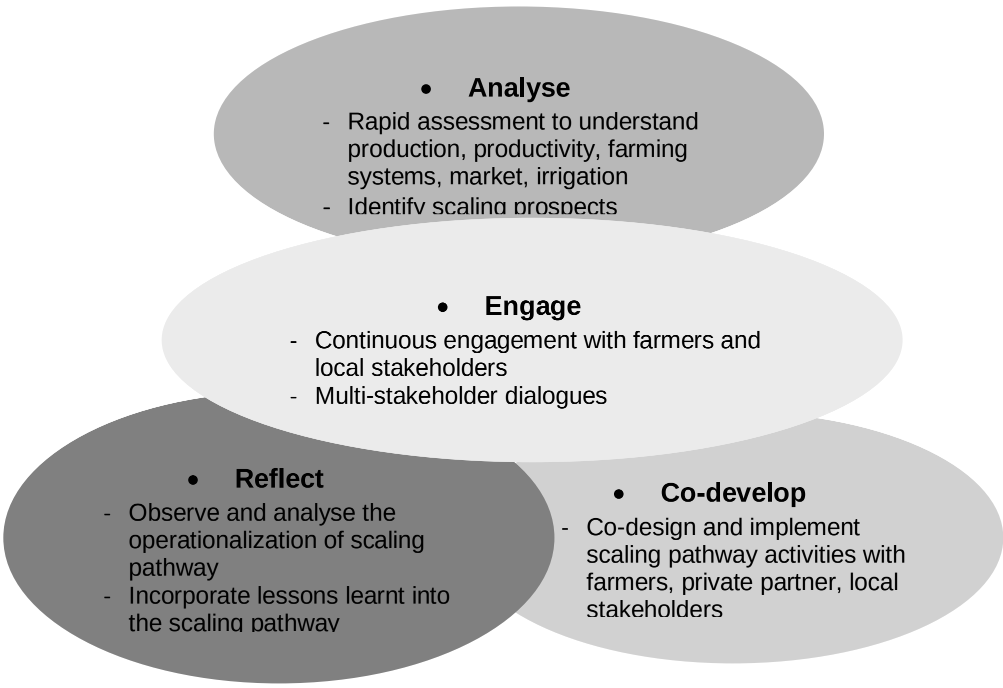
The farmers as business partners are another core component in which farmers and their organizations such as producer groups, communities, and religious platforms are seen as business partners. To strengthen their business capacity, it is necessary to build farmers' irrigation knowledge and skill and their collective organization of production and marketing, enhance their access to input market and services, and link farmer organizations with local irrigation equipment suppliers. This project actualizes the private-led scaling pathway for packages of irrigation technologies and agronomic practices for irrigated fruit and vegetable value chains in Lemo by:

- establishing market linkages for irrigated avocado and vegetables in partnership with private sector off-taker company, and
- linking the private-led scaling partnership with national multi-stakeholder dialogues

Brief methodology

To materialize private-led scaling of irrigated avocado production at Lemo, the action research approach is used with four interrelated steps: analyse, co-develop and implement, reflect, and engage (Figure 15).

Figure 15. Action research process: Steps and activities (Adopted from Minh and Schmitter 2020).



The **analyse step** included a rapid assessment by a team from IWMI, involving local researchers and facilitators from the agriculture bureau. The objectives were to better understand the context of farming systems, irrigation, and agronomic practices, and the market of target crop(s) at Lemo Woreda; assess the challenges, opportunities, and prospects for establishing a certified avocado supply chain in partnership with private actor and stakeholders; and learn from the practical experiences of farmer unions engaged in certified irrigated production and market linkage. The rapid assessment targeted high-potential areas (kebeles) for avocado production and Africa Rising areas in the SNNPR, Hadiya Zone, Lemo Woreda. Accordingly, data was collected from Shurumo, Dubancho, Hayse, Jawe, and Upper

Ghana kebeles. Various stakeholders and actors were also engaged in the rapid assessment and data were collected via semi-structured survey questionnaires, key informant interviews, stakeholder consultation, and field observations.

In this step, the survey was conducted with 200 households from Shurumo, Dubancho, Hayse, Jawe, and Upper Ghana kebeles. Semi-structured interviews were undertaken with informants from Meki Batu Farmer Cooperative Union (located in Meki town, Oromia Region), Gudiso Primary Fruit Cooperative (in Hayse Kebele, Lemo), Lemo Woreda of Agriculture staff (including head of the agriculture office, extension agents), farmers (avocado producers, seedling producers, and private actors including seedling nursery business in Hosanna Town, fruit retailers in Hosanna town, local pump distributor, and well-digger.

The key informant interviews were aimed at 1) learning from certification and market linkage experiences for irrigated horticultural crops, 2) understanding practical opportunities and challenges in the supply chain of inputs and production of avocado, and 3) gaining insights about existing irrigation technologies, supply and related services. Researchers also conducted field visits to supplement data collected from interviews, surveys, and stakeholder consultations. The visits and observations took place in different locations including avocado production farms of producers and Gudiso Primary Cooperative in the five kebeles, different seedling nursery sites (run by farmers, Wachemo University, and private businesses), and irrigation schemes and cold store facilities of Meki Batu Farmers' Cooperative Union (around Meki area).

The **co-develop step** involves processes and activities to communicate, jointly develop and implement the proposed market linkage activities through partnership with the private sector and stakeholders in the irrigated avocado value chain. Specific activities under this step are 1) organizing a stakeholder consultation workshop on 30 July 2021, to co-design the actualization of the private-led pathway for scaling irrigation technologies and services, 2) partnering with Rensys to establish a solar-powered irrigation pump supply chain to Lemo, and 3) organizing demand-supply linkage workshops to establish the sully chain of solar-powered irrigation pumps.

The **engage step** is carried out throughout the action research process, maintaining interactions with stakeholders, producers, and partners during the scaling process. These engagements identify and communicate key developments, involve new relevant actors and stakeholders as necessary, and provide crucial inputs for the **reflect step.** Linking the private-led scaling partnership with the MSD aims to accelerate the scaling pathways at the national level through integrating lessons learned, knowledge, experience, and the private-led scaling approach into the existing MSD and the Agricultural Water Management Task Force established by the Ministry of Agriculture. Through the dialogues, the private-led scaling approach can be leveraged to improve the enabling environment and uptake of appropriate scaling activities and approaches.

The **reflect step** is undertaken by the research team throughout the process to analyse feedback from farmers, partners, and stakeholders participating in the scaling pathways and integrate them into adapting the tested pathways. It also includes reflecting on approaches and scaling pathway, how to operationalize the identified scaling pathway, how local stakeholders, farmers, and private sector

participants appreciate the scaling approach, and how they react to it, incorporating these reflections and lessons into the scaling pathway and preparing for the further stakeholder engagement process.

Key results/findings

Enabling the agroecological avocado value chain in Lemo:

In Lemo, the farming system is commonly found with maize, wheat, teff, barley, beans, and peas in the field and mixed avocado, other fruits, and vegetables in the home garden. Agroforestry/mixed cropping in the home garden includes trees like avocado, coffee, and an inset with cereals and root and leafy vegetables. Avocado is grown with a mix of local and improved varieties are grown across farmlands and within farmlands. The most common varieties are Hass, Itinger, Fruiti, Nabal, and Red 30. There are some avocado farms with many trees (e.g. Shurumo).

Avocado farm management and agronomic practices are environmentally friendly and seem sustainable. Farmers use a mix of organic fertilizers to maintain soil fertility such as animal and plant residues and compost in the avocado growing areas even though inorganic fertilizers are used for cereal and some vegetable production. The majority also do not use inorganic crop protection chemicals for fruit production due to low commercialization from these farms and also low disease incidences so far. Most farmers have access to water for irrigation (e.g. shallow wells, rivers) and use water buckets to irrigate fields, only a few have access to different types of pumps. Irrigating avocadoes is common in the first 1-2 years of planting, followed by very limited or not undertaken in most cases to save labour and prioritize other crops. While most farmers keep mental records of the key farm activities, keeping written records is not a common practice.

