Australian Government

Australian Centre for International Agricultural Research

Final report

project	**Developing integrated options and accelerating scaling up of agroforestry for improved food security and resilient livelihoods in Eastern Africa - Trees for Food Security - 2**
project number	FST/2015/039
date published	2 December 2021
prepared by	Catherine Wangari Muthuri
co-authors/ contributors/ collaborators	Caroline Njoki, Ruth Kinuthia, Athanase Mukuralinda, Wondwossen Gebretsadik, Charles Galabuzi, Jean Damascene, Anne Kuria, Judith Oduol, Phillip Smethurst, Shiferaw Tadesse, Maimbo Malesu, James Kung'u. Kiros Hadgu, Canisius Mugunga; Abrham Girmay, Solomon Kiros, Patricia Masikati, Sammy Carsan, Joel Buyinza, Clement Okia, Emiru Birhane, Prossy Isubikalu; Hadia Seid, Alex Mugayi, Immaculate Sekkito, S. Micheal, Joseph Gafaranga, Awol Toib, Assefa Tofu, Fergus Sinclair
approved by	Dr Nora Devoe
final report number	FR2021-065
ISBN	978-1-922635-77-8
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

Contents

1 Acknowledgments

The 'Developing integrated options and accelerating scaling up of agroforestry for improved food security and resilient livelihoods in Eastern Africa - Trees for Food Security – 2 (T4FS-2)' project team wishes to thank the Australian Government through Australian Centre for International Agricultural Research (ACIAR) for approving and funding the second phase of the project and granting the six-months extension which was beneficial for delivering the outputs of the project.

We acknowledge the great leadership at the World Agroforestry (ICRAF), the lead institution in this project and the Forests, Trees and Agroforestry (FTA) program of the CGIAR for the co-funding.

We appreciate our project partners for their contribution in successfully implementing the project activities notably, Ethiopian Environment and Forest Research Institute (EEFRI), Oromia Agricultural Research Institute (OARI), Rwanda Agriculture and Animal Resources Development (RAB) and National Forestry Resources Research Institute (NaFORRI) in Ethiopia, Rwanda and Uganda respectively. Universities including Mekelle University (Ethiopia), Makerere University (Uganda) and the University of Rwanda. International organizations such as African Network for Agriculture, Agroforestry and Natural Resources Education (ANAFE), Commonwealth Scientific and Industrial Research Organization (CSIRO) and World Vision. Urugaga Imbaraga in Rwanda and Mount Elgon Tree Growers Enterprise (METGE) in Uganda.

Special thanks to the national governments of Ethiopia, Rwanda and Uganda for supporting the project and providing an enabling environment through instituting agroforestry-related policies in the relevant ministries. We also extend our gratitude to the local extension agents; the collaboration of the T4FS-2 project with the government at all levels was remarkable.

We are immensely grateful to the ACIAR Research Program Manager, Dr. Nora Devoe for her leadership and dedication in the project. Her participation in project-related meetings and activities including the steering committee meetings mid-term and end of project review proved instrumental in providing guidance towards project implementation. We thank the ACIAR Regional Manager for Africa, Dr. Leah Ndung'u for her support and contribution in steering committee and review meetings. including linking the team to the Australian ambassadors to Kenya (Rwanda, Uganda) and Ethiopia and support in communication of project outputs through ACIAR.

We thank our esteemed partners- the farmers, we learnt a lot from you through project resilience and commitment to the project activities and all stakeholders who actively participated in one way or the other. We hope that the interventions and the skills gained during this project on agroforestry-related activities will be sustained and refined to cause transformation in livelihoods and landscapes.

2 Executive summary

The Trees for Food Security project (T4FS-2) embedded research within development initiatives in the target countries. It was based on the premise that addressing the research and knowledge gaps identified in the first phase (FSC/2012/014) and scaling up the key lessons learned will accelerate adoption of new technologies at scale. The project aimed at improving food security and smallholder livelihoods through the widespread adoption of appropriate locally adapted agroforestry practices in key agricultural landscapes in Ethiopia, Rwanda and Uganda. It was implemented by the World Agroforestry (ICRAF) as the lead, in partnership with national, academic, development and international institutions.

Despite the interruptions witnessed in 2020 / 2021 due to Covid-19 travel restrictions, the impact on the project was manageable. This could largely be attributed adopting farmer-led approaches to matching options to context, the alignment of project to government priorities, participatory engagement and capacity strengthening of local stakeholders, leveraging on other projects' interventions in the country and use of online tools and meetings to engage with and support in country project teams.

Key achievements outcomes and impacts include but not limited to:

Increased uptake of agroforestry technologies and the associated benefits (environmental, social, economic) by over 145,000 beneficiaries with direct participation of over 48,000 households via various scaling up strategies (Muthuri et al, 2021). This included adoption of context-specific agroforestry technology options through establishment of 5,036 participatory trials (Mukularinda et al, 2019, Galabuzi et al, 2019, Gebretsadik et al, 2019); efficient quality germplasm supply with production of over 4.2 million from the RRCs and satellite nurseries in the three countries; provision of context appropriate water management options in Uganda, Rwanda and Ethiopia; and formation of a sustainable grazing platform including development of sustainable grazing management options (Kiros et al. 2018). and policy recommendations in Ethiopia.

Enhanced capacity development and strengthening in agroforestry of over 10,000 stakeholders including youths with a male to female ratio of 2:3, 1:1 and 3:7 in Rwanda, Uganda and Ethiopia respectively through targeted and gender responsive activities/trainings. Agroforestry curriculum was improved through development of an innovative agroforestry curriculum guide for tertiary academic institutions/ universities in Eastern Africa region; policy influence and engagement in Ethiopia, Rwanda and Uganda.

Improved modelling capability, knowledge and understanding of agroforestry especially tree-crop interactions through research undertaken in the five long-term trials established, the development of the APSIM Next Generation model, and contribution to scientific knowledge through over 100 outputs including journal articles and conference presentations and development of an 'Interactive Suitable Tree Species Selection and Management Tool' for Ethiopia, Rwanda and Uganda;

Improved livelihoods and income options through identification and support of key value chains in Rwanda, private tree nurseries, tree tomato and for timber. In Uganda, timber and fuelwood, dairy and avocado were selected (Sekatuba et al. 2019) while in Ethiopia 3 fruit tree value chains were identified: Mango, Avocado and Apple (Mawia et al, 2018).

Gaps in research and development that were identified during project implementation like further developing the tree products value chains and associated financing options, and undertaking impact assessment similar to that undertaken in Rwanda impact assessment study in Rwanda will inform priority areas of further research and resource mobilization efforts. Lessons learnt from COVID19 disruptions include the need for capacity strengthening of national partners, strong partnerships, and importance of embracing technology in project implementation and monitoring for to enhance sustainability of project activities even after project exit.

Further, contribution to scientific knowledge through publications will continue

More information about the Trees for Food Security project is available on http://www.worldagroforestry.org/project/trees-food-security-2-developing-integrated-options-and-accelerating-scaling-agroforestry

Project's data is available on https://dataverse.harvard.edu/dataverse/T4FS

3 Background

Over 110 million people in Ethiopia, Rwanda and Uganda depend upon smallholder farming practiced across 25 million ha of land. Smallholders generally focus on subsistence, use low levels of external inputs, depend on rainfall rather than irrigation and have limited market access. Most rural households are resource-poor, food-insecure and vulnerable to climate change. This is confounded by increasing population (3% per annum across the region). These pressures have resulted in an increased demand for food, water and energy coupled with declining farm productivity, over-exploitation of trees in agricultural landscapes and deforestation.

The first phase of the Trees for Food Security project showed that for enhanced food security and improved livelihoods, establishment of a greater diversity of trees on farms was essential. During the first phase, project stakeholders testified on the benefits obtained from the project. They also emphasized the need for project to reach more farmers in different sites or contexts. It is against this backdrop that the second phase of the project was conceived with the aim of improving food security and smallholder livelihoods through the widespread adoption of appropriate locally adapted agroforestry practices in key agricultural landscapes in Ethiopia, Rwanda and Uganda.

Having been aligned to national priorities and plans, the project benefitted from high level government support in all the countries. In Ethiopia, some of the strategies and policies that are well aligned to the project are: (I) Climate Resilient Green Economy (CRGE) strategy which takes tree integration into farms and landscape as one of the main pillars to achieve the strategy, (ii) Ethiopia's plan to restore and plant trees in 22 million hectare by 2025 (iii) Agriculture-Led Industrialization strategy which considers agriculture and forestry as main inputs to transforming rural commercialization, and (iv) Second (2016-2020) Growth and Transformation Plan (GTPII).

Engagement of the project with the government of Ethiopia demonstrated the importance of participatory farmer trials and appraisal of local knowledge to determine locally suitable agroforestry options and has shifted priorities away from promoting planting of vast numbers of a single tree species to broader options to improve food security of smallholders. The government now allocates 16% of its budget for agriculture and has pledged to rehabilitate 22 million ha of degraded land by 2025 to improve food security, environmental resilience, and carbon storage. It has recently positioned agroforestry as a directorate in the newly established Ministry of Environment and Forests.

In Rwanda, the project is aligned to part of Vision 2020, which focuses on increasing trees on farm for improving products and services from agroforestry. This is through a strategic plan (Working document) jointly managed by Rwanda Natural Resources Authority (RNRA) and Ministry of Agriculture and Animal Resources (MINAGRI). This strategy targets to establish agroforestry systems on 85% of land with trees on farm and 30 % of forestry. To achieve this target there is a need to avail high quality and enough seedlings for farmers and establish efficient extension services and networking across the country. The T4FS project widened the range of tree species being promoted through farmer participatory trials.

Additionally, sustainable supply of wood and trees on farm is a priority (Republic of Rwanda, 2013). Under the Economic Development Poverty Reduction Strategy (Republic of Rwanda, 2013) agricultural sector development and investment plan is very important and integration of trees on-farm is one of the options recommended for landscape restoration and improved resilience to climate change. The government aims at increasing trees on farm in the cultivated land (85% of total land) and in Vision 2020 (Republic of Rwanda, 2000), the target is to increase tree cover up to 30% from the current 20%. The government also supports tree growing by private investors and smallholder farmers to create a green economy. The private sector is therefore involved in tree planting through nursery construction and seedling production.

In Uganda, the project aligns well to the following: I) agricultural sector development and investment plan and Uganda government mechanisms in support of integration of trees in farming systems, ii) The Uganda Vision 2040 on reversing deforestation and increasing forest cover, iii) National Development Plan on increasing the contribution of forestry to GDP and livelihoods and iv) National Forest Plan on promotion of farm forestry. The policies relevant to agroforestry are: Forestry sector policy, planning and legislative frameworks include; the Uganda forestry policy (2001), the National Forestry Plan (2013) and the National Forestry and Tree Planting Act (2003) as well as the draft National Forestry and Tree planting regulations (2014). Others are Agriculture sector policy, planning and legislative frameworks including the National Agricultural Policy (2011), Agriculture Sector Development Strategy and Investment Plan (DSIP2010/11-2014/15), and the succeeding Agriculture Sector Strategic Plan 2015/16 – 2019/20, the Uganda Strategic Investment Framework for SLM (2010-2020), National Agricultural Advisory Services (NAADS) Act (2001), Rangeland Management and Pastoralism Policy (2013).

Theory of Change

The project's theory of change (Figure 1) was based on the premise that addressing the research and knowledge gaps identified in the first phase and scaling up the key lessons learned will accelerate adoption of new technologies by farmers, to better manage trees on farms and in farming landscapes, promote new marketing strategies and create awareness of financial options to enhance tree-based value chains.

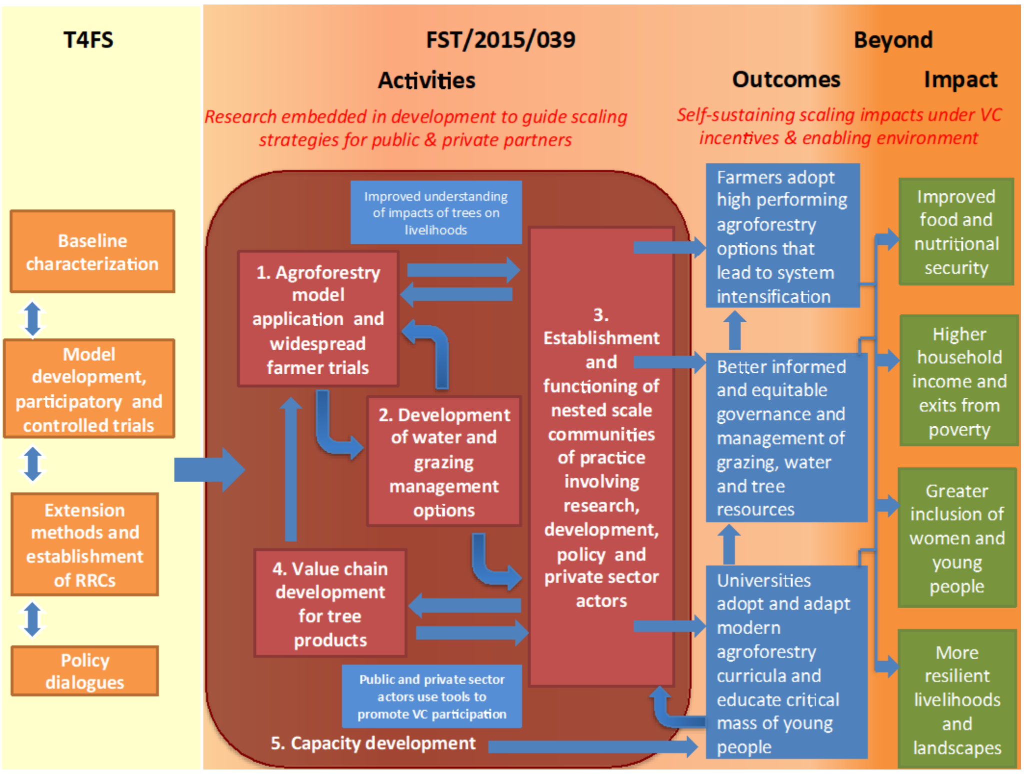


Figure 1: Theory of change. Activities in red boxes, outcomes in blue, impacts in green

During the second phase, the project reached over 48,000 households including smallholders and other stakeholders. This was achieved through the project's scaling out strategies implemented in the three countries. The project provided evidence on which options suit different sites and farmer circumstances.

4 Objectives

4.1 Key Objectives

The project aimed to improve food security and smallholder livelihoods through the widespread adoption of appropriate locally adapted agroforestry practices in key agricultural landscapes in Ethiopia, Rwanda and Uganda. It had five objectives.

1. To enhance knowledge of the impact of tree cover change on crop productivity, water, nutrients, and livelihoods
2. To integrate appropriate water management technologies and sustainable grazing options with promotion of agroforestry
3. To establish communities of practice capable of promoting scaling of locally adaptable agroforestry options supported by appropriate inputs systems
4. To examine smallholders and other market actor's ability to participate effectively and profitably in tree product value chains
5. To strengthen capacity of academic institutions in developing and implementing innovative agroforestry curricula.

4.2 Research questions

The project undertook research to address the following key questions:

Research question 1: What are the impacts of tree species and their management on crop productivity, water and nutrients dynamics across the range of national contexts?

Research question 2: What are the impacts of tree cover change on food production, water and smallholder across different socio-economic and environmental conditions?

Research question 3: What are the most appropriate water management technologies and sustainable grazing options for enhanced agroforestry practices in semi-arid areas within the region?

Research question 4: How can appropriate institutional arrangements be enhanced for large-scale adoption of agroforestry practices?

Research question 5: What organizational, institutional and financing arrangements are required and appropriate to increase the participation of farmers, traders and processors in value chains of priority products?

Research question 6: How can the capacity of academic institutions to develop and deliver innovative curricula in agroforestry be strengthened?

5 Methodology

5.1 Research Strategy

The project embedded agroforestry research within development initiatives of the target countries. This enhanced buy-in from national level stakeholders including national and local governments to ensure wide adoption and sustainability. The project was based on the integration and synthesis of diverse sets of information (i.e. biophysical, economic, social factors) across several spatial and temporal scales, from field and farm to the and landscape. Systematic planned comparisons and participatory scenario development and modelling were used to accelerate development impacts by matching tree management options and associated market and policy interventions to different sites and circumstances. Scaling was progressed by assessing best fit options and knowledge gaps for the target agro-ecologies in each country, and then, using a combination of methods including farmer participatory and controlled long term trials, disseminating knowledge, curriculum development and training to effect scaling. These elements were incorporated within communities of practice, at a range of scales that integrated promotion of tree diversity with effective learning about what management options work in different places. In response to feedback from research in phase one, specific components on water management, controlled grazing, access to credit, and value chain development were integrated in the project's research. Grassroots institutions such as farmer groups and cooperatives were strengthened to ensure significant uptake of agroforestry innovations among smallholder farmers including women and youths. Policy influence research was undertaken to identify factors and policies that support effective cross sector engagement in developing and promoting locally relevant and sustainable agroforestry options. The strategy is diagrammatically represented in Figure 2 below

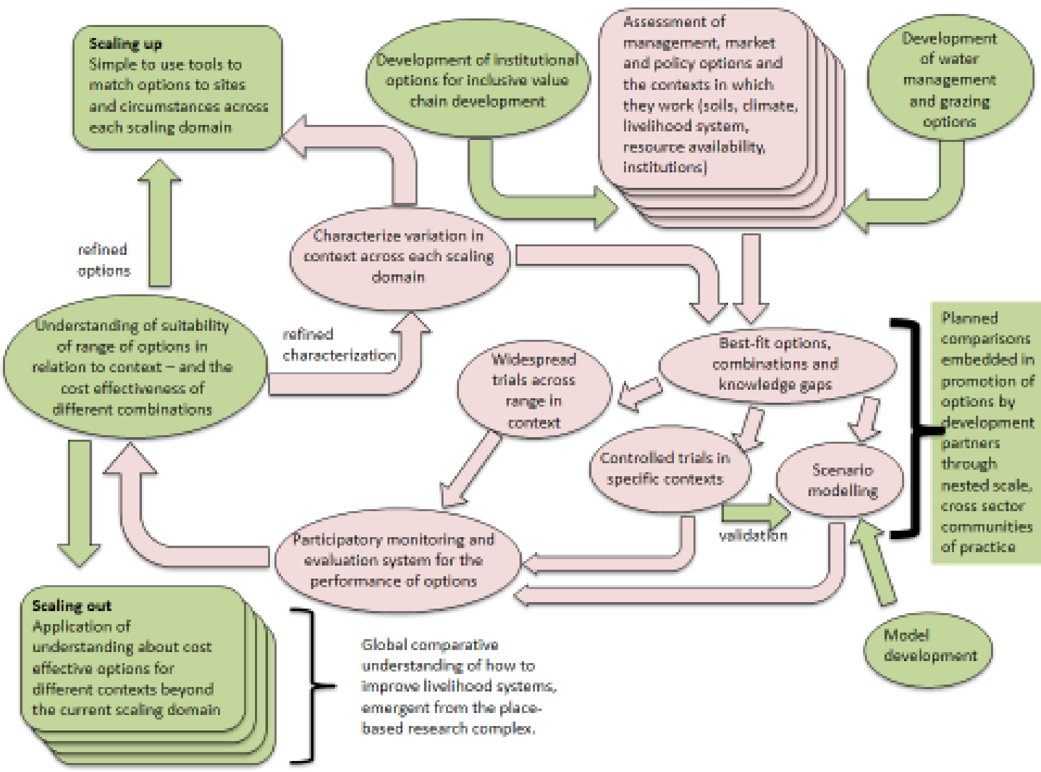


Figure 2. The research-in-development strategy adapted from the generic framework in Coe et al., 2014. Green elements denote key new aspects in the present proposal that augment the core elements in pink.

communications strategy, the project ensured that key findings were disseminated to the communities including women and youth. Different communication products it for different audiences were produced. Moreover, the project maintained relevant active communication links amongst the team members, partners stakeholders and the wider public during its implementation.

Success of the project is attributed to the robust Monitoring and Evaluation (M&E) framework that saw adequate tracking of project progress, timely reporting and implementation of the required corrective measures. Lessons learnt during the project implementation ensured that the project remained agile and adaptive in its delivery approach. As such, tangible results were achieved and new opportunities for development revealed.

The second phase of the project integrated more options from those initially implemented in the first phase to scale up and out agroforestry adoption in the target areas. These options include enhancing market access for high value tree products (including fruits, timber and charcoal); firewood and fodder production coupled with control of grazing of animals; and water management to ensure tree survival and crop productivity. Moreover, the second phase aimed at scaling up best fit options through enhancing government commitments and informing on national policies in the three countries, a gap that was identified during the first phase. This was achieved through the scaling strategy.

5.2 Project sites

The project was implemented in Ethiopia, Rwanda and Uganda. In Ethiopia, the project operates in Oromia and Tigray regions. In Oromia, the project was implemented in the semi-arid and sub-humid agroecologies. Districts in the semi-arid area include: Adami Tulu, Jido Kombolcha, Dugda, Lume, and Bora in East Shewa zone while districts in the subhumid area include: Guto Gida, Jima Arjo in East Wollega and Bako Tibe in West Shewa zone. The project was also implemented in Tsaeda Emba district located in the dry highlands of Tigray. In Rwanda, the project intervention sites are in Bugesera district within the semi-arid zone and in both Nyabihu and Rubavu districts within the humid agroecology of the country. In addition to the sites covered during the first phase, the second phase expanded interventions to new areas as follows: Bugesera district: Nyamigina in Mareba sector; Musenyi in Musenyi Sector; and Maranyundo in Nyamata Sector; Rubavu district: Bisizi and Gikombe in Nyakiriba sector; Kamuhoza in Kanama Sector; Nyabihu district: Gihira in Karago sector and Ruhengeri in Mukamira sector. In Uganda, the project was implemented in the sub-humid highlands of Eastern Uganda specifically in Mbale, Manafwa and Bududa Districts. The project sites are shown in figure 3 below

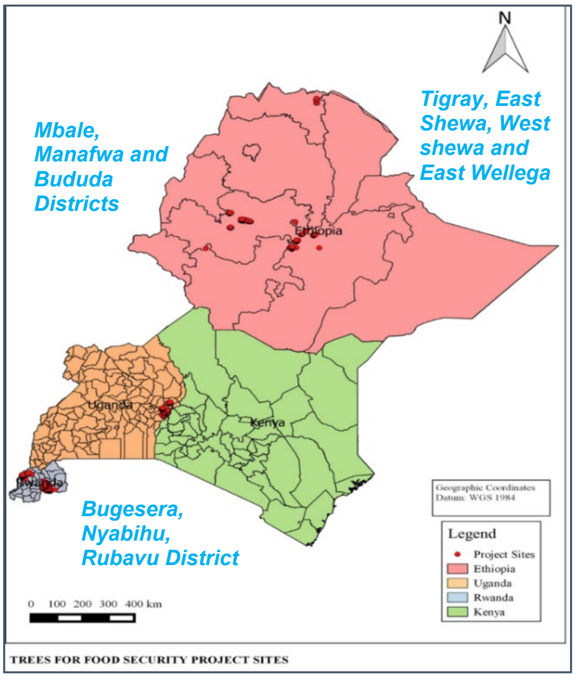


Figure 3: Map showing TF4S-2 project sites in Rwanda, Uganda and Ethiopia

5.3 Specific materials and methods per objective are highlighted below:

Objective 1: To enhance knowledge of the impact of tree cover change on crop productivity, water, nutrients, and livelihoods

1.1 Expand the networks of farmer trials across a range of contexts

Participatory trials

A total of 5,036 participatory trials were established representing 1,933, 2,290, and 813 in Ethiopia, Rwanda, and Uganda respectively. The participatory trials approach is where farmers are engaged from the design stage of the agroforestry technologies, testing and eventually adoption. This is in realization that farmers are critical of what is offered to them and choose only those technologies that appear the most useful and/or profitable for their specific conditions. It is therefore imperative that researchers work with the farmers to identify species and arrangements that provide maximum returns so that farmers will be motivated to continue with the technologies.

According to Coe et al (2014) the scale up process is risked by lack of well-designed research processes. To address this challenge, the project set up farmer participatory trials aimed at testing agroforestry innovations on farmers' fields and further disseminating them widely. Through this approach, farmers, researchers, and practitioners would observe the results and have an objective view of the performance of the technology. Through the trials, participants were able to innovate the technologies to suit their needs hence making the technology more relevant and sustainable. Moreover, the trials provide a learning platform for other farmers who observe and learn about the new technologies and eventually try them on their own farms. Coe et al 2014 further asserts that such an approach minimizes the risk of overreliance on a few successful case studies but rather provides an all-inclusive scenario of the performance.

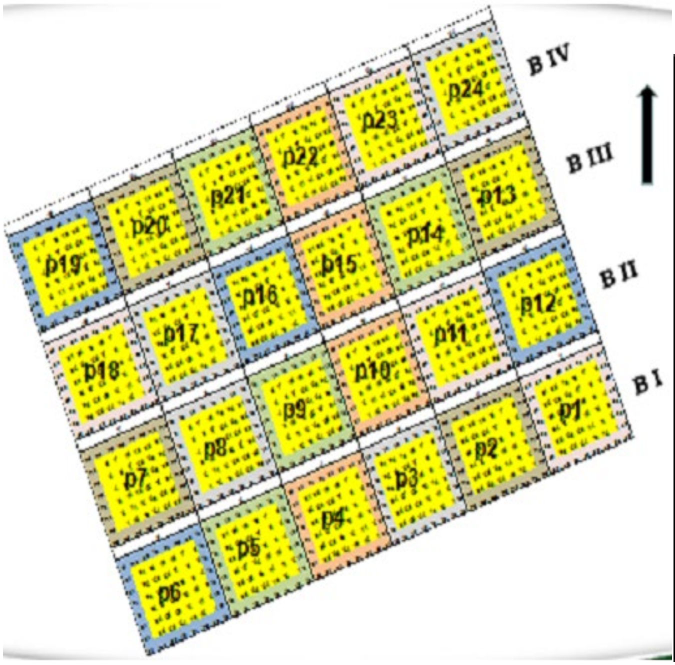
This component started with a participatory design workshop which were held in Ethiopia and Rwanda at the onset of the first phase of the project. During the workshop two sets of methodological tools and approaches were adapted. The InPaC-S participatory methodological tools were used to integrate local and technical knowledge (Barrios et al. 2012) on indicators of soil quality and existing constraints on key soil properties. Agroecology and soil management principles were then identified to address such constraints through integrated soil fertility management (ISFM) options involving agroforestry trees after which a relevant and robust trial design strategy was developed.

In designing the trials strategy, priority research questions were identified for each site. Designs for participatory experiments to investigate the questions were developed in conjunction with the extension staff. There after detailed protocols on the experimental design were produced and finally evaluated by farmers in an open meeting where comments and suggestions were collected to refine the experimental design. In Rwanda the trials consisted of four main types namely: stakes for climbing beans, fruits for nutrition and income (tree tomatoes, mango, avocado and papaya), biomass incorporation and soil conservation and erosion control (Mukularinda et al, 2019). In Uganda the trials comprised trees on farm, soil conservation, river bank stabilization, fodder banks, fruit orchards and woodlots (Galabuzi et al, 2019). In Ethiopia, the trials included fruit trees, multipurpose tree planting, apple root stock, sustainable grazing options and multipurpose trees with rainwater harvesting (Gebretsadik et al, 2019).

Long term trials

Data collection from existing long term four long term trials in Ethiopia and Rwanda (and the one to be established in Uganda), was carried out.
The trials in Ethiopia were established at Melkassa station in the semi-arid site and Bako Agricultural Research Center in the humid area. The treatments were continued and enhanced by including tree management options (shoot and root pruning at various degrees intensities) a wider crop species/ variety (as appropriate) and tree crop interactions instrumentation in the four trials in Rwanda and Ethiopia. The Melkassa long trial comprised

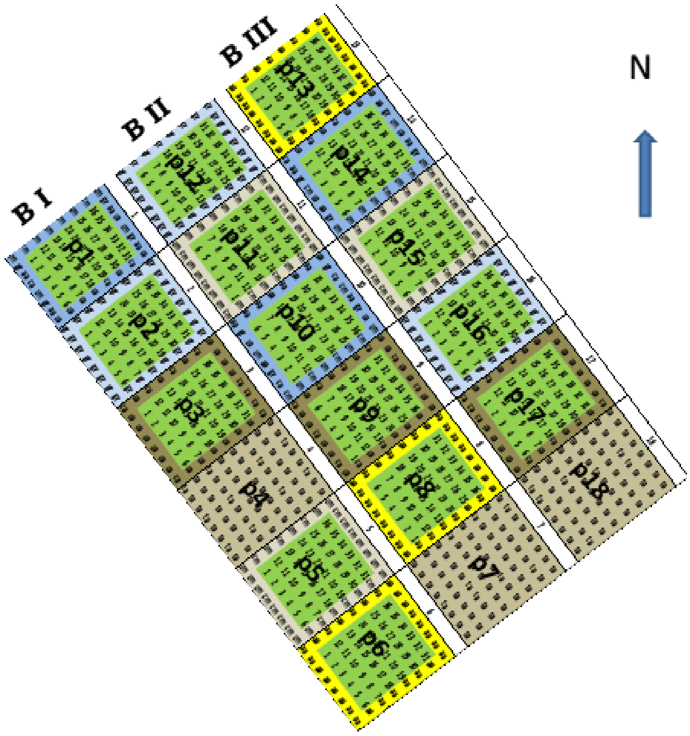
four different trees species including *Faidherbia albida*, *Moringa stenopetala*, *Acacia nilotica, Cordia africana*, a mix of tree species and crop alone plots were used as treatments arranged in RCBD with four replications (Figure 4). The tree species were intercropped with *Eragrostis tef*- teff, Teff of hybrid variety Boset was intercropped in 2017, 2019 and 2020 and in 2018 wheat was planted. Tree management was affected by pruning was affected in 2017 and crop and tree performance monitored as appropriate. Instrumentation of sap flow and soil moisture were also installed, and gaseous exchange of trees and crops monitored and light interception will be monitored through ceptometer mainly (decagon) Toib A PhD dissertation 2021.



P= plots
Plots 1,11,18 and 23 are planted with ***Cordia africana***
Plots 2,7,13 and 20 are planted with ***Moringa stenopetala***
Plots 3,8,17 and 24 are crop alone ***(Control plots)***
Plots 4,10,15 and 22 are planted with ***Acacia nilotica***
Plots 5,9,14 and 21 are planted with ***Faidherbia albida***
Plots 6,12,16 and 19 are planted with **mix of tree species**

Figure 4: Field layout of the Melkassa long term Long-term trial

In Bako, the trial was set up as a randomized complete block design (RCBD) (Figure 5) consisting of five treatments with replicated three times. Four tree species were planted in this trial which included *Cordia africana*, *Grevillea robusta, Croton macrostachyus*, and *Acacia abyssinica*. The treatments were (1) tree alone in monoculture (Cordia, Grevillea, Croton, and Acacia), (2) Tree alone in the four mixed species (3) crop alone (4) monoculture tree +crop, and (5) mix of tree species+crops. In the tree +crop treatments, teff (*Eragrostis teff*), maize (*Zea mays*) and finger millet (*Eleusine coracana*) were intercropped with the trees. A total of 16 trees were planted on each plot in August 2013 in planting pits having depth and width of 50 cm. Management treatments were carried through pruning of lower branches (25%) to reduce shading on crops with leaves and degradable twigs were incorporated into respective plots in the tree +crop integrated cropping during 2016, 2017, 2018 and 2019 growing seasons. Data on tree and crop performance were monitored throughout the project period. Gebretsadik et al 2018.



*Plots 1, 10 and 14 are mix of trees, Plots 2, 12 and 16 are planted with **Grevilliea robusta**, Plots 3,9 and 17are planted with **Cordia africana**, Plots 4,7 and 18 are **crop alone**. Plots 5, 11 and 15 are planted with **Croton macrostachus** and Plots 6, 8 and 13 are planted with **Acacia abyssinica**.

Figure 5: Field layout of the Bako Long term Long-term trial

In Rwanda, two long term trials were established in semi-arid Bugesera (Karama RAB Research and Extension Center) and humid Gishwati in Tamira RAB station figure 6, located in Rubavu district in Western Province. Both indigenous and exotic tree species were planted in the trials. In Tamira treatments included *Alnus acuminata* and *Croton megalocarpus* planted alone, their combination and maize (Zea mays or potatoes) planted alone in a Randomized Complete Block Design (RCBD). In Bugesera the treatment included: *Grevillea robusta* and *Faidherbia albida* as exotic tree species and *Markhamia Lutea* as indigenous. These trees were planted in a randomized complete block design with treatments combined as follows: Karama: Treatments include F+M; F+G; G+M; Crop alone- Faidherbia albida (F), Grevillea robusta (G), Markhamia lutea (M). in Tamira the treatments include A + C; Crop alone- Croton megalocarpus (C), Alnus Acuminata (A). Mukuralinda et al 2018, Similar instrumentation as those installed in melkassa trial were installed in Karama except for the gaseous exchange instruments while in Karama crop and tree performance under varied degrees of pruning was monitored.

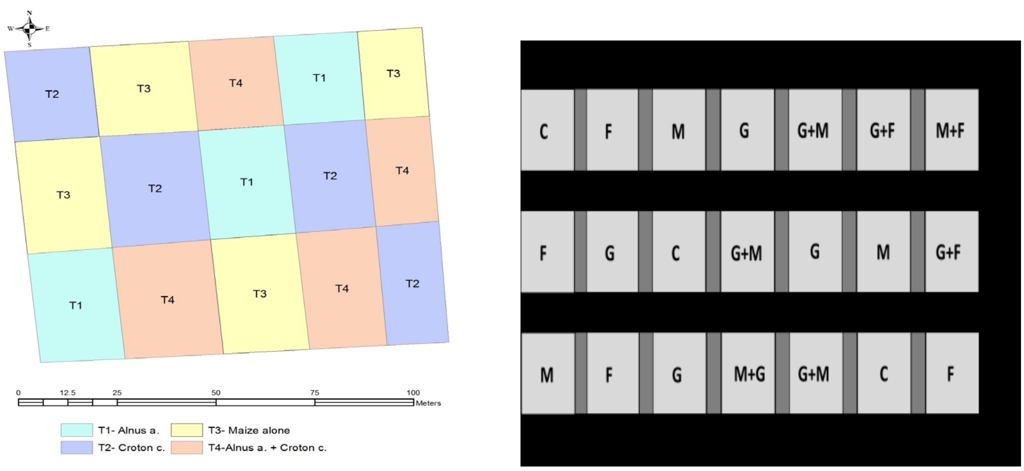


Figure 6: Experimental design in Tamira (left) and Karama (right) Rwanda

In Uganda, the trial was established at a research station of the National Agricultural Research Organization (NARO) in Bulambuli District in 2017. The approximate coordinates are 1°09'36.0"N, 34°23'48.0"E. Overall, the site is gently sloping (~ 8% slope) with an Udic moisture regime. The site has been under annual crop cultivation for > 40 years with limited external input. The major crops grown include cassava, maize and beans. A Randomized Complete Block Design to enhance understanding of tree-crop interactions and their impact on crop yield, water and soil resources was used. The experiment has a total of five (5) treatments, including, (1) *Cordia africana* and beans, (2) *Grevillea robusta* and beans, (3) *Albizia coriaria* and beans, (4) a mix stand *G. robusta*, *A. coriaria*, and *C. africana*, with beans, and a control of beans alone. Each of these were replicated three times. Three blocks were established with 5 plots each and the 5 treatments randomly assigned to the plots. Tree seedlings were planted at a spacing of 5m x 5m between rows and trees in 30m x 25m plots. A 5m buffer zone was created between the plots to prevent inter-plot influence. The trees were planted at the spacing of 5m x 5m making a total of 30 trees per plot. In the mixed plot, trees were planted in a random sequence while ensuring equal representation for all the species. In all the plots, trees were planted in the east-west orientation to minimize shading of the intercrop. A total of 450 seedlings were planted (Figure 7). Data was collected from the trial by randomly selecting 5 trees from each plot and assessing their growth performance. In addition, growth performance (Height increment, number of leaves, pods, flowers, leaf color, and yield) of five bean crops within an area of 2mx2m around each of the selected and tagged trees was assessed. Galabuzi et al 2018,

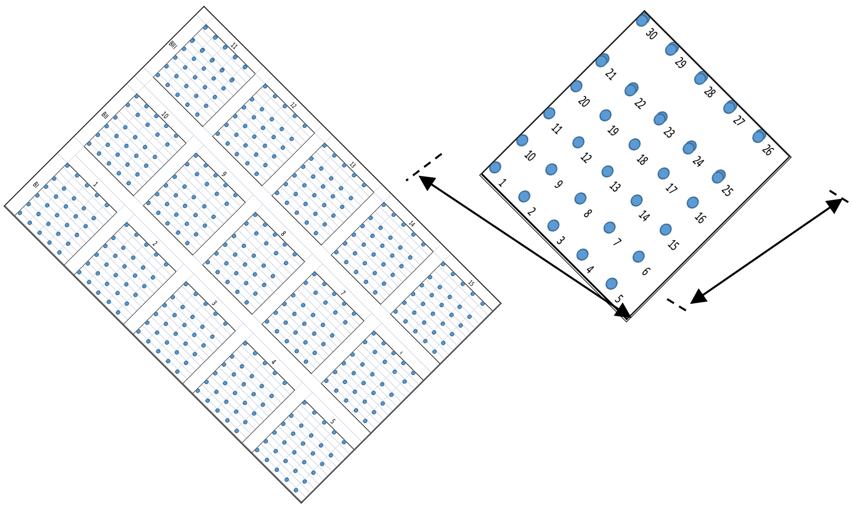


Figure 7: Experimental Lay Out at the LTT. Plot 2, 10, 14 Cordia africana and beans, Plot 1, 9, 11 Grevillea robusta and beans, Plot 3, 8, 12 Albizia coriaria and beans, Plot 4, 6, 15 a control of beans alone, Plot 5,7,13 a mix stands G. robusta, A. coriaria, C. africana, and M. eminii with beans

1.2 Enhance data collection on participatory and long-term trials

Data collection from the long-term and participatory trials, was carried out. A robust Open Data Kit (ODK) database was developed for Ethiopia, Rwanda and Uganda for data on farmer profiling, participatory trials, tree distribution, RRC performance and seedling survival and performance (Nyaga et al 2019a). Quality control checks were subsequently done, and data analyzed and reported. Data from long term trials included studying water potential, management options such as different levels of pruning, tree crop interactions and soil measurements. Tree water use was measured directly using portable sap flow gauges and that coming from rainfall distinguished from soil and groundwater. They were also used to understand how trees respond to water availability management actions such as pruning. Standard methods were used to measure soil moisture (profile probes) and stable carbon isotopes. Soil mineral nitrogen (N) was used as a standard measure of soil N availability and selected trees were labeled in situ to assess partitioning of above-ground and below-ground nitrogen contributions from trees to the soil and crop. The trees were intercropped with rotations involving different crops maize, wheat, potatoes, climbing beans and teff etc. as locally appropriate. Data on crop yields and tree growth in the newly planted trees into crop fields as well as the older existing trees in farming landscapes was also monitored.

1.3 Develop the APSIM X AF model for a wider range of tree species and cropping practices and complementary models at livelihood and landscape scales for local and national impact

Primary and secondary data collected in this project were used to enhance APSIM agroforestry modelling with calibrated trees (Gliricidia and Eucalyptus), crops (soybean and teff) and agro-ecologies (a humid agroecological zone in Indonesia. Semi-arid zone in Tanzania). These models were developed within the APSIM Next Generation framework (www.apsim.info), which uses modern software technologies. Phase 1 involved a proxy tree model used in linear (tree row) or circular (single tree or parkland) configurations in which tree behaviour in relation to competition for light, water and N was highly user-defined. Phase 2 involved an option to replace the tree proxy with 'active' tree model options that respond to environment, management, and genotype. Novel aspects for agroforestry modelling in APSIM include light modelling for alley systems, nutrient uptake based on mass-flow and diffusion principles, arbitration of C and N allocation to plant components, version control, auto-validation checking, auto-documentation, and model development methods for non-coders. SIMILE farm-scale modelling, interfaced with APSIM, was developed in collaboration with Jasper Taylor (https://www.simulistics.com/simile-apsim-communication) and Mary Crossland of Bangor University.

By reducing pollarding to 50% pruning, increasing fertiliser use; conducting research at a range of tree densities that quantifies below- and above-ground effects on soils, crop yields, wood production and carbon sequestration that could extend the tree-density range of validation of APSIM in *Faidherbia*-maize system, Ethiopia.

*C*onduct APSIM-SIMILE modelling as input to participatory experimental design for refining the *Gliricidia*-maize/bean system in Rwanda.

Widely advertise the APSIM and APSIM-SIMILE modelling capabilities, provide training, and include further application and validation in future agroforestry projects where it would be useful to conduct virtual experiments.

Ensure adequate below- and above-ground data are collected to develop and validate these aspects of agroforestry modelling in contexts where these new data would be useful.

Objective 2: To integrate water management technologies and sustainable grazing options with promotion of agroforestry

2.1 Conduct mapping of options in relation to context and, training in and facilitation of implementation of water management technologies appropriate for enhanced tree seedling establishment and growth.

This objective required collecting and preparing high-quality vector and high-resolution raster geospatial datasets for different roles in the analysis. Vector datasets required in this study were administrative boundaries, detailed road networks, complete town/market centres and entire river networks. For raster datasets, high-resolution gridded geospatial datasets of soil texture, rainfall, digital elevation model (DEM) and land use and land cover (LULC) were required. Most of these geospatial datasets were downloaded from known sites with quality datasets; however, the LULC layer was generated from high-resolution sentinel-2 satellite images to obtain the most recent LULC layers for the study areas.

Pre-processing of all these datasets followed, which involved clipping the datasets to limit the datasets to the study areas. This pre-process was carried out using administrative boundaries. Projection of these layers was also performed from the geographic projection system to the Universal Transverse Mercator (UTM) projection system. The UTM system was ideal for this study due to the possibility of performing calculations and measurements using the metric system.

Consistency in the resolution of the raster layers was also crucial. A resolution of 30 meters was selected for the study; therefore, all the layers had to have this spatial resolution. Whenever possible, interpolation was performed on the low-resolution datasets to achieve quality 30m raster products for the analysis. If interpolation was not possible, resampling of the low-resolution layers was performed to obtain the 30m layers. Vector datasets that were needed as raster layers were also rasterized to 30m gridded layers. Further, pre-processing of some layers was still required, such as the digital elevation model that required conversion into slope and reclassification of the slopes to match the traditional FAO recommended slope classes. The different slope classes were required due to the different implications they have on water harvesting and management.

Processing of the different geospatial layers mainly involved performing an overlay on the different layers to obtain detailed information on a pixel-by-pixel basis. The layers overlaid against each other were the slopes, soils, LULC and rainfall, thereby generating a single layer with the slope, soil type, LULC and rainfall information on a pixel-by-pixel basis. This information would assist with further analysis by providing valuable information during the characterization of the different scenarios of water harvesting and management.

Analysis of the overlay outputs entailed calculating runoff potentials and characterization of the layers based on the pixel information of slopes, soils, LULC and rainfall. The first analysis here was the computation of the runoff potentials by implementing the rational method of runoff estimation. The rational method involved estimation of runoff based on the surface area of a hydrological response unit (HRU) in square meters, the rainfall depth falling in that HRU in meters and the best estimate of the potential runoff coefficient for the HRU. The output of this computation was runoff volume in cubic meters (m^3) which were then converted to million cubic meters (m^3).

Characterization of this runoff potential was then performed to categorize the runoff potential into five classes of very low, low, moderate, high and very high runoff potentials. These categories are expected to support decisions related to water harvesting and management planning. In addition, due to the very close relation between runoff potentials and soil loss potentials, the overlay and runoff potential products were also used for potential soil loss mapping by employing a different characterization approach leading to the generation of seven potential soil loss classes of Extremely low or no soil loss, Very low –Tolerable, Moderate, High, Severe, Extreme and Exceptional.

Some of the recommendations made include:

- On cropland with slopes 0-5%, the recommended practices include Conservation Agriculture (CA), agroforestry, soil and water conservation measures including: Zai pits, trapezoidal bunds, level bunds, grass strips, stone bunds all constructed along the contour. This should be combined with soil fertility improvement measures such a green manure (such as sun hemp or velvet beans), crop rotations, compost and animal manure.
- On cropland with slopes 5-16%, we recommend the promotion of CA, graded bunds, Agroforestry parklands and Runoff ponds (for either irrigation or livestock), check dams, water pans for pasture (with baling) and livestock drinking and FMNR.
- Where the slope is 16-30% and the soils are deep and stable, the use of terracing combined with Agroforestry is highly recommended. Small earth dams for irrigated agriculture and livestock production can also be constructed where dam sites are present.
- For areas with slopes greater than 30%, we recommend the growing trees and if degraded to promote farmer managed natural regeneration and afforestation.
- Regarding forestland we recommend the conservation of all important indigenous tree species and controlled harvesting of the same. Shrublands should be used for

controlled grazing and FMNR. where the slope is 0-5% trapezoidal bunds can be used for harvesting rainwater for improved pasture production.

- The use of wetlands for irrigated agriculture should be highly regulated by the government to prevent loss of the vital ecosystem.
- The data generated is also helpful for new plans and projects. However, more work must include the socio-economic context to enrich the knowledge and enhance ownership of the recommendations.

2.2 Review existing policies, strategies and institutions on grazing, and identify barriers to their adoptions

Land users across all focal countries have converted large tracks of forest and grassland to cropland. This trend leads to the degradation of cropland through wind and water erosion. Farmers do not have adequate knowledge to place effective conservation measures to reduce the impact of soil erosion. Consequently, both livestock and crop production are below expected levels. Besides, maize yield, for instance, is less than one tonne per hectare per year. This production level is far below the potential on-farm yield of 5 tonnes on-farm. The good news is that farmers with conservation measures produce 3-4 times within the same project sites than those practising conventional farming practices.

The studies have demonstrated that with good data on biophysical and socio-economic aspects of farm landscapes, planners and extension agents can design context-based interventions, which results in the sustainable production of farmland. Farmers cope better with climate change, which is currently making farming highly vulnerable to changes in weather.

Land and water management requires a multi-disciplinary approach with several sectors, including agriculture, environment and water. Several stakeholders, including government, civil society, private sector, and local communities, should address degradation challenges collectively. The actions should be addressed over a relatively more extended period than the project cycle of 3 years. Experience shows that such actions should last between 10-20 years for significant impact to be achieved.

This component included consultative workshops/discussions with policy makers, relevant ministries, local authorities, communities, and farmers. Consultative discussions were held with three ministries namely Ministry of Agriculture and Natural Resource, Ministry of Livestock and Fishery, and Ministry of Environment, Forest and Climate Change on free grazing issues and enhance the integration of diversified tree species in mixed crops-livestock farming system and develop sustainable grazing strategies to utilize trees and shrubs grown on farmlands to encourage cut and carry feeding practices. In addition, household interviews and focus group discussion with community leaders, youth, women, elderly, religion and cultural leaders, to explore if there are policy gaps, poorly designed policies or limitations in enforcing bylaws on free grazing that do not match local demands and context. Discussions with Heads and experts for Tigray Region Bureau of Agriculture and Natural Resource, and Tigray Region Bureau of Justice were also done on the potentials and challenges of integrated sustainable grazing and agroforestry practices at the landscape scale. After the discussions, the heads and experts of both offices have recommended to develop a term of reference (TOR) with clear task description of each sector to promote sustainable grazing option and enhance agroforestry. A field survey was made in Oromia and Tigray regions to select trial sites and assess the impact of earlier introduced grazing and forage development technologies and governance mechanisms.

