Australian Government

Australian Centre for International Agricultural Research

Final report

Project full title	**Fruit Trees for Climate Adaptation and Mitigation in East Africa**
project ID	FST/2021/163
date published	05/08/2024
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approved by	Nora Devoe
final report number	FR2024-021
ISBN	978-1-923261-08-2
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

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1 Acknowledgments

The Fruits Tree for Climate Change Mitigation and Adaptation for East Africa project team would like to thank the Australian Government for funding this project through the Australian Centre for International Agricultural Research (ACIAR). This project was led by World Agroforestry (ICRAF) and we acknowledge the excellent support from ICRAFs leadership, finance, and project management units for their support in management of the project. We appreciate our project partners' contribution in successfully implementing the activities, notably Jomo Kenyatta University of Agriculture and Technology (JKUAT) and Rwanda Agriculture and Animal Resources Development (RAB).

We are indebted to the national governments of Kenya and Rwanda for their help and for making things easier by setting up climate change dockets and policies in their respective ministries. We also acknowledge the incredible support of the county government officials from Makueni and Kiambu counties in Kenya and the leadership of Bugesera district in Rwanda. We also want to thank the local extension agents. The project's team collaboration with the government at all levels was outstanding.

We are incredibly grateful to Dr. Nora Devoe, ACIAR’s Forestry Research Program Manager, for her leadership and dedication from design to implementation and end of project review which led to the recommendation to undertake the endline study. Dr. Leah Ndung'u, ACIAR’s Regional Manager for Africa, is thanked for her support, including regular communication with the team and participation in field visits alongside her colleague Kennedy Osano, whose inputs have been very valuable.

We wish to express our appreciation to all our partners on the ground notably Kiambu County Executive Committee Member (CECM) for Environment and Climate Change-David Kuria, Director for Crops and Irrigation-Ms Anne Koimburi and sub-county agriculture officers for Kiambu and Gatundu South-Jane Waihenya and Rachael Mwangi. Additionally, former Makueni CECM for Environment and Climate Change Dr Sonia Nzilani, Makueni County Forester-Damaris Mwikali, and Joseph Mbithe Biovision Kenya. Lastly, our key ambassadors and change agents- the farmers, for availing their time, local knowledge, farms, and trees for the project activities and all stakeholders who actively participated in our training and related awareness activities. Despite the short duration of this project, we are hopeful that the momentum gathered from the trainings and knowledge acquired will equip farmers better in tree growing and fruit farming. This eventually should result in better mitigation and adaptation to climate change, more resilient and profitable livelihoods, and less degraded landscapes.

2 Executive summary

The Fruit Trees for Climate Change Mitigation and Adaptation project is a 24-month project that was contracted in March 2022. It builds on the investment of the Trees4FoodSecurity Project -2 (FST/2015/039, 2017–2021) in Rwanda as well as bringing in some of the lessons and co-learning to Kenya.ICRAF led the project in partnership with JKUAT and RAB. The project aimed at enhancing farm-level climate adaptation and household food security and nutrition for smallholders in Kenya and Rwanda by increasing fruit trees on-farm and generating evidence on the carbon sequestration potential of fruit trees for use in international climate financing initiatives. It was implemented in Kiambu and Makueni counties in Kenya and Bugesera district in Rwanda.

Major achievements include but not limited to:

- The project directly reached **3578** beneficiaries, including 2403 (47% women) and 1154 (43% women) in Kenya and Rwanda, respectively. This was achieved through a training extension approach that involved collaboration between project staff, county government and the Training of Trainers (ToTs) model in Kenya, while in Rwanda, the partnership between district, ICRAF and RAB researchers and lead farmers. The project, therefore, improved linkage between farmers and government officials, thus strengthening knowledge sharing, extension for sustainable scaling.
- **Improved knowledge, attitude, and increased adoption** of good agricultural practices (GAP) by farmers and key stakeholders in tree / fruit growing. The endline survey revealed significant positive change between trained and untrained farmers in knowledge and practices on the role of fruit trees in climate resilience and adoption of GAP e.g., tree management, diversification, and quality tree seedlings sourcing.
- **Increased tree planting / growing** in Kiambu (125%) and Makueni (109%) counties and 50% in Juru and 67% in Rweru, Bugesera Rwanda in the past year between the trained and untrained farmers, thus contributing to Kenya's national commitment to grow 15 billion trees by 2032 and Rwanda Green Growth and Climate Resilience Strategy
- **Development of an "Interactive Suitable Tree Species Selection and Management Tool"** for Kenya (Muthuri et al., 2023a) and expansion for Rwanda tool (Kuria et al., 2023); and between 2023 and 2024 had been viewed by users 2,865 and 11,937 times respectively. The tools were based/expanded on tree inventory studies (Kuyah et al., 2022) and (Cyamweshi et al., 2022), where fruit trees comprised **31%** and 33% of species encountered in Kenya and Rwanda, respectively. This was followed by the development of **offline mobile Apps,** namely Kuza Matunda in Kenya and Igiti in Rwanda, with downloads and installations on users' devices 419 and 53 times respectively. This is a key milestone in enhancing access to information on tree growing.
- **Development of allometric equations** for estimating aboveground biomass in Kenya's mango and avocado fruit trees published by Kuyah et al., (2024), and for Rwanda as documented in (Cyamweshi et al., 2023c).
- **Formation of a farmer-led cooperative,** namely the avocado-macadamia cooperative (AVOMAC), with a membership of 1150 farmers (20% women) after the training in Kiambu. This has provided farmers with a unique platform for avocado/macadamia growing, collective action, better price negotiation and marketing, with farmers currently fetching over four times more for their avocados (from an average of KSh 20 to 90 per kg). In addition, significantly higher enrollment in co-operatives and reactivation of agricultural group membership was also reported where after the training, 63% and 27% joined new agricultural groups in Makueni and Kiambu, respectively, while 83% of farmers in Makueni and 64% in Kiambu activated their membership in existing groups.
- **Improved understanding of gender roles in household decision-making** around fruit tree growing, production, and income generation: The trainings contributed to improving farmers' understanding of gender principles, which resulted in gender mainstreaming in the farming activities of the communities.

Production of various knowledge products, including journal articles, manuals, and briefs.

3 Background

Smallholder farmers in East Africa largely rely on subsistence farming, use minimal external inputs, and utilise firewood (75% in Kenya) for their cooking and heating needs. They depend on rainfall rather than irrigation systems and have limited market access. As a result, many rural households struggle with poverty and food insecurity while facing increased vulnerability due to climate change. With the population growing 3% annually across the region, there is an ever-growing demand for land, food, water, and energy, all of which have seen low productivity from farms and declining tree resources within landscapes due to land deforestation. Climate change is projected to accelerate in the coming decade, bringing a range of challenges and opportunities. Africa will experience more extreme temperatures than the global average; heat waves and drought are expected to become increasingly common throughout East Africa (Niang et al. 2014). The increasing land degradation and declining food productivity leads to food and nutritional insecurity where in sub-Saharan Africa, 17.6 million children suffer acute malnutrition (UNICEF et al., 2020).

Recent trends have increased drought conditions, but annual rainfall is expected to become more extreme and intense. This could lead to reduced water availability during the drier times of the year, reducing crop yields, putting livestock under stress, and significantly heightening risks to human health due to direct climate impacts and increased exposure to parasites and diseases (Godde et al., 2021). Around 75% of the Kenyan population depend on only 20% of Kenya's land for agricultural production. This increases pressure on land thus leading to escalating land degradation, biodiversity loss, food insecurity and poverty with about 30% of citizens being unable to meet their food needs. The situation is further exacerbated by climate change characterized by recurrent and severe droughts, flooding, amongst others, a common occurrence in Arid and semi-Arid Lands (ASALs). For instance recently Kenya, experienced flooding with close to 300 people dead, hundreds injured, over 281,000 people displaced and 41562 acres of land damaged. To address the accelerating impacts of climate change, new approaches are needed to ensure that smallholders and rural people have access to secure livelihoods and food security. Additionally, agricultural development must contribute towards mitigating climate change to reduce its root cause: increasing climate extremes. With these strategies in place, we can help prepare those affected by climate change for what may come within the next 1-3 decades.

The Intergovernmental Panel on Climate Change (IPCC) report agroforestry is a promising agroecological approach to climate change adaptation because of the multiple co benefits they provide in addition to climate change adaptation and other ecosystems services (Kerr et al. 2022). Van Noordwijk et al. 2022 outline agroforestry (AF)-based adaptation to global climate change to consist of (1) reversal of negative trends in diverse tree cover as generic portfolio risk management strategy; (2) targeted, strategic, shift in resource capture (e.g. light, water) to adjust to changing conditions (e.g. lower or more variable rainfall, higher temperatures); (3) vegetation-based influences on rainfall patterns; or (4) adaptive, tactical, management of tree-crop interactions based on weather forecasts for the (next) growing season drawing from about four decades of reached initiated by Peter Huxley. A recent systematic review on the contribution agroforestry to livelihoods and carbon sequestration in East Africa revealed that agroforestry stores an average of 24.2±2.8 Mg C ha^{-1} in biomass and 98.8±12.2 Mg C ha^{-1} in the soil (Muthuri et al., 2023). Though growing trees is associated with high initial investment and delayed returns, the main livelihood benefits of food, fodder, firewood, income from agroforestry (Muthuri et al. 2023) coupled with generating additional income for farmers from mitigation through agroforestry is important for enhancing adoption.

Re-integrating and increasing the right trees into degraded agricultural landscapes is a promising approach to pursuing climate mitigation and adaptation, with the potential for fruit trees to optimize livelihoods through food security, nutrition, and climate benefits (Kuyah et al., 202; Chai et al., 20210). Additionally, fruit production also offers considerable marketing and income opportunities, particularly for small-scale producers of fruit trees in developing countries (Dagar et al., 2020) and as opportunities increase for rural households to move from subsistence to the cash economy, fruit tree cultivation will become more important in their farming systems. Findings from the Trees4FoodSecurity 2 (Muthuri et al. 2019) showed that fruit trees are priority tree species to farmers across Rwanda, Ethiopia, and Uganda and are usually protected by farmers mostly being grown around or near homesteads for better care. Therefore, access to climate-related financial mechanisms could provide added incentives through co- benefits that could further catalyse adoption and, consequently, the scaling out of agroforestry systems. Strong measurement, reporting, and verification (MRV) systems are needed to access and better negotiate these market-based mechanisms. One critical step towards achieving this is developing allometric equations for estimating biomass production and carbon sequestration by priority fruit trees species in agroforestry systems in East Africa.

Kenya and Rwanda government have supportive policies to address challenges of climate change, food insecurity, biodiversity loss and land degradation a number of which trees including fruit trees are expected to play a critical role. The Kenyan policies which include: i) increasing the national tree cover by 30%, planting 15 billion trees by 2032 and restoration of 10.6million hectares of degraded land by 2032. ii) reduction of greenhouse gas emissions by 32% by 2030 iii) Promotion of tree-based value chains to contribute towards a green economy, improved livelihoods and accelerate restoration efforts iv) Clean and affordable energy for all by 2030 In addition, the county governments of Makueni and Kiambu (the two project sites) have aligned to government priorities to tackle the same challenges. Makueni County is one of Kenya's leading producers of fruits and their top producer of mango. In 2017, the Makueni County Fruit Development and Marketing Authority (MCFDMA) established the Makueni Fruit Processing Plant (MFPP) in Kalamba to provide farmers with value-added opportunities currently used exclusively for mangoes. On the other hand, Kiambu County, is a sub-humid area with optimal ecological conditions for growing fruits such and proximity to the highly populated Nairobi city - Kenya's capital - provides high-potential business opportunities in fruit growth and sales due to the existing export market. The Kiambu County Integrated Development Plan 2023–2027 https://repository.kippra.or.ke/bitstream/handle/123456789/4431/Kiambu_CIDP_2023_2027_compressed.pdf?sequence=1&isAllowed=y lists increasing tree cover from 19% to 42% through promoting agroforestry, tree and fruit seedlings and value addition-agro processing (fruit) being among 19 key flagship county projects. In Rwanda, key priorities within the 2018 National Agricultural Policy[1] include mainstreaming fruit trees. Each household is required to plant three different fruit trees on the homestead to overcome stunting in children and improve nutrition for vulnerable people. Fruit trees and agroforestry are seen as contributors to climate smart agriculture, developing adaptations and mitigation of climate change, promoting green growth and low carbon emissions, promoting food security while conserving biodiversity, economic growth and poverty reduction, sustainability of the environment and natural resources, and gender equity. These policies and strategies are included in Vision 2050[2]. Bugesera district where the project was implemented was a site under Trees4Food Security project with suitable conditions for fruit farming limitations of water notwithstanding.

This project was inspired by the successful outcomes of the previous ACIAR Trees for Food Security projects (FSC/2012/014 and FST/2015/039, 2012–2021 (Muthuri et al., 2021). The projects demonstrated that agroforestry trees planted around homesteads, farmers' fields,

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[1] *https://www.minagri.gov.rw/fileadmin/user_upload/Minagri/Publications/Policies_and_strategies/National_Agriculture_Policy_-_2018___Approved_by_Cabinet.pdf*

[2] *http://www.minecofin.gov.rw/fileadmin/user_upload/Hon_Gatete_Umushyikirano_Presentation_2016.pdf*

or landscape niches could provide products and services to support food security and livelihoods. The rural resource centres (RRCs) model coupled with implementation of best fit on-farm trials through farmer-centred, all-inclusive approach (Derero et al., 2020) allowed communities to take the lead in scaling best practices for their close neighbours for multiplier effects. The knowledge of the "*Interactive Suitable Tree Species Selection and Management Tool for East Africa*" and "fruit tree portfolios" of chosen species of fruit trees that are both socio-ecologically suitable and nutritionally significant for Kenya (McMullin et al., 2019) have been a great resource. Building on this success and resources and adapting them to different contexts especially in Kenya, the fruit trees for climate change mitigation and adaptation project aimed to increase tree growing with a focus on fruit trees within agricultural landscapes of Kenya and Rwanda.

Despite the above livelihood and environmental benefits that fruits trees provide, and the enabling government policies, fruit growing hasn't reached its full potential due to various challenges that include: 1). Limited capacity/knowledge of farmers and key stakeholders in tree growing particularly fruit farming and management, matching suitable tree options to various contexts; 2). Climate change-related effects, especially prolonged droughts, leading to water shortages and incidence of pests and diseases; 3). Insufficient supply of quality and quantity of planting materials seed/ seedling including limited diversity of tree species, especially the indigenous ones; 4). Lack of structured markets and an underdeveloped value chain including inadequate farmer-driven interventions and limited community benefits; 5.) Limited government extension systems especially on environmental matters particularly fruit farming which is normally not captured under agricultural extension services.

This project therefore sought to address these challenges by aiming to enhance farm-level climate adaptation and household food security and nutrition for smallholders in Kenya and Rwanda through increasing fruit trees on-farm and generating evidence on the carbon sequestration potential of fruit trees for use in international climate financing initiatives. Farmers capacity was strengthened through trainings (from tree nurseries to managing trees on farm) that were participatory involving project team, farmers, and local government. In addition, the project offered methods for quantifying the carbon sequestered in fruit trees to lay the groundwork for potential access to climate finance and respond to farmers' concerns about their potential to contribute to climate change mitigation. Determination of carbon sequestered in fruit trees could help bridge one of the limitations of lack of capacity among land managers concerning co-benefits by raising awareness of the same.

4 The Study Objectives

Objective 1. Scale-out community-based fruit-tree growing, using multipurpose species where possible.

Objective 2. The right trees are in the right places. Show smallholders how to site trees on farms to maximize climate adaptation benefits.

Objective 3. To Estimate fruit tree carbon sequestration benefits to determine the potential for access to international climate finance that could further accelerate scaling out.

4.1 Research Questions

Research question 1: What are the enabling conditions for increasing community-based fruit-tree growing?

This component was to determine the status of agroforestry trees/practices with a specific focus on fruit and nut trees in targeted regions of Kenya and Rwanda to identify the opportunities for and challenges to scaling up smallholder uptake. A baseline study was undertaken and gender responsive approaches were integrated across these studies. Existing data from Rwanda and a tree selection tool developed under the Trees for Food Security project.

Research question 2: How can smallholder farmers' capacity in tree growing be enhanced to maximize their benefits, especially those relating to climate change adaptation and more gender-inclusive outcomes?

The focus of this component was to enable gender-inclusive, sustainable, and efficient supply of high-quality fruit-tree planting material, coupled with enhancing farmers' knowledge and capacity to match species to on-farm niches, make decisions based on likely future climate conditions and use appropriate agronomic, water and tree management practices. We explored routes to strengthening existing tree nurseries (individual, cooperative or group) and support news ones through capacity strengthening to enhance quality and adequate supply of planting materials. These nurseries are also capacitated to run as businesses and hubs for peer-to-peer learning on tree growing.

Research question 3: What is the contribution of fruit trees to climate change mitigation?

The contribution of fruit trees to climate change mitigation through carbon sequestration in Africa has not yet been assessed. Tree diversity studies were undertaken, and quantification of carbon associated with avocado and Mango fruit trees undertaken with eventual development of allometric equations. This was done to help create a framework to access support programs that provide incentives for fruit farming and thus catalyse for further adoption.

5 Methodology

5.1. Research Strategy

The project undertook to leverage on the existing government priorities/ policies to advance the aim of enhancing farm-level climate adaptation and household food security and nutrition for smallholders in Kenya and Rwanda by increasing fruit trees on-farm and generating evidence on the carbon sequestration potential of fruit trees. Examples of such are the National Strategy for Climate Change and Low Carbon Development (Byamukama et al., 2009) and Rwanda National Forestry Policy (Republic of Rwanda, 2018). In Kenya in addition, to the commitment of planting 15 billion trees by 2032, the government has developed the Kenya Climate Smart Agriculture Strategy (2017-2026)[3], which aims to build resilience and minimize emissions from agriculture. Under the Paris Agreement, Kenya and Rwanda have committed to reduce greenhouse gas emissions by 32% and 38%, respectively, by 2030. This study was therefore designed to analyse the current context in terms of understanding and knowledge of tree growing, especially fruit trees, and their impact on climate change mitigation and adaptation in the target sites. This baseline helped identify gaps that would be addressed through participatory, context-appropriate, and gender-responsive training targeting the capacity gaps across the tree (fruit tree) value chain from seed and seedling supply systems, a tree growing to market. An effort was also made to capacitate farmers on fruit tree biomass determination and development of allometric equations for avocado and mangoes, key fruit trees that are widely grown in Kenya and Rwanda and where farmers would benefit from carbon financing as a co-benefit alongside the direct benefits. These equations would also contribute to new knowledge relevant to helping design more reliable estimates of carbon in fruit orchards and or agroforestry systems and, hence, carbon financing. To ensure ownership and greater uptake, the project brought together different actors in trees, especially the fruit tree growing sector, either for capacity building and or to generate information targeted for different audiences on best practices for tree growing and the benefits of fruit trees for climate change adaption and mitigation. The target audience of the project findings is farmers and farmer organizations, tree nursery managers, tree seed dealers, academic institutions and researchers, donors, and government agencies, including extensionists and policymakers. To accelerate development impacts, stakeholder-sharing sessions were conducted around project sites.

Theory of Change

A Theory of Change and impact pathways guided this project throughout its development and implementation. The project outcomes from the activities of this project are that the smallholders in Kenya and Rwanda will be able to make a better living, be more resilient, and better manage their natural resources from the impact of this project. Figure 1 illustrates the three pathways to achieve through the following.

If: actions are taken to teach, equip, and provide small-scale farmers and other important parties with affordable, suitable fruit tree seedlings and information on the best ways to farm, multiple benefits can be achieved, such as using trees to adapt to climate change.

Then, community-based fruit tree planting will expand, farmers' and growers' skills will improve, and farmers and growers will be able to use fruit trees to make a living, improve nutrition and food security, and help farms adapt to and deal with climate change.

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[3] *https://www.adaptation-undp.org/sites/default/files/resources/kenya_climate_smart_agriculture_strategy.pdf*

Because the approach is participatory, focused on farmers, and takes gender into account. This way, the project's knowledge will directly and instantly apply to the needs and practices of smallholders. The participatory, farmer-centred, gender-responsive approach will ensure that the knowledge generated by the project will directly and immediately translate to the needs and practices of smallholders.

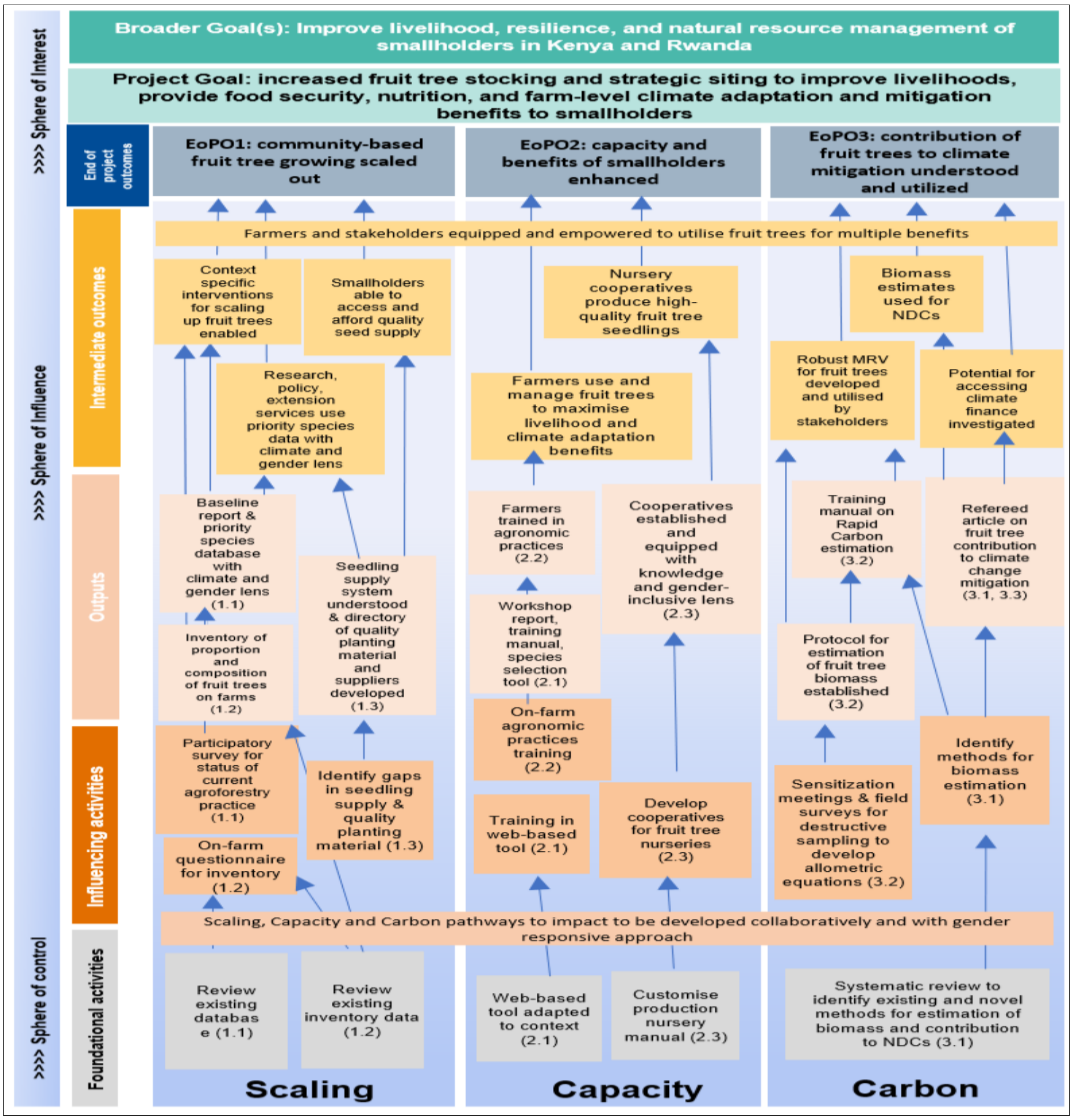


Figure 1: Theory of change and pathways to impact

5.2 Study site locations

The project was implemented in Kenya and Rwanda. In Kenya, the study sites included Makueni and Kiambu counties Fig. 2 and in Rwanda, the study was Rweru and Juru within the Bugesera district Fig. 3. The study sites (Table 1) were chosen using the elevation gradient as a criterion because it was anticipated that farming systems, management and growth restrictions on fruit trees, and farmer priorities would all change along this gradient The two counties in Kenya were selected based on their potential for fruit tree production and contrasting agroecological conditions (Dixon et al., 2019) as data and lessons learnt from these sites could be scaled out in similar agroecology in Kenya and East Africa.