Marketing of agricultural products including avocado is mainly to local wholesale and retail markets such as village/kebele markets and the larger markets in Hosaena town. Avocado farmers sell their products to traders, wholesalers, and cooperatives and sometimes by themselves. The role of brokers seems to be limited in avocado marketing. Farmers also mentioned general increases in the market demand and price trends for products including avocado although sometimes fluctuate. The main production constraints given by most are high input price, and lack of (access to) inputs like an improved avocado seedling.

Enabling the agroecological avocado value chain in Lemo has a number of advantages and opportunities. The area has suitable agroecological conditions for avocado to grow, a presence of surface/groundwater for irrigation, and high production potential. The current production of different improved varieties meets diverse demands for the domestic, export, and processing markets. The current avocado production is very close to the agroecological one as farmers mainly use sustainable and environmentally friendly agricultural practices. There are some avocado cooperatives and farmer groups established by Africa Rising Phase I. At the same time, farmers are highly interested in organizing the collective production for commercial avocado supply and are willing to switch crops, and agronomic practices if the price risk is minimized and the market is guaranteed. There is high demand for avocado in the local market especially during the fasting seasons as well as in the export market, particularly for the Hass variety. There have been interventions from the governments and development projects to support organizing producers and marketing of avocado to include the export markets.

However, challenges were also identified. Access to inputs, seedling, and water-lifting technologies is a challenge. Availability and cost of seedlings and materials for seedling production, propagation, and multiplication – only a few private businesses, trained farmers, and occasionally local agriculture offices supply seedlings for a price of ETB55-125/seedling, but most are sourced from neighbouring towns and regions. Especially nursery materials are sourced from long-distance markets in Debre Zeit and Addis Ababa. In addition to access, a major production constraint given is the high cost of these inputs and materials water availability (during the dry season) and access to technologies for water lifting and application, cost of digging shallow wells and boreholes (about ETB700/metre) were also mentioned by farmers in addition to limited availability of credit services for acquiring inputs and water resource development.

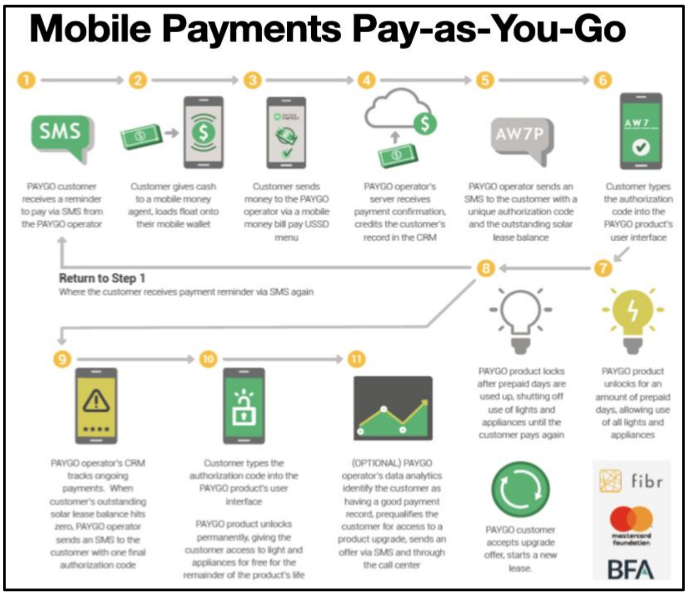
There are technical skill/information gaps when it comes to avocado production, irrigation requirements, estimating yield, tree management practices, and crop protection measures. There is also a lack of a local standard for good agricultural practices and product quality. There are also challenges when it comes to irrigation technologies. Lack of awareness, trained manpower, availability of pumps, and services was mentioned regarding solar pumps even though there is a preference for the technology. For treadle pumps, low quality and performance, and high labour demand are challenges. At the household level, avocado production is mainly for consumption and some for local markets. Most households that participated in the survey had few avocado trees, usually less than 10 trees. These consist of a mix of improved and local varieties, which may be challenging when it comes to supplying the required volume of a uniform variety of products – especially for the export market. Although the region has a high potential for increasing avocado production, it is still at a low commercial level.

Finally, Identifying and partnering with private off-takers for specific crops (like avocado), that have the right facilities, and that operate within a given geographical location of avocado production (to ensure logistics will not be a challenge) has been a challenge due for several reasons. The avocado supply is varying in terms of volume, quality, and variety for collective marketing.

PAYGO solar-powered irrigation pump supply chain in Lemo: Opportunities and challenges:

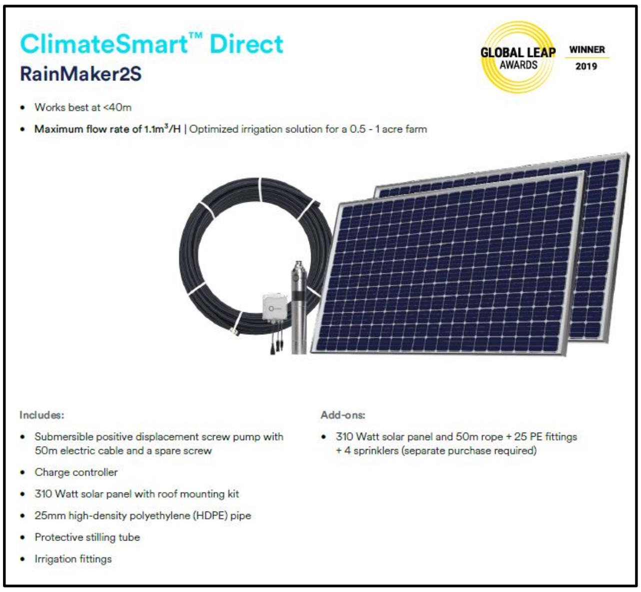
The pay-as-you-go solar-powered irrigation pumps are a bundle of the solar-powered irrigation pump with the pay-as-you-go financing service (PAYGO) when the distribution companies supply the pump (Figure 16). In partnership with ILSSI and Rensys, the company sells various types of pumps (e.g. Rainmaker 2S Direct, Rainmaker 2C Kubaw Direct, Rainmaker 2S with battery, and Rainmaker 2C with battery) and the PAYGO financing. The PAYGO is a pre-paid model, paying in small instalments to persons that cannot afford or are not willing to buy products in cash. A mobile money platform is created, and it sends a code to the product automatically once the customer pays monthly/under the agreed schedule. The platform monitors the system/product whenever the customer does not pay on the agreed instalment schedule and unlocks it while the payment is done.

Figure 16. Mobile pay-as-you-go financing service (PAYGO).



Rensys provides the PAYGO solar-powered irrigation pumps through the so-called credit sales customer Journey (Figure 17). Rensys agents/sales officers create the lead. The call centre team (number 8544 from Monday to Saturday) carries out a credit assessment. The customer finance officer reviews the credit eligibility status of the customer and transfers it to the technical team to carry out the Product-Client Fit Assessment and recommend the products. When the sale agreement is signed, the customers will be depositing 50% of the product down payment when installing the products as upfront cost and the rest as a loan over a period of 0.5 to 2 years. The technical team then carries out the product Installation and usage orientation. The customers pay their monthly payments using Mobile payments and in the PAYGO platform, payees are integrated with mobile payment operators and easily monitor remotely.

Figure 17. PAYGO solar-powered irrigation pumps.



The establishment of the solar-powered irrigation pump supply chain has several opportunities. First, the local presence of irrigation technology suppliers and service providers like manual pump manufacturers, distributors/retailers of motorized pumps, and well diggers provide a foundation for the establishment of solar-powered irrigation pumps in the area. There is also the presence of some farmers trained in seedling production who can engage if provided with the right support as well as access to some types of inputs (mainly inorganic fertilizers) via memberships in input supply cooperatives. The exiting services and support also create favourable conditions for the establishment of the supply chain. These services and support include the provision of diesel pumps for smallholders on credit, and the technical and financial support for water resource development at the community level (construction of wells, ponds) by local agricultural and irrigation offices as well as the successful demonstration and piloting of irrigation technologies including solar pumps by development actors.

Challenges have, however, been found in different forms. First, the limited development of water resources and year-round water access are the biggest challenges hindering the farmers' investment in water-lifting technologies such as solar-powered irrigation pumps. The lack of localized information on groundwater availability makes well-digging uncertain/risky investment and sometimes discourages users. The lack of deep sallow well-digging services is also hindering the farmers' investment in solar-based irrigation. Furthermore, the initial investment for solar-based irrigation is high as it is not only purchasing pumps but also constructing the water sources. There is a limited presence of tailored financial services and products for irrigation investment. There is also the low quality of locally manufactured manual pumps, and limited availability/access to spare parts and maintenance services. Due to market risks, and expectations to get pumps via project subsidies or for free, there are unclear intentions of making a major investment in solar-based irrigated production.

