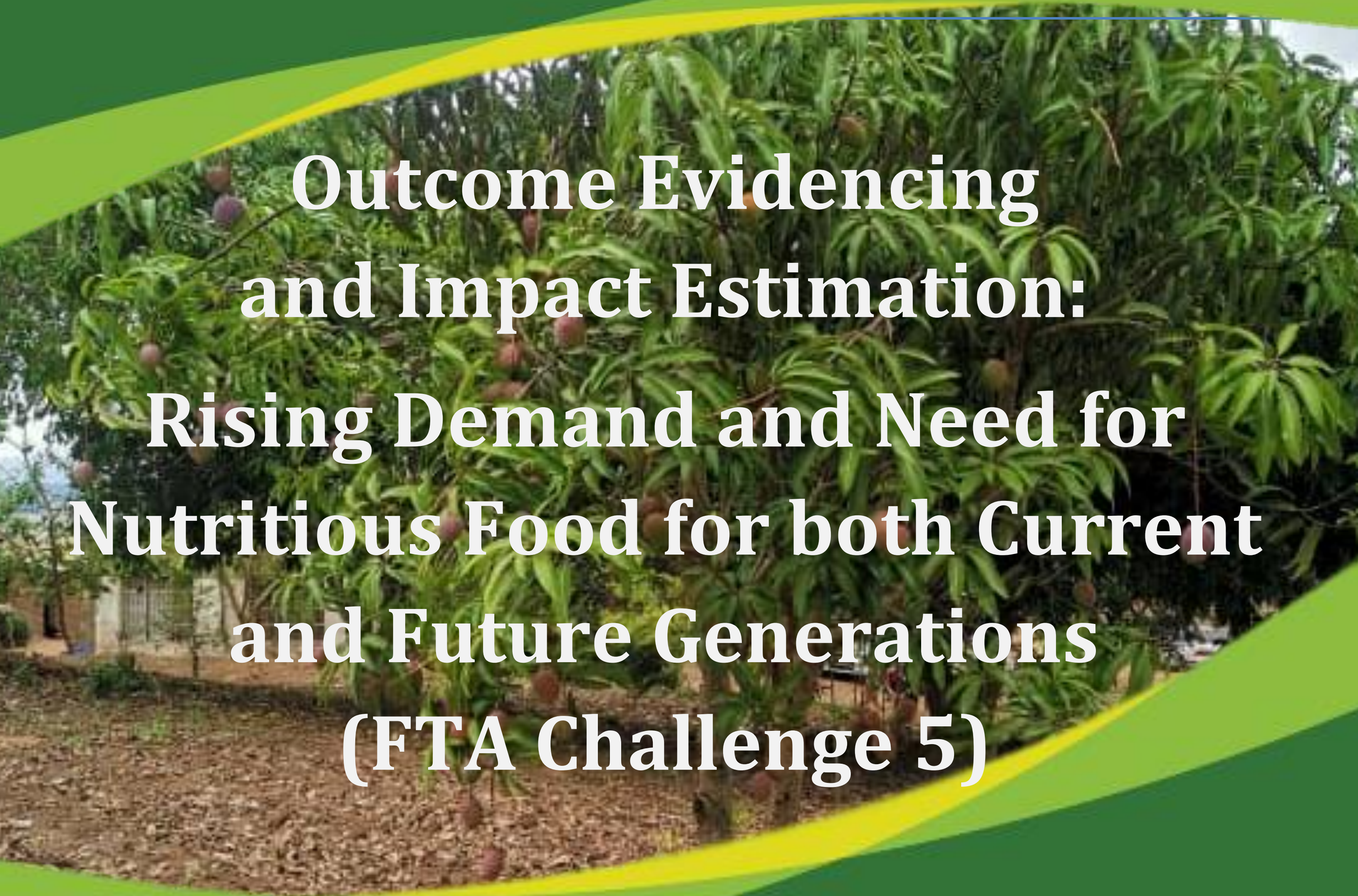

Outcome Evidencing and Impact Estimation: Rising Demand and Need for Nutritious Food for both Current and Future Generations (FTA Challenge 5)

An Integrative Evaluation of the Forests, Trees and Agroforestry Research Program (2010-2020)

CGIAR
RESEARCH PROGRAM ON Forests, Trees and Agroforestry

CIFOR
World Agroforestry
Alliance
Bioversity International
CIAT International Center for Tropical Agriculture Since 1967 Science to cultivate change
Royal Roads University

Cover photo: Improved mango orchard, Malawi.

Acknowledgements

The integrative study of the Forests, Trees and Agroforestry (FTA) Research Program is supported by the CGIAR Research Program on Forests, Trees and Agroforestry. The MELIA teams at CIFOR, ICRAF, and Bioversity International, in close partnership with the Sustainability Research Effectiveness Program at Royal Roads University in Canada, thank all interview respondents who participated in the assessment. We extend special thanks to FTA partners at CIRAD, CATIE, INBAR, and Tropenbos for their feedback and inputs to the assessment of Challenge 5. Linda Collette, a member of FTA's Independent Steering Committee (ISC), offered valuable and constructive comments as a peer reviewer We further thank Vincent Gitz and Alexandre Meybeck for their feedback on the report, as well as all other ISC members.

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This evaluation was carried out as part of the as part of the CGIAR Research Program on Forests, Trees and Agroforestry (FTA). FTA is the world's largest research for development program to enhance the role of forests, trees and agroforestry in sustainable development and food security and to address climate change. CIFOR leads FTA in partnership with ICRAF, the Alliance of Bioversity International and CIAT, CATIE, CIRAD, INBAR and TBI.

FTA's work is supported by the CGIAR Trust Fund.

Table of Contents

List of Tables

List of Figures

List of Acronyms

AGRENES	Agriculture, Environment and Ecosystem
AFSP	Agroforestry for Food Security
AOCC	African Orphan Crop Consortium
ASWAP	Agriculture Sector Wide Approach Programme (Malawi)
BAPPENAS	Indonesia National Development Planning Agency
GAIN	Global Alliance for Improved Nutrition
BRI	Bushmeat Research Initiative
EADD	East Africa Dairy Development Programme
CATIE	Tropical Agricultural Research and Higher Education Center
CBO	Community based Organization
CBD	Convention on Biological Diversity
CFS	World Committee on Food Security
CGIAR	Consultative Group on International Agricultural Research
CIFOR	International Forestry Research Institute
CIRAD	French Agricultural Research Centre for International Development
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COP	Conference of the Parties
CPW	Collaborative Partnership on Sustainable Wildlife Management
CRP	CGIAR Research Program
DALY	Daily Adjusted Life Years
DFID	Department for International Development (UK)
DMI	Dry Matter Intake
DRC	Democratic Republic Congo
DryDev	Drylands Development Programme
DVCIP	Developing Value Chain Innovation Platforms
EBI	Ethiopian Biodiversity Institute
EIAR	Ethiopian Institute of Agricultural Research
EOP	End of Program
ETH	Ethiopia
FAO	Food and Agriculture Organization of the United Nations
FCS	Food Consumption Score
FIES	Food Insecurity Experience Scale
FTA	Forest, Trees and Agroforestry
FTPC	Food Tree and Crop Portfolio
FTS	Fertilizer Tree Systems
FTT	Fodder Tree Technologies
GBD	Global Burden of Diseases
GDD	Global Dietary Database
GDP	Gross Domestic Product
GFEP	Global Forest Expert Panel
GLM	Governing Multifunctional Landscapes
HH	Household
HLP	Healthy Learning Program
HLPE	High Level Panel of Experts on Food Security and Nutrition
IAA	Impact Assessment and Acceleration
ICRAF	World Agroforestry
IDA	Iron Deficiency Anaemia

IDO	Intermediate Development Outcome
IEC	Information, Education and Communication
IFAD	International Fund for Agricultural Development
IFSTAL	Interdisciplinary Food Systems Teaching and Learning
INBAR	International Network for Bamboo and Rattan
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IUCN	International Union for Conservation of Nature
IUFRO	International Union of Forest Research Organization
KIBT	Kenya Institute of Business Training
KNOW-FOR	Knowledge on Forests is Understood and Used Internationally
LSCI	Livelihoods Coping Strategies Index
M	Million
MDD-W	Minimum Dietary Diversity, Women
MELIA	Monitoring, Evaluation, Learning and Impact Assessment
MGDS	Malawi Growth and Development Strategy
MINFOF	Ministry of Forests and Wildlife of Cameroon
MMU	Manchester Metropolitan University
MT	Million tons
NaCORRI	National Coffee Resources Research Institute (Kenya)
NaFoRRI	National Forestry Resources Research Institute (Uganda)
NARO	National Agricultural Research Organization
NARS	National Agricultural Research Center
NGO	Non-government Organization
KALRO	Kenya Agriculture and Livestock Research Organization
KDFF	Kenya Dairy Farmers Federation
OACPS	Organisation of African, Caribbean and Pacific States
OWC	Operation Wealth Creation (Uganda)
PDAZAM	Mali Drylands Development Project
POU	Prevalence of Undernourishment
PRUNSAR	Putting Research into Use for Nutrition, Sustainable Agriculture and Resilience
QPM	Quality Planting Material
RAE	Retinol Activity Equivalent
RCP	Representative Concentration Pathways
RCT	Randomized Controlled Trial
RDA	Recommended Dietary Allowance
RRC	Rural Resource Center
RWH	Rainwater Harvesting
SAGCOT	Southern Agricultural Growth Corridor of Tanzania
SBSTTA	Subsidiary Body on Scientific, Technical and Technological Advice
SIWI	Stockholm International Water Institute
SPE	Service Providers Entrepreneurs
SLO	System Level Outcome
SNV	Netherlands Development Organization
SSA	Sub-Saharan Africa
SWM	Sustainable Wildlife Management Programme
T4FS	Trees for Food Security
TIARA	Transforming Investments in African Rainfed Agriculture
TOC	Theory of Change
UCDA	Uganda Coffee Development Authority
UNFSS	United Nations Food Systems Summit

USAID	United Nations Agency for International Development
VAD	Vitamin A Deficiency
VCIP	Value Chain
VFT	Volunteer Farmer Trainers
VIP4FS	Value Chains Innovation Platforms for Food Security
WHO	World Health Organization
YLD	Years Lived with Disability
YLL	Years of Life Lost
YPS	Yangambi, pôle scientifique au service de l'homme et des forêts

Executive Summary

A key global challenge of our times is how to feed and nourish a growing population while minimizing the impact on the environment, against a backdrop of persistent rural poverty and rising levels of (absolute) inequality. The CGIAR's Research Program on Forests, Trees, and Agroforestry (FTA) undertook significant work—both research and scaling related—to address this challenge. Being one of five main global challenges addressed by FTA, we refer to it as *Challenge 5: Rising demand and need for nutritious food for both current and future generations*. The purpose of this report is to present the findings of our review of this work.

We implemented the following steps to carry out our review:

1. Identification and initial review of FTA projects and initiatives relevant to the above challenge.
2. Explication of the key means (clusters and pathways) through which FTA's work has sought or is seeking to address Challenge 5, culminating in the retrospective construction of an overarching Theory of Change (ToC).
3. Compilation of existing evidence and data on the extent to which the key pathways associated with each cluster and, in turn, the overarching ToC have unfolded.
4. Estimating potential benefits by aggregating numbers of people provided with means of improving their food and nutritional security and conducting an ex-ante impact simulation of a key body of FTA work directly targeting nutrition-related impacts.

We identified four primary clusters of FTA's work related to Challenge 5:

- Cluster 1: Scaling up the production of food-trees on-farm
- Cluster 2: Integrating trees in cropping fields for sustainable staple food production
- Cluster 3: Improving smallholder dairy production through tree fodder
- Cluster 4: Forest resources and the nutrition of forest proximate communities

Our findings are summarized in Table 1. Overall, we found that FTA reached over 760,000 households (comprising approximately 3.4 million individuals) with food security and nutrition related interventions, with evidence—primarily gathered via household surveys—of uptake of FTA innovations among approximately one-third of these households (248,398). This was achieved through the implementation of 14 projects, of which only two had relatively large budgets of more than USD 5M. Cluster 2, which focuses on the more traditional ICRAF pathway of integrating trees in cropping fields, had the largest documented reach (442,392 households). This cluster was also associated with the largest funding base.

For Challenge 5, we found that most projects comprised activities that support multiple inter-linked pathways simultaneously, e.g., those pertaining to influencing both policy and practice. Generalized impact pathways for each cluster are described as follows:

For cluster 1—*scaling up the production of food-trees on-farm*—increasing the number of food trees on farm is expected to lead directly to improve diets, while enhanced income diversification is expected to do the same but indirectly. Donors and implementing partners are critical in scaling up Food Tree and Crop Portfolios (FTCPs) in order to achieve nutritional impacts at scale.

For cluster 2—*integrating trees in cropping fields for sustainable staple food production*—the integration of trees in cropping fields is expected to both enhance a) crop productivity, e.g., by improving soil health; and b) total farm productivity, i.e., through increasing the scale and diversity of products produced on farm. Strategic engagement with local government agencies and other partners enhances agroforestry scaling work, which, in turn, accelerates the integration of trees in cropping systems.

Table 1. Summary of key findings

Key Achievements	Evidence of Reach	Evidence of Uptake and Use
Cluster 1: Scaling up the production of food-trees on-farm		
Food trees promoted under nine different projects in 11 countries. Three projects specifically focused on identifying Food Tree Crop Portfolios (FTCPs) to provide access to nutritious food year-round.	206,045 farming households (927,201 individuals)	139,045 farming households (625,702 individuals)
Cluster 2: Integrating trees in cropping fields for sustainable staple food production		
Work undertaken with development partners to support farmers to appropriately integrate trees into their cropping systems in 12 countries.	442,392 farming households (1,990,764 individuals)	163,164 farming households (734,237 individuals)
Cluster 3: Improving smallholder dairy production through tree fodder		
Work undertaken to scale out proven Fodder Tree Technology (FTT) with development partners and national resource institutions in 3 countries.	290,579 households (1,307,606 individuals)	85,240 households (383,578 individuals)
Cluster 4: Forest resources and the nutrition of forest proximate communities		
Primary research undertaken to evidence the contribution of forests in meeting the food and nutritional requirements of forest proximate communities at the global level and in 5 countries.	Stakeholder engagement initiated in four countries, disseminating research findings and co-developing policy and intervention options; strategic inputs feed into three global fora.	Anecdotal interest in taking on board research findings. Government of Ethiopia drew on FTA research to design its nutrition sensitive interventions
Bushmeat Research Initiative (BRI) created bushmeat research database BRI and influenced policies of key international bodies (CBD, OACPS) and the governments of Brazil, Colombia, Ecuador, and Peru.	Website set-up and operational, with various policy documents and scientific publications (138)	2,949 citations and 12 policies influenced, 10 of which are decisions or regulations adopted by official bodies and national governments
Totals (non-double counted)	**761,996 households (3,428,982 individuals)**	**248,398 households (1,117,770 individuals)**

For cluster 3—*improving smallholder dairy production through tree fodder*—fodder tree technologies that are appropriately grown and utilized on farm is expected to lead to increased milk yields. Effective communication and training are required to ensure their successful establishment, management, and utilization, e.g., through improved extension services.

For cluster 4—*forest resources and the nutrition of forest proximate communities*—national and local engagement is expected to lead to improved policies and interventions for promoting the safe and sustainable food provisioning role of forests. Simultaneous engagement at the global level to influence global policy processes and donor priorities is expected to strengthen the enabling

environment at the national level by increasing access to resources, capacity development, and supportive policy frameworks.

Under cluster 1, we identified a relatively new and promising approach: developing and scaling FTCPs. This approach involves co-developing locally appropriate FTCPs with communities, while building the necessary partnerships and capacities and mobilising resources to support their scaling. With such portfolios in place, the household in question has a 'bank' of accessible and nutritious food on farm which they can sustainably withdraw from all year round. We conducted a deeper investigation of this important body of FTA's work. We first assessed its associated policy impact pathway. Here we found—through both documentation analysis and in-depth interviews with key stakeholders—strong support for the FTCP concept among national governments, key NGO partners, and donors. Strategic partners, for example, explained how their engagement with this concept led to new insights, which were further promoted in national policy processes, such as Kenya's Nutrition Action Plan and global policy processes, such as the Scaling Nutrition Movement. Similarly, an interviewed IFAD representative reported that this work is directly influencing European Union development policy.