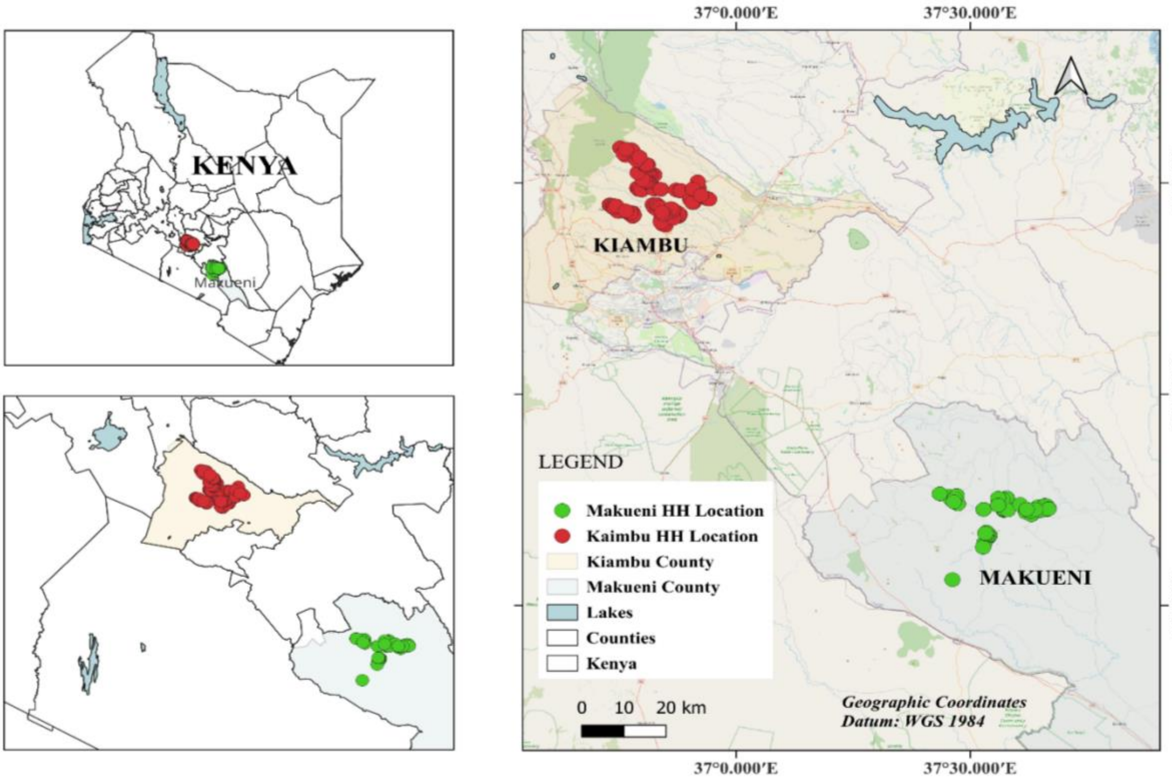


Figure 22: Fruits for climate change mitigation and adaptation study sites in Kenya (Makueni and Kiambu counties). Maps developed by David Lelei/CIFOR-ICRAF

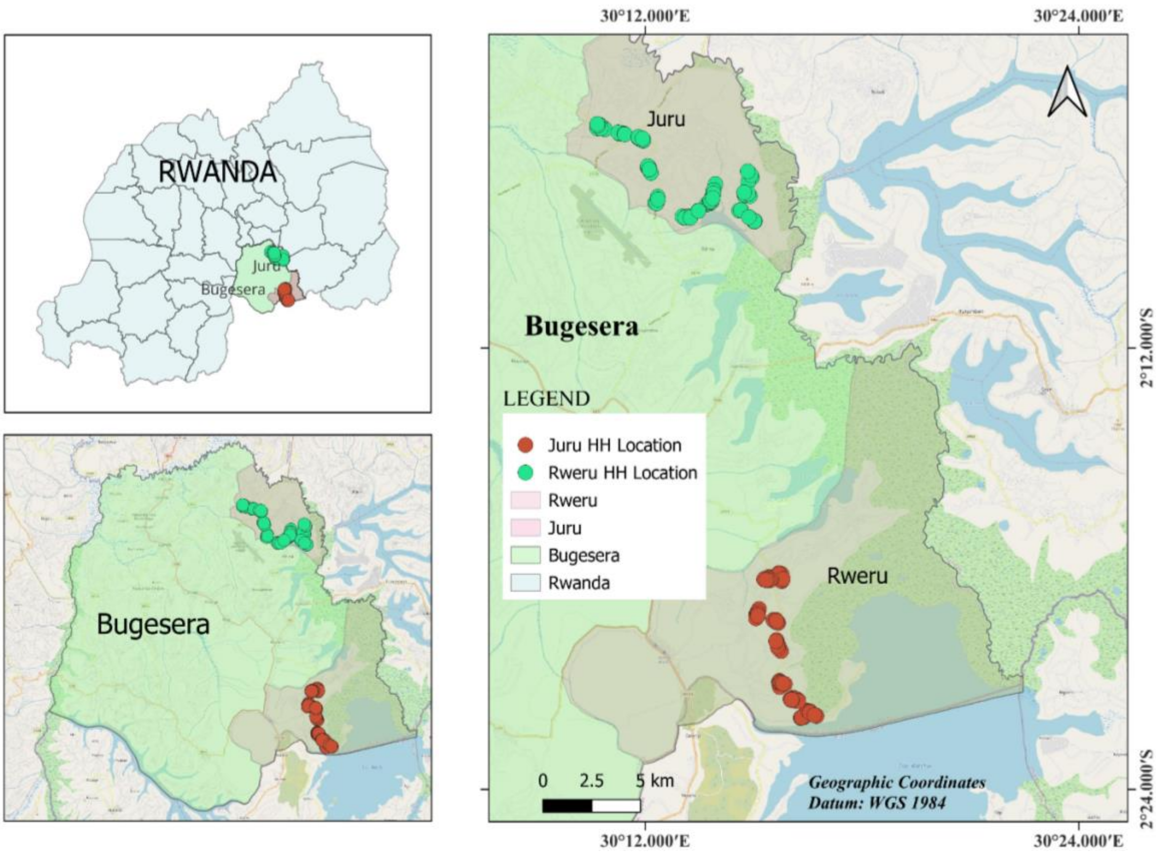


Figure 33: Fruits for climate change mitigation and adaptation study sites in Bugesera district, Rwanda (Rweru and Juru sectors). Maps developed by David Lelei/CIFOR-ICRAF

Kiambu County is one of the counties in Central Kenya, bordering Nairobi County to the south. The county's bi-modal rainfall patterns (up to 2000mm), a favorable climate, and fertile soils, make it highly productive. This provides optimal ecological conditions for farming for crops, (vegetables, horticultural products, coffee and tea) livestock especially dairy farming and trees (for timber, poles, fruit, firewood, charcoal, fodder, fertiliser and honey) most of these products contributing not only to the local but Kenya`s foreign earnings. Key fruit trees grown include avocadoes, macadamia, plums, pears mangoes, guavas and among others. On the other hand, Makueni County is in Eastern Kenya and its one pf the ASAL counties with varied rainfall amounts ranging from around 400mm in lower zones to 500mm-600mm in upper zones, the study sites being in the wetter zone. Despite the semi-arid climate and frequent drought in the county, farmers cultivate various fruit trees due to their fertile soils. These include mango, pixie mandarins, orange, and pawpaw, with mango as the main cash crop. It is estimated that 91% of all mango trees planted in the county were grown within the past seven years (Duuren, 2019). By combining irrigation techniques and water harvesting/conservation methods with horticultural production potentials, farmers across Makueni are overcoming agroecological challenges while increasing economic opportunities at home. Bugesera District is in the Eastern province of Rwanda. Although the region is blessed with considerable water resources (lakes and rivers), famine has been frequent following poor harvests due to prolonged drought and inadequate water control. Therefore, for this study, Makueni and Bugesera represent the semi-arid climates. while Kiambu County serves as the humid climate.

Makueni, Kiambu, and Bugesera have a high fruit tree population compared to surrounding countries and other areas with similar agroecological conditions. In Kiambu, Makueni, and Bugesera areas, communities have embraced fruit tree growing and are supported by local government non-government organizations. Semi-subsistence farming systems are the most widespread practice among farmers in the study sites.

Table 1: Sample sites and size in Kiambu and Makueni Counties in Kenya and Bugesera in Rwanda

Country	County	Sub-County (n=220)	Wards
Kenya	Kiambu	Githunguri (60)	Ngewa, Komothai, and Githunguri
		Gatundu South (60)	Ngeda, Ndarugu, and Kiganjo
	Makueni	Makueni (50)	Makueni and Wote
		Kaiti (50)	Ukia, Mukuyuni
Rwanda	**District**	**Sectors (n=135**	**cells**
	Bugesera	Juru (n=62)	Kabukuba, Mugorore, Rwinume
		Rweru (n=73)	Nemba, Batima, Kintambwe

5.3 Methodology per objective

5.3.1 Objective1. Scale-out community-based fruit-tree growing using multipurpose species.

Household study

Household study design

As part of the baseline, a household study was conducted, which combined qualitative and quantitative methodologies. The study aimed to gather data on the role of trees and fruit trees in people's livelihoods and farmers' perceptions and attitudes towards on-farm trees, including their benefits, challenges, opportunities, and contribution to climate adaptation and mitigation of climate change. For the household survey, the primary respondents were adults in the household. The survey covered the household's characteristics, farming practices, tree management, fruit consumption, future aspirations to plant trees, sources of fruit planting materials and varieties grown, climate change, and sources of household income. This survey was complemented by sex-disaggregated focus group discussions, farmer interviews, and key informant interviews to explore further local attitudes toward climate change, fruit trees' role, and the gender roles and relations surrounding fruit tree production.

A sampling of the respondents

The survey employed a multi-stage sampling method. Multi-stage sampling is a method of sampling that involves selecting a sample from a larger population in several stages. In the first stage, a sample of two sub-counties/districts was selected from each county based on the population of fruit trees. Then, in the second stage, a sample of wards/ cells was selected from each sub-county based on; proximity to physical and institutional infrastructure. In the third stage, a sample of villages was selected from the wards based on accessibility and distribution along the altitudinal gradient, and individual households were then randomly selected from each village. This process was repeated for each county until a full sample was obtained. This approach resulted in a total sample size of 220 and 135 households in Kenya and Rwanda. Because of their proximity and the small sample size for the interviews and focus groups, the sites were treated as one. Furthermore, the agroecological conditions at the sites are similar, and interviewees reported growing similar crops and fruit trees across the sites. Nonetheless, there are subtle differences between the sites that did not apply to all of them, with fruit tree production varying slightly between villages even within the same site. A government key informant was used to describe these differences and shed light on differences in fruit tree preferences and decision-making.

Data Collection and Analysis

Data collection occurred in June and July 2022 in ten Kiambu and Makueni wards and six Bugesera district cells in Rwanda. In Kenya, twenty enumerators and four supervisors were involved in the household survey, and five enumerators conducted the FGD and interviews. Key Informant Interviews (KII) were conducted with agricultural officers, officers within the Ministry of Gender and Social Protection, county foresters, and community service volunteers. The household survey was conducted using a digital form on ODK Collect. KII data was collected using audio recordings, charts, and note-taking. Quantitative data were analysed descriptively using STATA 17 and cross-tabulations and mean comparisons, cross-checked for errors and inconsistencies and presented in tables, graphs, charts, and figures. Qualitative data from interviews and FGDs were analysed using a thematic coding system, and textual information from interviews and FGD notes were compared across groups and individual cases to identify the predominant topics and issues.

Tree inventory Sampling method, data collection, and analysis

Tree inventory sampling was partially tied to the household sampling framework to collect information on tree sizes and the distribution of fruit trees. Before inventory, a reconnaissance survey was conducted to identify representative units, familiarize themselves with the landscape, and retool the inventory team: the reconnaissance survey involved transect walks, formal discussions with stakeholders, and informal discussions with selected farmers. Sub-country agricultural officers assisted in identifying farmers during the reconnaissance. A third (30%) of the households involved in the tree baseline survey were selected, and their farms were used for tree inventory exercise. Farms were chosen randomly from the baseline sample within the study areas based on their distance from the road, ensuring a minimum length of 1 km from each farmer. This was done to increase the variability of the tree species recorded. This approach allowed the team to capture a representative sample from all farmer groups and assess variations in the composition and proportion of fruit trees on farms. Tree inventories were conducted on the cultivated land of farmers, where a socio-economic survey was carried out. We defined cultivated land as the area used for growing crops regularly or permanently, including land that was (at the time of the survey) uncultivated but would be used for cultivation in the following season or year.

Depending on the type of land used, farms were divided into different categories. We identified and recorded every tree for every land use. A taxonomist, a field guidebook (Maundu and Tengnäs 2005), and a plant identification app were used to identify both local and scientific names of the trees in the field whenever it was possible. Trees with a DBH of 2.5 cm and a height of 2 m, the diameters at breast height (1.3 m above the ground) and collar diameter (30 cm above the ground) were determined using common tape. Lean trees, sloped trees, trees with swellings at breast height, forked trees, and multi-stemmed trees had their DBH measured according to specific procedures. Moreover, the crown measurements of the trees (the width and length of the longest axis) were determined.

Data analysis comprised species diversity indices (species richness, abundance, and Shannon-Weiner diversity index), and standing characteristics (system density, basal area, mean DBH/CD, and distribution of individuals in different diameter classes) were calculated across sites for each land use type. The Shannon diversity index was used to calculate the number of species in the land use and the distribution of a given species within the sample. Tree species' regeneration status was determined based on the number of seedlings, saplings, and mature trees. Regeneration was considered (1) good when seedlings > saplings > mature trees; (2) fair when seedlings > saplings > mature trees; (3) poor when there were saplings but no seedlings; (4) none when only mature trees were found with no seedlings or saplings; and (5) new when only saplings and seedlings were present, with no seeds.

5.3.2 Objective 2. The right trees are in the right places. Show smallholders how to site trees on farms to maximize climate adaptation benefits.

This objective built on the findings of the baseline survey, focus group discussions, and tree inventory surveys to tailor the training and capacity-building workshops to the gaps and needs identified. The tree inventory and household surveys captured places where different species were planted on farms. The data, alongside secondary data and local knowledge were used to come up with nine on-farm suitable species niches, namely, as a live fence, on cropland boundary, scattered in cropland, scattered in homestead, homestead boundary, woodlot, along soil conservation structures, lake/river shores and road boundary. Additionally, secondary data, local knowledge, and baseline reports were also used to identify multiple ways in which the identified species could be beneficial to smallholder farmers. The identified uses include 18 climate adaptation uses, such as income, and nutrition in the form of fruits, among others, and seven climate mitigation uses like nitrogen fixation and source of mulch just to mention a few. All this information was assembled to come up with a Tree Utilities sheet for the online tool. The Interactive Tree Species and Shrubs Selection and Management Tool for Climate adaptation and Mitigation in Kenya.
On the other hand, gaps identified in the seed and seedling supply systems especially seed /seedling sources like nurseries, and gaps in agronomic practices in farming fruit trees were used to design context-appropriate training in each site. The target audience was also carefully selected jointly with county / sector leadership for effective scaling. The project leveraged existing extension approaches that included TOTs, lead/champion farmers, cooperatives, and outreach events like Umuganda in Rwanda to train and reach beneficiaries.

5.3.3 Objective 3. To Estimate fruit tree carbon sequestration benefits to determine the potential for access to international climate finance that could further accelerate scaling out.

Sampling strategy

In Kenya, two administrative locations were selected in each county i.e., Wote-Nzui and Wote in Makueni, and Githunguri and Gatundu South in Kiambu. To have a representative sample, farms were randomly selected from six wards (Kiambu, Komothai, Githunguri, Kiganjo, Ndarugu, Ngenda, Ngewa) in Kiambu and four sub-wards (Kilala, Nziu, Ukia and Wote) in Makueni (Figure 1). While in Rwanda, two sectors in Bugesera district were selected; Rweru and Juru. These areas were selected because they represent different ecological conditions, farming systems, and market access. Trees selected for building allometric equations were chosen randomly from an inventory list created from a multistage sampling procedure with simple random selection as well as from the literature review. Using data from the inventory of fruit trees in the study area the choice of trees for constructing allometric equations was based on DBH/CD for the target species. DBH is the most familiar variable used to stratify populations based on tree size. In the case of grafted mangos, CD, or crown area, in the context of remote sensing, it was used to stratify the population. By choosing trees that represented the entire range of tree sizes encountered during tree inventory, a representative sample for this study was obtained. Trees listed in the inventory were organized into groups by diameter to stratify the sample based on size. Additional details like the canopy type, phenology, or management were also considered in tree selection. The development of allometric equations for biomass estimation was the goal of this study, which chose to use the mango (*Mangifera indica*) and avocado (*Persea americana*) tree species. Oversampling was avoided, and bias was kept to a minimum. To ensure the sample was as representative as possible, trees that were badly damaged, hollow, or whose growth was significantly impacted by diseases were excluded. However, trees that had been pruned or whose crown geometry had changed due to intersection with other trees were included in cases where they accounted for a sizable portion of the landscape's tree population. The study avoided randomly picking trees along the route to prevent a biased sample selection.

5.3.4 The endline study: Assess the effectiveness and uptake of selected project interventions/approaches on key intermediate outcomes

The endline study happened in the project sites where project interventions took place. Kiambu and Makueni sub-counties in Kenya and Bugesera district in Rwanda (Table 2)

Table 2: Fruits Trees for Climate Change Mitigation and Adaptation Project and Extension Sites

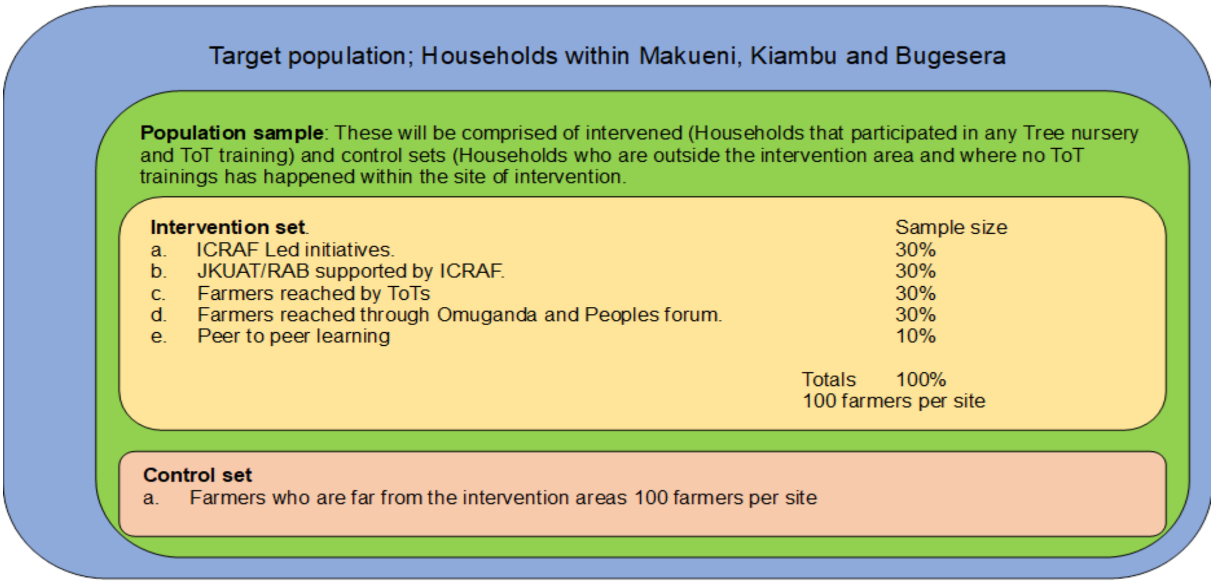
Country	Type of trainings	County/ sector	Baseline/Focused project sites	Areas covered by the extension
Kenya	GAP	Kiambu	Ngenda, Githunguri	Ngenda, Kiamwangi, Witeithie, Ikinu, Riabai, Kiambu township, Githunguri, Ting'ang'a, Wa Mwangi, Ndumberi,Chania,Githombokoni, Gatundu, Ndeiya, Ndundu, Kiganjo, Limuru, Thika, Githiga,Bibirioni, Togoni, Ngecha, Komothai
		Makueni	Wote-Nziu and Ukia	Ukia, Kilala, Nziu, Muvau-Kikumini, Kaiti, wote
	Tree Nursery Management	Kiambu	Gatundu South,and Githunguri	Ngenda, Kiamwangi, Witeithie, Ikinu, Riabai, Kiambu township, Githunguri, Tinganga, Wa Mwangi,Ndumberi,Chania a,Githombokoni,Gatundu, Ndeiya, Ndundu
		Makueni		Wote and Ukia
Rwanda	GAP and Tree Nursery Management	Bugesera	Njuru, Rweru	Juru, Rweru

The study used a quasi-experimental research design (Harris et al., 2006), where the participants were divided into two groups. One group received training or intervention from ICRAF, KALRO, JKUAT and the Rwanda Agricultural and Livestock Resources Board (RAB). The trained farmers who were the trainers of trainers (ToTs) further trained more farmers in their respective settings by customizing the training to address their challenges. Other farmers were reached through peer-to-peer learning by their fellow farmers through knowledge sharing and observation of practices on their farms. The other participants were farmers within the intervention site, far from where the ToT training came from. The training had not reached them, and they were termed control/non-trained farmers.
The sample was determined using Cochran's sample size determination formula.

$$n = \frac{Z^2.P.(1-P)}{e^2}$$

Figure 4

The ACIAR Fruit tree for climate change mitigation and adaptation project endline impact/output assessment sampling frame.