Capacity development

IWMI conducted one stakeholder consultation workshop on 30 July 2021 (see the methodology section) and the demand-supply linkage workshop on 31 March 2022. These workshops aim to raise awareness about solar-based irrigation and co-learning and co-designing the agroecological avocado value chain and PAYGO solar-powered irrigation pump supply chain in Lemo. Furthermore, IWMI also organized one demonstration for the PAYGO solar-powered irrigation pumps. In total 43 women and 150 men participated in consultation workshops and irrigation pump demonstration (Photo 6).

Photo 6. Irrigation pump demonstration.

Key messages, challenges and lessons

- The establishment of an agroecological avocado value chain is uncertain when targeting the export market channel. This is because the policy environment is discouraging foreign trading companies to invest in the exporting business as in the case of GreenPath.
- There is an expansion of avocado production in the region, attracting young farmers to establish new avocado farms. This is the right time to enhance the market linkages through the establishment of an agroecological avocado value chain.
- The biggest challenge to the establishment of the PAYGO solar-powered irrigation pump supply chain in Lemo is the access to more sustainable groundwater sources. Rensys has recommended integrating the well-drilling services into their PAYGO solar-powered irrigation pump bundle to capitalize the sale of the pumps.

Integrated landscape management

Introduction

Ethiopia is investing a lot in sustainable land management programs to curb land degradation problems and reverse its adverse effects on the ecosystem functions and peoples' livelihood (Adimassu et al. 2018). The landscape team (i.e. Alliance of Bioversity-CIAT), as a part of Africa RISING project, with its local and international partners, have been developing new ideas and approaches towards successful landscape restoration practices thereby supporting and facilitating the implementation of large national programs such as Sustainable Land Management programs (SLMP) in Ethiopia. To this end, we have followed two directions: (1) develop frameworks, indicators, and tools that can facilitate targeting and recommendation of appropriate land restoration practices, (2) implement a wide variety of physical and biological land restoration practices and technologies to test, pilot and showcase the proposed approaches. To this end, since the start of our engagement under Africa RISING, we have moved from two experimental sites to over six 'learning watersheds' across the country. With the support of the local community and bureaus, we have implemented a suit of technologies/options considering local specificity. We are conducting participatory action research and generating evidence of impact in those sites. In the last couple of years, Africa RISING has achieved milestones both in understanding landscape processes, developing frameworks and indicators as well as establishing and managing the learning watershed. Based on this background and challenges, the objectives of Africa RISING project under the landscape team for this year (i.e. 2021-2022) were: (1) to assess impacts of land restoration practices on different ecosystem services including soil, carbon, soil moisture, soil erosion, biodiversity, productivity etc. based on both data collected from on-site and modelling solutions, (2) develop scaling strategy using ex ante and modelling analysis and prepare compendium of technologies for various areas; (3) Finalize Landscape Doctor Toolbox – a toolbox that is designed to facilitate land assessment, technology targeting and impact assessment to be used by researchers and experts in support of restoration activities, and (4) provide capacity building for stakeholders. For this reporting period, we will focus on the activities related to the first two objectives.

Brief methodology

Impact assessment of restoration project investments:

Even though more than dozens of ecosystem services can be gained from well planned and executed restoration and conservation efforts, it will not be possible to measure, drive and/or assess all the benefits (under the provisioning, regulating, cultural and supporting services) (Keesstra et al. 2018). As a result, major ecosystem services that are representative of the three pillars of climate-smart agriculture (productivity, adaptation/resilience and mitigation), for which adequate field data are available and which can provide a good picture of landscape multifunctionality were selected.

Considering that we are interested in evaluating the multifunctionality of restored landscapes, crop yield, SOC, soil erosion, soil moisture, habitat quality, crop pollination and greenhouse gas (GHG) emission were identified for the associated analyses in this study. To estimate some ecosystem services at landscape level, we used the well-known InVEST (Integrated Valuation of Ecosystem Services and Tradeoff) model, developed by the Natural Capital Project (Nelson et al. 2019). Three ecosystem services that did not require the use of in situ data, and that could be supplemented with data from secondary sources were used to assess changes in ESs (ecosystem services) that are related to SWC interventions. Habitat quality, carbon sequestration, and crop pollination services were estimated based on modelling approaches that are supported by secondary data sources. The InVEST model was used to generate information on the estimation of only habitat quality, carbon sequestration, and crop pollination services. Finally, we compared changes before (baseline) and after (endline) land restoration investment, in this case 2010 and 2018 for four watersheds. In addition to the before and after situation, the optimal ecosystem service benefits that can be enjoyed provided that complementary and linked technologies have been implemented following the landscape continuum have been assessed for the study sites. This provides the optimal benefits that can be enjoyed provided that optimal allocation of interventions has been conducted. For all cases, the percentage changes between the three cases (i.e. before, after, optimal) were calculated.

Ex ante, scaling and visualization dashboard:

In the previous report period, for this specific deliverable, we have focused on the progress from the biophysical component of the work. Here we will outline the approached followed for ex ante and scaling of SLM/CSA technologies from socio-economic perspective. Systematic literature review on CSA practice adaptation has been conducted and synthesized. The helps to reduce bias and errors, improves the rigorous review process, and helps to organize the literature in specific contents/themes (Mihalache and Mihalache 2016; Tranfeld et al. 2003). Descriptive statistics such as mapping the spatial distribution of studied areas using the GIS, and ratios for scaling of adoption status and socioeconomic benefits of CSA practices have been used. Adoption rate of each practice was made based on the percentage of adopters out of the total studied sample size (Saguye 2019), i.e. practices with greater than 70%, 60-70%, 50-59%, 40-49%, and below 40% of adopters were classified as very high, high, medium, fairly low and very low rates of adoption, respectively.

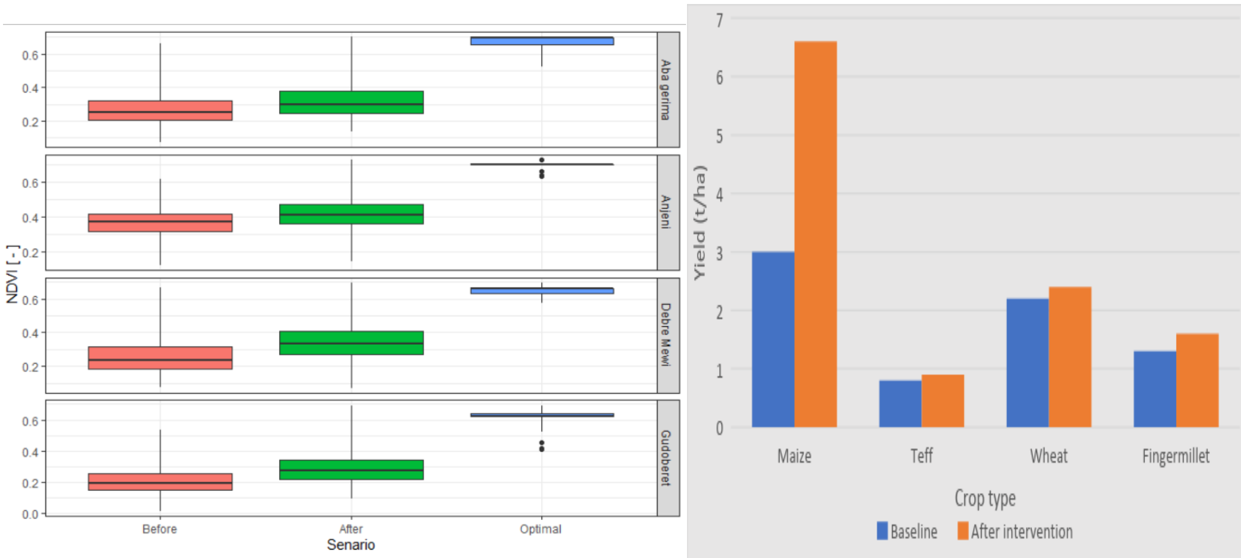
Key results/findings

The impacts of SLM interventions on ecosystem services:

The result shows that NDVI, which is the proxy of productivity, shows an increased trend from before to after scenario in all the watersheds due to SLM interventions (Figure 18a). Among the four watersheds, the highest change between after and before the SLM interventions was observed in Debre Mewi

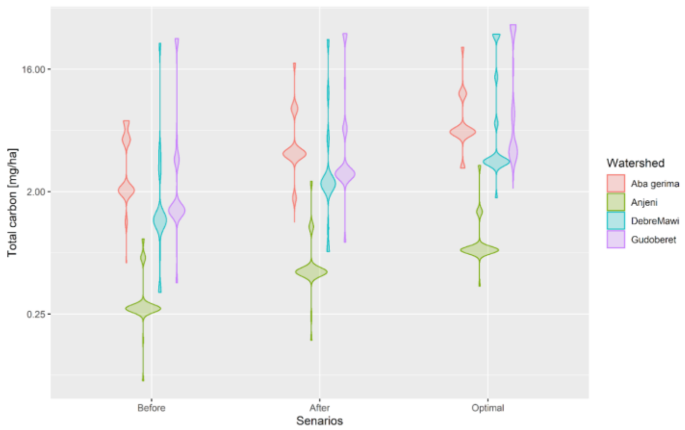
watershed. In all cases, the optimal scenario shows that there is still a possibility to improve the NDVI values significantly. In addition to the NDVI values, we have also obtained crop yield data for Debre-Mewi watershed (Figure 18). Crop production provides a good way of measuring direct economic gain of landscape rehabilitation projects. It is therefore a key indicator of landscape restoration efforts. In this regard, we have compared the baseline productivity data with yield for 2010 for four crops (Figure 18b). The result shows that the yield of four major crops (maize, wheat, teff, and finger millet) has increased following integrated land and water management interventions. The increase in yield varies from crop to crop, the highest being for maize (120%) while the lowest is for wheat (9%).

Figure 18. the impacts of watershed restoration on a) NDVI (before, after and optimal scenario) for four watersheds, b) crop productivity of four crops (maize, teff, wheat, and finger millet) in the Debre-Mewi watershed, north-western Ethiopia.



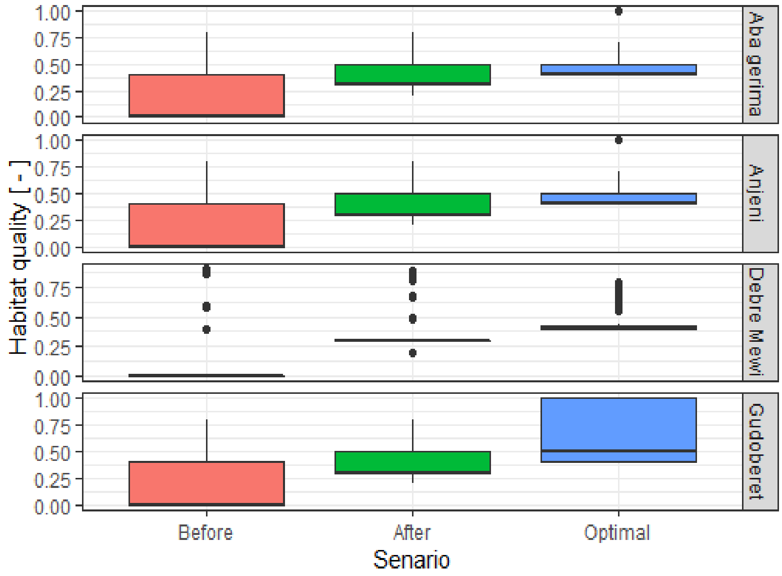
The results in Figure 19 show that there is an increase in the overall and average carbon stored in Mg per pixel for all watersheds following interventions. Among the four watersheds, Abagerima and Anjeni have the highest and the lowest total carbon storage, respectively. The optimal NDVI value shows that with more appropriate and enhanced management, there is still the possibility to sequester more carbon in all the watersheds (Figure 19).

Figure 19. Modelled carbon sequestration (Mg/pixel) across watershed and intervention scenario (i.e. before, after, optimal).



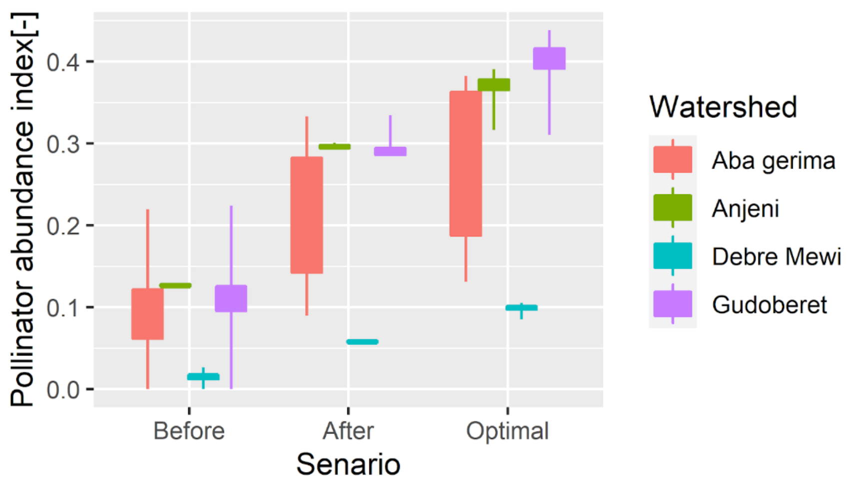
Habitat quality was modelled based on the LULC map of the watersheds and in consideration of the suitability of LU classes, and the threat/weight of other LU classes on suitable habitats (Abera et al. 2021). The habitat suitability index ranges between 0 and 1. The results show that the average habitat quality improved for all watersheds going from before to optimal SWC intervention cases (Figure 20).

Figure 20. Modelled habitat quality across watershed and intervention scenario.



Crop pollination was modelled based on the LULC change in the watersheds and in consideration of the presence of pollinator bee species, their relative abundance, availability of nesting grounds, and availability of floral resources. The values used here were mainly based on general literature and default values from the model builder were also adopted. Therefore, it is advised that the model gets customized with watershed specific values for more accurate estimations. The results in Figure 21 show that both the average and overall abundance of crop pollinators increased with improved landscapes across watersheds.

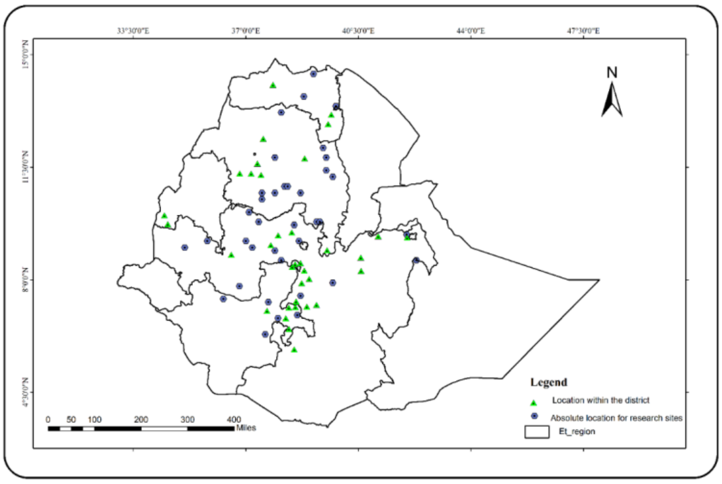
Figure 21. Modelled crop pollinators abundance across watershed and intervention scenario.



Ex ante, scaling and visualization dashboard:

We reviewed a total of 102 articles published between 2001 and 2021 in 60 agricultural and multidisciplinary journals. Since Scopus is one of the largest and most reputable abstract and citation databases for academic literature, we consulted 'Scopus List of Indexed Journals', and verified that all of these papers are drawn from reputable journals with 'Scopus site score'. Figure 22 shows the spatial distribution of case studies that presented adoption rate of various CSA practices and technologies.

Figure 21. the spatial distributions research sites from which papers have been published with consideration of adoption of CSA practices.