We further conducted an ex-ante impact simulation exercise to estimate potential impacts if the FTCP concept was taking to scale in 12 African countries, focusing on a key impact metric used in the health sector: Disability Adjusted Life Years (DALYs). These countries included Burkina Faso, Democratic Republic of Congo (DRC), Ethiopia, Gambia, Kenya, Malawi, Mali, Mozambique, Niger, Tanzania, Uganda, and Zambia. Background work for this exercise revealed that the disease burden due to Iron Deficiency Anaemia (IDA) and Vitamin A Deficiency (VAD) in the 12 study countries currently amounts to an annual loss of 6.8 million DALYs, and children under five are disproportionately affected. These losses can potentially be reduced by effectively scaling up the FTCP concept. Indeed, our ex-ante impact simulation revealed that such implementation will be effective in mitigating IDA and VAD deficiencies among children and women of reproductive age, with a health benefit gain of 2.17M DALYs per year. The benefit gain ranges from 0.01 M DALYs in Gambia to 1.6 M in Nigeria.

We conclude with the following three lessons, which can be considered for building upon this important body of work and enhancing its intended impacts:

1) Improving food security and nutrition outcomes through tree-based solutions has considerable potential but requires context-specific, inter-disciplinary, and iterative research and adaptive scaling with implementing partners, local communities, and other stakeholders.
2) Given the inherent complexity of bolstering nutrition, carefully thinking through impact pathways and the assumptions that need to hold true for one step in the causal chain to proceed to the next is critical for informing research and intervention design.
3) Integrating *ex-ante* impact modelling approaches in research and scaling efforts is useful for both informing these efforts and estimating longer-term potential impacts.

1. Background

This integrative study aims to assess the extent to which the CGIAR Research Program (CRP) on Forests, Trees and Agroforestry (FTA) has contributed to solving five key global challenges since its inception in 2011. FTA represents a substantial investment of 850 million USD over the past ten years. Its research agenda aimed to develop solutions to major societal problems, thereby seeking to contribute to developmental and environmental impacts on a large scale. In practice, FTA is an umbrella for different and often inter-related research initiatives that have been implemented in diverse country contexts, policy and research environments, geographies, landscapes, and socioeconomic conditions of local communities. This study seeks to investigate the extent and nature of FTA's contributions to addressing one of the key global challenges of our times—*the rising demand and need for nutritious food for both current and future generations*.

As a CGIAR research program, FTA aimed to address a set of End of Program (EOP), Intermediate Development Outcome (IDO), and System Level Outcome (SLO) targets (Table 2), which were specified in FTA's Phase II proposal. This study is one of four others that aims to determine whether and to what extent FTA's target contributions (right column in Table 2) were realized. To do so, FTA's Monitoring, Evaluation, Learning, and Impact Assessment (MELIA) team 'translated' these targets in a set of five challenges that represent the bulk of FTA's work in a more succinct and easy-to-communicate manner. The five challenges are:

- Challenge 1: Accelerating rates of deforestation and forest degradation;
- Challenge 2: High prevalence of degraded land and ecosystem services;
- Challenge 3: Widespread unsustainable land use practices;
- Challenge 4: Persistent rural poverty with increasing levels of vulnerability; and
- Challenge 5: Rising demand and need for nutritious food for both current and future generations

These challenges are not the only issues that FTA tackles. They are also interrelated with others. For instance, FTA also worked to address biodiversity loss and climate change through actions to address deforestation, land and forest degradation, and unsustainable land use practices. Therefore, the assessment around these five challenges can be seen as a first step to a wider assessment of other issues that FTA tackles.

The FTA lead and partner institutions are the Center for International Forestry Research (CIFOR), World Agroforestry (ICRAF), Bioversity International, the French Agricultural Research Centre for International Development (CIRAD), the Tropical Agricultural Research and Higher Education Center (CATIE), the International Network for Bamboo and Rattan (INBAR), and Tropenbos International.

Table 2. FTA target contributions with respect to CGIAR IDOs and SLOs.

End-of-Program Outcomes	Intermediary Development Outcomes (IDOs)	System-level Outcome (SLO) Target	FTA Target Contribution
1. 25 countries improve governance mechanisms, institutions & tools for a) safeguarding forests/tree diversity and b) equitably managing forests & trees within mosaic landscapes 2. About 20 multinational companies and 500 private sector actors pursue models & investments for a) improved mgt. & safeguarding of forest & tree resources and b) enhancement of inclusive landscape-based livelihoods & ecosystem services 3. National and sub-national public & private sector actors in 25 countries deliver more effective & equitable tree related breeding, delivery, extension & pedagogical services 4. At least 40 million smallholders & other users access more productive tree planting material & uptake higher performing, context appropriate & inclusive AF & small-scale forestry mgt. option	1. Improved ecological integrity, equitable mgt. & protection of forests & non-forest-based tree resources (IDOs 3.1 & 3.3) 2. Enhanced ecosystem service provision (e.g., carbon storage, nutrient cycling, water filtration & soil health) (IDOs 2.3 & 3.2) 3. Increased resilience of female, male & poor smallholders & other forest/tree users to climate change & other shocks (IDO 1.1) 4. Productivity, food & nutritional security & incomes for female, male & poor smallholders & other forest/tree users (IDOs 1.2-1.4, 2.1)	1. 100 million more farm households have adopted improved varieties, breeds or trees, and/or improved management practices 2. 30 million people, of which 50% are women, helped to exit poverty 3. Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year 4. 30 million more people, of which 50% are women, meet minimum dietary energy requirements 5. 5% increase in water and nutrient (inorganic, biological) use efficiency in agroecosystems, including through recycling and reuse (target same) 6. Reduce agricultural-related GHG emissions by 0.2 Gt CO_2^{-e} yr^{-1} (5%) compared with business-as-usual scenario in 2022 7. 55 million ha degraded land area restored 8. 2.5 million ha of forest saved from deforestation	1. 31 m 2. 19 m 3. 0.1845% 4. 17 m 5. 0.225% 6. 0.2 Gt CO_2^{-e} yr^{-1} 7. 30 m 8. 2.5 m

2. Introduction to Challenge 5

The High Level Panel of Experts on Food Security and Nutrition (HLPE) reports that one-third of humanity is now experiencing one or more forms of hunger or malnutrition. Following years of steady decline, the number of hungry people began to rise again in 2015, reaching 821 million by 2017 (HLPE, 2020). Indeed, despite years of progress, the 'Prevalence of Undernourishment' (PoU) has been steadily increasing since 2014, standing at 768 million (9.9 percent of the world population) in 2020 and with the highest prevalence in Africa at 21 percent. It is estimated that agricultural production will need to increase by 60 percent by 2050 in order to meet the demands of a larger, more urbanized population of the Global South (Alexandratos and Bruinsma, 2012). In addition to a rapidly urbanizing population, there are several other factors that worsen the availability of nutritious foods. For example, rising income levels (albeit unequal), together with urbanization, have also coincided with changes in dietary habits (e.g., increased animal product

consumption) and increased demand for energy, thereby intensifying non-food crop production for animal feed and biofuels (Silva, 2018).

Low-income countries rely more on staple foods and less on fruits and vegetables and animal source foods than high-income countries. Only in Asia, and globally in upper-middle-income countries, are there enough fruits and vegetables available for human consumption to be able to meet the Food and Agricultural Organization of the United Nations (FAO) and World Health Organization (WHO) recommendations of consuming a minimum of 400 g/person/day.

The crisis in SSA is more severe, with unique characteristics which sets the region apart. It suffers from a nutrition crisis where one in three people consume insufficient calories and nutrients (UNSCN 2010). Deficiencies in micronutrient and related diseases are disproportionately higher in Africa. For example, Black (2014) showed that two-thirds of 157,000 global Vitamin A Deficiency (VAD) related deaths in 2011 were in Africa. Income levels in SSA remain low and fortification and supplementation have limited success to control the burden of micronutrient deficiencies. Deficiencies in micronutrients because of poor quality diets increase disease burden and death in low and middle-income countries (Black, 2014), which ultimately have the greatest effects on human capacity and economic development.

Per capita intake of fruits and vegetables in SSA is far below the daily WHO-set requirements (McMullin et al., 2019a). A diet low in fruits was a dietary risk factor responsible for the greatest proportion of deaths and Disability Adjusted Life Years (DALYs) lost in SSA in 2017 (Afshin et al., 2019). A supply-side limitation is a major factor for the low intake of fruits and vegetables in low-income countries, including SSA. Dietary diversification based on the production, processing, and consumption of nutrient-rich foods is considered to be an ideal and sustainable approach to control micronutrient deficiencies in the long run (Jamnadass et al., 2015; McMullin et al., 2019b; Powell et al., 2015; Vinceti et al., 2013).

Scientists from different partner organizations developed a Nutrition Narrative[1] to enhance FTA's focus on this complex set of challenges. These include:

1. Nutrient composition data is often limited for tree foods, particularly for underutilized wild species, so their potential as natural sources of vitamins and minerals can easily be overlooked. Rigorous and standardized food composition data for underutilized tree crops are needed to inform decision makers on the most appropriate crops to promote and invest in, for meeting the food and nutrient needs of people and thereby enhance human wellbeing.
2. Mosaic landscapes characterized by trees and secondary forests with agriculture often result in high overall biodiversity as well as agrobiodiversity and dietary diversity. These

[1] FTA Nutrition Narrative (undated) was produced by the following scientists: Bioversity International (Barbara Vinceti, Celine Termote), CIFOR (Amy Ickowitz), ICRAF (Stepha McMullin and Kai Mausch), SRUC (Ian Dawson), and Gender CCT (Marlene Elias).

landscapes are, however, rapidly changing in favour of homogenous landscapes characterized by monoculture and high input agriculture options. FTA research investigates the dietary impacts of these land use changes to bring attention to the unintended consequences of transformations on local diets and health.

As diets are changing, there is a need for a greater understanding of the biological, economic, physical, social, and psychological determinants of choice, and the attitudes, beliefs and knowledge that surround food consumption. More research is required on what drives food choice motives for healthier foods, including those derived from trees, in lower-middle income countries, where little is known and documented.

One area that requires greater attention is the potential impact of Food Tree and Crop Portfolios (FTCPs), a relatively new and novel concept. This is specifically with respect to their potential for alleviating targeted micronutrient deficiencies and related negative health outcomes in children and women of reproductive age. Measuring nutritional impacts, especially estimating future impacts , is no trivial task. One way to do this is by using DALYs as the main outcome metric. This metric is widely used to measure health outcomes in general and to quantify the cost of micronutrient undernutrition. This modelling approach has been applied elsewhere, for example by HarvestPlus, to estimate the health benefits of biofortified staple crops (Stein et al., 2005). We explain the details of this ex-ante analysis in detail in the Methods section.

Another area that requires a more in-depth investigation is the role that bushmeat plays in food and nutrition security. The meat of wild animals is a crucial part of the diets of millions of families in the tropics and subtropics. It is often the most accessible and sustainable source of protein and micronutrients and can also be a significant source of revenue for many people. Enabling these local populations to continue consuming wildlife in a sustainable manner are the main challenges facing researchers and policymakers. At least one billion people worldwide depend on wild foods for their food security (Hickey et al., 2016). Wild foods[2] diversify diets, are source of nutrients, improve the palatability of staple foods, and generate income. They are also important safety nets during periods of shortages and shocks, especially amongst the poor living in rural, forested areas.

For the millions of Indigenous Peoples and non-Indigenous communities in tropical and subtropical environments, who are often among the world's rural poor, wild meat is frequently the most consumed source of protein, vitamins, and minerals. The hunting and consumption of wild meat is a widespread practice that often provides food security and supplements basic income for participating households. In the Global South, more than 150 million people have been estimated to depend on wild meat as a meat source. Additionally, hunting for wild meat tends to be most

[2] Muir et al (2020) provide a detailed overview of terminology used for different non-wood forest products and wild forest products. They report that 'wild food' is defined as anything edible that requires no human input to increase its production (Daudet, 2012). They also reference Maes et al (2013) and include plants, berries, fruit, nuts, mushrooms and game that are collected in the wild, to be consumed as food or drink.

prevalent in areas with greater biodiversity indices, which frequently coincide with regions that experience higher poverty and food insecurity.

The COVID-19 pandemic is expected to significantly accelerate the concerning trends highlighted above (FAO et al., 2021). A key global challenge of our times is therefore balancing how to feed and nourish a growing population while minimizing the impact on the environment (Petersen & Snapp, 2015), against a backdrop of persistent rural poverty and rising levels of (absolute) inequality.

3. Methods

Our methodology—common to all the above five challenges—is based on the documentation specific Theories of Change (ToC) relating to FTA's work vis-à-vis each challenge, including underlying hypotheses of how and why intended changes are expected to happen (Figure 1). The ToCs link FTA's research activities and engagements to changes and actions taken by other actors in the system (from next users to boundary partners to other users) and the enabling environment. FTA is organized by Flagship programs, which deploy their work through operational priorities. All these areas of work contribute to each of the challenges, which are cross-cutting, and our methodology therefore needed to be fully integrative. In order to assess the importance and scale of FTA's contributions to addressing the challenges, we applied the following steps:

First, we conducted a comprehensive mapping of FTA projects and related initiatives. Next, we constructed an overarching TOC for each of the five challenges. We subsequently identified and grouped FTA's activities into clusters by theme and developed sub-ToCs or impact pathways for each of these clusters. These nested-ToCs or impact pathways can be traced back to the overarching ToC for the specific challenge. Following documentation, we then began testing the ToCs. Available evidence was collected and organized for each cluster to test each element in the ToCs. Critical data and knowledge gaps were also identified during this process. Additional data from external sources (e.g., semi-structured interviews with stakeholders, policy documents, etc.) were collected as needed to assess outcomes, estimate impacts using projections from available documentation and evidence, and make plausible connections between FTA's contributions to outcomes and the likelihood for potential impacts to be realized in the future.

One key body of FTA's work directly related to nutrition is associated with FTCPs. While this work is relatively new and presently resides at the proof of concept stage of the research-to-impact development continuum, it has shown promise, and we, therefore, concluded that it warranted deeper interrogation (a 'deep dive') to understand its potential impact and present some concrete steps for how to support this work in the future. See Section 5.

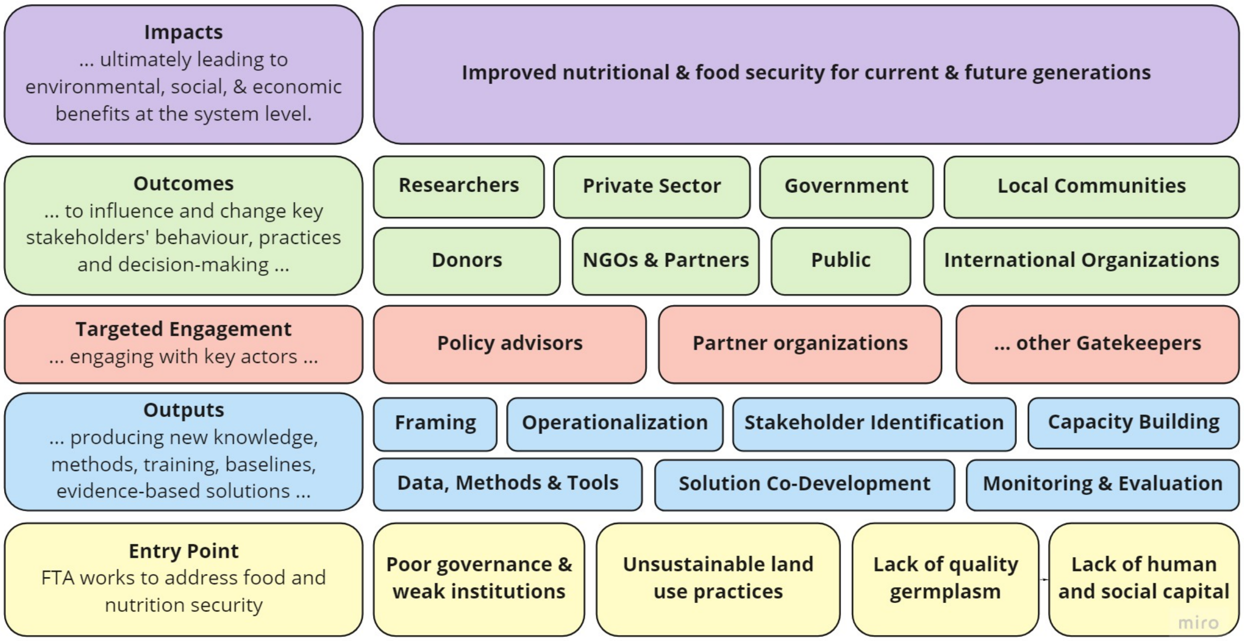

Figure 1. Theory of change (ToC) template used for the theory-based evaluation approach to model FTA research and engagement and to estimate potential contributions to impact targets

4. Results

The number of projects that were 'mapped' to FTA over the program's two phases was approximately 1,000. However, the number of projects that explicitly addressed nutrition was much smaller. In addition, there was overlap in the different reporting formats, e.g. blogs, FTA reports, project reports, etc. In order to manage these different reporting sources and varying degrees of reliability, we relied primarily on outputs reported in project technical reports, i.e., annual, mid-term, and final reports. It is assumed that any outputs reported in blogposts or annual FTA reports, should also have been reported in the project annual or final technical reports, and there is no need to 'double count' these as evidence sources. With respect to scientific publications, it is expected that these publications were mentioned in the project reports, and it is understood that the details of specific research findings were not. We therefore only focused on outputs and outcomes that were reported during project cycles. Those outcomes that occurred after projects may, or may not, be reported in other institutional communications, and we did not specifically search for these except in two cases. First, the 'deep dive' analysis specifically sought to understand the lasting outcomes and impacts of beyond the project end dates. Second, we also relied on several evaluation studies that were completed separately from the primary projects.