Where e is the desired level of precision, p is the fraction of the population that displays the attributes, and Z is the z value. Then, the total sample was apportioned into tertiles for those trained directly by ICRAF, those trained by ToT, and those trained by farmer-led and supported by ICRAF (Figure 4). The control set constituted farmers from the same project sites, where no ToT came from, and no similar training from ICRAF had happened in the last ten years. The study targeted a sample of 100 trained farmers and 50 non-trained farmers on GAP. However, the study managed to interview more farmers; 179 in Kiambu, 189 is Makueni and 296 in Bugesera.

This study method enhanced the generalizability of findings to broader populations and contexts. The method is also well-suited for longitudinal studies, allowing researchers to study variable changes over time and assess the impact of interventions or treatments longitudinally. The study assumed that project activities and interventions impacted farmers' KAP (Knowledge, Attitudes and Practices) and that farmers with training would differ from those without. The study also assumed that no organization had ever conducted similar training between baseline, capacity development, and endline activities at the same project sites for the same farmers. Therefore, the control group results would be similar to baseline analysis results. Therefore, the study assumed that there would be differences in the knowledge, attitude, practices, and intention of good agricultural practices, tree nursery management, and climate change adaptation and mitigation between trained and non-trained farmers.

Figure 34: Sampling frame of trained and non-trained farmers on GAP through FT4CCM&A

The study employed structured household interviews to gather data. The selection of this data collection approach was based on the study's quantitative nature, with the goal of ensuring consistency in comparing farmers who have received training and those who have not. An interview guide was developed using the Open Data Kit (ODK) platform to optimize data entry and administration procedures. Trained field enumerators, who received extensive training on interview techniques and data collection procedures, conducted the interviews in person, following a standardized protocol to ensure the data's consistency and dependability. The interview guide covered questions on demographic characteristics, tree growing, access to extension services, knowledge, attitudes, practices, and aspects related to the theory of change. Each interview was recorded in the ODK system to facilitate real-time data collection, immediate digital storage, and automated error reduction, hence effectively reducing errors linked to manual data entry. Before the data collection phase, a pilot test was conducted to refine the interview guide and ensure its clarity and relevance. Feedback from the pilot test was incorporated into the final version of the interview guide. Once the data collection was complete, the dataset was exported from ODK to Stata for analysis. The research concentrated on cross-tabulation, a technique that examines the relationship between trained and non-trained farmers regarding their participation and intermediate outcomes from training on Good Agricultural Practices (GAP) and nursery management.

6 Achievements against activities and outputs/milestones

Objective 1: To Scale-out community-based fruit-tree growing, using multipurpose species where possible

No.	*Activity*	*Outputs/ milestones*	*Completion date*	*Comments and supporting documents*
1.1	Conduct farm surveys and synthesize existing literature to assess dominant agroforestry practices and identify priorities, challenges, and opportunities for integrating diversified fruit trees on farms.	Baseline Report	Aug 2022	• Data collection tools for the household baseline survey and Tree inventory data collection sheet were developed and pre-tested. • Household baseline surveys and tree inventories were conducted in Kenya and Rwanda, and respective reports were produced (Wakaba et al., 2022d; Loreche et al., 2022). • The baseline survey involved 202 (120 Kiambu, 102 Makueni) and 169 (92 Rweru and 77 Juru) households in Kenya and Rwanda, respectively. • During data collection, 42 enumerators were involved; 20 (12 tree inventory and eight households) and 22 (14 households and 8 for tree inventory) enumerators were engaged in Kenya and Rwanda, respectively. • Key findings on current agroforestry practices were: i. The common agroforestry practices in the two countries are keeping livestock and growing crops together with trees. ii. The key challenges facing tree growing in Bugesera and Makueni were water shortages, pests, and diseases, while tree growing in Kiambu was hampered by limited knowledge of tree growing, a low survival rate, and poor-quality planting materials. iii. Farmers in Kenya (89%) and Rwanda (88%) have felt climate change. The farmers' Perception of climate change was that it is attributable to frequent droughts, temperature increases, unpredictable rainfall patterns, and increased pests and diseases. iv. Farmers plant trees for products and services. In Makueni, farmers are service-oriented (Rainfall), while in Kiambu and Bugesera, farmers are product-driven (Income). v. In the two countries, the priority tree was found to be a fruit tree species. In Kiambu and Bugesera, the most prioritized tree was *Persea americana*; in Makueni, citrus fruits were the most prioritized species. vi. There is a huge gap in extension supply across the study sites. In Kenya, only 19% and 16% in Kiambu and Makueni, while 10% in Bugesera. This was against an extension demand of 85% in Rwanda and 96% in Makueni, and 86% in Kiambu.

		Priority fruit species database developed.	June 2022	• A priority tree species database tools for Kenya and Rwanda were developed (Muthuri et al., 2023; Kuria et al., 2022). Between 2023 and 2024, the Rwanda and the Kenya online tools pages have been viewed by 11,937 users, 2,865 times. It captures fruit and non-fruit trees, both exotic and indigenous species encountered from tree inventory and baseline studies conducted in the project sites in the two countries. The Kenya tool (Muthuri et al., 2023) has 178 trees and shrubs that were identified in Makueni and Kiambu, which fall into 52 families: with the dominant three main families being: Fabaceae 32, Rutaceae 11 species, and Myrtaceae 10 species. Among the documented species, 101 are native tree species, while 77 are exotic species. Thirty-five species were found in both Makueni and Kiambu counties, while 143 species were only present in one of the counties. • For Rwanda (Kuria et al., 2022), the priority species selection tool captures the 57 species (31 exotic, 26 native) identified in the current tree inventory and the earlier ones captured under the T4FS project in Bugesera district, for a total of 164 tree and shrub species. The species spread across 60 families, mainly Fabaceae (18%). The majority of encountered tree species were native 110 species (67%) compared to 54 (33%) exotic tree species. • The tool provides a comprehensive list of uses of the tree species encountered such as climate adaptation (products), climate change mitigation (ecological services), cultural services and on-farm niches or locations where the tree species are found. It also provides the bio-physical profiles of the tree species, including general attributes, growth requirements, and reproduction information; and finally provides links to other databases where further information can be found. • The local communities will use this tool to identify tree species and their cultural and adaptive uses, mitigation, and niches. • The tools have also been converted into online versions found here: Kenya and Rwanda in order to reach wider audiences including extension, development organizations, and institutions of higher learning among others • Mobile offline applications on fruit trees have been developed and are available on Google Playstore. The app is dubbed Kuza Matunda (grow fruits) and provides information on uses and management in Kenya. Another offline mobile App was developed for Rwanda dubbed Igiti providing information on the uses and management of tree species under the 'suitable tree species selection and management tool' in Rwanda. Kuza Matunda and Igiti offline mobile Apps have been downloaded and installed on users' devices 419 times and 53 times respectively.

		Journal article on gender and fruit tree systems	Feb 2023	• In Makueni County, Kenya, a study focusing on gender decision dynamics regarding the planting and use of fruit trees on smallholder farms and how decisions regarding the future planting of trees can reflect each gender's aspirations was conducted. This resulted in an MSc dissertation (see Cohen, 2022). A draft manuscript from this MSc dissertation has been prepared and will be submitted to Frontiers – Sustainable Food Systems (Cohen et al., 2023) (in prep) titled, "Understanding gendered aspirations, decision-making, and fruit tree preferences in Makueni County, Kenya." Abstract: In Makueni County, fruit tree production offers a promising strategy for climate change adaptation and improved food and income security. However, little is known about local species preferences and how these may be changing in response to growing markets and climate change. • Further, tree species preferences and tree management and decisions are often gendered. Understanding the intrahousehold decision-making dynamics surrounding tree planting and women's and men's needs and aspirations concerning fruit trees is necessary to provide relevant support to smallholder farmers. To explore gendered species preferences and decision-making dynamics regarding fruit tree production and investment, we combined semi-structured interviews, focus group discussions, and a household survey (see Cohen, 2022 and Cohen et al., 2023) (in prep) to be submitted. • Our findings indicate that rural livelihoods in Makueni County are increasingly focused on fruit tree production. While this has potentially positive implications for income, food security, and climate resilience, farmers' preference for a narrow selection of exotic tree species may threaten both on-farm and landscape species diversity. • Further, compared to women, men held greater decision-making power over fruit tree species selection and management. Both men and women farmers attributed men's greater role in tree-related decisions to land ownership, knowledge, and cultural norms, which place men as household heads and the ultimate decision-makers. Based on these findings, we contend that more inclusive approaches that pave the way for transformative change in gender relations and amplify women's voices in species selection could help diversify future fruit tree portfolios and achieve more equitable production outcomes. Such interventions include more inclusive and gender-responsive training on fruit tree production and nursery management and an emphasis on the adaptive benefits of economic diversification for resilient livelihoods. • In Rwanda, a study identified areas of jointness and non-jointness in fruit-tree-related tasks and decision-making in training, nursery management, tree plantation tree management, fruit, timber, and non-timber products harvesting, product sales, and income uses. The focus group discussions were conducted in the Rweru and Juru sectors of the Bugesera district. In total, 20 participants were involved: five men and five women in each sector. • Key findings showed that avocado was the most sorted out fruit tree because it is produced all year and is popular because it can be used to vary the diet. Oranges and citrus were highly valued in Juru, while tree tomatoes and pawpaw are gaining ground in the Rweru Sector as they produce more consistently throughout the year. They saw their livelihood improve as a result of selling the fruits. Given the constraints,

				all participants stated: Fruit tree pests and diseases; knowledge gaps in pest and disease control; long droughts; knowledge gaps in water harvesting and storage; seedlings are too expensive because they take a long time in the nursery and require grafting materials.
1.2	Assess the proportion of fruit trees on farms and consult stakeholders on priority fruit trees.	Report of an analysis of existing fruit species proportions and recommendations of priority species from workshops.	Sept. 2022	• The number and proportion of fruit and nut trees (both exotic and indigenous) recorded and contained in respective tree inventory reports produced (Kuyah et al., 2022-Kenya tree inventory report) and Cyamweshi et al., 2022 Rwanda tree inventory report. • Results show, that 56 species (31%) out of 178 tree species were fruit tree species. • In Rwanda, 63 species (38%) Kuria et al., 2022 and Wamaitha et al., 2023a. of the 164 species (current 57 plus earlier 107). • Priority fruit tree species were identified in household baselines, which are recorded concerning all the tree species identified in Bugesera district (Rwanda) (Loreche et al., 2022 Rwanda Baseline report), Makueni, and Kiambu counties in Kenya (Wakaba et al., 2022d- Kenya Baseline report). • Workshops were held in Kiambu on the 4th and 5th of July 2022, Wakaba et al., 2022b Kenya Baseline report, and a reconnaissance study visit Wakaba et al., 2022c on 15th July 2022. A similar engagement with stakeholders in Makueni Wakaba et al., 2023a was done on 10th June 2022 with participation from various stakeholder groups, including researchers, tree growers, government representatives, and traders of tree products, to determine priority fruit trees for project sites and to consider which fruit trees would be most viable under future climatic conditions and have promising future demand.th June 2022 with participation from various stakeholder groups, including researchers, tree growers, government representatives, and traders of tree products, to determine priority fruit trees for project sites and to consider which fruit trees would be most viable under future climatic conditions and have promising future demand. • Six gender-disaggregated focus group discussions were also held with community members to complement the findings from the workshop findings (Cohen, 2022). • The findings revealed that priority tree species are chosen based on their contribution and significance in developing resilient production systems for both short-term coping mechanisms and long-term livelihood diversification in the face of climate variability and change. • As a result, fruit trees were the most sought-after tree species across all study sites—both households and the local government in Kenya prioritised avocado, macadamia, citrus, and Mango. In Rwanda, households preferred avocados and pawpaw.

1.3	Conduct assessment on different sources of planting materials required to promote fruit growing at scale.	Report on sources of quality planting materials.	Aug 2022	• The main sources of the planting materials were mapped out during households' baseline surveys conducted in Kenya and Rwanda, and findings are contained in the respective reports (Wakaba et al., 2022d_Kenya Baseline report; Loreche et al., 2022-Rwanda Baseline report • In Kenya, farmers primarily use seedlings, seeds, grafted plants, and buddings obtained from traders and tree nurseries, while some farmers purchase fruits and save the seeds. • In Rwanda (Bugesera), seedlings, seeds, and grafted materials are the most common planting materials used for fruit tree propagation. Most of these materials come from farms, government nurseries, rural resource centers, neighbors, family members, and friends.

PC = partner country, A = Australia

Objective 2. The right trees in the right places. Show smallholders how to site trees on farms to maximize climate adaptation benefits.

No.	*Activity*	*Outputs/ milestones*	*Completion date*	*Comments*
2.1	Enhance capacity to raise, use, and improve the stock of diverse tree species, especially Indigenous species, selecting species for multiple benefits, and maximising adaptation benefits including through farmer-managed natural regeneration (Makueni)	Workshop report	Aug 2022	• In Kenya, two training workshops on tree nurseries were conducted in Kiambu and Makueni directly reaching 81 (44M, 37F) participants (nursery operators, lead farmers, and county agriculture extension officers), equipping them with knowledge and best practices on seed/seedling production, pest and disease management, and tips to run and manage tree nurseries as a business (Gachuiri et al, 2022a-Nursery report). • In Rwanda, tree nursery training covered agronomic practices for 120 (64M, 46F) participants, including 111 farmers, 2 two sector agronomists, and 7 RAB staff (Cyamweshi et al., 2023a). • Trainees included nursery managers, spouses, and employees wherever possible to promote inclusivity. County Ward agriculture officers supported the selection of lead farmer participants to train per farmer and supported the training of trainers (TOTs). The inclusion of extension officers from different wards ensured that training could be replicated in their respective regions. Training topics covered: a. Tree nursery setup, management, and best practices b. Hands-on training on vegetative propagation techniques like grafting, budding, and marcotting c. Networking by tree nursery operators by bringing together local nursery operators and extension agents. d. Tree nursery business development/entrepreneurship e. Nursery certification: ICRAF is collaborating with KEPHIS to certify tree nurseries. • In Kiambu, 430 true-to-type avocado seedlings were distributed to 101 farmers of whom 31 farmers who offered trees for biomass estimation and 70 other community members. The ToTs provided training to the 101 farmers on proper tree planting and management. • 200 assorted tree seedlings were distributed towards the tree planting drive during the 2023 Children's Devolution Conference held at MPESA Foundation Academy in Kiambu County, with over 250 children from across 47 counties attending. • 30 assorted fruit tree seedlings were issued during school tree planting day at Githaruru Primary and Gatundu Secondary School.
		Training manual on tree growing and management for multiple benefits	Dec 2022	• A training manual on avocado agronomic techniques (fruit tree pest and disease management, pruning, spacing and orientation, fertilisation, and sitting) was developed (Gachuiri et al., 2023) • The avocado and mango training manual was also produced for Rwanda and translated into Kinyarwanda for farmers' ease of use (Cyamweshi et al., 2023b). • The manuals provide straightforward steps in conducting training of lead farmers and ToT to deliver training on good agronomic practices (GAP).

		Tree species selection tool for Makueni	March 2023	• A Tree Species Selection Tool based on tree inventories conducted in Kenya (Muthuri et al., 2023a) and Rwanda (Kuria et al., 2023) was developed. The tool contains 178 (101 indigenous and 77 exotic) and 164 (indigenous 110 and 54 exotic) tree species in Kenya and Rwanda, respectively.
2.2	*On-farm training for agronomic practices (Pruning, spacing, pest and disease management, fertilization, siting) for improving fruit-tree productivity and climate adaptation benefits*	250+ farmers are trained on agronomic practices for fruit tree benefits	April 2022-April 2023	• In Kenya, two workshops on good agronomic practices with a focus on improved avocado and mango production practices were conducted in Kiambu and Makueni with a total of 136 (64 Female, 72 male) participants. The workshops targeted farmers, nursery operators, and county agriculture extension officers (*Gachuiri et al, 2022a*; *Gachuiri et al, 2022b,* and Gachuiri et al 2022c) • In Rwanda, a similar training reported in 2.1 above incorporated a tree nursery component, bringing together 110 farmers, and sector agronomists, (64 males and 46 females (*Cyamweshi et al., 2023a*). **Participants were trained on.** a) Good Agricultural Practices (GAPs), orchard hygiene, and integrated pest and disease management practices. b) Scaling up improved avocado and mango farming technologies and practices that result in increased productivity. c) Fruit marketing to help farmers become more self-sufficient while increasing efficiencies and profitability. d) Field experience in food tree planting and management, as well as pest and disease identification and control. e) Gender-responsive agroforestry practices that consider the unique needs, priorities, and constraints of men and women. Farmers' perspectives on fruit tree farming and the challenges faced were assessed during the training. • In addition, in Kenya, a combination of ICRAF-led, County government / ICRAF / JKUAT partnership and ToT extension approach was employed whereby 1983 farmers (920 women and 1063 male) and extension workers were trained on different aspects of fruit growing and climate change; 23 of which attended more than one training thus translating to 1960 **beneficiaries reached.** In Rwanda, ICRAF in partnership with RAB, trained 445 farmers and extension officers (279 male and 166 female). Through Umuganda, 242 and 189 farmers were trained in Juru and Rweru. Additionally, 186 females and 201 males were trained in the citizen's forums.

2.3	Capacity-building of smallholders on fruit tree production, nurseries, and income-generation	Training manuals customised to context. Around 150 farmers were trained, and at least two cooperatives were set up	June 2022-May 2023	• Training manual for avocado and mango farmers for Rwanda context (Cyamweshi et al., 2023b) and Kenya (Gachuiri et al., 2023) were developed • In Rwanda, farmers were reached by the project through Lead farmers trained by the RAB and ICRAF. In total, the number of farmers trained by the lead farmers is 110, among which are 46 women and 64 men (Cyamweshi et al., 2023a). • Digital platforms, such as WhatsApp groups, have been formed to connect actors such as cooperatives, community nurseries, and extensionists. • In Kiambu, the Avocado and Macadamia Cooperative (AVOMAC) was formed following the training and officially registered in June 2023 with support from ICRAF. The cooperative brings together over 1158 members (922 Males and 236 females) to enable better price negotiation and develop the avocado and macadamia collective value chains in the Gatundu South sub-county.
		Four individual and six cooperative nurseries were strengthened or set up.	June 2022-May 2023	• In Rwanda of the 111 farmers trained in agronomic practices and tree nursery operations,**17 were nursery operators**. After the training, the project has continued to capacitate ***one existing cooperative*** nursery in Juru and another individual nursery in Rweru, whereas ***four individual nurseries*** (2 Juru and 2 Rweru) are being set up with technical support from the project. This totals **6 nurseries** • In Kenya of the 77 staff trained on nursery operations, **45 were nursery operators,** and currently, **30 individual nurseries** are being supported in Kenya (15 in Kiambu, especially nursery certification and access to quality true-to-type seedlings while 15 in Makueni are being strengthened on matters of accessing quality seeds of Indigenous fruit trees and their propagation.

Objective 3: To Estimate fruit tree carbon sequestration benefits to determine the potential for access to international climate finance that could further accelerate scaling out.

No.	Activity	Outputs/ milestones	Completion date	Comments
3. 1	A Systematic review on the estimation of aboveground biomass in fruit trees and contribution to NDC	Literature review report	April 2022	• An extensive literature review on the prevalence, density, and estimation of aboveground biomass in fruit trees was done https://drive.google.com/file/d/1q1av0-655WJSGtIY9M9dhFHPS2jnGLYR/view?usp=drive_link • A protocol was alos developed for building Allometric equations for estimating of biomass in Fruit trees Kuyah & Muthuri, 2022a.
		Refereed journal article		• A journal article on 'Agroforestry's contribution to livelihoods and carbon sequestration in East Africa' Muthuri et al., 2023 has been published in 'Trees, Forests and People'.

3.2	Development of allometric equations through destructive sampling and remote sensing	A protocol for establishing allometric equations for the estimation of biomass in fruit trees	March 2022	• Kuyah and Muthuri (2023a) developed a protocol for building an allometric equation for estimating biomass in fruit trees in East Africa. This protocol provides guidelines for building allometric equations for fruit trees through destructive sampling and practical guidance on conducting on-farm tree inventory to estimate carbon stocks. The protocol was applied to ensure rapid and accurate tree inventory and biomass estimation measurements in Kenya and Rwanda. • In Kenya, allometric equations were developed from data collected on 51 mango trees and 40 avocado trees harvested in Makueni and Kiambu Counties, respectively. In addition, from an inventory of 23 plots in Makueni (total area = 4.4 ha) and 36 plots in Kiambu (total area = 14.42 ha), aboveground biomass in mango trees was estimated to be 22.3±6.3 Mg ha^{-1} and 20.6±5.4Mg ha^{-1}, respectively. Kuyah et al., 2023. • In Rwanda, 60 mangoes and 48 avocado trees, and analysis of establishing allometric equations is ongoing in Rwanda (This activity was delayed since the instruments were delivered later) • Landsat 8 satellite imagery was used to estimate vegetation indices to serve as predictors within machine learning models, enabling the prediction of aboveground biomass by providing information regarding vegetation density, greenness, and moisture content.
		Training Manual on Rapid Carbon Estimation.	May 2023	• A training manual on carbon rapid carbon estimation was developed by Kuyah & Muthuri 2023c. The manual aimed to build the capacity of farmers, land managers, and community facilitators to monitor carbon benefits in fruit trees. Additionally, it brought users up to date with field measurements, selection of allometric equations, and calculating carbon stocks.
3.3	Quantification of carbon stocks in fruit trees	Refereed article on the carbon sequestration of fruit trees and potential for accessing climate finance.	May 2023	• A journal article on "Allometric equations and carbon sequestration in mango (*Mangifera indica*) and avocado (*Persea americana*)" in Kenya (Kuyah et al., 2024) was submitted and published in the Journal of Trees, Forest, and People. • Analysis of Rwanda data is a complete compilation of the report has been completed (Cyamweshi et al., 2023c)
		Infographics, policy briefs, and policy dialogues on the determination of carbon in fruit trees and their contribution to countries' NDCs.	April 2023	• As part of the lower-level (county) policy dialogue, 87 and 58 stakeholders (including county officials, farmers, and relevant local partners) in Kiambu and Makueni received training on climate change adaptation and mitigation following the biomass evaluation work in Kiambu and Makueni. The training aimed to sensitize farmers on how fruit trees can help adapt to and slow climate change; show how farmers can help stop climate change and what the international carbon finance market could do for them. • Infographic poster (Kuyah et al., 2024b) and policy brief (Muthuri et al., 2024) have been developed.