The adoption level of individual CSAP ranged between 34.7% for improved livestock and feed management to 60.1% for SWC (Table 18). The findings indicate that the adoption rate of individual CSA practices widely varies among smallholder farmers with a coefficient of variation (CV) ranging between 34.8% in improved livestock and feed management and 56.8% in conservation agriculture (Table 18). The most CSA practices adopted by smallholder farmers is SWC practice (60.1%) and followed by ISFM (56.6%) and agroforestry (44.2%).

Table 18. Adoption status of CSA practices and one way ANOVA test and post hoc analysis.

	N	**Mean**	**Std. deviation**	**CV**	**Std. error**	**95% Confidence interval for mean**		**Minimum**	**Maximum**
						Lower bound	**Upper bound**		
Integrated soil fertility management	24	56.63	21.649	38.2	4.419	47.48	65.77	11	90
Conservation agriculture	12	38.92	22.105	56.8	6.381	24.87	52.96	9	80
Soil and water conservation practices	46	60.07	24.161	40.2	3.562	52.89	67.24	14	100
Water harvesting and small-scale irrigation	20	38.55	19.728	51.2	4.411	29.32	47.78	9	67
Crop diversity and variety adoption	14	39.79	20.796	52.3	5.558	27.78	51.79	12	75
Agroforestry	17	44.24	18.133	41.0	4.398	34.91	53.56	16	69

Improved livestock and feed management	7	34.71	12.065	34.8	4.560	23.56	45.87	20	50
Total	140	49.37	23.227	47.0	1.963	45.49	53.25	9	100

Once the database based on studies from biophysical impact and the adoption studies of CSA/SLM is finalized, we will develop the ex ante and visualization dashboard. Once the maps are produced and validated, we will package and develop an interactive dashboard and visualization tool for users to enable them to extract the best-bet technologies in their area of interest. We will work on this in collaboration with federal and regional agricultural offices.

Capacity development

There was long-term support for PhD students, and there are seven PhD students that have been and are being supported through this sub-project. A total of 152 men and 105 women participated in surveys, training sessions, and workshops.

Key messages, challenges and lessons

Most of the SLM practices can provide multifunctional services. However, these services have not quantitatively evaluated and documented in a comprehensive manner. This undermines understanding the overall co-benefits of SLM practices and underestimates the gains that can be attained due to landscape restoration efforts. We are thus working to assess the multifunctional benefits that can be enjoyed as a result to SLM practices to inform decision-makers and promoting scaling methods and tools.

Nutrition (seasonal food availability assessment)

Introduction

Food availability almost all over Ethiopia is highly seasonal and understanding its dynamics is vital to identify entry points for sustainable diet diversity. Having as much seasonal food availability data as possible is advisable to get a better understanding of the type of foods available in the country. Therefore, a seasonal food availability assessment was conducted for the second time in all project sites incorporating the inputs received during the first nutrition seminar.

Brief methodology

The survey tool was updated to include animal-source foods /poultry, meat and eggs/. Data was collected mainly using focus group discussions (FGDs) and key informant interviews (KIIs) was added to verify the information provided by focus group participants (Table 19). Enumerators were selected by site coordinators in their respective area. Except in Lemo District, we used the same enumerators who conducted the first-round survey. The tool was shared with site coordinators and enumerators**.** A one-hour virtual training was given to ensure they had a full understanding of the work. The same participants who were involved in the first-round survey were interviewed – these includes experienced

farmers and merchants who are familiar with seasonal dynamics of foods, and both men and women with mix of ages, ethnicity, economic status.

Separate men and women FGDs were held in each site to promote participation of all and to identify differences in perceptions of food availability between women and men. Safety measures were implemented to avoid the transmission COVID-19. The participants were asked to list all the food items available for consumption in the community and to specify the months that each food item is available. Participants also specified the levels of availability each month. The level of availability was ranked on a four-level scale: not available (0), low availability (1), medium availability (2) and high availability (3).

Each food item was categorized to food group as follows: grains, white roots and tubers – starchy staples that are rich in carbohydrates. They are main source of energy (e.g. pasta, porridges, cereals, potato, sweet potatoes) = 1; pulses – foods including beans, lentils = 2; nuts and seeds – includes mostly tree nuts, groundnuts and seeds =3; meat, poultry and fish = 4; Eggs = 5; dark green leafy vegetables (DGLV) – this are rich in vitamin A (e.g. cassava leaves, pumpkin leaves) =6; other vitamin A-rich fruit and vegetables – this are typically orange, red or deep yellow fleshed both vitamin A-rich fruits and vegetables (e.g. ripe mango, papaya, melon, passion fruit) =7; other vegetables – vegetables not counted as dark green leafy or other vitamin A-rich vegetables (e.g. onion, garlic, cucumber, potatoes)= 8; other fruits – fruits aside from vitamin A-rich fruits (orange, apple, strawberries) =9; milk and other dairy products = 10

Microsoft Excel was used for data entry, cleaning and analysis. Result was organized by food item and food group for each site. Information on food items were provided by participants in local names– Amharic for Amhara and SNNP regions and Oromifa in Oromia region. Then the research team matched the local names to their English names.

Table 19. Summary of focus group discussion on seasonal food availability

Site	Group	Gender	Date	# of participants
Amhara, North Shewa Zone, Basona Worena	Merchants	Female	29/01/14 E.C	7
		Male	29/01/14 E.C	6
	Farmer	Female	27/01/14 E.C	7
		Male	27/01/14 E.C	7
Oromia, Sinana District, Selka Kebele	Merchants	Female	6 October 2021	4
		Male	6 October 2021	6
	Farmers	Female	5 October 2021	6
		Male	5 October 2021	7
SNNPR, Lemo District Jawe Kebele	Merchants	Female	14 October 2021	5
		Male	14 October 2021	6
	Farmers	Female	7 October 2021	7
		Male	7 October 2021	7

Key results/findings

The result has divided into three sections based on geographical area. Each section includes information about seasonality, diversity, culinary use, source of species, and seasonal food availability.

Seasonality in the three regions:

There are two rainy seasons in majority of the country and the seasons in the study areas are summarized in Table 20.

Table 20. Seasonality in the three regions.

Region/woreda	Season	Planting	Harvesting	Crop cultivated
Amhara/Basona Worena	Belg (short season)	Mid-Jan– Feb	Mid-June - July	Barley (major in this season), field pea
	Meher (main cropping season)	June – July	Nov – Dec	Wheat, barley, pulse crops, teff
SNNPR/Lemo	Belg	Mid Feb – Apr	June – July	Potato, haricot bean, barley, maize
	Meher	July – Mid-Aug	Nov – Dec	Wheat (dominantly grown), teff, barley, faba bean, field pea
Oromia/Sinana	Belg (short season)	March – Apr	Jul – Mid Aug	Barley (major crop in this season), potato, vegetables, maize, wheat (minor)
	Meher (main cropping season)	July – August	Nov – Mid Jan	Bread and durum wheat (dominant crop), pulses (faba bean, field pea, lentil), barley, emmer wheat (aja), linseeds, teff, vegetables

This assessment identified food species available in the area, how they are sourced, consumed, and perceived by the local population. In the culinary uses, the major edible parts and the methods of consumption were documented. The possible food sources include: 1) own production like from farm, home gardens and local trees; 2) market that includes nearby large market, local wet market, supermarket, shop/kiosk, street hawker; and 3) Wwild – uncultivated wild fruits and vegetables.

The availability of each food item was scored by participants on a scale of 0 to 3 in which 0 represents – no availability; 1 represents low availability; 2 represents moderate availability and 3 for high availability. As more than one FGD was conducted, we took the average of the availability score across all the focus group to integrate the dataset. Further analysis is proceeding to better understand the perceived seasonal availability of foods.

Capacity development

Trainings and workshops are included in the overall Africa RISING project capacity development of the current six months report.

Key messages, challenges and lessons

Initially, a survey was planned in a different season than the first SFAA survey which was at harvesting time for the main cropping season (Nov-Jan). However, all travels were suspended due to the election. Also, approval of the proposal took more time than expected and these could not allow us to carry out the survey during the period of June-Aug.

Capacity development at the project level

The Africa RISING project in the Ethiopian highlands managed to conduct different capacity development programs including training, field visits, field days, workshops and meetings and reached 3,063 beneficiaries in the current reporting period (Table 21). Two new PhD students were attached to the project during this reporting period, while two students (1 PhD and 1 MSc) completed their studies. One student dropped out for unknown reasons. The project has currently 14 students (Table 22).