The present study has reviewed different policy documents, proclamations, strategies, implemented technologies, reports and scientific publications (see Table 7) to understand and determine the contribution of the existing policies, institutions and technologies on restricting free grazing, and for adoption and scale up of agroforestry. Furthermore, the limitation of poorly designed technologies and polices that do not match local demands and context in implementing free grazing restrictions was explored.

Free grazing reflects technological, institutional and policy related problems on the landscape including on farmlands has result in poor performance of livestock productivity and damaging physical conservation structures, consume and trample on naturally growing and artificially planted seedlings on the landscape. Due to a top-down advisory approach, weak implementation capacities of local institutions for local bylaws, limited input access for forage, poor market linkage for livestock products, and shortages of feed processing enterprises, have been found to practice free grazing and low adoption of agroforestry. In addition, ineffective institutional and sectoral arrangements, and integration at different levels, and across levels, including limited involvement of informal institutions, has hampered restriction of free grazing and adoption of agroforestry.

Therefore, to enhance the livestock productivity and adopt the scale up of agroforestry, sustainable grazing options are required and supported by context specific technologies, policies, implementable institutional arrangement, and governance.

2.3 Develop and promote appropriate grazing technologies, governance, and institutional options

This component included co-designed and testing of diverse grazing options matched to fine scale variation in ecological conditions, institutional settings, and farmer circumstances. Field visits were conducted in 2017 in Tigray region to an area that had experienced successful hillside development and controlled grazing. Consultations with faith-based leaders and influential local/cultural leaders, heads of natural resource management from the region and representatives of Government, Universities, Research and NGOs were done. Key issues identified were on the impact of free grazing, sustainable grazing and agroforestry practices, protection of trees grown on farmlands, and the challenges for sustainable grazing and agroforestry practices. A taskforce comprising legal institutions from three universities was established and a concept note developed.

To examine the major factors affecting the adoption of controlled grazing and multipurpose agroforestry species, as well as to identify the constraints faced in adoption of controlled grazing and multipurpose agroforestry species, field trail was done at Saesei-tsaedaemba District, Tigray region at 0.25 ha of grazing land. Then, field trials are being undertaken for selected multipurpose trees/shrubs (*F.albida, A.alpina* and grafted orange), planting of grass strips (Rhodes grass) together with alfalfa which were selected depending on farmers' preference and agroecology suitability. The other trial was On-farm plot trial (at farmers' farmland and backyard) with various fodder tree seedlings and multipurpose indigenous tree species. The analysis of the field trial findings were compiled by the PhD candidate, and a report is under preparation.

Objective 3: To establish communities of practice capable of promoting scaling of locally adaptable agroforestry options supported by appropriate inputs systems.

3.1 Support strengthening of institutions for wide-scale promotion of agroforestry, incorporating co-learning from farmer trials.

A review of grassroots community types was undertaken, mapping community's social cultural and economic assets. Vision mapping was undertaken to test institutional arrangements, identify community owned interventions and enabling governance structures. Guided by a scaling strategy, scaling up and out of locally adaptable agroforestry options across many households and landscapes was contingent on fostered collective action. Social learning and the knowledge management of diverse agroforestry options was enhanced through the integration of horizontal adaptation of technologies and practices with the vertical governance support. The project scaled lessons and practices beyond the Kebeles, Sectors and Sub-Counties in Ethiopia, Rwanda and Uganda that had been reached during phase 1.

3.2 Facilitate country specific multi-stakeholder strategies for co-operation in scaling up agroforestry

The project hinged on fostered collective action and the networking farmers with broader community to promote agroforestry. Approaches for promoting long-term development impact through participatory action research were utilized. The second phase built on the tools, methods and approaches for rural institutional diagnostics, capacity needs assessments, policy dialogues, multi-stakeholder and rural enterprise development, designed during the first phase to enable the active participation of communities linked to a facilitation process across governance scales.

3.3 Empowerment of women and youth groups and trainers with skills in agroforestry, gender analysis and strategies that foster collective action.

Smallholder communities including men, women and the youth were trained on different aspects of agroforestry practices. Factors for enhancing the adoption of women and youth were determined using participatory tools. Training content and delivery methods were tailored to the needs of each institution and were highly participatory and interactive. Trainings were given to staff from partner organizations and collaborating government departments as well as directly to community members including women and youth.

3.4 Strengthen local mechanisms for effective wide scale distribution of quality tree germplasm and agroforestry knowledge.

This involved instituting appropriate arrangements to support improved production and distribution of quality germplasm. Production of quality tree germplasm was focused at the Rural Resource Centers (RRCs), cooperative, group and satellite nurseries. Capacity building activities were undertaken to enable communities participate in tree planting and management. The training sessions were further used to also discuss policy aspects in germplasm sourcing and provision highlighting critical elements on survival, pest and diseases. Capacity building among community members was imparted through different capacity building sessions including peer learnings through RRCs, field visits, sensitization meetings, Umuganda (in Rwanda) and workshops.

Objective 4: To examine smallholders and other market actors' ability to participate effectively and profitably in tree product value chains

An assessment of potential tree-based value chains for development was done through key informant interviews and FGDs in the three countries. In Ethiopia, a survey was conducted in Oromia and Tigray regions covering three districts namely Adami Tulu Jido Kombolcha and Bako in Oromia and Tsaeda Emba in Tigray. The two regions and the three districts were purposively selected for the value chain assessment because they constitute the sites where T4FS project work is currently on-going. Besides, the three sites are potential areas for production of tree products.

The key informants were selected based on their knowledge on fruits tree production, input supply, trading and processing. Given that the aim of the study was to obtain information on production and marketing of tree products, care was taken to recruit respondents with relatively long-term experience in the production and marketing of tree products. These respondents were more likely to have relevant information on the cost of producing tree products as well as the quantity of each product harvested and marketed. Three FGDs were conducted in Adami Tulu Jido Kombolcha, five in Bako and four in Tigray region. Each FGD consisted of between 8 to 12 farmers on average. For the input suppliers, three private and three government nursery operators were interviewed. In addition, one group that owned a tree nursery was interviewed. The traders interviewed included four fruit traders in Adami Tulu Jido Kombolcha; two fruit traders in Bako town and two avocado traders in Darbas Kebele respectively. A total of two processors who buy fruits and process them into finished products such as juice were interviewed.

In Rwanda, a study on competitiveness of tree tomato value chain was conducted. The study used primary collected from both supplier's consumers and traders and secondary data collected through farmer profiling data to estimate the quantity of tree tomatoes produced, cost of production, quantity consumed and sold by the households and gross margins. The study also used secondary data from the horticulture department on estimated hectare under tree tomato, average yield, national average consumption, price trends. Focus group discussions for tree tomato producers were conducted to map the tree tomato value chain (identify potential actors, chain enablers, and supporters, seek farmer's perceptions on their production and marketing plans among other questions, and establish weaknesses and strengths of the producers.

In Uganda, value chain assessments were done through a desk study, focus group discussions and key informant interviews. A review of literature was done to inform the sampling design and data collection processes. The key documents reviewed included case studies, research reports and peer reviewed publications. Interviews were conducted with relevant district technical personnel including District Forestry Officers (DFOs), District Environment Officers (DEOs), District Production Officers (DPOs), District Natural Resource Officer (DNROs) of Mbale, Bududa and Manafwa Districts, to obtain a general overview on tree value chains trends in the respective districts, and priority key tree products for the analysis. In each district four respondents representing key tree product value chains were interviewed. Up to 36 actors including 12 participants per district were engaged in focus group discussions. Discussions focused on nature, processes, ways and means of obtaining, and processing, producing and marketing of the selected tree products in the Mt. Elgon region of Uganda and value chain nodes (e.g. fruit producers in Mbale District or timber traders in Manafwa District. In addition, the challenges and opportunities for developing selected tree product value chains were identified. Results of the scoping exercise and FGDs were produced and analyzed to articulate issues surrounding each of the tree products value chains. Key findings were presented to stakeholders through a validation workshop. In all the countries, options for financing fruit tree value chains were identified through a systematic review.

Objective 5: To strengthen capacity of academic institutions in developing appropriate curricula and materials for agroforestry

Tools for collection of data from tertiary agricultural education institutions on agroforestry and extension training needs, and assessment of curricula for tertiary agricultural education programs for agroforestry and extension training were developed with the involvement of the collaborators from Uganda, Ethiopia and Rwanda to enhance their relevance, contextuality and usability. National assessments of agroforestry curricula offered at Universities and the processes required to adopt new curricula were carried out in each country. A one-day national validation workshop was organized in each country to present findings of the curriculum assessment and to agree on key changes needed to improve them. These institutions offered forestry or agroforestry training as independent courses or as courses embedded on other course contents, topics or chapters. Owing to the gaps identified during the institutional assessment of the agroforestry curricula within the project regions, ANAFE organized a regional agroforestry curricula development workshop which was held in Nairobi, at Kenyatta University. The workshop resulted in the development of an innovative curriculum guide for use in harmonize training in tertiary institutions. ANAFE also conducted an online training workshop on training material development that drew participation of trainers from the three countries.

Impact Assessment- Rwanda

Sampling procedure and design

A sector was chosen as an entry point to select initial sites for baselining and implementation in Phase 1. Three sectors were chosen for the semi-arid (Nyamata, Mareba and Rweru) and sub-humid (Nyakiliba, Nyundo, Karago) agroecologies to represent diversity in tree-crop management systems possibly dictated by variations in topography, socioeconomic and institutional factors. In phase 2, two more sectors-were added, namely Musenyi and Mukamira in the semi-arid and sub-humid regions respectively. Scaling up was done within the sectors as well, in which one more cell was added in Mareba, Nyamata and Karago sectors.

The three districts were selected purposively for inclusion in the study because they were the project sites. similarly, sectors and cells where the project activities were being undertaken were included in the study because the number was too small to lend itself to sampling. Given that project activities were implemented in some and not all sectors in the district, comparison sectors were selected from the rest of the sectors where the project had not implemented. Attempts were made to identify sectors that were like the intervention sectors in all respects except receipt of T4FS interventions. While it is highly likely that the comparison sectors may have benefitted from agroforestry interventions being implemented by other projects, it was confirmed by the implementing partners that T4FS had not scaled out its activities to the proposed sectors. Once a matching comparison sector was selected, the second step was to select a matching cell within the sector that possesses similar biophysical and socio-economic characteristics as the intervention cell.

Attempts were made to identify comparison cells that are like the intervention cells in the baseline and time invariant characteristics except receipt of the programme. This involved mapping sectors and cells that had been targeted by T4FS, then looking for comparison cells in the neighbouring sectors within the district where T4FS interventions had not been implemented. Specifically, each matched comparison cell needed to (i) fall within the same political, economic and socio-cultural setting but be sufficiently farther away from the intervention cells to reduce the likelihood of spill-over effects; (ii) have similar baseline poverty and food security levels;(iii) have similar proximity to urban centres, markets, road infrastructure, and other social amenities ;(iv) have similar agroecological features and time invariant biophysical features (e.g. elevation, rainfall pattern, soils (v) have similar population densities and land use settlement patterns and (vii) limited or complete absence of considerable efforts to promote agroforestry interventions similar to those implemented under Trees for Food Security project.

The matching exercise was informed by key informants (e.g. implementing partners). Further screening of the selected cells was undertaken to include only those that allow for generalisability of the results (external validity).

Stratified random sampling was used to select between 2 and 4 villages from the intervention cells. The timing of the implementing partners' engagement with the villages in question was one key consideration when selecting intervention cells for the survey. Villages that had been exposed to the interventions long enough, for example five years, were considered candidates for inclusion because of the high likelihood of sampling households that had benefitted from or participated in the programme. Simple random sampling was used to select villages from comparison cells.

Data collection methods

Mixed methods approach was used in which both quantitative and qualitative data was collected from Bugesera, Nyabihu and Rubavu districts where Trees for Food Security interventions have been implemented. The qualitative study involved focus group discussions (FGDs) and key informant interviews (KIIs). FGDs were conducted with a group of farmers who were hosting participatory trials to understand the effectiveness of participatory trials in scaling out agroforestry interventions being tested by the farmers. KIIs involved in-depth interviews with officials of farmer cooperatives who were engaged by the implementing partner (World Vision Rwanda) to produce and distribute seedlings to the farmers. The qualitative study was instrumental in unravelling the pathways through which impacts from the interventions manifested. The quantitative study involving face-to-face interviews with farming households provided insights into the extent to which the interventions were being taken up by the farmers including the magnitude of impacts of adoption on productivity, household livelihood strategies and environmental resilience.

Prior to implementation of T4FS, baseline survey was conducted in all the sectors and cells that were earmarked for implementation in Phase 1. However, there was no clearly defined rule used to decide on which cells got the intervention or not. In other words, there was no randomisation of the treatment. As a result, programme placement bias was likely to occur. Similarly, owing to the few number of cells that benefitted from Phase 1 intervention, it was imperative that Phase 2 cells be included in the study as well. Therefore, it was necessary to reconstruct baseline information for some variables. Baseline data were obtained in two main ways. First, during the field survey, geocoordinates (polygons) of the fields that the interviewed households had farmed at present and at baseline was captured. This was to enable biophysical changes experienced within these farms over time to be measured via remote sensing. The second method was through respondent recall. Baseline scenarios for some variables were reconstructed through recall data. In this case respondents in both the intervention and comparison sites were asked to recall certain questions relating to agroforestry practices, land productivity, and their wealth status prior to and after the implementation of T4FS interventions. This method was used to capture data that the respondents were expected to reasonably recall such as ownership of farm and non-farm assets among others before T4FS. 2013 was the reference period for the baseline data. Historical reference periods were used to assist the respondents to accurately report their baseline status. Limitations, however, do exist regarding the extent to which baseline data can be reconstructed. Nevertheless, it was possible to obtain differenced estimates on several socio-economics and biophysical measures of interest. Care was taken not to overstretch the memories of the respondents by asking questions that were difficult to recall.

To administer household survey, population statistics were first compiled for each cell and a fixed sample size of 24 households allocated for each cell irrespective of the total number of households in the cell. A total of 573 female and male farmers were interviewed, and data were captured via remote sensing from 573 randomly sampled fields.

Focus Group Discussions

Focus group discussions (FGDs) were conducted with farmers hosting participatory trials in Nyabihu, Rubavu and Bugesera districts. The FGDs were conducted at cell level in 6 out of the 12 cells earlier planned (Figure 6). Selection of the cells was purposive and based on whether the cell was hosting participatory trials or not. While there were plans to conduct 8 FGDs in 4 out of 7 cells in Bugesera District, 4 of the FGDs were cancelled because of a ban imposed by the government on gatherings involving more than 5 people to curb the spread of Covid-19. The different types of trials namely biomass incorporation, soil erosion control and fruit trees were considered when deciding on the number of participants to include in each focus group. The FGDs consisted of between 6 and 8 participants with at least 2 participants representing each trial, except in Karago and Nyamata sectors where participants from two cells were combined because of miscommunication on the timing by the person who was responsible for mobilising participants. Efforts were made to hold separate FGDs for men and women to document gender related challenges and preferences relating to participatory trials.

Key informant interviews

In the absence of Rural Resource Centre in Bugesera, farmer cooperatives were used as one of the approaches of scaling out agroforestry practices in addition to participatory trials. In addition, farmer cooperative was used as avenues through which the project's vision of improving access to quality germplasm by the farmers could be fulfilled. World Vision Rwanda, one of the implementing partners, contracted farmer cooperatives to produce and supply tree seedlings to farmers. An in-depth interview was conducted with officials or members of cooperatives to ascertain the extent to which the cooperatives reached the farmers including fulfilling T4FS's objectives associated with access to quality germplasm and scaling out agroforestry practices. Therefore, the key informant guide was developed with the said objective in mind.

6 Achievements against activities and outputs/milestones

Objective 1. To enhance knowledge of impact of tree cover changes on crop productivity, water, nutrients and livelihoods

No.	Activity	Outputs/ Milestones	Due date of output / milestone	Comments/ Supporting documents
1.1	Expand the networks of farmer trials across a range of contexts and establish a long term trial in Uganda.	1.1.1 Networks of farmer trials established across a range of contexts Ethiopia (750); Rwanda (550) Uganda (350) Ethiopia (1500); Rwanda (1200) Uganda (800)	Yr1 M12 - Yr 4. Yr2 M11 Yr4 M10	By the end of the project 5,036 networks of farmer trials were established across the three countries. Discussions on the trials designs were held during a Planning meeting in 2017 conducted with the country coordinators and work package leaders In Rwanda, 2,290 participatory trials were established hosted by 3183 farmers. The trials consist of four main types namely: stakes for climbing beans, fruits for nutrition and income biomass incorporation and soil conservation and erosion control (Mukularinda et al, 2019) In Uganda 813 participatory trials were established involving 513 farmers. These trials include trees on farm, soil conservation, river bank stabilization, fodder banks, fruit orchards and woodlots (Galabuzi et al, 2019) In Ethiopia, a total of 1933 trials involving 1454 farmers were established. These include fruit trees, multipurpose tree planting, apple root stock, sustainable grazing options, multipurpose trees with rainwater harvesting (Gebretsadik et al, 2019)
		1.1.2 Establishment of trials a) Uganda long term trial (LTT) established. b) Management trials established in existing LTTs in Rwanda and Ethiopia and later Uganda	Yr1 M6 E&R Yr1 M12 U-MTR	In Uganda, a Long-term Trial (LTT) was established in 2017 at Buginyanya-Zonal Agricultural Research Division (Bugi-ZARDI) with *Cordia africana, Albizia coriaria* and *Grevillea robusta.* Soil profile studies were conducted on the trial (Fungo et al, 2018) and data collection tree and crop performance has been ongoing. . Management options of thinning and pruning were implemented on the three year old trees at Karama Bugesera RAB research stations in Rwanda. Two long term trials in Melkassa (semiarid) and Bako (subhumid) sites were managed by pruning and thinning as described. Details on establishment of the long-term trials are found in specific country reports: Galabuzi et al 2018, Mukuralinda et al 2018, Gebretsadik et al 2018, steering committee meeting presentations made in 2018, 2019 and 2020 and in the methodology section.
1.2	Collect targeted data on tree-crop interactions	1.2.1 Databases developed on crop productivity and tree products and services under different agroforestry	Yr1 M10-Yr 4 M6.	A robust Open Data Kit ODK database was developed for all countries for data on farmer profiling, participatory trials, tree distribution, RRC performance, seedling survival and performance. Quality control checks were then done, and data analysed and reported.

	and tree products and services from the existing long-term, on-station and farmer trials and develop suitability maps for different sites and contexts	practices from the farmers trials		Experiences and lessons on development of databases in ODK were presented at the World Congress on Agroforestry (WCA) (Nyaga et al 2019a). Results available in (Nyaga et al 2018; Muthuri & Kinuthia 2019). Findings are published in 12 peer reviewed journals and presented in 15 posters during the WCA (*refer section 1.2.3)*
		1.2.2 Databases developed on tree-crop interactions (water, light nutrients) and tree and crop productivity from LTT for use in activity 1.2.3, 1.2.4, 1.3 and 1.4	Yr2 M6-end of project	In Rwanda, databases include on tree growth, (biomass yields, light interception and soil samples) of crop growth parameters and yields, sap flow and soil moisture data in the LTT in Bugesera and Gishwati. Results showed that tree management by pruning was recommended. In Ethiopia, database is on crop yields and tree growth data for both Bako and Melkassa LTTs. Sap flow, soil moisture and gaseous exchange were done in Melkassa and the findings were reported in A PhD dissertation by Toib 2021. In Uganda ODK database is on tree and beans growth. Results show that *C. Africana* experienced more mortality than other species irrespective of subsequent beating up, while *G. robusta* the highest survival rate (98%). Records for 554 tree survival data are available Details on tree-crop interactions from the LTT are contained in the country specific findings are contained in Galabuzi et al., 2020, Gebretsadik et al, 2020 and Ndayambaje et al, 2020 Results on Rainfall variability, soil heterogeneity, and role of trees in influencing maize productivity in a comparative long-term trial in Kenya is contained in Njoroge et al 2019.
		1.2.3. Report on a) Achievements and farmer opinions and lessons from networks of participatory trials (MTR). b) Final Report on Farmer trials c) Journal articles and thesis.	Yr 2 M12. (MTR) Yr 4 M9. Yr 4 M12	**Country-specific reports** on establishment and farmer opinions of the participatory trials were prepared for Rwanda (Mukularinda et al, 2019); Uganda; (Galabuzi et al, 2019) and Ethiopia (Gebretsadik et al, 2019). **Conference Presentations:** 2019 World Congress on Agroforestry in Montpellier, France. (Derero et al 2019, Kinuthia et al 2019, (Mukuralinda et al 2019b, Mukuralinda et al 2019c, Cyamweshi et al 2019, Musana et al. 2019) (Galabuzi et al 2019c) CIFOR-ICRAF: FTA conference Galabuzi et al 2020; NARO-Makerere Conference: Buyinza et al 2020 **journal articles** Derero et al, 2020. 1) Buyinza et al 2020.: 2) Buyinza et al 2020 **Thesis** A PhD dissertation by Awol Toib on 'Ecophysiology of *Faidherbia albida* and . A Master's thesis by Ruth Kinuthia entitled Farmers perceptions **Five other paper are under review in various journals**
		1.2.4. Reports, databases and publications on long term experiments, a) Interim report at MTR	Yr2 M12 (MTR)	**Reports, Mid term review report (Muthuri et al 2019)** reports; Rwanda (Mukularinda et al, 2019); Uganda; (Galabuzi et al, 2019) and Ethiopia (Gebretsadik et al, 2019). Presentations during WCA: Ethiopia: Assefa et al. 2019; Dilla et al. 2019. Uganda: Buyinza et al. 2019 and Rwanda: Ngoga et al. 2019; Cyamweshi et al. 2019. (Njoroge et al. 2019

		1.2.4 b) Final report c) Journal papers, PhD and MSc thesis from the tree crop interactions studies	Yr4 M9 Yr4 M10	**Journal articles on Long term trials include**: 1) Dilla et al 2019. 2) Dilla et al 2018 3) Tadesse et al. 2021 4) 1) Cyamweshi et al 2021. Buyinza et al 2019-:Njoroge et al 2019. (Buyinza et al, 2019). Toib et al, 2021 **Under review / Tenge et al.** 2021 agroforestry Systems; Musana et al 2021; A refresher training involving 7 staff from ICRAF and JKUAT was conducted at the LTT site in JKUAT on tree-crop water interaction using the sap flow equipment Other mmodelling information from steering committee meetings in 2018, 2019 and 2020
		1.2.5 a. Suitability maps for species and management options across different sites and farmer circumstances produced b. Tools (like species selection tools) to match options to sites and circumstances. Developed	Yr2 M12 - Yr 4 M3 Yr3 M12 - Yr 4 M9	An "Interactive Suitable Tree Species Selection and Management Tool for East Africa", a web-based tool that aids in understanding trees diversity and its contribution to livelihoods and landscape health and promotes the right tree for the right place for the right purpose developed. The tool was developed for Ethiopia consisting of 209 (147 native and 62 exotic), Rwanda consisting 115 (54 native and 61 exotic) tree species in Rwanda; and for Uganda consisting of 58 (31 native and 27 exotic) tree species. The database enables the user to easily access information either based on tree species, their agro-ecological zone suitability, products, ES, origin (native or exotic) and niche. Tree management options across different sites and farmer circumstances are contained in the tools.
1.3	Develop the capacity of the APSIM X AF model and other linked models for use on a wider range of tree species and cropping practices.	1.3.1 Reports on modelling (a) Interim ((dynamic tree model development) (b) Final (Model application)	Yr2 M 12 (MTR) Yr4 M10	APSIM Next Generation framework fully available and functional including agroforestry layout, species and functionality options. Several tree and crop model options available Models currently Available are: • Tree models: Gliricidia, Eucalyptus, oil palm. • Crop models: maize, wheat, barley, sugarcane, generic weed, flatweed, chicory, soybean, pasture, barley, fodder beet, chicory, oats, red clover, white clover • Prototypes on teff, tropical grass and early draft of Alnus available. The APSIM Next Generation framework model is fully available and functional for public use www.apsim.info.
		1.3.2 Plot: Progress report a) Extended APSIM agroforestry model applied to new agro-ecologies (e.g. Uganda where data are available). b) Simulated farming systems that include crop rotations. c) Developed datasets on tree -crop interactions at plot level	Y2 M12 (MTR) Yr2 M12 – Yr4 M6	Extended APSIM agroforestry model applied to new agro-ecologies: Faidherbia-wheat, northern Ethiopia 2. Eucalyptus model, Australia and Brazil 3. Acacia-maize/soybean, Indonesia 4. Gliricidia-maize, Tanzania Mostly crop datasets are available for the Faidherbia-maize (Ethiopia), Alnus-potato/maize (Rwanda), Acacia-soybean/maize (Indonesia), and Gliricidia-maize (Rwanda). For the latter, Gliricidia data are available as well as the crop data Two papers presented during WCA on APSIM modelling: Smethurst et al (2019); Huth et al 2019 and the modelling workshop side event: (Smethurst et al 2019)

		1.3.3 Farm: Examples of integrated assessments using Simile or APSIM carried out in 3 countries to predict impacts on livelihoods	Yr2 M9- (MTR) Yr3 M9	A modelling capability is now available that dynamically links the SIMILE a farm-scale livelihood modelling dynamically to APSIM plot-scale biophysical modelling for agroforestry. To implement this in Rwanda, data were collected from a field experiment in a Gliricidia-maize/bean system, and modelling has commenced for plant production using APSIM, and farm-scale modelling has been designed using SIMILE. Data indicate that including Gliricidia in the farming system and using its biomass to fertilize adjacent cropping zones can improve the yield of maize within these zones if Gliricidia rows were 6 m or more apart. Maize yields were suppressed if rows were only 3 m apart. These general responses could be simulated using APSIM, and simulated yields averaged across the whole field (effective yield) were only higher if maize rows were 6 m or more apart In Ethiopia, the effects of each of these factors (rainfall, distance from tree, pruning and fertiliser) were adequately simulated and then the model used to develop hypotheses about the effects of un-tested management scenarios on wood production and maize yields. The simulations suggested that maize yield could be improved by applying fertilizers and by at least 50% pruning of trees. fertile microsites, soil organic matter transfers via erosion from crop-only areas, and bird manure stimulating crop growth and residue loads.
		1.3.4 Landscape: Reports on use of Polyscape models to predict ecosystem services impacts.	Yr2 M6- (MTR) Yr4 M3	Using AKT5 in combination with INPAC-S methodologies, a local knowledge study was undertaken in Rwanda to elicit local indicators of soil quality at the landscape scale ad to inform on ecosystem services impacts. A manuscript on Farmers' knowledge of soil quality indicators along a land degradation gradient in Rwanda, was published in Geoderma regional (Kuria et al, 2019).
1.4	Conduct scenario modelling using the enhanced APSIM X AF model and other linked models to inform national agroforestry scaling	1.4.1 Reports and maps on scaled and linked modelling, including species-management options (a) plot scale nationally ; (b) Farm and landscape scales	Yr2 M9- (MTR) - Yr4 M9 Yr2 M9 (MTR) - Yr4 M9	(a) This capability is available in CSIRO for project testing as a prototype. APSIM run and outputs mapped for crop, tree and agroforestry simulations across Rwanda. (b) Rwanda soil maps were shared with CSIRO for developing a Rwanda's APSIM soil module, but instead gridded soils data for Rwanda were sourced from ISRIC, which is a capability that can be used for any other location in the world.
		1.4.2 Modelling for participatory process: a) Trained in-country modellers and extension staff b) Developed plot-farm and landscape modelling	Yr2 M6- Yr4 M6 Yr2 M9 Yr3 M10 Yr4 M8	The APSIM agroforestry tree proxy model is currently active within the APSIM initiative, and already applied with others outside this project (i.e. Indonesia, Tanzania) APSIM-SIMILE modelling that dynamically integrates plot-scale biophysical modelling with farm-scale livelihood modelling also developed (https://www.simulistics.com/help/submodels/communication.htm) and its application commenced for the Faidherbia-wheat system in Tigray.

		approaches for tree-crop systems. , c) Model evaluated with different stakeholders		A soil and plant measurement workshop was conducted in Rwanda where training on modelling was conducted with different stakeholders. Training in modelling in several countries was conducted via students involved in the modelling work The project ran the Agroforestry Modelling Workshop side-event at WCA 2019 in which, the 60 participants, were provided a detailed introduction to four agroforestry models (APSIM, WaNuLCAS, Hi-SAFE, and Programmable Structures).
		1.4.3 Reports on national scale agroforestry modelling predictions	Yr2 M12 (MTR)-Yr4 M6	Progress towards this achieved via 1.4.1 (a)
		1.4.4 Report of outcomes from policy dialogues in 3 countries	Yr4 M6	Policy dialogues to be conducted as part of national workshops to be organized virtually or blended depending on COVID 19 situation in respective countries by June 2021
		1.4.5 Journal article on national scale modelling	Yr4 M10	Three Journal articles were published as follows: Dilla et al 2018a, Smethurst et al 2017), Dilla et al 2020

Objective 2. To integrate water management technologies and sustainable grazing options with promotion of agroforestry

No.	Activity	Outputs/ Milestones	Due date of output/ milestone	Comments/ Supporting documents
2.1	Conduct mapping of options in relation to context and, training in and facilitation of implementation of water management technologies appropriate for enhanced	2.1.1a) Training needs assessment report b) Mapping report on appropriate water management technologies.	Yr1 M7 Yr2 M 3	186 maps were produced on context-based land and water management options in Ethiopia, Rwanda and Uganda including 126 base maps depicting the digital elevation model (topography in 3D), land use, soil, rainfall, slope and temperature; 63 thematic maps of the appropriate land and water management options, potential run-off and the amount of soil loss with no conservation. Mapping reports were completed the three countries: Uganda (Nyolei et al, 2018c), Rwanda (Nyolei et al, 2018a) and Ethiopia (Nyolei et al, 2018b). The recommended practices include Conservation Agriculture (CA), Agroforestry, Zai pits, trapezoidal bunds, level bunds, grass strips, stone bunds. This should be combined with soil fertility improvement measures such green manure (crop rotations, compost, and animal manure. Others include graded bunds, runoff ponds check dams, water pans etc. and can be applied as appropriate depending on the slope angle and land use systems.
		2.1.2 Training manual/guidelines on water	Yr2 M9	Based on the results of the mapping work, A training curriculum was then developed and training of trainers' course (ToT) conducted for 67 participants, the majority of whom were farmers (Uganda (Sekatuba et al, 2018).. ICRAF presented the findings in Uganda Water

	tree survival and growth	management for Agroforestry development		and Environment Week (2019),. A watershed management approach is recommended during upscaling of interventions.
2.2	Determine cost effectiveness of appropriate water management options in different contexts to enhance tree growth and survival	2.2.1 Report with recommendations on cost effective water management technological options	Yr2 M9	The mapping reports produced in Uganda (Nyolei et al, 2018c), Rwanda (Nyolei et al, 2018a) and Ethiopia (Nyolei et al, 2018b) capture cost-effective, context appropriate and management options. The maps depict the areas in hectares requiring treatment with soil and water conservation practices Details on water management technological options presented during the steering committee meetings in 2018, 2019 and 2020
		2.2.2 Five thousand (5,000) households implementing water management technologies	Yr2 M9 - end of project	In all the countries, land and water management was integrated in the project's various initiatives through the participatory trials. In Uganda, at least 289 farmers-, 8 model demonstrations established on farmers' land and 4 parish level soil and water conservation committees with 10 members formed for community outreach, scaling up and out of different soil management and water harvesting technologies In Ethiopia, 633 households were engaged mainly through fruit and fodder trials. Farmers in East Shewa have continued benefitting from 5 shallow wells with a hand pump that not only serve the host but neighbours including livestock. In Rwanda, 1379 households have benefitted from soil and water management technologies through establishment of erosion control structures such as terraces and use of agroforestry trees to harness the structures in mainly in Rubavu and Nyabihu.
2.3	Review existing policies, strategies, and institutions on grazing, and identify barriers to their adoptions	2.3.1. Report on the review of existing policies, strategies and (formal and informal) institutions on grazing management.	Yr1 M6	Discussions on existing policies and strategies on grazing were held and sustainable grazing management options agreed upon with officials from three government ministries- namely Agriculture; Livestock and Fisheries; and Environment, Forest and Climate Change; officials from four regional states, Universities and research institutions, district experts, development agents, farmers, and different faith and cultural leaders. Findings are contained in 'Sustainable Grazing Strategy Options for Ethiopia' Kiros et al. 2017a. From these discussions: • Concept note was developed (Kiros et al. 2017b) and sent to Regional Justice office on Exploring options on legal recognition and enforcement of grazing bylaws • A Sustainable Grazing Platform (SGP) was developed, submitted and discussed with Tigray regional state government office, and other stakeholders (Kiros et al. 2018). • A policy brief on sustainable grazing options was developed (Kiros et al. 2018)., Additional details available steering committee reports in 2018, 2019 and 2020
		2.3.2. Report and MSc thesis on adoption barriers to the	Yr1 M12 and Yr2 M6	Two PhD students were recruited under this work package and studies are ongoing. Adoption barriers to the grazing policies, strategies and institutions included in the journal article on "Locally Adaptive, Low Cost and Sustainable Grazing Options: Accelerating

		grazing policies, strategies and institutions.		Adoption and Scaling of Agroforestry Practices in Ethiopia" Practices in Ethiopia" by Solomon et al. submitted to Sustainable Environment and Development journal
2.4	Develop and promote appropriate grazing technologies, governance and institutional options.	2.4.1. a) Report on trade-offs and benefits of grazing options linked to market-oriented livestock production b) Journal article on trade off and benefits of grazing options	Yr3 M6 Yr4 M6	Report on trade-offs and benefits of grazing options contained in an article entitled 'Sustainable grazing options for enhancing accelerated adoption and impacts of agroforestry in Ethiopia' submitted to Agroforestry Systems Journal
		2.4.2. a) Report on grazing options fit to ecological conditions, institutional settings and farmer circumstances b) Journal article on 'a' above	Yr2 M3 to end of project Yr4 M12	Grazing options fit to ecological conditions, institutional settings and farmer circumstances are contained in the report on 'Sustainable Grazing Strategy Options for Ethiopia' (Kiros et al., 2019). A Journal article on "Locally Adaptive, Low Cost and Sustainable Grazing Options: Accelerating Adoption and Scaling of Agroforestry Practices in Ethiopia" Practices in Ethiopia" by Solomon et al. submitted to Sustainable Environment and Development journal
		2.4.3 Trials of sustainable grazing management at 2 sites in Ethiopia	Yr2 M6	Two sites namely Zeway in Oromia and Saesei-Tsaeda-Emba in Tigray facing free grazing problems were selected and trials established Types of trials selected- 1. On-farm plot trial 2. At communal grazing land trial. Over 10 species selected- e.g. *F. albida*, *F. thonningii*, Highland bamboo, Orange, Grazing options are contained in (Fantaye et al. 2019)
		2.4.4. Experience sharing a) Field visits to successful farm exclosures in Adama and Haraghe. b) Reports and lessons on experience sharing	Yr1 M12 Yr3 M6	Experience sharing was done to Bishoftu district comprising key leaders like district experts, farmers, women, youth, religious and aba-gada leaders, district experts and development agents from three districts, and reported in (Kiros et al, 2019) A presentation was done on Regreening Ethiopia with trees: mapping a collaborative approach and Regreening Africa workshop held on November 19-23, 2018, at Addis Ababa in the presence of high government officials and delegation from EU.
		2.4.5. a) Two evaluation reports on benefits from locally fit (formal and informal) institutional strategies to control (1) local free grazing, and (2) grazing problem by the migratory herds 2.4.5 b) Policy Brief	Yr4 M6 Yr4 M6	Instead of reports, two journal aarticles were developed, one by Gebremariam et al (Evaluation of woody species composition and regeneration in controlled and free grazing users for scaling up of agroforestry in the highlands of Northern Ethiopia) and submitted to Agroforestry Systems. Another one by Girmay et al. (Response of four tree species to fertilizer, watering and weeding regimes in the sub humid conditions of west Oromia, Ethiopia) which is under internal review. Policy brief on grazing issues is in the final stages of review.

Objective 3: To establish communities of practice in the promotion of locally adaptable agroforestry options supported by appropriate inputs systems.

No.	Activity	Outputs/ milestones	Due date of output/ milestone	Comments/ Supporting documents
3.1	Support strengthening of institutions for wide-scale promotion of agroforestry, incorporating co-learning from farmer trials.	3.1.1 Country specific reports on the current institutional arrangements: for scaling up agroforestry options: Process documentation on coalition formation and developing protocols for communities of practice a) A Trainers guide on institutional strengthening and support to governance processes and stakeholder negotiation produced b) Process documentation on the facilitation of multi-scale linkages in the promotion of agroforestry options	Yr1 M6- Yr2 M6 Yr2 M6- Yr3 M12 Yr3 M12	The project has various institutional arrangements for scaling up agroforestry options specific to each country. In Rwanda, scaling strategies include participatory trials, RRC in Karago, sensitization meetings and community work (Umuganda), model farmers and cooperatives. Details of the strategies and scaling up of AF options contained in (Mukuralinda et al, 2019) In Uganda, scaling strategies include participatory trials, model farmers, RRC in Mbale, sensitization meetings and farmers groups. Moreover, a task force to scale up agroforestry and setting up a national agroforestry strategy was set up (Galabuzi et al, 2019, Sekkito et al, 2019a, 2019b) In Ethiopia, scaling strategies include participatory trials, model farmers, RRCs in Zeway and Bako, Government/woreda agricultural offices/nurseries, field visits/ farmer exchange visits including church forest groups (Gebretsadik et al, 2019) To enhance co-learning and lesson learning from the different strategies, communities of practice guidelines were developed (Kuria et al, 2019a, Kuria et al 2019b). These were applied in Rwanda and findings contained in Mugambi et al 2020. Results from application of CoP gave insights on stakeholder engagement, farmer feedback from the trials and appropriate scaling strategies to promote agroforestry
		3.1.2 a) A working paper developed highlighting drivers of institutional strengthening in tree crop development b) A facilitators' guide on effective cross-scale governance and linkages in the landscape level management of tree crops	Yr2 M1 Yr 4 M8	In Rwanda, a refined list of drivers for institutional strengthening in agroforestry as well as the effective cross-scale governance and linkages in the landscape level management of tree crops incorporated in the agroforestry strategy and action plan for Rwanda that the project, trough ICRAF contributed to its development In Uganda, drivers of institutional strengthening in tree crop development contained in the report on institutional arrangements for scaling up agroforestry in Eastern Uganda (Fungo et al, 2018). In Ethiopia, drivers of institutional strengthening in tree-crop-livestock development conducted as part of establishment of sustainable grazing management system (Kiros et al, 2017)

		3.1.3 Country reports on social network analysis and institutional vision mapping	Yr2 M11	Reports on social network analysis could not be producedsince the final country workshops were not held due to covid-19 restrictions
		3.1.4. Peer review publications on country specific and regional policy processes in tree crop development	Yr4 M6	Peer review publications developed under 1.2.3, 1.2.4, 3.2.3
		3.1.5. Policy brief on partnerships in agroforestry development	Yr3 M4	Partnerships in Agroforestry development and strategies already on course. Refer 3.2.1
3.2	Facilitate a multi-stakeholder strategy for co-operation in scaling up agroforestry.	3.2.1. a) Multi-stakeholder strategies for each country b) Report on implementation of strategy framework.	Yr2 M6 Yr4 M6	In Rwanda, ICRAF contributed to the development of the National Agroforestry Strategy and Action Plan and is a member of the Task Force that oversees the implementation of the Strategy. On request by the Ministry of Natural resources, ICRAF developed various training and extension materials e.g. manuals on agroforestry options, tree nurseries, planting, management, pests and diseases management and grafting of fruit trees. In Ethiopia, the project through ICRAF is a member of National Agroforestry Platform (NAP), The platform is chaired by the Ministry of Agriculture (MoA) and ICRAF is serving as permanent secretariat. This further led to formation of a National Watershed and Agroforestry Multi-Stakeholder Platform (NWAMP) with various government ministries and NGOs and a strong agroforestry component. In Uganda, the project, trough ICRAF in conjunction with the Ministry of Water and Environment (MWE) has contributed to the formation of a National Forestry Consultative Forum (NFCF), Under the Forum, ICRAF together with other stakeholders have contributed towards the revision of the National Agroforestry Strategy which is under review and stakeholder validation. Once approved, it will guide efforts on sustainable food production, restoration, and long-term financing of agroforestry. (Wamala et al, 2017)
		3.2.2 50,000 households implementing agroforestry practices. a) Progress report on achievements and challenges and lessons learned in scaling up of agroforestry options to 20,000 households. b) Report on achievements and benefits	Yr 1 M6-Yr 4M 12 Yr2 M10 Yr4 M10	In Rwanda, 32,452 households have been reached in the project's course of promoting agroforestry practices. 11,299 have been reached in Uganda and 4,482 in Ethiopia totalling to 48,233. Specific details are contained in the specific partner reports. These farmers have been reached through participatory trials (5,036), capacity development initiatives such as trainings and demonstrations (10,347), RRC activities (11,002), nursery management, tree distribution and planting activities outside RRC (12,920), Umuganda in Rwanda (4,056), sensitization meetings, exhibitions, field days (4,748) and support of 10 post graduate students. Report on achievements and benefits

		from scaling agroforestry to 50,000 households.		from scaling agroforestry in the three countries contained in final country and project reports by July 2021
		3.2.3 Peer review publications	Yr2-Yr4	The following journal articles produced under participatory trials have extension components they include Buyinza et al 2020 entitled "Assessing smallholder farmers' motivation to adopt agroforestry…and .Derero et al. 2020 on farmer led approaches Other two articles from Uganda aby Galbuzi et al are uder review, In Rwanda, three manuscripts focusing on tree tomato and climbing beans and tree biomass incorporation trials are under preparation.
3.3	Facilitate dialogue on policies to enhance adoption of agroforestry technologies.	3.3.1 National workshops on scaling of agroforestry technologies	Yr1 M6	Scaling of agroforestry technologies conducted as part of national workshops held to assess agroforestry curricula and extension trainings offered in tertiary institutions in the three Ethiopia, Rwanda and Uganda (Birhane et al, 2018c; Mugunga, 2018: Isubikalu, 2018c).
		3.3.2 Key policy recommendations on drivers of agroforestry adoption summarized through policy briefs	Yr2 M9–Yr4 M6	Project's alignment to national polices and government's commitment to project initiatives defined during the inception workshops conducted in Rwanda, Uganda and Ethiopia In Ethiopia, reviewed grazing policies will provide a basis for testing and customizing grazing policy dialogue tools. A policy brief on sustainable grazing management options is under review (Kiros, et al, 2018). In Uganda ref on key policy recommendations on drivers of agroforestry adoption contained in (Ntakimanye et al, 2019). In Rwanda, they are incorporated in the new agroforestry strategy and action plan
		3.3.3 Workshop on options for improving grazing management in Ethiopia	Yr1 M10	Covered under WP2b on grazing. The project participated in a church forest workshop to share experiences on impacts of free grazing on the environment. The churches agreed to raise awareness on agroforestry for enhancing scaling up of agroforestry and landscape restoration.
		3.3.4 Mid-project policy workshops on progress and lessons from scaling activities	Yr2 M11	Experience sharing done during the mid-term review in Uganda, Ethiopia and Rwanda. Moreover, in Uganda, policy dialogue meetings with the local governments took place in three districts. In Ethiopia, a regional meeting was held with the Ministry of Agriculture about Agroforestry strategy plan development in December 2018. In Rwanda meetings were conducted with local authorities and stakeholders during Umuganda
		3.3.5 A report developed on effective cross sector strategies for the adoption of agroforestry	Yr3 M3	The project has developed engagements across various sectors. In Ethiopia, the project is involved in the national watershed and agroforestry multi-stakeholder platform with various government ministries and NGOs. In Uganda, ICRAF has received an endorsement from the ministry of water and environment to develop agroforestry options manual for Uganda. In Rwanda, the project has contributed to the National Strategy for Transformation (NST) developed by MINAGRI that aims to reduce malnutrition and increase household income among others. 61,500 fruit trees- avocado, mango, Pawpaw, and Tree tomato have been distributed towards this initiative (Kinuthia et al, 2019)

		3.3.6 End of project national workshops	Yr4 M11	End of projects National workshops could not be done due to Covid 19 restrictions but once countries reopens the final report will be shared with all stakeholders
3.4	Train and motivate women and young farmer trainers about agroforestry practices	3.4.1 Report on factors enhancing adoption of agroforestry by women & youth	Yr1 M6	Reports on enhancing adoption of agroforestry to women and youth contained in Uwimbabazi et al 2018; Isubikalu et al 2018, Rwanda- Ndayambaje et al 2019, Ethiopia- Gebretsadik et al, 2018
		3.4.2 About 20 staff from each partner country trained; About 250 youth and female trainers trained About 15,000 women and youth farmers trained	Yr1 M 6 Yr2 M 4 Yr2 M 8- Yr4 M 6	In Ethiopia, refresher training on high-value agroforestry tree species involving 70 farmers (50M, 20F) and 6 extension workers (5M, 1F) was conducted. Practical training on RRC management was conducted to 11 (8M, 3F) youths in Bako In Uganda, three Training of trainer's workshops on empowerment of women and youth in agroforestry, gender analysis and strategies was conducted in three Districts. 427 women and youth were trained. In addition, 199 farmers (99 men and 103 women) were trained on appropriate on-farm tree identification and integration. Findings contained in (Uwimbabazi et al 2018; Isubikalu et al 2018). In Rwanda, 19 staff (14M, 5F) and were trained on agroforestry practices and related research and extension skills. 90 youths and female trainers in Bugesera and Gishwati were trained on seedlings production and agroforestry practices A total of 1,292 women, men and youths have been trained in Ethiopia, 4,609 in Uganda and 4,446 In Rwanda totalling to 10,347 members were trained across the work packages.
		3.4.3 Training manuals developed	Yr1 M 12	In Rwanda, four training manuals have been developed on: tree nursery, tree products and services, tree security and maintenance and tree identification and tree benefits In Uganda, a draft training manual on sourcing quality tree germplasm was developed (Kisseka et al, 2018). A report on engagement of women and youth in agroforestry and gender analysis was developed. ICRAF Ethiopia team in collaboration with Ministry of Agriculture, Agroforestry infotech manual was prepared that could be used for Rural community technical guide.
		3.4.4 Cross country exchanges undertaken	Yr2 M8-Yr4 M6	Cross-country exchanges have occurred at project level for project staff and partners through; I) Steering committee meeting held in 2017, 2018, 2019 and 2020. Prior to the SCM, all project staff were trained on data quality control and management iii) Virtual meetings in which development of cross-cutting agroforestry learning materials was discussed. Minutes of the meeting can be accessed here. Iii)Conference/ workshop participation during, World Congress on agroforestry held on 15-17 September 2020, (TropAg) conference in 2019 (Muthuri et al, 2019)and other national level workshops. iii) publication of blog stories and social media to the wider public reported in 3.4.6