Step 1 of the evaluation involved the review of FTA projects and related initiatives that were relevant to Challenge 5. A project database was obtained from ICRAF in MS Excel format, which contained metadata for 871 projects, of which 256 projects showed that they were mapped to FTA. Out of these FTA projects, 72 were mapped to multiple CRPs including FTA, and the remaining

184 projects were mapped only to FTA and no other CRP. After a further screening exercise[3], we remained with 50 priority projects for all five challenges of which only 14 projects both focused on nutrition security and had sufficient evidence available in the project reports.

In addition, we recognized the importance of one initiative, the Bushmeat Research Initiative (BRI). This work does not present itself as a series of funded projects but rather as a continuous engagement at important forums with policy makers at local and global levels. We furthermore recognize that one potential pathway to improve household food security and nutrition is by bolstering household income. Hence, there are many more livelihood focused FTA projects that could potentially have been included. However, income growth is not necessarily associated with healthier diets (Colen et al., 2018), and, therefore, assuming that such projects—if successful in elevating income—would automatically lead to improved food security and nutrition was not entertained. Moreover, if a project's TOC was not developed specifically for improved nutrition impact, then it is to be expected that no nutrition outcomes data were measured and reported.

Overarching Theory of Change

During the mapping exercise, we identified the core outputs, knowledge products and technologies, that are associated with the identified Challenge 5 projects. These range from focused research on identifying context-specific FTCPs to enable the production of nutritious foods all year-round on the one hand through to the development and promotion of improved farmer engagement and extension approaches, tree germplasm, and agroforestry technologies, such as fertilizer trees and tree fodder, on the other. Researching the nutrition enhancing potential of understudied tree foods through the African Orphan Crops Consortium (AOCC) is another area of FTA's work, as is understanding and evidencing the contribution of forests to the diets of forest-proximate communities.

We then developed the composite overarching ToC (Figure 2) based on the mapping exercise and original project proposals. The latter indicated specific impact pathways required for generating long-term impact. In addition, we focused on the key 'products' delivered under each cluster (outputs) and stakeholder engagement processes that would logically need to take place for these projects' activities, engagement processes, and outputs to translate into changes in policy, practice, and behaviour (i.e., outcomes) and ultimately impacts. For validation purposes, a draft of the overarching ToC was shared with the two key FTA scientists working on nutrition and modified based on their feedback.

From this overarching ToC, we identified four main clusters that represented mature bodies of research and scaling efforts carried out by FTA relating to Challenge 5. The clusters, their associated projects, and the BRI are presented in Table 3 below.

[3] Projects were removed if they matched one of these criteria: projects with a budget of less than USD 10,000; headquarter-related projects; projects for the AWARD program; projects funded by CGIAR Systems Organization; and projects with indicative descriptions such as 'meeting' or 'consultancy service.'

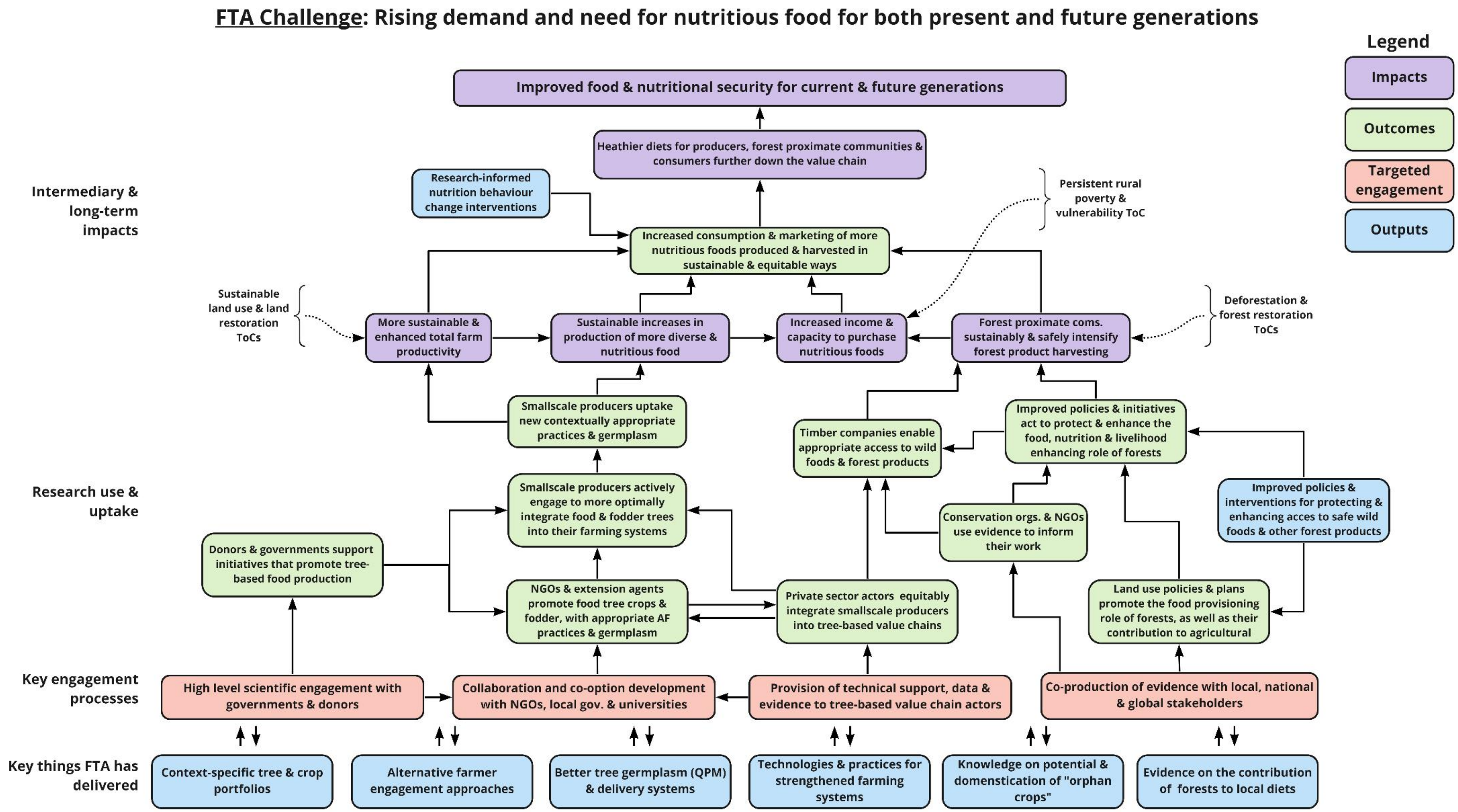

Figure 2. Overarching ToC outlining FTA contributions to Challenge 5 (Rising demand and need for nutritious food for both current and future generations).

There were several project impact evaluations undertaken on the 14 reviewed projects that we reviewed for Challenge 5. Some of these reported adoption figures for the types of agroforestry practices that are linked to Challenge 5, and we were able to undertake supplementary data analysis to ascertain this in the case for three large agroforestry scaling projects. These evaluations were independent to the extent that they were conducted by ICRAF's MELIA team and not by the project team. Given the thoroughness of these studies with adequate sampling sizes, we were able to generate two types of figures. We estimated the number of people residing in households that a) were reached by components of these projects that promoted improved tree germplasm and/or practices directly addressing Challenge 5, i.e., food trees or practices to bolster stable food production; and b) actually took up ('adopted') such germplasm and/or practices. People falling into category b are a subset of those falling under category a. Since we cannot be certain that all households exposed to the promotional efforts of these projects took up the germplasm or practices, we provide both lower and upper bound estimates of the people who were provided with means of improving their food and nutritional security. The results of these analyses, semi-independent post-project evaluations, are incorporated in the different cluster sections below.

Table 3. Main projects that contributed to the evidence collection in specific geographies

N	Project Name	Duration	Budget	Countries
Cluster 1: Scaling the production of food trees on farms				
1	Agrobiodiversity and Landscape Restoration for Food Security and Nutrition in East Africa	2016-2020	USD 1,841,000	Kenya, Uganda
2	Fruiting Africa: Tree Crops Development in Africa to Benefit the Poor	2016-2018	n/a	Kenya, Mali
3	Machakos Fruit Tree Development Project	2015-2016	n/a	Kenya
Cluster 2: Integrating trees in cropping fields for sustainable staple food production				
4	Agroforestry Food Security Programme - Phases I & II	2012-2019	€5.75M	Malawi
5	A Regional Programme in the Sahel and Horn of Africa, enhancing Food and Water Security for Rural Economic Development (DRYDEV)	2013-2019	USD 48,472,228	Ethiopia, Kenya, Mali, Niger, Burkina Faso
6	Enabling Small Holders in Odisha to Produce and Consume More Nutritious Food through Agroforestry Systems	2018-2021	USD 2,779,878	India
7	Trees for Food Security - Phase II: Developing Integrated Options and Accelerating Scaling up of Agroforestry for Improved Food Security and Resilient Livelihoods In Eastern Africa	2017-2020	USD 5,100,000	Ethiopia, Rwanda, Uganda
Cluster 3: Improving smallholder dairy production through tree fodder				
8	East Africa Dairy Development (EADD) - Phase II	2013-2018	USD 1,696,681	Ethiopia, Kenya, Tanzania, Uganda
9	Developing Value Chain Innovation Platforms to Improve Food Security in East and Southern Africa	2015-2019	USD 2,310,300	Uganda, Zambia
Cluster 4: Understanding the relationship between forest resources and the food security and nutritional status of forest proximate communities				
10	From Growing Food to Growing Cash: Understanding the Drivers of Food Choice in the Context of Rapid Agrarian Change in Indonesia	2016-2019	n/a	Indonesia
11	Scaling up Data on Non-wood Forest Projects in Zambia	2018-2020	n/a	Zambia
12	Yangambi, pôle scientifique au service de l'homme et des forêts (YPS)	2017-2020	USD 3,557,700	Congo (Democratic Republic)
13	Improving the way Knowledge on Forests is Understood and Used Internationally (DFID KNOW-FOR Phase 1 & 2)	2013-2015 2016-2017	(phase 1) n/a	Burkina Faso, Cameroon, Congo (Democtratic

N	Project Name	Duration	Budget	Countries
			(phase 2) USD 636,011	Republic), Ethiopia, Indonesia, Nicaragua, Uganda, Zambia
14	Governing Multifunctional Landscapes (GLM) in Sub-Saharan Africa: Managing Trade-Offs between Social and Ecological Impact	2017-2021	USD 480,649	Cameroon, Ghana, Liberia, Congo (Democratic Republic), Gabon, Sierra Leone, Tanzania
N	**Initiatives**	**Duration**		**Countries**
15	Bushmeat Research Initiative	n/a	n/a	Global
N	**Project Reviews**	**Date**		**Countries**
16	Malawi Agroforestry Food Security Program (AFSP) Evaluation study (Hughes et al., 2019)	n/a	n/a	Malawi
17	DRYDEV Evaluation Study	n/a	n/a	Ethiopia, Kenya, Mali, Niger, Burkina Faso
18	Trees for Food Security (T4FS) Evaluation Study	n/a	n/a	Ethiopia, Rwanda, Uganda

Cluster-level work targeting Challenge 5

In this subsection, we present the four main clusters of FTA's work vis-à-vis Challenge 5. The main results are summarized in Table 4. Next, we summarize the work associated with each cluster, followed by relevant FTA achievements and stakeholder engagement efforts. We then articulate the main impact pathways associated with the cluster, including their underlying assumptions, and conclude by reviewing available evidence on achieved outcomes and impacts. More detailed information for each research cluster, e.g., project proposal summaries, sub-ToCs, and cluster-level narratives, are presented in Appendix A.

The overall TOC and sub-TOCs show that we have categorized project activities in five categories: framing, data and evidence, co-developing solutions, capacity building, and operationalization. These form parts of the primary and secondary pathways, namely research, policy and practice. For this challenge, we found that most projects implemented activities that support multiple pathways simultaneously that cannot easily be separated. For example, no policy pathway was pursued without a research pathway to support it with evidence-based knowledge products. Similarly, the practice and research pathways are often closely aligned, as is evident from the activities (e.g., co-developing solutions, capacity building, and operationalization) and pathway connections in the sub-TOCs. While a project can have multiple pathways, these are, nevertheless, supporting the same long-term goal of improved nutritional and food security for current and future generations. We show in Appendix B how we collected evidence for specific activities that support the different pathways. For the remainder of the report, we focus on primary and secondary impact pathways for each sub-TOC without differentiating whether they supported the research, policy or practice pathways. As we explain in the sections below, each sub-TOC pathway for Challenge 5 shows a unique combination of different pathways.

Table 4. Key achievements and impact pathways of FTA's challenge 5 work.

Key Achievements & Stakeholder Engagement Efforts	Evidence of Reach	Evidence of Uptake and Use
Cluster 1: Scaling up the production of food-trees on-farm		
Food trees promoted under nine different projects in 11 countries. Three projects specifically focused on identifying Food Tree Crop Portfolios (FTCPs) to provide access to nutritious food year-round.	206,045 farming households (927,201 individuals)	139,045 farming households (625,702 individuals)
Cluster 2: Integrating trees in cropping fields for sustainable staple food production		
Work undertaken with development partners to support farmers to appropriately integrate trees into their cropping systems in 12 countries.	442,392 farming households (1,990,764 individuals)	163,164 farming households (734,237 individuals)
Cluster 3: Improving smallholder dairy production through tree fodder		
Work undertaken to scale out proven Fodder Tree Technology (FTT) with development partners and national resource institutions in 3 countries.	290,579 households (1,307,606 individuals)	85,240 households (383,578 individuals)
Cluster 4: Forest resources and the nutrition of forest proximate communities		
Primary research undertaken to evidence the contribution of forests in meeting the food and nutritional requirements of forest proximate communities at the global level and in 5 countries.	Stakeholder engagement initiated in four countries, disseminating research findings and co-developing policy and intervention options; strategic inputs feed into three global fora.	Anecdotal interest in taking on board research findings. Government of Ethiopia drew on FTA research to design government's nutrition sensitive interventions
Bushmeat Research Initiative (BRI) created bushmeat research database BRI and influenced policies of key international bodies (CBD, OACPS) and the governments of Brazil, Colombia, Ecuador, and Peru.	Website set-up and operational, with various policy documents and scientific publications (138)	2,949 citations and 12 policies influenced, 10 of which are decisions or regulations adopted by official bodies and national governments
Totals (non-double counted)	**761,996 households (3,428,982 individuals)**	248,398 **households (1,117,770 individuals)**

Cluster 1: Scaling up the production of food trees on-farm

This cluster focuses on the contribution of food trees to improve food security and nutrition. FTA's projects aimed to increase the availability and consumption of nutrient-rich food trees (i.e., fruits and nuts, seeds for protein and oils, and leaves as vegetables) among both smallholder farmers and downstream consumers. This work was also expected to indirectly address Challenge 5 by increasing and diversifying farm income and enhancing sustainable land management. FTA made Quality Planting Material (QPM) available (e.g., through setting up community nurseries) and provided technical training and institutional strengthening support to national partners and smallholder farmers, so that the latter appropriately integrate the trees into their farming systems. Greater dietary diversification and food security are thus expected to result from the integration of trees that produce nutrient-dense foods. In addition to food and nutritional security, this approach

aims to strengthen smallholder livelihoods and contribute to landscape restoration by harnessing ecologically suitable food tree and crop portfolios in ways that enhance livelihood and landscape resilience.

Key achievements and stakeholder engagement efforts

From an analysis of project documents and project-related data, it is documented that 206,045 households were directly supported through at least nine FTA-affiliated projects to scale up the production of food trees on their farms. There is further evidence that 139,045 households have established such food trees (Table 5). Key countries where this work took place include Ethiopia, Ghana, India, Kenya, Malawi, Mali, Niger, Rwanda, Senegal, Somalia, and Uganda. In general, scaling up food trees on-farm has taken place primarily in the context of development-focused projects. FTA provided technical support to implementing partners (i.e., NGOs and local government agencies) to source and produce QPM (e.g., through setting up 'mother blocks', seed orchards, or community nurseries) and provide training in key areas, such as nursery establishment, grafting, and budding.