Table 21. Africa RISING capacity development for 2021/2022 (1 Oct 21–31 March 22).

AR site name	Activity	Farmers (M)	Farmers (F)	Experts (M)	Experts (F)	Others (M)	Others (F)	Total
Basona	Field days	68	10	49	23	17	5	172
	Meetings	0	0	0	0	0	0	0
	Surveys	122	25	10	4	11	2	174
	Training	0	0	0	0	0	0	0
	Visitors	0	0	0	0	0	0	0
	Visits	0	0	0	0	0	0	0
	Workshop	0	0	12	6	16	3	37
Basona Total		*190*	*35*	*71*	*33*	*44*	*10*	*383*
Endamehoni	Field days	150	30	9	3	6	2	200
	Meetings	0	0	0	0	0	0	0
	Surveys	0	0	0	0	0	0	0
	Training	0	0	0	0	0	0	0
	Visitors	0	0	0	0	0	0	0
	Visits	0	0	0	0	0	0	0
	Workshop	0	0	0	0	0	0	0
Endamehoni Total		*150*	*30*	*9*	*3*	*6*	*2*	*200*
Lemo	Field days	290	90	45	13	9	0	447
	Meetings	0	0	25	1	0	0	26
	Surveys	124	7	14	7	8	7	167
	Training	2	5	24	0	0	4	35
	Visitors	0	0	0	0	0	0	0
	Visits	0	0	3	0	0	0	3
	Workshop	45	5	17	6	8	3	84
Lemo Total		461	107	128	27	25	14	762
Sinana	Field days	0	0	0	0	30	1	548
	Meetings	10	2	40	1	8	0	61
	Surveys	13	13	2	0	2	1	31

	Training	0	0	0	0	0	0	0
	Visitors	0	0	0	0	0	0	0
	Visits	13	13	2	0	7	0	64
	Workshop	0	0	0	0	0	0	0
Sinana Total		36	28	44	1	47	2	704
Various								1014
Various total								*1014*
Grand total		837	200	252	64	122	28	3063

Note: various refers to training, workshops, meetings, surveys, and visits conducted by CIMMYT, ICRISAT, CIAT and IWMI within and outside Africa RISING sites.

Table 22. List of students attached to the Africa RISING project in the Ethiopian highlands.

Name	University	Affiliation/program	Thesis title	Duration and status
Mekonnen Misganaw	Haramaya University	ICARDA/PhD	Genetic analysis and biochemical profiling of faba bean (*Vicia faba* L.) genotypes resistance *Orobanche crenata*	2018–2022/data collection and writing
Anteneh Ademe	Addis Ababa University	ICARDA/PhD	Genetic diversity of pea seed borne mosaic virus and identification of sources resistance from lentil genetic resources	2018–2022/data collection
Beyene Bitew	Haramaya	ICARDA/PhD	Genetic identity, epidemiology and management of faba bean gall disease in Ethiopia	Submitted his Thesis for May 2022 open defence
Getachew Kiros Gebremariam	Raya University	ILRI/MSc	The impact of Insosila production on household income and asset accumulation: The case of Endamehoni Woreda, Tigray region	2020-2021/ Finalized writing the thesis
Beletew Bekele	Debrebirhan University	ILRI/MSc	The effect of cutting height and frequency on biomass yield and foliage nutritional quality of tree lucerne	1 June 2021 to July 2022
Melkamu Berhan	Wachemo University	ILRI/MSc	The effect of intercropping Desho grass with vetch on biomass yield, nutritional quality and soil nutrient dynamics	1 June – 30 March 2022
Yonas Getaneh	Addis Ababa University	CIAT/PhD	Analysing risks of the Ethiopian Rift Valley lakes and proposing suitable management options	2019–2021/data collection and writing
Misiker Aragaw	Addis Ababa University	CIAT/MSc	The impact of restoration efforts on ecosystem services	2019–2020/data collection- dropped
Kibebework Getachew	Wondogenet University	CIAT/MSc	Prioritization of landscape restoration measures based on preferences of local communities for ecosystem services: the case of Basona and Hosanna, Ethiopia	2020 (completed)
Berhan Mohammed	AAU	CIAT/PhD (partial support)	The effect of water hyacinth on fish and fisheries in Lake Tana under natural and experimental conditions	2018–2021
Minychil Gitaw	Bahir Dar University	CIAT/PhD (partial support)	Hydrology and dynamics of water hyacinth on Lake Tana, Ethiopia: Understanding land-lake linkage and process	2018–2021 (Completed)

Wubneh Belete	Bahir Dar University	CIAT/PhD (partial support)	Establishing flow-ecology-livelihood relationships for Gumara river of lake Tana, Ethiopia	2018–2021
Ashenafi Ali	Addis Ababa University	CIAT/PhD (partial support)	Soil Resources Mapping Using Machine learning Techniques	2021–2024/proposal writing
Habtamu Sewnet	Addis Ababa University	CIAT/PhD (partial support)	Spatially explicit land use and land management optimization to facilitate informed decision making	2021–2024/proposal writing
Meseret Dawit	University of Johannesburg	CIAT/PhD	Optimizing irrigation efficiency of surface-groundwater with respect to climate change and gender sensitive	New
Abera Assefa	Haramaya University	CIAT/PhD	Hydrological Processes and Ecosystem Services under different Land Use/Cover and Management Practices in the Changing Climate of Central Rift Valley, Ethiopia	New
Konjit Abreham	Hawassa University	ICRISAT/ MSc	Effects of topography and different land use systems on selected soil properties and phosphorus sorption characteristics at upper Gana sub-watershed, Hadya Zone, Southern Ethiopia	2019-2021 writing thesis

Communications and knowledge sharing

The main communication channels supported are:

- Wiki internal workspace: http://africa-rising-wiki.net/Home
- Project updates on the program website: africa-rising.net/category/countries/Ethiopia/
- A Yammer network with internal updates
- Photos: https://www.flickr.com/photos/africa-rising/sets
- Repository: https://cgspace.cgiar.org/handle/10568/16500

Events from our sites, coordination office and CGIAR partners

Coordination office

6 October 2021: Africa RISING project in the Ethiopian highlands project coordination team discussed return on investment, RHoMIS and the upcoming annual planning meeting of Africa RISING– Virtual.

9 December 2021 Africa RISING project in the Ethiopian highlands project coordination team discussed the project activities and way forward– Virtual.

24 January 2022: Africa RISING project in the Ethiopian highlands project coordination team and site coordinators discussed project activities and annual planning for each site– Virtual.

2 February 2022: Africa RISING project in the Ethiopian highlands, project coordination team discussed policy brief production for crop-livestock-NRM technologies – Virtual.

9 February 2022: Africa RISING project in the Ethiopian highlands, project coordination team discussed extension manual preparation crop-livestock-NRM technologies – Virtual.

CGIAR centres

18-19 November 2021: Africa RISING project in the Ethiopian highlands organized progress update and planning workshop with CGIAR partners – Virtual.

30 November 2021: Africa RISING project in the Ethiopian highlands discussed planning and the way forward with CGIAR partners – Virtual.

12 January 2022: Africa RISING project coordination team, crop and livestock CGIAR partners discussed field update with site coordinators – Virtual.

7 March 2022: Africa RISING project coordination team, crop and livestock CGIAR partners and site coordinators discussed the establishment of tech parks and identification of key exit strategy interventions – Virtual.

Africa RISING sites

Amhara

26 February-13 March 2022: Africa RISING Basona Worena research site facilitated a household survey on the spill over effect of Africa RISING tested technologies. During the survey project, direct beneficiaries on bread wheat (Tsehay, Wane and Deka), durum wheat (Utuba, Fetan and Bulala), malt barley (HB1964, Bekoji-1 and IBON 174), faba bean (Dosha, Gora and Numan), oat and vetch mixture and vetch seed multiplication participants were parts of the survey technologies. A total of 119 farmers from Basona Worena, Moretina Jiru and Siyadebirna Wayu districts were directly interviewed. Moreover, a questionnaire was distributed to experts for the farmer-to-farmer seed diffusion study. We have collected filled questionnaires from North Shewa Zone livestock office; Basona Worena office of agriculture and livestock office, Tegulet Union, Mush Cooperative, Debre Birhan Agricultural Research Centre And University.