		3.4.5 Report on benefits and lessons from engagement of women and youth	Yr2 M12 - Yr4 M6	In Ethiopia, Margarrisa Youth Group continues to benefit from the RRC activities, having made a net income of 77,200 ETB (USD 2,000). Details on lessons learnt contained in Gebretsadik et al 2020). In Rwanda, 6 cooperatives benefited from the project through support trainings and support in establishment of trees in the nurseries. As a result, they were contracted by the forest landscape restoration programme contracted to produce tree seedlings for wider distribution (Mulindangabo et al 2020) Report on factors enhancing the adoption of agroforestry by women and youth for Uganda available (Ntakimanye et al. 2019).
		3.4.6 Preparation of "Stories of Change" from empowerment activities: At least 3 stories from each country At least 6 stories from each country	Yr2 M9 Yr4 M10	Stories prepared cutting across the three countries as follows: COVID-19 and women's leadership: a conversation with ICRAF senior scientist Prof Catherine Muthuri; Researcher Committed to Safeguarding Women's Economic Empowerment; Q &A: How women and girls can succeed in science; Trees for food security in Eastern Africa Ethiopia- Stakeholder engagement and policy impact- 1. Apple production in Tigray, 2. Trees for food security project bearing fruits in Ethiopia Rwanda- 1. Tree tomato growing paying-off for a smallholder farmer in Rwanda. 2. More stakes, more climbing beans, less malnutrition: Rwanda finds a solution in Agroforestry 3. Agroforestry project to improve food security launched in Kigali Uganda-. The stories include 1. The art of pruning, 2. Women and youth turning to tree-based enterprises for livelihoods in Mount Elgon, Uganda. 3. Agroforestry in the Mt.Elgon sub-region: Scaling up farm practices for food security in Eastern Uganda. These stories can be found on the T4FS project's news section here .The project also leveraged on ICRAF's social media platforms to disseminate information and enhance visibility
3.5	Strengthen local mechanisms for effective wide scale distribution of quality tree germplasm and agroforestry knowledge.	3.5.1 a) A stakeholder analysis report on quality germplasm exchangeb) Proceedings of 3 linkage forums on quality germplasm exchange for farmers, tree nursery managers, private sector and rural advisory services using RRCs as local hubs for learning and dissemination c) Protocols on quality tree seed sourcing demonstration trial d) RRC quality tree seed sources demonstrations	Yr1 M6 Yr2 M8 Yr1 M12 Yr2 M6- Yr4-M6	A stakeholder analysis on quality germplasm exchange conducted in Uganda (Ntakimanye 2017). Ethiopia and Rwanda Stakeholder analysis conducted in phase one In Uganda a stakeholder analysis on quality germplasm was done and a training workshop held at Mbale RRC Proceedings documented in Ntakimanye et al, 2018). Protocols on quality tree seed sourcing demonstration trial have been developed and implemented in the three countries through the RRCs and satellite nurseries In Ethiopia, *Grevillea robusta, Cordia africana* and avocado demonstration in the trials set up in Batu and Bako RRC. Linkages with PATSPO project were identified. Quality seeds were sourced from different seed providers in Ethiopia. More than 4.2 million quality germplasm has been produced with more than 75% distribution rate across the countries

		3.5.2 Country level Training to enhance National Tree Seed System in Rwanda	Yr1 M12	Achieved through farmer trainings in RRC in model villages, Refer 3.4
		3.5.3 Report on stakeholder analysis of agroforestry knowledge dissemination	Yr1 M12	Stakeholder analysis of agroforestry knowledge in Uganda contained in the proceedings of the 4th national agroforestry conference (Wamala et al, 2017). In Rwanda, stakeholder analysis contained in in Mugambi et al 2020. In Ethiopia, stakeholder analysis conducted during establishment of sustainable grazing platform (Kiros et al, 2018)
		3.5.4 Two regional workshops held to facilitate co-learning between AF institutions	Yr1 M12 Yr3 M3	Co-learning between agroforestry institutions achieved through agroforestry curriculum workshop through work package 5, refer 5.2
		3.5.5 a) Training guide on quality material sourcing, distribution, pest and disease management support b) Recommendations for simple nursery accreditation systems evaluated c) Sources of quality propagation materials availed for 2 fruit types per country	Yr1 M12 Yr3 M4 Yr3 M6	ICRAF tree seed for farmers tool kit availed in all the three countries. Training guide on sourcing quality germplasm, pest and disease management in Uganda was developed. In Uganda development of simple nursery piloted a survey on tree nursery accreditation systems for quality fruit propagation materials sourcing (Galabuzi et al, 2019b). In Rwanda, sources of quality propagation materials for various varieties of tree tomato were established from germplasm introduced from Kenya. Also, tree tomato, mango, and guava were supported by the RRC and farmer cooperatives to provide scion gardens.Sources for Ethiopia complemented by PATSPO project. Lessons from RRC and fruit satellite nurseries are being gathered for syntheses to help with quality fruit material supply. In collaboration with ICRAF AgBio project, a food tree mother block established at Batu RRC and the demonstration site fenced.
		3.5.6 Report and Working paper on principles for effective cross-linkages and support structures; One peer review publication	Yr4 M3 Yr4 M3	Covered under 3.4.4 through steering committee meetings and considering Covid-19 impacts, cross-country interaction were disrupted. Output also linked to country national workshops whereby a summarized comparative synthesis report on key lessons learnt will be generated

Objective 4: To strengthen smallholders and other market actors ability to participate effectively and profitably in tree product value chains

No.	Activity	Outputs/ milestones	Due date of output/ milestone	Comments/ Supporting documents
4.1	Improve value chain actors' skills to adopt	4.1.1Training report on farmer business schools in each country	Yr1 M12	Key tree product value chains on which the formation and strengthening of farmer business schools were to be based were identified and guidelines drafted and shared

	appropriate strategies for enhancing the value chains of tree products			In Rwanda,: Tree tomato, Grevillea and Tree seedling value chain was identified Guidelines for the formation of farmer business schools were developed (Oduol, 2018c). In Uganda, 3 value chains were identified through FGDs and KIIs 1. Timber and fuelwood-Eucalyptus 2. Dairy 3. Avocado. Avocado and dairy selected as value chains for the Farmer Business Schools (Isubikalu et al, 2018e) and guidelines shared (Oduol, 2018a). In Ethiopia, 3 fruit tree value chains were identified and validated with farmers and other value chain actors: Mango Avocado, Apple- and guidelines developed (Oduol, 2018b). In Ethiopia, Lessons, challenges, and opportunities on enhancing the selected value chains focused more on the production and less on the value chain financing options
		4.1.2 M&E plan report for number of beneficiaries	Yr3 M12	Final M&E plan report with the up-to-date numbers of beneficiaries against indicators provided (Oduol et al. 2021)
4.2	Assess financing options in each country which can support tree planting and its commercialization	4.2.1 Report for each country on financing options for tree planting and its commercialization	Yr2 M12 (MTR)	Options for financing fruit tree value chains were identified through systematic review and validated as follows: In Ethiopia; Formation and/or strengthening of existing Village savings and loans association; Linking VSLAs and semi-commercialised farmers to financial institutions (Mawia et al. 2018). In Rwanda financing options identified include Equity capital-building of savings; Group savings- cooperative; Linking of cooperatives to financial institutions. In Uganda, financing options identified include: Farmer incomes and savings, village saving schemes; financial institutions linking (Ntakimanye and Namuyanja, 2018)
		4.2.3 Journal article on financing options for tree planting and its commercialization	Yr4 M 6	A draft manuscript entitled "Contests, Prospects and Strategies for Enhancing Performance of Avocado Value Chains in Mt. Elgon Region, Uganda is under preparation (Sekatuba et al. 2020) Journal articles in preparation for submission by August 2021
4.3	Design a decision support tool for selection of appropriate financial instruments and organizational strategies to support development of Micro, Small and Medium Enterprises.	4.3.1 Decision support tool to select investment options	Yr 2 M 6	Achieved through a systematic review of financing options for tree planting and commercialisation in Ethiopia, Rwanda and Uganda (Oduol et al, 2019).
		4.3.2 Training on use of decision support tool	Yr2 M9	The systematic review found the main small-scale farmer finances are generated from farmer incomes from non-farm ventures. Also, borrowing from family and friends and agricultural cooperatives in some countries are source of funds for small-scale farmers. In addition, Village Savings and Loans Association (VSLAs) farmer groups, agricultural cooperatives and SACCOs have been found to be effective to small-scale farmers in other agricultural products unlike fruits. Semi-formal and formal financing institutions were found to be very detached from small scale farmers as their interaction is minimal due to information asymmetry, farmer perceptions, high interest rates and requirements for collateral from farmers (Oduol et al, 2019).

4.4	Encourage private sector investment in business opportunities for tree products.	4.4.1 Report on new tree product business opportunities refined through experiential learning process Workshops in 3 countries	Yr2 M 5 Yr2 M10 (MTR)	Tree tomato was identified and validated in Rwanda as the potential value chain for business opportunities. In Ethiopia, 3 potential value chains: Avocado, mango and apple were identified including strategies for developing them (Mawia et al. 2018). In Uganda, 2 value chains were identified, and business opportunities associated with the selected value chains highlighted in report on strategies for enhancing performance of tree product value chains in Mt. Elgon region The value chain was evaluated through producer, trader and consumer surveys
		4.4.2 Profile of stakeholders interested in new businesses around trees in 3 countries and strategies for engaging them.	Yr2 M12 (MTR)	Potential stakeholders were mapped and profiled during value chain (Avocado, mango and apple) validation in Ethiopia (Mawia et al. 2018) and Uganda (Avocado, fodder and timber). In Rwanda (tree tomato, avocado, Grevillea robusta) stakeholders in the tree value chain were identified. In Uganda stakeholders' interest in new businesses around trees are highlighted in a study on strategies for enhancing effective production and distribution of quality tree germplasm in Mt. Elgon region, Eastern Uganda (Galabuzi et al. 2019b).
		4.4.3 Report on key lessons from supported businesses	Yr4 M 6	The reports on key lessons from supported businesses couldn't be prepared as final surveys couldn't be done due to Covid-19 restrictions. However it was evident that In Uganda, tree seedlings/nurseries for income generation by youth groups in Uganda revealed total growth of (USD 1350) with profit margin of 540) In Rwanda, the analysis of the profitability of tree tomato cultivation at model farm level in Bugesera district indicated that tamarillo cultivation is highly profitable, with benefit/cost ratio of 4.36. The study concluded that more investments are needed in tamarillo production for raising the production to meet the market requirements. Value chains in Ethiopia are at the production level and should be improved through participatory trials.
		4.4.4 Dissemination of key findings	Yr2 M6 - Yr4 M6	Key findings disseminated through reports, guidelines and systematic review (Oduol et al, 2019), MSC theses, (Grant, 2018); and Mutamba 2021
4.5	Assess competitiveness of supported tree products value chains in Rwanda	4.5.1. Report on competitiveness of tree tomato value chain including strategies for broadening the products' market share locally and regionally	Yr3 M12	Findings of the study on tree tomato value chain competitiveness show that the factors that hamper the value chain competitiveness include e.g. the bargaining power of suppliers and buyers and the severity of the threat of new entrants, The strategies proposed to improve the competitiveness of tree tomato value chain comprise, the improvement of linkage between and collaboration of actors, and farmers' technical know-how and production capacities amongst others. The tree tomato value chain in Rwanda has a strong rivalry from imports from Tanzania, however there is opportunity for the spread of innovation making the tree tomato industry in the Rwandan sector more competitive on local, regional, and international markets (Mutamba 2021)
		4.5.2. Validation Workshop proceedings	Yr4 M2	Validation workshop were affected by COVID-19 pandemic

		4.5.2. 1. Policy brief 4.5.3 2 Journal article on tree tomato value chain	Yr4 M6	A journal article "Competitiveness of tree tomato in Rwanda is under preparation and will be ready by August 2021. MSc thesis on tree tomato value chain in Rwanda is contained here

Objective 5: To strengthen capacity of academic institutions in developing and implementing innovative agroforestry curricula.

No.	Activity	Outputs/ milestones	Due date of output/ milestone	Comments/ Supporting documents
5.1	Assess agroforestry curricula and extension training offered at tertiary agricultural education institutions in partner countries.	5.1.1 Report on status of agroforestry curriculum in each country and report on gaps in provision.	Yr1 M12	Reports on assessment of Agroforestry Curricula for training programmes offered in Tertiary institutions for Ethiopia, Rwanda & Uganda developed (Birhane et al, 2018a; Bucagu et al, 2018a; Isubikalu, 2018a).
		5.1.2 Report on status of extension trainings in each country and report on gaps in provision	Yr2 M 3	Reports on assessment of extension training programmes offered in Tertiary institutions for Ethiopia, Rwanda and Uganda highlighting gaps in provision developed (Birhane et al, 2018b; Bucagu et al, 2018b; Isubikalu, 2018b).
5.2	Facilitate revision of agroforestry curricula used in tertiary institutions and training of national extension staff.	Workshop proceedings on innovative agroforestry curricula for universities in the region	Yr2 M 6	Validation workshops on agroforestry curricula assessment and extension training held and reports prepared for Ethiopia Rwanda and Uganda (Birhane et al, 2018c; Mugunga, 2018: Isubikalu, 2018c). Following country specific workshops, a regional workshop aimed at curricula development was held on March 27th – 30th 2019 at Kenyatta University, with twenty participants from Ethiopia, Rwanda, Uganda and Kenya in attendance. Workshop proceedings were prepared (Kung'u et al. 2019a).
5.3	Promote the use of appropriate agroforestry learning materials and methods.	5.3.1 A community of practice in agroforestry amongst agroforestry educators, researchers and farmers developed.	Yr2 M 6	Discussions and synthesis of the status of agroforestry curricula, extension training carried out and a curriculum guide developed (Kung'u et al. 2019b). Universities and colleges in the 3 countries incorporated training suggestions given during the workshop. In Rwanda, the reviewed modules were introduced to the undergraduate Agroforestry students and some to Forestry students. In the University of Rwanda alone, an average of 200 students are estimated to benefit from the reviewed program each academic year Workshop on development of compendia learning materials was held virtually in July 2020
		5.3.2 5,000 tertiary students trained in agroforestry courses.	Yr4 M9	Application of the agroforestry curriculum was affected by COVID 19 pandemic which disrupted the academic year. The curriculum is expected to be enforced fully once the training institutions commence fully later in 2021/2022 academic year

7 Key Results and Discussion

7.1 To enhance knowledge of the impact of tree cover change on crop productivity, water, nutrients and livelihoods

7.1.1 Participatory Trials

A. Participatory trials in Ethiopia

Cognizant that farmers are cautious of the technologies offered to them and choose only those technologies that appear the most useful and/or profitable for their specific conditions, the project engaged farmers and other relevant stakeholders from the onset in setting up farmer participatory trials. These trials were aimed at testing agroforestry innovations on farmers' fields and homesteads and further adoption. In Ethiopia, a total of 1933 trials involving 1454 farmers were set up (Table 1).

Table 1: Farmer participatory trials established in T4FS-2 sites in Ethiopia

Site	Type of trial	Total farmers	Total trials
East Shewa (Semiarid)	Fruit tree trial	182	260
	Home garden fodder & Guava trial	37	33
	Lead farmer fodder trial	3	3
	MPT distribution	461	461
East Wellega/West Shewa (Sub humid)	Fruit tree and MPT trial	131	287
	MPT distribution	210	210
	Forage development trial (WP2)	15	75
Tsaeda Emba-Tigray (Dry highlands)	Fruit tree and MPT trial	90	189
	Apple root stock distribution	22	22
	MPT with RWH structures	63	63
	Fruit tree trial (Apple, Guava &Coffee)	90	180
	MP tree distribution	150	150
	Total	**1454**	**1933**

Additional participatory trials for the second phase of the project were established in June 2017 mainly at homesteads and on farm plots in the semi-arid sites following the approach used in phase 1. This included improved avocadoes, papaya, improved mangoes, coffee (semi-arid aez) and improved avocadoes and *Grevillea robusta* (sub-humid area only). Data was collected on survival, height growth and crown diameter of planted seedlings. Survival and growth scenarios across the locations were compared.

In East Shewa (Adamitulu), farmers reported that they watered seedlings either weekly (43%) or bi-weekly (23%). In Dugda, 77% of the participants watered their papaya seedlings daily and 33% watered theirs bi-weekly. In Lome, farmers mostly water their seedlings bi-weekly (44%) followed by weekly (42%). Tree survival results in the semi-arid indicated a relatively higher survival of Papaya seedlings in Lome (47.4%) compared to that of Dugda (27.8%) and Adamitulu (30.9%).

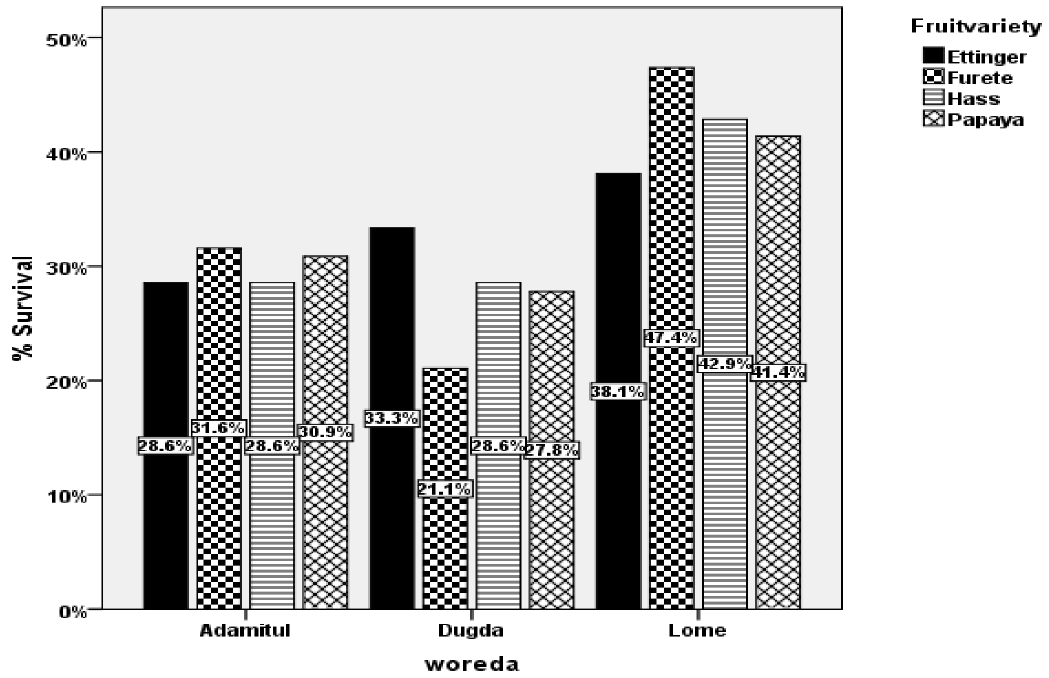


Figure 8: Survival of planted seedling at homesteads

In Tigray, results of seedling survival are presented below. Survival of *Psidium guajava* was found out to be one of the highest at Guila abenae, Dimollo, Hadush hiwet, Maymegelta and Takot (East Tigray sites) ranging from 82-100%. The survival of Malus domestica was also found very appreciable in Hadush hiwot, Dimollo and Takot ranging from 72-80%.

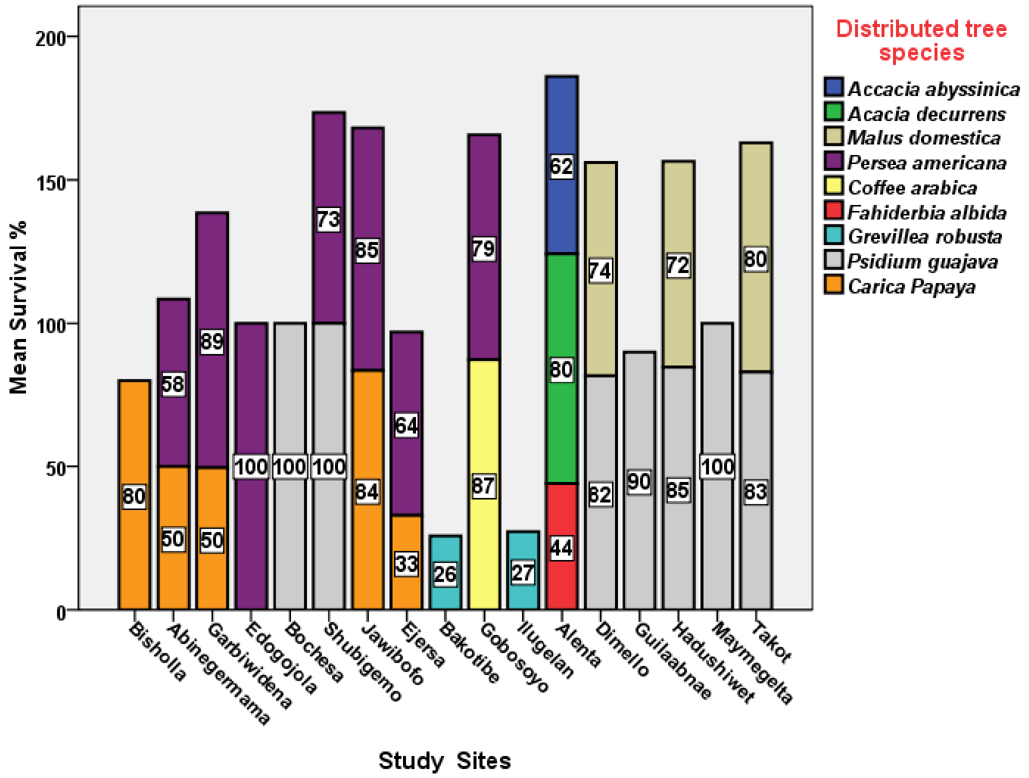


Figure 9: Survival of tree seedlings in various intervention sites

Differences in height and diameter growth were also observed in different sites. The height growth of *Malus domestica* was highest in Dimollo, Hadush hiwot and Takot at 87-126cm.

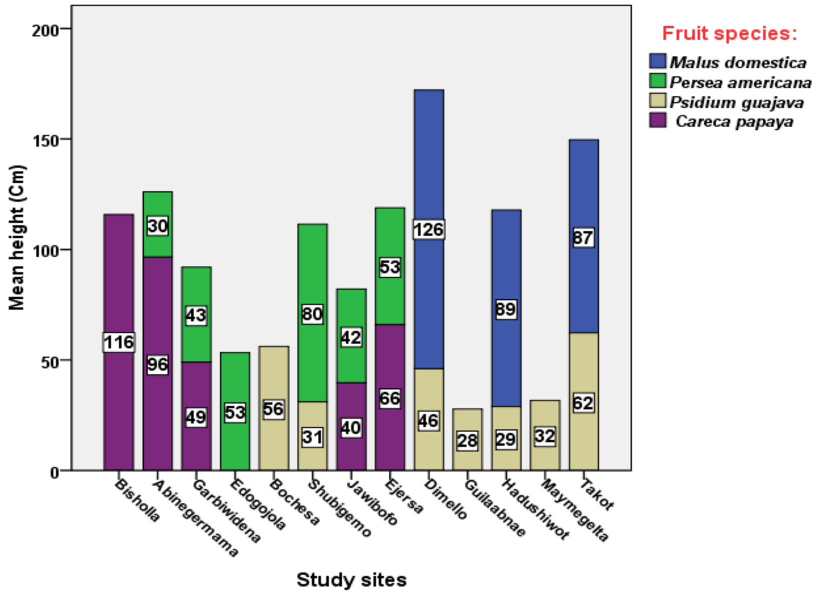


Figure 10: Height growth of fruit tree seedlings in different intervention sites

Further lessons on farmer-led approaches for increasing tree diversity on farms indicated that the actual tree planting did not fully reflect priorities as the seedling production and planting mainly depended on the tree seeds that could be availed from nurseries or the fruit tree seedlings that could be procured and availed during planting time. Differential survival between species and niches meant that the connection between desired and realized tree diversity was further reduced. The overall mean survival of the seedlings in both agroecologies was 45.6 (± 32.6) at 6 months and 33.6 (± 25.5) at 14 months. Findings further revealed that farmers in Ethiopia have an interest in high species diversity. Farmers' preference of tree species was determined by availability of space and the already available tree stock and its composition; ease of tree protection and care after planting; the challenges that free grazing poses to seedling survival and growth; and potential conflict with neighbours. Understanding the species and planting niche preferences with appropriate seedling supply and management was proposed as a means to increase the diversity of trees in farmed landscapes. (Derero et al, 2020).

Additional results on the participatory trials are presented in a PhD dissertation entitled 'Ecophysiology of *Faidherbia albida*; effect of pruning on tree water relations, cambium dynamics and understorey wheat productivity in Ejerssa Joro, Ethiopia', a Master's thesis entitled Farmers perceptions and adoption of micro catchments for establishment of agroforestry trees in East Shewa zone, Ethiopia'. Lessons from participatory trials were also communicated through poster presentations made at the World Congress on Agroforestry in Montpellier France (Derero et al 2019, Kinuthia et al 2019).

B. Participatory trials in Rwanda

In Rwanda, a total of 2,290 trials have been established in Bugesera and Gishwati.

Table 2: Types and number of farmer trials established between 2017-2020

Types of participatory trials	Bugesera		Gishwati		Total	
	Number of trials	Number of farmers	Number of trials	Number of farmers	Number of trials	Number of farmers
Tree biomass incorporation	401	306	208	153	609	459
Soil Conservation	9	9	174	1370	183	1379
Stakes for climbing beans	193	114	347	273	540	387
Sub-total	*603*		*729*	*1796*	*1,332*	*2,225*
Fruits for improved nutrition and income generation						

• Tree tomato	504	504	245	245	749	749
• Grafted avocado	85	85	23	23	108	108
• Grafted Mango	62	62		0	62	62
• Pawpaw	39	39		0	39	39
Sub-total	*690*	*690*	*268*	*268*	*958*	*958*
Total	1,293	690	997	2,064	2,290	3,183

Survival of Fruit and Multi-Purpose Tree seedlings

In various sites at Gishwati, the survival rates of two agroforestry species - *Alnus acuminata* and *Acacia angustissima* - and three fruit species – Tree tomato, Avocado and Pawpaw (mountain papaya) – were high, greater than 85%. In Bugesera, the survival rate of nearly all fruit species was approximately 75% with some differences among the fruit species and within the sites. The high survival rates indicated the importance attributed to fruit trees for nutrition and income generation hence the farmers had implemented the required management practices to increase the fruit survival after planting. The more common practices by the farmers included weeding, fencing, watering, fertilizer and pesticide application.

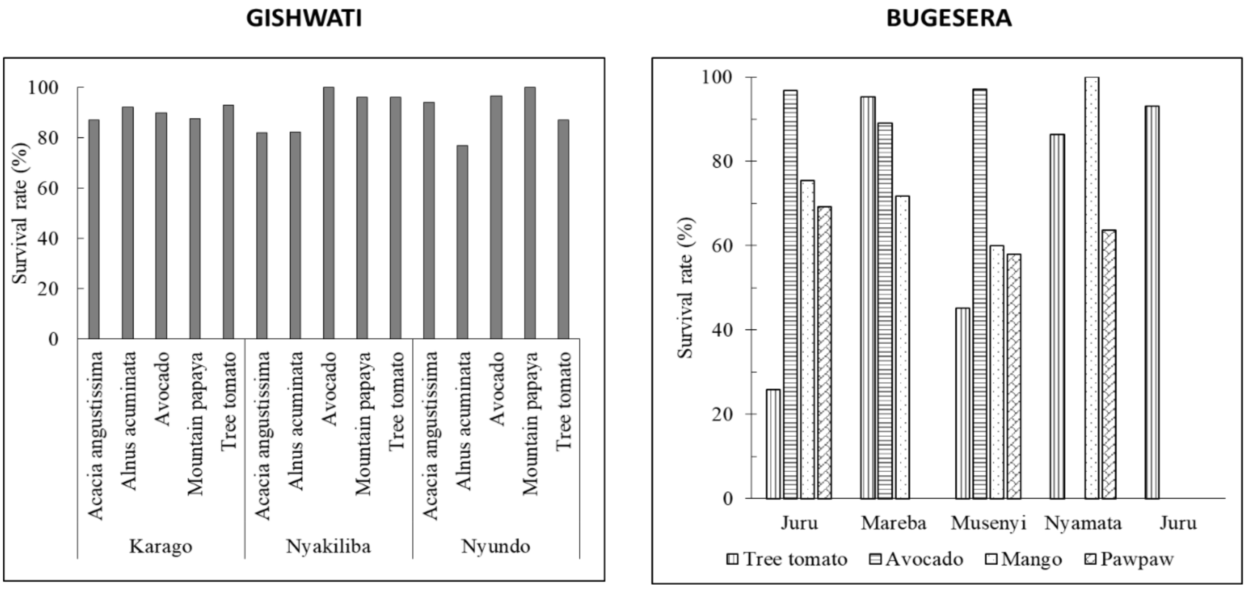


Figure 11: The survival rate (%) of fruit species and MPTs planted on different sites at Gishwati (left) and Bugesera (right)

Performance of climbing beans by using different stakes

Climbing beans require strong stakes for high yields. However, high prices and lack of quality staking materials have hindered growing of climbing beans. Previously farmers used overgrown napier grass, maize and sorghum stalks and cassava as stakes. To address this challenge, the project tested selected MPTs specific to contexts - *Eucalyptus* sp., *Calliandra calothyrsus*, *Senna spectabilis*, *Vernonia amygdalina*, *Gliricidia sepium, Grevillea robusta, Lantana camara and Leucaena diversifolia* in Bugesera, and *Alnus acuminata, Acacia angustissima* in Gishwati. In Bugesera, the use of wood stakes increases the yield of climbing beans from the baseline of 0.7 tha^{-1} to 2.5 tha^{-1} depending on the type of stake used. Climbing beans had 3 to 4 times greater yield than that of the bush beans in farmer trials. The highest yield of climbing bean was recorded when *Senna spectabilis* and *Gliricidia sepium* stakes were used. In Gishwati, the use of *Alnus* and *Acacia* stakes increased climbing bean yield from the baseline of 1.3 Tha-1 to 2.0 Tha-1.

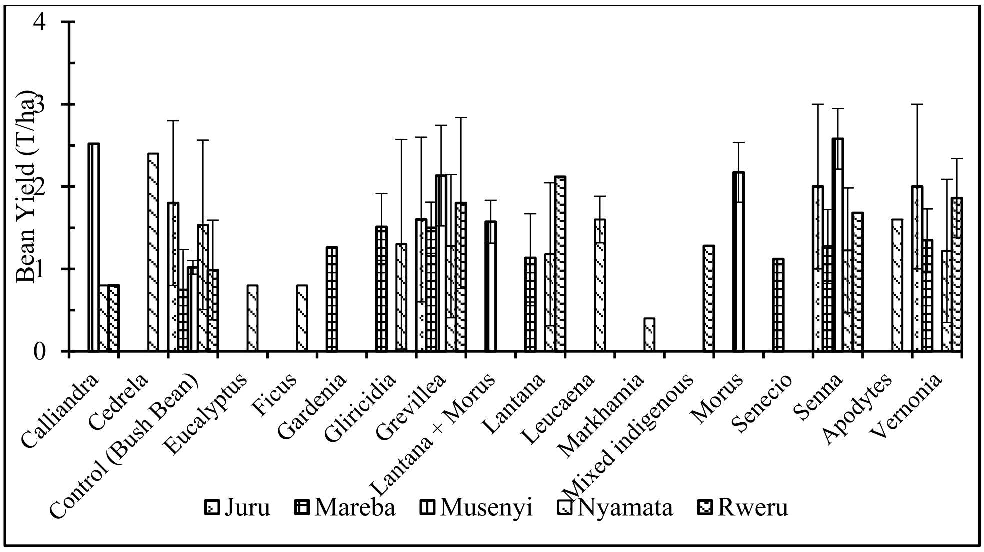


Figure 12: Bean yield using different stakes in Bugesera

Tree biomass incorporation improved soil fertility and led to higher crop yields

Findings from trials on tree biomass incorporation in Bugesera showed that the application of tree biomass combined with mineral fertilizer (Urea and DAP) increased bush bean yield from the baseline of 0.7 tha-1 to 3 tha-1, while Gliricidia biomass + DAP increased maize yield from the baseline of 1.6 tha-1 to 3.8 tha-1. The findings further revealed that the tree biomass of all species combined with mineral fertilizers led to higher crop yields where soils and climate factors were favorable. The application of DAP and Urea coupled with tree biomass resulted into comparatively the highest maize grain yield

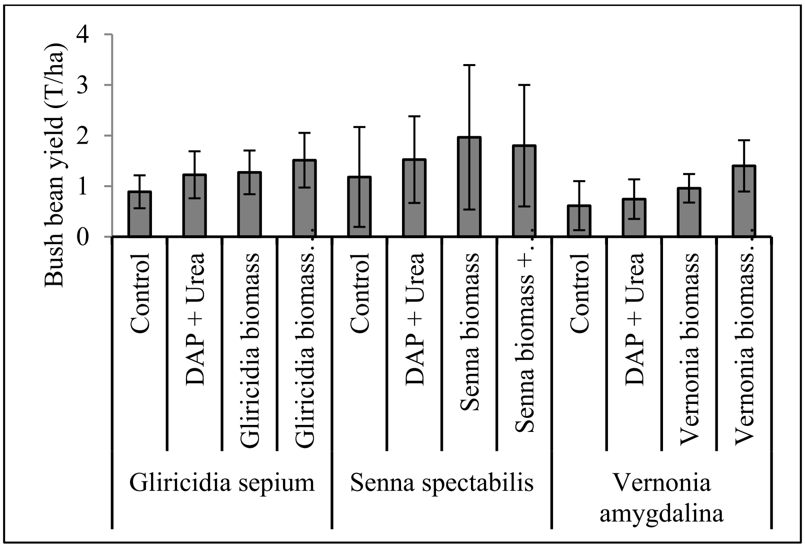


Figure 13: Bush bean yield response to application of tree biomass and mineral fertilizers in Bugesera

Performance of tree tomato

In Bugesera, tree tomato fruit maturity occurred from 9 months to about 11 months after planting. Plants with larger Root Collar Diameter (RCD) were likely to produce many fruits. The number of fruits per tree ranged from 16 to 66 depending on site conditions. The average production of fruits of tree tomato was evaluated at 159kg per beneficiary household, per season.

In Gishwati, the average total height and diameter of tree tomato were 1.94m and 3.90cm respectively. The average number of fruits produced per tree was about 100, with no significant differences among farms (p>0.05).

C. Participatory trials Uganda

In Uganda, 813 participatory farmer trials were established across a range of contexts.

Table 3: Number of participatory trials established and farmers hosting the trials per district

Type of Trial	Mbale		Manafwa		Bududa		Number of trials		
	No. of trials	No. of farmers	No. of trials	No. of farmers	No. of trials	No. of farmers	Year 1	Year 2	Year 3
Trees on farms	95	28	85	26	78	35	148	82	79
Boundary planting	48	35	62	25	73	55	30	29	116
Woodlots	32	20	21	16	33	28	41	13	38
Fruit orchards	20	25	14	26	30	15	8	40	16
Fodder bank and hedge rows	24	16	18	10	29	31	24	15	7
Soil and water conservation	16	16	16	21	12	13	14	16	22
Integrated	9	9	24	18	19	16	0	29	0
Riverbank stabilization	22	8	15	6	18	15	9	18	19
Total	**266**	**157**	**255**	**148**	**292**	**208**	**274**	**242**	**297**
Farmers									**513**
Trials									**813**

Findings from participatory trials indicated that the intention of farmers to integrate trees in coffee plantations was mainly driven by their evaluation of the benefits of shaded coffee (attitude) followed by beliefs about their own capability (perceived behavioral control). This renders attitude and perceived behavioral control as reliable predictors of farmer tree planting behavior, especially in the context of developing countries (Buyinza et al 2020).

Another study to identify differences in farmer motivations to adopting agroforestry practices in the Mt. Elgon region of Uganda showed that About 40% of the variation in farmer motivation to integrate trees in their coffee plantations was explained by the significant variables of ‘attitude’ and ‘perceived behavioural control’ among farmers actively participating in the T4FS project from phase 1. However, the neighbors of participating farmers and farmers who had never interacted with the project were only motivated by ‘attitude’ and ‘social norms’ respectively. Farmer motivation resulting from social pressure was strongest among farmers who had never interacted with the project, and in the absence of project interventions, they rely on existing social structures to drive change in their community. The findings indicate that psychological factors are key drivers to the farmers’ internal decision-making process in agroforestry technology adoption and can be context specific. The adoption behaviour of smallholder farmers is mainly shaped by existing community social norms and beliefs that tend to promote knowledge exchange, as opposed to the conventional knowledge transfer extension approaches (Buyinza et al 2020).

7.1.2 Long-term Trials

A. Long term trials in Ethiopia

Two long term trials in Melkassa (semiarid) and Bako (sub-humid) sites were established and managed over the entire project period. The main objective of the long term experiments was to assess effects of tree species and management on crop productivity, water resources and nutrients at field, farm and landscape scales to inform scaling up to improve food security and enhance adaptability to climate change.

Analysis results from the long-term trial in Melkassa indicated that there is significant difference between survival of tree species tried out in the trial at p=0.05. Growth of trees planted also revealed marked differences across the years. *Acacia nilotica* revealed significantly higher survival rate (90%) followed by *Cordia africana* (70%). Analysis of tree growth data in 2018 indicated that *Acacia nilotica* had significantly higher growth (p=0.05) in height, DBH and RCD with 6m, 12.6cm and 16cm respectively compared to the other tree species six years after planting (Figure 14).Tree growth under mixed tree plots seconded in performance. *Faidherbia albida* revealed the least growth in height, DBH and RCD.

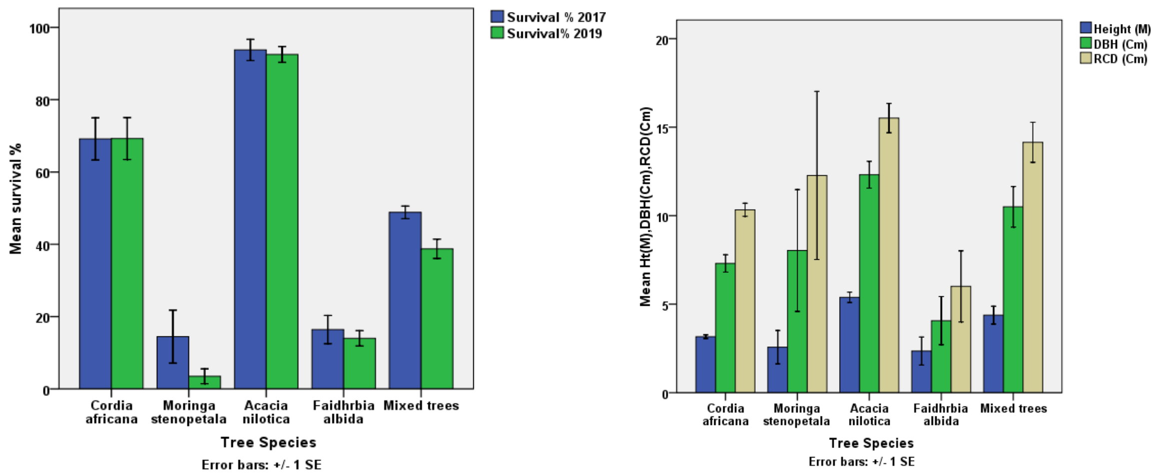


Figure 14a: Survival of trees between 2017 and 2019; Figure14b: Comparison of tree growth between species

Crop yield and biomass results showed that the teff straw (biomass) under sole crop plots (1182kg/ha) was significantly different from the remaining combinations with the exception of the straw yield (1035kg/ha) under *Acacia nilotica* (Figure 15) .This could be an indication that *A. nilotica* was complementary to teff therefore, maintaining trees that have complementary role to crops on farm lands helps to diversify products from a parcel of land without reducing yield of the associated crop compared to monocropping treatments on the same unit of land.

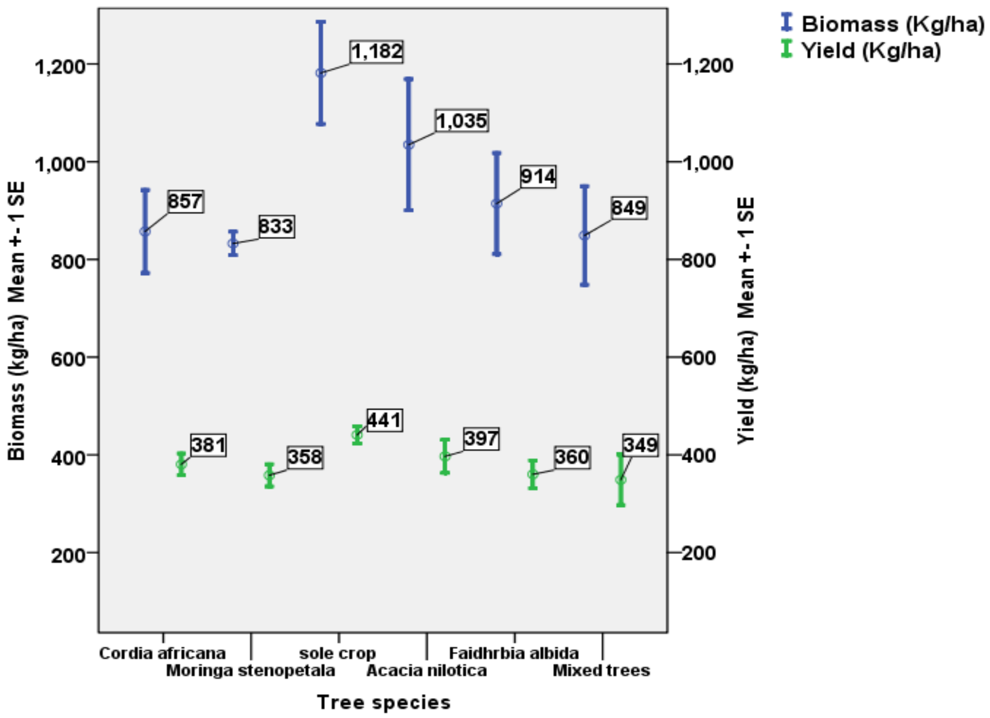


Figure 15: Biomass and teff yield under varying treatments at Melkassa long term trial (2017)

The teff biomass and yield (5459.91kg/ha & 589.53 kg/ha respectively) under *Faidherbia albida* was found to be significantly higher compared to sole crop in 2019 (Figure 16). This could indicate that *Faidherbia albida+tef* intercropping systems complement more resulting in significantly higher biomass induced by positive interaction of components under the conditions of the study site.

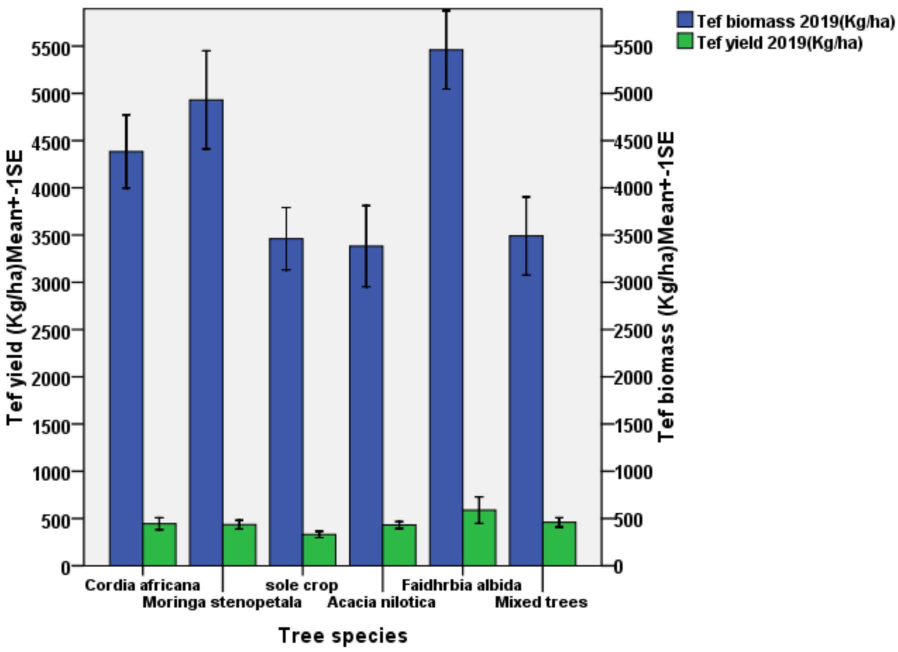
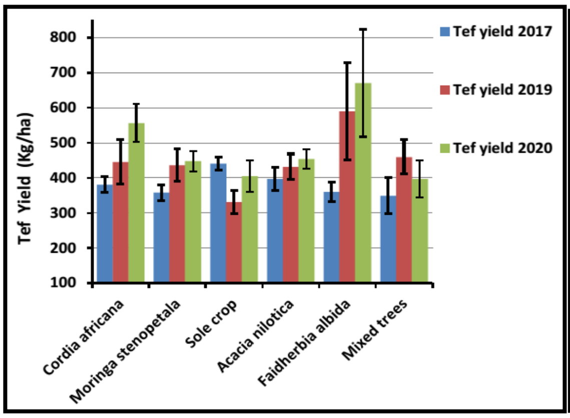


Figure16: Teff yield and biomass at Melkassa long term trial (2019)

In 2020, teff yield was found to be significantly higher (p= 0.05) under *F.albida* to the other treatment conditions. The teff yield under C.*africana* was also significantly higher seconding that of the yield under *F.albida* with statistically comparable mean yield in

2020.This implies that over time, trees in agroforestry systems play their complementary roles accompanied by significant increase of crop yield in tree based systems over crop alone systems (Figure 17a). The tef biomass was found to be significantly higher under *F. albida* in 2020 (Figure 17b).



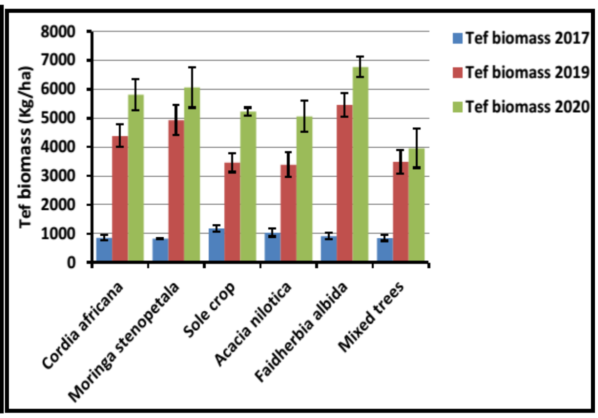


Figure 17a: Comparison of teff yield under different tree species 2017-2020; Figure 17b: Comparison teff biomass under different tree species 2017-2020

In Bako Long term trial, *Grevillea robusta* and *Cordia africana* had the highest growth rates in terms of diameter and height compared to the other tree species, while *Croton macrostachyus* had the lowest growth rate (Appendix 1).