Objective 4: Endline Survey-Assessing the effectiveness and uptake of selected project interventions /approaches on key intermediate outcomes

4.0	Assessing the effectiveness and uptake of selected project interventions /approaches on key intermediate outcomes	March 2024	• Endline surveys were conducted, capturing 367 (179 Kiambu and 188 Makueni) and 296 households in Kenya and Rwanda, respectively. • The survey included farmers who were trained under this project on Good Agricultural Practices, *(*Gachuiri et al, 2022a; Gachuiri et al, 2022b) *and (Cyamweshi et al., 2023a)* and tree nursery (*Gachuiri et al, 2022a-Nursery report) and (Cyamweshi et al., 2023a)* and non-trained farmers who were selected within the project site where the project did not intervene, nor other organisations had offered similar training within the same period. • Eight and Six enumerators were employed to conduct endline surveys between November and December, and January 2024 in Kenya and Rwanda, respectively. • Two reports were produced in Kenya *(Wakaba et al., 2024)-Kenya Endline Report* and the Cyamweshi et al., 2024-Rwanda *Endline Report.* • The reports highlighted the differences in Agroforestry and tree growing, Knowledge attitude and perception between trained and non-trained farmers. The work further looked at behaviour change the theory of change, using farmers' attitudes, subjective norms, perceived behaviour, Injunctive, descriptive and intention. **Key finding results showed that:** • In both countries, the training had a direct contribution to tree planting. In Kenya, a trained farmer planted an average of 27 different tree species while Rwanda 77 trees were planted in farms and Umuganda forums by trained farmers over the last one year. Farmers who had received GAP and tree nursery management training planted more trees than non-trained farmers. • Comparing the number of farmers who had received extension services in the last two years before the project. The use of ToT training approaches led to an increase in the number of farmers, by 200% in Kiambu and Makueni in one year. While in Bugesera, the proportion of farmers who received training increased from 7.5% to 65%. • In both countries the training impacted more knowledge on grafting and understanding of climate change. It changed attitudes on pest management, seedling sourcing, and taking responsibility in fighting climate change, and it led to the adoption of practices on tree management, soil water management, and proper harvesting timing. • The training strengthened the linkages between farmers and government extension services (Kiambu-77%, Makueni-60%, and Bugesera 79%). • The training led to changes in gender inclusion in decision-making in Makueni 91% and Bugesera 50%, and benefit-sharing in Kiambu 63% among the members of the households based on gender and age • The training has raised the standard of socio-cohesion and cooperation to make societal differences by extending training to other farmers. 97%, 99%, and 98% of farmers from Kiambu, Makueni, and Bugesera, respectively. Are freely willing to extend their knowledge to other farmers • More trained farmers newly joined agricultural groups after the training (27% in Kiambu and 63% in Makueni), while 64% in Kiambu and 83% in Makueni activated their membership status. While in Bugesera, group enrolment increased to 71% among the trained farmers.

7 Key results and discussion

7.1 Scale-out community-based fruit tree growing, using multipurpose species where possible.

This component aimed at addressing the research question of 'What are the enabling conditions for increasing community-based fruit-tree growing?'. This was through determining the status of agroforestry trees/practices with a specific focus on fruit and nut trees in targeted regions of Kenya and Rwanda to identify the opportunities for and challenges to scaling up smallholder uptake. The baseline assessment included an analysis of intra-household gender dynamics surrounding fruit trees' uptake, management, and benefits and an analysis of the climate adaptation benefits of on-farm trees. This enabled the identification of knowledge gaps/bottlenecks for the identified priority species. Options for improvement in fruit tree propagation systems, management practices, and pests and diseases were identified. The existing database of tree species data from Rwanda was to be expanded based on the tree inventory studies while a similar tool was developed for Kenya (https://apps.worldagroforestry.org/suitable-tree/). Gender-responsive, impact-oriented interventions involving site-specific fruit trees will be promoted, whilst also considering their climate change adaptation potential for smallholder farming systems.

The detailed findings are presented below.

7.1.1 Household profile

Baseline household studies in Kenya and Rwanda which aimed at assessing dominant agroforestry practices and identify priorities, challenges, and opportunities for integrating diversified fruit trees on farms Wakaba et al., 2022-Kenya Baseline Report and Loreche et al., 2022- Rwanda Baseline Report. found that households in Bugesera are male-dominated (72%), while in Kiambu males are slightly higher than females 51% while in Makueni, more households are run by women (51%) (Table 3). The average age of the household in Kiambu was 56%, the highest among the study sites. The highest level of education reported for household heads across all the sites was tertiary with most heads being at secondary and primary levels at (42% and 31%) in Kiambu, (31% and 37%) in Makueni, and (11% and 63%) in Bugesera respectively. Households own and manage an average of one farm in Kiambu and Makueni, while Bugesera has two farms. Household sizes in Bugesera and Makueni had an average of five members, constituting an average of two females in Kiambu and Makueni, while in Bugesera (2), there were more females (3). On average, households in Makueni and Bugesera (2) had more children under 16, while Kiambu had an average of one. Households own and manage land of an average size of 2.6 in Kiambu, 1.7 in Bugesera, and 6.0 acres in Makueni. The land has been acquired by customary inheritance in Kiambu (91%) and Makueni (78%), while in Bugesera, the land was acquired through purchase (64%). Farm labour is mainly provided for by the household members across the three sites.

Table 3: Household demographics in Makueni and Kiambu Counties in Kenya and Bugesera District- Rwanda

Household profile table.

Household demographics	Kiambu	Makueni	Bugesera
Linear Variables			
Age (years)	56	52	45
Household size	4	5	5
Number of females	2	2	3

Number of children		1	2	2
Land size (acre)		2.6	5.97	1.73
Number of fields		1	1	2
Categorical Variables				
Gender of the household's head (Male)		51%	49%	72%
Land tenure	Purchased with title deed	11%	20%	64%
	Inherited	91%	78%	25%
The education level of the household's head	No Education	8%	10 %	25%
	Primary	31%	37%	63%
	Secondary	42%	31%	11%
	Tertiary	19. %	21%	2%
The primary source of labor	Family	78%	86%	96%

7.1.2 Agroforestry practices

Agroforestry is a type of land management where trees or other woody plants are grown alongside crops or livestock on the same plot of land. Agroforestry encourages the sustainable use of land, improves biodiversity, strengthens the soil's health, gives farmers access to new sources of income, and helps to slow global warming through carbon fixation. Agroforestry increases productivity while maintaining the long-term viability of the land by incorporating trees into agricultural systems. According to preliminary findings, Kuyah et al., 2022 Cyamweshi et al., 2022 cropland, the home compound, improved fallow, and natural fallow are the four most common land use types for farmers in Bugesera. However, natural farrow lands seem quasi-existent because they are practised on less than 0.7% of the cultivated lands in the study area. Juru has larger agricultural lands and home compounds, while Rweru has smaller farms. The difference in land size may be due to urbanization and competition for resources in city centres, where the population needs to constrain cultivated lands. In Kenya, the two main land use types are homestead compounds, where only family members manage perennial woody plants, and small crop fields, typically used to create kitchen gardens. Second, cropland is located outside the homestead and serves as the primary crop production area. Orchards are another land use for meticulously growing fruit trees: Mango (*Mangifera indica*) and *Citrus* spp. in Makueni, while avocado and macadamia orchards are mainly found in Kiambu.

The farming systems (semi-subsistence) are similar at the three sites, with slight variations in orientation in Kiambu, where horticultural and perennial crops are grown purely for sale (coffee, tea, and pineapple- *Ananas comosus*) Wakaba et al., 2022d. The main semi-subsistence crop growing along with trees growing in Bugesera is 72% maize and 85% beans, with livestock keeping (69%). In the last five years, 49% of households were found to have planted seven diverse fruit species on their farms, mainly avocado, mango, and papaya Loreche et al., 2022. In Kiambu, perennial cropping systems are practiced for commercial porpoises. Farms in Kiambu are also characterized by small woodlots dedicated to small-scale wood production. The main crops grown are maize (89%), beans (76%), Irish potatoes (53%), bananas (48%), vegetables (48%), and coffee (33.3%). Farmers keep livestock such as cows, sheep, and poultry while integrating these practices with trees. Due to small farm sizes (2.6 acres), there is a perfect integration of crops, trees, and livestock (83%). In Makueni, there are no crops or signs of crops from the previous season, but a few scattered trees that identify grazing land. While Makueni farms are relatively bigger (6 acres), farmers have integrated tree growing with crops such as maize (99%), beans (74%), cowpeas (28%), and kale (10%) in their kitchen gardens. Farmers also rear animals such as cows, goats, and free-range chickens Wakaba et al., 2022d.

7.1.3 Tree diversity and the proportion of fruit trees on the farm

Tree diversity refers to the variety of tree species present in each area or ecosystem, often measured as the total number of tree species in a particular area (species richness). Tree diversity is an important aspect of biodiversity and is crucial in maintaining ecosystem health and functioning. In Rwanda, the household study (Laroche et al., 2022) found that farmers have fruit trees on their farms (84.6%), with an average of three fruit tree species. *Persea americana* (69%), *Mangifera indica* (57%), *Carica papaya* (39%), and *Citrus limon* (33%) were the most prevalent fruit trees on farms. A tree inventory exercise (Cyamweshi et al., 2022) encountered 57 tree species in the Juru and Rweru Sectors, of which 31 are exotic, 26 are native and 19 are fruit tree species (Table 4). Including those from this study and the previous T4FS project, the total number of tree species in Bugesera district is 164, including 54 exotic, 110 native, and 63 fruit tree species. Among these, 14 fruit tree species are exotic, and 49 are native. Interestingly, among all tree species, the most dominant were the fruit trees: *M. indica* (17.3%), *P.americana* (17.1%), and *C. papaya* (14.3%), which are also the most dominant fruit trees in terms of the number of trees per farm. Other dominant non-fruit tree species in the Bugesera include *Grevillea robusta,* the most prevalent (14.03%), and *Senna spectabilis* (9.3%). The number of tree species across growth stages was high in cropland with 3 to 24 tree species across the cells of Juru and Rweru sectors. A lower number of species was recorded in fallowed lands across land use categories (Table 3). The higher the number of tree species, the higher was also the number of individual trees on a farm. In croplands and home compounds, farmers generally adopted more intensive management and higher tree density planting thus justifying the higher tree species richness. The Shannon Wiener index (H) was used to evaluate diversity per land use category and ranged from 1.04 to 2.3 in croplands across the cells Juru sector with a mean value of 1.67 indicating a low evenly distributed diversity of identified tree species. The same range of values of (H) was also observed in home compounds with values varying from 0 to 2.61 with a mean value of 1.3 thus indicating lower levels of diversity and evenness of agroforestry trees in farms of home compounds in Juru sector. The fallow recorded a very low level of diversity with H values ≤1.37. In Rweru sector, all the land use categories recorded lower values of the Shannon index ranging between 1.39 and 2.43 in croplands and home compounds thus indicating also lower level of tree species diversity (Woldearegay et al. 2018).

Table 4: Land use type, species diversity, and richness in Rweru and Juru sectors across growth stages

Sectors	Growth stages	Land use types	Number of households	Number of individual trees	Species richness	Shannon Weiner index
Juru	Tree	Cropland	46	434	24	2.3
		Home compound	29	209	26	2.61
		Fallow	3	16	5	1.37
	Seedling	Cropland	3	4	3	1.04
		Home compound	1	1	1	0
	Shrub	Cropland	9	19	7	1.08
		Home compound	3	9	3	0.68
	Sapling	Cropland	17	50	11	2.04
	All growth stages	Cropland	46	507	25	2.4
		Fallow	3	16	5	1.37
		Home compound	30	219	27	2.69
		Across land use types	64	742	34	2.57

Rweru	Tree	Cropland	37	277	23	2.27
		Home compound	50	464	33	2.43
		Fallow	3	13	4	1.03
	Shrub	Cropland	2	4	4	1.39
		Home compound	3	6	6	1.79
	Sapling	Cropland	5	12	6	1.54
		Home compound	10	21	9	1.77
		Fallow	1	1	1	0
	All growth stages	Cropland	37	293	26	2.36
		Fallow	3	14	4	0.99
		Home compound	50	491	37	2.47
		Across land use types	75	798	45	2.48

In Kiambu, species diversity for mature trees was highest on the homestead and lowest in orchards (Table 5). A similar trend was observed for saplings, with a value of 3.00 and 2.23 in home gardens. Woodlots had the highest Shannon diversity index for seedlings; perennial crop systems and orchards had the lowest sapling and seedling diversity. Species richness also varied across the land use types. Croplands and homesteads are Kiambu's most dominant land use types, with the highest number of species for the different growth stages. The average number of tree species per household ranged from 3 to 33. Orchards had a narrow range of species for seedlings, saplings, and mature trees. While in Makueni, nearly two-thirds (68%) of the species and 38% of the individuals recorded in Makueni are native to Africa. The homestead has the highest Shannon diversity index and species richness compared to grazing and cropland. Most individual tree species were found on homestead land, followed by orchards (Kuyah et al., 2022).

Table 5: Land use type, species diversity, and richness in Makueni and Kiambu across growth stages.

		Makueni			Kiambu		
Growth stage	Land use type	No of individuals	Species richness	Shannon index	No of individuals	Species richness	Shannon index
Trees	Boundary	40	8	1.46			
	Cropland	205	43	2.94	1090	43	1.92
	Grazing land	264	43	2.85			
	Homestead	708	79	3.29	434	57	3.03
	Orchard	488	9	1.3	119	13	1.41
	Soil conservation structures	87	13	1.79	203	21	2.21
	Woodlot	101	7	0.91	548	23	1.52
	Across land use types	1893	98	3.29	2488	82	2.51
Saplings	Cropland	12	2	0.29	485	31	2.16
	Grazing land	40	4	0.88			
	Homestead	71	9	1.65	98	29	3
	Orchard	37	3	0.96	27	8	1.64
	Soil conservation structures	7	2	0.41	200	10	1.49
	Woodlot	10	1	0	296	21	1.83
	Across land use types	177	14	2.21	1111	54	2.71
Seedlings	Cropland	2	1	0	308	22	2.11
	Orchard	121	4	0.76	144	25	2.23

	Across land use types	123	5	0.84	89	9	1.53
	Tree-crop systems				119	13	1.86
	Woodlot				119	16	3.25
	Across land use types				788	38	2.53
All growth stages	Boundary	40	5	1.46			
	Cropland	217	43	2.95	1883	52	2.15
	Grazing land	311	45	2.86			
	Home garden	781	80	3.24	667	68	3.21
	Orchard	646	10	1.54	235	17	1.73
	Soil conservation structures	94	13	1.94	522	24	2.14
	Woodlot	111	7	0.85	963	37	2.01
	Across land use types	2193	99	3.29	4389	99	2.75

The most numerous tree species were *G. robusta*, *Eucalyptus spp*., and *P. americana*, accounting for 61% of the recorded individuals. *G. robusta* (30%), *Eucalyptus spp*. (21%), and *P. americana* (19%) comprised 70% of the individuals identified in Kiambu for mature trees. Croplands are dominated by *G. robusta* (47%) and *P. americana* (22); homesteads by *P. americana* (21%), *E. saligna* (15%), and *G. robusta* (10%); orchards by *P. americana* (62%), *Macadamia integrifolia* (13%), and *G. robusta* (26%); and perennial tree-crop systems by *G. robusta* (26%) and *P. americana* (26%) (table 4). In Makueni on average, there were 85 trees per farm, but there were farms with as few as 24 trees and farms with as many as 178. *G. robusta* (17%), *P. americana* (11%), and *Citrus sinensis* (10%) made up the majority of the tree species when all growth stages were compared, making up 37% of the total number of individuals recorded. Of the mature trees (individuals) recorded, these species made up 40%. In Makueni, *G. robusta* dominated homesteads (24%), cropland (25%), woodlots (75%), and boundaries (50%), *Terminalia brownii* dominated grazing land (27%), *C. sinensis* dominated orchards (40%), and *Mangifera indica* was the most common species on soil conservation structures (39%). Twenty-four species, were represented by one individual, making them rare tree species (Kuyah et al., 2022).

7.1.4 Gender roles and relations surrounding fruit tree production

Focus groups were conducted in Makueni and Bugesera districts, where men and women were separately engaged in discussions on priority fruit species and decision-making. In Makueni County, fruit tree production offers a promising strategy for climate change adaptation and improved food and income security. Yet, little is known about local species preferences and how these may be changing in response to growing markets and climate change. Further, tree species preferences and tree management decisions are often gendered. Understanding the intrahousehold decision-making dynamics surrounding tree planting and both women's and men's needs and aspirations in relation to fruit trees is necessary to provide relevant support to smallholder farmers. To explore gendered species preferences and decision-making dynamics regarding fruit tree production and investment, we combined semi-structured interviews, focus group discussions, and a household survey (Cohen, 2022; Cohen et al., 2023-draft). Our findings indicate that rural livelihoods in Makueni County are increasingly focused on fruit tree production. While this has potentially positive implications for income, food security, and climate resilience, farmers' preference for a narrow selection of exotic tree species may threaten both on-farm and landscape species diversity. Further, compared to women, men held greater decision-making power over fruit tree species selection and management.

Although a gendered study was not conducted, similar trends in tree preferences due to product benefits were observed in Kiambu Wakaba et al., 2022d. Again, through workshop participation, it was observed that there was a difference in preference for tree species across genders. Both men and women farmers attributed men's greater role in tree-related decisions to land ownership, knowledge, and cultural norms that place men as household heads and the ultimate decision-makers. Based on these findings, we contend that more inclusive approaches that pave the way for transformative change in gender relations and amplify women's voices in species selection could help diversify future fruit tree portfolios and achieve more equitable production outcomes. Such interventions include more inclusive and gender-responsive training on fruit tree production and nursery management and an emphasis on the adaptive benefits of economic diversification for resilient livelihoods.

In Bugesera, all groups prefer avocado, which is available all year and is widely consumed because it can be used to vary the diet (considered a vegetable while eating potatoes), and mango, a high-value fruit. Men and women in the Juru sector prefer oranges and citrus because they are used as medicines. Furthermore, they generate income because of the market's high demand. Participants also mentioned jackfruit as a high-value tree that is resistant to pests, diseases, and drought. They began planting it on their farms, and while it is not yet producing, they are hopeful that it will produce more yield, as other farmers in Kirehe and other districts of Eastern Province have. Tree tomatoes and pawpaw are gaining ground in the Rweru sector as they produce more consistently throughout the year. They saw their livelihood improve because they sold the fruits.

7.1.5 Key challenges and opportunities

Baseline studies (Wakaba et al., 2022d; Loreche et al., 2022); and focus group discussions (Cohen, 2022;) identified challenges to tree growth and perceived future challenges to tree growth. The study also identified existing and future opportunities for growing trees on farmland. Based on the current and perceived benefits, 83% of households are willing to grow more trees in the future. The main challenges facing tree growth were similar across the study sites, with variations in magnitude. Water shortage is a persistent problem hampering tree growth in Bugesera (66.2%) and Makueni (47%). Pests and diseases are a more serious problem that affects all the sites; the problems are particularly serious in Bugesera (67%) while in Makueni (40%) and Kiambu (40%). The problem is a demotivator to growing trees in the future. Other similar problems are more context-specific. In Bugesera, the lack of high-quality planting material (35.0%) and tree seedlings' low survival rate once planted in the fields (26.3%) are less significant obstacles. Therefore, besides having high-quality seedlings, climate change is another cause of and contributes to farmers' biggest problems in Bugesera. In Kenya, the main challenges facing tree planting and growing especially fruit trees, are the limited knowledge of tree growing (18%), the low survival rate of the seedlings (14%), a lack of suitable planting materials (15%), and a lack of knowledge of tree management. especially fruit trees, are the limited knowledge of tree growing (18%), the low survival rate of the seedlings (14%), a lack of suitable planting materials (15%), and a lack of knowledge of tree management.

The mentioned problems hamper the future willingness to increase trees. The level of willingness to increase diverse trees in the future was highest in Kiambu and lowest in Makueni. In Makueni, limited knowledge of fruit tree management is among the main challenges as well as market challenges (28%) that demotivated farmers to increase the number of trees in the future. In Makueni and Bugesera, water shortages, which are affecting the area increasingly, are the most frequently mentioned problems (66% in Bugesera and 47% in Makueni). Further, pest and disease incident were ranked second but very severe in Bugesera (61.7%). The pests and diseases problem are directly related to the high incidence of fruit flies and powdery mildew in mango trees, poor farming practices (no treatment), and the high price of pesticides. Other conspicuous problems were limited knowledge of tree management (38%), a low tree survival rate of the seedlings (25%), and theft cases (13%) in Kiambu.