Table 5. Household reach and uptake data: Scaling up food tree production

Project/Project Cluster	Reach	Uptake	Evidence Source(s)
Malawi Agroforestry scaling projects (improved fruit trees)	44,038	33,909	Project reports combined with analysis of survey data
Odisha, India Agroforestry Project	9,041	9,041	Report submitted to Government of Odisha
Food Trees for Diversified Diet	8,472	n/a	Project report
Fruiting Africa	2,360	n/a	Project report
Agrobiodiversity & Landscape Res.	8,500	n/a	Project report
Regreening Africa Project	133,634	96,095	Analysis of 3 years of uptake survey data
Total Households	**206,045**	**139,045**	

A good example of FTA's work on addressing Challenge 5 is the Enabling Small Holders in Odisha to Produce and Consume More Nutritious Food through Agroforestry Systems project, which is being implemented in the state of Odisha in India. The state government engaged ICRAF to scale up tree-based agricultural practices in rice-based production landscapes to enhance food production and nutritional diversity. This included the setting up of demonstrations on 6,523 hectares, which are designed to provide year-round access to nutritious food, as well as the establishment of 38 nurseries for food and timber tree species. The project is being implemented in close collaboration with the India Council of Agricultural Research (ICAR) and state agricultural universities. At the time of writing, the project had held over 300 nutrition-sensitive workshops involving 18,650 farmers. A mobile agroforestry app was also been developed and is being rolled out to assist farmers self-identify which trees are appropriate for their farming systems and production objectives, as well as where to source QPM.

Recent FTA work on developing and evidencing FTCPs—through the 'Food Trees for a Diversified Diet', 'Agrobiodiversity and Landscape Restoration for Food Security and Nutrition

in East Africa', and 'Fruiting Africa' projects—has a more explicit research focus. This is not just about scaling up the production of food trees on-farm to diversify food and income sources; rather, work is undertaken with communities and implementing partners to identify food trees that can be produced, together with other food crops, in order to meet the food and nutritional needs of households throughout the year. This is particularly relevant in contexts that experience a 'hunger season' (especially in unimodal rainfed systems) and/or have limited access to diverse sources of food at specific times of the year. At the time of writing, a total of 16 tree-crop portfolios were developed for different landscapes across East Africa. FTCP implementation requires significant investment, both private and public, in producing and facilitating access to suitable QPM. The approach relies on the identification of ecologically suitable and socio-economically relevant food tree and crop portfolios through in-depth consultations with communities, combined with insights from the scientific literature. Section 5 explicitly narrows in the FTCP concept in the form of a 'deep dive'.

Primary impact pathways and assumptions

Given that much of the work associated with this cluster is development-focused, as opposed to research-focused, there are two primary impact pathways that are of interest.

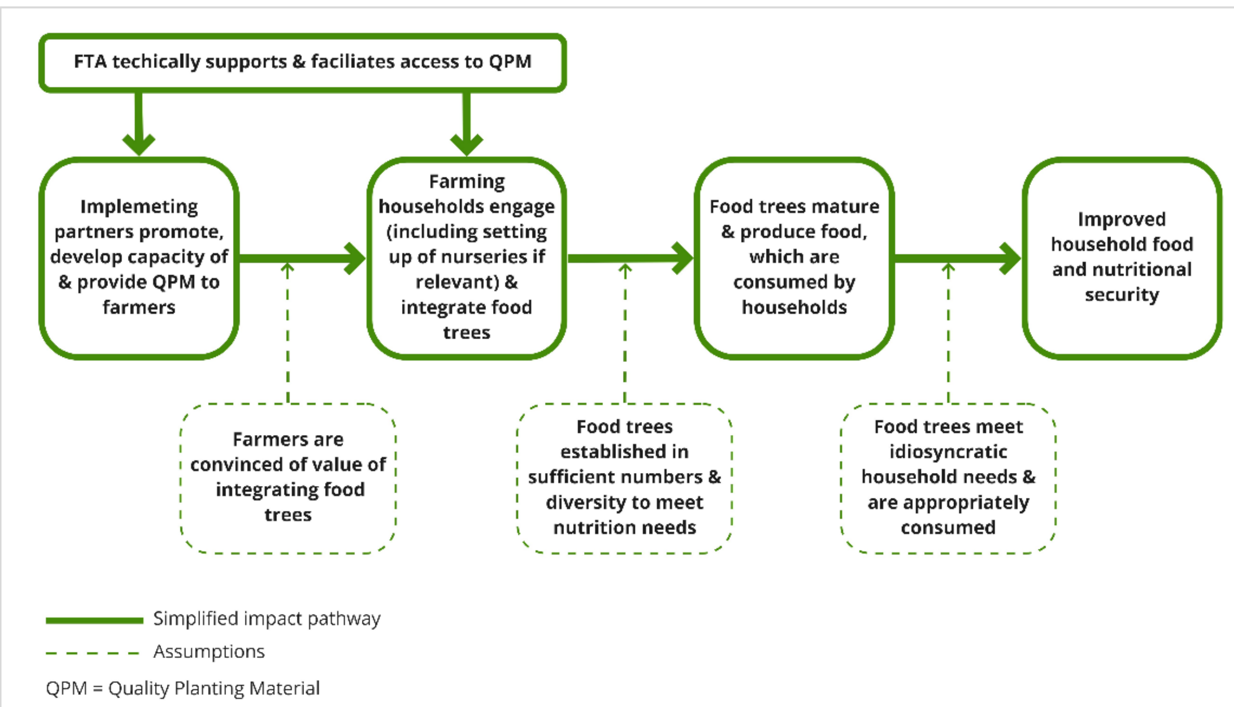

Figure 3. Simplified depiction of food tree product consumption impact pathway

The first is the *food tree product consumption pathway* (Figure 3), where implementing partners are expected to effectively promote and develop the capacity of farming households to scale up the production of food trees on farm. Households are expected to actively engage in such efforts and, in turn, integrate the trees appropriately into their farming systems. This is even though there may be tradeoffs vis-à-vis the production of annual crops, e.g., the introduction of competition for

sun light and nutrients. Once appropriately integrated and trees start producing edible food, a sufficient proportion is consumed, either by the producing household, other community members, and/or consumers further down the value chain. This is expected to improve dietary diversity and address key nutritional deficiencies among producer households and other consumers.

Key assumptions underpinning this pathway include:

- Farmers are convinced of the value of integrating food trees into their farming systems and are therefore interested in engaging.
- Households scale up the production of food trees in sufficient numbers and diversity (in terms of both nutritional offer and production cycle timing).
- Food trees grown at household level meet idiosyncratic household and intra-household food security or nutritional needs.
- Household members (and/or others) consume a significant proportion of the food tree products produced (rather than prioritizing all for sale) and in the relevant quantity and frequency to significantly affect dietary intake and, in turn, food security and nutritional outcomes.

As is clear, nutritional impact is not automatic, and we found that the FTCP work associated with this cluster is the sub-cluster that explicitly targets the various steps of this pathway.

The second primary impact pathway is the *food tree product income diversification pathway* (Figure 4). This is particularly relevant for high value tree foods, such as the grafted mango and avocado promoted under the Malawi Agroforestry Food Security Program and other related projects. It is expected that the increased income earned through the marketing of high value fruits enables households to procure more and better-quality food. At the same time, livelihood resilience is promoted through the associated income diversification. While the relationship between household income and nutrition is not necessarily causal, there is a general association between rising income levels and better diets (Colen et al., 2018).

Key assumptions particular to this pathway include:

- Farmers are convinced of the value of integrating food trees into their farming systems and are therefore interested in engaging.
- Households scale up food trees for which there will be adequate market demand in the future when the associated food tree products mature.
- Food tree producing households will be effectively linked (have access) to these markets once the trees start producing their associated products.
- At least a portion of the additional income earned through the sale of the food tree products will be sufficiently large and be used to procure more and more diverse foods on a regular basis.

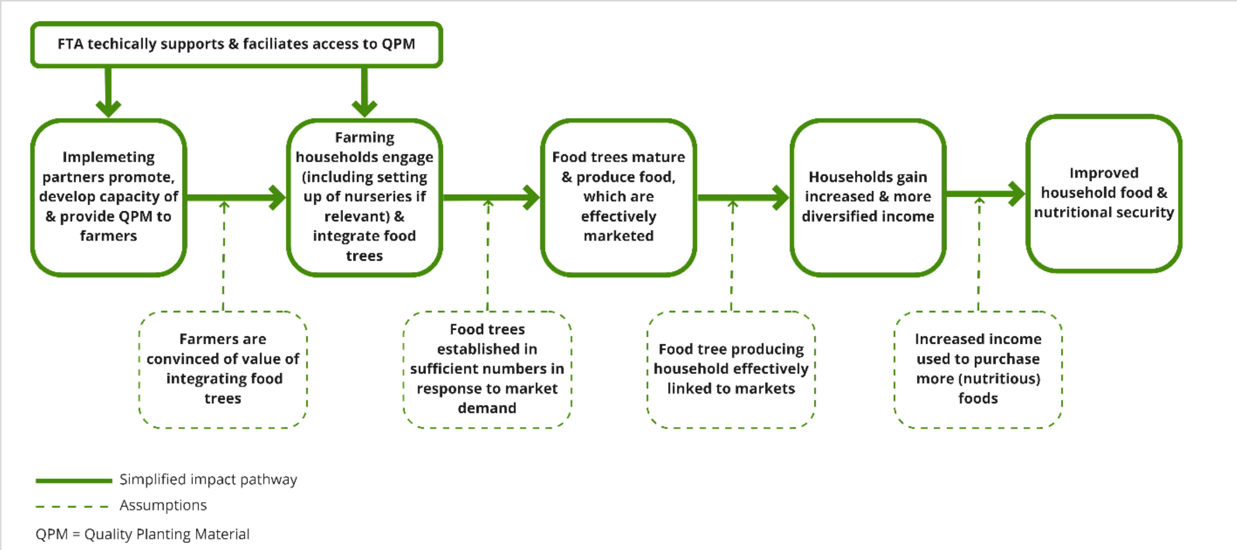

Figure 4. Simplified food tree product income diversification pathway

Clearly, the two above pathways are not mutually exclusive, and, arguably, hold greater potential for addressing Challenge 5 when employed together.

There is a third pathway that is perhaps more relevant to the tree crop portfolio work: *the food tree model horizontal scaling pathway.* This is where models and approaches for scaling up food tree production on-farm—following engagement and capacity with implementing partners—are taken up by other relevant actors and promoted and/or directly implemented, preferably using leveraged resources and at a larger geographic scale. While it is early on in the research cycle, this is what is expected to come out of the FTCP work (i.e., scalable models). However, this horizontal scaling pathway can also be applicable to the above development-focused work. A good example, again, is the Enabling Small Holders in Odisha to Produce and Consume More Nutritious Food through Agroforestry Systems project in Odisha, India. ICRAF is practically demonstrating to the state government, the private sector, and other actors how fruit trees can be integrated into farming systems for enhanced income and resilience.

Key assumptions associated with the food tree model horizontal scaling pathway include:

- ‘Scaling stakeholders’ find the portfolio model attractive vis-a-vis other options for achieving their objectives.
- The model can be practically replicated in the absence of heavy-handed FTA technical support.
- All the above assumptions associated with the other two pathways.

Evidence on achieved outcomes and impacts

To comprehensively evaluate the extent to which the first two impact pathways have materialized, adoption studies would first be needed to be undertaken in the areas where such food tree

promotion work has been carried out in order to evidence the numbers of smallholder households that have successfully established the trees. Reliably evidencing what would have happened to these households (e.g., in terms of their food and nutritional security) had they never established the trees would further be needed to evaluate impacts. Perhaps, unsurprisingly (i.e., because trees typically take years to grow and produce food), there is limited evidence on both longer-term adoption and impact. One evaluation, however, of the above referenced Malawi Agroforestry Food Security Program (AFSP) (Hughes et al., 2019) assessed the adoption of the improved fruit trees that were promoted as a subsidiary component of the overall evaluation. Out of the survey sample of 631 program participants, 117 participants (19 percent) reported that they had received improved fruit tree planting material. Among these participants, 89 (76%) reported that they had at least one tree present on their farms, but only 24 (21%) reached the project target of 10 or more productive improved fruit trees. Assuming these percentages can be extrapolated to all participants who participated in the four projects that promoted improved fruit trees in Malawi using a similar approach, and that each participant represents a farming household (231,777 households in total), it can be estimated that approximately 33,909 and 9,248 households managed to successfully establish at least one and ten of the improved fruit trees, respectively.

In 2020, an FTA supported impact study was undertaken to estimate the downstream impacts on a sub-sample of the latter category of households, particularly given that eight to 10 years had passed for the trees to be sufficiently mature to produce the high value fruits. To avoid bias, the study sought to compare households with at least ten fruit trees with others residing in the same villages that attempted to establish the trees but failed due to one or more quasi-random factors (e.g., livestock or pest damage, unexpected dry spell, or theft). In two out of the three study districts (Kasungu and Mzimba), a substantial number of such households (n=186) were successfully identified and interviewed. Both these households and the sample with improved fruit orchards (n=182) were deemed comparable, given their statistical similarity vis-à-vis their baseline and time invariant characteristics (Chi-squared test of joint orthogonality = 13.23 [p=0.66]). However, little difference was found between the two groups of households with respect to the income and food security indicators for which data had been collected. These indicators included a household asset index; the Livelihoods Coping Strategies Index (LSCI); the Food Consumption Score (FCS); the Food Insecurity Experience Scale (FIES); and Minimum Dietary Diversity, Women (MDD-W).

Further exploration revealed that the likely key reason why no impacts were identified is because the households were not selling their improved fruit, i.e., they were not linked to markets—a key assumption in the second pathway presented above. Ex-ante modelling work was then undertaken over a 10-year time horizon to evaluate what the impact could be on farm-related income if the households were effectively linked to markets. The results are presented in Figure 5. While the net returns for farming households in Mzimba District are considerably greater than their counterparts in Kasungu District, the potential income gained over time from the selling of the improved fruit is significant, with a median gain for both districts of €820 (adjusted for Malawi's relative purchasing power).

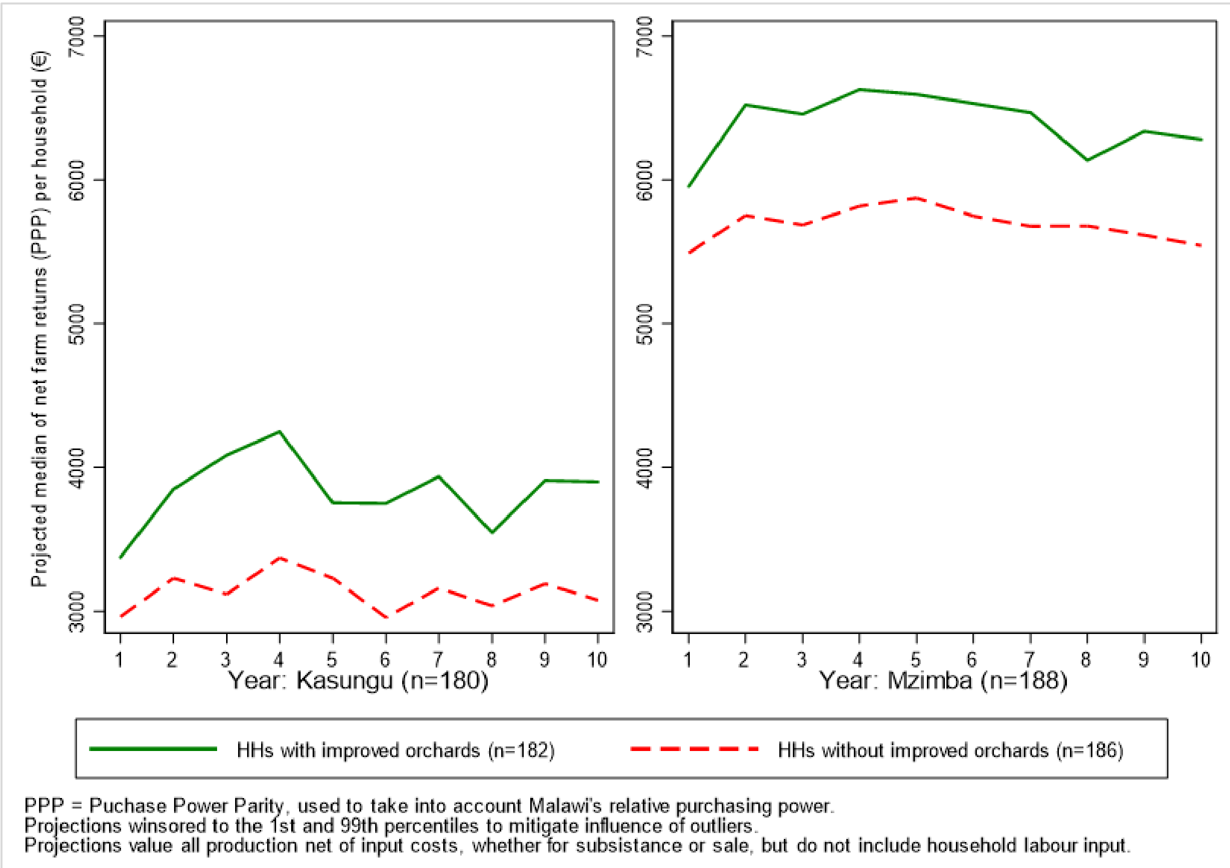

Figure 5. Projected median net farm returns (PPP adjusted) over time: Households with improved fruit orchards compared with those without

Another source of reliable evidence comes from Regreening Africa scaling project (2017 to 2022). Here, the uptake of agroforestry practices is being periodically monitored through representative 'uptake surveys', led by CIFOR-ICRAF's Impact Assessment and Acceleration (IAA) team. These surveys, undertaken in all eight countries, monitor the uptake of specific agroforestry practices, including households that have established food trees. The following table shows the estimated numbers of households that have established food trees using the ascertained adoption rate from the analysis of uptake survey data for each project site (Table 6). Over 96,000 households had adopted food trees, with a slight bias in favour of indigenous species.