18-22 March 2022: Africa RISING Basona Worena site has facilitated a scaling assessment study. The first part of the study was a separate small group discussion with experts from the zone office of agriculture and livestock office. By doing this, it was possible to set scaling ambitions for the next 5 years on selected crop and livestock Africa RISING tested technologies. Five experts from the site have attended the meeting to set the scaling ambitions.

Oromia

11 December 2021: Africa RISING Sinana Research site organized a farmer field day in Goba District. It was organized in collaboration with Goba District Agriculture and NRM Office, and Sofumer Union. The field visit was taking place at Weltayi Kubsa, Aloshe, Welteyi Magida and Ashuta kebeles. The objective of the field day was to aware farmers and stakeholders of Africa RISING's best technologies, create interest and opportunities for further scaling, discuss and devolve responsibility among stakeholders to sustain Africa RISING legacies. The field visit includes durum and bread wheat varieties clustered seed multiplication, faba bean- Numan variety clustered seed multiplication, malt and food barley varieties seed multiplication. Oat seed and oat vetch mixture, fodder beet, alfalfa, and vetch demonstrations on Aloshe kebele FTC were also visited. More than 294 participants from Bale Zonal Agriculture and NRM Office, Madda Walabu University, Sinana, Goba, Dinsho and Agarfa District Agriculture and NRM offices, Bekume Oyora Primary Cooperative and Sofumer Union, model farmers and DAs participated in the event.

20 December 2021: A field trip was organized to evaluate the field performance of livestock feed seed multiplication and scaling in Ginnir District of the East Bale Zone. The field visit helped to observe the status of Africa RISING technologies on the ground and evaluate the effect of the current drought

condition on the technologies in the area. The visit also included oat seed multiplication on FTCs and model farmers' farms in the highland areas. The effect of the drought condition is seen in the neighbouring kebeles of the lowland districts, and most farmers still striving to persist in the changing hard weather condition. In some highland kebeles of the district, the oat seed multiplication is found to be in a good condition but needs moisture for grain filling.

28 October 2021: the Africa RISING Sinana Research site organized a field visit in Goba District. The objective was to see the field performance of the different crop seed multiplication implemented within the district. The faba bean Numa variety clustered seed multiplication on more than 6 hectares of land, the food barley Adoshe variety (3.3ha), the malt barley HB1964 variety (3.3ha) in W/Kubsa kebele and the bread wheat wane variety clustered seed multiplication (14.6ha) in W/Magida kebele were visited. Participants from Goba zonal, district and kebele agriculture offices, DAs and farmers attended the event.

24 February 2022: Africa RISING Sinana Research site organized a briefing meeting for Bale Zone Agriculture and NRM office. The objective was to evaluate the performance of Africa RISING crop seed multiplication and scaling of the 2021 cropping season, challenges, lessons learned and way forward. At the meeting, participants from Bale Zone Agriculture and NRM office, Sofumer Union, Goba, Sinana, Dinsho and Agrafa district representatives joined. Addisu Asfaw, Africa RISING site coordinator made a brief presentation on the achievements, challenges and lessons learned over the last eight years. In addition, the discussion was made to evaluate the achievements of the 2021/2022 seed multiplication activities. Prevalence of disease and shortage of rainfall were reported as major challenges encountered and agreement was made for the establishment of the Africa RISING technology park establishment. 'Africa RISING project is our strong partner that has been strengthening our extension system in delivering quality seed based on research findings. We need to learn from them and take up the best technologies for further scaling,' said Debele Habebe, Bale Zone Agriculture and NRM Office deputy head. He also added that the field performance of the seed multiplied last year was encouraging. Despite disease and drought pressure, the reported amount is impressive that could contribute to alleviating quality seed shortage at least within the target districts.

SNNPR

9-10 February 2022: The Africa RISING Lemo site organized a field visit to monitor enset field progress in Shurmo Kebele, Lemo District. Participants from Hadiay Zone and Lemo Districts agricultural office officials took part in the field visit.

4-5 January 2022: The Africa RISING Lemo site organized on-the-job training for farmers on avocado grafting in Lemo and Analemo districts. The training is aimed at in improving farmers' skills in grafting, seedling and land preparation basic skills to plant Avocado.

30-31 March 2022: The Africa RISING Lemo site organized a two-day workshop to discuss with partners irrigation technologies and demand-supply linkage. The workshop aimed to identify possible irrigation technology for farmers and sources. Participants from Wachemo university, Metmamen microfinance, private pump supplier and farmers took part in the workshop.

4-5 January 2022 Site level review and planning meeting was conducted in Hossana with the objectives to monitor multiplied forage seed status and availability to market for the coming season. Participants from Hadiya Zone Agriculture Department and district officials from offices of agriculture, livestock and fishery attained the meeting.

Africa RISING Ethiopia outputs by type

Blog posts

Quality barley seeds and linkages with breweries unlock better incomes for Ethiopian farmers

https://africa-rising.net/quality-barley-seeds-and-linkages-with-breweries-unlock-better-incomes-for-ethiopian-farmers/

Africa RISING partners update achievements and plans for the Ethiopian highlands

https://africa-rising.net/africa-rising-partners-update-achievements-and-plans-for-the-ethiopian-highlands/

Africa RISING contributes to sustainable agricultural intensification in the Ethiopian highlands

https://africa-rising.net/africa-rising-contributes-to-sustainable-agricultural-intensification-in-the-ethiopian-highlands/

Journal articles

Mokria, M., Gebrekirstos, A., Said, H., Hadgu, K., Hagazi, N., Dubale, W. and Bräuning, A. 2022. Volume estimation models for avocado fruit. *PLoS ONE* 17(2):e0263564. https://hdl.handle.net/10568/118006

Hammond, J., van Wijk, M., Teufel, N., Mekonnen, K. and Thorne, P. 2021. Assessing smallholder sustainable intensification in the Ethiopian highlands. *Agricultural System*s 194:103266. https://hdl.handle.net/10568/115011

Habermann, B., Vogl, C.R., Mekonnen, K., Bekele, K. and Felt, U. 2021. Farmers and scientists in AR4D: Looking at a watershed management project through an STS lens. NJAS: Impact in Agricultural and Life Sciences 93(1):126-151. https://hdl.handle.net/10568/116497

Bitew, B., Fininsa, C., Terefe, H., Barbetti, M. and Ahmed, S. 2021. Spatial and temporal distribution of faba bean gall (Physoderma) disease and its association with biophysical factors in Ethiopia. *International Journal of Pest Management.* https://hdl.handle.net/10568/116138

Desta, G., Amede, T., Gashaw, T., Legesse, G., Agegnehu, G., Mekonnen, K. and Whitbread, A., Bitew, B., Fininsa, C. and Terefe, H. 2022. Estimating yield loss of faba bean (Vicia faba L.) caused by gall disease in north Shoa, Ethiopia. *Experimental Agriculture*. https://hdl.handle.net/10568/118461

Research briefs

Hammond, J., Mekonnen, K. and Thorne, P. 2021. Valuation of the benefits to smallholder farmers from the Africa RISING program in Ethiopia 2011-2020. Africa RISING Brief. Nairobi, Kenya: LRI. https://hdl.handle.net/10568/117272

Presentations

Mekonnen, K. and Thorne, P. 2022. Africa RISING in the Ethiopian highlands: Project overview from 2012 to 2022. Presented at a project briefing virtual meeting with SLS management team 10 Feb 2022. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/118175

Gebreyes, M. 2021. Scaling Assessment of Africa RISING Interventions. Presented at the Africa RISING progress update and planning virtual workshop with CGIAR partners 18-19 Nov 2021. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/116702

Mekonnen, K. and Thorne, P. 2021. An overview of Africa RISING project in the Ethiopian highlands: Achievements and challenges from 2017 to 2021. Presented at Africa RISING progress update and planning virtual workshop with CGIAR partners 18-19 Nov 2021. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/116700

Gebru, M. 2021. Nutrition assessment results and lessons Learned. Presented at Africa RISING progress update and planning virtual workshop with CGIAR partners 18-19 Nov 2021. Addis Ababa, Ethiopia: Alliance of Bioversity International and CIAT. https://hdl.handle.net/10568/116703