Maize and finger millet yield under tree+crop treatments were not significantly different (p= 0.05) from crop yield in the sole crop treatments, except crop yields under *Acacia abyssinica* in 2017. Teff yield was significantly greater under tree +crop treatments than the sole crop treatments in 2017. Crop yields (teff, finger millet, and maize) under *Acacia abyssinica* were significantly lower than crop yields under the rest of tree +crop, tree mix, and sole crop conditions (Appendix 2).

Results of the Bako Long term trials are published in [Tadesse et al 2021]

B. Long term trials in Rwanda

Two long term trials were established in sub-humid (Gishwati, Karago site) and semi-arid (Bugesera, Karama site) regions of Rwanda to assess the long-term effect of tree cover change on soil fertility, water and crop productivity.

Effect of trees on crop yields

In Karama long term trial, maize planted was subjected to various treatments. These included different combinations of tree species in a plot and a crop alone treatment. The specific treatments are: (1) *Faidherbia albida*, (2) *Faidherbia* + *Markhamia lutea*; (3) *Faidherbia*+*Grevillea robusta*, (4) Markhamia l. (5) *Markhamia L.* +*Grevillea r.*; (6) *Grevillea robusta;* (7) Crop alone. The evaluation of the effect of tree species and their combination on maize yield indicated that yield in sole crop (without trees) was significantly higher (2.6 tha^{-1}) than the yields recorded in other treatments.

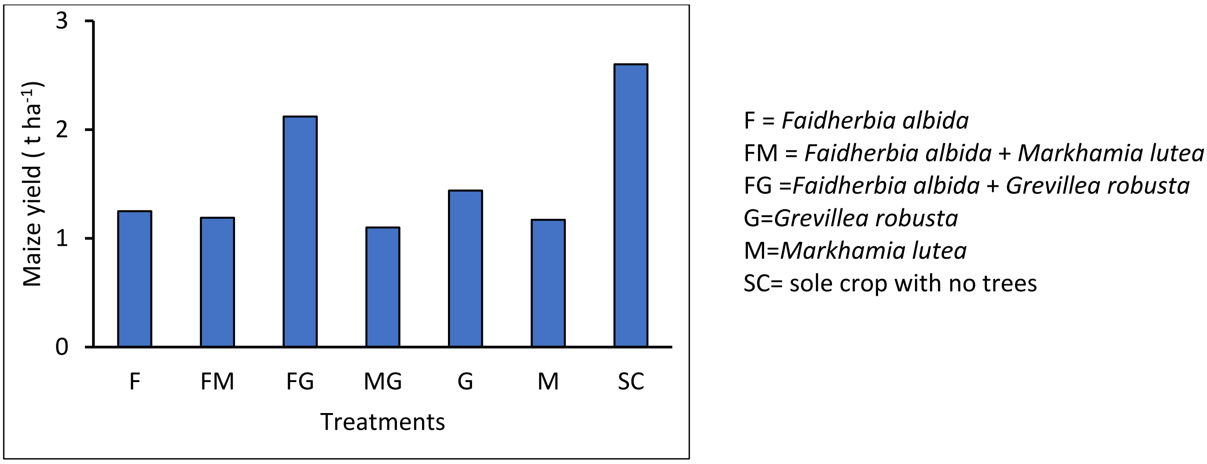


Figure 18: Maize yield under different tree species, plantation mixtures and in open field in Karama Long term trial

Effect of tree management (pruning) on crop productivity

Pruning of *Grevillea robusta* at 50% and 75% was introduced to assess the effective tree management practice to be recommended to farmers. Results showed that the highest maize yield was recorded for *Markhamia lutea* (6.1 t ha^{-1}) treatment followed by sole maize crop (5.2 tha^{-1}) treatment. Plots consisting of the combination of pruned *Fairdherbia* and *Grevillea* following farmers' practice (50% pruning) resulted into higher maize yield, similar to the yield obtained in sole crop. In general, pruning *Grevillea, Fairdherbia* and *Markhamia* at 50% recorded highest yield.

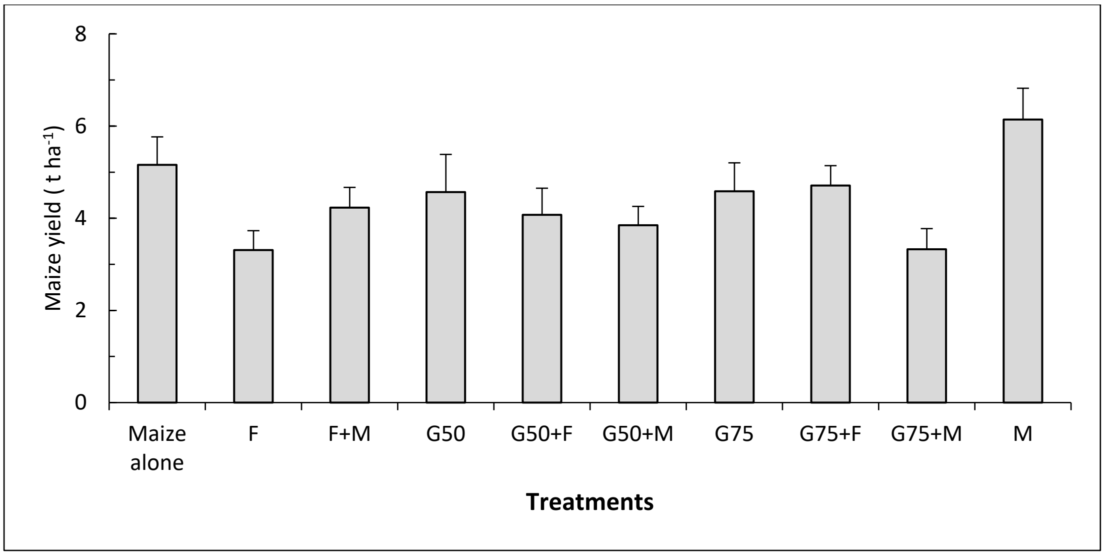


Figure 19: Tree species and management effect on maize yield in Karama long term trial

F, G and M represent *Faidherbia albida; Grevillea robusta and Markhamia lutea*, respectively. 50% and 75% mean the levels of pruning) of G. robusta. Error bars represent standard error of means.

In Tamira Long Term Trial, the effect of tree management on wheat yield was assessed, the treatments comprised pruning *Alnus* trees at 75% and 90% (farmer practice), application of alnus biomass (B), no alnus biomass application (NB) and crop alone without trees (C). The results showed that treatments with *Alnus* biomass yielded higher than without the biomass. The highest yield was found in plots with no trees, followed by the plot with 90% pruning.

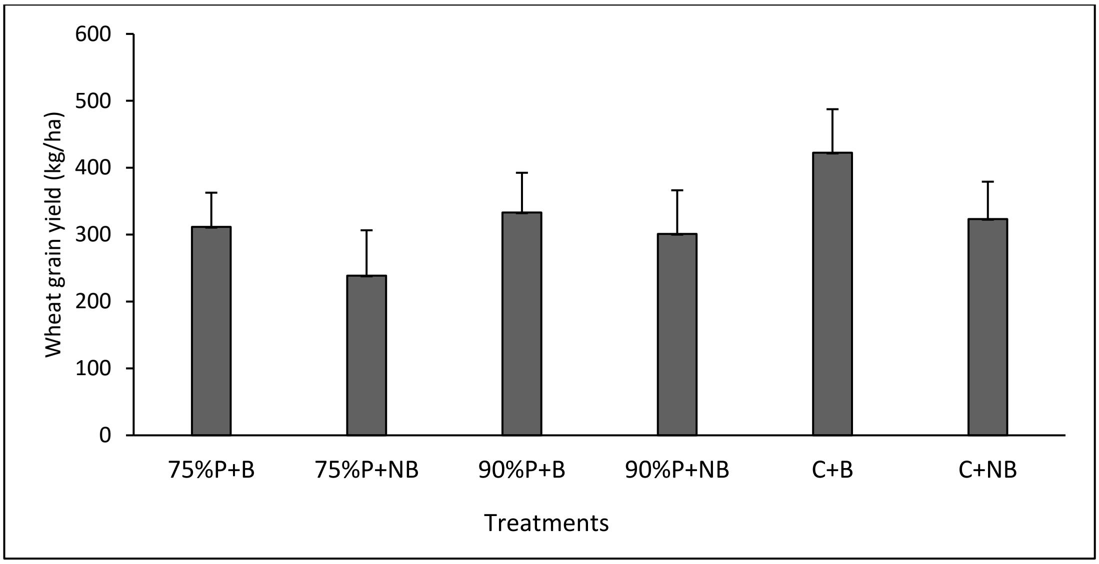


Figure 20: Alnus tree pruning and green manure effects on wheat yields in Tamira Long Term Trial.

B represents treatment with incorporated Alnus green manure. NB treatment with absence of green manure; C plots with crop alone without trees; the values 75% P and 90%P correspond to the percentage of Alnus tree pruning.

Impacts of *Alnus*-based agroforestry system on carbon sequestration and ecosystem services in the Sub-humid region of Rwanda

To understand carbon sequestration and other benefits of *Alnus acuminata*, a survey of 146 households, tree inventory over 13 ha of farmland and destructive measurements of 172 stems were made in the sub-humid project area. It was found that over 75% of the sampled households had alnus trees in their farms. The trees provided stakes for climbing beans, firewood and timber. The trees also were reported to improve soil fertility and control soil erosion. The average alnus tree density per farming household ranged from 130 and 161 trees per hectare, with an average total height of 7.7 m and diameter at breast height of 16.3 cm.

Figure 21: Estimation of tree biomass including standing tree measurements (A); destructive sampling for tree biomass partitioning (B) and determination of oven-dry weight of tree biomass samples (C)

C. Long term trials in Uganda

Through the project, six sap flow meters were deployed on stems of three selected trees each of *C. africana* and *A. coriaria* on-farm. The objective of the study was to assess the daily water use patterns of these agroforestry tree species at different times of the year. Results showed that there was a significant effect of the interaction between tree species and season on daily water use. The two species showed contrasting patterns of seasonal water use across leaf shedding schedules characterized by episodes of reverse flow in *A. coriaria* at specific periods of the year.

In another study, sap flow meters (SFM1s) were used to monitor the impact of pruning on tree water use in *Cordia africana* (Cordia), *Albizia coriaria* (Albizia) and *Coffea arabica* (coffee) trees on two farms in Eastern Uganda. The trees were subjected to a 50% pruning regime at a 6-month interval over a period of 20 months. The results from the Albizia site showed that the mean daily sap flow was generally lower in pruned *Albizia* than in the unpruned trees. Daily sap flow generally declined during high rainfall events (for example August to September and mid-October to early November) and increased during the dry seasons (January to February) in 2018 and 2019. From December, *Albizia* trees begin shedding their leaves through January. During this period, daily sap flow declined and the trees eventually experienced episodes of reverse flows in January 2019 and 2020.

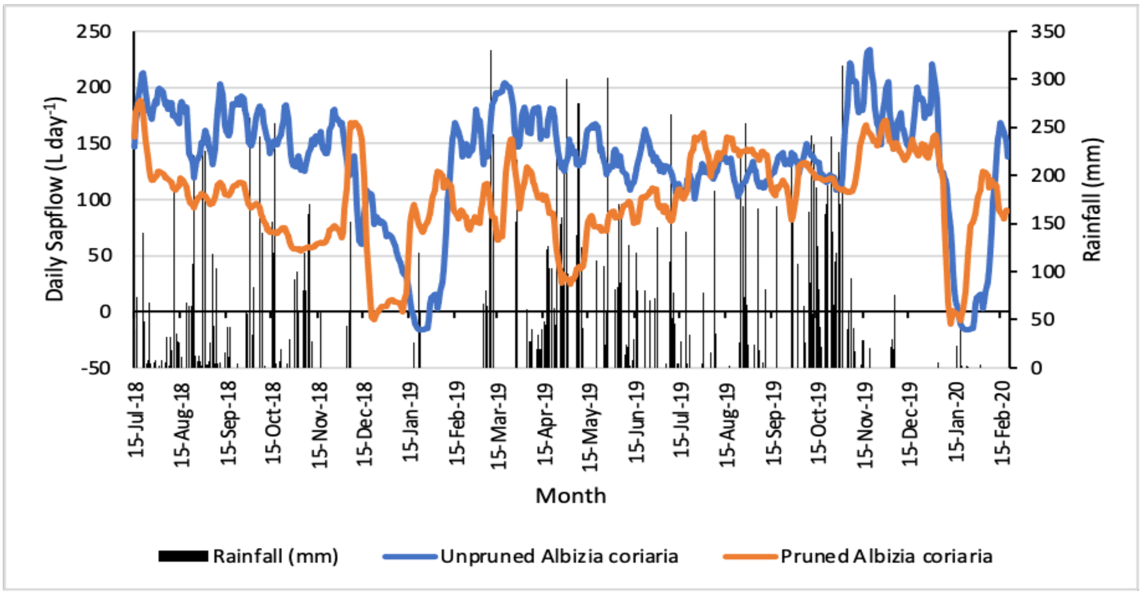


Figure 22: Time courses in daily sap flow in pruned and unpruned Albizia trees over a 20-month period

7.1.3 Develop the APSIM X AF model for a wider range of tree species and cropping practices and complementary models at livelihood and landscape scales for local and national impact

A modelling capability is now available that dynamically links the SIMILE farm-scale livelihood model to the APSIM plot-scale biophysical model for agroforestry. To implement this in Rwanda, data were collected from a field experiment in a gliricidia-maize/bean system, and modelling has commenced for plant production using APSIM, and farm-scale modelling has been designed using SIMILE.

In Rwanda, data indicate that including gliricidia in the farming system and using its biomass to fertilize adjacent cropping zones can improve the yield of maize within these zones if gliricidia rows were 6m or more apart (Figure 23). Maize yields were suppressed if rows were only 3m apart. These general responses were simulated using APSIM, and simulated yields averaged across the whole field (effective yield) were only higher if maize rows were 6 m or more apart (Fig. 23).

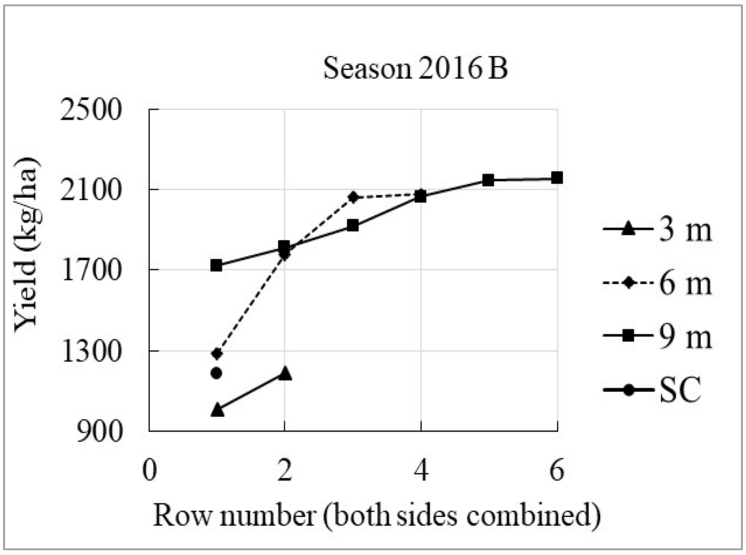


Fig 23: Effect of gliricidia row spacing and maize row number (away from the gliricidia row) on maize yields for the 2016B season at the gliricidia experiment in Rwanda

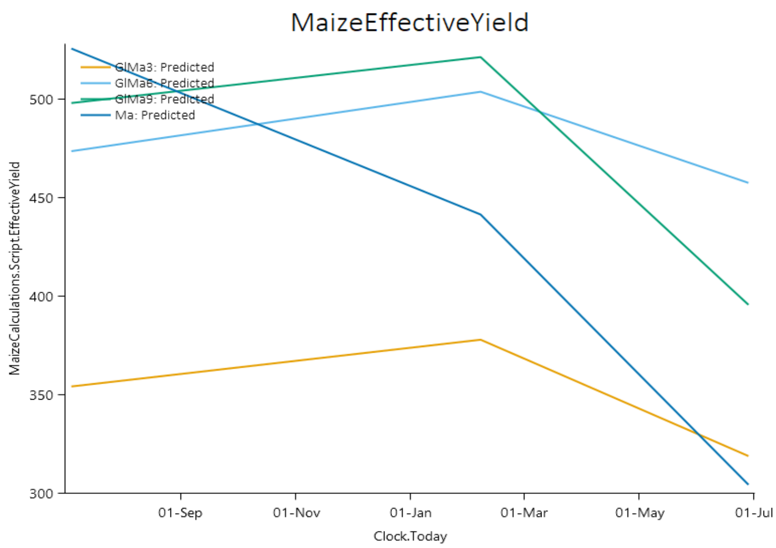


Figure 24: Simulated effect of gliricidia row spacing on effective maize yields

Using *Gliricidia* branches as stakes for climbing beans in a maize/bean rotation system increased bean yields 61-135% (Table 4), but simulation of beans has not yet commenced. The schematic diagram below indicates interactions of plot- and farm-scale models using APSIM and SIMILE, respectively, that will follow soon.

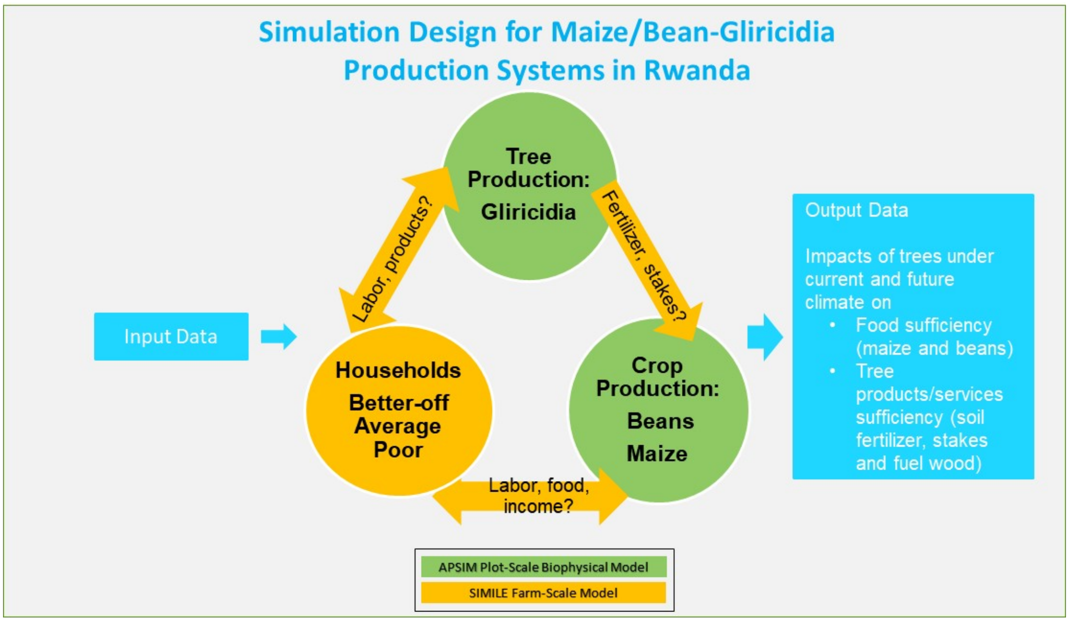


Figure 25: Simulated effect of maize/bean -Gliricidia production system in Rwanda

Table 4: Effect of Gliricidia row spacing on yields of bush and climbing beans

Spacing Treatment	Bush beans [1]Beans (kg ha^{-1})	Climbing Beans (kg ha^{-1})	Increase (%)
3 m	212 ^{a}	499 ^{a}	135
6 m	486 ^{b}	776 ^{b}	60
9 m	473 ^{b}	826 ^{b}	75
Sole Crop	704 ^{c}	1130 ^{c}	61

[1] The same letters within a column are not statistically significant ($P = 0.05$)

In addition, maize yield in the maize zones relative to maize-only was simulated in a gridded pattern across the whole country of Rwanda. Competition for water and nitrogen led to relative yields less than 1.0, with the least (0.2) in the east where competition was greatest (Figure 26.

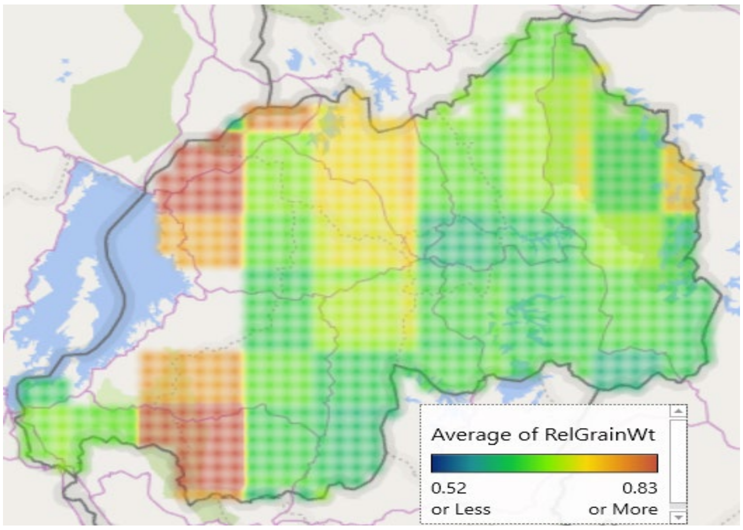


Figure 26 Average grain weight

In Ethiopia, APSIM modelling results for effects of *Faidherbia albida* on maize productivity and carbon sequestration showed that maize yields were maximised with 50% pruning and NP fertilisation in the 2-6 m zone (Figure 25).

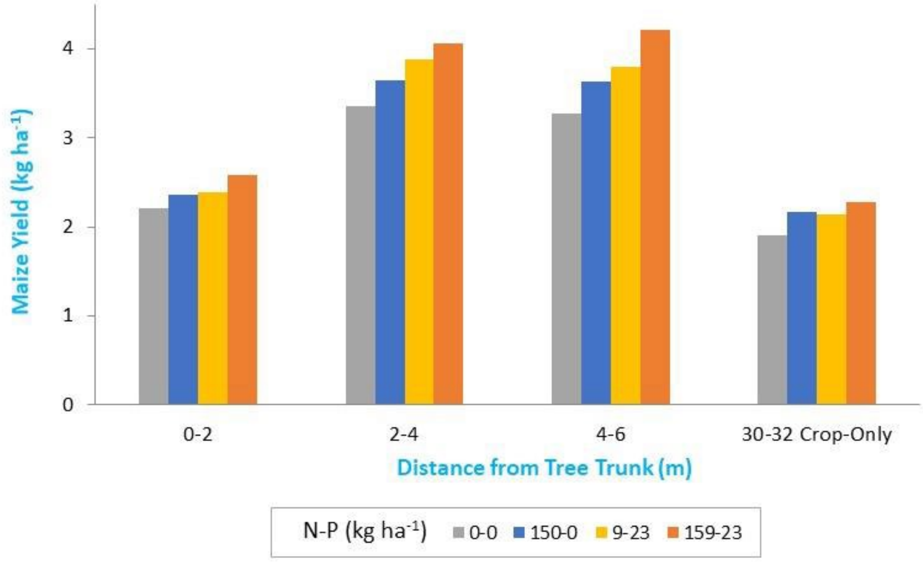


Figure 27: Maize yield in relation to distance form tree trunk pruning level and fertilization.

Factors influencing maize production include rainfall, distance from tree, pruning and fertiliser application rates. Higher rates of fertiliser would have led to further increases in maize yield. The study concluded that 50% pruning (instead of 100% pruning, i.e. pollarding) reduces shading enough to maximise maize grain yield under trees. Fertilisers increase yield and are best used in normal or wet seasons. If *F.albida* trees were the cause of higher soil fertility, incorporating more trees into these farmlands could improve crop production and deliver ecosystem services including carbon sequestration.

More findings on APSIM modelling found in Dilla et al 2018a - Potential of the APSIM model to simulate impacts of shading on maize productivity; Smethurst et al 2017- Accurate crop yield predictions from modelling tree-crop interactions in Gliricidia-maize agroforestry; Dilla et al 2020 -Plot-Scale Agroforestry Modelling Explores Tree Pruning and Fertilizer Interactions for Maize Production in a Faidherbia Parkland and posters- Smethurst et al, (2019); Huth et al 2019.

7.2 To integrate water management technologies and sustainable grazing options with promotion of agroforestry

7.2.1 Objective 2a: Conduct mapping of options in relation to context and, training in and facilitation of implementation of water management technologies appropriate for enhanced tree seedling establishment and growth.

186 maps were produced on context-based land and water management options in Ethiopia, Rwanda and Uganda including 126 base maps depicting the digital elevation model (topography in 3D), land use, soil, rainfall, slope and temperature; 63 thematic maps of the appropriate land and water management options, potential run-off and the amount of soil loss with no conservation. Mapping reports were completed the three countries: Uganda (Nyolei et al, 2018c), Rwanda (Nyolei et al, 2018a) and Ethiopia (Nyolei et al, 2018b).

In Ethiopia, a total of 24 maps depicting slope, land use/cover, soil texture, rainfall, runoff potential, potential soil loss were produced. Of these maps, 15 are base maps depicting the digital elevation model (topography in 3D), land use, soil, rainfall, slope and temperature. The rest are nine (9) thematic maps showing the appropriate land and water management options, potential run-off harvestable and potential soil loss without conservation. East Shewa, East Wellega and West Shewa are zones within the Oromia region, central Ethiopia. The zones form part of the Ethiopian highlands and therefore characterized with varying terrain for gentle to very steep slopes. The zones also receives medium to high rainfalls annually and are dominantly cultivated (Appendix 4)

In Rwanda, the study identified suitable land and water management options in eleven sectors including Gashora, Juru, Kanama, Karago, Mareba, Mukamira, Musenyi, Nyakiriba, Nyamata, Nyundo, Rweru and produced 99 maps. Of these maps, 66 are base maps depicting the digital elevation model (topography in 3D), land use, soil, rainfall, slope and temperature. The rest are 33 thematic maps showing the appropriate land and water management options, potential run-off that can be harvested and potential soil loss if no conservation is practiced. In the case of Rwanda, we produced more maps because the mapping even covered the villages where the project operates. Although we found that most of the project areas mapped are well conserved and require limited interventions (i.e. Gashora, Juru, Kanama, Nyakiriba, and Rweru), some of the sites (Karago, Mareba, Mukamira, Musenyi and Nyamata), especially with steep slopes presented serious land degradation potential.

The use of wetlands for irrigated agriculture should be highly regulated by the government to prevent loss of the vital ecosystem. The recommended measures are presented in the maps in Appendix 5.

In Uganda, the study identified suitable land and water management options in Mbale district and six Counties including Busiu, Butha, Nakatsi, Nalwanza, Namabya and Namanyonyi and produced 63 maps. Of these maps, 42 are base maps depicting the digital elevation model (topography in 3D), land use, soil, rainfall, slope and temperature. The rest are 21 thematic maps showing the appropriate land and water management options, potential run-off that can be harvested and potential soil loss if no conservation is practiced.

The study found that 40.9% of the district is sustainable but can be improved. The sustainable areas include open forests, wetlands, irrigated agriculture, bushland and rock outcrops. However, the wetlands are especially sensitive to degradation and should be protected by law.

Recommended land and water management options on cropland with slopes 0-5% include: conservation agriculture (CA), agroforestry, soil and water conservation measures including: Zai pits, trapezoidal bunds, level bunds, grass strips, stone bunds all constructed along the contour. This should be combined with soil fertility improvement measures such a green manure (such as sun hemp or velvet beans), crop rotations, compost and animal manure.

Regarding forestland we recommend the conservation of all important indigenous tree species and controlled harvesting of the same. Shrublands should be used for controlled grazing and FMNR. where the slope is 0-5% trapezoidal bunds can be used for harvesting rainwater for improved pasture production.

The use of wetlands for irrigated agriculture should be highly regulated by the government to prevent loss of the vital ecosystem. Maps in Appendix 6.

7.2.2 Objective 2b: Review existing policies, strategies, and institutions on grazing, and identify barriers to their adoption

Analysis of Relevant livestock policies, strategies and institutions in Ethiopia

The Ethiopian government has developed several policies, strategies and institutions to improve and enhance the quality of life and health of all Ethiopians and to promote sustainable social and economic development through the sound management and use of natural, human-made and cultural resources and the environment as a whole so as to meet the needs of the present generation without compromising the future generations.

However, the current livestock free grazing and overstocking practices on the environment, which was opposite to the policies and strategies, are among the major contributors to land degradation and low livestock and land productivity. In the last 20 years, the Ethiopian government launched several policies and strategies on forest protection, afforestation and state forest development to encourage tree planting on the landscape so as to improve productivity of the land.

However, due to lack of clear policies and guidelines, unclear institutional set up and weak governance and implementation capacity of the experts, development agents and farmers and as well as low awareness of policy and decision makers on impact of free grazing have resulted insignificant success. Important policies and strategies relevant to sustainable grazing management / system are summarized in Appendix 7.

Major Challenges to Adoption and Scaling up of Agroforestry

1. Poor Livestock Production Systems

The contribution of the livestock sector to the national economy of Ethiopia is low (CSA, 2015). This is attributed to poor livestock management, lack of feed quantity and quality, low productive traits, prevalence of disease and parasites and limited accesses to market and finance (Shapiro et al., 2017). The impacts of climate change and low technical implementation capacities of the extension systems also contributed to the poor livestock production (MoA and ILRI, 2013a).

The free grazing system resulted in tramping or damaging of planted or maintained seedling survival and adoption of agroforestry. The low adoption of agroforestry is also aggravated by lack of appropriate land use policies and strategies, weak capacities of national and local institutions, inappropriate technology and management options unfit to local contexts and circumstances. Furthermore, the potential of livestock production system could not be realized due to issues related to technical problems such as shortage of quality and sustainable feed availability which often leads to the common free livestock grazing practices.

2 **Free Livestock Grazing Managements and Practices**

Free grazing, controlled grazing and the cut and carry feeding are the three main livestock grazing systems in Ethiopia. The free grazing practice is an extensive system of livestock production where animals, regardless of their number and type, are left to graze on the same areas along the landscape for prolonged period. The free grazing system is also strongly practiced during the growing seasons (Benin and Pender, 2002). Azage et al. (2012) indicated that practicing of free grazing during rainy season, has significant contribution to land degradation in Ethiopia. This is due to the concentration of large numbers of livestock to farmland boundaries, designated communal grazing areas, uncultivated farmlands, hillsides and on the border of farmlands and gullies.

Aftermath grazing is a common practice regardless of the type and number of livestock (Tesfay et al., 2016; Berhanu et al., 2012; Gebregziabher and Gebrehiwot, 2011).

3 Weak Policy - Strategy Enforcement and Institutions

Gaps on policies and strategies due lack of land use and grazing policy in Ethiopia. The policies lack the integration and clear understanding to optimize the interphases between the trees species and controlled free grazing within the communities' socio-cultural setting, farmers' circumstances and ecological domain. The introduced technologies were not supported by clear grazing land use policies, regulations and guidelines, coupled with presence of weak institutional integration and effective arrangement, weak law enforcement and governance, and poor implementation capacities of the institutions at different levels. There is also a lack of scaling up of good practices (Azage et al., 2012; Gebregziabher and Gebrehiwot, 2011; Berhanu et al, 2010; Zewdu, 2003). These in turn discourage people from introducing or continuing long term investments on agroforestry practices along the scale. The local institutions and by-law enforcement on free grazing restriction are also weak (Gebremedihin et al., 2001).

Institutional gaps: Currently, there are various institutions directly or indirectly involved in regulating free grazing. Some of the institutions lack respective coordination at grass root level. There is limited intersectoral integration between the institutions. Moreover, the seed sector has limited involvement in forage seed production.

Limited participation of Informal institutions: The contribution of traditional/informal institution is undermined (Derera, 2015). Notwithstanding, informal institutions are not only organizations but also include rules, regulations, common values and mechanisms of enforcement of the bylaws that regarded as adaptive solutions to resource management problems and conflict resolution at the grass-roots level (Dixon and Wood, 2007). They use their indigenous knowledge to categorize landscapes not only in terms of seasons of restriction, management and use, but also in terms of grazing capacity as well as setting responsibility of individuals on the development activities and determine the user right who gets what, when, and how.

Technological, Management and Socio-economic Gaps: There is a limited knowledge, skill and motivation on sustainable grazing management. In all the project districts, livestock management practices are based on the traditional knowledge of the farmers and it was noted that the farmers lack adequate knowledge, skills and experiences in improved livestock management. This implies that lack of knowledge and skills, different labor requirements and less established markets lead to more uncertainties with sustainable grazing system, mainly cut and carry feeding practices. It is commonly observed that most smallholder farmers are reluctant to accept the production of improved forage crops, because they prioritize their land and labor to the production of food and cash crops rather than forages (Gebregziabher and Gebrehiwot, 2011).

Despite the presence of few examples of successful improved forage development and utilization, there are key challenges constraining the uptake of fodder development include limited species appropriate to different agro-ecological zones, scarcity of forage seeds and that farmers lack knowledge and skills needed to grow them (Tesfay et al., 2016; Steven et al., 2014; Getnet et al., 2011).

Proposed Priority Options and/or Findings

A. Options for Enhancing Sustainable Livestock Grazing in Ethiopia

To improve the food security and nutrition of the rural people and to accelerate adoption of agroforestry and build climate resilience green economy, the government, NGOs, donors and communities must prioritize controlled free grazing system and overstocking on their developmental endeavour. The options for enhancing sustainable grazing system should consider the ecological, socioeconomic and cultural domains and need to be supported with appropriate policies, institutions, resources, technology and investments.

B. **Technological and Management Options *include:***

Research and capacity building to empower the actors; forage development options to improve green feed availability, promoting foliage and Pods from Naturally Growing Trees and Shrubs; identifying Grazing and stocking strategies to improve communal grazing land productivity, management and utilization and improve the availability and access of agro-industrial by products and processed animal feeds. Other options include: strengthening crop residue feed improvement and conservation technologies for hay and crop residue, implementing cut and carry feeding practices, identifying technological options to enhance supply of better livestock breeds and improve husbandry and promoting agricultural mechanization to replace the use of draught power

C. Policy, strategy and institutional options include: Developing and implementing sustainable grazing land use policies; Improving the institutional arrangement,Improving policies on agricultural taxation and inputs; enhancing and strengthening technology dissemination to farmers and scaling up of successful grazing strategies and agroforestry. Other options include: improving and encouraging the extension service to bring the desirable changes; Strengthening and improving livestock research and extension linkage; improving farmers' access to inputs useful for market-oriented livestock production system; strengthening farmers' access to markets; strengthening and improving accessibility to credit and land for forage seeds and feed processing production and identifying strategic options to improve forage production and better breeds.

D. Strengthen the partnership and coordination among institutions and stakeholders

Institutions and stakeholders' collaborations and linkages are a key for success due to the presence of different institutions operating in the rural communities. A successful partnership enhances the impact and effectiveness of action through combined and more efficient use of resources. Hence, facilitating linkages in scaling up/out initiatives and soliciting the full and genuine participation of actors is, therefore, important in enhancing agricultural technology generation, development, transfer and utilization as well as in accelerating agricultural and rural transformation (Kaimowitz et al., 1998). For example, several partners are participating on rehabilitation the upstream of landscape that are supported by different physical and biological conservation structures to reduce soil erosion and improve the moisture; consequently, the forage productivity of the downstream grazing land, gullies and farmland strips are improved.

E. Socio-economic and cultural Options

Farmers have bylaws through which they administer grazing lands. These by-laws could act as a basis for establishing rules and regulations on how to use communal grazing lands and closure areas. The by-laws are different from place to place but indicate the need for having certain rules, and they have to be fine-tuned and supported by the government. Granting tree user rights helps to address the land security issues.

Utilize the traditional associations for advertising the issue of free grazing and develop their own recommendation to restrict free grazing. Since most farmers from Tigray and Oromiya regions have high respect and trust for the church and mosque, integrating the environment including forest/agroforestry and development including restriction of free grazing issues with this institution would be more effective.

7.3 To establish communities of practice capable of promoting scaling of locally adaptable agroforestry options supported by appropriate inputs systems.

Following the successful completion of the first phase of the Trees for Food Security project, that saw the award and support of the second phase by ACIAR, successes and lessons learnt during the first phase of the project were scaled out to additional sites during the second phase. Scaling-out was achieved through development of a comprehensive scaling strategy that was adapted for the various countries. Examples of successes in scaling include introduction of two agroforestry options (tree tomatoes and climbing beans including promoting appropriate stakes for supporting the beans) which were very successful in sub-humid areas of Gishwati and adapting them to the semi-arid areas of Bugesera in Rwanda, introduction of apple production in Tigray, Ethiopia and fodder production in Manafwa, Uganda.

7.3.1 Rural Resource Centres for promotion of agroforestry scaling up and out and production and distribution of quality germplasm

The five Rural Resource Centres (RRCs) and five satellite nurseries established by the project in Ethiopia, Rwanda and Uganda have been instrumental in production and distribution of quality germplasm, training and demonstration of agroforestry technologies.

Following an understanding of farmer contexts, the project focused of production on quality germplasm from the RRCs and satellite nurseries through which, 738,100, 1,140,000 and 2,324,026 seedlings have been produced in Uganda, Rwanda and Ethiopia respectively. More than 3,400 households in Uganda, 1,700 in Ethiopia and 18,700 in Rwanda have benefited from the high-quality germplasm. These species include high-value timber trees such as *Grevillea robusta*, fruit trees, ornamental trees as well as other multipurpose trees. In addition to tree distribution, the project facilitated trainings and demonstrations on quality germplasm, tree planting and management and improved nursery practices

They have also provided opportunities for farmers to share their experiences with their peers as well as receive technical guidance and other services from public and private extension services. More than 4.2 million quality tree germplasm have been produced with more than 75% distribution rate across the countries. Moreover, farmers and farmer groups were observed to have started their own private nurseries after acquiring training from the RRCs. This indicates that through the RRCs, the communities are able to acquire quality tree planting materials which have better survival rates and receive technical assistance on tree planting and management. This coupled with the potential for income generation from the tree-related practices undoubtedly makes agroforestry technologies attractive to the communities

In Ethiopia, Batu and Bako RRCs, established in Zeway and Bako respectively are special hubs for wide scale dissemination of agroforestry knowledge and quality germplasm to end users. They are technically backed up by the project through provision of inputs for production of quality planting materials and facilitating trainings related to agroforestry technologies Through the project an irrigation scheme was installed at the RRC to aid in watering the tree nurseries as well as the demonstration plot. To date more than 2 million tree seedlings of various species have been produced from the RRCs out of which more than 1.1 million quality planting materials have been provided to farmers and the government through the Green Legacy national project. In addition, more than 900 community members have benefitted from training/ capacity development activities on tree nursery management, production of quality germplasm, entrepreneurship, etc. from the RRCs.

Owing to production of high-quality germplasm at the RRCs, a generally high tree survival rate has been recorded to date. Survival of fruit trees such as *Psidium guajava*, Carica papaya, and *Persea americana* was above 50% in most sites. This could be attributed to the watering treatments introduced for the fruit trees through the participatory trials. This indicates that with enhanced post-tree management practices, higher survival of trees can be achieved.

In Rwanda, the two Rural Resource Centres (RRCs)-Karama and Karago established during the first phase of the project continue to facilitate production of quality fruit and multipurpose tree planting materials as well as serve as platforms for dissemination of agroforestry knowledge. Another fourteen RRCs have been established- ten in Mulindi and one each in Bugesera, Kayonza, Gatsibo and Nyagatare by Rwanda Agricultural and Animal Resources Development Board (RAB).

In addition, the project also partnered with community-based groups, farmer cooperatives to establish satellite nurseries to produce and provide quality tree germplasm. These have been distributed to the wider community including schools, churches, and health centers for planting on their land. Through the RRCs, and satellites nurseries supported by World Vision Rwanda and IMBARAGA, a total of 1,019,965 seedlings have been produced and distributed during the second phase. These seedlings are valued of about USD 128,820.

The satellite nurseries are operated by farmers cooperatives and individual farmers provided employment and generated substantial income to their members, enabling them to buy assets such as land, build or rehabilitate houses, pay for health insurance and school fees.

In Uganda, Mbale RRC has increased access to good quality tree germplasm materials to farmers. Up to 417,000 quality tree seedlings of various fruit and multipurpose tree species have been produced from the RRC and other tree nurseries run by community groups. The seedlings have been distributed to farmers, churches and schools for planting in their land spaces to increase tree cover, derive various products and contribute to restoration efforts. The Centre also serves as a hub where farmers and the wider community access a wide range of reference materials and technical advice to enable them to select and grow trees that match their specific contexts.

The project has been at the forefront to build the capacity of tree-seed dealers, nursery operators and smallholder farmers on identifying quality tree seeds sources, management of tree pests and diseases in nurseries and basic practices for quality seedling production. This is geared towards raising standards in tree germplasm production and ensuring availability of tree planting material of desirable traits.

Capacity building on agroforestry interventions

T4FS-2 project implementation approaches were gender responsive and endeavoured to ensure women and girls benefit from our interventions. A total of 10,347 members benefited through capacity development activities including training and demonstrations, at least a third comprised of women and youth. In addition, the project supported 8 PhD and 2 MSc students.

Scaling out activities through Umuganda

In Rwanda, every last Saturday of the month has been set aside for community work commonly known as ‘Umuganda’. The project used this as a platform to sensitize communities on importance of agroforestry. This action has brought together farmers, local authorities, and diverse stakeholders in agroforestry to plant trees on sites participatory selected. Messages on the importance of agroforestry, agroforestry species and tree management as well as sustainable land management were disseminated. Umuganda has also been used as an approach to distribute seedlings and promote tree planting efforts for soil conservation and erosion control. A total of 4056 farmers were reached through Umuganda within the second phase of the project.

Women and Youth Empowerment in Agroforestry

A study on factors affecting adoption of agroforestry by women and youths in Uganda showed that land size and family size affected adoption decisions. Land scarcity, seed shortage, lack of market and limited technology were among the challenges identified (Figure 28). The incentives however, involved farmer trainings, rising demand for tree products and access to free seedlings while the strategies comprised of strengthening farmer capacity building programs, community sensitization on climate change and promoting fast growing tree species.

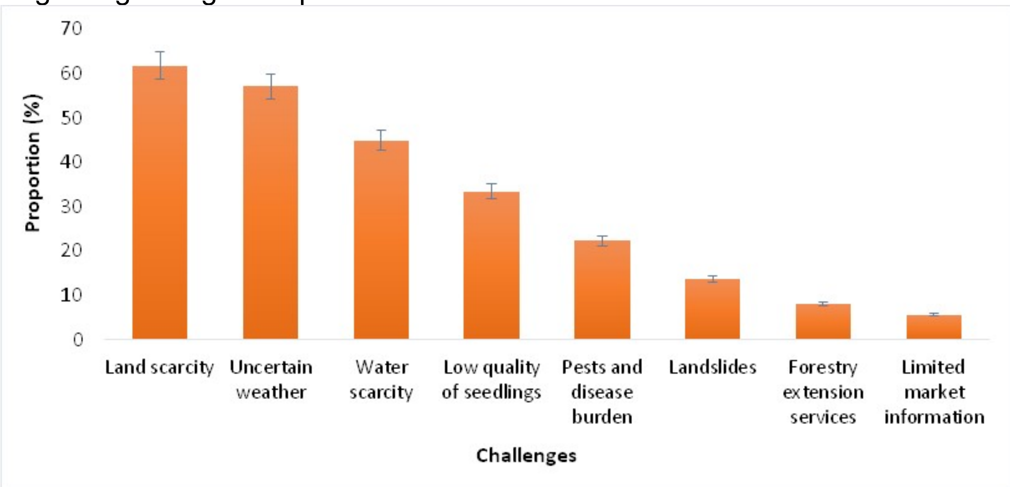


Figure 28: Factors affecting adoption of agroforestry

Agroforestry presents an opportunity to undo the effects of deforestation and climate change in the region but selection of incentives for adoption will be most effective if tailored and kept updated to address specific needs according to farming contexts.

The youth and women have been engaged during the various field days and training workshops in which [awareness about agroforestry for increased soil productivity and food security has been increased]

7.4 To strengthen smallholders and other market actors ability to participate effectively and profitably in tree product value chains

Country-specific tree value chains were identified as follows: Tree tomato-Rwanda, Avocado-Ethiopia, Timber and avocado-Uganda, value chain actors and financing options were also identified for possible future engagement.

In Ethiopia, findings from the survey indicated that producers are aware of the fruit trees that are preferable for cultivation and those that suit the climatic conditions of the areas. Some of the most preferred fruit trees by farmers were avocadoes, apples, mangoes and bananas. Avocado was the most preferred because it does well in both sub-humid and semi-arid areas such as West and East Shewa. The demand for avocado was high, but farmers are not able to meet the growing demand due to low production. Low production of Avocado and other fruit trees is due to inadequate water, and limited knowledge on tree production and management among other constraints. The value chains identified to have the greatest potential for further development in the study sites include avocado, mango and apple. Mango is well adapted in Bako, however due to the white scale disease, its production and consumption has decreased. In the Tigray region, the results showed that apple production is viable because of its ecological suitability and the rising demand.

Individual income (from farm produce, casual labour, small enterprises etc.) was reported to be the major financing option in all the study sites. Only a few farmers obtained credit from financial institutions.

7.4.1 Avocado Value Chain

The most common market channel for Avocado is that of producer to consumer. This is the preferred market channel because direct consumers are consistent in their purchase, although the amounts are small. However, while traders buy in bulk, they offer lower prices as they deduct costs such as storage and transport. Apart from individual farmers, avocado is produced by farmers groups.

Farmers reported that there is growing and unmet demand for Avocado owing to changes in lifestyles locally and regionally. Most of the business services indicated in Figure 29 are reported to be available in the Woredas, although farmers in the FGDs expressed concern that the services are unavailable or unsatisfactory. For instance Agriculture Growth Program (AGP) in Bako is one of the government programs that disseminate information about new technologies in Avocado production. However, the programme does not reach most of the farmers in the Woreda since it has the mandate to work in specific Kebeles. In addition, technical advice is provided by Woreda agricultural office, but advisory services on agroforestry practices are not readily available or are not part of the package provided by the development agents. Farmers reported that they relied on buyers for market information regarding prices of the products and quality attributes among others.