Finally, as part of the piloting of the tree crop portfolio approach, a baseline and endline study was carried out (N>600). Here, the portfolio adoption evidence appears mixed. In Ethiopia, the food tree species index increased from 3.7 to 4.9, while it decreased from 7 to 5 in Uganda. In other words, tree species diversity increased in the former country but decreased in the latter. Moreover, while non-project related factors may be solely or partly responsible, reported food insecurity dropped considerably in Ethiopia (34% to 18%) but increased in the Ugandan sites (52% to 70%). Dietary diversity further did not seem to change significantly in the sites of either country between the two time periods.

Table 6. Number of households taking up fruit trees and adoption rate in 8 country Regreening Africa projects

Country	Cumulative number both reached and adopting		
	All fruit trees	**Exotic fruit trees**	**Indigenous fruit trees**
Ethiopia	2456(926)	1833(748)	844(462)
Adoption rate	0.16	0.13	0.03
Kenya	1912(255)	1362(224)	866(138)
Adoption rate	0.14	0.10	0.06
Rwanda	8273(968)	8273(968)	n/a
Adoption rate	0.40	0.40	n/a
Somalia	3443(488)	2131(484)	1914(430)
Adoption rate	0.52	0.32	0.29
Senegal	5155(1448)	3828(1392)	3545(897)
Adoption rate	0.21	0.13	0.14
Ghana	30,978(4223)	26,483(2588)	13,754(3632)
Adoption rate	0.67	0.58	0.28
Mali	15138(5194)	8621(3310)	14142(4959)
Adoption rate	0.46	0.27	0.43
Niger	28740(4840)	6550(2736)	28293(4768)
Adoption rate	0.68	0.14	0.67
Totals	**96,095**	**59,081**	**63,358**

Note: adoption figures are estimated from the latest uptake survey data (Year 3 for Ethiopia, Kenya, Rwanda, Niger and Mali; Year 4 for Ghana and Senegal) and close out survey for Somalia; Standard errors in parentheses.

Cluster 2: Integrating trees in cropping fields for sustainable staple food production

This cluster focuses on integrating trees into cropping fields to enhance the sustainable production of staple crops, such as maize and rice. This may be achieved by enhancing soil fertility, for example, via 'fertilizer trees' (nodal nitrogen fixation or the incorporation of nitrogen rich biomass into soils); reducing soil erosion caused by water runoff or wind; maintaining soil moisture; facilitating water infiltration and cycling; enhanced pollination; or cooling ground surface temperature. The integration of appropriate tree species at appropriate densities are expected to further diversify farm production and income; generate additional products like fodder, firewood, and tree foods; and, in turn, bolster overall farm productivity. There is some overlap with the food tree and fodder tree clusters, as this work also encourages smallholder farmers to adapt and target fertilizer, fruit, fodder, and timber trees in appropriate planting niches where they can improve crop and livestock productivity.

Key achievements and stakeholder engagement efforts

Prior to FTA, significant 'discovery', 'proof of concept', and 'piloting' work was undertaken on the integration of trees into farming systems. A seminal synthesis of this work is a meta-analysis of maize yield response when it is intercropped with woody and herbaceous legumes (G. Sileshi et al., 2009). The general conclusion from this research was that Fertilizer Tree Systems (FTS) offer considerable potential for improving long-term soil fertility and health, as well as bolstering yields and farmer income. Hence, this was followed by efforts in seven countries (Burkina Faso, Kenya, Niger, Malawi, Rwanda, Tanzania, and Zambia) to promote fertilizer tree systems among smallholder farmers, i.e., through training and providing then with the requisite QPM.

Recently, however, FTA research (Coe et al., 2016) called into question these early research findings, particularly as it applies to ‘real world’ and highly heterogeneous farmer circumstances. This is linked to another significant body of FTA research, the ‘Options-by-Context paradigm’(Sinclair & Coe, 2019), which postulates that the performance of agro-ecological innovations generally varies significantly across biophysical, socio-economic, and institutional settings. Using an 11-district dataset comprising farms with fields both with and without fertilizer trees, Coe et al. (2016) conclude that the performance of such trees, while generating an overall average maize yield gain, varies considerably, with many farmers experiencing maize yield losses. However, this conclusion was critiqued by the scientific pioneers of this work (Sileshi and Akinnifesi 2017), arguing that the nature of the dataset analyzed was not conducive for the type of analyses undertaken. Several additional exchanges between these researchers via the *Experimental Agriculture* journal platform followed suit. Additional FTA-related research emphasized the need to carry out functional ecological and socio-economic assessments, prior to promoting particular tree-crop integration options among farmers (Chomba et al., 2020).

Despite conclusions about the need for further research embedded within the context of scaling-up initiatives, the bulk of FTA’s work under the integrating trees in crop fields cluster is associated with promoting (or scaling) such integration. Key scaling projects include Evergreen Agriculture Partnership, the Malawi Agroforestry Food Security Program (AFSP), Trees for Food Security, the Drylands Development Programme (DryDev), and Regreening Africa. The former project has since evolved into a partnership platform, involving a large number of national and international organizations. The former two projects were heavily focused on promoting Evergreen Agriculture (i.e., the integration of trees in cropping systems), whereas for the others, this is only one aspect. DryDev was a large ‘mega project’ implemented in five countries (Burkina Faso, Ethiopia, Kenya, Mali, and Niger). It was originally designed to scale out evergreen agriculture and other sustainable land management practices, but it was subsequently expanded to include other components, such as value chain strengthening and the promotion of improved crop varieties. Regreening Africa (Ethiopia, Kenya, Rwanda, Somalia, Ghana, Mali, Niger, and Senegal) is more focused on supporting the integration of trees into farming systems, but not limiting itself to cropping fields. All of the above projects were and are being implemented in collaboration with research and development partners (some of which are very large and influential, e.g., World Vision, Oxfam, CARE, and Catholic Relief Services), with the bulk of financial resources being directed to these partners. It is also worth mentioning that at the regional level in Asia, together with the FAO, FTA developed and launched a practical manual on how to incorporate trees in rice production landscapes in Southeast Asia and initiated a systematic review of the impacts of trees on rice yields. However, our discussions with a FAO contact revealed that this manual has yet to be applied.

Looking across all these projects and based on project documentation and reports (see Table 7), we estimate that FTA-related work directly supported over 442,000 farming households in Burkina Faso, Ethiopia, Ghana, Kenya, Malawi, Mali, Niger, Rwanda, Uganda, and Senegal to integrate

trees into their staple cropping systems with the aim of bolstering total farm productivity and climate resilience.

Table 7. Household reach and uptake data: Integrating trees in cropping fields

Project/Project Cluster	Reach	Uptake	Evidence Source(s)
Restoring degraded land for food security & poverty reduction	6,000	6,000	Project report
Odisha, India Agroforestry Project	9,041	9,041	Report submitted to Government of Odisha
Regreening Africa	115,441	96,105	Analysis of 3 years of uptake survey data
Malawi AF scaling projects	231,777	32,448	Final project reports combined with analysis of survey data
Drylands Development Programme	23,400	17,000	Supplementary data analysis
Trees for Food Security	48,233	2,569	Final project report with supplementary analysis impact study data
Agrobiodiversity & Landscape Res.	8,500	n/a	Project report
Total	**442,392**	**163,164**	

Primary impact pathways and underlying assumptions

The first pathway is the *staple crop productivity enhancement pathway* (Figure 6), where the integration of trees in the cropping field positively affects crop productivity.

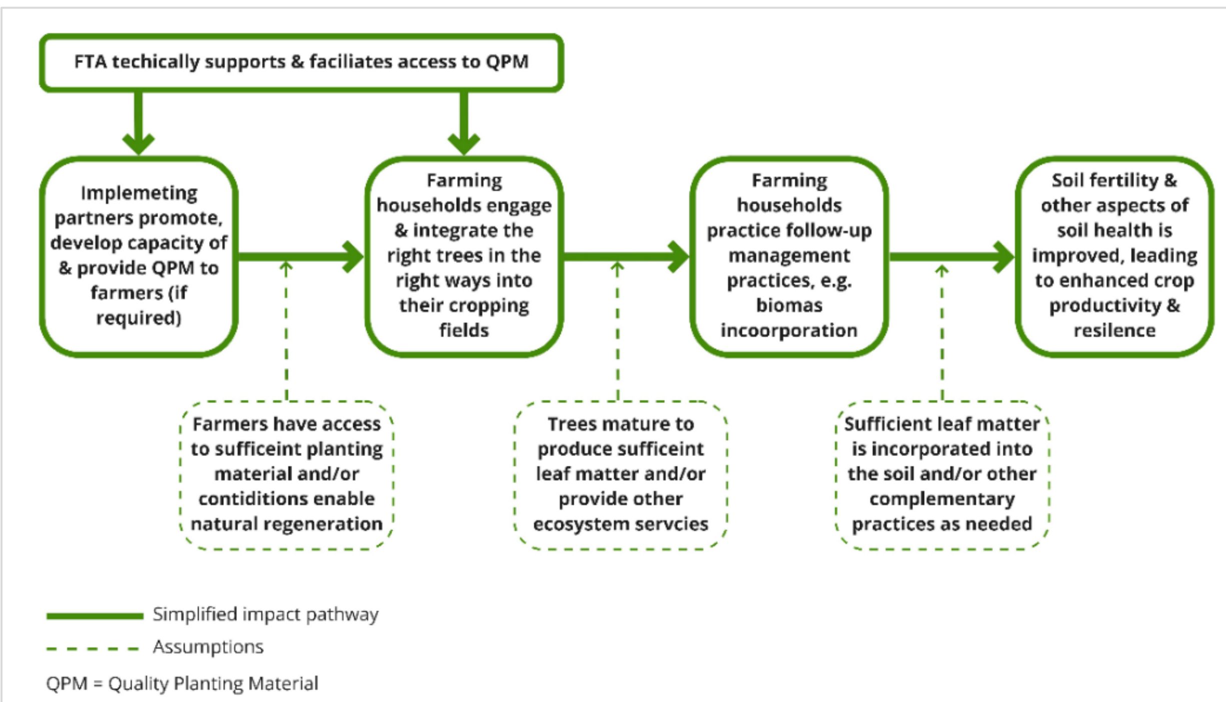

Figure 6. Simplified staple crop productivity enhancement impact pathway

In collaboration with implementing partners, FTA promoted the integration of trees into cropping fields, most notably ‘fertilizer trees’, coupled with enabling access to the requisite QPM. Farmers were then expected integrate the right trees in the right ways into their cropping fields and follow species specific management practices, for example, periodically cutting back leaf biomass and

integrating it into the soil. With more nitrogen and organic matter, soil fertility is improved, and, consequently, coupled with the other environmental regulatory services provided by the trees and shrubs mentioned above, crop productivity is enhanced and becomes more sustainable. As a result, more food is available for domestic consumption or sale, thereby both directly and indirectly improving household food and nutritional security. Moreover, production expenses further decrease, given less need for chemical fertilizers.

Key assumptions associated with this pathway include:

- Farmers have access to the requisite planting material or sufficient stumps and shoots exist on the field if such trees are being naturally regenerated.
- Planted or naturally regenerating trees mature (e.g., are not eaten by goats), so that they produce sufficient leaf matter and provide other intended ecosystem services.
- Sufficient leaf matter is incorporated into the soil and/or other complementary management practices depending on the system in question.

The second pathway is the *total field net productivity pathway* (Figure 7).

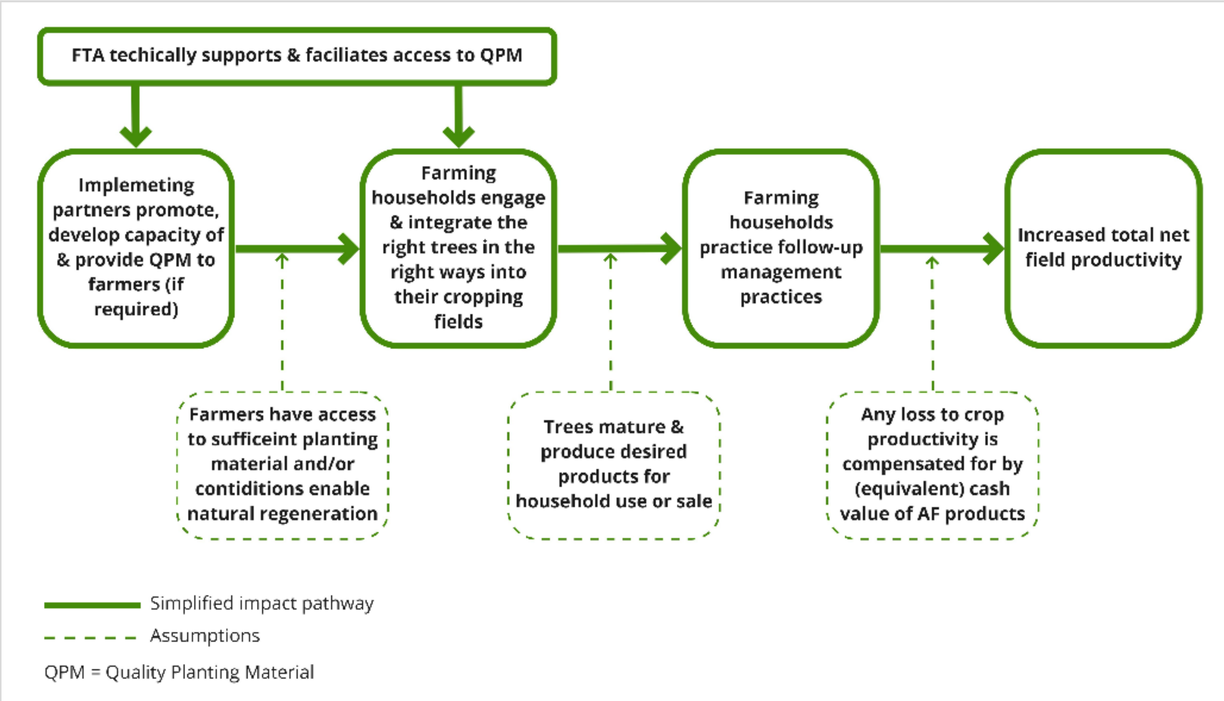

Figure 7. Simplified total net field productivity impact pathway

Integrating trees into a cropping field may have a neutral or even negative effect on crop production, e.g., through the introduction of competition for sun lights and nutrients. However, the benefits of doing so (e.g., from the additional income or products generated) may outweigh such associated costs. Planting of timber species along the boundaries of the cropping field or along contour ridges would be a good example of an agroforestry practice relevant for this pathway. The

integration of food trees into the cropping field could be another example, linking this path to the ones associated with the food tree cluster above.

The first assumption of this pathway is the same as the one preceding it. The other two include:

- Trees integrated into the cropping fields mature well, so that they produce the required products either for household use (e.g., fuelwood) or sale (e.g., timber).
- In practice, any loss to crop productivity is compensated for by the cash or cash equivalent value of the resulting agroforestry products.

As is the case for the food tree cluster, the two above impact pathways are biased towards the direct scaling efforts in which FTA has been involved. However, this direct scaling work lends itself to the *partner practice influence pathway*. At its most basic level, this pathway operates through the provision of technical advice on what trees to integrate, where, and how vis-a-vis the farming systems being targeted (i.e., 'the right tree for the right place for the right purpose'). However, the engagement, including any associated 'co-learning' processes, may also alter the partners' entire approach (e.g., how they design and/or implement their interventions). This would, in theory, lead to the better promotion of trees in cropping fields and, by extension, better and more appropriate farmer-level adoption and ensuing impacts. This pathway's key assumptions include:

- Conducive professional and social relationships are forged between FTA scientists and the partners in question.
- FTA scientists possess the requisite knowledge, insights, tools, and/or advice that are relevant and have potential to positively influence the partner's mindset or practice.
- Resource availability and/or intra-organizational power dynamics permit practice change.