7.1.6 Farmers' Perception of Climate Change

To develop and effectively implement adaptation policies in agriculture and forestry, it may be necessary to understand farmers' perceptions of climate change. According to Whitmarsh and Capstick (2018), understanding how people perceive climate change involves a variety of psychological concepts, including knowledge, attitudes, beliefs, and concerns about whether and how the climate is changing. Individual characteristics, life experiences, the quality and quantity of information available, and the cultural and geographic environment in which one is immersed all play a role in shaping an individual's perspective. Therefore, measuring climate change perception and trying to find its determinants is not an easy task. Depending on their geographic location, particular farming techniques, and personal experiences, farmers may have different perspectives on climate change. While it can be difficult to generalize the opinions of all farmers, the following are some prevalent perceptions and worries that farmers have voiced regarding climate change:

Generally, farmers recognize that they have observed climatic changes in the past five years-88% in Bugesera, 93% in Kiambu, and 86% in Makueni. Farmers in the study areas attribute climate change to microclimate attributes such as heat, high temperatures, strong winds, reduced rainfall, droughts, and changes in rainfall patterns. Results show that 75% of farmers attributed climate change to frequent occurrences of drought in Bugesera, 98% in Makueni, and 96% in Kiambu. During the dry season, it becomes hotter than it used to be. Farmers compared the temperatures they are experiencing now to five years ago, the same period; 74% of farmers attributed the seasonal temperature increase to climate change in Kiambu 50%, Bugesera (74%), and Makueni (82%). Results reveal that pests and diseases are among the most significant issues related to climate change. The frequent invasion of new pests and diseases was also reported to indicate the effect of climate change in Kiambu (56.64%). Makueni (77%), and Bugesera (40%). Some microclimate-related problems related to climate change, such as hailstones, frost (27%), and strong wind (Makueni 2.27% and Kiambu 4.4%), did not seem to be serious threats to farmers across the sites. Unpredictable rainfall patterns sometimes cause the rain to come very late and end before the expected time, resulting in flooding (Bugesera 66%), Makueni 89%, and Kiambu 82% Loreche et al., 2022; Wakaba et al., 2022d.

7.1.7 Why do farmers plant trees?

Farmers know that trees have many benefits. Hence, they plant trees to be sustainable, productive, and good stewards of the environment. Adding trees on farms is often done out of a concern for sustainability, a need to boost productivity, a desire to deal with environmental concerns, or as an income-generating venture. This study demonstrates the primary reasons why farmers choose to plant trees on their farms in Bugesera, Kiambu, and Makueni. The findings indicate that the main motivations behind tree growing in Bugesera District are income generation (28%) and intercropping (43%). Fruits in markets within Bugesera are not readily available, which keeps their prices high. Again, food security is a key concern for households living in Bugesera. Therefore, households grow fruits mainly for home consumption (68%), which generates income (28%). Households in Bugesera also grow non-fruit trees on their farms, mainly for firewood (82%), timber (52%), and live fencing (21%) Loreche et al., 2022.

The results show that farmers in Kiambu planted and managed trees based on the benefits they got from them. Products like firewood (91%) and timber (85%), live fences (32.4%), ornamental (13.9%), and fruits (15.3%) are what drive. The ecosystem benefits of tree planting did not come out strong in Kiambu. However, households in Makueni valued the shade (10%) and windbreak (22%) that the trees on the farm provided. Therefore, the findings suggest that Kiambu households are product-driven and prioritize trees that can be harvested for products. Like in Kiambu, farmers in Makueni plant trees for products, but there is a higher need for the ecological services trees provide. Timber (74%), charcoal (27%), and firewood (57%) are the main products derived from the priority trees grown on the farms. However, there was a higher interest in agroecological benefits such as shade (32%) and windbreak (32%), particularly in the elevated areas of the sub-county. To understand the driving force behind the preference for tree species for products and ecological services. We asked the farmers why the product was essential for them too. The results showed that income (66%) is the main driving factor in Kiambu. The products harvested from the tree are consumed at the household level or sold to generate revenue. At the same time, tree species for ecological services such as windbreak and shade were vital because they are friendly to crops (25%) and improve soil fertility (25%). In Makueni, the choice of tree species to grow is informed by products and services (ability to improve soil fertility and can be intercropped). Tree growing in Makueni on the farm is driven by the direct and e indirect benefits derived from them.

7.1.8 Priority fruit tree species

Priority fruit tree species are usually selected based on local conditions, market demand, and how easy they are to grow. Farmers also think about how resistant a plant is to disease, how well it will grow in their area, how many suitable cultivars are available, and how much space is available on the farm. Farmers have been growing mainly exotic fruit trees on their farms. In Bugesera district, farmers mostly grow avocados (18%), *Carica papaya* (17%), and mangos (15%). However, farmers do not know the varieties they grow in the area. They intend to increase the number of trees (80%) with an average of three species per farm in the future to increase yield for home sufficiency and market demand. Most farmers would like to plant mango (64%), avocado (57%), orange (53%), and pawpaw (46%) trees (Loreche et al., 2022; Cyamweshi et al., 2023a).

In Kenya, avocado trees accounted for half of the trees planted in the Kiambu region, and mangoes accounted for a quarter of the trees planted in the Makueni area (Kuyah et al., 2022). Therefore, cultivating indigenous species can meet the need to diversify fruit trees. Farmers expressed the desire to increase trees on the farms by growing three more tree species: avocado (24%), citrus (32%), macadamia (17%), mango (21%), and papaya (17%). The intention is to generate income from the sale of fruits (63%) and domestic consumption (95%). The results show that avocado variety species are the most common fruit tree species found on farmlands in Kiambu; Hass (77%), Fuerte (53%), and local variety (33%), varieties of *P. americana*, were found to be the priority tree species and were found to be the most dominant tree species. *Macadamia integrifolia* (48%) and *M. indica* (47%) are other fruit trees found on farms. In Makueni, the farms' most widely grown fruit tree species is *M. indica* (74.2%). *Citrus sinensis* (64%), and *Persea americana* (52%), are other fruit tree species on household farms. Another citrus fruit tree, *Citrus limon*, was a widely cultivated species (43%), mainly used as *C. sinensis'* rootstock. Interestingly, the focus group discussion and workshop engagement revealed that citrus is gaining preference over mango and Hass avocado in Makueni and Kiambu respectively due to their high yield and ready market Wakaba et al., 2022d; Gachuiri et al, 2022b; Cohen, 2022. Gachuiri et al 2022c)

7.1.9 Sources of Planting Materials

Farmers can benefit from improved quality, reduced risks, increased confidence in variety authenticity, support for sustainable practices, and access to expert knowledge by sourcing tree materials from certified sources. It ultimately contributes to their fruit tree plantations' overall success and sustainability. The baseline study assessed types and sources of tree planting material. The study found that farmers in Bugesera mainly use seedlings (54%), seeds (29%), and grafted materials (12%). These materials are sourced from neighbours, relatives, and friends (16%), government nurseries (20%), Rural Resource Centres (12%), forests and wild places (13%), and from own farms (13.5%).

The result shows that seedlings were the main form of planting material in Kiambu (79%) and Makueni (52%). The second primary source of tree-planting materials was seeds extracted from the fruits and planted directly. Other significant sources of seedlings are grafting, cutting, and wilding. Where they source the planting materials, the study shows that tree nurseries and traders are the primary sources of tree planting in Kiambu (60%) and Makueni (41%). While there was an element of buying tree seedlings from the market (40%), we can see that in Kiambu, farmers cultivated 17% of the seedlings on their own farms.

7.2. The right trees are in the right places. Show smallholders how to site trees on farms to maximize climate adaptation benefits.

The focus of this component was to address the research question of 'How can smallholder farmers' capacity in tree growing be enhanced to maximize their benefits, especially those relating to climate change adaptation and more gender-inclusive outcomes? The focus was to enable a gender-inclusive, sustainable, and efficient supply of high-quality fruit-tree planting material, coupled with enhancing farmers' knowledge and capacity to match species to on-farm niches, make decisions based on likely future climate conditions and use appropriate agronomic, water, and tree management practices. Deliberate capacity strengthening efforts of existing nurseries/seedling supply systems as well as sustainable knowledge-sharing platforms in target sites in Bugesera district Rwanda and Makueni and Kiambu Counties in Kenya. Context-appropriate options for enhancing capacity, like through training and peer learning for other fruit tree sources such as cooperatives as well as private and farmer nurseries, were explored. Gaps in fruit tree availability were identified and routes/options to introduce improved varieties of priority fruit species were explored. These improved seedlings supply systems, coupled with knowledge of the right trees for the right place, enable farmers, including youth, women, and marginalized persons, who are often excluded from fruit value chains, to learn about participatory domestication and the options for combining fruit trees with other crops and trees. In addition, capacity strengthening on proper agronomic, tree management, and care practices and options for water management, including carbon aspects would enable farmers to achieve the desired practices, benefits, and environmental services and better mitigate and adapt to climate change.

The capacity-strengthening efforts around quality seed supply systems, good agricultural practices, and carbon through training, peer learning forums, and public engagements are detailed below and in table 6.

In Kenya, two separate trainings covering nurseries and agronomic practices were held at each site (2), while in Rwanda, one training covering both nursery and agronomic practices was held. The tree nurseries workshops in Kenya were conducted in Kiambu and Makueni counties, involving 81 participants (44 M and 37 F) while the agronomic workshops focusing on improved avocado and mango production practices were conducted with a total of 136 participants (56 male and 83 female; Gachuiri et al, 2022b and Gachuiri et al 2022c). At the same time, another 1766 were trained on GAPs, tree nursery management, climate change, and carbon through a partnership between ICRAF, ToT, county government, and JKUAT, thus resulting to a total of 1983 of those trained. In addition, 441 beneficiaries were reached through outreach in schools and the provision of quality fruit tree planting materials; thus, the total number of beneficiaries directly reached through project activities in Kenya were 2424 (Table 5). However, of these 23 (11 men and 12 women) attended more than one training, hence translating to **2401** total number of people reached through training and outreach in Kenya. In Rwanda a total of *1264* people trained *were* reached, however 101 attending more than one training thus resulting with **1154** beneficiaries were reached with a. This included the training of 329 farmers (211 male / 118 female) and extension officers (120 of whom were RAB/ICRAF led training participants GAP and nurseries (64 males/49 females) were involved in Rwanda (Cyamweshi et al., 2023a). Another 432 farmers (254 male and 178 female) were engaged in tree-growing activities through Umuganda (community work), located in Rweru and Juru sectors, while an additional 387 farmers (201 women and 186 men) were trained in the citizens forum (Table 6).

Table 6: Number of Beneficiaries trained and engaged through various project activities in Kenya and Rwanda.

Engagement/ Training/	The focus of Training/Engagement	Kenya			Rwanda		
		Male	Female	Total	Male	Female	Total
Training	Farmers reached by ToT and County government officers on GAPs and marketing of avocado	681	486	**1167**	64	46	**110**
	Farmers trained on GAPs, disease, and pest management, and marketing of avocado and Mango by ICRAF	64	72	**136**			
	Sensitization on tree growing and establishment of markets through collective action (TiVOMAC)	8	2	**10**			
	Tree nursery managers/operators trained directly by ICRAF	44	37	**81**	64	46	**110**
	Training of women self-help groups on nursery and orchard establishments by ToT.	0	23	**23**			
	Fruit trees for climate change mitigation and adaptation and research findings feedback	88	77	**165**			
	baseline/tree inventory	100	122	**222**	91	48	**139**
	Enumerator training in Open Data Kit (ODK) for baseline and endline data collection	17	11	**28**	27	9	**36**
	The basic protocol for destructive measurement	55	83	**138**	29	14	**43**
	County/sector government extension officer training/ engagement	6	7	**13**	4	3	**7**
Sub Totals	**Training totals**	**1063**	**920**	**1983**	**279**	**166**	**445**
Public engagement	Issuing avocado seedlings	44	57	101			
	School tree planting day – information on tree growing	42	48	90			
	Children's Devolution Conference	133	117	250			
	Citizen Forum				186	201	387
	Umuganda				254	178	432
Subtotal	Other engagements	219	222	441	440	379	819
Grand Total		**1282**	**1142**	**2424**	**719**	**545**	**1264**

***NB: Twenty-three people** attended more than one training in Kenya, thus leading to the beneficiaries reaching **2401** (i.e., 2424-23) while in Rwanda* 110 farmers *attended more than one training; therefore, the number of farmers reached **1154** (i.e. 1264-110).*

In both countries, special efforts were made to ensure the gender inclusion and participation of nursery managers, local government officials, lead farmers, TOTs, and extension officers from different wards/sectors besides farmers, who were the majority, to ensure that training could be replicated and adopted in their respective regions. The topics covered were geared towards equipping the farmers better in the areas identified for training, need seed/seedling production, and tips on running and managing tree nurseries as a business (and for Kenya, support for nursery certification by Kenya Plant Health Inspectorate Service-KEPHIS), propagation techniques, pest and disease management, fertilisation, spacing, amongst others. A training manual on avocado production was developed for Kenya (Gachuiri et al., 2023) and another on avocado and mango for Rwanda (Cyamweshi et al., 2022). The development of a Tree Species Selection and Management Tool based on tree inventories conducted in Kenya (Muthuri et al., 2023a) and expanding the existing one for Rwanda (Kuria et al., 2023) both under Interactive Suitable Tree Species Selection and Management Tool for East Africa. An important milestone is the development of 'KuzaMatunda', meaning grow fruits, an offline application to support farmers in accessing an offline database of key fruit trees with critical information on how to grow and manage them. Another is the Igiti for in Rwanda. Both Apps contain names in the local languages of the sites.

The training and engagement efforts were geared towards supporting the fruit tree extension services, which are weak based on the findings of the baseline in both countries, yet like other crops, they require special attention compared to most other tree species, which require less attention once established. Extension services are very important for spreading knowledge, providing training and support, making it easier for people to use new technologies, connecting people to markets, giving rural communities more power, and speaking up for farmers as well as enhancing their knowledge on the contribution of fruit trees in climate mitigation and adaptation and particularly matters carbon. They help the agricultural sector grow and be more stable by bridging the gap between research and farmers, improving farming methods, and improving farmers' and rural communities' lives. Our baseline data showed that even where training is done, it is mostly not structured and often not targeted, with farmers from the same county or sector receiving training with a different focus, making it hard for follow-up training.

Our findings revealed that access to extension services in both countries was very low; in Bugesera, only 10%, while in Kenya, only 18% and 16% of households in Kiambu and Makueni counties, respectively, had a member get extension services in the last two years. Besides, most training/extension is also done by word of mouth in both countries; (72% and 68%). In both countries, most of the extension recipients were mainly male households, constituting 75% in Makueni, 91% in Kiambu, and 88% in Bugesera. The provision of extension is mainly supplied by government extension agents in Kiambu (52%), Makueni (43%), and Bugesera by non-governmental agencies (77%). Despite the gaps in the extensions, there was a high willingness to enrol to receive training. In Bugesera, Kiambu, and Makueni, 85%, 87%, and 97% of the households were willing to participate if training was offered for free. The extension needs of the farmers varied from region to region, but training on pests and diseases; (Bugesera 63%, Makueni 87%, and 75% Kiambu). Secondly, tree management aspects such as pruning, spacing, grafting, and thinning were other areas of training needed; in Makueni (50%), Kiambu (39%), and Bugesera (61%). However, there were unique needs per site in Makueni (27%), farmers desired water management, niche selection in Kiambu (37%), and use of organic fertilizer in Bugesera (42%). In case training was to be offered for free, majority of the households in all sites felt that household heads were more suitable to receive the extension, which accounted for 68% in Bugesera, 67% in Makueni, and 68% in Kiambu (68%) (Wakaba et al., 2022d; Loreche et al., 2022). The training extension / scaling approaches used in the two countries are summarised in figure 5 below.

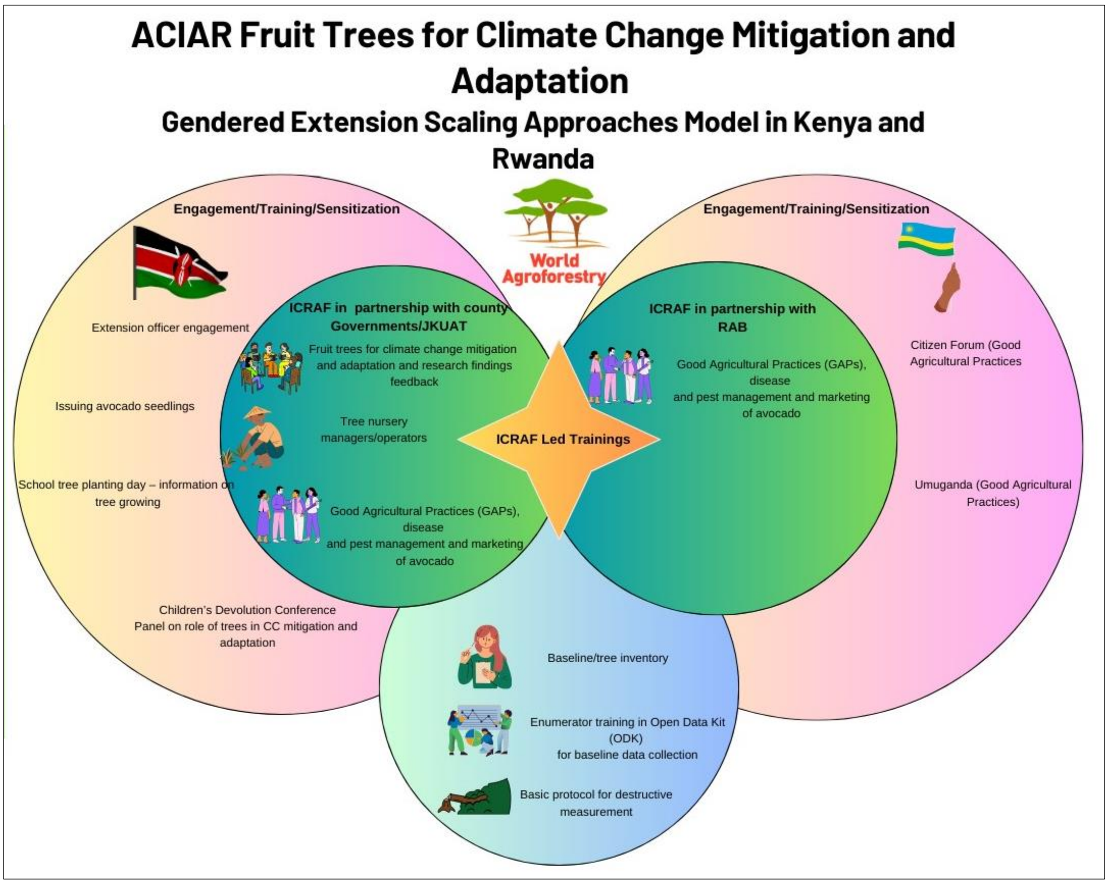


Figure 55: Training scaling approaches in Kenya and Rwanda

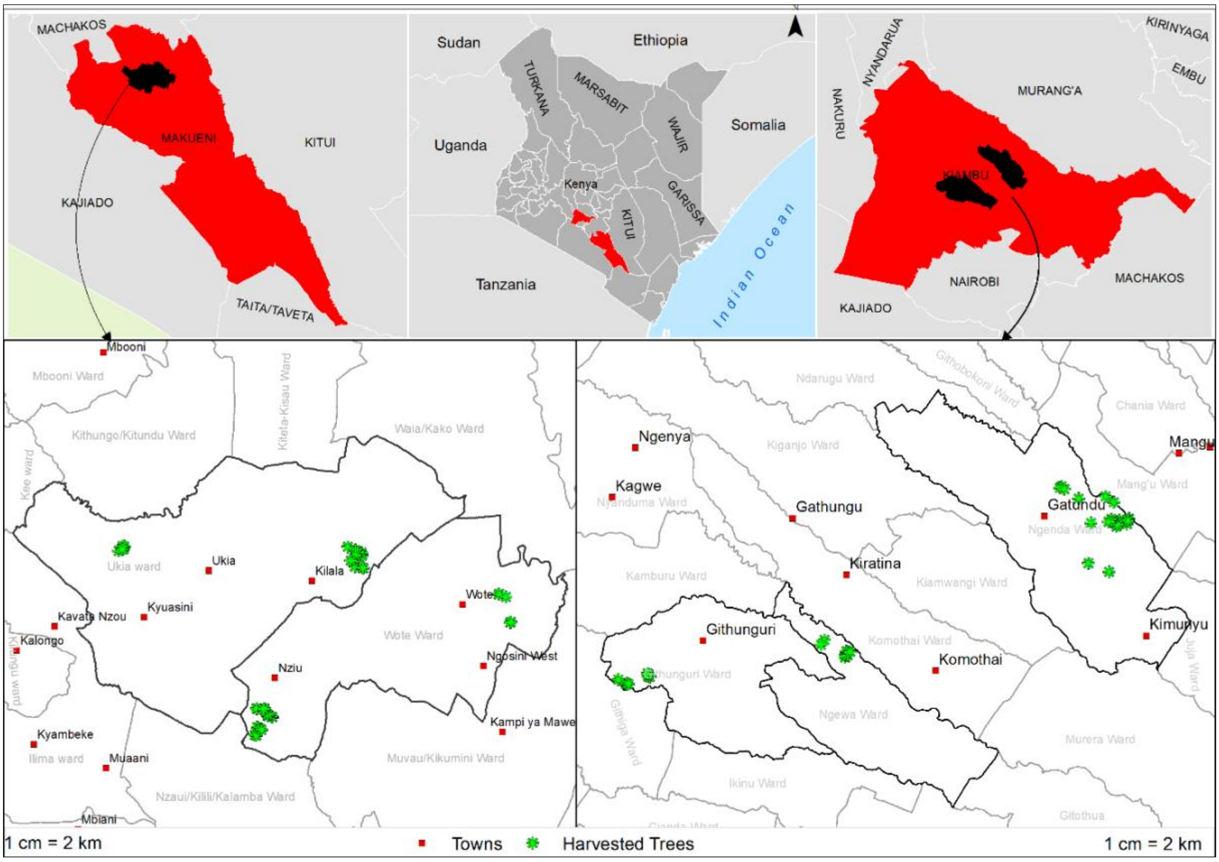
7.3 To estimate fruit tree carbon sequestration benefits to determine the potential for access to international climate finance that could further accelerate scaling out.

The research question that this objective sought to answer was 'What is the contribution of fruit trees to climate change mitigation?

Fruit trees play a significant role in climate change mitigation through carbon sequestration. This is exemplified by the storage of large amounts of carbon in the aboveground biomass of dominant fruit trees and the high proportion of fruit trees on farmed landscapes. This is supported by our findings that avocado and mango tree species make up 34% (n = 82 species) and 40% (n=98 species) of all the species documented on farms in Kiambu and Makueni, respectively. The allometric equations developed in this study for mango and avocado will support the quantification of aboveground carbon stocks on farms and restoration initiatives that include fruit trees in the landscape. It also demonstrated that mango and avocado hold significant amount of aboveground biomass in standing trees, with a mean of 20.55±5.35 Mg ha^1, equivalent to 9.66±2.51 Mg C ha^1 estimated for avocado trees in Kiambu, and 22.3±6.26 Mg ha^1, equivalent to 10.5±2.94 Mg C ha^1 estimated for mango trees in Makueni. The qquantification of carbon associated with fruit trees is essential for helping farmers access income from emerging market-based mechanisms and therefore the development of allometric equations is a significant contribution towards this effort.