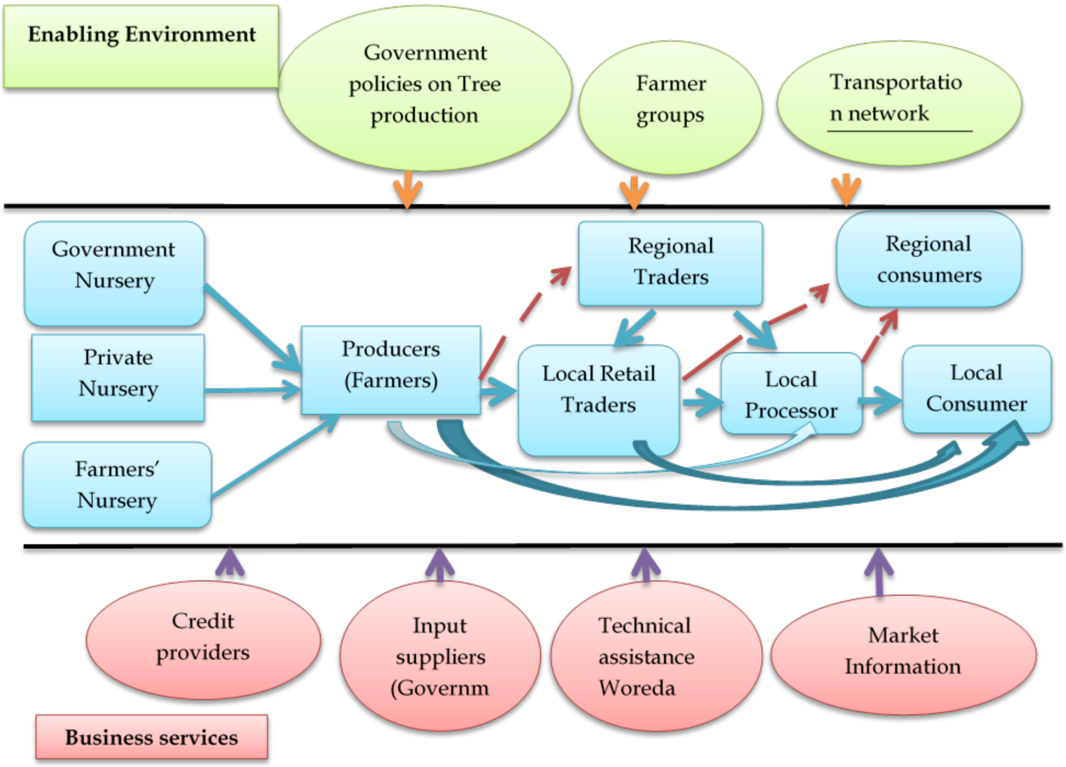


Figure 29: Value chain map for Avocado in Bako region

Key

Existing linkages

Non-existing Linkages

7.4.2 Mango value chain in Ethiopia

The main players in the Mango value chain are shown in Figure 31. Two main market channels for Mango were identified as producer to consumer and producer to local trader. The mango value chain in Adami Tulu Jido Kombolcha although underdeveloped has the potential to grow owing to the growing demand for mangoes and mango juice. However, the supply in the Woreda is very low. Hence, many traders get Mango from the Southern Region. Mango value chain is much shorter in areas such as Ziway where there is scarcity of water as the few farmers who manage to produce sell their fruits to consumers. Mango production and generally fruit trees cultivation is not considered a priority due to water shortages especially in the dry seasons. However, with provision of water harvesting methods and capacity building on production and management of fruit trees, farmers can take up mango production in Adami Tulu Jido Kombolcha.

According to key informants such as traders and processors there is a huge unmet demand for mangoes. Interventions should focus on increasing mango production, particularly the grafted type. The market for mango is growing tremendously because of population increase as well as change in lifestyle. The traders mentioned that they sold the fruit to consumers directly and some to local processors.

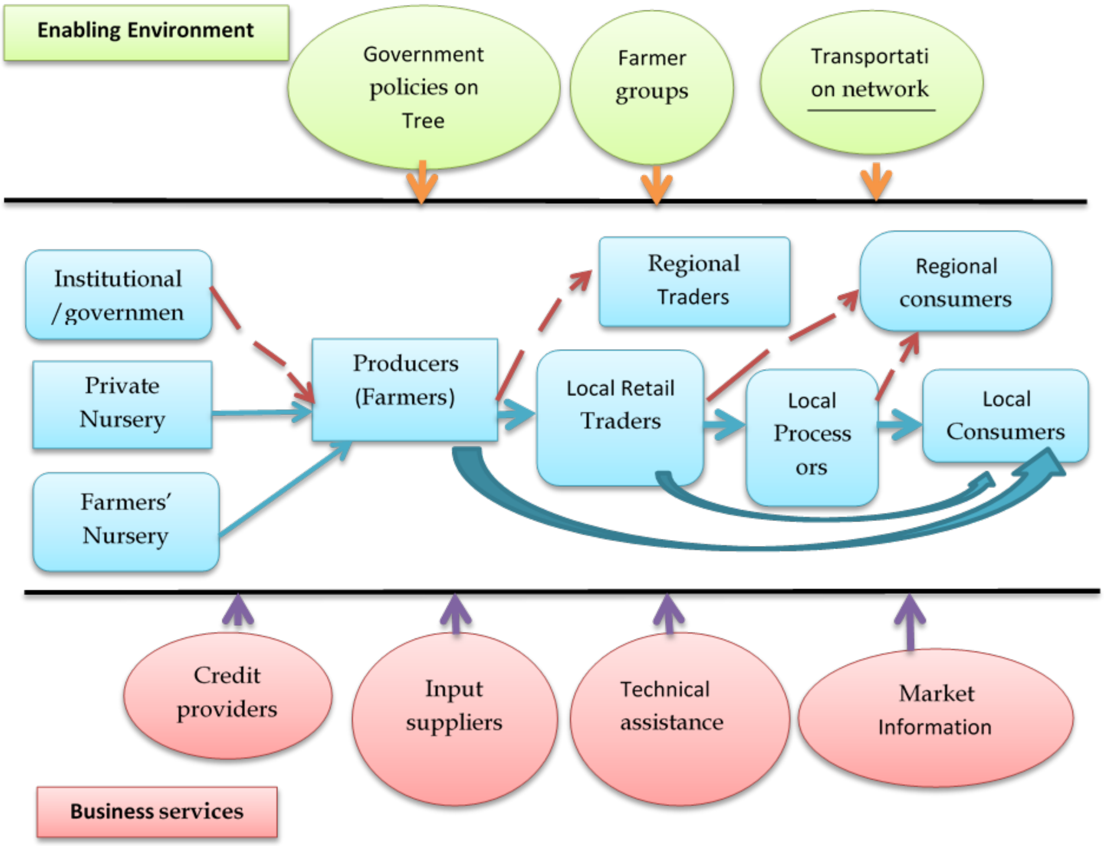


Figure 30: Value chain map for Mango in Adami Tulu Jido Kombolcha Woreda

Key

Existing linkages

Non existing Linkages

7.4.3 Apple Value Chain

Apple production in Tsaeda Emba is a viable venture because the agro-ecological condition is suitable for the fruit. Apples are more resistant to pests, diseases and frost, which are major setbacks to fruit production in this Woreda. Moreover, apples mature after three years unlike the current fruits being produced in the area (though in small quantities) such as avocado and oranges, which take up to seven years and are highly susceptible to frost damage. Farmers mentioned the expected benefits from apples include nutritional, financial gain, and health inter alia. Producers reported that apples have high productivity. A single apple tree can yield as much as 20kg of fruits in a single season if well maintained. Therefore a farmer with 10 trees can earn as much as 7,000 Birr (USD 250) in a production season. One of the major challenges in apple production was reported to be inadequate planting materials, as these have to be sourced from other woredas.

The farmers that reported to have harvested apples in this region only sold directly to consumers. No traders or processors were identified for the apple value chain in this region. However, the value chain is expected to develop and include other actors such as local and regional traders if the number of producers and the quantities produced increase. It was reported that institutions such as WVE and ICRAF as well as the government are very supportive in providing apple seedlings, technical advice and training on apple production. For the one year that the farmers have been involved in apple production, financing of the value chain at production level through subsidized costs for apple seedlings has been supported by the project.

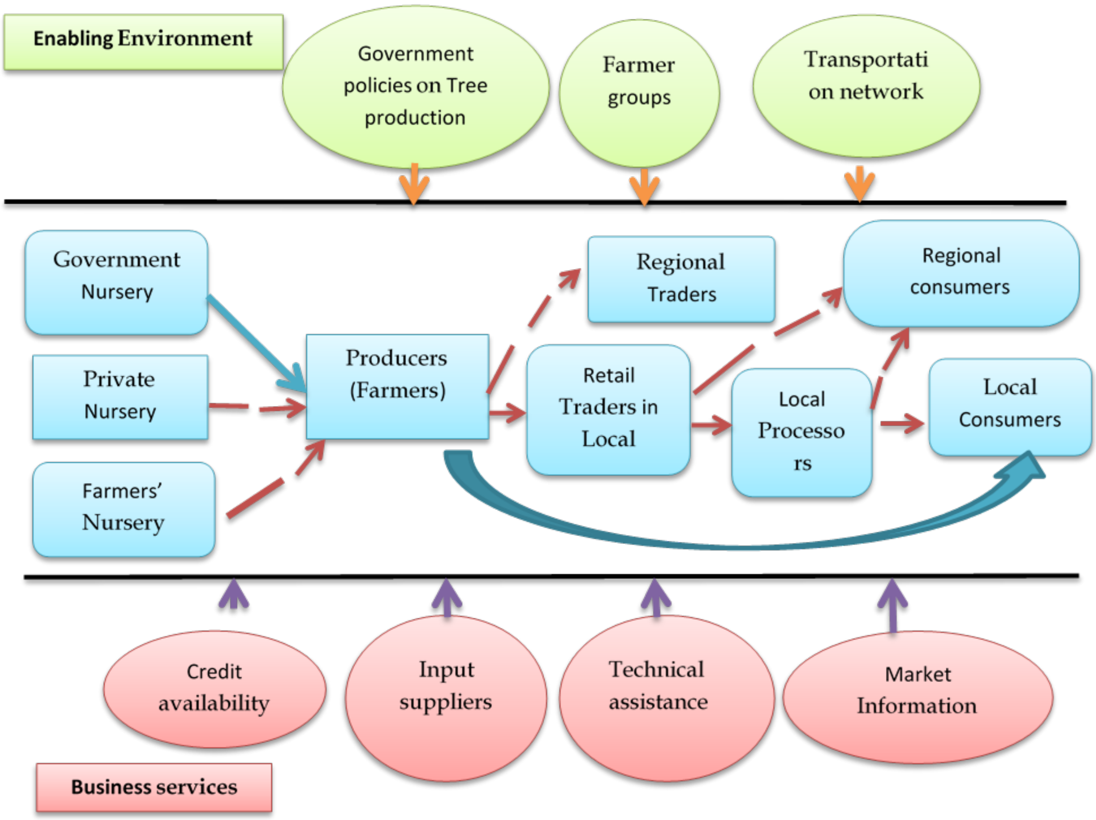


Figure 31: Value chain map for Apples in Tsaeda Emba

Key

Existing linkages

Non-existing Linkages

In Uganda, avocado and timber were identified as the potential tree-based value chains for development. Avocado is produced by the farmers and sold to both large and small-scale traders, while timber consisted of a number of actors including tree farmers, timber brokers, timber traders and timber transporters. The other actors included timber processors (constituting of loggers and carpenters), consumers of semi processed materials and consumers of finished products. Opportunities for developing both value chains included forestry/tree growing increasingly becoming a viable business due to high demand for tree seedlings; existing research knowledge generated on tree management and value addition and growing interest by financing institutions in tree growing as a viable enterprise.

Most of the tree-based enterprises accessed financial services from Savings and Credit Cooperatives Societies (SACCOs), followed by self-funding, microfinance institutions and lastly commercial banks. SACCOs were preferred to other sources because they are less stringent in their requirements when issuing of loans as well as low interest rates on loans compared to commercial banks.

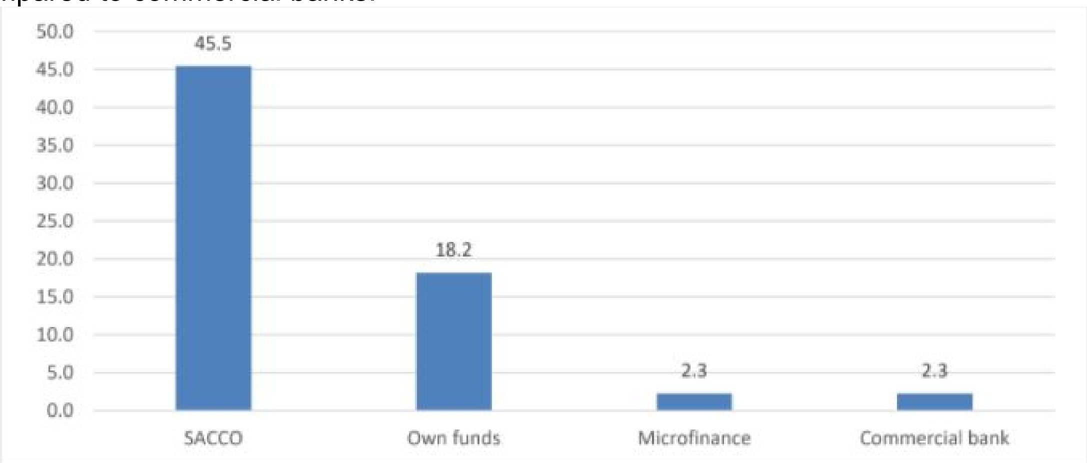


Figure 32: Financial options accessed by tree-based enterprises in the Eastern Highlands of Uganda

The private financing mechanisms are more suitable for tree-based enterprises which are largely informal, small-scale and long term in nature. The downside is that the cost of capital is very high and reduces the profit margin. Other constraints include skills and knowledge gaps, lack of subsidy system for tree-based enterprises, and risks of credit, production and marketing tree-based products. The tree-based enterprises could be expanded if cost of capital is reduced, training in risk management is done and providing production subsidies for the tree-based enterprises.

Knowledge gap on smallholders and other market actor's ability to participate effectively and profitably in tree product value chains was identified and validated with farmers and other value chain actors through key informant interviews and focus group discussions in Oromia and Tigray regions. Potential tree-based value chains were identified as mango in Zeway, avocado in Bako and apple in Tsaeda Emba, Tigray.

7.4.4 Tree tomato value chain competitiveness

To shape the tree tomato industry in Rwanda for the benefit of smallholder farmers and the Rwandan economy at large, it is critical to understand the industry's competitive forces and their underlying causes. A study on the competitiveness of tree tomato industry was conducted in order to determine factors that influence the competitiveness of the tree tomato value chain and propose strategies that could help to improve the competitiveness of tree tomato value chain in Rwanda. The findings of the study show that the bargaining power of suppliers reported by 63 percent of interviewees, the bargaining power of buyers reported by 58.43%, the severity of the threat of new entrants reported by 22.28%, the intensity of rivalry in existing key competitors reported by 65.60%, the severity of the threat of substitutes reported by 71.74% as factors hampering the tree tomato value chain competitiveness in Rwanda.

The strategies proposed to improve the competitiveness of tree tomato value chain comprise the improvement of linkage between and collaboration of tree tomato chain actors which could lead to the reduction in transaction costs, improvement of the farmers' level of integration into the value chain and farmers' technical know-how and production capacities in order to play an improved crucial role in the value chain. The formation of farmer cooperatives will also give voice to the farmers. Further, the potential buyer of restaurant/hotels/other institution consumers can spell out certain product criteria and also assist farmers in their production activities to ensure a regular supply of tree tomatoes to the buyers. The tree tomato value chain in Rwanda has a strong rivalry from imports from Tanzania. This competition can provide an opportunity for the spread of innovation along the tree tomato value chain which in the long run will make the tree tomato industry in the Rwandan sector more competitive either on local, regional, and international markets.

A summary on financing options for tree products value chains in Uganda, Rwanda and Ethiopia is found in Appendix 8.

7.5 To strengthen capacity of academic institutions in developing and implementing innovative agroforestry curricula.

7.5.1 Curriculum development across the countries

A regional agroforestry curriculum guide was developed after a comprehensive assessment of agroforestry curricula and extension training involving Universities/Colleges, Integrated Polytechnic and Technical and Vocational Education and Training (TVET) institutions offering forestry and/or agroforestry courses in all countries. Validation workshops were held and skill gaps on pertinent agroforestry components identified, which will act as entry points for incorporation of agroforestry aspects in the institutions' curriculum. The reviewed curriculum guide will be applied in academic institutions. This will ensure that unlike the past when agroforestry was either offered as a course embedded on other content, topic or chapter, it will be offered as a comprehensive course integrating all the relevant components.

In Ethiopia, an assessment of agroforestry curriculum and the status of extension training was done for in universities: Wollo, Mekelle, Adigrat, Aksum, Selale and Addis Ababa University, two Polytechnics: Wukro agriculture polytechnic, WAPT, one college: Wukro St.Marry college and two TVETs: Shire and Maychew offering forestry or agroforestry. Findings showed that in all the institutions, agroforestry was either offered as a course embedded on other content, topic or chapter. Findings further indicated that similar modules are taught at the University level and TVET level. However, allocations of contact hours for many courses are relatively larger at TVET. It was noted that staff respondents had poor knowledge and competency level on many agroforestry-related modules/courses/topics. It was suggested that extension should be an important part of agroforestry education and recommend that project planning and management should be included in agriculture extension education. A revised curriculum was developed, and this is to be applied in tertiary institutions.

In Rwanda, an institutional assessment was conducted to gather as well as provide current information on how agroforestry is incorporated in existing education programs. The survey targeted teaching staff and programme managers from two universities, one Integrated Polytechnic and six Technical and Vocational Education and Training (TVETs) Institutions offering forestry or agroforestry courses. Some of the challenges highlighted from the survey include lack of access to electronic resources and teaching which is more theoretical as opposed to practical due to lack of training equipment and tools. Among the key recommendations include integration of entrepreneurship, continuous training for TVET trainers especially those teaching agroforestry/forestry and review of the agroforestry curricula for adaptation and integration of emerging concepts.

In Uganda, an assessment of curriculum on agroforestry and extension for eight tertiary institutions was conducted. The institutions that participated in the assessment include: Busitema University, Bukalasa Agricultural College, Ndejje University, Makerere University, Gulu University, Nyabyeya Forestry College, Busoga University and Uganda Christian University. Findings from the assessment revealed that the agroforestry curriculum is comprehensive and rich in content though this might not be adequately covered due to limited time allocated per module. Most of the teaching has been delivered in theory since resources to facilitate practical learning are usually unavailable especially in the private institutions. Some relevant agroforestry content is missing in the curriculum notably: developing agroforestry interventions, biodiversity conservation, environment management, landscaping, modelling agroforestry systems and nutrition and food security. However, the tertiary institutions are willing to introduce the missing content periodically during the curriculum review processes. Using the Regional Innovative Agroforestry Curriculum Guide developed during the ANAFE regional workshop, Gulu University conducted an agroforestry curriculum review to update its content for undergraduate students pursuing agroforestry/forestry undergraduate degrees.

7.5.2 Findings of the Impact Assessment in Rwanda

A. Programme participation

The first step towards impact evaluation is to assess the level of interaction of the households with the project activities. Not all households who are assigned to receive the intervention will partake of the intervention because of economic, social, technical factors. Still some factors could be related to an individual's ability or attitude which may not be observable. Project participants are defined as households who received training, advice or planting materials including other inputs from the implementing partners or any other organisation affiliated with the implementing organisation.

Overall, 30% of the households in the intervention site reported that they interacted with the T4FS project partners in one way or another. Likewise, 2% of those in the comparison sites reported that they were exposed to T4FS activities. Figure xxx. shows that relatively more households in the intervention sites in Nyabihu district participated in the project activities while the lowest participation rate was in Rubavu district. Forms of participation varied from receipt of germplasm to training and/or advice .

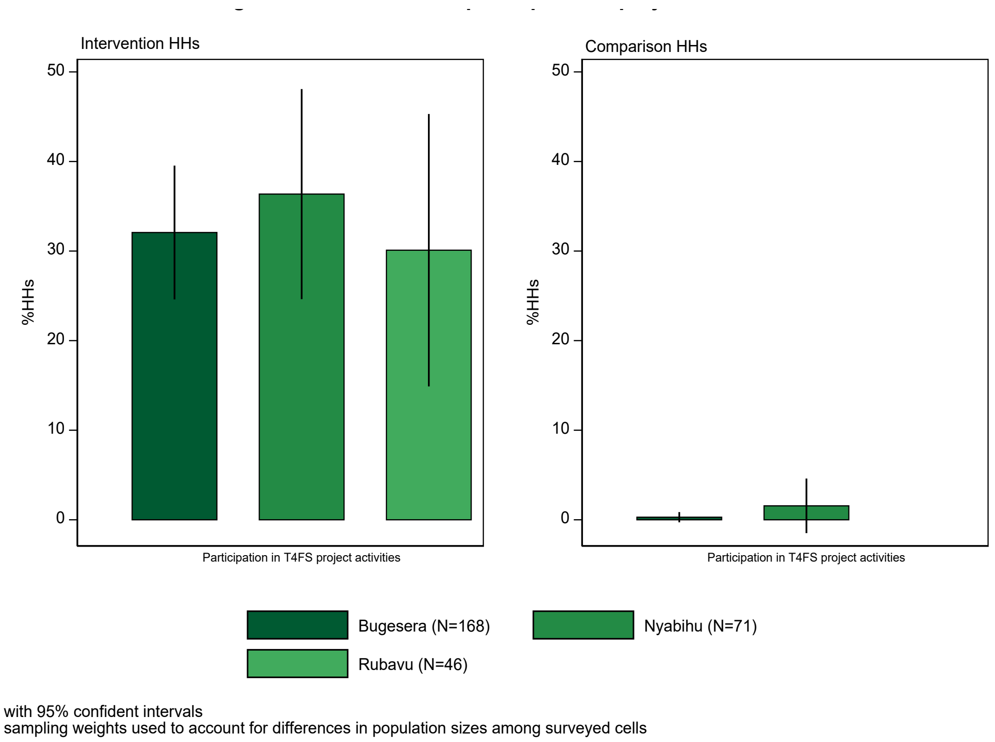


Figure 33: Percentage of households who participated in T4FS project activities

B. Adoption of agroforestry practices

Figure 34 shows that percentage of households taking up agroforestry practices increased in both the intervention and comparison sites by 36% and 29% respectively. An increase in the uptake of specific practices from baseline to endline is noted among households in the intervention and comparison sites except for integration of trees with crops in which there was a decline of 6% and 5% respectively. More households integrated trees with crops before T4FS project compared to the project period.

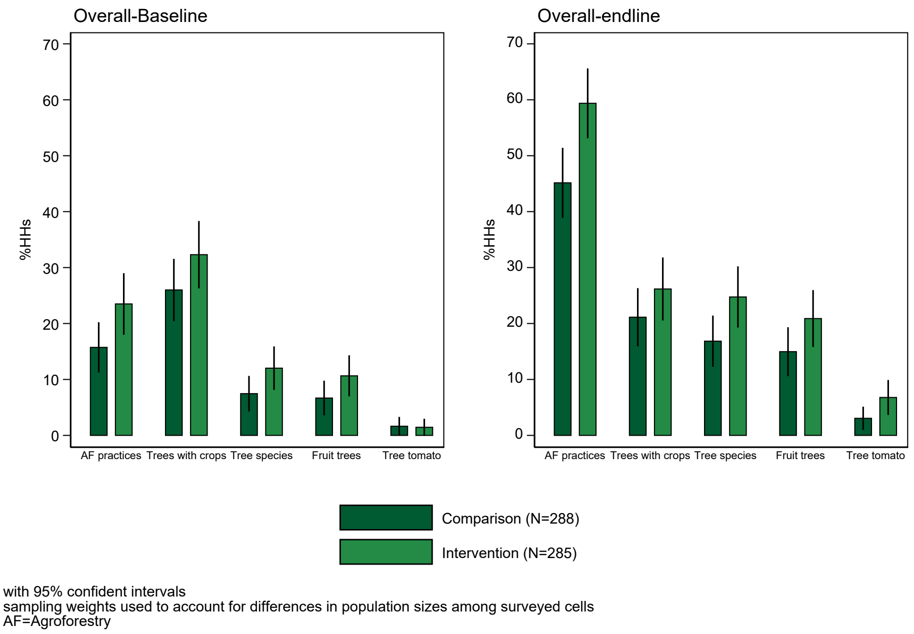


Figure 34: Percentage of households taking up promoted AF practices and tree species at the baseline and endline

Overall, adoption rate is higher among project participants than non-participants by (16%). Likewise, adoption of specific practices and tree species is higher among project participants than non-participants. The results suggest that participation in T4FS increased the likelihood of households taking up promoted practices and tree species.

C. Impact of T4FS on adoption of promoted agroforestry practices and tree species

Impact assessment results shown in Table 5 indicate that more farmers in the project sites than in the non-project sites are taking up promoted agroforestry practices such as tree planting, use of quality germplasm, grafting, and biomass incorporation. The results indicate that there was significant increase in the percentage of households taking up different agroforestry practices in the sites that have benefited from the two phases of the project. The results indicate that being in phase 1 project sites increases the likelihood of households taking up at least one promoted agroforestry practice by 15 percentage points (p=0.023) and any of the promoted tree species by 8 percentage points, although the change in uptake of promoted species is marginal (p=0.076). When the combined sample is considered, the likelihood of taking up tree tomato production by households in the project site increases by 4% irrespective of the phase, perhaps because tree tomato has a short maturity period, which allows farmers the recoup their investments early enough.

The significant increase in the uptake observed only in the sites that received the intervention from 2014 except for tree tomato suggests that the learning curve for agroforestry practices may be long due to the complexity of some practices. As a result, farmers require considerable time to learn, test and adapt the practices to their context before applying on a large scale on their farms. The findings therefore point to the need to incorporate innovative scaling approaches that induce behaviour change to shorten the curve and lead to high multiplier effects.

Table 5: Impact of T4FS on promoted agroforestry practices

	DiD		Single diff. (pooled N=538)		Single Diff. (Phase 1 N=269)	
	Pooled (N=573)	Phase 1 (N=269)	ATE	ATET	ATE	ATET
AF practices	0.06(0.05)	0.15**(0.06)	0.11*(0.06)	0.29*(0.17)	0.19**(0.18)	0.44**(0.20)
Promoted tree species	0.03(0.03)	0.08*(0.04)	0.05(0.04)		0.10*(0.05)	
Promoted fruit trees	0.02(0.03)	0.03(0.05)	0.05(0.04)		0.09(0.07)	
Integrating trees with crops	-0.01(0.04)	-0.02(0.05)	0.02(0.04)		0.08*(0.04)	
Tree tomato	0.04**(0.02)	0.04(0.03)	0.04**(0.01)		0.05(0.03)	

* p<0.1, ** p<0.05, *** p<0.01; Inter. = Respondent comes from intervention, Com. = Respondent comes from comparison site, standard errors in parenthesis are clustered at the cell level

D. Adoption of tree tomato

The percentage of households taking up tree tomato cultivation increased significantly by 4 percentage points (p=0.039) in the intervention sites compared to comparison sites. The results suggest a positive trend towards uptake of tree tomato growing. This was corroborated by the focus group discussion results in which farmers indicated that there was increased demand for tree tomato seedlings following most of the farmers' realisation that the fruit matures early and generates the much-needed income for the family. Farmers attested to selling tree tomatoes and purchasing small stocks such as chicken, sheep or opening of-farm businesses. Others used the proceeds to purchase insurance and pay school fees for their children.

Although a few farmers have been able to set up tree nurseries to address the shortage of quality seedlings, the demand for quality seedlings still outstrips supply, indicating a largely unexploited business opportunity to commercialise tree tomato seedling production and distribution beyond the project sites. Farmers are willing to buy seedlings of tree tomato provided they are assured of quality. Farmers who established nurseries reported that they were not able to meet the demand from the neighbours.

7.5.3 Lessons learnt

A. Potential to maximise impact of agroforestry interventions through well-designed and targeted scaling approaches

Given that the percentage of households reached with the intervention was small (30%), there is potential to increase gains from agroforestry interventions by improving breadth and depth of reach in the three districts in Rwanda. Where low exposure rates are reported as was the case, reviewing and restructuring programme delivery mechanism being used in scaling out interventions is the first key step towards realising adoption at scale. However, we also recognise that through the random sampling design, every farmer in the selected villages had an equal chance of being interviewed, which may have contributed to a higher number of non-project farmers being interviewed compared to project farmers since the intensive and detailed participatory approach was a major adoption strategy of this project yet it didn’t encompass many farmers. Therefore, mechanisms for targeting and measuring a few productivity indicators to allow testing of options over a wider population of farmers would help achieve the breadth required to realise impact at scale.

C. Maximising long-term gains from agroforestry interventions by fostering adoption at scale

The results from the quantitative study were inconclusive on productivity, and welfare outcomes, both for the phase 1 households and the overall sample. Therefore, a well-designed and targeted scaling strategy that seeks to address context specific constraints to adoption is critical. Such scaling strategies should have high multiplier effects and embody mechanisms that induce behaviour change among households to relax constraints that limit intensive application of promoted agroforestry interventions by farmers. Effective implementation of such a strategy hinges on the presence of development partners and scaling stakeholders with the skills and expertise to connect with the farmers’ unique challenges. Where developmental outcomes are anticipated, the scaling stakeholders should be identified and involved right from the project inception phase and the targets for each stakeholder including the scaling pathway clearly defined to ensure maximum saturation and adoption.

D. Need for a different sampling and impact estimation approach

Given that higher level impacts of agroforestry interventions take time to manifest and may not have been detectable from the population sampled for the survey, it is necessary to use modelling approaches that attempt to project what such impacts are likely to be more than 10 years beyond the project implementation phase. The endline data collection took place three years into the actual implementation or scaling phase. As such it will be critical to further interrogate data for economic and environmental impacts using ex-ante modelling approaches.

8 Impacts

8.1 Scientific impacts – now and in 5 years

The project applied the systems approach in its research and development initiatives with all the work packages being inter-related and interdependent. This allowed feedback loops and cross-learning to occur across different objectives, thus further refining the agroforestry-based solutions developed in the project. For instance, trees survival is dependent on water availability, good seedling supply systems, management (and controlled grazing in Ethiopia). While the uptake / scaling up of the same is affected by markets, financial options and capacity building amongst others. On the other hand, using the options by context approach different options/ solutions are provided based on the prevailing contexts to ensure suitability and enhance level of success of the interventions. This is done in a participatory way where key stakeholders especially farmers using farmer led approaches actively participate from planning, design and implementation phases so as to ensure ownership and sustainability of the interventions (Muthuri et al, 2021).

The project's scientific impacts were focused on generation of scientific knowledge through participatory trials, long term trials experiments, modelling, water management strategies, sustainable grazing management and tree-based value chains. Project findings and lessons learnt have been published in 16 journal articles, technical reports, manuals, master's and PhD theses. Eight articles have been submitted to various journals. Ten project researchers presented their findings through 12 posters and 3 oral presentations at the World Congress on Agroforestry (WCA) in Montpellier, France, on 19-23 May 2019. In addition, project findings have been presented in other conferences including FTA and TropAg.

Further, scientific knowledge on staff was enhanced though ODK trainings in Ethiopia, Rwanda and Uganda. These trainings resulted in collection of quality data from the various project initiatives and management of the same. A soil and plant measurement workshop was held in Rwanda where training on modelling was conducted with different stakeholders. The project ran the agroforestry modelling workshop, a side-event at WCA 2019, in which 60 participants, were provided a detailed introduction to four agroforestry models (APSIM, WaNuLCAS, Hi-SAFE, and Programmable Structures). A refresher training involving 7 staff from ICRAF and JKUAT was conducted at the long term trial site in Jomo Kenyatta University of Agriculture and Technology (JKUAT) on tree-crop water interaction using the sap flow equipment (Buyinza et al, 2019).

Enhanced understanding of farmer-led agroforestry options in the three countries was achieved through establishment of 5,036 farmer participatory trials. The types of trials were agreed upon during the project's planning meeting after a careful analysis of farmer contexts and circumstances. Specific types of trials in each site and results have been documented in the country-specific reports (Mukularinda et al, 2019; Gebretsadik et al 2019 and Galabuzi et al, 2019). Establishment of the trials led to adoption of options suitable for the different contexts. Through the trials, all stakeholders observe performance interventions and have an objective view of their performance. The trials are also a learning platform for other farmers who observe and learn about the new technologies and eventually try them on their own farms. In addition to the site-specific trials, the project successfully scaled out newly tested agroforestry-based technologies as follows; introduction of tree tomatoes and stakes for climbing beans in Bugesera, Rwanda; apple production in Tigray, Ethiopia and fodder production in Manafwa, Uganda.

Through the project, an improved understanding of tree-crop interactions of different species and contexts was achieved through establishment of five long-term trials. Tree-water-crop interactions of different tree species as interacting components in agroforestry systems were assessed through sap flow meters in the three countries. The trials will continue to be used as experimental sites for further agroforestry research after the project phases out and will be managed by the national research partners.

Further, enhanced tree-crop modelling capability including agroforestry layout, species and functionality options and several tree and crop model options was achieved through completion of the APSIM Next Generation framework. The model is fully available and functional for public use www.apsim.info.

The mapping work firstly brought to light the extent of land degradation in the study areas. This information is crucial for policy planning and the design of strategies programmes and projects. In addition, ICRAF used the results of the studies to customise training curriculum for 97 trainers in the three countries. The studies also produced context-based interventions aimed at conserving the farmlands, forest land and grasslands. Although the T4FS project had a limited budget for implementing the recommendations, the project directly reached out to 2301 households on appropriate soil and water conservation measures.

In the case of Uganda, the project shared the results of the mapping work with the Government of Uganda during the Uganda Water and Environment Week held in March 2019. The paper presented emphasised the need for the Government of Uganda to embrace this and other similar planning approaches, which provide context-based solutions to natural resources management. The data generated is also helpful for new plans and projects. However, more work must include the socio-economic context to enrich the knowledge and enhance ownership of the recommendations. The partners in Uganda have been engaging the local governments to ensure that the recommendations are taken into account during future interventions. In Rwanda, ICRAF shared the mapping results with the Rwanda Water Board, a new institution tasked with implementing watershed management, amongst other interventions. The Board will use the information to inform the ongoing catchment planning and implementation across Rwanda. Watershed management in Ethiopia has been very successful due to the firm government policy and community participation. The results will come in handy to guide the already vibrant conservation work in Ethiopia.

Discussions on existing policies and strategies on grazing management were held and appropriate recommendations given to policy makers, research organizations and other relevant actors to enable them to integrate sustainable grazing management options within agroforestry at local and national levels. This resulted to the formation of a Sustainable Grazing Platform and development of a policy brief highlighting sustainable grazing policy recommendations which will continue to be applied towards the promotion of sustainable grazing management options (Kiros et al, 2019). Implementation of sustainable grazing system in the mid- and highland of Ethiopia has had significant impact on the Ethiopian agricultural sector in which production has significantly increased to meet the food requirements of its growing population. It helped to restrict the free grazing in tree growing niches, farmlands, gullies and hill sides which have had significant contribution in reduction of deforestation and land degradation in the country.

Potential value chains and financing options were identified in the three countries through literature review and validated through focus group discussions and key informant surveys. In Ethiopia potential value chains identified include mango in Zeway (East Shewa), avocado in Bako (West Shewa) and Apples in Tsaeda Emba (Tigray). In Rwanda, potential value chains include establishment of private tree nurseries, tree tomato and *Grevillea robusta* (for timber) while in Uganda, fodder value chain using *Calliandra sp*p. was deemed as the most feasible.

A regional agroforestry curriculum guide was developed after a comprehensive assessment of agroforestry curricula and extension training involving Universities/Colleges, Integrated Polytechnic and Technical and Vocational Education and Training (TVET) institutions offering forestry and/or agroforestry courses in all countries. Validation workshops were held and skill gaps on pertinent agroforestry components identified, which will act as entry points for incorporation of agroforestry aspects in the institutions' curriculum. The reviewed curriculum guide will be applied in academic institutions. This will ensure that unlike the past when agroforestry was either offered as a course embedded on other content, topic or chapter, it will be offered as a comprehensive course integrating all the relevant components.

The project's research focus led to valuable learning about context-specific factors that affect adoption of agroforestry technologies and practices such as farmer's self-perception of their own capacity, the influence of social norms, and factors affecting adoption of agroforestry. Therefore, adoption of agroforestry technologies is expected to increase owing to the application of participation approaches in the project's research activities and the success of the interventions. The research also highlighted constraints to adoption, including the need for policies governing livestock free grazing, that need continued attention. This led to recommendation of suitable bylaws and policies that promote sustainable grazing management. This is expected to result in increased tree survival rates and associated benefits from trees to the local communities. The impact assessment conducted in Rwanda, showed higher rates of adoption of agroforestry in project sites compared to non-project sites. higher adoption rates are expected in the project sites as well as spill over of project-initiated technologies in the non-project sites.

Knowledge generated on tree crop interactions emanating from the long-term trials on tree water use, tree management, effects on soil fertility, water and crop productivity, and carbon sequestration has and will continue to provide essential information needed to adapt agroforestry technologies to meet farmers' needs. The long-term trials will continue to provide critical insights for climate change adaptations and development of the knowledge products tree-water-crop interactions that will greatly benefit other projects in the region and elsewhere.

Within 5 years, we expect that agroforestry researchers in other projects will have applied the agroforestry modelling capability of APSIM for new tree-crop-management-environment contexts, and that additional tree and crop models will have been added. For example, models for Pinus and temperate Eucalyptus genotypes have been added, along with several new crops and stock. Although new tree and crop additions would mostly be based on monoculture datasets, the modularity of APSIM ensures that they can be used also for agroforestry modelling. So, the modelling impacts from this project, including APSIM-SIMILE dynamic modelling, are very likely to multiply with time.

Results of the geospatial mapping and site characterization will be used by national institutions and governments in land use planning and to promote cost-effective solutions to land and water management issues. Land health in the project sites is expected to improve including increased afforestation, reduced soil erosion and enhanced soil fertility. The identification of potential tree-based value chains suitable for the specific countries, provided an entry point for private sectors/ relevant stakeholders to partner with the local communities to promote the proposed value chains. It is expected that communities will engage commercially in the specific value chains thus improving their livelihoods.

In Ethiopia, the restriction of free grazing will enhance the scale up of sustainable grazing management which will encourage the adoption and scale up of agroforestry, in turn sustain a significant level of food security and mitigate the risk of climate change.

Policy makers will have clear understanding on the impacts of free grazing on the country economic development, so that they will develop, introduce and implement incentivize policies, strategies, technologies and institutional integration to improve the livestock productivity and greening of the country.

The developed and introduced policies will empower communities, district and village agricultural experts and administrations to have decentralization and sufficient capacity to stimulate the realization of participatory agricultural extension.

Improving access to capacity building, markets, credit and inputs and extension programs targeting livestock management and agroforestry can enhance the role of livestock and trees in the mixed crop-livestock farming systems the country. This in turn inducing farmers to plant multipurpose trees and replace part of their local stock having low yielding with a smaller number of animals of improved breeds and adopt stall feeding so that reduce the pressure on natural resources while improving the productivity of their herds, in turn farmers' income will be improved from their livestock and agroforestry.

The involvement of religious and informal institution leaders, elderly, youth and women in decision making will be improved, so that free grazing of livestock on grazing and farmlands will be restricted through the bylaws and religious laws, as a result, adoption and scale up of agroforestry will be enhanced.

Integrated grazing and natural resources management options will be implemented, where communities will be empowered to manage and utilize their resources coupled with flexible and driven by the communities' needs and agro-ecological conditions. Such options provides a broader framework where various stakeholders will interact to restore the ecological balance and generate positive synergies that will enhance productivity in mixed crop-livestock-trees production and reduce vulnerability and overcome the natural resources degradation among poor farmers and rural households.

Improved the livestock production management through the introduction and implementation of local context best fit technological and supportive policy to gear to market oriented livestock production that can improve the income and livelihood of smallholder farmers.

Integration of free grazing and agroforestry issues into other development partners as well as incorporation of indigenous knowledge in the design of technical and policy messages and extension programmes attaining long-term benefits.

The innovative agroforestry curriculum is expected to enhance the quality of agroforestry course being offered at the institutions of higher learning. As a result, more students are expected to take up the agroforestry studies resulting in seasoned agroforestry specialists who will continue driving the agroforestry agenda forward.

8.2 Capacity impacts – now and in 5 years

The project focused on capacity building at multiple levels from local community organizations and individual participants, national research agencies, other government partners, district level local stakeholders, and universities. Training of partner organizations enhanced their capacity to plan, implement, monitor and evaluate agroforestry interventions. Research institutions developed research proposals for funding by other donors. This was enabled through capacity development initiatives by the project. Researchers from partner institutes are in a better position now to generate ideas related to agroforestry and translate them to action research.

Capacity building was critical to successes in terms of reach, scaling and sustainability. Capacity was built through training-of-trainers’ workshops, training for extension workers, and field visits. Training and demonstrations were also provided through existing organizations such as cooperatives and producer groups, including 7 cooperatives in Rwanda, 4 farmer groups and 350 clusters in Uganda, and 5 RRCs. These approaches were effective for organizational and individual capacity building to reinforce training, information dissemination, and integration of farmers into value chains.

A total of 1,292, 4,446 and 4,609 community members were supported in Ethiopia, Rwanda and Uganda respectively through training and demonstration activities at the RRCs, workshops and sensitization meetings. In Uganda, trainings were focused on tree planting and management, tree-crop management practices, nursery management, sourcing of quality germplasm, pest management, soil and water management, product marketing and value chains. In Ethiopia, trainings were focused on high value agroforestry tree management and marketing, water management, soil acidity management/ fertilizer application, tree-crop-livestock interaction, tree and nursery management, grazing management. In Rwanda, trainings were focused on soil sampling and measurement, tree seedlings production, agroforestry extension, nursery management, production of climbing beans and tree tomatoes through model farmers and cooperative members. Upon request by the Ministry of Natural Resources in Rwanda, ICRAF developed various training and extension materials including manuals on agroforestry options for Rwanda, tree nurseries, tree planting and management, pests and diseases management in agroforestry and grafting of fruit trees.

Through on-farm participatory trials, demonstrations and trainings offered by the project to farmers through established Rural Resource Centres (RRCs), nursery management, tree distribution, and planting activities, farmers' knowledge re on tree-crop-water management increased to the point where some lead farmers play extension roles in the distribution of seedlings but also use their farms for a demonstration to new adopters of new tree species and fruit trees. Also, various training modules and manuals were developed to support the training activities.

The project further supported 8 PhD students and 2 MSc students. Moreover, the assessment of agroforestry curricula and extension training resulted in development of comprehensive agroforestry curriculum guidelines that universities in the 3 countries are using to upgrade their programs.

The training materials developed through the capacity development initiatives are expected to continue enhancing knowledge on agroforestry. In addition, more capacity development activities will be effected through the RRCs where community members will continue accessing information on improved tree planting and management. Technology spill over is expected because of farmer-to-farmer extension. Trained farmers are expected to train other farmers within and beyond the project areas. It is envisioned that these farmers will adequately consist of women and youth. Following substantial capacity development of project partners and extension staff, it is expected that the skills imparted will enable them positively influence implementation of agroforestry initiatives in their organizations. The agroforestry curriculum development is expected to have the long-term impact in terms of strengthening educational program standards, preparing students for careers in extension, research, development or educational organizations, and elevating professionalism within the agroforestry sector.

Training to partner institutions enhanced their capacity to plan, implement, monitor and evaluate agroforestry interventions. Research institutes developed research proposals for funding by other sponsors. This was enabled through the training they got from the project. Researchers from partner institutes are in a better position now to generate ideas related to agroforestry and translate them to action research. Proposals developed by higher education and research institutes have garnered funding from different sources to undertake research and development on agroforestry systems. This resulted from the training on research proposal writing and mobilizing resources for research given by the project.

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

In all the countries, improved livelihoods for participating farmers as a result of project interventions was reported. In Uganda, the use of *Calliandra spp* as fodder for livestock and beekeeping boosted milk and honey production in the region. As a result, farmers' income increased, and livelihoods changed, e.g. from traveling long distances to collect stakes/fuel wood and animal feeds. Nkoma Youth Development Association, a youth group located in Namanyonyi Sub-county, Mbale District is one example of a group that was formed as a result of the various engagements by the project. Some of the skills learnt during the trainings were helpful to the youths and women to start up tree-based enterprises. The

Nkoma Youth Development Association (NYDA) established a commercial tree nursery where they raise and sell assorted fruit and multipurpose tree seedlings. The project provided potting bags, shade mats, watering cans and seeds to start them off. "The trainings opened our eyes not only on the numerous benefits of trees but also on tree nursery operations and management. We took it up and applied what we learnt to start and run a tree nursery as business" explained Bashir Wapaya, Chairperson of Namanyonyi Youth Group. The youths have raised more than 9,000 seedlings of various species and have so far sold and expanded their capital investment to UGX 3,610,000, (AUSD 1,100). The group members managed to access small loans from their savings to meet their immediate social needs (including paying school fees, medical expenses, purchasing food stuff), and made investments in various livelihoods activities including purchase of inputs such as improved seed and hoes. Efforts to link the group to Microfinance Institutions (MFIs) including Vision Fund to access bigger loans were reported.

Testimonies from farmers in Bududa indicated that individual farmers were receptive of the economic benefits that agroforestry brings along. One farmer, Mr. Waninga Noah indicated that "After I prune my Grevillea trees, I get firewood for home use and more for sale. I sell a bundle of firewood at 2000 UGX. Recently I sold 6 bundles of firewood (earning approximately USD 3) and managed to buy maize seeds for planting." Some farmers have started receiving carbon credit from ECOTRUST at the rate of 6-8 USD for 1 ton of carbon. The money is paid in 7 instalments (from 0 - 10 years) until the tree is 25 years old. So far 27 farmers have been paid. Plans to engage more farmers in this scheme are underway.

In Ethiopia, the Margarissa group at Batu RRC established during the first phase of the project was legally organized during the project's second phase and obtained a tax payer's tin number as an identification by the woreda revenue and tax administration office. The group continues to be actively engaged in production of improved planting materials of avocado, mango, papaya, different multipurpose tree seedlings, and ornamental plants. In addition, farmers are benefiting from sale of tree seedlings in both Batu and Bako RRC. The group members recorded an income of more than ETB 265,000 (USD 6,400) from nursery operations and sale of quality germplasm. Currently the group members earn a net income of approximately USD 200 per month from the RRC operations. Similarly, 11 youths in Bako RRC took management of the RRC activities. Through the leadership of the project coordinator in Bako and Head of Agriculture and Natural Resources for Bako Tibe district, the group continues to work at the RRC in producing tree seedlings that have been distributed to project's participatory trials and tree planting activities. In 2019, the group earned an income of ETB 25,000 (USD 600) mainly from the sale of coffee seedlings, banana suckers.