Hammond, J. 2021. Two Assessments of Africa RISING: Sustainable Intensification and Return on Investment. Presented at the Africa RISING progress update and planning virtual workshop with CGIAR partners 18-19 Nov 2021. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/116701

Alene, T. 2021. Collaborative potato seed multiplication activity of Africa RISING and Debre Birhan Agricultural Research Center. Presented at the Africa RISING progress update and planning virtual workshop with CGIAR partners 18-19 Nov 2021. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/116704

Gebreyes, M. and Mekonnen, K. 2021. Capacity building and scaling of forage seeds supply systems for livestock value chains in Ethiopia. Supervision mission presentation—Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA),18 October 2021. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/116088

Mekonnen K, Getnet M, Abdulkadir B. 2021. Livestock feed and forage options: Briefing meeting with national partners. Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA), Nairobi, Kenya. 11 p. https://hdl.handle.net/10568/115545

Reports

Kangethe, E., Sartas, M. and Dror, I. 2021. The Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) in the Ethiopian highlands: Scaling scan report. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/116956

Caulfield, M., Abdulkadir, B., Mekonnen, K., Duncan, A., Thorne, P., Dabess, A., Muleta, T. and Hammond, J. 2021. LegumeSELECT: Rural Household Multi-Indicator Survey (RHoMIS) report for characterization of smallholder farming in Sinana and Digga Woredas, Oromia, Ethiopia. ILRI Research Report 84. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/116603

Abdulkadir B, Gebreyes M, Mekonnen K. 2021. Training need assessment report on livestock feed and forage production and utilization. Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA). https://hdl.handle.net/10568/116332

Mekonnen, K., Gebreyes, M., Abdulkadir, B. and Seifu, H. 2021. Africa RISING progress update and planning workshop with CGIAR partners: Virtual workshop, 18-19 November 2021. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/117271

ILRI. 2021. Africa Research in Sustainable Intensification for the Next Generation Ethiopian Highlands project, technical report, 1 April – 30 September 2021. Nairobi, Kenya; ILRI. https://hdl.handle.net/10568/116139

Posters

Minh, T. and Melaku, D. 2021. Operationalization of the private-led scaling pathway for irrigation technologies and avocado and vegetable in Lemo woredas. Poster prepared for the Africa RISING Progress Update and Planning workshop with CGIAR partners, 18-19 November 2021. Colombo, Sri Lanka: International Water Management Institute. https://hdl.handle.net/10568/116698

Abera, W., Tamene, L. and Mulatu, K. 2021. Creating multifunctional climate resilient landscapes: synthesis, packaging and exit strategy. Poster prepared for the Africa RISING Progress Update and Planning workshop with CGIAR partners, 18-19 November 2021. Addis Ababa, Ethiopia: Alliance of Bioversity International and CIAT. https://hdl.handle.net/10568/116593

Agegnehu, G., Rooyen, A., Desta, G. and Legesse, G. 2021. Validation of landscape-based site-specific fertilizer recommendations and integrated soil fertility management practices for wheat production. Poster prepared for the Africa RISING Progress Update and Planning workshop with CGIAR partners, 18-19 November 2021. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/116628

Gebrekirstos, A., Seid, H., Mokria, M., Hagazi, N., Hadgu, K., Hailemariam, G. and Dubale, W. 2021. Scaling up of high value multipurpose trees and their management practices at multiple scales: Homestead to landscape. Poster prepared for the Africa RISING Progress Update and Planning workshop with CGIAR partners, 18-19 November 2021. Nairobi, Kenya: World Agroforestry. https://hdl.handle.net/10568/116602

Mupangwa, W., Yahaya, R., Tadesse, E. and Kassa, A. 2021. Scaling out small-scale mechanization in the Ethiopian Highlands. Poster prepared for the Africa RISING Progress Update and Planning workshop with CGIAR partners, 18-19 November 2021. Mexico: International Maize and Wheat Improvement Center. https://hdl.handle.net/10568/116581

Nigir, B., Gebrehawaryat, y., Gebru, M. and Tilahun, M. 2021. Assessing the seasonal Food Availability and enhancing cultivar diversity of faba bean and durum wheat in Ethiopia. Poster prepared for the Africa RISING Progress Update and Planning workshop with CGIAR partners, 18-19 November 2021. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/116699

Bezabih, M., Mekonnen, K., Adie, A., Gebreyes, M., Abdulkadir, B., Dubale, W., Alene, T., Ebrahim, M., and Asefaw, A. 2021. Strengthening best-bet practices in feeds and forage development. Poster prepared for the Africa RISING Progress Update and Planning workshop with CGIAR partners, 18-19 November 2021. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/116627

Ahmed, S., Aynewa, Y., Bishaw, Z., Mekonnen, K., Asefaw, A., Alene, T., Ebrahim, M., Dubale, W., Gebreyes, M., Seifu, H. and Thorne, P. 2021. Diversification of wheat-based cropping system in the highlands of Ethiopia. Poster prepared for the Africa RISING Progress Update and Planning workshop with CGIAR partners, 18-19 November 2021. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/116592

Training materials

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

Opportunities and challenges

Opportunities

- Increasing demand for the Africa RISING validated technologies/innovations.
- Alignment of most Africa RISING validated technologies/innovations with development priorities Ethiopian government.
- Strong partnership with CGIAR centres, local universities, research institutions, extension services, NGOs, communities, private entrepreneurs, and development partners.
- The COVID-19 pandemic situation improved the use of digital communication tools among project team members, local partners, and farmers.

Challenges

- Security related problems has challenged us not to implement research and scaling activities in Endamehoni Africa RISING site in Tigray.
- The COVID-19 pandemic has limited field operations, restricted travel from the coordination office to different Africa RISING sites, affected survey and capacity development activities.

Project partners

Table 23. Africa RISING partners in the different regions and sites in 2020.

Partner	**Region and site**	**Organization type**
Inter Aide France	SNNPR/Lemo	NGO
Send-a-Cow	SNNPR/Lemo	NGO
World Vision	SNNPR/Lemo	NGO
Cooperazione Internationale Ethiopia (COOPI)-Ethiopia	Oromia/Sinana	NGO
Livestock and fishery development offices, and agriculture and natural resources development offices	SNNPR, Amhara, Oromia and Tigray	Government
Graduation with Resilience to Achieve Sustainable Development/Relief Society of Tigray (GRAD/REST)	Endamehoni in Tigray	NGO
Raya Brewery	Endamehoni in Tigray	PLC
Oromia Seed Enterprise	Bale-Robe in Oromia	Government
Local universities	Madda Walabu, Wachemo, Debere Birhan, Mekele and Raya universities	Government
Saint Mary and Michew ATEVT colleges	Tigray	Government
Regional research institutions	ARARI, SARI, IQQO, TARI	Government
Federal research centres	EIAR	Government
Cooperatives and unions	Amhara, Tigray, Oromia and SNNPR	Government and communities
Projects	TAAT, ILSSI, Grass2cash	Collaborative

Private entrepreneurs	Faji integrated farm, Eden Field seed company	Private farm
International research organizations	ILRI, ICARDA, CIAT, CIMMYT, ICRISAT, IWMI, ICRAF, Bioversity International, IFPRI	CGIAR centres
Fruit tree multiplication and training centres	Butajira	Government and communities

References

Adimassu, Z., Langan, S. and, & Barron, J. (2018). *Highlights of soil and water conservation investments in four regions of Ethiopia* (Vol. 182). International Water Management Institute (IWMI).

Keesstra, S., Nunes, J., Novara, A., Finger, D., Avelar, D., Kalantari, Z. and, & Cerdà, A. (2018). The superior effect of nature-based solutions in land management for enhancing ecosystem services. *Science of the Total Environment*, 610, 997-1009.

Mihalache, M. and, & Mihalache, O. R. (2016). A decisional framework of offshoring: Integrating insights from 25 years of research to provide direction for future. *Decision Sciences*, 47(6), 1103–1149.

Saguye, T. S. (2017). Determinants of adoption of sustainable land management (SLM) practices among smallholder farmers' in Jeldu District, West Shewa Zone, Oromia Region, Ethiopia. *Journal of Resources Development and Management*, 8(5), 96-116.

Tranfield, D., Denyer, D., & and Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal Of Management*, 14(3), 207-222.