Current evidence on achieved outcomes and impacts

While there were considerable efforts to test the efficacy of integrating trees in cropping fields in research station and farmer field trial settings that predate FTA, work to assess adoption and, to a greater extent, impact has been limited. The evaluation of the abovementioned Malawi AFSPII project (Hughes et al., 2019) did seek to ascertain adoption rates and impacts. However, the quasi-experimental strategy to assess the latter failed, given problems with project monitoring data. Nevertheless, substantive efforts to assess adoption levels were undertaken. Of the sample of 402 older program participants, 42 percent were found to have fertilizer trees in their cropping fields. However, the actual FTS adoption rate was ascertained to be much lower at 14 percent. The reason is as follows: In order to experience the expected effects of fertilizer trees, there needs to be sufficient numbers on-farm to generate the requisite leaf matter, and this leaf matter must be incorporated into the soil e.g., prior to seed sowing. Assessing adoption in binary terms (i.e., simply having or not having one or more fertilizer trees on farm) is therefore not insightful. Nevertheless, given that a total of 231,777 farmers participated in the various projects in Malawi promoting FTS and assuming that the ascertained 14% adoption rate is somewhat representative, it can be estimated that over 32,000 households have adopted FTS through FTA-related support.

To generate supplementary adoption evidence, endline datasets compiled for the following FTA projects were re-analyzed to provide specific estimates on the number of households that integrated trees into their farming systems: Trees for Food Security (T4FS) in Rwanda (2,569 among the 3,100 supported); and DryDev in Burkina Faso, Ethiopia, Kenya, Mali, and Niger (17,000 among the 23,400 supported). We further analyzed the uptake survey data collected for Regreening Africa in Kenya, Rwanda, and Senegal. Our findings show that over 96,000 households are estimated to have integrated trees into their cropping fields, among the 115,000 supported.

One source of actual impact evidence comes from the Coe et al. (2019) paper cited above using data also collected in Malawi. The sample is not statistically representative but comprises households with fields both with and without fertilizer trees. They found that maize yield gains were slightly higher on average for fields where fertilizer trees had been established (0.32 to 1.04 t ha^{-1} more maize), but with huge variation across households. Moreover, while positive, these average yield gains were also much lower than those established through the more tightly controlled field trials that predate FTA. However, a key shortfall of the data analyzed by Coe et al. (2019) is that it does not comprise variables indicating how much biomass was produced and incorporated into the fields with fertilizer trees. Hence, and extrapolating for the findings of the abovementioned AFSPII evaluation, it is likely that many of the fertilizer tree fields were only partially treated, thereby diluting the estimating effects and possibly partially explaining why many of these fields experienced relative losses compared with the maize only comparator fields. It is also worth noting that in the AFSPII evaluation, self-reported maize yields were compared between successful and unsuccessful FTS adopters, with the former reporting statistically significantly higher yields. However, this comparison is biased, given that the successful FTS adopters possessed greater asset wealth at baseline, and the statistical significance of the average yield difference disappears when this is controlled.

Cluster 3: Improving smallholder dairy production through tree fodder

As is the case with FTS, considerable research had taken place prior to FTA (largely concentrated in East Africa) on the potential of leguminous, high protein fodder trees and shrubs—also referred to as FTT—in bolstering milk yields. This research evidenced, for example, that two kilograms of dried *Calliandra calothyrsus* (equivalent to six kilograms fresh) is an effective protein supplement to basal feed comprising napier grass (*Pennisetum purpureum*) and crop residues. Under farmers' management, milk production was shown to increase by 0.6–0.75 kilograms per kilogram of dried *calliandra*. These results correspond with the wider literature. For example, in a recent meta-analysis of the impact of tropical forage technologies, including *calliandra*, on livestock productivity, Paul et al. (2020) found that these technologies improved milk yields by 39%, dry matter intake (DMI) by 25%, nitrogen content of manure by 24%, and manure quantity by 12% when compared with baseline diets.

The profitability of FTT was further demonstrated, with net benefits of $114 per cow per year when FTT is used as additional feed and $122 when substituted for commercial dairy meal entirely

(Place et al., 2009). FTT is purported to be particularly relevant for smallholder dairy producers, given that they do not operate at the economies of scale to make the utilization of commercially available feed financially viable. There are also other potential benefits. For instance, they can be integrated into cropping fields to enhance soil fertility, similar to FTS as described above, as well as aiding in the control of soil erosion. Cow manure from FTT fed cows is typically higher in nitrogen and hence can be used to further improve soil fertility when applied on cropping fields (Katuromunda et al., 2012). Finally, smallholder dairy farmers are often challenged with sourcing quality feed during the dry season and the variability in such sourcing is being exacerbated by climate change. Fodder trees and shrubs are available all year-round if appropriately managed.

Key achievements and stakeholder engagement efforts

Again, similar to FTS, much of FTA's focus on FTT has been in relation to its promotion among smallholder dairy farmers. One significant effort began in 2008 through the East Africa Dairy Development (EADD) Program. Funded by the Bill & Melinda Gates Foundation, this program targeted 315,000 small-scale dairy households in Kenya, Tanzania, and Uganda. In its first phase, ICRAF led its feeds and feeding systems component, which included the promotion of FTT, with a strong emphasis on supporting the role out of rural advisory services.

Under FTA's Value Chains Innovation Platforms for Food Security (VIP4FS) project, efforts were undertaken to 'nudge' farmers over the FTT 'adoption hurdle'. In particular, FTA scientists consulted the Busara Centre for Behavioral Economics in 2016, and this engagement led to the delivery of an innovative extension approach in Uganda where—in addition to basic training and scaling up FTT seedling production—similar dairy farmers with similar cows were paired together at the village level. One of the pairs in each village was supported to feed sufficient quantities of *calliandra* to their cow, while the other followed status quo feeding practice. Both were supported to keep records on feeding and milk yields, periodically feeding back results to their peers. Milk yields nearly doubled among the *calliandra*-fed cows (5 to 9.22 litres/day) but only increased by less than one litre in the status quo feeding group. Mean and median gains were 3.24 (p=0.008) and 3.0 (p=0.033) litres, respectively (n=28).

These experiences under VIP4FS were used to develop and access funding for the BMZ-funded Shrubs for Change scaling project, which is ambitiously targeting 120,000 smallholder dairy farmers in Kenya and Malawi. Similar to the work in Uganda, this effort is explicitly operationalizing insights from behavioral science to facilitate farmers over the adoption hurdle, i.e., by ensuring that quality planting material is easy to access; educating farmers on the potential idiosyncratic benefits they can experience early on; relaying knowledge and information in small digestible seasonally sized chunks; decoupling planting material collection and payment (so payments are made closer to the time when benefits are experienced); and facilitating social recognition for good practice. The reach and uptake of the three projects described above are presented in Table 8. Unfortunately, COVID-19 has created challenges for scaling this work but efforts are currently underway to support more farmers to adopt the shrubs.

Table 8. Household reach and uptake data: Tree fodder for improved milk yields

Project/Project Cluster	Reach	Uptake	Evidence Source(s)
East Africa Dairy Projects	255,235	84,288	Final project reports & working paper
VIP4FS	1,300	388	Submitted manuscript
Shrubs for Change	34,044	674	Project data
Total	**290,579**	**85,240**	

Primary impact pathways and key assumptions

There are three impact pathways associated with the tree fodder cluster (see Figure 8). The first is the *FTT uptake and utilization pathway*. This pathway is foundational, as it needs to be fully 'ignited' for smallholder farmers to experience the potential milk yield gains. Implementing partners impart relevant information and knowledge to smallholder farmers and ensure access to the required QPM. Smallholders are then expected to plant FTT seedlings in sufficient numbers (400-500 per cow) on their farms and manage them well until they mature (i.e., in about 18 months time). They then harvest 5-6 kgs of fresh leaf matter per cow daily, mixing it with basil feed, for example, napier grass or crop residues. Evidence shows that, assuming the requisite genetic potential, health, climatic conditions, and suboptimal baseline feeding practices, significant increases in milk yields should follow suit, as was the case under the VIP4FS project described above. While much of the milk is sold, some of the excess is consumed domestically.

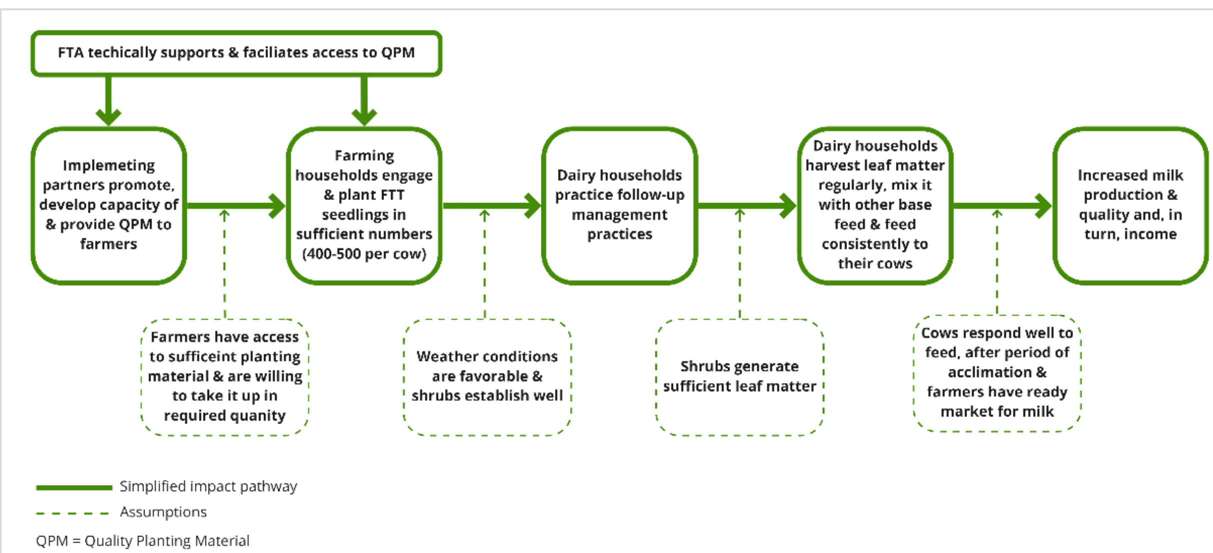

Figure 8. Simplified Fodder Tree Technology (FTT) uptake and utilization impact pathway

There are obviously several key assumptions underlying this impact pathway:

- Implementing partners deliver quality training and ensure access to the requisite planting material.
- Farmers find FTT an attractive option, despite the initial cost and labour investment.
- Farmers collect and plant FTT seedlings in the requisite numbers at the correct time, e.g., at the start of the rainy season.

- Weather conditions remain favourable, so that the seedlings establish well.
- The shrubs generate sufficient leaf matter.
- Cows respond well to new feed, and there is ready market for resulting increases in milk yields.

FTT is not the only improved feed option available to smallholder farmers, so implementing partners have others they can promote. This is particularly relevant, given that encouraging farmers to plant 400-500 seedings per cow can appear daunting. However, FTT is, arguably, a good feed option for smallholder dairy farmers for the reasons explained above. Hence, it is desirable that partners working in the smallholder dairy sector promote it, even if alongside other feed options. The *FTT partner scaling impact pathway* is where partners become convinced of the appropriateness of FTT through training and demonstrations and appropriately promote it among the smallholder target groups in question. If this pathway was actualized in the context of the EADD project, for example, we would expect to see this project continuing to promote FTT, despite ICRAF no longer leading its improved feed component. Key assumptions include:

- Implementing partners are aware of the potential benefits of FTT and have the knowledge, skills, and capacity to effectively promote it.
- Implementing partners perceive the cost-benefit ratio associated with FTT on both the scaling side and farmer utilization side as being equivalent or even better vis-a-vis alternative options.

The FTT scaling work is being undertaken in tandem with improved extension approaches. Through EADD, this was through volunteer farmer trainers, and through VIP4FS and S4C this was and is done by integrating behavioral science insights into the scaling effort. Hence, a third pathway can be dubbed as the *improved extension scaling pathway*. Here, collaboration with implementing partners in co-developing, implementing, and adapting these alternative extension approaches leads to changes in their extension and scaling practices in other contexts. In other words, they and the institutions they work with (e.g., local government departments) become more effective in supporting smallholder farmers to take up appropriate innovations and, thereby, become more effective in facilitating rural development and transformation. Again, this particular pathway relies on several key assumptions:

- Implementing partners are convinced that the alternative extension approach in question is more effective than the status quo, and that the perceived benefits of pursuing it outweigh the associated costs.
- Implementing partners have the motivation, materials, and capacity to implement the improved extension approaches.

Current evidence on achieved outcomes and impacts

An end-line study (*n*=181) was carried out in the context of the EADD project mentioned above in Kenya. It found that 33% of the targeted farmers adopted fodder shrubs, despite 67.5 percent

being aware of them. The main reasons for the lower than desired uptake included: low accessibility of planting material and limited technical knowledge and knowledge on utilization (Kiptot et al., 2015). Assuming the majority of the FTT promotion work took place in Kenya, it can be estimated that over 84,000 smallholder farmers adopted FTT following this scaling effort.

Under the VIP4FS project, a cluster randomized control trial (RCT) was used to evaluate the effectiveness of the 'citizen science' add-on intervention in 'nudging' FTT uptake. Results indicate that such uptake increased from 25% to 61% in the intervention clusters, against 26% to 42% in the control clusters, a relative difference of 20% ($p<0.001$; $n=879$). The increase in the latter is likely indicative of spill-over effects, possibly due to increases in local supply of *calliandra* and/or knowledge diffusion. If we assume that such spillover effects took place, the uptake of FTT increased by 26 percent among the 1,300 dairy farmers that were being targeted, (i.e., 338 took up FTT).

While revealing, FTT, like FTS, is not a binary agroforestry innovation. A farming household requires at least 400 shrubs on-farm per cow to generate the requisite leaf matter. And this leaf matter must be fed at the appropriate frequency, in the appropriate quantity, and mixed appropriately with basil feed in order to positively affect milk yields.

Cluster 4: Understanding the relationships between forest resources and the food security and nutrition of forest proximate communities

It was recently estimated that 1.6 billion rural people live within five kilometers of a forest (Newton et al., 2020). By extension, the livelihoods of many of these people are linked in some form or another to these forests, with many relying on them for sources of nutritious foods. This cluster of FTA's work related to Challenge 5 is therefore focused on both evidencing and better understanding the extent to which forest proximate communities rely on local forests, including their contribution to meeting household food and nutritional requirements. This is both directly through food provisioning and indirectly through enhancing agricultural production. It is further devoted to raising awareness on this critical provisioning role, as well as co-developing policy and intervention options to promote continued, enhanced, and safe access to desirable forest foods by forest proximate communities.

Key achievements and stakeholder engagement efforts

FTA researchers undertook primary research to evidence the contribution of forests to meeting the food and nutritional requirements of forest-proximate communities at the global level (Rowland et al., 2017), as well as in Indonesia (Ickowitz et al., 2016), Cameroon, the DRC, Ethiopia (Baudron et al., 2017), and Zambia (Ickowitz et al., 2021). This included the administration of household surveys. Key findings were disseminated and shared through multi-stakeholder platforms and focus group discussions, with the aim of raising awareness among policymakers and other relevant stakeholders on the contribution of forests to local diets. In Indonesia, for example, recommendations were co-developed with local communities, informed by evidenced of food

consumption patterns among traditional and oil palm producing households. In Ethiopia, Uganda, and Burkina Faso, a total of 1,750 stakeholders participated in such platforms, complemented with approximately 200 focus group discussions with communities where data were presented for participatory validation and further qualitative interrogation.

At the global level, FTA has sought to raise awareness of and provide policy options for enhancing the food and nutrition provisioning function of forests by providing inputs to (a) the International Union of Forest Research Organization's (IUFRO) Global Forest Expert Panel (GFEP) process; (b) the International Conference on Forests for Food Security and Nutrition; and (c) the high level panel of the World Committee on Food Security (CFS).

Primary impact pathways and assumptions

From the above, there are two primary impact pathways that can be ascertained: the *national and local policy and practice influencing pathway* and the *international policy influencing pathway*. Both are related but distinct. In the former, awareness is raised in specific contexts on the food and nutrition provisioning role of forests, and appropriate policy responses are co-developed with stakeholders. National and local policies and supporting interventions are then implemented to uphold the rights of local communities to safely and sustainably access wild foods from local forests. Key assumptions that underlie the national and local policy and practice influencing pathway include:

- Political will exists to integrate the generated evidence into decision-making, as well as to participate in joint policy formulation processes.
- Capacity to enforce and ensure sound implementation of relevant policy options is in place.
- Local communities are willing to fulfil their responsibilities in the sustainable management and protection of local forests.