In Rwanda, farmers reported substantial income from tree tomatoes, biomass incorporation using and use of stakes for climbing beans. Since the successful scaling out of tree tomato in Bugesera, farmers from Bugesera Innovation Platform (IP) have managed to plant more tree tomatoes and earned income from selling tree tomato fruits, seeds and seedlings. Many more farmers are investing in tree tomato production to meet the rising market demand. One such farmer, Emmanuel Tuyireze started with only 500 tree seedlings of tree tomato where during the first harvest, he obtained one ton of tree tomato fruits. He sold the fruits at the market (at 500 RWF per kg) earning approximately USD 600. Tuyireze has now increased the number of planted tree tomato to nearly 8,700 plants and owns a nursery where he raises and sells seedlings to the farmers. The income accrued from tree tomatoes has enabled him to buy additional land where he is able to grow diverse crops including tree tomatoes. Twagiramungu Vianney is another champion farmer at Mareba sector, Bugesera district, who has planted 116 tree tomatoes. At maturity, he was able to harvest 20 kg of fruit per week, which he sold to his neighbours and at the local market. Towards the end of 2019, he reported earning income of RWF 230,000 (USD 250) after only few months of harvest (Ndayambaje et al, 2021). In Rwanda, following the acquisition of knowledge and skills on nursery management, tree planting and management from T4FS project, 10 farmer groups entered into collaborative agreements with the Forest Landscape Restoration Programme where they were contracted to produce tree seedlings in the nurseries. In addition, initial farmers who adopted fruit trees from the project have started earning income from the sale of fruits. In 2020, a farmer group from Nyamata sector signed a contract amounting to RWF 8,000,000 (USD 8,695) with National Agricultural Export Development Board (NAEB) to produce fruits.

Farmers in Rwanda have also benefitted from green manure as illustrated by the farmer testimonies. Maniriho Beatrice of Nyundo Sector had this to say, “I have been in this project for 3 years. Before the project, I used to cultivate crops using farmyard manure only and the productivity was very low. When I joined the project, we were trained on how to mix leaves with soil for green manure and combine it with chemical fertilizers. We were also trained that we can use green manure if chemical fertilizer is not available. I was further trained on using Alnus stakes for climbing beans. After implementing those practices, crop production has increased, and I am able to adequately feed my family. I thank the project for training us on how to combine chemical fertilizers and green manure in cultivation. I also request that this project provides us with more fruit trees so that we can benefit from the fruits and improve our livelihoods. On my 20x20m field, I used to harvest 25kg of beans, now I harvest almost 50kg after using green manure. I also learnt that trees and crops can grow together on the same field.” Another farmer, Nyiramahirwe Joselyne from Karago Sector highlighted “I have been in the project for 2 years. Initially I used traditional planting methods, now I have learnt about the use of fertilizer and planting 2 seeds in a hole as opposed to the 4-5 seeds that I was planting before. I have also been trained on the use of stakes from Alnus. Now I am able to use less stakes, so more land is utilized for planting seeds. With the use of green manure, the land remains fertile for a long time. My land area is 40X15m. I used to plant 40kg of bean seeds and harvest 100kg now I use 7kg of seeds and harvest 170kg.”

Through the project, potential for tree-based value chains as potential sources for increased income was identified in all the countries. In Uganda, Calliandra spp, Avocado and timber were identified as the potential tree-based value chains for development. Avocado is produced by the farmers and sold to both large- and small-scale traders while timber consisted of a number of actors including tree farmers, timber brokers, timber traders and timber transporters. The other actors included timber processors (constituting of loggers and carpenters), consumers of semi-processed materials and consumers of finished products. Opportunities for developing both value chains included; forestry/tree growing increasingly becoming a viable business; due to high demand for tree seedlings; existing research knowledge generated on tree management and value addition and growing interest financing institutions in tree growing as a viable enterprise. In Ethiopia, potential tree-based value chains were identified as Mango in Zeway, Avocado in Bako and Apple in Tsaeda Emba, Tigray. An existing demand for all the fruits was reported by farmers, traders and processors implying that fruit production had a high potential for income gain. In Rwanda, tree tomato and Grevillea value chains were identified as potential tree-based value chains. Given the scope of the project, development of these value chains was focused at the production level. It is expected that opportunities for further development of the tree-based value chains will be taken up the national development partners, private sectors or funders as areas for further development.

8.3.2 Social impacts

Following the different capacity development and scaling initiatives on agroforestry implemented by the project, there was increased participation in agroforestry-related activities as evidenced by the large tree distribution and planting amongst the communities. Improved participation among communities including women and youth was also been observed in all the project sites. As of June 2021, the project had directly reached over 48,000 participants in the three countries. Cognizant of the nature of agroforestry practices, which are characterised by lagged impacts, the T4FS project carefully designed scaling strategies that respond to smallholder farmers’ widely held myth of “seeing is believing” such as peer-to-peer learning and evidence-based approaches including participatory trials, capacity development initiatives such as trainings and demonstrations, RRC activities, nursery management, tree distribution and planting activities in satellite nurseries, Umuganda in Rwanda, sensitization meetings, exhibitions and field days. The project to a large extent focused on gender integration with emphasis on women and youth. In all the countries, deliberate efforts were made to ensure that gender/youth balanced groups are involved in running operations at the RRCs, cooperatives and farmer groups. At least one third of women and youth were actively involved in the project activities.

The participatory trials and RRC approaches were instrumental for co-learning and experience sharing amongst farmers leading to widespread adoption. As a result, the technologies gained interest amongst various stakeholders. In Ethiopia, the participatory trials approach was adopted by the Integrated Watershed Development and Productive Safety Nets Program financed by the World Bank in implementation of its activities. In addition, the RRC approach was adopted up by the Packard Foundation financed project to create women and youth centered green jobs. More than 16 RRCs (by ICRAF through other projects and other NGOs) were established across different sites in the country. In Rwanda, 14 more RRCs were established in Mulindi, Bugesera, Kayonza, Gatsibo and Nyagatare through RAB as hubs for quality germplasm production as well as training and demonstration of agroforestry technologies. In Uganda, an additional RRC was established in Arua.

A change in behaviour and farmer practices was observed as evidenced by the successful scaling out of project-related initiatives. In Rwanda, success was observed for two agroforestry options (tree tomatoes and climbing beans including promoting appropriate stakes for supporting the beans) which were scaled out from the sub-humid areas of Gishwati to the semi-arid areas of Bugesera. The project introduced tree species like *Acacia augusitissima, Alnus acuminata* and *Vernonia amygdalina, Gliricidia sepium, Calliandra calothyrsus* among others as a solution to stakes for climbing beans in Rubavu district. These trees are fast growing and contribute to the improvement of soil fertility through biomass incorporation, nitrogen fixation, soil erosion control and reduction of distance travelled by famers to collecting stakes. The project leveraged on the monthly community work ‘umuganda’ to sensitize communities on importance of agroforestry. This action has brought together farmers, local authorities, and diverse stakeholders in agroforestry to plant trees on sites participatory selected. Messages on the importance of agroforestry, agroforestry species and tree management as well as sustainable land management were disseminated. Umuganda has also been used as an approach to distribute seedlings and promote tree planting efforts for soil conservation and erosion control especially at Karago and Nyundo.

In Uganda, awareness about agroforestry tree-based enterprises among women and the youth has increased. Consequently, more groups were formed especially among the youth and women. Tree nursery establishment and beekeeping activities for income generation became popular among these groups.

In Tigray, Ethiopia, apple production was successfully adopted and appreciated as a worthwhile intervention. According to the participating farmers, apple production is a potential profitable venture because the agroecology is suitable for apple production and unlike other fruits, apples are more resistant to pests and diseases and frost, which are major setbacks to fruit production. Moreover, apples mature after three years and the current fruits being produced in the area (though in small quantities) such as avocadoes and oranges take up to seven years to mature and are highly damaged by frost. Expected benefits from the apples include inter alia, nutritional benefits, financial gain, health benefits.

The project had significant spill over effect, with agroforestry best practices being continually adopted by non-project farmers. Some farmers in Nakatsi, Uganda had this to say, “Due to the over extraction of trees in this village, only a few fruit trees planted by our grandparents were remaining prior to the T4FS project. These few trees were susceptible to over-use in terms of pruning for fuel wood by the wider community. While we tried to protect them, other people wanted to utilize them, and this created a rift with our neighbours. Sometimes we had to take these cases to the local authorities, and this tainted our friendship further. After the project created awareness on tree planting and benefits of trees, more people took up tree planting and the pressure on the few trees that were there has reduced. Our relationship with the neighbouring communities has also improved."

Adoption of the RRC model in the various countries at the national level is considered a project legacy as the model will be utilized by various institutions to create employment for the youths. The RRCs initiated by the project will continue to act as hubs for capacity development and distribution of quality germplasm to the communities as well as sources of livelihood for the youths and women working at the centers.

The coming together of farmers in cooperatives has continued to empower them and provide forums for peer learning amongst other income generation and socio support systems. Such groups also provide suitable platforms that farmers can use for tree value chain development initiatives.

Not only did farmers utilized the technical skills delivered to them but were observed to innovate and adapt practices more suitable for their specific sites and contexts. This indicates that farmers' way of thinking was broadened, and the project has acted as an eye opener to more techniques that the farmers can try to meet their needs. For example, after training on grafting fruit trees established in nurseries, farmers went ahead and grafted the planted trees on their individual farms and the process was reported to be successful. As such, it is expected that there will be continuous adoption of the technologies even beyond project life.

8.3.3 Environmental impacts

Through the participatory trials and tree planting initiatives, project sites witnessed increased tree planting and protection, wider diversity of trees planted as well as higher quality of trees germplasm established. Approximately 4.2 million diverse multipurpose seedlings have been produced from the five RRCs and satellite nurseries across the three countries. Out of these, more than two thirds has been distributed for planting by the communities. The species promoted by the project provide various products such as fodder, fences, firewood, poles, timber, food, fruits, as well as services such as soil and water conservation, erosion control, river bank stabilization, improvement of soil fertility and carbon sequestration.

In Rwanda, different stakeholders (in addition to the farmers) were engaged in tree planting initiatives. These include among others, schools, churches, and health centres who were mobilized to plant trees on their individual and communal lands. The planting of multipurpose tree species in Rwanda such as *Alnus acuminata, Acacia angustissima* and *Gliricidia sepium* helped to improve soil fertility as well as reduce erosion. At the same time, these trees are contributing to the increase of tree cover in the country hence contributing to local microclimate moderation and carbon sequestration. In Gishwati site, households benefitted from soil and water management technologies through establishment of erosion control structures such as terraces and planting of agroforestry trees to strengthen the structures. Tree growing on farms, terracing as well of adoption of sustainable farming practices largely contributed to reduced siltation in Lake Karago in Nyabihu District. The project contributed to the government's initiative in which the newly established model villages are required to adopt agroforestry in their home compound and surroundings. This is in line with the nutrition sensitive agriculture policy where each household is expected to plant at least 3 fruit seedlings.

In Uganda, beans and tomatoes are two commonly grown crops by farmers in Mount Elgon region. Both crops require staking for support during flowering to enhance yields. However, lack of stakes had hindered production and high post-harvest losses in the case of beans. To help smallholder farmers overcome the staking challenge, the TF4S-2 project provided seedlings of fast-growing tree species such as *Calliandra calothyrsus, Neolamarckia cadamba; Grevillea robusta, Alnus sp; Gliricidia sepium, Eucalyptus sp. Maesopsi eminii*, and *Melia volkensii*. Stakes were obtained by pruning and thinning the trees woodlots.

These thinnings and prunings also offered other benefits such as soil fertility improvement, livestock fodder and fuelwood.

In Ethiopia, a higher tree survival rate was recorded in Tigray. This could be attributed to the colossal efforts in sensitization and awareness creation on tree protection and management practices. A survival rate of 73% for apple, 74% for guava and 75% for coffee was recorded in November 2019.

Through the project, an "Interactive Suitable Tree Species Selection and Management Tool for East Africa" was developed. This web-based tool aids in understanding trees diversity and its contribution to livelihoods and landscape health and promotes the right tree for the right place for the right purpose. The tool was developed for Ethiopia consisting of 209 (147 native and 62 exotic), Rwanda consisting 115 (54 native and 61 exotic) tree species in Rwanda; and for Uganda consisting of 58 (31 native and 27 exotic) tree species. The tools include a collation of tree species encountered during the two phases of the project through the various study approaches employed by the project namely: tree diversity, baseline studies, seed and seedling systems surveys, local knowledge and Land Degradation Surveillance Framework. The database enables the user to easily access information either based on tree species, their agroecological zone suitability, products, environmental services, origin (native or exotic) and niche. The tool also provides specific details on the trees' biophysical growth conditions and management requirements as well as links to other agroforestry databases.

The 'Interactive Suitable Tree Species Selection and Management Tool for East Africa' will be converted into a mobile-phone application that will be accessible to extension providers and local communities as a guide on suitable tree species and associated management practices matching the specific sites.

Following the establishment of RRCs and satellite nurseries, coupled with continue capacity development on tree planting and management, production of high-quality tree germplasm is expected resulting to higher tree survival rates. Benefits from the trees planted are expected to accrue in the next five years and more. Maturing of the trees is expected to yield tree-based products and services. Further, positive results from the tree-crop-water interactions will not only encourage farmers to adopt trees on farm but also encourage proper management practices. Continued adoption of agroforestry, soil and water conservation practices will help to build resilience to climate effects especially prolonged drought. There has been evidence of soil erosion control in the project areas especially in the sloped lands which has contributed to better crop yields.

8.4 Communication and dissemination activities

Communication and dissemination of project technologies was guided by the communications strategy. Different communication products for different audiences were produced. Moreover, the project maintained relevant active communication links amongst the team members, partners stakeholders and the wider public during its implementation.

As part of internal project communication process, the project held four steering committee meetings in 2017, 2018, 2019 and 2020. During these meetings, progress in each country was presented, gaps identified, and work plans for the following year prepared and implementers clear on the expected deliverables.

The project held regular internal meetings as well as virtual meetings with the partners based on need. Furthermore, country management meetings were held in all countries to keep track of the progress of activities.

The project website is a major platform for both internal and external communication. http://www.worldagroforestry.org/project/trees-food-security-2-developing-integrated-options-and-accelerating-scaling-agroforestry

Communication to the wider scientific audience was done though the publication of peer reviewed journals, conferences and technical reports that are published on the website. T4FS-2 project findings have been published in 16 journal articles, five technical manuals, and over 100 technical outputs including reports, theses/dissertations, posters, tools and databases.

The project further capitalized on ICRAF's social media platforms (twitter, facebook and LinkedIn) where short and quick project updates are given to the wider public. Please find featured tweets on the project here

The project further makes use of share points such as drop box and google drive folders to make its documentation accessible to the relevant stakeholders. Project's data is collated and archived at ICRAF's dataverse for public access and use and also in compliance with ICRAF's policy on IPG: https://dataverse.harvard.edu/dataverse/T4FS.

Blogs were also published to further communicate project outcomes. Below are links to the blogs:

- Q& A: How women and girls can succeed in science
- https://worldagroforestry.org/blog/2021/03/08/qa-how-women-and-girls-can-succeed-science
- More stakes, more climbing beans, less malnutrition: Rwanda finds a solution in Agroforestry: http://www.worldagroforestry.org/blog/2020/04/03/more-stakes-more-climbing-beans-less-malnutrition-rwanda-finds-solution
- Women and youth turning to tree-based enterprises for livelihoods in Mount Elgon, Uganda http://www.worldagroforestry.org/blog/2020/07/10/women-and-youth-turning-tree-based-enterprises-livelihoods-mount-elgon-uganda
- Trees for Food Security Project bearing fruit in Ethiopia http://www.worldagroforestry.org/blog/2019/11/15/trees-food-security-project-bearing-fruit-ethiopia

Project-related work/findings have also been published in other outlets. Below are the links:

- Farmer-led increase in tree diversity across agricultural landscapes in Ethiopia. In Agroecological transformation for sustainable food systems: Insights on France-CGIAR research 2021.26: 23
- Tree stakes for climbing beans in Rwanda. In Agroecological transformation for sustainable food systems: Insights on France-CGIAR research 2021. 26:26
- Rural resource centers provide extension support for diversified food production options. In Agroecological transformation for sustainable food systems: Insights on France-CGIAR research 2021. 26: 83-84
- Researcher committed to Safeguarding Women's Economic Empowerment http://www.jkuat.ac.ke/researcher-committed-to-safeguarding-womens-economic-empowerment/
- COVID-19 and women's leadership: a conversation with ICRAF senior scientist Prof Catherine Muthuri https://aciar.gov.au/media-search/blogs/covid-19-and-womens-leadership-conversation-icraf-senior-scientist-prof
- New funds could help grow Africa's Great Green Wall. But can the massive forestry effort learn from past mistakes? https://www.sciencemag.org/news/2021/02/great-green-wall-could-save-africa-can-massive-forestry-effort-learn-past-mistakes
- The art of pruning: https://aciar.gov.au/media-search/blogs/art-pruning
- Agroforestry: Development underdog headed for center stage in global sustainability efforts https://www.foreststreesagroforestry.org/news-article/agroforestry-development-underdog-headed-for-center-stage-in-global-sustainability-efforts/
- Agroforestry in the Mt. Elgon sub-region Scaling up farm practices for food security in Eastern Uganda http://apps.worldagroforestry.org/downloads/Publications/PDFS/2018036.pdf

- Long walk after genocide: How Rwandan farmer made it https://theexchange.africa/industry-and-trade/agribusiness/long-walk-after-genocide-tree-tomatoes-impact-rwandese-farmers-life-as-he-smiles-to-the-bank/
- Trees are best bets for rural food security https://search.proquest.com/openview/5d88244fe22e7a39648bfaef10a2c3b8/1?pq-origsite=gscholar&cbl=25518
- Agro-forestry project to improve food security launched in Kigali https://www.newtimes.co.rw/section/read/208204

International, regional, and national conferences and workshops have also been key in disseminating project outcomes. Approval of the Launch event fund application totaling AUD52,837 to attend the World Congress on Agroforestry in Montpellier, France, from 19th to 23rd May 2019 was done. The fund enabled 17 researchers from five ACIAR projects including 9 from T4FS to attend. One keynote, two oral and ten posters were presented at the congress. The researchers also participated in the ACIAR side event. Another six abstracts were submitted to other conferences such as International Tropical Agriculture Conference (TropAg) 2019; Forests, Trees and Agroforestry (FTA) in September 2020 and the 3rd joint National Agricultural Research Organisation and Makerere University Scientific Conference (NARO-MAK) that is yet to be held in Uganda. In Uganda, a presentation on 'Geospatial Assessment of Land and Water Management Options for Enhanced Tree Survival and Growth in Eastern Uganda' was made during the Water and Environment Conference in June 2019.

T4FS-2 project team also presented the outcomes of the study at a workshop entitled, "Regreening Ethiopia with trees: mapping a collaborative approach and Regreening Africa", organized by ICRAF, the European Union (EU), Catholic Relief Services (CRS) and others held on November 19-23, 2018 in Addis Ababa, Ethiopia. Participants agreed that free grazing issues should be one of the main planned activities of the Regreening project in Ethiopia project starting in 2019.

In Uganda, the project was accredited to the Queen's Commonwealth Canopy (QCC) initiative. The title of the project is 'The Mount Elgon Trees for Food Security Project' under this initiative. This has provided a great visibility opportunity and profile to project activities in Uganda.

9 Conclusions and Recommendations

9.1 Conclusions

There was enhanced understanding of farmer-led agroforestry options in the three countries achieved through establishment of farmer participatory trials, with the types of trials being agreed upon after a careful analysis of farmer contexts and circumstances. Participatory trials generated a learning platform and are efficient and an impact-oriented scaling strategy. They are mechanisms for sharing findings as well as farmer generated innovations with other farmers to realize impact at scale.

Through long-term trials, an improved understanding of tree-crop interactions of different species and contexts has been achieved, that allowed for data collection and analysis on tree growth, crop yields, biomass and soil samples. Knowledge generated demonstrated the importance of various management practices such as pruning of trees resulted in efficiency of water use while application of green manure led to soil nutrient cycling thereby resulting in high crop productivity.

Enhanced tree-crop modelling capability including agroforestry layout, species and functionality options and several tree and crop model options was achieved through completion APSIM Next Generation frameworks. APSIM was validated for diverse contexts inside and outside the project, applied to suggest management improvements, and remains as a growing modelling resource for simulating crop and wood yields and other biophysical impacts that can be utilised in other projects. The range of crop models is continually increasing in APSIM, which enhances its usefulness for contexts outside this project.

Identification of cost-effective water management practices suitable for the various sites was achieved through completion of site-specific land and water management mapping processes. 184 maps depicting land types and suitable interventions were completed and shared with partners and stakeholders during ‘Training of Trainers’ sessions. The maps have been integrated in the partners’ plans as guidelines towards future establishment of land and water management related technologies.

Discussions on existing policies and strategies on grazing management concluded that free livestock grazing problem in Ethiopia can be sustainably addressed through design of context specific sustainable grazing options by understanding ecological, socio-cultural and economic domain of landscapes, and supported with incentivize policies and institutional arrangement. This resulted in the formation of a Sustainable Grazing Platform and development of a policy brief highlighting sustainable grazing policy recommendations which will continue to be applied towards the promotion of sustainable grazing management options.

The establishment of 5 Rural Resource Centres (RRCs) and 18 satellite nurseries (cooperative, group or Individual) across Rwanda, Ethiopia and Uganda has been instrumental in production and distribution of quality germplasm of key tree species including the promotion of the previously ignored native species, have promoted training and demonstration of agroforestry technologies, created job opportunities and provided opportunities for farmers to share their experiences with their peers as well as receive technical guidance and other services.

The project also examined smallholders and other market actor’s ability to participate effectively and profitably in tree product value chains and led to the identification of potential country-appropriate tree value chains (Tree tomato-Rwanda, Avocado-Ethiopia, Timber and avocado-Uganda) and country-appropriate value chain financing options. Further, an impact assessment study conducted in Rwanda concluded that there was significant increase in the percentage of households taking up different agroforestry practices; and with the existing and growing demand of agroforestry trees in all project sites, there is a potential for uptake of agroforestry.

Through the T4FS-2 project, a regional agroforestry curriculum guide was developed after a comprehensive assessment of agroforestry curricula and extension training involving Universities/Colleges, Integrated Polytechnic and Technical and Vocational Education and Training (TVET) institutions offering forestry and/or agroforestry courses in all countries. Validation workshops were held and skill gaps on pertinent agroforestry components identified, which will act as entry points for incorporation of agroforestry aspects in institutions' curriculum.

9.2 Recommendations

- Successful implementation of participatory trials testing different agroforestry options across varying biophysical and socio-economic contexts demonstrates the need participatory (farmer-led) approaches in conducting research for development activities in agroforestry, which should be demand-driven and best-fit as communities innovate the technologies to suit their needs hence making the technologies more relevant and sustainable.
- Long-term trials will continue to be used as experimental sites for further agroforestry research in the respective countries and will be managed by national research partners. There is need to ensure continued security of land on which the experiments are located to enable continued collection of data from the trials. Long-term effects of agroforestry on soils, e.g. carbon sequestration needs intensive sampling at the start of the experiment, and archiving of samples for later sub-sampling, re-measurement and comparison with later samples.
- The APSIM model that is available for public use will be utilized further for agroforestry trees-crop modelling. There is therefore need for continued collaboration on this with CSIRO to complement on project data
- Guided by the maps generated which will be useful in new plans and projects, local governments and development stakeholders need to provide context-based land and water management solutions through agroforestry, reforestation and FMNR.
- Selection and introduction of best fit technologies and sustainable grazing management options should be supported by appropriate policies, institutional setup, resources allocation and investments which promotes improved livestock production system. There is a need for awareness creation, capacity building, inter sectoral coordination, stakeholder participation and partnerships for better implementation of grazing policy and strategy options.
- Where participatory trials are adopted as a scaling strategy, mechanisms for sharing findings from the trials as well as farmer generated innovations with other farmers need to be put in place to realise impact at scale.
- Having identified successful and viable country and country-appropriate models for seed supply systems, there is need for local governments and development partners to provide enabling environments for the establishment of individual and cooperative tree nurseries for production of high-quality germplasm; and offer more intensive and targeted training and demonstrations. There is also need to scale to wider geographical regions so that benefits such as income generation and promotion of diverse tree species across farms can be realized by a wider number of farmers, especially women and youths.

- Regarding agroforestry curriculum, the reviewed curriculum guide should be applied in academic institutions to ensure that unlike the past when agroforestry was either offered as a course embedded on other content, topic or chapter, it will be offered as a comprehensive course integrating all the relevant components.

10 References

10.1 References cited in report

Adugna, T and Heidhues, F. 2000. Determinants of farm households' access to informal credit in Lume District, central Ethiopia. African Review of Money Finance and Banking, 27-45

Asratie D. 2014. The Socio-Economic Role of Savings and Credit Cooperatives in Promoting Gender Equality: The Case of Estie Woreda, Ethiopia. European Journal of Business and Management. ISSN 2222-1905 (Paper) ISSN 2222-2839 (Online) 6:1.

Atieno L.2017. Banks, agric cooperatives look to increase farmer access to finance. The New Times https://www.newtimes.co.rw/section/read/225877

Azage T, Berhanu G, Hoekstra D, Gebremedhin W, Zewdu A and Kahsay B (2012). Market-oriented livestock production and sustainable watershed management in Astbi and Mieso districts, Ethiopia: IPMS experience. In "Training on Participatory Integrated Watershed Management Planning and Implementation", Bahir Dar, 22-27 November 2012, International Livestock Research Institute (ILRI), P.O. Box 5689, Addis Ababa, Ethiopia.

Barrios E, Coutinho H.LC, Medeiros, C.A.B. 2012. InPAC-S: Participatory Knowledge Integration on Indicators of Soil Quality. World Agroforestry Centre (ICRAF), Embrapa, CIAT. Nairobi, 178p.

Benin S and Pender J (2002). Community Management of Grazing Lands and Impact on Environmental degradation in the Ethiopian Highlands. Paper presented at the International Association for the Study of Common Property Conference Victoria Falls, Zimbabwe, June 17-21, 2002.

Benin S, Ehui S, and Pender J (2002). Policies for livestock development in the Ethiopian highlands. Socio-economics and Policy Research Working Paper 41. ILRI (International Livestock Research Institute), Addis Ababa, Ethiopia. pp 29.

Berhanu G, Gebremedhin W, Yigzaw D, Tilahun G and Worku T (2010). Sustainable land management through market-oriented commodity development: case studies from Ethiopia. IPMS (Improving Productivity and Market Success) of Ethiopian farmers Project Working Paper 21, ILRI (International Livestock Research Institute), Nairobi, Kenya, 42 pp.

Berhanu G., Hoekstra D., Bogale A., Kahsay B, Azage T. (2012). Summary Report of Market-oriented Developmental Changes in the IPMS Pilot Learning Woredas, Working Paper No 30. Addis Ababa, Ethiopia.

Berhe K, Tedla A, and Mohamed-Saleem M.A (1993). Establishment and evaluation of multipurpose trees for sustainable farming systems in the Ethiopian highlands. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 8 pp.

Bernard, T and Taffesse A.S. 2012. Returns to Scope? Smallholders' Commercialization through Multipurpose Cooperatives in Ethiopia. Journal of African Economies 21 (3):440–64.

Bultossa T.W and Adeba G. 2016. Determinants of Market Participation and Financial Profitability of Smallholder Dairy Farming: The Case of Bako Tibe, West Showa, Ethiopia. Trends in Agricultural Economics 9:29-44.

Carley K and Palmquist M (1992). Extracting, representing and analyzing mental models. Social Forces 70 (3): 601-636.

Coe, R., Sinclair, F. and Barrios, E. (2014). Scaling up agroforestry requires research 'in' rather than 'for' development. Current Opinion in Environmental Sustainability 6(2014):73–77

Coates J, Maxwell D, Tadesse G, Hailu S, Nugussie W.Z and Gebrekiros, A. 2010. Institutional Assessment Report: Tsaeda Amba Woreda, Eastern Tigray, Ethiopia. Medford MA: Feinstein International Center

CSA (Central Statistical Agency of Ethiopia) (2007). Agricultural Sample Survey 2006/ 07. Report on Land Utilization. Volume IV: Statistical Bulletin 388. Addis Ababa, Ethiopia.

CSA (Central Statistical Agency of Ethiopia) (2010). Agricultural Sample Survey 2009/10. Report on Livestock and Livestock Characteristics. Volume II: Statistical Bulletin 468. Addis Ababa, Ethiopia.

CSA (Central Statistical Agency of Ethiopia) (2015). Agricultural Sample Survey 2014/15. Report on Livestock and Livestock Characteristics. Volume II: Statistical Bulletin 578. Addis Ababa, Ethiopia.

Derera K.T (2015). Beyond the commonality and expression of Oromo civilization: the mediating role of Gada system for commons management of natural resources. International Journal of Current Research 7 (9): 20223-20229.

Dixon B.A and Wood P.A (2007). Local institution for wetland management in Ethiopia: Sustainability and state intervention. CAB International 2007. Community-based Water Law and Water Resource Management Reform in Developing Countries (eds B. van Koppen, M. Giordano and J. Butterworth). Pp: 130-145.

Dorsey J and Tesfaye A. 2005. Evaluation of Agricultural Cooperatives (ACE) Program Activities for USAID/Ethiopia. Washington D.C: USAID.

EBI (Ethiopia Biodiversity Institute) (2014). Ethiopia's Fifth National Report to the Convention on Biological Diversity. Ethiopian Biodiversity Institute, Addis Ababa, Ethiopia.

Ekise, E. I., Nahayo, A., Mirukiro, J. D., & Nsengiyumva, B. (2013). Analysis of the impact of agricultural input subsidies voucher programme on the livelihoods of small-scale maize producers in Kirehe District, Eastern Rwanda. New York Science Journal, 6(9):32-44.

Emana, B. 2009. Cooperatives: a path to economic and social empowerment in Ethiopia. CoopAFRICA Working Paper No.9. Dar es Salaam: International Labour Office

Feyissa F, Assefa G, Kebede G, Mengistu A, and Geleti D (2015). Cultivated forage crops research and development in Ethiopia: In: Alemu Yami, Getnet Assefa and Lemma Gizachew (eds). In the Proceedings of pasture and rangeland research and development in Ethiopia. Pp 89–118.

Fisseha, M. (2011). A case study of the Bechera agricultural development project, Ethiopia. International Land Coalition. Rome, Italy.

Freweini A, Getachew A, Yoseph M and Mengistu U (2014). Assessment of the feeding potential and utilization of *Erythrina burana* and *Casimiroa edulis* in Eastern Harerghe zone of Ethiopia. Livestock Research for Rural Development 26 (5).

Gebregziabher G and Gebrehiwot H (2011). Challenges, Opportunities and Available Good Practices Related to Zero Grazing in Tigray and Hararghe, Ethiopia. Drylands Coordination Group Report No. 66, pp 10

Gebremedhin B, Pender J and Tesfay G (2001). Community Resource Management: The Case of Grazing Lands in Northern Ethiopia. International Conference on African Development Archives. Paper 49

Getnet A, Aemiro K and Mengistu A (2011). Overview of major feed resources availability and utilization in the highlands of Ethiopia. Proceedings of National workshop on innovations, actors and linkages in the dairy value chain in Ethiopia. FAO, Addis Ababa. Pp: 15 – 31

Goceljak, G.W. III. 2017. Financial Institutions and the Global Farming Industry: the Impacts of Large-Scale Agricultural Investments Observed in Ethiopia. Senior Projects Spring 2017. 200.

Hatega, G. 2007. SME development in Uganda. Private Sector Foundation Uganda. Paper presented at Local SMEs Conference on 14th March, 2007, Sheraton Kampala. Kampala, Uganda.

Hinman, R., & Matovu, J. (2010, April). Opportunities and challenges for mobile-based financial services in rural Uganda. In CHI'10 Extended Abstracts on Human Factors in Computing Systems (pp. 3925-3930). ACM

Honja, T. 2014. Review of mango value chain in Ethiopia. Journal of Biology, Agriculture and Healthcare 4(25):230-239.

Hudson R. 2003. An In-Depth Quantitative Assessment of the Ugandan Microfinance Environment. TMS Financial/MicroSave. Nairobi: MicroSave

IFAD. (2009a, August). Rural Finance Policy. IFAD. Rome, Italy. Retrieved from https://www.ifad.org/documents/38711624/39417948/rf_eng.pdf/b60b1440-9986-4b39-88dd-2ad035484053

Kaimowitz D, Byron RN and Sundertin WD (1998). Public policies to reduce inappropriate tropical deforestation. In: Lutz E., Binswanger H., Hazell P. and McCalla A. (Eds.), Agriculture and the Environment: Perspectives on Sustainable Rural Development. Washington, DC, USA, World Bank, Pp: 303-322.

Kairu P.K. 2009. Credit Management. Nairobi: Focus Publishers Ltd.

Kakungulu Y, Munzingiti G and Schimdt O. 2010. The state of business and operations of rural Microfinance Institutions (MFIs) in Rwenzori region, Portal unpublished.

Kamara, Y. 2011. Existing and Potential Forest Financing Mechanisms for Smallholders and Community Forestry in West Africa. Ouagadougou, Burkina Faso. Initiatives Conseil International. Pp 1–67.

Karlan, D, Savonitto B, Thuysbaert B, Udry C. 2017. Impact of Savings Groups on the Lives of the Poor. PNAS 114 (12): 3079-3084. https://doi.org/10.1073/pnas.1611520114

Kiptot E, Kinuthia R, Kelemu K and Mebrahtu T. 2013. ACIAR baseline survey 'trees for food security project' the agricultural extension system in Ethiopia: A focus on East Shewa. West Shewa and East Wollega Zones

Kodama Y. 2007. New role of cooperatives in Ethiopia: the case of Ethiopian coffee farmers' cooperatives. African Study Monographs 35: 87-108

Kwapong N.A and Korugyendo P.L. 2010. Revival of agricultural cooperatives in Uganda. USSP IFPRI Policy Note, 11

Lecup, I. 2011. Community-based tree and forest product enterprises: Market Analysis and Development Manual. Rome, Italy. FAO.

Lemma T. 2008. Growth without structures; the cooperatives movement in Ethiopia. In Cooperating out of Poverty: the renaissance of the African cooperative movement, Develtere P,Wanyama F. (eds). ILO: Geneva.

Mastewal Y, Christian V and Michael H (2009). Comparing the Effectiveness of Informal and Formal Institutions in Sustainable Common Pool Resources Management in Sub-Saharan Africa. Conservation and Society 7(3): 153-164.

Meena MS and Singh KM (2014). Fodder Production Scenario and Strategies for Revitalizing Fodder Production Technologies. Munich Personal RePEc Archive Paper No. 56367.

MEFCC (Ministry of Environment, Forest and Climate Change) National REDD+ Secretariat (2016). Final Draft on National REDD+ Strategy (2016-2030). Addis Ababa, Ethiopia.

Melaku G.J (2016). Oromo Indigenous Knowledge and Practices in Natural Resources Management: Land, Forest, and Water in Focus. Journal of Ecosystem and Ecography 6 (2): 181-189.

Millar J and Connell J (2010). Strategies for scaling out impacts from agricultural systems change: the case of forages and livestock production in Laos. Agric Hum Values 27:213–225.

MoA (Ministry of Agriculture) (2012). Annual report on Animal production and forage development. Addis Ababa, Ethiopia.

Ministry of Finance and Economic Development (MoFED) (2010). Growth and Transformation Plan of Federal Democratic Republic of Ethiopia (FDRE). Addis Ababa, Ethiopia: MoFED.

MoA and ILRI. (2013a). Animal production vision and strategy for Ethiopia. Addis Ababa, Ethiopia: Ministry of Agriculture and International Livestock Research Institute.

MoA and ILRI. (2013b). Livestock extension vision and strategy for Ethiopia. Addis Ababa, Ethiopia: Ministry of Agriculture and International Livestock Research Institute.

Mugabekazi D. 2014. Evaluation of factors influencing membership in coffee cooperatives in Huye District, Rwanda. Doctoral Dissertation, The University of Nairobi. Nairobi, Kenya.

Mukwana P and Sebageni G. 2003. An In-Depth Assessment of the Ugandan Microfinance Market: Qualitative Side Study Report. Kampala: MicroSave Consulting

Munyambonera E.F and Lakuma C.P.2015. Determinants of Commercial Banks' Total Factor Productivity Growth in Sub-Saharan Africa (SSA). Journal of Applied Finance and Banking 5 (5):73

Musahara, H. (2012). Perspectives on cooperatives with reference to Rwanda. ILO working paper no.13. International Labour Office.

Natarajan V, Reddy O.C.S and Rao K.V. 2015. Capital Mobilization Practices of Ambo Farmers' Cooperative Union's Affiliated to Multipurpose Cooperative Societies: A Case of West Shewa Zone, Oromia Regional State, Ethiopia. International Journal of Basic Applied Sciences 4 (4): 194-205

Nnyanja, W. (2017). The Role of Saving and Credit Cooperatives in Improving Household Income: the Case for Teachers in Mukono District. Master's thesis, Ugandan Technology Management University. Kampala, Uganda.

Nsingize G. 2013. The contribution of agricultural cooperatives to small holder farmers' household income: A Case of COAMV Cooperative, Burera District, Rwanda. Master's research project https://edepot.wur.nl/279035.

Nyolei D, Malesu M, Oduor A. R, 2018. Geospatial Assessment of Land and Water Management Options for Enhanced Tree Survival and Growth in T4FS Project sites in Uganda. ICRAF Nairobi.

Nyolei D, Malesu M, Oduor A. R, 2018. Geospatial Assessment of Land and Water Management Options for Enhanced Tree Survival and Growth in T4FS Project sites in Ethiopia. ICRAF Nairobi.

Nyolei D, Malesu M, Oduor A. R, 2018. Geospatial Assessment of Land and Water Management Options for Enhanced Tree Survival and Growth in T4FS Project sites in Rwanda. ICRAF Nairobi.

Republic of Rwanda. 2013. Economic Development and Poverty Reduction Strategy II (2013-2018). Kigali, Rwanda

Republic of Rwanda. 2000. Rwanda Vision 2020. Kigali, Rwanda. Ministry of Finance and Economic Planning.

Sabit J.M and Mohamed A. 2015. Role of Credit and Saving Share Company in Poverty Reduction in Rural Communities of Gumay District, Jimma Zone, South West Ethiopia. The International Journal of Applied Economics and Finance 9(1):15-24

Shapiro BI., Gebru G., Desta S., Negassa A., Nigussie K., Aboset G. and Mechale H. (2017). Ethiopia livestock sector analysis. ILRI Project Report. Nairobi, Kenya: International Livestock Research Institute (ILRI). Pp: 1-127.

Steven F, Sammy C, Ben L, Judith S and Charles W (2014). Fodder trees for improving livestock productivity and smallholder livelihoods in Africa. Current Opinion in Environmental Sustainability 6: 98–103.

Takele G, Lisanework N and Getachew A (2014). Ecological and Socio-Economic Importance of Indigenous Multipurpose Fodder Trees in Three Districts of Wolayta Zone, Southern Ethiopia. Journal of Biodiversity and Endangered Species 2 (4): 136-140.

Tefera D.A, Bijman J and Slingerland M.A. 2017. Agricultural Co-operatives in Ethiopia: Evolution, Functions and Impact. Journal of International Development 29: 431-453

Tesfaye, T, Karippai R.S, and Tesfaye T. (2010). ‘Farmers training effectiveness in terms of changes in knowledge and attitude: The case of Holeta, Melkassa and Debre zeit Agricultural Research Centres, Ethiopia. Journal of Agricultural Extension and Rural Development, Vol 2 (5): 89-96

Tesfay Y, Gebrelibanos A, Woldemariam S. and Tilahun H (2016). Feed resources availability, utilization and marketing in central and eastern Tigray, northern Ethiopia. LIVES Working Paper 11. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Thomas W, Guush B and Fanaye T (2016). The state of Ethiopia’s agricultural extension system and effects on modern input use and productivity. Ethiopian Economics Association (EEA) 14th International Conference on the Ethiopian Economy July21-24, 2016 Addis Ababa, Ethiopia.

Toyiba S, Lemma Z and Endrias G. 2014. Market analysis of papaya (Carica papaya): The case of Dugda District, Eastern Shewa, Oromia National Regional State of Ethiopia. Journal of Agricultural Economics and Development 3(8):120-130

Verhofstadt E and Maertens M. (2014). Can agricultural cooperatives reduce poverty? Heterogeneous Impact of Cooperative Membership on Farmers' Welfare in Rwanda. Applied Economic Perspectives and Policy 37(1): 86-106.

West, P C et al. (2016). Assessing risk to biodiversity and smallholder farmers from land grabs. University of Minnesota.

Yunlong C and Smit B (1994). Sustainability in agriculture: a general review. Agriculture, Ecosystems and Environment, (49): 299–307.

Zewdu A. (2003). Community-based forage development program: the experiences of FARM Africa Goat Project in Ethiopia. Tropical Grasslands 37: 257–261.

10.2 List of publications produced by project

Journal articles

1.Toib A A, Muthuri C.W, Gebrekirstos A, Hadgu K, Njoroge J, Sinclair F and Fetene M. 2021. To prune or not to prune Faidherbia albida: competing needs for water, wheat and tree products in semi-arid Ethiopia. Agroforestry systems. https://doi.org/10.1007/s10457-021-00675-x

2. Buyinza J, Nuberg I.K, Muthuri C.W, Denton M.D. 2021. Farmers Knowledge and Perceptions of Management and the Impact of Trees on-Farm in the Mt.Elgon Region of Uganda. Small-scale Forestry. DOI: 10.1007/s11842-021-09488-3

3. Buyinza J. Nuberg I.K, Muthuri C.W, Denton M.D. 2020. Assessing smallholder farmers' motivation to adopt agroforestry using a multi-group structural equation modelling approach. Agroforestry Systems 94: 2199-2211 https://doi.org/10.1007/s10457-020-00541-2

4. Buyinza J, Nuberg I.K, Muthuri C.W, Denton M.D. 2020. Psychological Factors Influencing Farmers' Intention to Adopt Agroforestry: A Structural Equation Modeling Approach. Journal of Sustainable Forestry 39: 854-865. https://doi.org/10.1080/10549811.2020.1738948

5. Buyinza, J., Muthuri, C., Downey, A., Njoroge, J., Denton, M., & Nuberg, I. (2019). Contrasting water use patterns of two important agroforestry tree species in the Mt. Elgon region of Uganda. Australian Journal of Forestry. https://doi.org/10.1080/00049158.2018.1547944

6.Cyamweshi A.R, Kuyah S, Mukurulinda A, Muthuri C.W. 2021. Potential of Alnus acuminata based agroforestry for carbon sequestration and other ecosystem services in Rwanda. Agroforestry Systems 95: 1125-1135. https://doi.org/10.1007/s10457-021-00619-5

7. Derero A, Coe R, Muthuri C, Hadgu K.M, Sinclair F. 2020. Farmer-led approaches to increasing tree diversity in fields and farmed landscapes in Ethiopia. Agroforestry Systems. https://doi.org/10.1007/s10457-020-00520-7

8. Dilla, A. M., Smethurst, P. J., Huth, N. I., & Barry, K. M. (2020). Plot-Scale Agroforestry Modeling Explores Tree Pruning and Fertilizer Interactions for Maize Production in a Faidherbia Parkland. Forests, 11(11), 1175. https://doi.org/10.3390/f11111175

9. Dilla A.M, Smethurst P. J, Barry K, Parsons D, Denboba M. A.2019.Tree pruning, zone and fertiliser interactions determine maize productivity in the Faidherbia albida (Delile) A.Chev parkland agroforestry system in Ethiopia. Agroforestry Systems 93:1897-1907. https://doi.org/10.1007/s10457-018-0304-9

10. Dilla, A.M., Smethurst, P.J., Barry, K., and Parsons, D. (2019). Preliminary estimate of carbon sequestration potential of Faidherbia albida (Delile) A.Chev in an agroforestry parkland in the Central Rift Valley of Ethiopia. Forests, Trees and Livelihoods. https://doi.org/10.1080/14728028.2018.1564146

11. Dilla, A., Smethurst, P.J., Parsons, D., Barry, K., and Denboba, M. (2018). Potential of the APSIM model to simulate impacts of shading on maize productivity. Agroforestry Systems, 92(6), 1699-1709. https://doi.org/10.1007/s10457-017-0119-0

12. Dilla, A.M., Smethurst, P.J., Barry, K., Parsons, D., and Denboba, M.A., (2018). Tree pruning, zone and fertiliser interactions determine maize productivity in the Faidherbia albida (Delile) A.Chev parkland agroforestry system of Ethiopia. Agroforestry Systems. https://doi.org/10.1007/s10457-018-0304-9

13. Kuria, A., Barrios, E., Pagella, T., Muthuri, C., Mukuralinda, A., and Sinclair, F. (2019). Farmers' knowledge of soil quality indicators along a land degradation gradient in Rwanda. Geoderma Regional. https://doi.org/10.1016/j.geodrs.2018.e0019

14. Njoroge M. Julius, Muthuri W. Catherine, Kuyah Shem, Nyaga John & Sinclair Fergus (2019): Rainfall variability, soil heterogeneity, and role of trees in influencing maize productivity—the case from an on-station agroforestry experiment in semi-arid Kenya, Forests, Trees and Livelihoods. https://doi.org/10.1080/14728028.2019.1685410

15. Smethurst, P.J., Huth, N.I., Masikati, P., Sileshi, G.W., Akinnifesi, F.K., Wilson, J., and Sinclair, F. (2017). Accurate crop yield predictions from modelling tree-crop interactions in gliricidia-maize agroforestry. Agricultural Systems 155:70-7. http://dx.doi.org/10.1016/j.agsy.2017.04.008

16. Tadesse S, Gegretsadik W, Muthuri C, Derero A, Hadgu K, Said H, Dilla A. 2021. Crop productivity and tree growth in intercropped agroforestry systems in semi-arid and sub-humid regions of Ethiopia. Agroforestry Systems 95:487-498. https://doi.org/10.1007/s10457-021-00596-9

Journal articles submitted

1. Solomon, K.F, Hadgu, K.M., Wolde-meskel, E., Bourne, M., Birhane, E., Said, H., Mowo, G.J., Muthuri, C., Georgis, K., Haile, M., Aklilu, N. Locally Adaptive, Low Cost and Sustainable Grazing Options: Accelerating Adoption and Scaling of Agroforestry Practices in Ethiopia. Agroforestry systems

2. Awol Asefa Toib, Catherine Muthuri, Aster G.Kirstos, Kiros Hadgu, Masresha Fetene. 2020. Faidherbia albida improves underneath microclimate and soil chemical nutrients properties in Ejerssa Joro, Ethiopia. *Agroforestry systems*

3. Gebremariam Yaebiyo, Emiru Birhane, Tewodros Tadesse, Solomon Kiros, Kiros Meles Hadgu, 2020. Evaluation of woody species composition and regeneration in controlled and free grazing users for scaling up of agroforestry in the highlands of Northern Ethiopia.

4. Girmay Gebru, Gebrekiros Gebremedhin, Philip Smethurst, Emiru Birhane, Kiros Hadgu, Araya Alemie, 2020. Response of four tree species to fertilizer, watering and weeding regimes in the sub humid conditions of west Oromia, Ethiopia.