The findings from this objective include:

An extensive literature review on the prevalence, density, and estimation of aboveground biomass in fruit trees was done Kuyah & Muthuri, 2022b. A review of allometric equations for fruit trees found a limited number of equations for major tropical fruit trees. Eight (8) power-law equations for estimating biomass in mangoes grown in orchards in Réunion (2) and, parklands in Burkina Faso (2) and homesteads in Bangladesh were found with only two studies from one country in Africa (Burkina Faso) and none from East Africa. As for Avocado, no allometric equation had been developed thus clearly showing that our work was targeting an important gap in view of the high demand for avocados and emerging carbon financing markets. A protocol for building allometric equations for the estimation of biomass in fruit trees was was therefore developed Kuyah & Muthuri, 2022a. It provides guidelines for building allometric equations for fruit trees through destructive sampling and practical guidance on conducting on-farm tree inventory to estimate carbon stocks. In addition, a training manual on rapid carbon estimation was developed by Kuyah & Muthuri 2022c. The manual aims to build the capacity of farmers, land managers, and community facilitators to monitor carbon benefits including field measurements, selection of allometric equations, and calculating carbon stocks in fruit trees. As a result, 12 (8 male 4 female) staff from Kenya and 18 (12 males 6 female) from Rwanda trained on this to enable rapid and accurate tree inventory and biomass estimation measurements. Eventually, allometric equations for estimating aboveground biomass in mango and avocado trees were developed using the 51 mangos and 40 avocado trees in Kenya and 60 mangos and 48 avocado trees Rwanda. The harvested trees sampled in Kenya are shown in the map below (Fig 6 a & b).



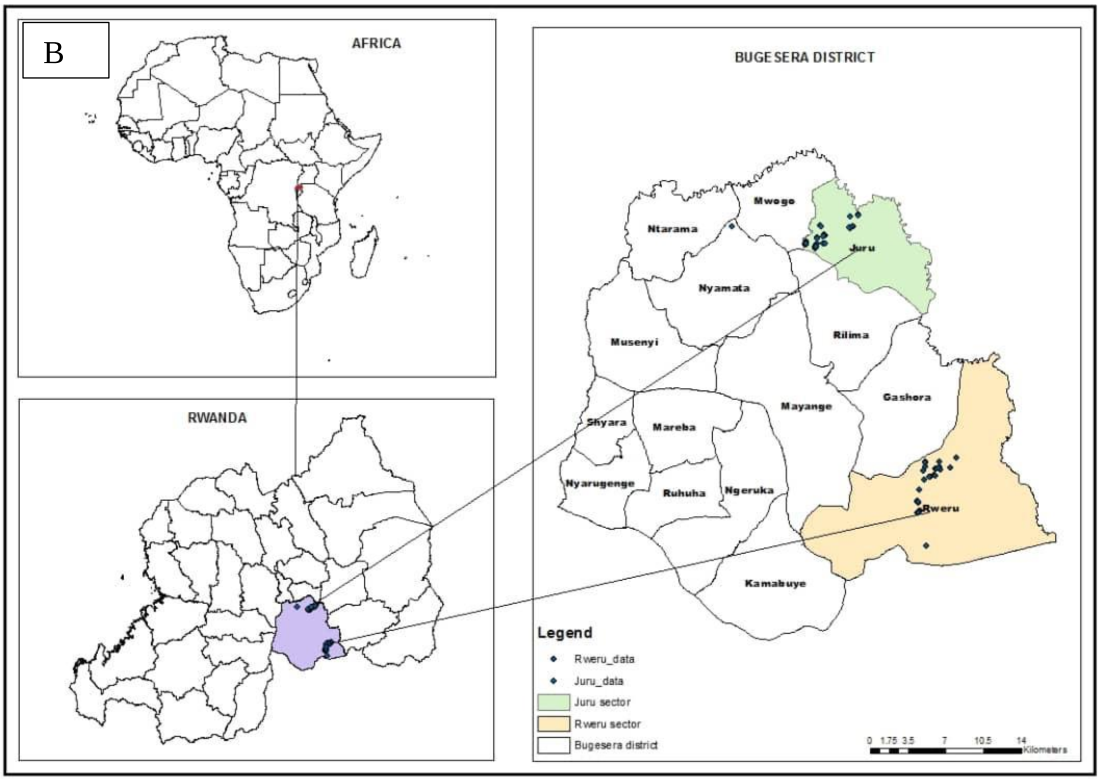


Figure 6 6: a and b. Map showing the GPS points of the trees harvested for destructive measurements in Makueni and Kiambu counties, Kenya, and Juru and Rweru -Bugesera District, Rwanda, respectively.

Additionally, to complement this effort, a journal article on 'Agroforestry's contribution to livelihoods and carbon sequestration in East Africa; a systematic review' Muthuri et al., 2023 has been published in 'Trees, Forests and People'. The findings (Kuyah et al., 2024) from the aboveground biomass destructive measurements for Kenya revealed that mango trees stock on average 22.3±6.3Mg ha^{-1}, which equates to 10.5±2.9 Mg C ha^{-1}, whereas avocado trees stock on average 20.6±5.4 Mg ha^{-1}, which equates to 9.7±2.5 Mg C ha^{-1}. This amount is within the range of carbon stocks in Africa's semi-arid (9 Mg C ha^{-1}) and sub-humid (21 Mg C ha^{-1}) tropics, and it is close to the maximum values of the conservative estimates of 1.0 and 18 Mg C ha^{-1} in aboveground biomass that have been suggested for African agroforestry systems. Much of the carbon in avocados and mangos comes from orchards and homesteads.

Orchards and homesteads are farmland-use systems that have a high tree density and are home to larger trees. In mango and avocado trees, the mean diameter of primary branches (DPB) and diameter at breast height (DBH) are recommended as the best predictor variables for estimating aboveground biomass. As a result, allometric equations with DPB (AGB = 0.083´DPB$^{2.184}$) or DBH ($AGB = 0.0638 \times dbh^{2.5435}$) as the only independent variables provide accurate estimates of aboveground biomass. The bias of the predictions from the different equations is illustrated using scatter plots of actual (measured) and predicted biomass below (Figure 7). The two species did not significantly differ between actual and predicted biomass.

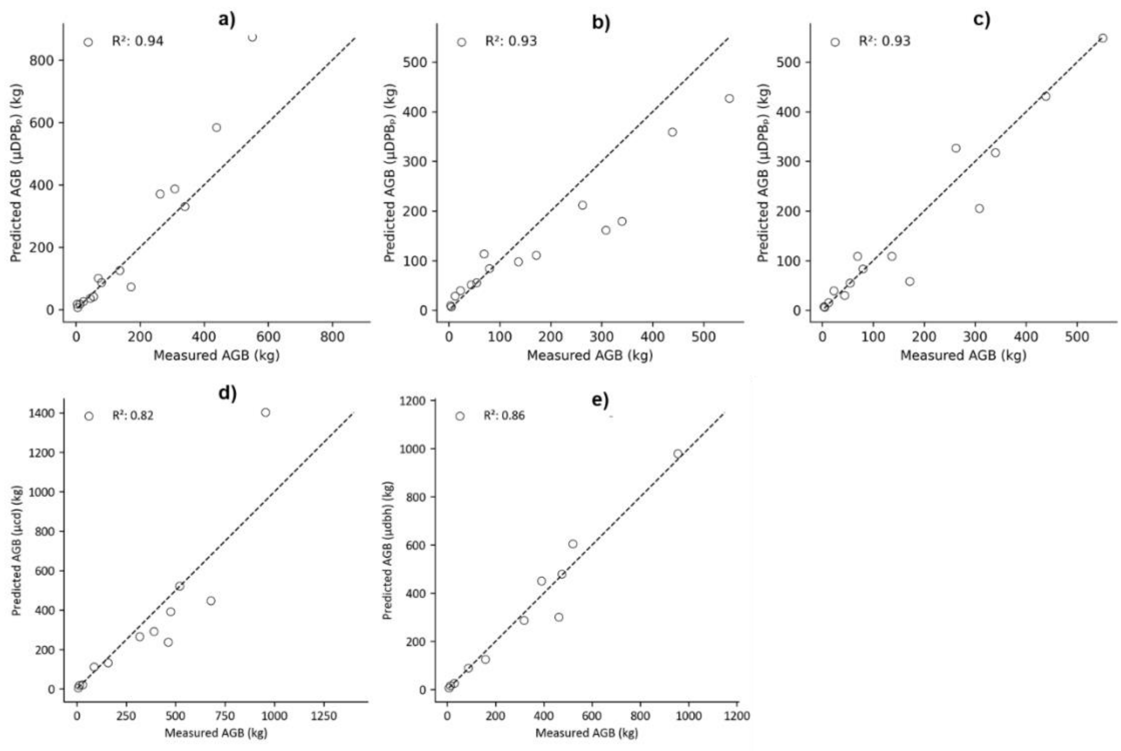


Figure 7 7: Scatter plots of actual (measured) aboveground biomass (AGB) and AGB predicted using allometric equations developed in this study for mango trees (a-c) and avocado trees (d-e). The subscript p denotes predicted; DBP, DBGU, DBH, and CD refer to the diameter.

A journal article on "Allometric equations and carbon sequestration in mango and avocado in Kenya" Kuyah et al., 2024 has also been published in *Trees, Forests and People.*

7.4: Endline Survey - Assess the effectiveness and uptake of selected project interventions/approaches on key intermediate outcomes

This section demonstrates the outcomes realized from this project's activities and interventions. The report highlights the contribution to extension, agroforestry, tree growing, change in Knowledge, Attitude, Practices, group enrolment, and gender. The findings showed that:

Training offered through the ToT model increases the number of farmers who receive training on good agricultural practices. The study asses the proportion of farmers who had access to extension services provided by ICRAF and those who were trained by other organizations (Figure 7). A baseline study conducted a year before the training in the same sites showed that less than a quarter of the households within the last two years had access to extension services. With the training offered to farmers through this project, we have increased the number of trained by 111%, 158%, and 63% in Kiambu, Makueni, and Bugesera. Peer-to-peer farmer training influenced 8% and 55% of farmers to plant trees; most importantly, 52% and 71% planted trees after training in Kiambu and Makueni, respectively.

Increased household farm management, technical capacity uptake, food security, and nutrition status improvement. Trained farmers acknowledged that the training increased the capacity of government extension workers (89% and 100%) and the number of experts in GAP (93%). It also enhanced the capacity of youth and women (97% and

100%) and promoted farmers joining agricultural cooperatives (85% and 100%) in Kiambu and Makueni, respectively. In Makueni, the training established strong links between farmers' universities (73%). However, in Rwanda, due to many farmers trained by Tree for a food security project (33%), we could not compare them with those trained in the project. Their ability to effectively understand market operations will improve (74%, 80%, and 98%), and they can improve their family food security (90%, 96%, and 99%) and nutrition (89%, 97%, and 99%) in Kiambu, Makueni and Bugesera respectively. Further, in Kiambu, farmers are confident they can estimate and negotiate for carbon credits (54%).

Improved agroforestry practices and increased tree growing: Trained farmers planted more trees than non-trained farmers for products and ecosystem services in Kiambu (97%) and Makueni (93%). On average, trained farmers in Kiambu planted 18 trees (11 fruit and nine non-fruit trees) and 23 (seven fruit and 16 non-fruit trees) in Makueni, within the same period. Meanwhile, non-trained farmers planted 12 trees (seven fruits and five non-fruit) in Kiambu and 11 (six fruits and five non-fruit) trees in Makueni. In Rwanda, after one year of the project implementation, trained farmers planted a higher number of different species by 50% in Juru and 67% in Rweru, this translates to an increase of number of planted trees across the two sectors to be by 58%. Trained farmers planted an average of 78 trees (29 fruits and 49 non-fruits) against 52 trees (18 fruits and 34 non-fruits) planted by non-trained farmers. In Rweru, trained farmers planted 77 trees (21 fruits and 56 non-fruits), while non-trained farmers planted 46 trees (17 fruit and 29 non-fruits).
Farmers in Kiambu mainly planted *Persea americana* (81%), *Eucalyptus* (21%), and *Grevillia robusta* (31%). Further *Persea americana* (Hass). In Makueni, the most grown tree species were *citrus sinensis* (42%), *citrus lemon* (70%), *Mangifera indica* (43%), *Annona senegalensis* (4%), *Carica papaya* (15%), *citrus reticulata* (5%), and *G. robusta* (43%). During the baseline study, we identified farmers not growing *C. papaya* due to difficulties in germination, disease control, and propagating the desired species. With the training, 41% of the farmers have adopted the growing of papaya fruits. In Kiambu farmers planted trees for financial benefits (77%), knowledge, and skills to grow trees (36%). And farmers were able to obtain the desired species (29%). In Makueni, farmers grew trees for income (72%), seeing and hearing their neighbours (37%), and after receiving training (37%). In Bugesera district, farmers reported a variety of trees. *P. americana* (53.8%) and *M. indica* (49.7 %) were the most dominant fruit trees owned by all respondents. *G. robusta* (89.4%) and *M. lutea* (44.2%) were the most dominant non-fruit trees planted by trained farmers. In Bugesera the decision to plant more trees was motivated by the training obtained and financial benefits from the sale of tree products (49.5%). The proportion of respondents who were influenced by their neighbours (63.5%) or planted trees to avail seedlings on the market (40%).

Improved Knowledge, Attitude and Practices of farmers through GAP

A summary of the findings is provided in table 7.

The trained were more knowledgeable than the untrained farmers on tree growing and management aspects: Generally, farmers in Makueni are more knowledgeable than farmers in Kiambu. In Makueni, the government and other development partners, such as ICRAF, have intervened in many issues for a longer period. In Kiambu (75%) were knowledgeable about the importance of growing fruit trees in closing the seasonality gap (79%) due to the contextual setting. Growing diverse fruit species for the ecological balance of the farm to improve the farm yield. Grafting for maturing of trees (79%). In Makueni, farmers became knowledgeable about tree diversification in closing the seasonality gap (100%), making holes for tree planting (85%), and grafting trees for early maturity (99%). Trained farmers In Kiambu (46%) and Makueni (81%) know that fruit trees absorb and store carbon. In Bugesera, the training increased farmers' knowledge of tree growing and management aspects by more than 75%: Role of fruit trees in closing the seasonality gap, selection of best rootstock, soil water management, tree establishment, and marketing of the fruit trees. However, there is little knowledge of the role of the fruit tree in carbon sequestration (21%). Carbon measurement and determination training was conducted in Kenya, where carbon buyers were invited. The carbon market in Rwanda has also yet to be explored, unlike in Kenya.

***Lead to a change of attitude on the role of fruit trees in climate change mitigation, use of synthetic pesticides, application of fertilizer on trees, and value chain*:** The general attitude for most farmers in Kiambu was that growing trees on the farms reduces the land size that would have otherwise been used for food production and commercial purposes (81%). Makueni farmers believe synthetic pesticides are more effective than organic pesticides (86% and tree diversification influence fruit production (88%). All the trained farmers felt that fruit trees could help adapt to climate change and lessen the effects of climate change (96%), pruning (59%), and safe use of organic pesticides (59%). There was a higher positive attitude towards value addition and tree diversification for marketing by trained farmers. Grading and sorting fruit improves the prices of the produce (99%), and growing diversity of tree species on farms increases fruit production (97%). However, untrained farmers in Kiambu (41%) and Makueni (53%) felt it was the government's role to fight climate change, as farmers were incapable. Further, in Makueni, untrained farmers felt it was not important to apply fertilizer to trees because they are hardy crops and can thrive on thin, unfertile soil (24%) and that fruit trees were more critical than non-fruit trees on the farm (47%). In Bugesera, trained farmers developed a positive attitude toward grading and sorting fruit trees before marketing (95%). The role of fruit trees in climate change mitigation (94%), adaptation (98%), and the use of organic pesticides (84%).

The training led to farmers adopting Good Agricultural Practices: Through endline surveys, we observed farmers' actions and evaluated their ability to apply theoretical knowledge to real-world scenarios. Farmers who actively participate in practices help to deepen their understanding of concepts. Practicing on the farm exposes farmers to real-life situations, allowing them to develop critical thinking skills and adaptability when solving agricultural problems. Training farmers in Kiambu and Makueni always practice fruit fly traps on their farms with effective baits (17% and 51%) and prune trees immediately after harvesting (45% and 91%). Followed the recommended timing and standards for harvesting export fruits (47% and 83%). Farmers planted diverse species in Kiambu on my farm (58%) and did soil testing (19%). Grew trees to lessen (78%) and cope (76%) with the effects of climate change. Meanwhile, in Makueni, trained farmers (97%) grow soil-cover crops on their farms. They also keenly identify pests and stages before applying pesticides or insecticides (96%). In Bugesera, training led to influencing farmers in grading and sorting the fruits when selling them (65%), using protective gear (26%), and growing trees to help in climate change mitigation (89%). Recommended timing and standard for harvesting export fruits (50%), identifying pests and stages before applying the pesticide or insecticide (50%), and planting diverse species on the farm (67%).

Assessment of farmers' behaviour using the Theory of Planned behaviour

The project influenced farmers' behaviour and choices, especially gender and household inclusion. farmers in Kiambu are more likely to be influenced by government workers (72%) and NGOs (91%) because that has been the main source of extension services. At the same time, other farmers in Makueni are likely to be influenced by family members because farmers copy each other (74%). In Bugesera, we observed that trained farmers were likely to be influenced by family members and relatives (100%), government environment workers (90%), non-government organizations (87%), political leaders, and people in social groups (87%).

The training also aimed to enhance farmers' belief in their ability to carry out a particular action successfully. Results show that regardless of whether a farmer was trained on GAP, farmers felt confident they could make sound tree growth and management decisions in Kenya. However, in Bugesera, trained farmers became more confident that they could make sound decisions regarding tree growing and management (94%), and growing fruit trees would contribute to food security and income (96%). Trees will contribute towards reducing carbon emissions (50%), and people around them think they can be champions for fighting climate change (85%).

Table 7: Knowledge, Attitude, and Perception of GAP for Farmers from Kiambu, Makueni and Bugesera

Project site	Kiambu				Makueni				Bugesera			
Knowledge on GAP	Pooled	Non-trained	Trained	p-Value	Pool	Non-trained	Trained	p-Val	Pooled	Non-trained	Trained	p-Value
Positive (Correct)												
A growing variety of fruit tree species closes the seasonality gap	79.33	77.23	82.05	0.67	98.94	98.32	100.00	1.00	63.50	55.50	74.80	0.00***
Avocado/Mango flowers have both male and female organs	51.96	50.50	53.85	0.29	68.25	58.82	84.29	0.00***	33.10	24.90	44.70	0.00***
It is recommended to mix the topsoil with manure two weeks before planting a tree	64.80	62.38	67.95	0.44	85.19	85.71	84.29	0.79	63.20	54.90	74.80	0.00***
The grafting ensures the early maturing of trees.	79.33	79.21	79.49	0.96	96.83	95.80	98.57	0.30	53.00	46.80	61.80	0.005**
Negative (Correct)												
If one has a good scion, it can be grafted with any tree variety	37.43	31.68	44.87	0.07*	51.32	37.82	74.29	0.00***	40.90	32.90	52.00	0.00***
The best rootstock is those from grafted variety.	44.69	33.66	58.97	0.00***	51.32	38.66	72.86	0.00***	28.00	20.80	38.20	0.00***
Are grafted trees suitable for any climatic condition?	33.52	30.69	37.18	0.36	48.68	47.90	50.00	0.57	53.70	44.50	66.70	0.00***
Waterlogged soil is good for trees as it makes trees grow fast	56.98	52.48	62.82	0.17	65.61	57.14	80.00	0.00***	36.10	30.60	43.90	0.00***
The first inorganic fertilization should start immediately after planting trees	64.80	62.38	67.95	0.44	53.44	52.94	54.29	0.86	41.60	35.80	49.60	0.001***
Irrigation can lead to root diseases	15.64	12.87	19.23	0.25	41.27	33.61	54.29	0.01**	36.80	27.70	49.60	0.00***
Spacing of tree is standard regardless of the type of soil	43.58	41.58	46.15	0.54	23.28	20.17	28.57	0.19	33.10	24.30	45.50	0.00***
Fruit trees do not absorb carbon	39.11	33.66	46.15	0.09*	65.08	55.46	81.43	0.00***	21.00	13.40	31.70	0.00***
The export market desires only the big size of fruits	64.25	60.40	69.23	0.22	42.33	38.66	48.57	0.19	54.70	45.10	68.30	0.00***
Attitude on GAP												
Positive attitude (Agreed)												
Grading and sorting of fruit improves the prices of the produce	91.62	89.11	94.87	0.17	91.01	86.55	98.57	0.01**	95.30	93.20	98.20	0.00***
Fruit trees can help farmers cope with climate change	96.09	93.07	100.00	0.02**	98.94	98.32	100.00	0.28	97.50	96.20	99.20	0.00***
Fruit trees can help farmers lessen the effects of climate change	91.62	88.12	96.15	0.05**	98.94	99.16	98.57	0.70	94.20	91.50	97.50	0.00***
Growing diversity of tree species on farms increases fruit production	26.82	28.71	24.36	0.52	88.36	83.19	97.14	0.00***				
Negative Attitude (Agreed)												
No other fruit tree species are in high demand than Hass and Citrus.	78.77	78.22	79.49	0.84	66.14	42.02	20.00	0.00***	30.10	30.70	29.50	0.70
Trees with more branches and big crowns produce more fruits	39.66	40.59	38.46	0.07*	30.69	29.41	32.86	0.62	41.00	43.10	39.40	0.23
Punning trees reduces the yield of the next season	60.34	61.54	59.41	0.77	31.75	36.97	22.86	0.04**	50.20	42.60	55.80	0.58
Clean water is just sufficient to clean the pruning tools on the farm	52.51	59.41	43.59	0.04**	47.09	46.22	48.57	0.76	53.30	61.30	46.70	0.02*
Chemical pesticides are the most effective way to control pests and diseases	48.60	59.41	34.62	0.00***	85.71	91.60	75.71	0.00***	15.80	19.20	13.30	0.01**
It is the role of the government to fight climate change, as farmers are not capable	32.96	40.59	23.08	0.01*	42.86	52.94	25.71	0.00***	79.60	82.00	77.80	0.08
Applying fertilizers wastes resources because trees can get nutrients deep in the soil.	19.55	22.77	15.38	0.22	19.58	24.37	11.43	0.03**	72.90	69.90	75.10	0.05**
Fruit trees are more important than non-fruit trees on the farm	63.13	62.38	64.10	0.81	41.80	47.06	32.86	0.06*	25.00	29.30	22.00	0.01**
Adopted Practices on GAP												
Have you grown soil-cover crops on your farm?	60.34	55.45	66.67	0.13	91.01	87.39	97.14	0.02**	66.60	68.80	63.40	0.34
Grow trees to lessen the effect of climate change	68.16	60.40	78.21	0.01**	94.18	93.28	95.71	0.49	63.20	49.70	82.10	0.00***
Grow trees to help cope with the effects of climate change	68.72	62.38	76.92	0.04**	95.24	93.28	98.57	0.10	74.70	64.20	89.40	0.00***
Prune tree immediately after harvesting?	37.43	31.68	44.87	0.07*	74.60	64.71	91.43	0.00***	43.60	36.40	53.70	0.00**
Grade and sort of fruit when selling?	53.07	53.47	52.56	0.91	55.56	51.26	62.86	0.12	55.70	49.10	65.00	0.017**
Have fruit flies trapped in my farm all the time with effective chemicals/ hormones	11.17	6.93	16.67	0.04**	31.75	20.17	51.43	0.00***	18.60	16.20	22.00	0.21
I have had my soil tested	11.73	5.94	19.23	0.00***	2.12	1.68	2.86	0.59	0.70	1.20	0.00	0.23
I follow the recommended timing and standards for harvesting export fruits	47.49	37.62	60.26	0.00***	65.08	54.62	82.86	0.00***	32.40	20.20	49.60	0.00***
I keenly identify pests and stages before applying the pesticide or insecticide	42.46	37.62	48.72	0.14	76.72	65.55	95.71	0.00***	36.50	26.60	50.40	0.00***
I'm now planting diverse species on my farm	49.72	43.56	57.69	0.06*	92.59	90.76	95.71	0.21	57.80	51.40	66.70	0.01 **

The training helped align farmers with family, societal and market needs to be deemed fit. Farmers in Kiambu (83%) and Makueni (96%) believe their spouse/ family members would like them to participate in the coming agricultural training. However, we found that in Makueni, when it comes to tree growing, farmers want to do what their partner/ family members think they should do (80%). In Makueni (91%) and Kiambu (83%), trained farmers would want to do what their partner/family members think they should do on tree-growing decisions. In Makueni, family members highly influence participation in extension (96%) and the decision to grow a tree (73%). In Bugesera, trained farmers were likely influenced by partners and family members and would do as they thought (94%). However, as opposed to trained farmers in Kenya, farmers in Bugesera would do as the brokers need them to do (78%). In Kiambu, regarding good agricultural practices, farmers like to be like their trainers (89%), and non-trained farmers want to do what buyers/brokers recommend (33%). In Makueni, trained farmers 91% would stop practicing good agricultural practices if the trainer/ no other farmers in my area were practicing. Trained farmers in Bugesera showed the urge to be like their trainers (86%) and would do what the brokers wanted them to do (79%).