The international policy influencing pathway intends to also uphold (or enhance where relevant) the food and nutrition provisioning role of forests, albeit indirectly. Influencing such high-level policy processes is ultimately intended to influence national policies and interventions, as well as donor funding priorities, thereby helping to facilitate the national and local policy and practice influencing pathway. Key assumptions underpinning this work include:

- Global bodies and international organizations find FTA research in this area credible, relevant and actionable.
- Influenced global level policy and funding priorities and decisions have the potential to meaningfully shape those at the national and, eventually, local level.

Current evidence on achieved outcomes and impacts

According to project reports and CIFOR's database, extensive FTA work on evidencing the food and nutritional contribution of trees and forests has generated significant interest and engagement

from national and international policymakers, research institutions, and international NGOs. In Indonesia, national and sub-national governments expressed interest in taking up the results and recommendations of FTA research on nutrition and food shifts in the course of rapid agrarian change. Moreover, in Zambia, ministries and national universities expressed their interest in future collaboration on this topic. In Ethiopia, the government formulated recommendations drawing on the findings from the above cited research for the inclusion of nutrition-sensitive interventions in their government's nutrition program. However, other than participation in research-related processes, we did not find any information on numbers of households or people exposed to interventions or policies influenced from this work.

Focus on the Bushmeat Research Initiative (BRI)

The BRI is an 'envelope' for CIFOR's work on bushmeat. As an initiative, it differs from the clusters we have reviewed above, which are comprised of projects with similar foci that are implemented independently from one another. While the BRI does comprise several related projects, the outcomes of this work would not be captured well if reported as a cluster of projects. This is because it consists primarily of a series of strategic engagements at key national and global policy for a, which are not supported by projects per se. Along with CIFOR, the main BRI partners are CIRAD, FAO, USAID, Manchester Metropolitan University (MMU), Zerca y Lejos, (a Spanish NGO), Ministry of Forests and Wildlife (MINFOF) of Cameroon, and The Darwin Initiative of the UK government.

The initiative works towards three main strategic objectives:

1. To strengthen the evidence base for effective interventions to promote the inclusive and sustainable utilization and management of wild meat.
2. To identify knowledge gaps and main areas where further work is required.
3. To recommend potential policy changes to mitigate the impacts of overexploitation of wild meat.

Since its inception in 2011, peer-reviewed research by the initiative and its partners has resulted in a total of 138 scientific papers in 40 different peer-reviewed journals, four book chapters, and two books. Publications accrued a total of 2,949 citations by April 2021. Among the more than 100 organizations that publish on wild meat (or bushmeat), BRI stands out, contributing 10 percent of all publications on the topic since 2011. Below, we summarize BRI research outcomes as of 2020, strategic membership in global partnerships, and policy engagement at national and global levels. Much of this evidence is also published in the FTA Highlights of a Decade 2011-2021.

The overall body of work focused on two areas that advance the initiative's main goals. First, it conducts research to determine the financial and economic benefits derived from bushmeat. For example, in Cameroon there are an estimated 552,000 people who hunt for income, subsistence, or a combination of both. Lescuyer and Nasi (2016) calculated a net financial benefit of hunting in rural areas as €10 million a year and a net economic benefit of €24 million. Second, there is a

tendency to assume that all bushmeat consumption should be illegal, which ignores the fact that some of the world's most marginalized and vulnerable communities depend on bushmeat for their nutritional and, perhaps more importantly, fat intake. BRI research therefore seeks to highlight the importance of bushmeat in order to create a counter-narrative. A blanket ban on the trade of bushmeat would endanger both humans and wildlife.

Third, CIFOR research aims to increase the awareness of bushmeat for nutritional security, specifically by changing the focus of bushmeat as solely a conservation issue. If wild animals were to disappear from local diets (e.g., because of continued biodiversity loss), and no adequate measures were put in place to replace them by other healthy proteins, local diets would suffer from micronutrient deficiencies. Moreover, as the availability of wild meat and fish decreases, the most immediate and serious effect would be a reduction in fat intake. Wild meat provides fat as well as protein, and animal fat is energy-rich and contains important vitamins.

BRI outcomes cover a range of issues. First, BRI supported several engagements to increase the capacity of local communities in sustainable hunting. For example, with support from the Darwin Initiative Fund, BRI partners provide training in sustainable hunting practices. BRI team members further encourage families to produce more and better grown local food crops, so that they could provide the nutrients that are not provided by natural resources.

Second, collaborative action and research on the sustainable use of bushmeat is limited by a lack of mechanisms for sharing data. The BRI created the bushmeat research database: https://www2.cifor.org/bushmeat/resources/bushmeat-database/ to address this shortcoming. BRI aims to provide a comprehensive open-access database of bushmeat-related research in tropical forests, intended to support institutions in their efforts to build networks, acquire data, and share and collaborate with partners. The searchable Bushmeat Database contains more than 700 citations, including peer-reviewed journal articles, books and book chapters, technical papers, reports, and conference proceedings.

Third, BRI achieved significant results through engagements at key national and global policy events. Overall, BRI influenced 12 policies, 10 of which are decisions or regulations that were adopted by official bodies and national governments. A toolkit for implementing initiatives based on linkages between great ape conservation and poverty alleviation has been produced and circulated for comment. After revision, the document will be published as part of the "best practice" conservation series of IUCN. Further, the General Secretariat of the Organization of American States and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Secretariat developed a guide to the rapid assessment of the effects of implementing CITES provisions on the livelihoods of poor rural communities. The guide, published in 2016 (Gómez et al. 2016), provides tools for identifying mitigation or adaptation strategies that address the impacts of implementing the various CITES decisions.

Indirectly, BRI seeks to influence wildlife conservation policy decisions through memberships in key bodies. For example, BRI partners have contributed to different initiatives of the Collaborative Partnership on Sustainable Wildlife Management (CPW), which is a voluntary partnership of 14 international organizations with substantive mandates and programmes to promote the sustainable use and conservation of wildlife resources. It works to promote and increase cooperation and coordination on sustainable wildlife management issues among its members and partners. CIFOR and BRI researchers sought to influence CPW in several ways. For example, at the CPW Forum in 2015, CIFOR Researcher, Nathalie van Vliet, delivered the keynote address on the community engagement in wildlife management. CIFOR-ICRAF's Managing Director, Dr. Robert Nasi, also gave a keynote presentation at the same forum, providing an overview of the role of bushmeat for food security and nutrition.

The BRI research team is active in the Convention on Biological Diversity (CBD) Liaison Group on Bushmeat. At the 2017 meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA), the body recommended that a decision be adopted on sustainable wildlife management which provides guidance for a sustainable wild meat sector. At the Fourteenth meeting of the CBD in 2018, this decision was adopted by the Conference of the Parties to the Convention on Biological Diversity (CBD COP). A comprehensive technical report, "*Towards a sustainable, participatory and inclusive wild meat sector*" (DOI: 10.17528/cifor/007046), was published in 2019 by CIFOR and the CBD (Coad et al. 2019), as a companion to CBD Decision 14/7[4] . The CBD report has been cited widely in the draft chapters of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) thematic assessment of the sustainable use of wild species.

Another important membership is with the Sustainable Wildlife Management (SWM) programme. SWM is under the umbrella of the Organisation of African, Caribbean and Pacific States (OACPS) for the period 2018-2024, and responsible for implementing projects in 13 African, Caribbean and Pacific countries, with the aim of improving both biodiversity conservation and food security. By developing innovative, collaborative and scalable new approaches to conserve wild animals and protect ecosystems, the programme will also improve the livelihoods of Indigenous Peoples and local communities who depend on these resources. The SWM Programme involves four main action areas: how wildlife hunting is regulated; how sustainably produced meat products and farmed fish can be supplied to replace wild meat; how the management capacities of Indigenous and local communities can be strengthened; and how the demand for wild meat, particularly in towns and cities, can be reduced. The BRI's membership in the SWM is another example of FTA's strategic engagement.

BRI has effectively engagement with national governments. For example, the BRI was instrumental in changing the rules for environmental assessments to include the impact of plantations on game and wild meat in Peru. In Ecuador, as part of creating legal and financial

[4] https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-07-en.pdf

support for the sustainable management of game species, incentives for managing game in forests and fallows as part of the Socio Bosque Program have been established at the provincial level in Napo and Pastaza. A framework on the impact of road building on wild meat and other forest resources will be included in environmental assessments on road building in the Ecuadorian Amazon. In Brazil, the BRI focused on hunting quota proposed for the states of Pará and Amapá. A technical document is being prepared by BRI partners, and a participatory wild meat monitoring system was designed for district and provincial authorities based on BRI's research. In Colombia, the government is currently revising its wildlife policy through a participatory process. A BRI-CIFOR team was invited by the policy review team to provide recommendations based on the research results from Leticia.

A final note regarding the term 'bushmeat'. The term which originated in Africa and has been used to refer to the meat of wild animals. Recently, however, there has been a move towards using the more generic term "wild meat," since it has no geographical associations. Thus, the World Conservation Union (IUCN) General Assembly Resolution 2.64 (IUCN 2000) adopted the term 'wild meat' to refer to terrestrial animal wildlife used for food in any part of the world.

5. 'Deep Dive': Food Tree Crop Portfolios

Better integration of suitable and nutritionally important fruit tree species into food production systems of smallholder farmers in SSA is considered to be a feasible and sustainable intervention approach to deal with the challenges of micronutrient gaps and the risks of associated diseases (McMullin et al., 2019b). FTA's FTCPs (McMullin et al., 2019a, 2019b) aimed at filling this gap. This tree-based nutrition intervention identifies combinations of socio-ecologically suitable and nutritionally important fruit tree species for production on the smallholder farms to provide fruits that address nutritional gaps in local diets (McMullin et al., 2019a).

For our deep dive into this work, we conducted two complementary exercises: a) documentation review and in-depth interviews with key stakeholders; and b) an ex-ante impact simulation exercise to explore potential impacts of the FTCP concept if it were taken to scale.

5.1 Documentation review and in-depth interviews

Documentation review:
The documents we reviewed included:

1. *AR4D-PRUNSAR: 2019 Consolidated Report* (2019). A report from the International Fund for Agricultural Development (IFAD) that focuses specifically on the Putting Research into Use for Nutrition, Sustainable Agriculture and Resilience (PRUNSAR) program which funded the FTCP research.

2. *Catalogue of Innovations: Enhancing Smallholder Agriculture and Food System Resilience* (no date). An IFAD communication that showcases of IFAD-funded programs in the wider East and Southern Africa region.
3. *Project Disrupt: Game-Changing Innovations for healthy Diets on a Healthy Planet.* This is a GAIN (Global Alliance for Improved Nutrition) Working Paper (2020) that highlights some of the FTCP work.
4. *Advance Equitable Livelihoods: A Paper on Food System Summit Action Track 4.* This communication was written to in preparation for the UN Food System Summit 2021.
5. *Fruits and Vegetables for Healthy Diets: Priorities for Food Systems Research Action*. Another brief written in preparation for Food System Summit.

This review found evidence of the FTCP concept being promoted in several influential donor documents and reports. For example, an IFAD report (2019) explained that FTCPs are developed to "ensure year-round availability of key micronutrients while promoting greater local diversity of foods to address malnutrition and diet-related chronic diseases" (IFAD 2019, p.13). The report goes on to show the specific months when food shortages occur and how a portfolio of different fruits and crops, including fruits, vegetables, staples and pulses can eliminate specific nutritional deficiencies in key months, including Iron, Vitamin A+, Folate and Vitamin C. The report also highlights the reach for this research at the time of publication, including: 570 school children engaged in a pilot school program, 280 participants in agroforestry training, 266 participants in nutrition training (266 women and 2 men), and 185 participants in enterprise development.

The Catalogue of Innovations report (IFAD, 2020) also strongly recommends the FTCP work as an appropriate model to address food and nutrition security across a variety of geographies. The community benefits that were highlighted include (p.69):

- More than 90 food tree and crop species have been identified across nine sites in Kenya, Uganda and Ethiopia, with an average of 30 species recommended per portfolio.
- The portfolios not only support direct food production–consumption pathways but also support diversified income-generating pathways through engagement in nursery enterprises for the supply of tree seeds and seedlings, with the potential to sell surplus produce from the prioritized food trees once they fruit.
- Increased household nutrition and incomes of smallholders through food production diversity are the important benefits from this project. Many households can meet their seasonal dietary needs through a combination of their own production on farm or from the market.

The GAIN Working Paper (Pederson et al., 2020) focuses on "game-changing technologies." The paper is based on the initial findings of a multi-disciplinary expert panel of 52 individuals from over 25 countries. Out of 85 proposed innovations, twenty were selected as being the most likely

to have impact by 2030. Two in this shortlisted group are related to FTCP: promotion of native and orphan crops[5] and agroforestry for fruit production and soil health.[6]

Key informant interviews:
Additional insights were obtained through key informant interviews. Here, we distinguished between two types of policy impact pathways. 'Big P' policy pathways represent officially negotiated government policy processes that result in national (or sub-national) legislation. 'Small P' pathways refer to formal and informal rules and strategies that partner organizations, including donors, adopt for project implementation.

We developed a survey instrument with input from CIFOR-ICRAF's FTCP lead and staff from Royal Roads University. Interviews were recorded after receiving permission from the respondents, and subsequently transcribed and analysed. Out of the 10 stakeholders targeted for interviews, we interviewed six. These included representatives from strategic NGO implementing partners, government NARS partners, and donors.[7] Implementation partners included representatives from Feed the Children and the Kenya Institute of Business Training (KIBT), whereas the NARS actors were representatives from the Kenya Agricultural and Livestock Research Organization (KALRO). One person from the IFAD agreed to be interviewed. The interviews took place in June 2021via video conferencing.

One of the steps in the pathway (See Box 8, Figure 12, Appendix A) is that strategic NGO partners integrate the promotion of FTCP into program plans. All respondents that represented NGOs and NARS reported that the research was critical and had some level of impact within their respective institutions. However, the evidence for this impact was anecdotal. Respondents "knew" that the work had changed their organizations, but they could not point to formal changes to rules or strategies. For example, when Feed the Children was asked if the FTCP projects changed how their organization does its internal planning and programming, the response was:

> *"Yes, it absolutely did. One of the ways it influenced the work that we do – from the project – to put an emphasis on production and consumption of local indigenous fruit trees and vegetables. One of the key takeaways there was that – in terms of nutrition – the different food crops we have and the nutrient contribution, the nutrient value, there is a tendency to focus on exotic fruits – foods that are not readily available and are not indigenous to Kenya, we talked a lot about oranges and apples, etc, but through this project we learned*

[5] This innovation represents a whole value chain approach to promote the production, processing, and consumption of local underutilized and culturally appropriate crops to benefit farmers, diets, and the environment and make them desirable for both farmers and consumers.
[6] This innovation proposes to implement nutritious fruit tree plantations through agroforestry practices. This could regulate land degradation and provide income, nutritional benefits, and carbon retention. Further, planting trees in (mountain) watersheds generates resilient and effective watersheds. Drought-resistant fruit trees could be chosen, but other options, such as fodder crops, are also possible and could be used to create multi-functional landscapes.
7 This group is represented in boxes 7, 8, and 9 of the Sub-TOC in Figure 12 in Appendix A.

> *that there are a lot of indigenous fruit tree species that provide the same nutrients and that are readily available to the communities …"*

Evidence of 'Small P' influence was in relation to Feed the Children's active involvement in the global **Scaling Nutrition Movement**, as well as the national **Nutrition Action Plan**. The former represents a global network where information is shared, especially on new approaches and technologies. Feed the Children explained that there is a direct link between the knowledge they gained from working with the FTA-funded FTPC work and sharing this knowledge within their large networks and other forums. The KIBT also agreed that there had been an internal organizational change which was difficult to specify.

KALRO was clear about how this work influenced their programming. As one respondent explained about the portfolios:

> *"This was very unique because previously there were mainly projects based on particular crops … so this I can say was very unique to have different types of fruit crops that produce at different times of the year so that farmers were able to have fruits throughout the year. So, by combining different types of fruit crops also considering their contents in terms of different vitamins … so that farmers can have all their nutrients … So, any time they would be having a fruit that would sustain them."*

Another step in the policy pathway indicates that NARS and policy makers support creation of appropriate policies (Box 9, Figure 12, Appendix A). The NARS representatives strongly supported the creation of appropriate (Big P) policies to scale the FTCP concept. A KALRO representative saw an urgent need for policy development and proposed several ways to achieve this. Similarly, donors also play a role in terms of reproducing evidence of FTPC findings (see Box 7 in the Sub-ToC). While the archival review section showed evidence of this, the donor representative was a strong proponent of supporting Big P policy. The respondent stated the following:

> *Policy is key key key. … We need strong engagement with NARS. Some donors sometime fail. Donors who deal with giving loans to the government spend time with the Ministry of Finance. This Ministry looks at it from a macro-economic perspective. But you need to go back to the NARS. They can decide what they will deliver. Then look at the market.*

The donor representative also had two points of caution. First, more emphasis is needed on income generating crops or activities, and, second, greater integration of portfolios into existing or new markets. This is somewhat of a departure from the FTCP concept, which emphasizes self-sufficiency with respect to nutritional requirements. The donor is of the opinion that self-sufficiency does not mean that the farmer must grow all nutrient sources throughout the calendar year but that some can be purchased. The respondent stated in particular:

> *"The portfolios don't need to produce everything. The whole thing about self-sufficiency is outdated. You can go look at it and say, these farmers have an advantage. These farmers can produce moringa. And if these farmers … if these farmers can sell moringa and make money, then they can go buy maize, beans and meat. They don't have to grow all that. The problem is … there is something they keep calling intensification. A farmer has one acre and they want him to grow maize, beans, moringa, … that cannot work."*

Overall, our 'deep dive' shows that there are many instances of Small P influence with partner NGOs and NARS, but that these manifested themselves primarily in terms of behavioral change and not in formal documented procedural changes. Our investigation did not find instances of documented Small P influence at the organizational level in terms of new or changed strategies or policies. There are only anecdotal examples of people 'doing things differently' as a direct result of their collaboration with ICRAF on FTCPs. We did find Small P evidence at the donor-level in terms of communication materials that explain and promote the research in official donor documents. There was further evidence of this research in briefs and papers of different organizations that can be important pathways to influencing policy further down the line.