5. Charles Galabuzi, Hillary Agaba, Prossy. Isubikalu Clement Akias Okia, Judith Odoul, Catherine Muthuri. Factors affecting adoption and diffusion of agroforestry by women and youths in Mt. Elgon region, Uganda. *Agroforestry Systems*

6. Charles Galabuzi, Hillary Agaba, Sammy Carsan, Clement Akias Okia, Catherine Muthuri. Strategies for enhancing production and management of tree germplasm in Mt. Elgon region, Uganda. *Journal of Forestry Research*

Thesis/Dissertations

1. Awol, Assefa Toib. 'Ecophysiology of Faidherbia albida; effect of pruning on tree water relations, cambium dynamics and understorey wheat productivity in Ejerssa Joro, Ethiopia'. PhD Dissertation

2. Kinuthia, Ruth. 'Farmers perceptions and adoption of micro catchments for establishment of agroforestry trees in East Shewa zone, Ethiopia.' Master's Thesis

3. Aynalem, Dilla. 'Agricultural productivity and carbon sequestration potential of a Faidherbia albida parkland agroforestry system in the Central Rift Valley of Ethiopia'. PhD Thesis

4. Rebecca Joy Gent. 'Women's Participation Through Tree Nursery Value Chains in Rwanda'. Master's thesis

5. Mutamba, Angella. 'Competitiveness of tree tomato value chain in Rwanda, case study of Bugesera and Nyabihu districts'.

Posters presented at 4th World Congress on Agroforestry (WCA) in Montpellier, France

Abstracts available under WCA's ***Book of Abstracts***

1. Assefa, A., Muthuri, C., Gebrekirstos, A., Hadgu, K and Fetene, M. (2019, May). Pollarding Faidherbia albida tree reduces the complementarities benefit of underneath wheat productivity in Mojo, Ethiopia. Poster presented at the 4th World Congress on Agroforestry, Montepellier, France. Book of abstracts pp 675.

2. Buyinza J., Muthuri C., Downey A., Njoroge J., Denton M., Nuberg I. (2019, May). Contrasting water use patterns of two agroforestry tree species in Mt. Elgon region of Uganda: Implication on management. Poster presented at the 4th World Congress on Agroforestry, Montepellier, France. Book of abstracts pp 727.

3. Cyamweshi R.A., Muthuri W.C., Mukuralinda A., and Kuyah S. (2019, May). Alnus acuminata: an effective fertilizer tree for smallholder farmers in sub-humid regions of Rwanda. Poster presented at the 4th World Congress on Agroforestry, Montepellier, France. Book of abstracts pp 345.

4. Derero, A., Muthuri, C., Coe, R., and Sinclair, F. (2019, May). Farmers seek high tree diversity in the semi-arid and sub-humid areas of Ethiopia. Poster Presented at the 4th World Congress on Agroforestry, Montepellier, France. Book of abstracts pp 264.

5. Dilla A., Smethurst P., Barry K., Parsons D., Denboba M. (2019, May). Faidherbia albida improves maize productivity and carbon sequestration in a parkland agroforestry system in Ethiopia. Poster presented at the 4th World Congress on Agroforestry, Montepellier, France. Book of abstracts pp 664.

https://collaboratif.cirad.fr/alfresco/s/d/workspace/SpacesStore/749ecda5-317d-4635-b5f1- a9635caa78f8/L18.P.10_DILLA%20Aynalem.pdf

6. Fantaye, S.K., Hadgu, K.M., Birhane, E., Haile, M., Muthuri, C., Mowo, G.J., Georgis, K., Negussie, A. (2019, May). Sustainable grazing options for enhancing accelerated scaling ups and impacts of agroforestry innovations in Ethiopia

Poster presented at the ACIAR side event during the WCA in Montpellier, France

1. Galabuzi, C., H. Agaba., J. Buyinza., J. Sekatuba., P. Isubikalu., I. Sekitto., G. Werikhe., S. Michael., C. Okia., G. Kimenya., I. Wanambwa., & C. Muthuri. (2019c). Implementing the ACIAR Trees for Food Security-2Project: Our Observations, Experiences and Lessons from Uganda.

Abstracts for conference presentation

1. Joel Buyinza, Catherine W. Muthuri, Ian K. Nuberg and Matthew D. Denton, 2020. Impact of tree management on water use and crop productivity of smallholder agroforestry systems. Abstract submitted to NARO-MAKERERE Conference Sub-theme 3: Intensification of Crop Productivity and Seed Systems https://drive.google.com/file/d/1sRRTMM_YTyRdy6QunRXpLpwLgsqIEJNR/view?usp=sharin g

2. Joel Buyinza, Catherine W. Muthuri, Ian K. Nuberg and Matthew D. Denton, Hillary Agaba, Clement Okia, Charles Galabuzi, Geofrey Kimenya, Ivan Wanambwa and Kenneth Eryau, 2020. Sapflow technology for monitoring agroforestry tree water use transforming management of smallholder farming systems in Uganda. Abstract submitted to NARO-MAKERERE Conference Sub-theme 6: Embracing ICT-based Innovations for Agricultural Transformation https://drive.google.com/file/d/1sRRTMM_YTyRdy6QunRXpLpwLgsqIEJNR/view?usp=sharing

3. Charles Galabuzi, Hillary Agaba, Gerald Eilu. 2020. Farmers' Philosophy, Socio-economic and Political stakes: What stimulates adoption of Prunus africana on-farms in Central Uganda? Abstract submitted for FTA Science Conference 2020. https://drive.google.com/file/d/15EZow09ahIF8G7i4krshJnryYtHBTYiz/view?usp=sharing

4. Charles Galabuzi, Hillary Agaba, Jude Sekatuba, Geoffrey Werikhe, Immaculate Sekitto, Sammy Carsan Clement Okia, Catherine Muthuri, 2020. Strategies for enhancing effective production and distribution of quality tree germplasm in Mt. Elgon region of Uganda. Abstract submitted for FTA Science Conference 2020 https://drive.google.com/file/d/1bArTzycxCiqbgMIq8NzdhIcpMV3gsPp/view?usp=sharing

5. Charles Galabuzi, Hillary Agaba, Jude Sekatuba, Geoffrey Werikhe, Immaculate Sekitto, Sammy Carsan, Clement Okia, Catherine Muthuri, 2020. Factors affecting adoption and diffusion of Agroforestry by smallholders in the Mt. Elgon Region of Uganda. Abstract submitted for FTA Science Conference 2020

https://drive.google.com/file/d/1IABoADhYXn05-Ij8ws16cuA8udsLzW14/view?usp=sharing

6. Muthuri C, Mukuralinda A, Galabuzi C, Gebretsadik W, Okia C, Ndayambaje J, Hadgu K, Sinclair F. 2020. Trees for Food Security: How is it Stacking up in Eastern Africa? TropAg Conference 2019. Session, Farming system intensification for small holders. https://drive.google.com/file/d/1C7chS2OBf0b3HSHhfNeN9kfGft7aqnGl/view?usp=sharing

Technical/Study/ Training Reports

1. Birhane, E., Muruts, H., Birhan, A., Haile, M., and Kasolo, W. (2018c). Proceedings of a validation workshop on the status of agroforestry curricula and extension training of Tertiary and TVET institutions in Ethiopia, 23pp. (WP 5)

2. Birhane, E., Muruts, H., Gebrelibanos, T., and Kasolo, W. (2018a). Assessment of the status of agroforestry curricula of Tertiary and TVET Institutions in Ethiopia, 36pp. (WP 5).

3. Birhane, E., Muruts, H., Gebrelibanos, T., and Kasolo, W. (2018b). Assessment on the status of Extension training in Tertiary and TVET Institutions in Ethiopia, 20pp. (WP 5).

4. Bucagu, C., F. Niyitanga, C.P. Mugunga, A. Mukuralinda, W. Kasolo, and C. Muthuri (2018a). Assessment of status of agroforestry Curricula of Tertiary and TVET Institutions in Rwanda extension curricula Rwanda WP 5, 32pp (WP 5).

5. Bucagu, C., F. Niyitanga, C.P. Mugunga, A. Mukuralinda, W. Kasolo, and C. Muthuri (2018b). Status of Agroforestry extension training in Rwanda WP 5, 32pp (WP 5).

6. Cyamweshi, R., A. Mukuralinda, J.D. Ndayambaje, P. Mujawamariya, C. Muthuri and S. Kuyah. 2018. Reconciling crop production with tree management: overview of research conducted in Agroforestry long term trials in Rwanda. Report (WP 1)

7. Eryau, K., C Galabuzi, J. Ssekatuba, S. Nansereko, B. Fungo, C. Okia, M. Sunday H. Agaba, G. Kimenya, P. Isubikalu, I. Sekitto G. Werikhe & C. Muthuri. (2019). Empowering women and youth in agroforestry for increased soil productivity and food security. Proceedings of the second ToT workshop, Uganda. 49pp.

8. Fungo, B., Galabuzi, C., Kimenya, G and Nankya, E. (2018). Soil profile description in a site with a long-term trial in Bugunyanya ZARDI Uganda, 4pp (WP 1).

9. Fungo, B. (2018). Institutional arrangements for scaling-up agroforestry in Eastern Uganda Report

10. Galabuzi, C., Kimenya, G., Wanambwa, I., Werikhe, G., Alinyo, F., Sekatuba, J., Okia C., and Agaba, H. (2019a). Uganda Long-term and Participatory trials progress report, 10pp (WP 1).

11. Galabuzi, C., M. Uwimbabazi, D. Wabwire, J.B. Odoi, , R. Akellem, A. Ntakimanye, I. Sekitto, G. Werikhe, C. Muthuri, S. Micheal, F. Alinyo & H. Agaba. (2019b). Strategies for enhancing effective production and distribution of quality tree germplasm in Mt. Elgon region, Eastern Uganda. National Forestry Resources Research Institute, Kamplala, Uganda. 42pp. (WP 3)

12. Gebretsadik, W., Tadese, S., Asefa, A., Muthuri, C., Derero, A., Meles, K., and Seid, H. (2019a) Ethiopia Progress- Participatory trials and Long term Trials, 19pp (WP1).

13. Gebretsadik, W., Muthuri, C., Seid, H., Tadese, S., Nyaga, J., Asefa, A., Girmay, A., Kuria, A., Kinuthia, R., and Hadgu, K. (2019b) Participatory trials and progress report 19pp (WP1).

14. Isubikalu, P. (2018a). Agroforestry Curriculum Review in Uganda, 36pp (WP 5).

15. Isubikalu, P. (2018b) Assessing Agroforestry curricula and extension training in Tertiary Agricultural Education Institutions in Uganda- Focus on extension, 33pp (WP 5).

16. Isubikalu, P. (2018c) National curriculum assessment Validation workshop report in Uganda, 44pp (WP 5).

17. Isubikalu, P. (2018f) Report On-Farm trials established Uganda, 11pp (WP 1)

18. Isubikalu, P. Tuhaise, I., and Kimenya, G. (2018d). Training and motivation of women and young farmer trainers on agroforestry practices, 15pp, (WP 3).

19. Isubikalu, P., S. Kizito, I. Tuhaise and G. Kimenya (2018e). The potential of tree value chains to be promoted among communities in Bugisu Region, through Farmer Business School Uganda, 6pp (WP 4)

20. Kinuthia, R., Nyaga, J., and Kuria, A. (2017). ODK training report Ethiopia. EEFRI Addis Ababa, Ethiopia, 11pp (WP 1).

21. Kiros, S., Hadgu, K. M., Hagazi, N., Haile, M., and Muthuri, C. (2017b). Concept note-Exploring options on legal recognition and enforcement of grazing bylaws, 3pp (WP2).

22. Kiros, S., Hadgu, K. M., Hagazi, N., Haile, M., and Muthuri, C. (2018a). Terms of Reference (TOR) for establishment of sustainable grazing platform in Tigray, 13pp (WP 2).

23. Kiros, S., Hadgu, K. M., Hagazi, N., Haile, M., Muthuri, C. and Mowo, J. (2017a). Sustainable Grazing Strategy Options for Ethiopia, 45pp (WP 2).

24. Kung'u J., Kasolo, W., Muchiri, B (2019). Proceedings of a Curriculum Guide Development Regional Workshop for Agroforestry Education in Tertiary Institutions. Kenyatta University Nairobi, Kenya. 63pp (WP 5).

25. Kung'u J. B., Kasolo W., Muthuri C., and Muchiri B. (2019). Facilitating the up scaling of Agroforestry adoption and innovation in East Africa: A curriculum guide for tertiary education institutions (WP 5).

26. Kuria, A., Nyaga, J., and Kinuthia, R. (2017). Rwanda ODK Training Report La Palme Hotel, Musanze, Rwanda, 19pp (WP 1).

27. Mawia, H., Oduol, J., Kinuthia, R., Seid, H., Shiferaw, T., and Muthuri, C. (2018). Assessment of Fruit tree value chains in Ethiopia, 54pp (WP 4)

28. Mugambi, J., Kinuthia, R., & Oduol, J. (2020). Report on farmers Focus Group Discussions (FGDs) carried out in Bugesera, Nyabihu and Rubavu districts, Rwanda.

29. Mugunga, C. (2018). Curriculum validation workshop in Rwanda, 8 pp (WP 5)

30. Mukuralinda, A., Ndayambaje, J.D., Nyaga, John, Bambe, C., Mujawamariya, P., Senzoga, A., Nyiraneza, C., Gakwavu, T., and Muthuri, C. (2019a). Farmer participatory trials in Rwanda, 14pp (WP 1).

31. Ntakimanye, A. (2017). Stakeholder analysis Tree germplasm exchange in sub-humid highlands of Eastern Uganda, 37pp (WP 3).

32. Ntakimanye, A., and Namuyanja, V.M. (2018). Assessing financial options to support Tree planting and commercial nurseries' development for processing and distribution of tree products in Eastern Uganda, 42pp (WP 4).

33. Ntakimanye, A., Galabuzi, C., Kimenya, G., Wanambwa, I., Werikhe, G., Sekatuba, S., Kisseka, R., Odoi, J.B., and Agaba, H. (2018). Stakeholder Training workshop proceedings

on Sourcing quality tree germplasm, disease and pest management in tree nurseries of eastern Uganda, 24pp (WP 3).

34. Ntakimanye, A., Galabuzi, C., Kwaga, P., Werikhe, G., Sekitto, I., Wanambwa, I., Kimenya, G., Agaba, H., and Muthuri, C. (2019). Factors Affecting Adoption of Agroforestry Technologies by Women and Young Farmers in the Mt. Elgon Region, Eastern Uganda. Research report, 40pp.

35. Nyaga, J. and Kalanzi, F. (2017). ODK training in Uganda report, 11pp (WP 1).

36. Nyaga, J. and Njoroge J. (2018). Sap flow meters installation and ODK training report, Addis Ababa, Melkassa, Ethiopia 19pp (WP 1).

37. Nyaga, J., et al 2018. Report on Data collection status and initial household characteristics for Ethiopia, Rwanda and Uganda.

38. Nyolei, D., Malesu, M., and Oduor, A. (2018a). Geospatial Assessment of Land and Water Management Options for Enhanced Tree Survival & Growth in T4FS Project sites in Rwanda, 130pp.

39. Nyolei, D., Malesu, M., and Oduor, A. (2018b). Geospatial Assessment of Land and Water Management Options for Enhanced Tree Survival & Growth in T4FS Project sites in Ethiopia, 35pp.

40. Nyolei, D., Malesu, M., and Oduor, A. (2018c). Geospatial Assessment of Land and Water Management Options for Enhanced Tree Survival & Growth in T4FS Project sites in Uganda, 76pp.

41. Oduol 2020 Impact assessment study in Rwanda- Summary of findings 5pp.

42. Oduol, J., Mawia, H., Kinuthia, R., and Muthuri, C. (2019). Systematic review on financing options for fruit trees in Ethiopia, Uganda and Rwanda (WP 4).

43. Sekatuba, J., Nansereko, S., Kwaga, P., Sekitto, I., Werikhe, G., Okia, C., Wabwire, D., Galabuzi, C., Kimenya, G., Mudondo, S., Galabuzi, C., Agaba, H., & Odoul, J. (2019). Contests, prospects and strategies for enhancing performance of avocado and timber value chains in Mt. Elgon region, Uganda, 43pp.

44. Sekatuba, J., C. Galabuzi, C. Okia and H. Agaba (2018). Training of Trainers workshop on Appropriate Water Management Technologies to Support Tree Establishment and Growth Program, 28pp (WP 2).

45. Smethurst, P. (2019) 2019 Modelling summary results for Ethiopia, Rwanda and Uganda. (WP 1)

46. Uwimbabazi, M., Ntakimanye, A. and Galabuzi, C. (2018). Training of Trainers on Empowerment of women and youth in agroforestry, gender analysis and strategies that foster collective action. 27pp (WP 3)

47. Wamala, P., Okia C., and Buyinza, J. (2017). Proceedings of the Uganda 4th National Agroforestry Conference. Scaling up Agroforestry impacts through Policy, Innovations and Partnerships. Kampala, Uganda, 59pp (WP 3)

48. Oduol, J. 2018a. Guidelines for the formation of farmer business schools in Uganda

49. Oduol, J. 2018b. Guidelines for the formation of farmer business schools in Ethiopia

50. Oduol, J. 2018c. Guidelines for the formation of farmer business schools in Rwanda

Project progress and meetings/workshops

1. Kalanzi, F., Buyanza, Sekatuba, J., Kimenya, G., Isubikalu, P., Okia, C., and Muthuri, C. (2017). Uganda T4FS-2 project Inception Workshop proceedings, Imperial Resort Beach Hotel, Entebbe, Uganda. February 2017, 67pp.

2. Kinuthia, R., Muthuri, C., Ndayambaje, J., Gebretsadik, W., Galabuzi, C., Mukuralinda, A., Hadgu, K., Okia, C., Nyaga, J., et al 2019. Proceedings of the Developing integrated options and accelerating scaling up of agroforestry for improved food security and resilient livelihoods in Eastern Africa - Trees for Food Security – 2 project steering committee meeting held on 7 November 2019, ICRAF, Nairobi Kenya. 55pp.

3. Kinuthia, R., A. Kuria, J. Nyaga, F. Kalanzi, C. Muthuri (2017). T4FS-2 Project Steering Committee Meeting Proceedings, World Agroforestry Center, Nairobi, Kenya, 48pp.

4. Kinuthia, R., A. Kuria, J. Nyaga, F. Kalanzi, C. Muthuri (2017). T4FS-2 Project Steering Committee Meeting Proceedings, World Agroforestry Center, Nairobi, Kenya, 48pp.

5. Kinuthia, R., D. Ndayambaje, A. Mukularinda and C. Muthuri (2017). Rwanda T4FS-2 project Inception Workshop Proceedings, Umubano Hotel, Kigali Rwanda, February 2017, 62pp

6. Mujawamariya, P., E. Ntawuhiganayo, A. Mukuralinda, J. Damascene, J. Njoroge, C. Muthuri (2018). Steering Committee Meeting Proceedings, Kigali, Rwanda. October 2018, 37pp.

7. Nigussie, H., Kinuthia, R., Birhane, E., Seid, H., Hadgu, K, and Muthuri, C (2017). Ethiopia T4FS-2 Inception Workshop Proceedings, Addis Ababa, Ethiopia. February 2017, 48pp.

8. Njoki, C., Kinuthia, R., Muthuri C., et al 2020. Proceedings of the Developing integrated options and accelerating scaling up of agroforestry for improved food security and resilient livelihoods in Eastern Africa - Trees for Food Security – 2 project steering committee meeting held virtually on 21 October 2020.

Training Guides and Manuals

1. Kisekka, R., Odoi, J.B., Ntakimanye, A., Okia, C., Galabuzi C., and Agaba, H. (2018). Sourcing quality tree seed/germplasm, pests and disease management: A Training Manual 50pp. (WP 3)

2. Mukuralinda, A., Ntawuhiganayo, E., & Mujawamariya, P. 2018a. Training Manual Module 1 Agroforestry principles and systems and benefits, World Agroforestry, Rwanda 63pp (WP 3)

3. Mukuralinda, A., Ntawuhiganayo, E., & Mujawamariya, P. 2018b. Training Manual Module 1 Trees Nursery & Planting. World Agroforestry, Rwanda 63pp (WP 3)

4. Mukuralinda, A., Ntawuhiganayo, E., & Mujawamariya, P. 2018c. Training Manual Module 1 Tree Security and Maintenance. World Agroforestry, Rwanda 63pp (WP 3)

5. Mukuralinda, A., Ntawuhiganayo, E., & Mujawamariya, P. 2018d. Training Manual Module 1 Tree Products and services. World Agroforestry, Rwanda 63pp (WP 3)

Project key documents

1. APSIM Next Generation with, potato, and eucalyptus available at http:/www.apsim.info

2. Gathigo, M., Kinuthia, R., Muthuri, C. (2017). T4FS-2 Project Communication strategy

3. Muthuri et al, 2017 T4FS Project information factsheet

4. Muthuri et al, 2017 T4FS-2 ACIAR 2017 Semi Annual Report

5. Muthuri et al, 2019 Mid Term Review Report 2019. T4FS-2 Project

6. Muthuri et al, 2018 T4FS Project Information Factsheet- Annual report May 2017-June 2018

7. Muthuri et al, 2018, T4FS-2 ACIAR 2017-2018 Annual Report

8. Nyaga, J. (2017). ODK Training manual (WP 1)

9. Oduol, J., Kinuthia, R., and Muthuri, C (2017). T4FS-2 Project Monitoring and Evaluation Plan

10. Galabuzi, C., J. Ssekatuba, C. Okia, M. Sunday H. Agaba, G., Kimenya, P. Isubikalu, I. Sekitto G. Werikhe & C. Muthuri. (2019). Proceedings of the Mid-Term Review in Uganda, Trees for food security-2 project. 31pp.

11. Kinuthia, R., Mukuralinda, A., Ndayambaje, J.D., Ntawuhiganayo, E.B., Mujawamariya, P., Cyamweshi, A., Mugayi, A., Canisius, M., Gafaranga, J., & Muthuri, C. (2019). Proceedings of the Mid-Term Review in Rwanda, Trees for food security-2 project. 41pp.

12. Nyaga, J., Gebretsadik, W., Seid, H., Girmay, A., Tadesse, S., Kiros, S., Assefa, A., Birhane, E., Hadgu, K., & Muthuri, C. (2019). Proceedings of the Mid-Term Review in Rwanda, Trees for food security-2 project. 42pp.

Interactive Suitable Tree Species Selection and Management Tool

13. Kuria, Anne; Dawit, Samuel; Endale, Yemenzwork; Derero, Abayneh; Iiyama Miyuki; Muthuri, Catherine; Hadgu, Kiros ;Kinuthia, Ruth; Betemariam, Ermias; Asantewaa, M.; Muriuki, Jonathan ;Kindt, Roeland; Dedefo, Kassim; Senbeto, K; Njenga, Maureen; Lamond, G; Pagella, T; Sinclair, Fergus, 2018, "Interactive Suitable Tree Species Selection and Management Tool for East Africa- Ethiopia", https://doi.org/10.34725/DVN/ZTT9EF, World Agroforestry - Research Data Repository, V4

14. Kuria, Anne; Uwase, Yvonne; Mukularinda, Athanase; Iiyama, Miyuki; Twagirayezu, D; Njenga, Maureen; Muriuki, Jonathan; Mutaganda, Amini; Muthuri, Catherine; Kindt, Roeland; Betemariam, Ermias; Cronin, M; Kinuthia, Ruth; Migambi, Felix ;Lamond, G; Pagella, T; Sinclair, Fergus, 2018, "Interactive Suitable Tree Species Selection and Management Tool for East Africa- Rwanda", https://doi.org/10.34725/DVN/RLQV3H, World Agroforestry - Research Data Repository, V3

Project summary documents/ Magazines

1.Galabuzi et al, 2021. Trees for Food Security-2 Project: Uganda Highlights. Nairobi, Kenya. ICRAF

2.Gebretsadik et al, 2021. Trees for Food Security-2 Project: Ethiopia Highlights. Addis Ababa, Ethiopia. ICRAF

3. Muthuri et al, .2021. Trees for Food Security-2 Project: Overview and Achievements. Nairobi, Kenya. ICRAF

4. Ndayambaje et al. 2021. Trees for Food Security-2 Project: Rwanda Highlights. Nairobi, Kenya. ICRAF

5. Galabuzi et al. 2019. Trees for Food Security-2 Project: Overview in Uganda. ICRAF

6. Gebretsadik et al, 2019. Trees for Food Security-2 Project: Overview in Ethiopia. ICRAF

7. Muthuri et al, 2019. Trees for Food Security-2 Project: Overview and Progress. ICRAF

8. Ndayambaje et al, 2019. Trees for Food Security-2 Project: Overview in Rwanda. ICRAF

9. Ethiopia Brochure 2017

10. Rwanda Brochure 2017

11. Trees for Food Security-2 Project in Rwanda Magazine-2018

12. T4FS Overview Magazine-2018

13. Trees for Food Security Overview and Achievements-2017

14. Trees for Food Security: Transforming Lives and Landscapes in Uganda Brochure-2017

Videos

1.T4FS Rwanda https://www.youtube.com/watch?v=nA46C_1GvhM&t=4s

2.T4FS Project empowering women through Agroforestry https://www.youtube.com/watch?v=Pamgbg6IOYQ&t=1s

3.Trees for Food Security https://www.youtube.com/watch?v=XE2S6XGV8Pg&t=1s

Appendixes 1: Tree height and DBH with different intercropping at Bako long term trial

Tree type	Treatment	Tree Height (cm) (2017)		DBH (cm) (2017)		Tree Height (cm) (2018)		DBH (cm) (2018)	
		Mean	SE (+)	Mean	SE (+)	Mean	SE (+)	Mean	SE (+)
G. robusta	Grevillea /maize	397	30.34	6.00	0.47	546	33.15	8.00	0.63
	Grevillea /finger millet	368	32.33	5.78	0.38	562	22.41	10.06	1.00
	Grevillea /teff	234	25.84	4.37	0.58	360	35.20	5.36	0.89
	Mix of trees+crops	229	38.67	4.17	0.42	338	53.23	4.84	0.88
	Mix of trees	118	61.59	1.70	1.25	191	120.20	3.90	0.10
C. africana	Cordia/maize	294	21.51	5.60	0.50	352	26.27	5.77	0.67
	Cordia/finger millet	272	34.05	4.83	0.68	286	21.63	4.68	0.78
	Cordia/teff	320	33.91	5.08	0.47	390	29.09	6.74	0.78
	Mix of trees+crops	337	28.16	5.66	0.82	401	29.82	8.59	0.74
	Mix of trees	168	33.60	4.50	0.40	269	9.00	3.77	0.77
C.macrostachyus	Croton/maize	225	34.49	3.95	0.18	314	23.09	3.79	0.40
	Croton/finger millet	229	29.44	3.25	0.44	304	22.46	3.74	0.50
	Croton/teff	186	1.60	3.09	0.22	257	16.29	3.43	0.27
	Mix of trees+crops	213	37.62	3.70	0.36	321	28.78	4.10	0.04
	Mix of trees	137	30.33	0.97	0.13	181	10.67	1.37	0.03
A.abyssinica	Acacia/maize	219	17.37	3.81	0.53	282	22.80	4.19	0.67
	Acacia/finger millet	175	14.46	3.60	0.61	289	15.50	3.93	0.59
	Acacia/teff	206	19.31	3.89	0.35	290	19.99	3.98	0.43
	Mix of trees+crop	224	25.52	3.16	0.59	255	15.58	4.19	0.64
	Mix of trees	207	89.74	1.60	0.21	298	73.39	6.00	2.21

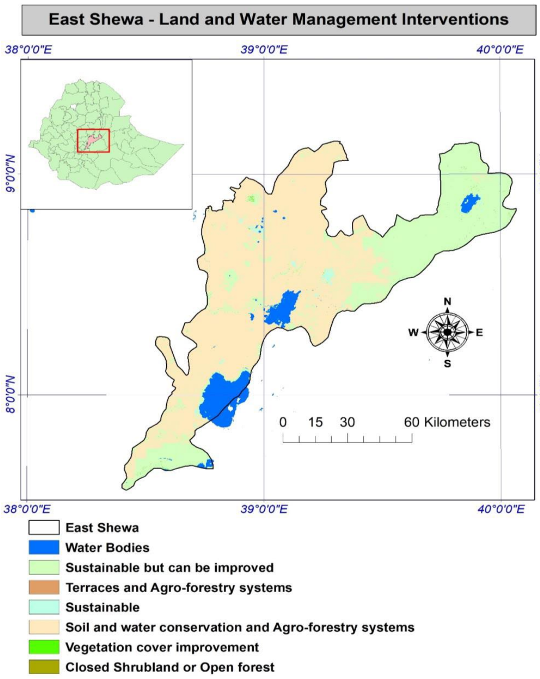
Appendixes 2: *Treatment effects on crop yield for 2017 and 2019 growing seasons in Bako long term trial.*

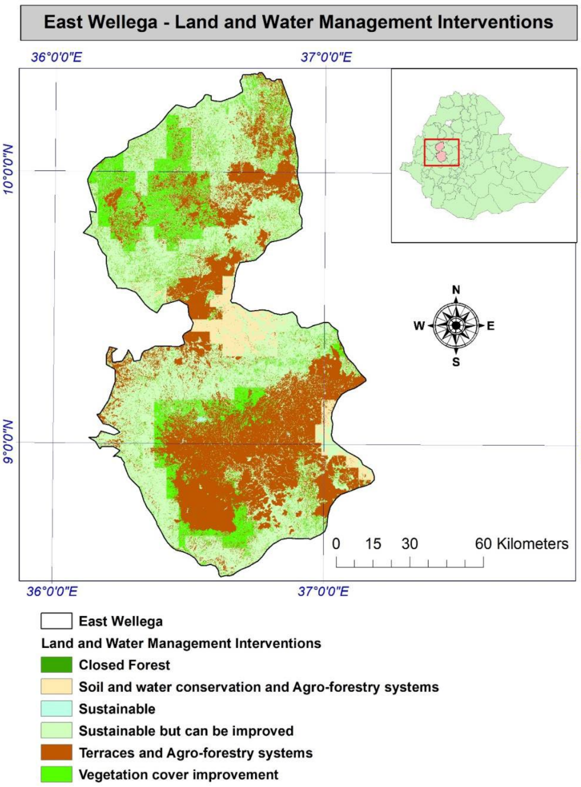
		Crop Yield (2017)			Crop Yield (2019)		
Crop type	Treatment	Std. Error	t value	Pr(>|t|)	Std. Error	t value	Pr(>|t|)
Maize	*Mix of trees- Sole*	93.16	0.62	0.99	150.89	1.77	0.49
	Grevillea- Sole	93.16	-2.16	0.27	150.89	-0.66	0.99
	Cordia- Sole	93.16	1.55	0.63	150.89	2.38	0.18
	Croton- Sole	93.16	1.46	0.69	150.89	2.59	0.11
	Acacia-Sole	93.16	-3.69	0.01 **	150.89	2.59	0.11
	Acacia- Mix of tees	71.45	-3.69	0.01 **	106.69	-6.17	0.00 ***
	Acacia- Grevillea	71.45	-3.06	1.01 **	106.69	-6.74	0.00 **
	Acacia- Cordia	71.45	-4.89	0.00 ***	106.69	-7.03	0.00 ***
	Acacia- Croton	71.45	-4.78	0.00 ***	106.69	-7.97	0.00 ***
Tef	*Mix of trees- Sole*	49.46	4.28	0.00 ***	44.40	2.60	0.11
	Grevillea- Sole	49.46	3.70	0.01 *	44.40	0.63	0.99
	Cordia- Sole	49.46	3.42	0.01 *	44.40	-2.28	0.21
	Croton- Sole	49.46	3.98	0.00 **	44.40	2.28	0.21
	Acacia-Sole	49.46	-0.07	1.00	44.40	-2.96	0.05 *
	Acacia-Mix of tees	34.97	-5.96	0.00 ***	31.39	-7.87	0.01***
	Acacia- Grevillea	34.97	-3.72	0.01 **	31.39	-5.08	0.00 ***
	Acacia- Cordia	34.97	-4.74	0.00 ***	31.39	-7.406	0.00 ***
	Acacia- Croton	34.97	-5.53	0.00 ***	31.39	-8.50	0.01 ***
F.millet	*Mix of trees- Sole*	77.49	1.22	0.82	104.55	0.52	0.99
	Grevillea- Sole	77.49	2.59	0.11	104.55	0.08	-1.00
	Cordia- Sole	77.49	1.37	0.74	104.55	1.91	-0.40
	Croton- Sole	77.49	1.82	0.46	104.55	0.39	-0.10
	Acacia-Sole	77.49	-4.20	0.00 **	104.55	-2.85	0.06
	Acacia- Mix of tees	54.79	-7.67	0.00 ***	77.93	-3.90	0.05 *
	Acacia- Grevillea	54.79	-9.62	0.00 ***	77.93	-3.70	0.01**
	Acacia- Cordia	54.79	-7.88	0.00 ***	77.93	-6.73	0.00***
	Acacia- Croton	54.79	-8.51	0.00 ***	77.93	-4.56	10.1 **

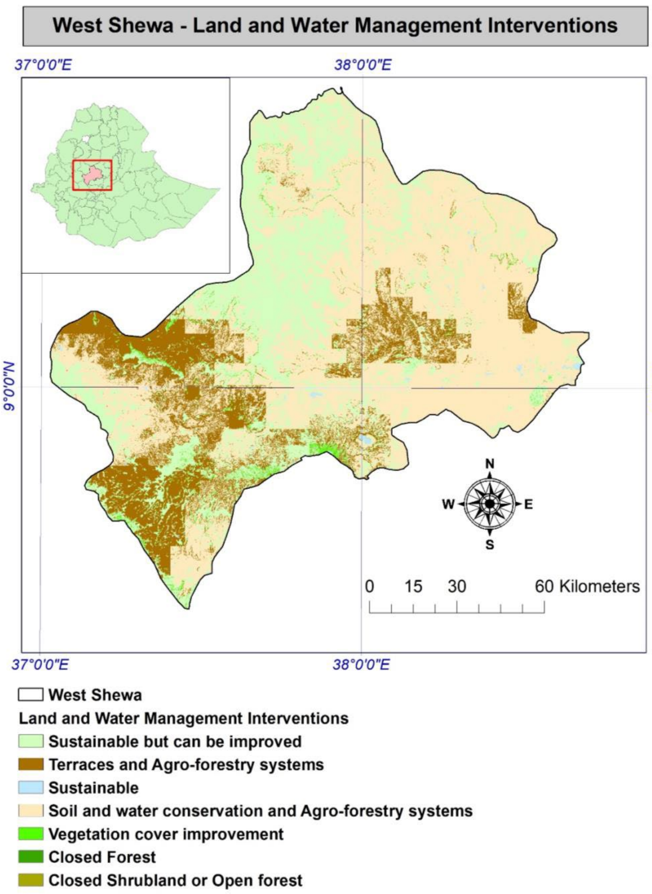
Appendix 3: Summary of the mean survival and mean height growth of tree seedlings in different sites

Fruit tree type	Zone	Study site	Mean survival%	Mean height growth (Cm)
Malus domestica	Eastern Tigray	Dimello	74	126
		Hadush hiwot	72	89
		Takot	80	87
Persea americana	East shoa	Abine germama	58	30
		Gerbi widena	89	43
		Edogojola	100	53
		Shubi gemo	73	80
		Jawi bofo	85	42
		Ejersa	34	53
	East Wellega	Gobo soyo	79	Not captured
Psidium guajava	East shoa	Bochesa	100	56
		Shubi gemo	100	31
	Eastern Tigray	Dimello	82	46
		Guila abnae	90	28
		Hadushiwot	85	29
		May megelta	100	32
		Takot	83	62
Careca papaya	Arsi	Bisholla	80	116
	East shoa	Abine germama	50	96
		Gerbi widena	50	49
		Jawi bofo	84	40
		Ejersa	33	66

Appendix 4: *Land and water management interventions for East Shewa, East Wellega and West Shewa in Ethiopia*

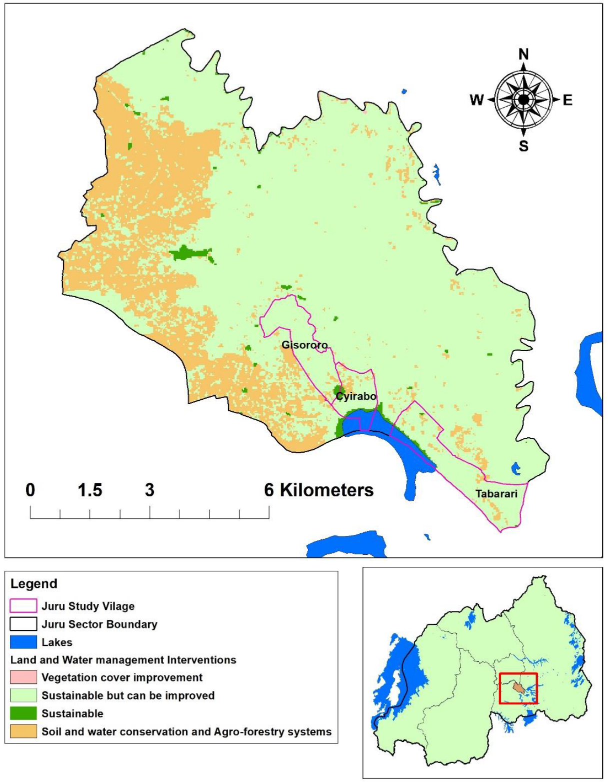




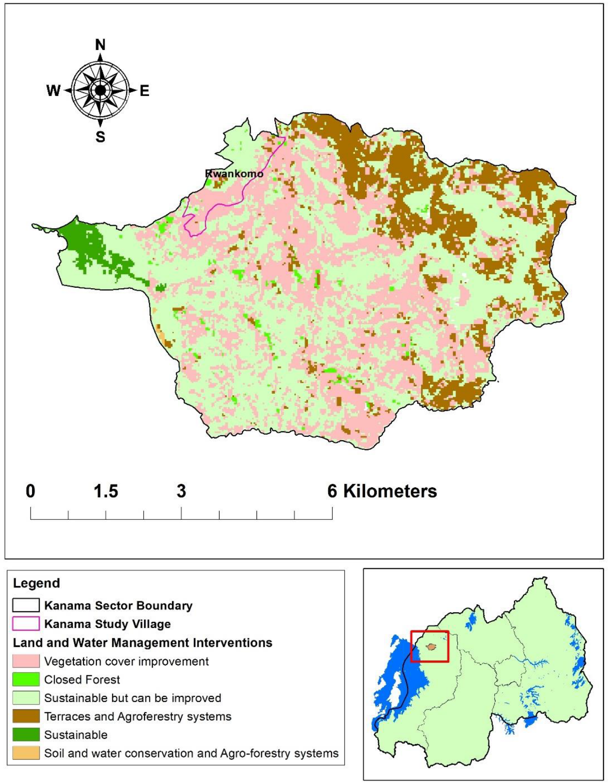


Appendix 5: Land and water management interventions for Rwanda

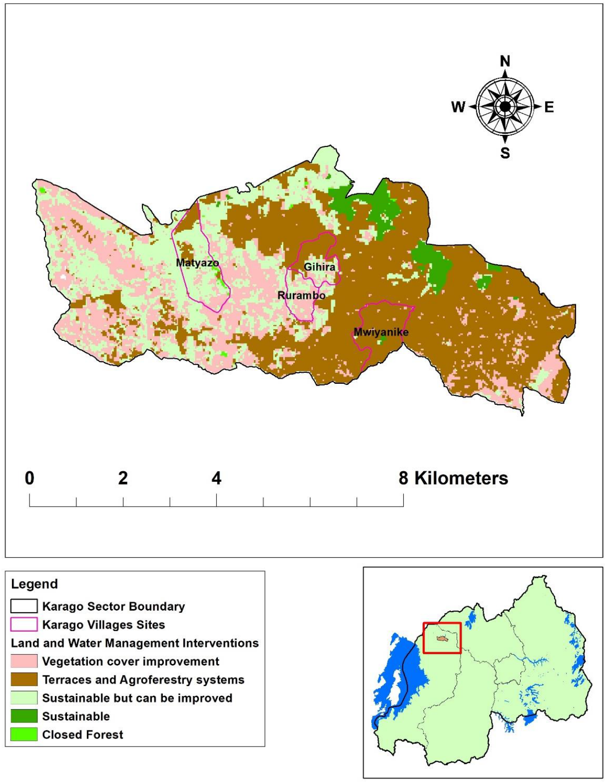
Juru Sector Land and Water Management Interventions



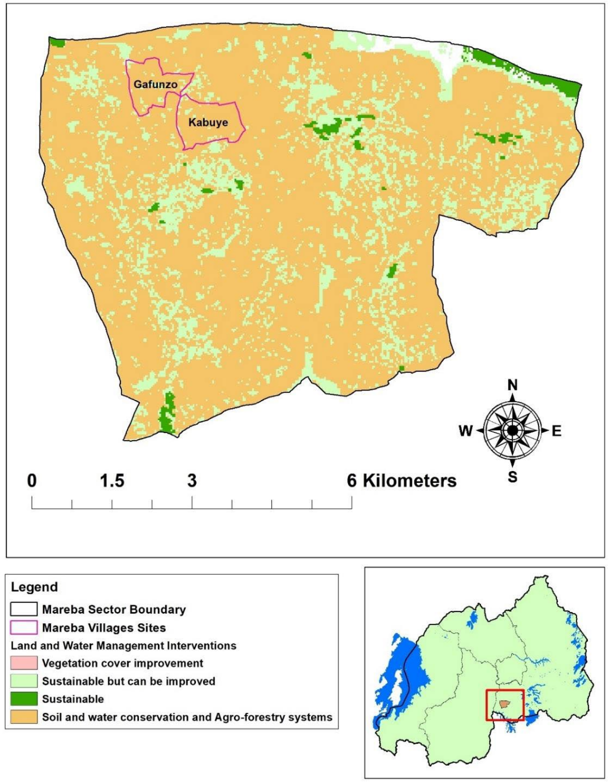
Kanama Sector Land and Water Management Interventions



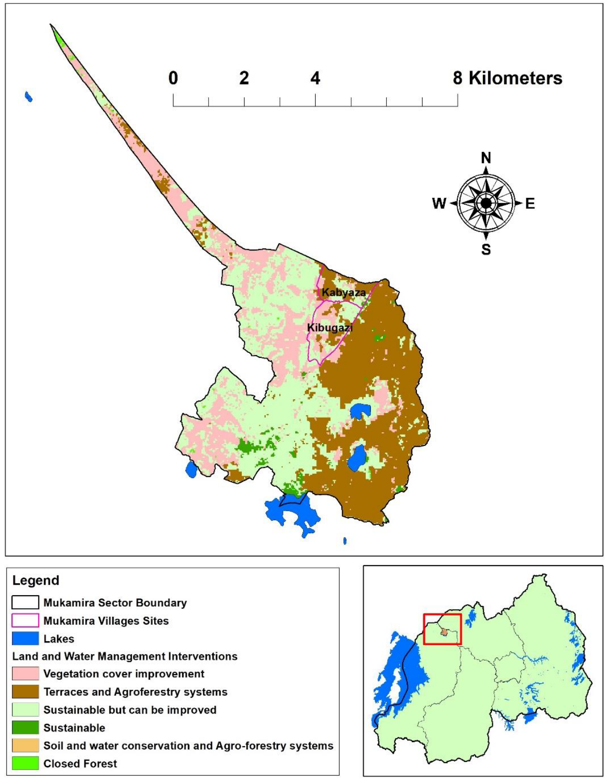
Karago Sector Land and Water Management Interventions



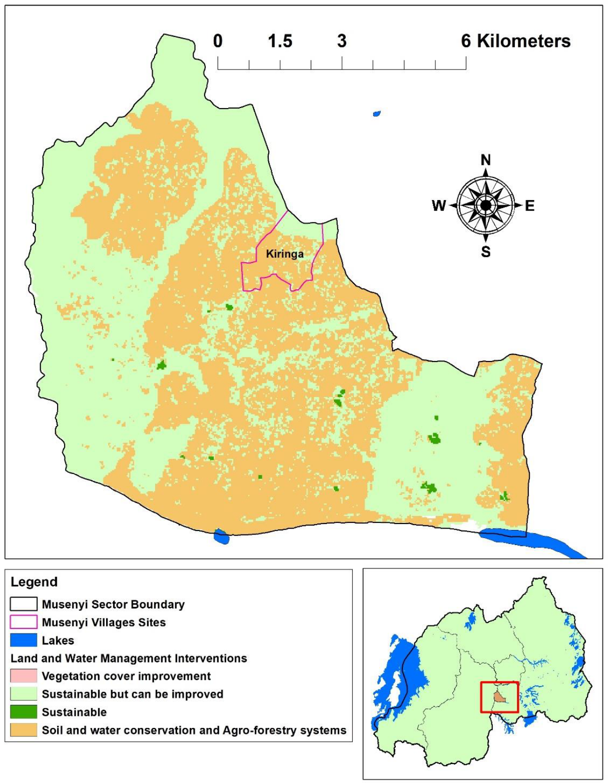
Mareba Sector Land and Water Management Interventions



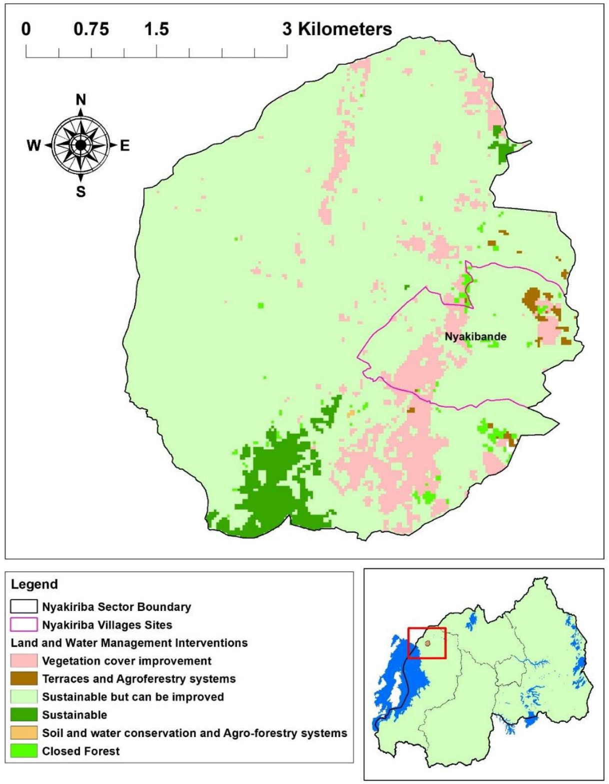
Mukamira Sector Land and Water Management Interventions



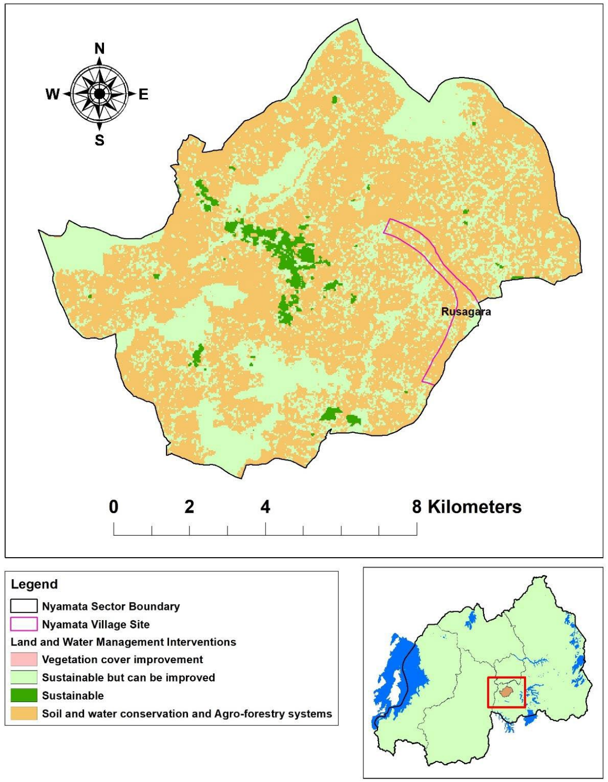
Musenyi Sector Land and Water Management Interventions