Trained farmers expressed the intention: In Kiambu, trained farmers were willing to extend the knowledge they received from the training to other farmers and people close to them (97%). sign in for carbon finance schemes to tap into the carbon market (93%). Makueni farmers will extend the knowledge from the training to other farmers and people close to them (99%). Grow more (98%), and diverse trees (98%), with less direct product benefits to their household (89%), to fight climate change (98%). Join a marketing group or a cooperative to enjoy the collective action benefits (96%) Boost their income (99%) and sign in for carbon finance schemes to tap into the carbon market (90%). if they only consider exotic trees (63%). In Bugesera, trained farmers intended to extend the knowledge they received from the trainer (98%) and grow diverse tree species that directly benefit their households (93%). They will join a marketing group to enjoy the collective action benefits (94%). They will sign up for a carbon finance scheme to tap into the carbon market (22%) and if the carbon market considers only exotic tree species (23%).

Increased Group activation and membership enrolment for collective action: There was a significant difference in the number of farmers in collective action, active groups, and those who joined the groups after training. The proportion of trained farmers in agricultural groups was higher compared to non-trained farmers in Kiambu (64%), Makueni (83%) and Bugesera (71%) (Figure 8). Compared to non-trained farmers on GAP, trained farmers joined groups after training and were more active in the groups they belonged to in all project sites. In Kiambu, 80%, in Makueni, 83%, and 71% in Bugesera in one of the seven common groups in the society. Most active members in any group formation had received training, 88% in Kiambu and 97% in Makueni. A year after training, trained farmers joined an agricultural group in Kiambu (27%), Makueni (63%), and 71% in Bugesera.

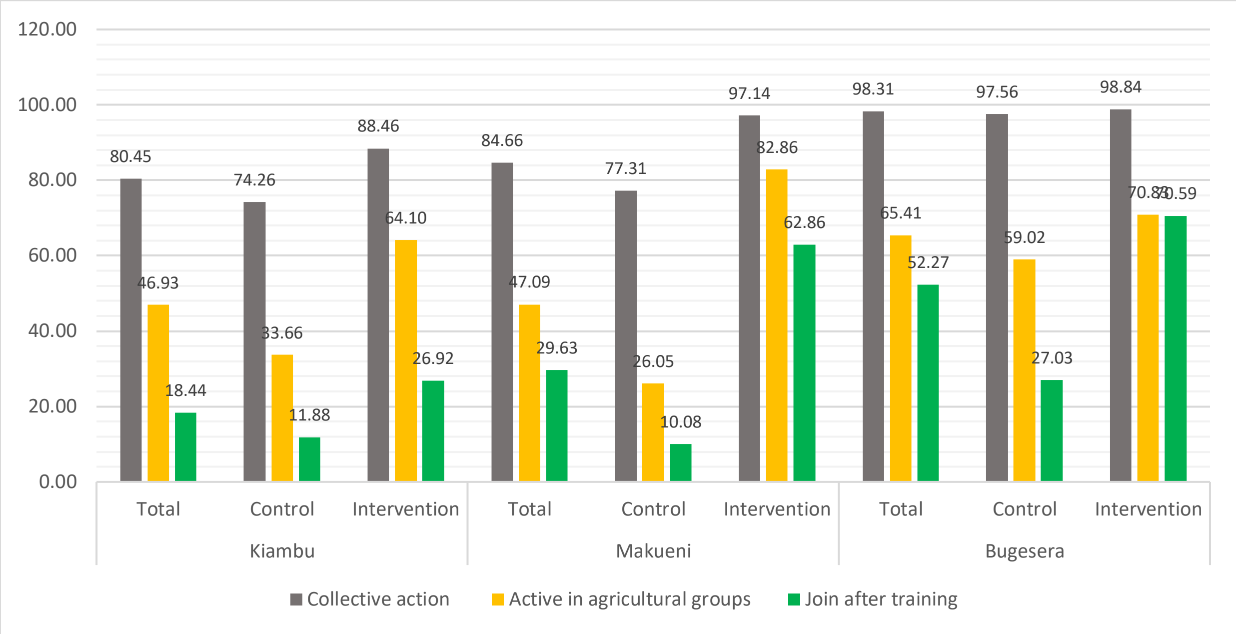


Figure 8 8: Groups belonging, enrolment, and activeness of farmers in Kiambu and Makueni after GAP training.

Promoted gender inclusion in commercial tree growing (Table8): The baseline study result showed that women were most invited to participate or lead in decisions on subsistence crops or trees. However, if the trees generated income or were in high quantities, men would take over or control the commercialization and income generated from these enterprises. During the training, men and women were trained on the importance of gender inclusion. The result in Table 13 shows that in Kiambu, women were involved when all or most decisions regarding commercial tree farming were made. We observed a significant change in women's participation between trained and non-trained households across the study sites. In a trained household, women were involved in decision-making, benefit sharing of income, and making high-degree decisions. In Makueni, we observed similar trends with significant changes in the involvement of women in decision-making and benefit sharing on tree products. In Bugesera, we observed that females participated in commercial tree farming 61%, and they felt that they could not make high-level decisions on their own (38%). Despite being a short-duration project and part of it happening during COVID-19, with a significant period when drought was experienced in the two countries, the project has registered significant achievements.

8 Impacts

Despite being a short-duration project and part of it happening during COVID-19, with a significant period when drought was experienced in the two countries, the project has registered significant achievements.

8.1 Scientific impacts – now and in 5 years

Some of the key scientific impacts are the contribution of new knowledge on allometric equations in mangoes and avocados and the production of key knowledge products on fruit trees' role in mitigating and adapting to climate change, databases, and apps.

Published Peer reviewed journals

- Kuyah S, Muthuri C.W, Wakaba D, Kiprotich P, Cyamweshi A. R, Mukuralinda A. **2024**. Allometric equations and carbon sequestration potential of mango (*Mangifera indica*) and avocado (*Persea americana*) in Kenya. Published in *Trees, Forests and People*
- Muthuri, C.W. Kuyah S, Njenga M, Kuria A, Öborn I, Van Noordwijk, M. **2023.** Agroforestry's contribution to livelihoods and carbon sequestration in East Africa' A Systematic Review. Published in *Trees, Forests and People'*.

Submitted under review

- Wakaba D, Kuria A, Crossland M and Muthuri C.W (2023). Willingness to grow trees for Climate Change Mitigation and Adaptation. A case study from Kiambu County, Kenya. Submitted to Agroforestry Systems Journal

Manuscript under author review

- Cohen M, Crossland M, Mollee E, Laroche G, Gachuiri A, Wakaba D, Muthuri C. 2023. Understanding gendered aspirations, decision-making, and fruit tree preferences in Makueni County, Kenya

Tools

- The development of the 'Interactive Suitable Tree Species Selection and Management Tool for Kenya' (Muthuri et al., 2023a) and expansion for Rwanda (Kuria et al., 2023) from the tree inventory studies. Both are accessible online
  -Kenya: https://apps.worldagroforestry.org/suitable-tree/kenya
  -Rwanda: https://apps.worldagroforestry.org/suitable-tree/rwanda

Manuals / Protocols

The project also strived to create training and nursery manuals (Activity 2.3), to be used when carrying out smallholder capacity-building activities. The project also aims to provide an in-depth understanding of how much carbon is sequestered by fruit trees to comprehend the potential for requesting climate finance to aid scaling.

- A protocol for building an allometric equation for the estimation of biomass in fruit trees was developed in East Africa was developed Kuyah & Muthuri 2022c.
- Development of training manual for avocado and mango farmers for Rwanda context (Cyamweshi et al., 2023b) and Kenya (Gachuiri et al., 2023***)***

Mobile Applications

The development of **Kuza Matunda** offline mobile apps for fruit growing in Kenya and another dubbed '**Igiti'** for all other tree species in Rwanda is a key milestone in enhancing access to critical information on tree growing from the comfort of the beneficiaries' homes, even in remote areas with no internet connection.

- Kuza Matunda App:

https://play.google.com/store/apps/details?id=com.icraf.fruittrees&hl=en_US&pli=1
Igiti App: https://play.google.com/store/apps/details?id=com.icraf.igiti&hl=en&gl=US

8.2 Capacity impacts – now and in 5 years

The baseline studies identified training and capacity development gaps in various aspects, such as farmers' tree management gaps with respect to fruit tree growing and nursery / technical gaps in seedling establishment. Lack of knowledge and skills regarding suitable improved technologies, limited access to appropriate planting materials, inadequate agronomic guidance, significant issues with pests and diseases, insufficient understanding of post-harvest handling and value addition, and difficulties in effectively marketing their products due to a lack of awareness about target markets and optimal timing. In both countries, the capacity of farmers and key stakeholders, including extension and local government officials, to improve tree growing, especially fruit trees, for increased production, resilient systems to climate change, and enhanced markets and livelihoods. This included capacity of / in:

i. ***Nursery operators in raising high-quality seedlings and especially fruit trees and running nursery as a business****:* The training of 45 and 17 nursery operators in Rwanda will no doubt increase the capacity of quality seedling supply in the target sites, especially for fruit trees. In Kenya, this will enable them to acquire certification from the government, a critical component in opening new market frontiers, including with county government in driving the 15 billion tree growing initiative by 2032. In Rwanda, the seven nurseries being capacitated will also enhance the quality of fruit seeding supply in Bugesera.

ii. ***Good agronomic practices in fruit growing for farmers and extension officers****:* Capacity of farmers and extension officers through training workshops on good agricultural practices, including fruit tree management incorporating a mix of theoretical and practical sessions, and sharing knowledge, experiences, and perspectives regarding gender-related roles, constraints, and opportunities in fruit tree farming was enhanced. Farmers are, therefore better equipped to overcome the challenges in fruit farming, ultimately increasing the productivity and profitability of the fruit value chain, ensuring a stable food supply for farming households in the study sites (and beyond) in Rwanda and Kenya.

iii. ***Extension, training, peer learning, knowledge sharing, and scaling****:* Capacity was built through training-of-trainer workshops and training for extension workers to scale interventions and ensure their sustainability beyond the project timeframe. The ToTs/lead/champion farmers became and continue to become knowledge multipliers within their communities within and beyond the project areas. The training on a tree nursery and GAP has increased the training beneficiaries by 211 and 206 percent in Kiambu and Makueni, respectively. In Rwanda, the number of trained farmers in agroforestry in both intervened areas and control sites (16%) was relatively higher because of the tree for climate change and the fruit tree for the Food Security 2 project.

iv. ***Technical capacity of students/technicians in allometric and aboveground biomass determination in trees.*** The engagement of students, youth, and technicians in project activities from baselines to carbon biomass determination workshops and data collection allowed them to learn new research skills, making them more competitive, knowledgeable, and marketable. The endline results showed that farmers in Kenya were confident and willing to engage in carbon trading because of an increased understanding of carbon estimation.

v. ***The Gender-responsive approaches:*** These approaches were used to help farmers select and tailor training materials and agroforestry options to their needs to facilitate scaling up context-appropriate, affordable fruit tree-growing. This tactic helped focus instruction on web-based tools (Activity 2.1) and on-farm agronomic practices, like planting seedlings, caring for existing trees, and diversifying tree species on farms for advantages like climate adaptation (Activity 2.2). These activities assisted in enhancing smallholders' knowledge and agronomic practices while actively promoting transformative changes in unfair gender relations and asymmetries in men's and women's capacities for growing trees and marketing tree products. The endline results showed an increase in the involvement of decision-making, labor, and benefits-sharing for the households that participated in the GAP Training.

vi. ***In building partnerships/ networks***. The project fostered partnerships with various stakeholders, including NARs, universities, especially JKUAT, lead farmers, Training of Trainers (ToTs), tree nursery operators, schools, local NGOs, farmer agriculture training centers, and county government extension agents. Trained farmers showed a willingness to work closely with the local extension system.

Beyond the project, it is anticipated that the participatory, gender-sensitive, inclusive approach applied in the project will be sustainable and scalable as it is embedded in county/ district structures, owned by farmers' trees, and with the capacity support of trained TOTs. On the other hand, researchers now have a better understanding of the needs of smallholders and are therefore better placed to provide agroforestry/multipurpose tree options and tailor the training materials to suit these needs as well as align research support to farmers/county/districts' priorities and needs.

8.3 Community impacts – now and in 5 years

The project aimed to improve the livelihoods of smallholder farmers, including women and youths, by promoting the selection and production of suitable fruit trees that benefit farmers' nutrition and income. In this project, tree nursery operators were connected to the community of practice focused on maximizing the productivity and benefits of fruit trees for climate adaptation. This increased their market opportunities as well, besides their capacity to run tree nurseries more professionally and as a business was enhanced and this is influencing more nursery operators to be capacitated or some to start nurseries.

Improved inclusivity and the involvement of women and young people in some instances, cooperatives for fruit trees (Activity 2.3) have been formed, and strong collaboration with the communities to grow diverse fruit tree species on for example, public lands such as schools has been witnessed. By educating and empowering the cooperative, the communities where they operate will quickly adopt the technologies taught and easily assimilated by the communities in which they serve.

Enhanced use of community-level communication and local leadership structures to solve societal problems such as theft cases. Through the capacity development approach, one of the key anticipated benefits of the project was to create co-learning and experience-sharing avenues among farmers. This has been achieved in Kenya where through WhatsApp Groups and using the county agriculture staff, farmers share experiences and hence have 'peer learning'. The project promoted critical discussions and reflection on the gender roles and relations surrounding fruit tree production in households and communities by utilizing gender transformative action methods and tools, and it also encouraged joint labour and decision-making. As a result, tree planting, survival, and management will become more sustainable.

Beyond 5years, the project anticipates a change in farmers' behaviors and practices regarding fruit tree growing and consumption. Also, because of the project, fruit-growing farmers may work collectively more for social support or form cooperatives. The project may also have spill over effects, especially where non-project farmers adopt agroforestry and fruit-growing best practices, particularly where there is evidence that tree growing is a profitable undertaking.

Training through the ToT model raised the standards of social cohesion and cooperation to make a societal difference. Farmers were willing to extend the knowledge gained to others (97%). The training has brought attitudinal and general behavioural change to society regarding tree-growing management and marketing of tree products. Women have been empowered and are taking part in all aspects of tree growing and management.

8.3.1 Economic impacts

The project aimed to improve the livelihoods of smallholder farmers, particularly women and youths, by encouraging the selection and production of suitable fruit trees that benefit farmers in terms of nutrition and income.

The project was especially keen to ensure that fruit-growing farmers are planting the right quality fruit trees in the right place and management / proper agronomic practice to get the right quantity and quality for the local and international markets. Therefore, the team linked closely with country-specific priorities and government initiatives such as the county-integrated development plans in Makueni and Kiambu, Kenya, and sector initiatives in Bugesera, Rwanda. The economic benefits are therefore projected to be realized through:

Increased fruit tree production system and overall resilience and profitable systems*:* Access to modern climate-smart agronomic techniques and appropriate agronomic practices is essential for enhancing fruit production quality and utility. Training on proper agronomics is helping improve fruit production efficiency by minimizing costs and losses to increase profit. Diversification of stock by nursery operators will increase the visibility of their business, the stock portfolio, and the income stream. Strong linkages between trained farmers and key agricultural institutions, such as County/ sector Governments' agriculture extension officers, Farmer agriculture training centres, and research institutions like KALRO, JKUAT and RAB, will enhance knowledge transfer and promote innovation. These linkages facilitate continuous learning, access to updated market information, technical guidance, and research-based practices. By leveraging the expertise of these institutions, farmers will optimize their production systems, mitigate risks, and improve overall profitability. The strong network between farmers and county government could lead to entrepreneurship relations through government tendering to supply the government with trees, seedlings or fruit.

Nurseries as a business: Enhanced capacity for seedling nursery operators has resulted in most operating nurseries as a business and especially getting quality fruit trees. This has led to a few being supported by the project to get certification from the Kenya government agency. This eventually translates to having access to a broader market within the county and nationally hence more income. Also, producing quality seedlings will lead to income generation by smallholders. On the other hand, after the training, in Rwanda, four individuals are being supported to set up fruit tree nurseries as a business to help raise income for their families.

***Formation of cooperatives for collective bargaining action and marketing**:* Our primary organizations for organizational capacity-building were cooperatives and farmer organizations. The improved technical information dissemination, cultivating negotiating abilities for tree-based commodity trading, and creating management and decision-making frameworks that are Gender Equality and Social Inclusion GESI-responsive (Section 3.3). By creating a cooperative, the community can pool its resources to create a common market, secure high prices for its products, and cut costs by making purchases as a group, all of which will encourage self-reliance. As part of the effort to create a local innovation network, lead farmers, private tree nursery owners, and government extension services increased their skills in quality planting material, handling, and management. For example, the formation of Gatundu South Avocado and Macadamia Farmer Cooperative (AVOMAC) in Kiambu will create a platform for collaboration, knowledge-sharing, resource pooling, and market access. The cooperative will enable farmers to collectively address challenges, negotiate better prices, access credit facilities, and engage in value addition activities. By working together, farmers can strengthen their market position, improve income generation, and enhance overall economic empowerment. For instance, during the January season, farmers under AVOMAC reported improved prices for their avocados from Ksh 20 to Ksh 90 per kg (currently 1 US$ =130 Ksh). Additionally,100 youths were trained and engaged in harvesting, earning Ksh 5/per kilogram (3-5 fruits depending on size). This has created jobs for youth most of whom were unemployed and engaged in non-productive activities like drinking.

Finally, workshops on information on the role of trees in climate mitigation and adaptation and understanding of carbon sequestration will provide a good basis for farmers to interrogate different carbon finance schemes as well as provide useful data as the potential basis for future design of climate finance schemes. This is a co-benefit that could encourage farmers to retain trees on the farm even as they accrue all other benefits from trees a number of which are financial. Trained farmers showed more confidence in engaging in the carbon market and tapping into the carbon finance schemes.

8.3.2 Environmental impacts

One of the anticipated environmental impacts of the fruit project will be to increase the density and diversity of fruit trees, which will lead to higher amounts of carbon sequestration, thereby reducing greenhouse gas emissions.

Training farmers and tree nursery operators are expected to increase newly planted trees' survival rate. Capacity development of tree nursery operators will lead to the stocking of various tree species because of the entrepreneurial spirit fostered there, which could encourage the planting of diverse species. Farmers can gauge their carbon holdings with the help of allometric equations developed for mango and avocado, prompting them to plant indigenous and retain trees for longer to benefit from carbon finance.

Another impact will be to enhance climate change mitigation and adaptation, whereby more fruit trees in the landscape will provide ecological benefits such as micro-climate improvement by providing shade, water regulation, and reducing the rate of evapotranspiration and windbreak.

Also, general environmental resilience will be enhanced by promoting the diversity of fruit trees to encourage better adaptation to a changing climate. The findings and associated methodology of quantifying carbon stocks in fruit trees will contribute and be incorporated in monitoring and reporting into respective NDCs to realize the benefits of climate mitigation and adaptation, especially those related to access to international climate finance.

Through some benefit sharing involving carbon credits with communities, governments can drive home that fruit trees are important for mitigating and adapting to climate change. Farmers who gave up their trees for destructive biomass studies received compensation of five to ten trees for replacement, thus increasing the number of newly planted trees on farms.

8.4 Communication and dissemination activities

As summarized below, the project used various channels to communicate, tailor-made and disseminated communication products suited for different audiences, including farmers, extension agents, researchers, children, and the wider public.