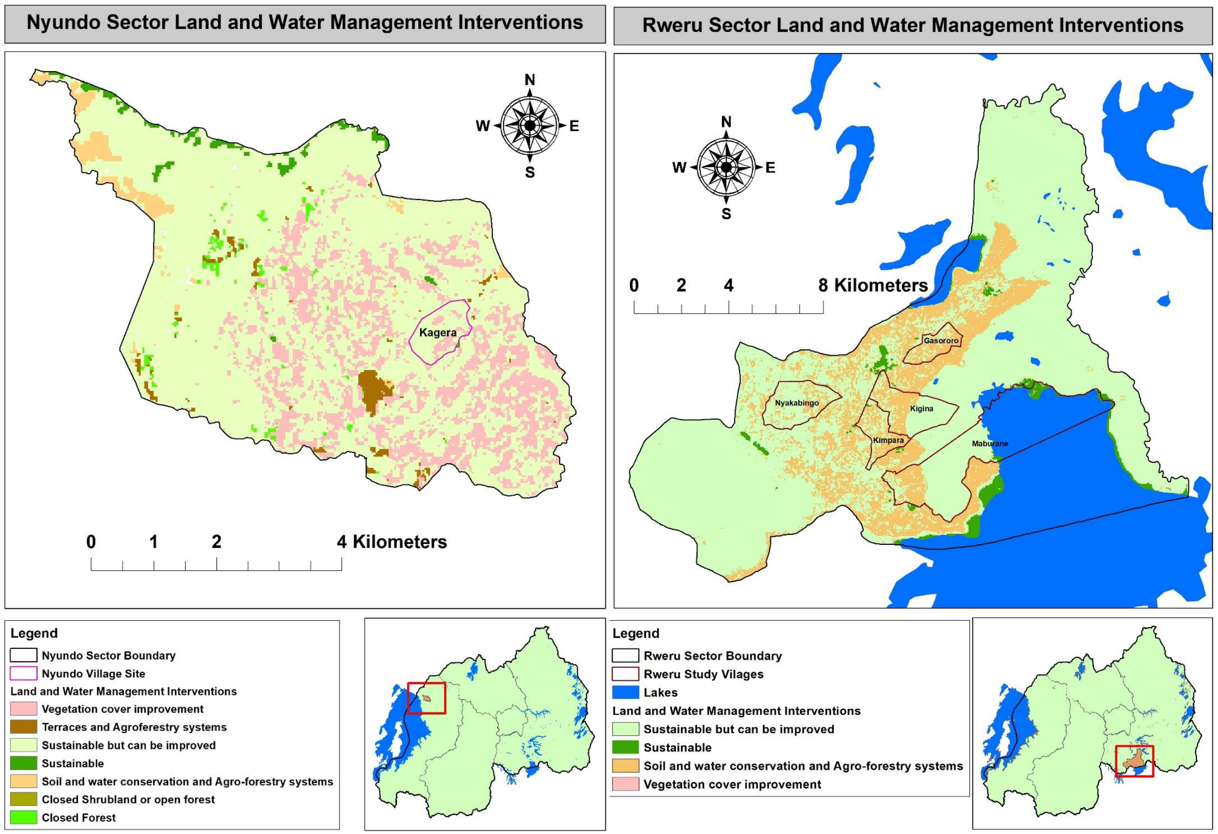


Nyakiriba Sector Land and Water Management Interventions



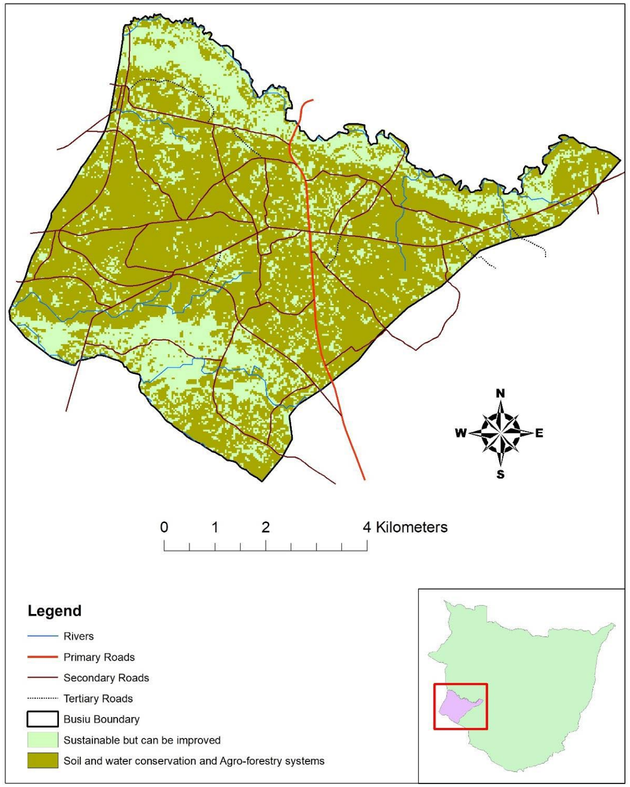
Nyamata Sector Land and Water Management Interventions



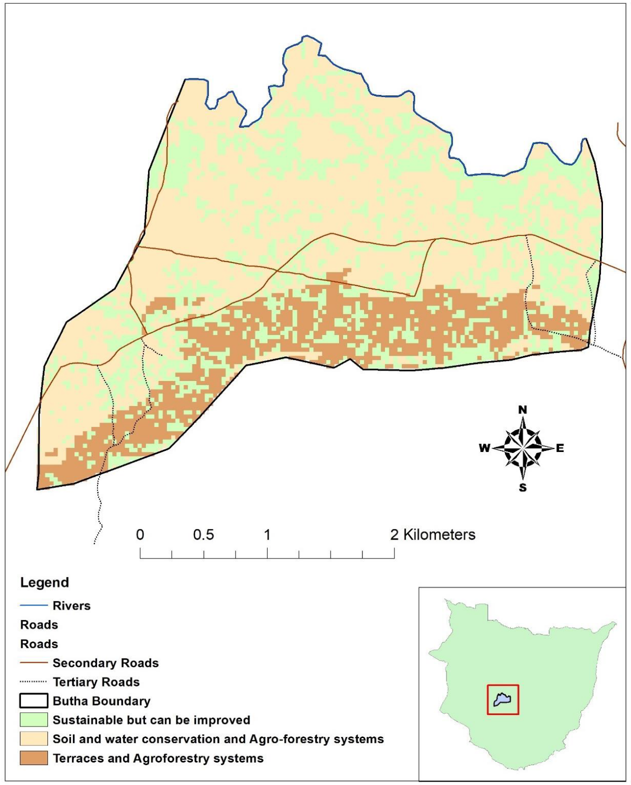

Nyundo Sector Land and Water Management Interventions
N
W
E
S
Kagera
0 1 2 4 Kilometers
Legend
Nyundo Sector Boundary
Nyundo Village Site
Land and Water Management Interventions
Vegetation cover improvement
Terraces and Agroforestry systems
Sustainable but can be improved
Sustainable
Soil and water conservation and Agro-forestry systems
Closed Shrubland or open forest
Closed Forest
Rweru Sector Land and Water Management Interventions
N
W
E
S
0 2 4 8 Kilometers
Gasororo
Nyakabingo
Kigina
Kimpara
Maburane
Legend
Rweru Sector Boundary
Rweru Study Vilages
Lakes
Land and Water Management Interventions
Sustainable but can be improved
Sustainable
Soil and water conservation and Agro-forestry systems
Vegetation cover improvement

Appendix 6: Land and water management interventions for Uganda

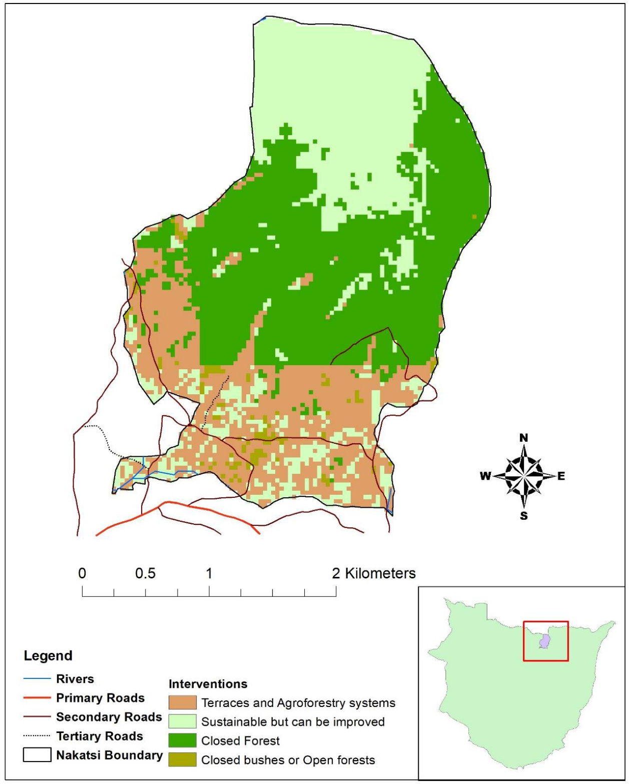
Busiu Land and Water Management Interventions



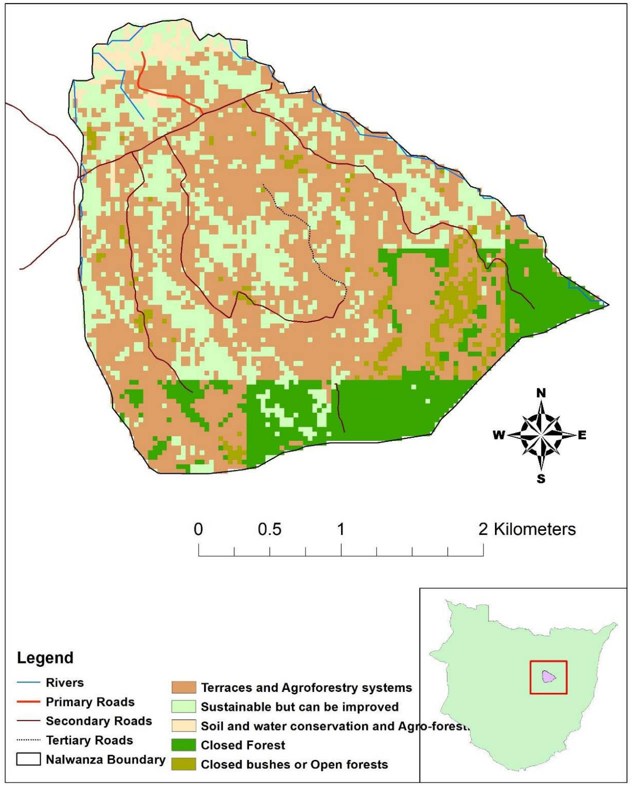
Butha Land and Water managament Interventions



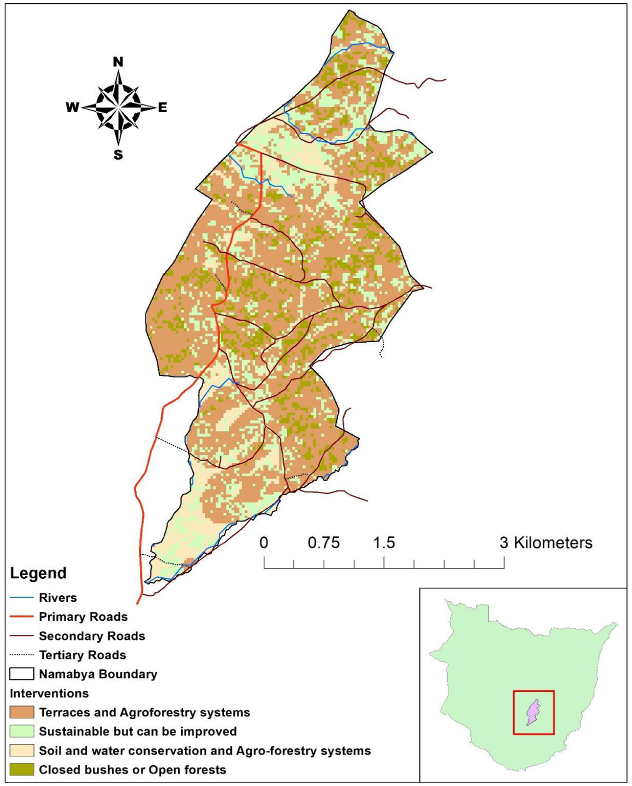
Nakatsi Land and Water Management Interventions



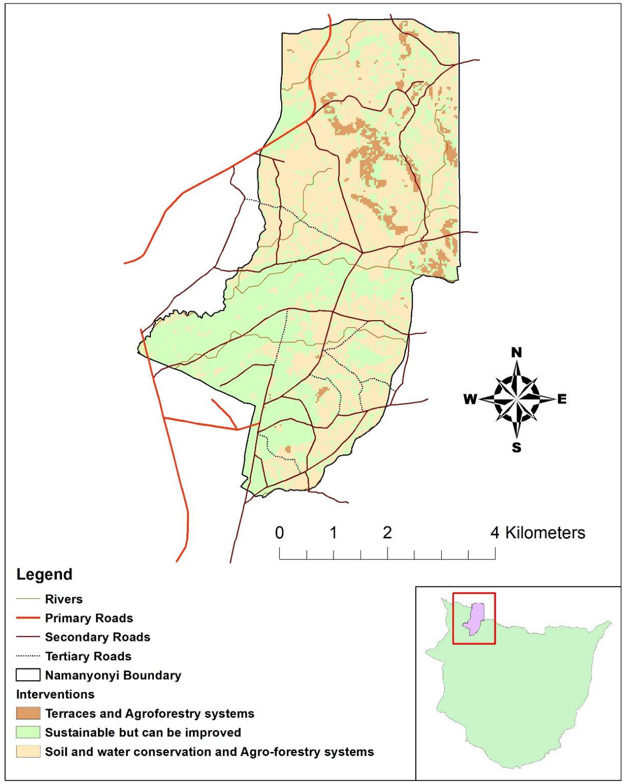
Nalwanza Land and Water Management Interventions



Namabya Land and Water Management Interventions



Namanyonyi Land and Water Management Interventions



Appendix 5: Policies and strategies relevant to sustainable grazing in Ethiopia

No	Policies/Strategies	Importance in promoting sustainable grazing management and systems, rate of implementation and gaps
1	The Ethiopian rural development policy and strategy	It supports the development of animal feed in the high and midlands of Ethiopia and shall change fron free grazing into cut and carry system. It supports the change of vulnerable steep slopes and othe sensitive areas into restricted closed areas forage and forest development. However, it was no implemented due to lack of clearly assigned institution that can monitor and implement.
2	Fourth Livestock Development Project (FLDP)	It promoted a range of strategies for forage development and cut and carry feeding systems througl restricting free grazing, so that implemented at several Ethiopian farming systems. However, the introduced forage development strategies have had limited success due to free grazinc practices, among others.
3	Agricultural development led industrialization (ADLI)	This strategy is mainly focused on food security and agricultural productivity challenges. The majo interventions were focused on improving livestock quality, expansion of animal health services, wate points, feed production and improvement of breeds and development of market infrastructure. Howeve the success on livestock productivity improvement was not achieved since the introduced technologies dic not consider the ecological, social and economic issues and the poor institutional setup.
4	Forest development, conservation and utilization proclamation	It promotes conservation, development of forest and forest products and introduce farm-forestry (agroforestry) practices to ensure food security by maximizing land use practice in the farming and semi-pastoral communities through prohibiting the free movement of the animals. However, due to weal sectoral integration, lack of guidelines, weak commitment by all parties and others, the success wa insignificant.
5	Rural Land Administration and Land Use Proclamation	Gives communal lands delineation, registration and and certification. All rural lands, the slope of which i more than 60%, shall not be used for farming and free grazing. It enhances agroforestry, livestock anc crop development by prohibiting land use change, allowing a room for forage production and protection o the planted land from free grazing. But, it was not implemented.

6	Plan for Accelerated and Sustained Development to End Poverty (PASDEP) strategy	It aims at addressing the problem of animal feed availability and quality by introducing various interventions such as forage production and supply, expansion of improved pasture, development of animal feed processing, improvement of the quality of crop residue, bush clearing, and water development. In addition conservation-based resource management was pursued using proven structural and biological measures including enclosing the degraded land from human and livestock interference and undertaking measures that enhance the rehabilitation processes. However, production of enough and quality animal feed and enclosure of farmlands from livestock was not implemented correctly due to lack of grazing land-use policies and guidelines, unclear institutional arrangement and responsibilities, low implementation capacity of experts at each level, technological gaps and low access of inputs.
7	Environmental Policy	The policy describes aspects of stall feeding of domesticated animals through a combination of provision of agricultural residues, on-farm produced forage and fodder as well as the cutting and carrying of green feed from several sources. However, it has not been implemented due to lack of institutional setup capacity and weak governance.
8	Livestock Master Plan	The plan clearly indicates the need for technical support and investment interventions on feed, breeding health services, markets and policy and institutional support which could help to meet the GTP II targets of improved productivity and overall livestock production in the key livestock value chains. However, i requires motivated and skilled experts at grassroots and higher levels, well informed decision and policymakers, administrative bodies and fund.
9	Proclamation on the establishment of the Ministry of Livestock and Fisheries (MoLF)	The MoLF's responsibility include addressing feed supply (quantity and quality), availability of forage seed increase milk and meat production and promote the feed and carry feeding system. However, success requires institutional arrangement up to the village level.
10	Proclamation on the establishment of the Ethiopian Meat and Dairy Industry Development Institute	The role of the include research in animal nutrition and fodder production, optimal feeding and as well as supporting private investors involved in feed processing. However, the institute has shortage of well skilled human resource, laboratory facilities and lacks institutional setup at grassroots level.

Appendix 6: Summary on financing options for tree products value chains in Uganda, Rwanda and Ethiopia

Country/ District (site)	**Financing option e.g. VSLA-table banking, cooperatives, commercial banks, MFIs**	**Which category/typology of farmers uses this option (e.g. smallholders, men, women, and youth?**	**What are the requirements to access this financing option?**	**Why are smallholder farmers not using this option? (Barriers to accessing this financing option)**	**Which category of farmers face the greatest barrier in accessing this financing option and why?**	**Which organizations are currently addressing these barriers? How are they addressing it?**	**What is the identified researchable issue or research question?**	**Reference**
Ethiopia Bako Tibe	Credit givers: Micro-Financial Institutions (MFIs) Commercial banks; Private banks;	-Large scale farmers -Men -Some small-scale farmers	- Ownership of an asset -The applicants have to present detailed feasibility study and must commit at least 40% of the total estimated agricultural project cost.	-High interest rates -Lack of assets by farmers -Lack of information -Very restricted in amount and involve restrictive conditions in terms of re-payment and interest	-Small scale farmers (Due to High interest rates) -Women (Due to gender bias) Youth (Due to unemployment hence lack capital)	-New Alliance for Food Security and Nutrition (by releasing yearly progress reports on policy progress as well data regarding financial commitments) -Agricultural Gross Programme (AGP); Rural capacity development program; and Oxfarm America, Sustainable Land Management (SLM) -All the three fund different projects in the Oromia region	Can reducing high interests in lending organization increase small scale farmer’s interests for credit acquisition?	(Bultossa and Gemecho, 2016) (Goceljak, 2017)

	Informal credit (from family or friends (love capital), Conventional lenders Usurers	- Smallholders -Men -Women	-Friendship -Trust	- High interest rates from Usurers	-Small scale farmers (due to poverty; Lack of trust among farmers) -Women (Harsh traditions limiting women financial empowerment)	-The commercial bank of Ethiopia (In helping small scale farmers to access affordable credit)	How can the boosting of trust solve constraints on the use of informal credit?	(Adugna and Heidhues 2000) (Desse et al., 2016)
	Farmer cooperatives (Primary cooperatives;)	-Large scale farmers -Some small-scale farmers -Men	-Must be a registered member -Member participation	-High transaction cost -Farmers with small farms are not likely to get input credit compared to large farms -Absence of adequately trained man power in cooperatives -Lack of enough financial resources	-Women (harsh traditions on women roles) -Youth (Lack of resources such as capital and farms) -Small scale farmers (lack of large farms)	-Ethiopian Investment Agency (EIA)- (Involved in funding large scale farmers)	-How can farmer cooperatives benefit farmers with small farms in supply of input credit?	(Fisseha, 2011)
Ethiopia Dugda	Credit facilities Public and private Banks Micro-financial institutions	-Large-scale farmers -Men -Small scale farmers	-Applicants have to present detailed feasibility study and must commit at least 40% of the total estimated agricultural project cost -Ownership of assets as guarantee	-Weak capacity and government support -High Transaction costs -Lack of assets such as land by small scale farmers	-Women (lack of assets; lack of farms) -Youth (Unemployment) -Small scale farmers (lack of large farms)	Ethiopian Agricultural Transportation Agency (ATA) -The Commercial Bank of Ethiopia (Working on developing contract-farming agreements between farmers and private investors and large institutional buyers) Ethiopian Commodity exchange (Avail markets for exportation of crops such as coffee)	-How can transaction costs be reduced for small-scale farmer's access for credit?	(Goceljak, 2017) (Toyiba et al., 2014)
	Farmer cooperatives (Oromia Coffee Union) (Oromia Region	-Large – scale famers -Men -Small scale famers	-Membership -Be a farmer of a particular crop of interest (in some cooperatives)	-Lack of informal network to promote products and mutual values in outside markets such as USA and Europe markets	-Women (harsh traditions on women roles) -Youth (lack assets such as land)	Catholic Relief Services – (Promotes farmer cooperatives among other activities-allocate financial capita)	Can the creation of informal network help promote products in foreign markets	(Lemma, 2009). (Emana, 2006) (Kiptot et al., 2013) (Kodama, 2007)

	Cooperative Promotion Commission)			-Lack of guidance in credit acquisition -Insufficient resources in cooperatives -Difficulty in markets acquisition		Agricultural Cooperatives in Ethiopia IFAD African Development Bank- (Financing rural farmers)	for increased revenue? Is expansion of membership to non-farmers able to increase resources for the running of cooperatives?	
	General Farmer Savings and credit cooperatives	-Small-scale farmers -Men	-Membership -Members' participation -Ability to contribute monthly/weekly	-Funds shortages -Insufficient resources -High transaction costs	-Women (Due to lack of women empowerment very few women are engaged in women savings) -Small-scale farmers (lack of funds)	-Agricultural cooperatives in Ethiopia (ACE) (Encourage women in Dugda and Ethiopia to save and avail credit inputs to cooperatives; also oversee cooperatives)	- Can capacity building and training improve savings groups' performance among women?	Farm Africa Website https://www.farmafrica.org
	Women Savings and credit cooperative	-Women -Small-scale farmers	-Be a woman -Small scale farmer	-Lack of enough funds -Mistrust	-Youth (as many young women engage in early marriage and lack empowerment)	-Farm Africa (Working on Rural women empowerment project; by encouraging women to form savings groups)	-How can Young women be included in saving groups for older women?	(Mossissa, 2013) Farm Africa Website https://www.farmafrica.org
Ethiopia Gutu Gida	Credit facilities -Public and private Banks -Micro-financial Institutions	-Men -Large scale farmers -Small scale farmer	-High Transaction Costs -Tedious application process	-Inadequate or ineffective policies, -High transaction costs to reach remote rural populations. -Lack of expertise of financial institutions in managing agricultural loan portfolios.	-Women (Lack of women empowerment) -Youth (unemployment and lack of assets)	-The commercial bank of Ethiopia (Provide affordable credit to farmers) -Fruit and Vegetables and Horticulture Development Department of the Ministry of Agriculture and Rural development (MoARD) -The Netherlands Development Organization (SNV) in its program to support business Organizations and their Access to Market	-Are there ways that effective policies can be implemented for small scale farmer to be able to access credit in Gutu Gida?	(Honja, 2014)

	Farmer cooperatives (Primary cooperatives; Oromia Coffee Union)	-Large – scale famers -Small scale famers -Men	-High Transaction Costs -Less number of farmer participation -Low member loyalty	-Lack of guidance on credit -Insufficient resources -Difficulty in market acquisition	-Women (Harsh traditions on women roles) -Youth (lack of farms)	-Catholic Relief Services (Promotes farmer cooperatives among other activities-allocate financial capita) Agricultural Cooperatives in Ethiopia IFAD African Development Bank (Financing rural farmers)	Are there measure that can aid improve farmer participation in farmer cooperatives?	(Coates et al., 2010)
Ethiopia Bora	Credit facilities -Public and private Banks -Micro-financial Institutions	-Small scale farmers -Men -Large scale farmers	-Famers have to be growers of certain commodities -Asset ownership	-Absence of adequate instruments to manage risks, -Low levels of products' demand due to fragmentation and incipient development of value chains, hence less revenue	-Women (Lack of assets) -Youth (lack of assets) -Small scale farmers (lack of large farms and assets)	Fruit and Vegetables and Horticulture Development Department of the Ministry of Agriculture and Rural Development (MoARD) (Aid in providing credit via input to farmers)	Are there other options for credit acquisition for smalls scale farmers with less interest rate?	Honja, 2014)
	Farmer cooperatives (Primary cooperatives; Oromia Region Cooperative Promotion Commission)	-Large – scale famers -Small scale famers -Men	-Membership -Member participation	-Lack of guidance in credit acquisition -Insufficient resources in cooperatives -Difficulty in markets acquisition	-Women (harsh traditions on women roles) -Youth (lack assets such as land) - Small scale farmers (small farms)	Catholic Relief Services – (Promotes farmer cooperatives among other activities-allocate financial capita) Agricultural Cooperatives in Ethiopia (provide credit in terms of inputs to primary cooperatives)	Can the creation of informal network help promote products in foreign markets for increased revenue?	(Emana, 2006) (Kiptot et al., 2013) (Natarajan et al., 2015)
	Savings and credit cooperatives	Small scale farmers -Women -Men	-Membership -Money contribution	-Lack of enough funds - Lack of entrepreneurship skills -Lack of member loyalty	-Women (less women are empowered) -Youth (lack of assets)	Catholic Relief Services – (Promotes farmer cooperatives among other activities-allocate financial capita)	-What measures can be put in place to increase member loyalty in savings and credit cooperatives?	(Kiptot et al., 2013)
Ethiopia Jima Arjo	Farmer cooperatives (Kenteri Primary Cooperative Society)	-Small scale farmers -Men Large scale famers	-One has to be a Member -Member participation	-Lack of Trust and a sense of ownership by members of cooperatives	-Women (Due to traditions that don't allow women to take part in some roles such as credit	Agricultural Transformation Agency (ATA) (Financial aid to cooperatives) Food Security and Rural Entrepreneurship (FSRE)	-Can collective action help in building of trust in farmer cooperatives in Jima Arjo?	(Tefera et al.,2017)

				-Corruption and misappropriation of funds	borrowing; lack of assets) -Youth (lack of assets)	(Provide funds to small scale farmers)		
	Credit facilities -Micro financial institutions -Public and private Banks	-Men -Large scale farmers -Some small-scale farmers	-Ownership of an assets -Willing to pay back after a specified time	-Poor access to credit -Absence of adequately trained man power to educate farmers on credit acquirement Lack of enough financial resources	-Women (Lack of ownership of assets) -Youth (lack assets; lack of farm lands)	-Oromiya credit and saving share company (OCSSCo) (reducing poverty in rural communities) Food Security Project (FSP) (Provide funds to small scale farmers)	-What kind of policies and institutional support are necessary to improve micro financial environment?	(Sabit and Mohammed 2015)
	Savings and credit groups Savings and credit cooperatives	-Small scale farmers -Women -Men	-Membership -Ability to pay monthly/weekly/ amount agreed on	-Lack of Trust in saving group -Insufficient funds -Low member loyalty	-Youth (lack of employment and assets ownership)	Food Security Project (FSP) (Provide funds to small scale farmers)	-How can women participate more in saving and credit cooperatives?	(Kiptot et al., 2013) (Asratie, 2014)
Ethiopia Adami Tulu Jido Kombo Icha	Farmer Cooperatives (Primary Cooperatives; Busa Ganofa)	-Small-scale -Men -Women (small percentage)	-Membership -Member participation	-High transaction costs -Lack of enough funds -Poor entrepreneurship skills	-Small-scale farmers (Lack of large pieces of farms); -Women (harsh traditions on women roles) -Youth (lack of assets and unemployment)	ICRAF (Capacity building) Catholic Relief Services - Promotes farmer cooperatives among other activities-allocate financial capita	-What strategies can facilitate women participation in cooperatives?	(Gyao, 2013) (Kiptot, 2013)
	Women Savings and credit cooperatives Savings and credit cooperatives	-Women -Small-scale farmers	- Membership -Member participation and contribution	- Lack of enough funds -Lack of Trust	-Youth (Lack of farms and lack of assets) - Small-scale farmers (Poverty and inability to pay contributions)	-Food Security Project (FSP)	-Can women empowerment result in an increase of women participation in savings and credit cooperatives?	(Mosisa, 2013) Farm Africa Website https://www.farmafrica.org
	Credit facilities -Public and private Banks -Microfinance Institutions	-Small scale farmers -Men -Large scale farmers	-Asset ownership	-Absence of adequate instruments to manage risks, -Voluntary and involuntary default	-Women (Lack of assets) -Youth (lack of assets) -Small scale farmers (lack of	-Cooperative Bank of Oromia, which provide collateral (free loans to agricultural exporters and cooperatives, respectively)	-Are there other options for credit acquisition for small scale farmers with less interest rate?	(Honja, 2014)

					large farms and assets)			
Ethiopia Tsaeda Emba	Framer cooperative (Setit Humera Cooperative Union)	-Small scale farmers	-Membership -Be a farmer	-Lack of trust Lack of member ownership of the cooperative	-Women (women tradition roles limitations) -Small scale farmers (lack of huge farms)	-Feinstein International Center	-Can collective action help in building trust among members in a cooperative?	(Dorsey, 2005) (Coates et al., 2010)
	Savings and credit cooperative Women Savings and Loan groups	-small-scale farmers -Women -Small scale	-Membership -Ability to save monthly or weekly depending on the group's policy	-Poverty -Lack of asset ownership	-Youth (unemployment, lack of land) -Women (Lack of assets) -Small scale (poor farmers)	-Farm Africa (Working in developing women savings and loans groups in Tigray)	-What are different strategies to increase the productivity of savings group in Tsaeda Emba?	(Farmafrica.org2018) (Tesfaye, 2010)
	Credit Facilities (Public and private banks; Micro-financial institutions)	Large scale farmers Small scale farmers	-Ownership of an assets -Willing to pay back	-Lack of assets by poor farmers -Involuntary and voluntary default	-Small scale farmers -Women	-Drylands Development (DRYDEV) programme (2013-2018) funded by the Dutch government and World Vision Australia, (enhancing market access, and strengthening the local economy for different categories of farmers.	-What types of credit loans can small scale farmers from Tsaeda Emba benefit from?	(Tesfaye, 2010) (Tesfu, 2016)
Ethiopia Lume	Farmer cooperatives (Primary Cooperatives; Woreda Cooperatives)	-Large scale farmers -Men -Small scale farmers	-Membership -Member participation	-Lack of Trust -Acquisition of small farms	-Women (Due to lack of women empowerment) -Youth (Lack of farms)	-Food security and Rural Entrepreneurship (FSRE) -Irish Aids (Working with farmers to improve their productivity)	-How can policy instruments be strengthened for farmer cooperatives management?	(Natarajan et al., 2015) (Emana, 2006)
	Informal credit From friends, family, Usury lenders	-Small-scale farmers -Women -Youth	-Friendships -Trust	-High interest rates -Trust issues	-Small scale farmers (Due to inability to payback) -Women (Lack of assets) -Youth (Poverty and lack of cash)	-The commercial bank of Ethiopia (Helping small scale farmers to access affordable credit)	-What measures can be used to reduce constraints on the use of informal credit?	Adugna and Heidhues (2000)
	Credit facilities -Public and private Banks Micro-financial Institutions	-Large scale farmers -Small scale farmers -Men	-Assets ownership	-High interest rate -Long waiting periods for loan approval	-Small-scale farmers (lack enough capital) -Women (harsh traditions)	Cooperative Bank of Oromia, which provide collateral	What kind of policy and institution support is necessary to alleviate long	Commercial bank of Ethiopia website https://combanketh.et/en/

					-Youth (lack assets to act as guarantor in the loan acquisition)	(free loans to agricultural exporters and cooperatives, respectively)	waiting periods for loan approval?	
	Savings and credit cooperatives	-Small scale farmers -Men -Women -Large scale farmers	-Willing to give monthly/Weekly savings or contribution - Membership	-Lack of income and general income generating ventures - Lack of member loyalty	-Women (Women participation is generally low due to traditions on roles of women) -youth (Lack of assets)	-IFAD (International Fund for Agricultural development/encouraging gender interaction in which women inclusion in agricultural saving and credit cooperatives is paramount)	-Can the implementation of a monitoring system help in boosting saving groups' performance?	(Dossey and Assefah 2005) (Asratie, 2014)
Uganda	Agricultural Cooperatives (Examples: Bugisu Cooperative which deals with the buying and processing coffee for local and export markets Masaka Cooperative Union MCU; deals with coffee but MCU is also teaching farmers about natural environment preservation and encouraging them to plant trees such as	-Small scale farmers (especially cash crop growers e.g coffee) -Women -Men -Large scale farmers	-Must be a registered member (18 years and above and a resident within or in occupation of land within the society's area of operation as prescribed by the relevant bylaw) -Membership fee - -Member participation and monthly contribution	-External problems such as political instability and mismanagement of the cooperatives - Rural Farmers incur high transaction costs such as transport cost etc. while accessing the cooperatives offices and loans - Failure to respond to all credit requests and in a timely way to the needs of the members contributes to small-scale farmers not using the cooperatives	-Poor farmers; because they lack money for registration and contribution to the Cooperatives -Large scale farmers; as agricultural cooperatives cannot meet their expectations of huge sums of loans -Youths who lack resources such farms and have little financial literacy -Small scale farmers due to lack of large farms to act as guarantee)	-Ugandan government -By Funding the cooperatives so as to avail funds to farmers; also, via improvement of farmer accessibility to the loans. -Uganda Cooperative Alliance-By emphasing on supporting cooperatives as independent profitable business units, building autonomous democratic institutions, providing technical education to improve the productivity and profitability and trainings on best practices, and promoting clear policy guidelines for the cooperatives.	Can better management of cooperatives result in increased famer benefits such as incomes? Is there governmental support for cooperatives to reduce transaction costs for rural small-scale farmers?	(Korugyendo, 2010)(International Fund for Agricultural Development [IFAD], 2009). The cooperative societies act, 2016-Uganda

	Mangoes and passion fruits. (Primary cooperatives;)							
Uganda	Micro-Financial Institutions (MFIs) examples: Pride, Letshego, BRAC, P-save, Participating Financial institutions (PFIs	-Low income Clients -Smallholders farmers -Men -Women -Youth	-Members must have accounts of savings -Agreed collateral security -Membership and some request	-Mistrust between micro-financial institutions and farmers which has blocked any kind of understanding between the two parties -Some have high interest rates -Complicated conditions -Corruption -Terms of payment not easy -Expensive processing fees Reasons for choosing MFI financial service Ease to access savings	-Poor small-scale farmers who have no income completely and assets to act as security for loan access -Large scale farmers as they require large sums of money that most MFI do not have - Women	-Commercial banks (Availing loans to famers at a low interest rate and on time; Diversified collateral assets; also, by having terms of payment that are easy). Offering alternatives to usual MFI products, either directly (in terms of savings services and, in the case of Orient, group-based loans) or indirectly (through salary-based loans which are beginning to be used as a substitute for group or household asset-collateralized loans).	-Can reduction of high interests' rates in lending institutions increase small scale farmers' interests for credit acquisition?	(Ntakimanye and Namuyanja, 2018) (Mukwana and Sebageni, 2003) (Hudson et al. 2003)

				Perceptions of institution stability Interest paid on savings		-Uganda National Farmers Federation via advocating for the formulation of a National Agricultural Financing Policy and Strategy		
Uganda	Commercial banks such as; Uganda Development Bank Ltd (UDBL), Uganda Commercial Bank; Cooperative Bank	-Large scale farmers as they have collateral -Accessible to men more than women	-Ownership of an asset for collateral -A bank account -Rigorous assessment of the farmers before issuing of a loan -Reliable guarantors	-Long waiting period for funds due -Mistrust as most small-scale farmers think banks are there to cheat them -Informality of the tree-based enterprises -Higher interest rate -Lack of incentives to farmers from most banks -Stringent conditions for collateral on long rotation enterprises -Expensive processing fees	-Small scale farmers due to lack of assets to act as collateral; - financial illiteracy of small-scale farmers is a barrier from accessing loans from commercial banks -Youths as they lack assets for collateral – Lack of financial information -Women due lack of capital and income	-The Ugandan Government; through standardizing the interest rates for commercial banks to control very high interest rates - Uganda National Farmers Federation has been advocating the formulation of a National Agricultural Financing Policy and Strategy that considers loan access to small-scale farmers Uganda Agribusiness Alliance (UAA), SNV Uganda and Economic Policy Research Centre (EPRC) come together in 2017 to launch a programme that aims to move agriculture financing higher up on the government's agenda via provision of agribusiness development service by all sectors to improve bankability of farmers and agricultural SMEs.	Can diversification of collateral contribute to more farmer acquisition of credit/loans?	(ILO, 2013) https://www.theeastafrican.co.ke/ business/New-lenders-coming-in-but-Ugandan-farmers-suspicious/ 2560-4655330-622s69/index.html http://www.africanfarming.net/technology/infrastructure/focus-on-agriculture-financing-in-uganda

Uganda	Savings Account and Credit Cooperatives (SACCOs) (e.g) Funkiris SACCO Namaganda SACCO Butuuro People's SACCO	-Small scale farmers - Men -Women - Young people	-Some SACCOS a farmer has to own shares worth 10 percent of the loan value -Membership of the farmer -Member contribution - Member involvement in the making of constitution that governs the SACCOs activities	-Lack of assets by farmers -Lack of financial literacy by farmers -Very restricted in amount and involve restrictive conditions in terms of re-payment and interest. - Lack of common interest among members resulting in mismanagement -High interest rates -Most SACCOs lack well trained and able leaders and this affects small holders' commitment due to underperformance	-Small scale farmers (Due to High interest rates) -Women (Due to gender bias) -Youth (Due to unemployment hence lack funds) - External reasons such as poor governance of Saccos, corruption and nepotism	-Agricultural Cooperatives by providing some funding to SACCOs for increased loans. -The Ugandan government via training and provision of knowledgeable employees; Subsidizing the founding of new SACCOS as newly established SACCOS can apply for a start-up grant from the government owned apex-institution Microfinance Support Centre (MSC). MSC also gives out interest free loans to the SACCOS or other subsidized loans.	Is there a direct positive contribution of small loans provided by Sacco's in improving smallholder income? How can SACCOs in Uganda be improved for increased small-scale farmer benefits?	(Kakungulu et al., 2010) (Kairu, 2009) (William Nnyanja,2017)
Uganda	Informal credit (from family or friends (love capital), Conventional lenders Usurers	-Small-scale farmers -Both men and women access this form of credit	-Friendship between the parties involved -A lot of Trust between the parties -Some lenders require the small-scale farmer to present a form of security	- High interest rates from Usurers - Lack of trust -Provision of security or collateral	-Small scale farmers (due to poverty; Lack of trust among farmers) -Large scale farmers	-The commercial banks in Uganda (By helping small scale farmers to access affordable credit)	What is needed to boost trust to solve constraints in the informal credit acquisition? Is collective action an appropriate approach for farmer acquisition of funds informally?	(Munyambonera et al., 2015)
Uganda	Out-grower Schemes (provide farmers with input loans/credit)	-Small scale farmers -Large scale farmers	-Contract's requirements	-Side selling -Weak institutional arrangements -Contract enforcement -Third party financing -Risk sharing	-Poor farmers (As they own Limited land for cultivation) - Youth (Lack of information)	-Local Investors (Sadolin Limited and Abi Trust) via increasing Sales outlets and promoting better access to credit to farmers.		(B. Busuulwa, 2014) https://www.theeastafrican.co.ke/business/Contract-farming-boom-Uganda-beverage-makers/-/2560/2451530/-/s64ylu/-/index.html

Uganda	Village Savings and Loans Association (VSLA)- Table banking	-Small scale farmers -Women	-Contribution of savings to a common pool of funds -Membership (as members contribute to their kitty and whoever asks for a loan is given and pays with some interest)	-Lack of member commitment (hence makes some farmers not to commit) -Lack of loyalty resulting in misuse of money	- Large scale farmers (as it is impossible for them to integrate with small scale farmers) -Youths (Due to lack of capital to save and invest)	-Innovations for poverty Action organization (IPA) working with poor farmers to link them to markets and via encouraging them to save - Local Agricultural Cooperatives via reaching out to small scale farmers in remote areas and having favorable terms that encourage them to save and join groups -Care Uganda coordinates assistance and intervention by providing financial and technical support, quality control, assuring sustainability and encouraging learning.	Can VSLA result in increased income availability to aid farmer production and improve their livelihoods.	(Karlan, 2017) IPA website
Rwanda	Agricultural Cooperatives	-Small-scale farmers - Women -Low income earning individual - Extend training and other capacity building initiatives.	-Membership of the farmer in the cooperative -Membership fee (which is low in the initial stage) -Certification of some members such as coffee farmers	- Constraints such as mismanagement of funds make small-scale farmers reluctant to save and access loans from cooperatives - Dishonest and untrained managers of the cooperatives - Small-scale farmers lack knowledge and financial capacity -No benefit -Barriers such as certification for farmers to join -High transaction costs	- Some cooperatives have no clear idea about Cooperative function -Small scale farmers -Used for different purposes such national leadership and culture saving	- Commercial banks have become proactive and are training cooperative managers in loan management to ensure they use credit for activities for which it was planned		https://www.ica.coop/en/media/news/co-operatives-help-increase-food-security-rwanda (D. Mugabekazi, 2014) (G. Nsingize, 2013) (International Fund for Agricultural Development [IFAD], 2009). (Atieno, 2017)
Rwanda	Savings Account and Credit cooperation's (SACCOs)	-Small scale farmers as many can afford to	-Membership (Members should have a "common bond" based on	-Community elites or net borrowers dominate the SACCOs hence some small-scale farmers keep off!	-Large scale farmers (As they require huge sums of money which	-The Government of Rwanda via aiding in establishment/administratio n of SACCOs of	Is there a difference in production for farmers that are at a close range to	(Nangizi, 2014) (Alliance for Financial Inclusion [AFI], 2014) http://www.findevgate way.org/library/rwand

	Examples: Umurenge SACCO	save with the SACCOs -Women -Men	geographic area, employer, community, industry or other affiliation) -Members are required to open savings account	-Lack of enough funds and credit to all farmers' requests -Complicated internal conditions -Corruption and nepotism - The types of loans available are not flexible enough to meet member's diverse credit needs, including short-term working capital for micro-entrepreneurs and agricultural inputs for small-holder farmers. - Terms of payments not easy -Long distances to where the SACCOs offices are!	rural SACCOs cannot supply!) -Youth (Lack of involvement in SACCOs a) -Very Poor farmers (Low financial literacy; inadequate financial products as financial institutions done offer products designed specifically to meet the needs of the poor)	-The National Bank of Rwanda via organizing training and prudential meetings and establishment of the Rwanda Institute of Cooperatives, Entrepreneurship and Microfinance (RICEM) so as to harmonized internal policies and procedures for SACCOs and to strengthen the supervision of SACCOs. -The central bank of Rwanda is involved in the supervision and monitoring of SACCOs and this helps to address different problems	the SACCO offices with those far from them?	a's-financial-inclusion-success-story-umurenge-saccos
Rwanda	Commercial Banks (Bank of Kigali; Cooperative bank; Equity, Kenya Commercial bank;)	-Large scale farmers as they have the assets and capability to pay back the loan -Men are capable of acquiring loans from the banks unlike women	-Required assets as collateral - One has to opening an account with the bank -One must agree to the terms of payments recommended - Farmers' financial illiteracy and lack of market information	-High interest rates -Many farmers' activities are not insured; hence the banks are reluctant to offer any credit resulting in limiting small-scale farmers access to the loans -Lack of diverse collateral types which is important for easing access to credit for small scale farmers -Requires certain assets as collateral -High transaction costs for small scale farmers -A lot of terms for payment	-Low-income earning farmers and small-scale farmers as they lack collateral -Youth (Unemployed and lack assets and farms)	-Rwandese government by having in Innovation in agriculture and reliable markets; and poor infrastructure to ease reduce the risks associated with farming that hinder commercial banks from giving loans to farmers.	- How effective are commercial banks in Rwanda in providing farmer loans?	(International Fund for Agricultural Development [IFAD], 2009a). (Atieno, 2017) https://www.newtimes.co.rw/section/read/182664

Rwanda	Village Saving and Loan Association (VSLA) and Personal savings	-Small-scale farmer -Women are more dominant in VSLA than men as they are disproportionally affected by poverty	- Commitment to save and contribute in the agreed times -Trust among members	- High risk of management as some VSLA do not save their contributed money in bank -Mistrust and internal conflicts -Many small-scale farmers in VSLA do not access formal funding such as banks -Dishonest of some managers of VSLAs	-Large scale farmers as they really require huge sums of money for their activities -Men as most of VSLA are women based with women who mobilize it to work -Very poor farmers as they lack enough to save and have difficulty in paying back the loans	-CARE International Rwanda through its' Economic Empowerment programming follows a Market Driven Value Chains approach, undertaking needs assessments, and using findings to support VSLA members entering profitable value chains. This process links groups and individual members to formal financing and strengthens the capacity of individuals to interact with the market through increased knowledge, confidence, and negotiation experience.	Can involvement of men (male gender) in VSLAs result in increased production and commercialization of fruit trees?	(Small Enterprise Evaluation Project (SEEP) website, 2018) https://seepnetwork.org/Blog-Post/How-CARE-Aims-to-Uplift-800-000-Women-in-Rwanda-SG2018-Peer-Exchange-to-Visit-Savings-Groups-Members
Rwanda	Informal credit (from family or friends (love capital), Conventional lenders Usurers Money lenders)	-Small scale farmers -Men -Women	-Assets as collateral - Trust -At times high social cost	-High interest rates -High transaction cost -Terms of payment not easy	-Large scale farmers (As they require huge sums of money that in most times informal sector is not able to provide) - Poor farmers (as they lack assets for collateral)		What role does trust play in farmer acquisition of funds from informal sources?	(Ali et al., 2014)