Channel	Activities
Project web page	• Project web page created serving as a repository for communication/knowledge products https://www.worldagroforestry.org/project/fruit-trees-climate-adaptation-and-mitigation-east-africa
Blogs	• From corporate comfort to a green venture of raising fruit trees • New forestry app empowering fruit tree farmers to become more climate resilient • RAB organizes training on good agricultural practices for mango and avocado • Empowering farmers on climate-smart farming practices to boost avocado productivity and profitability in Central Kenya • Transforming tree nurseries into gender-inclusive enterprises in Central and Eastern Kenya • Fruit trees- an essential climate change adaptation pillar in Eastern Rwanda (due to be published)
Conference and Events	• CIFOR-ICRAF Common Board of Trustees field visit to one of the project sites-Gatundu South in Kiambu County to gain first-hand experiences from the beneficiaries and deeper understanding of the impact on the ground on 20th May 2024. • Keynote presentation titled, *'Agroforestry: A solution for sustainable livelihoods and resilient landscapes'* at 18th JKUAT Scientific, Technological and Industrialization Conference held on March 21-22, 2024. Another oral presentation titled, '*Does Climate Change Mitigation and Adaptation Motivate Farmers to Grow Trees? A case study from Kiambu County, Kenya*' made during the two-day 17th JKUAT's Scientific, Technological and Industrialization Conference held in March 2023. The conference enabled to share findings with academics, researchers, policymakers, and funders. • Participation in a panel discussion on Children Leading Climate Action and provision of 200 assorted tree seedlings towards the tree planting drive during the 2023 Children's Devolution Conference held at MPESA Foundation Academy, Kiambu County, bringing together over 250 children from the 47 counties attending. • Project lessons sharing during ACIAR side event on How to implement food systems change at UNFCC COP 27 held in November 2022. • Training on good agronomic practices, tree nurseries, and climate change adaptation conducted for farmers, and extension agents in Kenya and Rwanda • Distribution of 430 true-to-type Hass avocado seedlings to 31 farmers who offered their trees for carbon biomass estimation and 70 community members in Kiambu County, Kenya. Another 60, including 30 assorted fruit

	and 30 hass avocado seedlings distributed to Githaruru Primary School and Gatundu High School in Gatundu South sub-county
Tools and Databases	• Development and expansion of Interactive Suitable Species Selection and Management Tool- an online web-based tool, based on tree inventories conducted in Kenya and Rwanda. The tool contains 178 (101 indigenous and 77 exotic) and 164 (indigenous 110 and exotic 54) tree species in Kenya and Rwanda, respectively. • Mobile offline apps- Kuza Matunda (grow fruits) and Igiti have been developed and available on Google Play Store. The apps will assist in fruit and multipurpose tree growing and management efforts by providing information on uses and management without an internet connection.
Media Coverage	• Smart Farmer Africa: CIFOR-ICRAF's New App Boosts Climate Resilience and Income for East African Farmers • Citizen Tv: Makueni Farmers turn to fruits farming as Kenya is grappling with effects of climate change • Citizen Tv: Mapato ya Hewa ya Kaboni | Mabadiliko ya tabianchi yachochea wataalamu kubadili mbinu ya upanzi • Smart Farmer Africa: Avocado farmers empowered on climate-smart practices to boost productivity • Farmers Review Africa: A new project launched in Kenya and Rwanda to empower avocado and mango farmers on climate-smart practices •
Publications	• Kuyah S, Muthuri C, Wakaba D, Cyawmeshi AR, Kiprotich P, Mukuralinda A. 2024. Allometric equations and carbon sequestration potential of mango (Mangifera indica) and avocado (Persea americana) in Kenya.Trees, Forests and People 15: 100467 • Muthuri, C.W. Kuyah S, Njenga M, Kuria A, Öborn I, Van Noordwijk, M. **2023.** Agroforestry's contribution to livelihoods and carbon sequestration in East Africa' A Systematic Review. In *Trees, Forests and People'*. • MSc dissertation titled, *Gender Dynamics and Fruit Trees in Makueni County, Kenya: Who Decides Which Fruit Trees to Plant and Why Is This Important?'* • Training manuals on avocado and mango targeted at farmers and extension agents developed for Kenya and Rwanda provide information on good agronomic practices for enhanced productivity and multiple benefits (Gachuiri et al., 2023; Cyamweshi et al., 2023b). • Another training manual on rapid carbon estimation was produced aimed at building the capacity of farmers, land managers, and community facilitators to monitor carbon benefits in fruit trees. • Journal articles aimed at scientific audiences developed for submission to peer-reviewed journals
Social media	• Leveraged CIFOR-ICRAF's social media platforms (Twitter, LinkedIn, and Facebook) to increase the project's visibility by sharing updates on activities and events (social media summary)

The project's capacity-building, communication, and dissemination strategies increased the capacity of stakeholders to self-sustain many of the crucial activities, increasing the likelihood that these longer-term impacts will be realized. This included making the most of early results to involve and educate stakeholders on determining how much carbon is in fruit trees and how that affects a country's NDCs.

9 Conclusions and recommendations

9.1 Conclusions

The project registered good progress despite starting during COVID-19 restrictions partly because it addressed an important topic of fruit trees and climate change at a time when climate crises, such as drought, floods, and rising temperatures, are happening.

Fruit trees are priority species for farmers. The baseline studies and tree inventory survey showed fruit trees are preferred for their multi-benefit purposes with a third (31-33%) of the tree species on farms being fruit trees. This clearly demonstrated the importance of fruit trees in food and nutritional security, livelihood improvement, incomes, ecosystem services including carbon financing. Findings from endline survey also reaffirmed this considering that the new plantings were dominated by fruit trees species.

Positive impact of training- The endline survey reported that the trainings enhanced farmers knowledge, skills and understanding of tree growing (the right trees for the right place, purpose) and management including control of pests and diseases. The trainings also improved farmers awareness and positively impacted attitudes towards the role of fruit trees in climate change and the importance of sustainable farming practices and environmental conservation, leading to a more holistic approach to fruit tree cultivation and resilience to climate change impacts.

Development of an "Interactive Suitable Tree Species Selection and Management Tool" for Kenya and expansion for Rwanda tool and accompanying offline mobile Apps namely Kuza Matunda in Kenya and Igiti in Rwanda, are remarkable achievements. The current data on downloads and access by users one year down the line shows the timely and importance of these resources in improving information access on tree / fruit growing to complement government extension systems and other relevant stakeholders.

Development of allometric equations for estimating aboveground biomass in Kenya's mango and avocado fruit trees and published by " Kuyah et al., 2024, and for Rwanda as documented in (Cyamweshi et al., 2023c). This knowledge is not only critical to researchers but coupled with the climate change sensitisation workshop is helping trained farmers estimate the carbon stocks in their fruit orchards thus better equipped to bargain for better carbon markets.

Quality of sufficient and diverse tree seedlings critical for increasing fruit farming. The capacity of the tree nursery operators was also enhanced, and many nursery operators and some farmers have expressed interest in having their nurseries capacitated or set up nurseries respectively. Many fruit trees were encountered during tree inventory exercise in project sites, yet only a narrow range of species were found in nurseries. With the trainings its projected nursery operators with enhance quality and diversity of their tree seedings. Thirty tree nurseries 15 in each county in Kenya and seven in Rwanda are being supported in different ways on need basis to enable them to operate as businesses.

Extension through partnerships. Due to the great demand for training, the project used the TOT, champion/ lead farmers, and other avenues like a partnership with county officials as an extension approach to reach many more farmers and scale up these trainings. This has proved to be very successful and sustainable, extending knowledge beyond the project's life. Trainers (ToT) model increased the number of farmers reached, significantly boosting the proportion of trained farmers.

The importance of using a gender-inclusive approach to identify opportunities, challenges, capacity gaps, and roles of trees on farms is critical. Differences were observed in the specific species preferred by each gender and in most cases with women's focus being on family consumption needs. Therefore, women's increased involvement in fruit tree decisions could impact the farm tree composition and household income, potentially improving food security.

Enhanced collective action is critical in fruit growing and marketing in Kenya. Endline survey revealed increased enrolment into new agricultural group membership and reactivation of old ones amongst the trained farmers in Kenya. This has provided farmers a platform to exchange experiences and best practices in tree growing and management, thus contributing to resilient landscapes and livelihoods (incomes). For example, formation of AVOMAC following training in Kiambu with current membership of 1150 farmers and growing.
Development of knowledge products, were key achievements targeting different audience

9.2 Recommendations

The gaps identified in this project were partially addressed through capacity building precisely training and extension using a participatory gender transformative approach. This has resulted in great interest to farm fruit trees and there is a lot of goodwill and support by farmers and local governments to take this to the next level of scale in production, market, and business. Therefore, a follow-on phase of support to the implementation of the best-fit options or priority interventions in the following areas is needed.

- *Markets and Value chains* -With the increased growing of fruit trees, especially mangos and avocados, the whole value chain and market for fruit trees need to be developed. Support to existing agricultural groups like AVOMAC and those that are reactivated will be critical including matters of managing a corporative and value addition.
- Encouraging active participation in agricultural groups and facilitating knowledge sharing and collaboration among members to maximize the benefits of collective action. Providing incentives or support mechanisms for farmers adopting sustainable agricultural practices, such as carbon finance schemes or certification programs
- *Continued capacity strengthening of existing fruit nursery operators including certification is recommended* - In addition setting of more fruit tree nurseries including a rural resource centre in each county/ district that stocks diverse tree seedlings including both exotic and indigenous fruit trees would be ideal. This will make the nursery a great business that even the youth can be attracted to, thus reducing unemployment and 'creating green jobs as well as building climate and livelihood resilience and productivity.
- *Water* is one of the biggest barriers to tree growing in ASAL districts/counties like Bugesera and Makueni. Support for investments in coupling tree growing with water management, like rainwater harvesting, is critical, considering that most of Kenya and Rwanda's agriculture is rainfed.
- *Allometric equations*-More research is needed to develop allometric equations for citrus (and Macadamia) fruits due to their abundance and popularity across the two countries, belowground biomass allometric equations of avocado and mango as well as apply allometric equations for grafted avocado varieties.
- *Strengthening capacity on the nutritional benefits of fruit consumption;* there is a need for more education on nutrition and value addition.

Overall, continued investment in agricultural training and extension services, coupled with efforts to promote gender inclusion and community collaboration, can contribute to sustainable agricultural development and improved livelihoods for farmers in the regions studied.

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10.2 List of publications produced by the project.

Journal articles published.

Kuyah S, Muthuri CW, Wakaba D, Kiprotich P, A. M. and A. C. (2024). Allometric equations and carbon sequestration potential of mango (Mangifera indica) and avocado (Persea americana) in Kenya. In Trees, Forests and People 15:100467 https://doi.org/10.1016/j.tfp.2023.100467

Muthuri C.W, Kuyah S, Njenga M, Kuria A, Öborn I, van Noordwijk M. 2023. Agroforestry's contribution to livelihoods and carbon sequestration in East Africa' A systematic Review. In Trees, Forests and People. https://doi.org/10.1016/j.tfp.2023.100432

Journal articles submitted

Wakaba D, Kuria A, Chiputwa B, Crossland M, and Muthuri C.W (2023). Willingness to grow trees for Climate Change Mitigation and Adaptation. A case study from Kiambu County, Kenya. ***Accepted with revisions at Agroforestry Systems-*** *Being revised*

Draft manuscript

Cohen M, Crossland M, Gachuiri A, Laroche G, Wakaba D, Muthuri CW. (2023). Understanding gendered aspirations, decision-making, and fruit tree preferences in Makueni County, Kenya.

Thesis/Dissertation

Michelle Cohen. (2022). Gender Dynamics and Fruit Trees in Makueni County, Kenya : Who Decides Which Fruit Trees to Plant and Why Is This Important ? Dissertation submitted in partial requirements for the degree of Master of Science (MSc) in Agroforestry and Food Security. Bangor University UK.

Abstracts for conference presentation

Wakaba D, Crossland M, Kuria A, Muthuri, C.W. (2023). Does Climate Change Mitigation and Adaptation Motivate Farmers to Grow Trees? A case study from Kiambu County, Kenya.

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Muthuri CW, Kuyah S, Wakaba D, Njoki C. 2024. Carbon sequestration in fruit trees. Bogor, Indonesia: CIFOR (Center for International Forestry Research); and Nairobi, Kenya: World Agroforestry (ICRAF).

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Wakaba D, Njoki C. and Muthuri, C.W. (2022). Reconnaissance field visit in Makueni county on 10th June 2022.

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10.2 Appendix 1:

Scale-out community-based fruit-tree growing, using multipurpose species where possible	
Baseline report-Kenya	Wakaba et al., 2022d
Baseline report- Rwanda	Loreche et al., 2022
Tree Inventory-Kenya	(Kuyah et al., 2022)
Tree Inventory-Rwanda	Cyamweshi et al., 2022
Priority setting	Wakaba et al., 2022b
Kiambu Reconnaissance	Wakaba et al., 2022c
Makueni Reconnaissance	Wakaba et al., 2022a
Cohen Manuscript	Cohen et al., 2023
Presentation PowerPoint	Wakaba et al., 2023b
Presentation abstract	Wakaba et al., 2023a
FGD Guide	Crossland et al., 2022a
KII-Guide	Crossland et al., 2022b
Interview guide	Crossland et al., 2022c

The right trees are in the right places. Show smallholders how to site trees on farms to maximize climate adaptation benefits	
Tree nursery in Kenya	Gachuiri et al, 2022a
Avocado training	Gachuiri et al, 2022b
Mango Kenya	Gachuiri et al 2022c)
Training Rwanda	Cyamweshi et al., 2023a
Avocado Manual	Gachuiri et al., 2023
Rwanda Manual	Cyamweshi et al., 2023b
Mango Manual	
Michelle Thesis	Cohen, 2022
Kenya Interactive tool	Muthuri et al., 2023a
Summary of interactive tree species-Kenya	Wamaitha et al., 2023a
Rwanda interactive tree species	Kuria et al., 2023
Summary interactive tree species Rwanda	Wamaitha et al., 2023b

To Estimate fruit tree carbon sequestration benefits to determine the potential for access to international climate finance that could further accelerate scaling out.	
Biomass sampling sheet	Kuyah 2022
protocol	Kuyah & Muthuri, 2022a
Systematic review	Kuyah & Muthuri, 2022b
Biomass report Kenya/allometric	Kuyah et al., 2023a
Journal-Agroforestry contribution to livelihood and carbon sequestration	Muthuri et al., 2023b
Journal-Allometric equations and carbon sequestration of mango and avocado	Kuyah et al., 2024
Training Manuals	Kuyah & Muthuri 2022c
Endline Surveys	
Kenya Endline surveys	Wakaba et al., 2024
Rwanda Endline surveys	Cyamweshi et al., 2024

Table 7: Assessment of farmers' attitudes, subjective norms, perceived behavioural control, injunctive norm, descriptive normative behaviors, and Intentional normative behaviours of farmers.

	Kiambu				Makueni				Bugesera			
	Pooled	Non-Trained	Trained	p-value	Pooled	Non-trained	Trained	p-value	Pooled	Non-trained	Trained	p-value
Attitudes (I would like to ask you how strongly you agree with the following statements.)												
Positive statement (Agree)												
Buying seedlings from certified sources is the most desirable thing	89.39	84.16	96.15	0.01**	71.43	58.82	92.86	0.00***	88.90	86.70	91.90	0.005**
It matters to me who buys fruits from me	58.66	52.48	66.67	0.05**	80.42	77.31	85.71	0.16	79.40	79.20	79.70	0.84
I feel good when I see my farm full of trees	99.44	100.00	98.72	0.26	100.00	100.00	100.00	.	99.00	98.30	100.00	0.003**
Planting trees on my farm saves me a lot from buying tree products	98.32	98.02	98.72	0.72	100.00	100.00	100.00	.	95.90	93.60	99.20	0.00***
Farms full of trees stand out from the rest	98.88	99.01	98.72	0.85	98.94	98.32	100.00	0.28	98.30	97.10	100.00	0.00***
Negative Statement (Agreed)												
Fruit trees are more IMPORTANT to men than youth and women	68.72	71.29	65.38	0.40	61.38	63.03	58.57	0.55	88.90	86.70	91.90	0.005**
I have no problem growing trees at any place on the farm if they benefit me	58.66	60.40	56.41	0.59	4.23	5.88	1.43	0.14	87.50	87.90	87.00	0.66
It doesn't matter to me the source of the seedling as long as they are grafted	37.99	47.52	25.64	0.00***	40.74	42.86	37.14	0.44	71.60	73.40	69.10	0.11
Subjective Norm (How likely would the following people influence your involvement in tree-growing and management activities?)												
Family members	54.19	47.52	62.82	0.04**	70.37	68.07	74.29	0.37	96.30	93.60	100.00	0.00***
Government environment workers	67.04	59.41	76.92	0.01**	68.37	76.47	60.00	0.02**	79.40	73.40	87.80	0.00***
People in social network/group	40.78	37.62	44.87	0.33	63.49	66.39	58.57	0.28	82.10	78.60	87.00	0.00***
People from the non-government organization	79.33	70.30	91.03	0.00***	60.32	57.14	65.71	0.25	78.00	70.50	88.60	0.00***
Administrative officials and political leaders	44.13	42.57	46.15	0.63	51.32	63.03	31.43	0.00***	77.40	72.80	83.70	0.00***
Perceived behavioral control (Now think about yourself, i.e., your power regarding decision-making in tree growing and management. To what extent do you agree with the following statements)												
I am confident that I can make sound decisions regarding tree-growing and management	96.04	97.44	96.65	0.61	96.64	98.57	97.35	0.43	89.90	86.70	94.30	0.00***
I am confident that tree growing will contribute to food security and income in my household	98.02	98.72	98.32	0.72	100.00	98.57	99.40	0.20	93.60	91.90	95.90	0.005**
I am confident that I can contribute significantly toward the reduction of carbon stocks	98.02	97.44	97.77	0.79	99.16	100.00	99.47	0.44	40.10	32.50	50.40	0.00***
The decision to involve my spouse and my children in farm management is within my control	86.14	84.62	85.47	0.78	97.48	100.00	98.41	0.18	90.20	89.60	91.10	0.41
Whether or not I participate in the carbon market is entirely up to me	89.11	83.33	86.59	0.26	95.80	98.57	96.83	0.30	24.00	23.00	25.40	0.36
Most people who are important to me think that I should be a champion to fight climate change	91.09	91.03	91.06	0.99	96.64	97.14	96.83	0.85	75.70	69.40	84.60	0.00***
Injunctive Norms												
My spouse/ family member would like me to participate in the coming agricultural training	83.24	82.18	84.62	0.67	96.30	96.64	95.71	0.75	95.30	94.80	95.90	0.36
When it comes to a decision on tree growing, I want to do what my partner/ family members think I should do	53.63	51.49	56.41	0.52	80.42	73.95	91.43	0.00***	89.90	87.30	93.50	0.00***
When it comes to marketing, farm management, and tree growing, I want to do what society requires of me	28.49	28.71	28.21	0.94	65.61	61.34	72.86	0.11	81.40	80.90	82.10	0.61
When it comes to tree product marketing, I would do what the buyers/brokers want me to do	20.11	22.77	16.67	0.32	28.57	25.21	34.29	0.18	68.20	61.30	78.00	0.00***
Descriptive normative behaviors												
I would stop doing good agricultural practices if the trainer/ extensionist stopped the support	7.26	8.91	5.13	0.34	96.30	96.64	95.71	0.75	87.50	87.90	87.00	0.66

I would stop practicing good agricultural practices if the trainer/ no other farmers in my area were practicing.	11.17	10.89	11.54	0.89	80.42	73.95	91.43	0.00***				
When it comes to good agricultural practices, I would like to be like my trainer	88.83	90.10	87.18	0.54	65.61	61.34	72.86	0.11	85.50	77.50	96.70	0.00***
When it comes to the tree product business, I want to do what buyers/brokers recommend.	27.37	32.67	20.51	0.07*	28.57	25.21	34.29	0.18	73.00	68.80	78.90	0.00***
Intention normative behaviors												
I will extend the knowledge that I got from the training to other framers and people who are close to me	93.85	91.09	97.44	0.08*	99.47	100.00	98.57	0.19	88.90	82.10	98.40	0.00***
I will grow non-fruit trees that have less direct product benefits for my household in my next tree planting.	63.69	64.36	62.82	0.83	88.89	88.24	90.00	0.71	88.20	85.00	92.70	0.00***
I will grow trees in the next tree-planting cycle to fight climate change.	88.27	89.11	87.18	0.69	97.88	97.48	98.57	0.62	92.60	90.20	95.90	0.00***
For sure, I will grow diverse trees in my next cycle of tree planting	88.27	88.12	88.46	0.94	97.88	98.32	97.14	0.59	92.20	90.80	94.30	0.023*
I will join a marketing group or a cooperative to enjoy the collective action benefits	91.06	88.12	94.87	0.12	97.35	95.80	100.00	0.08*	88.90	85.50	93.50	0.00***
I would like to grow more trees on my farm	89.39	87.13	92.31	0.27	98.41	98.32	98.57	0.89	91.90	91.30	92.70	0.40
I will grow fruit trees to boost my income	97.21	97.03	97.44	0.87	99.47	100.00	98.57	0.19	94.30	93.60	95.10	0.28
I will sign in for carbon finance schemes to tap into the carbon market	87.15	82.18	93.59	0.02**	89.95	94.96	81.43	0.00***	19.40	17.40	22.30	0.039*
I will sign in for carbon credit trading if they are only considering exotic trees	68.16	68.32	67.95	0.96	63.49	55.46	77.14	0.00***	18.70	15.60	23.00	0.002**

Table 8: Gender (Women in tree growing and inclusion on benefit sharing in Makueni and Kiambu

	Kiambu				Makueni				Bugesera			
	Pooled	Non-Trained	Trained	P-Value	Pooled	Non-Trained	Trained	P-Value	Pooled	Non-Trained	Trained	P-Value
Did you participate in commercial fruit tree growing	50.60	28.85	87.10	0.00***	50.47	43.94	60.98	0.11	52.94	49.48	61.54	0.01**
How much input did you have decision making (Input into most or in all inputs)	76.19	73.33	77.78	0.34	35.19	27.59	44.00	0.02**	30.56	27.08	37.50	0.23
How much input did you have benefit sharing (Input into most or in all inputs)	59.52	53.33	62.96	0.24	35.19	27.59	44.00	0.02**	81.94	81.25	83.33	0.56
To what extent do you feel you can make your own decision (High)	69.05	66.67	70.37	0.32	35.19	37.93	32.00	0.63	63.89	77.08	37.50	0.00***