We found no evidence Big P influence. That said, respondents were convinced of the need for such policies. The NARS, which have a close relationship with policymakers, made this clear in their responses, and they also provided a pathway for how such policies can be created. They envisioned working closely with FTA partners to produce further evidence, followed by the drafting of policies.

There are several possible reasons why respondents reported that the research impacted their organizations and changed their behaviour internally yet with no evidence in changes to official organizational strategy. First, a respondent from KALRO explained that organizational mandates are set and do not easily change. Internal policies and procedures rarely change as a result of a new technology or collaboration, partly because this is a lengthy and complicated process. Second, several respondents indicated that the research was still in the pilot phase. It could be that they had this perception as a result of the relatively small size of the projects in terms of reach, budget, and timeline. Lastly, influencing policy typically takes time, and the influence of FTA's FTCP research may yet lie in the future. Finally, there is a possibility that we missed Small P and Big P influence was due to the relatively small number of respondents we interviewed. Ten potential respondents were contacted and four were either unable to, or decided not to, participate.

5.2 Ex-ante simulation: What nutritional impacts could be achieved by taking the FTCP concept to scale?

<u>Methods</u>:

In this exercise, we followed the approach developed by Stein et al. (2005) for ex-ante DALY simulation. This method enables the expression of negative health outcomes associated with

micronutrient deficiencies in terms of DALYs, as well as to, thereby assess the effectiveness of interventions in terms of DALYs saved. As the FTCP concept has only been piloted thus far, we conducted an ex-ante simulation that estimates potential nutritional impacts if it were to be successfully taken to scale. When combined with the GDP per capita indicator, our simulation provides insightful information on DALYs that could be potentially saved per dollar invested in scaling the FTCP concept, i.e., cost-benefit analysis.

We focus on dietary iron and vitamin A deficiencies because of their important global distribution and disease burden, especially among children and women in Sub-Saharan Africa. We define health loss due to these micronutrient deficiencies under the base scenario based on the current dietary intake and epidemiological data. We compared this with the intervention scenario where micronutrient deficiencies and associated disease burdens will be reduced as a result of adopting recommended FTCPs (See Figure 16 in Appendix C).

Our estimation strategy followed two steps: First, we predicted ecologically suitable areas for 14 prioritized fruit tree species selected based on their dietary iron and vitamin A contents of their fruits. Based on this information, we identified a portfolio of fruit tree species for scaling up in each country and estimated conservative micronutrient yields that can be made available. Our analysis focused on 12 countries in Sub-Saharan Africa with a high prevalence of vitamin A and dietary iron deficiencies based on data from Global Burden of Diseases (GBD, 2020). These include Burkina Faso, DRC, Ethiopia, Gambia, Kenya, Mali, Mozambique, Malawi, Nigeria, Tanzania, Uganda and Zambia. Second, we computed DALYs lost under the baseline and counterfactual scenarios and thus DALYs saved as a result of adopting prioritized FTCPs.

<u>Current micronutrient related disease burden</u>:

The disease burden of IDA and VAD in the 12 study countries amounts to an annual loss of 6.8M DALYs. Of the total DALYs lost, 51% is due to IDA and 49% is due to VAD. The biggest DALYs lost are in the two most populous countries, Nigeria and Ethiopia, which we expected (Figure 9). Regarding the target group, the most significant burden is borne by children under the age of five. The total health cost due to iron deficiency anaemia and vitamin A deficiency borne by children under five and women of reproductive age is 4.8M and 2M DALYs per year, respectively.

The largest share (68%) of the total DALYs lost for children under five are due to IDA. This indicates IDA continues to be a significant public health issue, especially for pre-school children in SSA counties. The estimated annual death toll due to IDA and VAD in the 12 countries is 59,597. Three countries account for more than 70% of children and adult women's deaths due to IDA and VAD. The most populous country, Nigeria, leads by 48%, followed by DRC and Ethiopia with 10 and 13 percent, respectively.

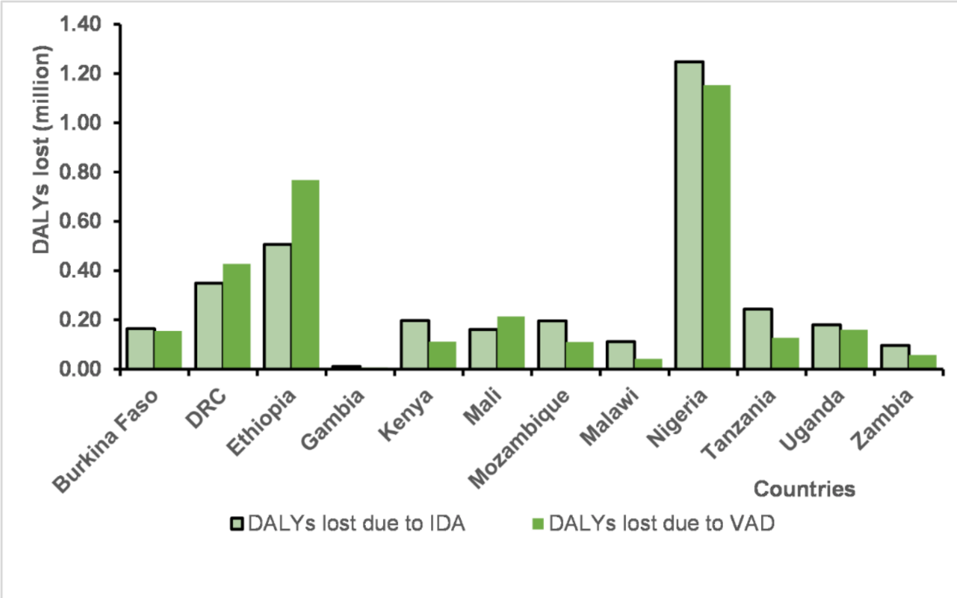

Figure 9. DALYs currently lost as a result of micronutrient deficiencies

Potential impacts:

Based on the current iron and vitamin A intake and deficiencies in these nutrients that can be reduced with the potential of successfully scaling FTCPs, the new prevalence of diseases related to IDA and VAD, and the remaining number of DALYs lost with FTCPs was calculated (Figure 10). The difference between these values and DALYs lost without FTCPs in the base scenario is the projected annual benefit, expressed in years of "healthy" life gained. This result is presented in Table 9 with YLL and YLD and disaggregated by IDA, VAD and countries.

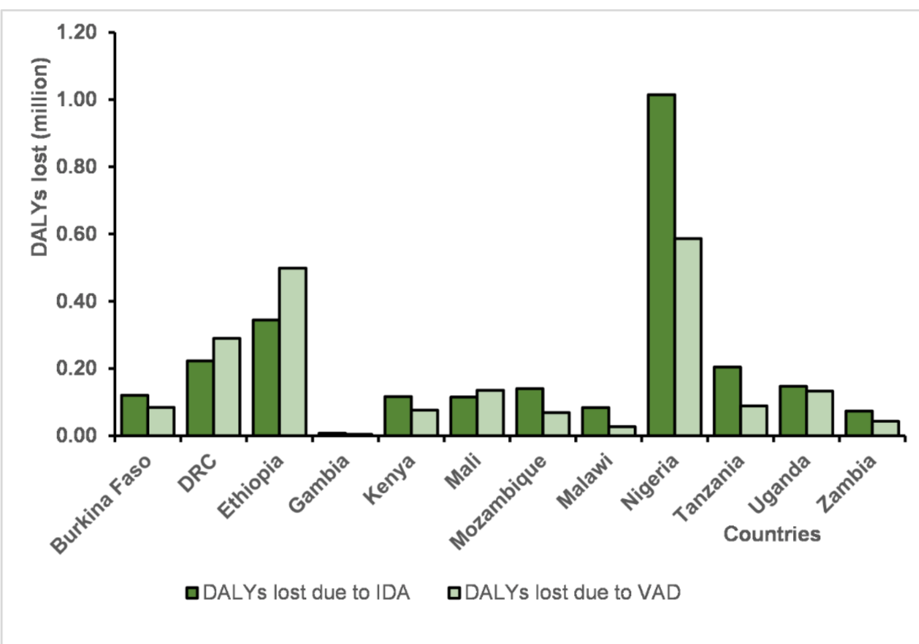

Figure 10. DALYs lost with FTCPs scenario

Compared to the base scenario, the gain is 2.17M DALYs, reduced from 6.8M to 4.63M DALYs. That means the health burden is reduced by 32% per year compared to the situation without FTCPs. Although the overall projected benefit mostly occurs in three countries, namely, Nigeria (32%), Ethiopia (20%); and DRC (12%), each country experiences considerable gain from the adoption of prioritized FTCPs, as shown in Table 9.

Our results indicate that 2.17M DALYs are projected to be saved due to reduced iron deficiency anaemia and vitamin A deficiencies and related negative health outcomes per year. Approximately 30,866 deaths per year in reproductive aged women (1,722) and children under five (29,144) could potentially be averted from consumption of nutritious tree foods if the FTCPs were scaled up in the 12 countries. The full details of these simulations, including data sources and assumptions, are in Appendix C.

Of the two target groups, the biggest overall benefit accrues to children under five. The gains due to the reduced burden for children under five is 1.67M DALYs (77%) compared to 0.51M DALYs (23%) for women of reproductive age. Improvement in iron and vitamin A status with the scaling of prioritized FTCPs can also lower the death toll significantly. Overall, the adoption of FTCPs can avert 30,862 child and women deaths per year in the 12 countries, reducing from 59,597 in the base scenario to 28,735 with FTCPs. The number of death cases averted for children under five is relatively higher (29,144) than for women of reproductive age (1,722). This is because maternal mortality is only likely in cases of severe IDA.

Table 9. DALYs gained (loss averted) with the adoption of FTCPs

Countries	IDA			VAD			Total		
	YLL	**YLD**	**DALYs gained**	**YLL**	**YLD**	**DALYs gained**	**YLL**	**YLD**	**DALYs gained**
Burkina Faso	1,438	42,067	43,504	40,202	31,660	71,862	41,640	73,726	115,366
DRC	8,873	117,260	126,134	68,298	69,212	137,510	77,171	186,473	263,643
Ethiopia	12,026	149,884	161,910	52,776	215,692	268,468	64,802	365,576	430,378
Gambia	162	2,726	2,888	1,039	1,900	2,939	1,200	4,627	5,827
Kenya	3,873	77,637	81,509	15,634	19,595	35,229	19,506	97,232	116,738
Mali	3,191	43,308	46,499	45,897	32,884	78,781	49,088	76,192	125,280
Mozambique	1,250	54,413	55,664	35,151	6,758	41,910	36,401	61,172	97,573
Malawi	701	27,262	27,963	6,103	9,623	15,726	6,805	36,885	43,690
Nigeria	24,650	207,894	232,545	502,042	65,470	567,512	526,692	273,364	800,056
Tanzania	2,465	37,232	39,697	28,974	9,419	38,393	31,439	46,651	78,090
Uganda	1,549	31,187	32,736	15,801	11,664	27,465	17,350	42,850	60,200
Zambia	435	22,448	22,883	10,453	4,727	15,179	10,888	27,175	38,062
Overall	**60,614**	**813,318**	**873,932**	**822,369**	**478,605**	**1,300,972**	**882,983**	**1,291,923**	**2,174,904**

6. Discussion and Conclusion

As illustrated above, FTA spearheaded substantive efforts to address Challenge 5: Rising demand and need for nutritious food for both current and future generations. Our review identified four main ways FTA has sought and is seeking to address this pressing challenge:

1. Promoting the upscaling of food trees in smallholder farming systems for improved food security and nutrition.
2. Enhancing sustainable staple crop producing through the integration of appropriate tree species in cropping fields.
3. Improving small-scale dairy production through the promotion of leguminous tree fodder as high protein supplementary feed.
4. Evidencing and seeking the recognition of the role of forests in sustaining and enhancing the food security and nutritional wellbeing of forest proximate communities.

This is even though none of FTA's flagship programs were structured specifically to address this challenge. Indeed, the framing and specification of this challenge, including the construction of the impact pathways associated with the above clusters and an overarching ToC, were identified retrospectively. While there are certainly gaps in information and evidence on the extent to which outcomes and impacts of this ToC have manifested, there are some promising signs. Under FTA, for example, several large agroforestry innovation scaling projects were implemented that reached considerable numbers of people (Figure 11). Moreover, where adoption studies and data were accessible, we did find evidence supporting significant 'FTA innovation uptake'. However, survey data and evaluative studies both reveal challenges. Once an innovation is promoted (e.g., fertilizer tree systems), it does not automatically mean that farmers will successfully take it up and, in turn, experience the benefits. Many agroforestry innovations, for example, tend to be complex, and many assumptions along their impact pathways may not hold true in practice.

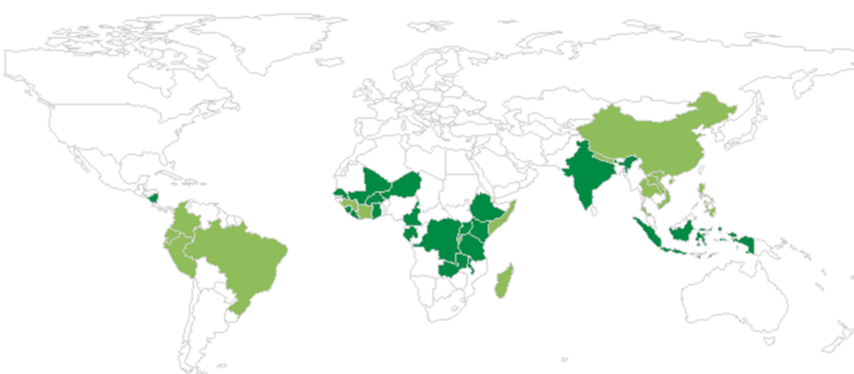

Figure 11. Summary of contribution of FTA research and engagement to Challenge 5: Rising demand and need for nutritious food for current and future generations

While the bulk of the numbers summarized in Figure 11 are associated with FTA's development-leaning projects that predominately focused on out-scaling agroforestry innovations that pre-date FTA, we identified two distinct research efforts directly related to Challenge 5: Food Tree and

Crop Portfolios (FTCPs) and the fourth cluster presented above focusing on the relationships between forests and the food security and nutrition of forest proximate communities. We specifically targeted the former for deeper investigation vis-à-vis: a) the extent to which there is traction among policymakers and developmental partners in taking this concept forward and promoting its out-scaling; and b) what the potential nutritional impacts could be if the FTCP concept was taken up and implemented at scale.

The deep dive investigation of the FTPC concept indicates that there is a high level of anticipation from donors and that the work has already led to important behavioural changes of people at partner organizations and national government offices. The potential impact of this work could be transformative. Our ex-ante simulation exercise reveals that iron and vitamin A deficiencies are significant and that these can be reduced through the successful scaling up of FTPCs. The potential health benefit gain could be 2.17M DALYs annually.

As noted above, considerable engagement with stakeholders took place to present findings related to FTA's work on the role of forests in promoting and sustaining food security and nutrition. However, other than the case of Ethiopia where research in the cluster informed recommendations for nutrient sensitive interventions, we did not find that this work has matured sufficiently to bring about the anticipated outcomes emanating from this engagement, as depicted in our retrospectively constructed ToC. For example, ideally, we would have liked to have seen evidence of land use policies and plans more overtly recognizing and promoting the inclusive food and nutrition provisioning role of forests, as well as conservation organizations and NGOs using this evidence to support their own work and advocacy.

That said, BRI was one of the most important contributors to wild meat research across the tropics and subtropics over the last decade, adding to the knowledge of species used, volumes hunted and traded, and drivers of use. This research helped confirm the importance of wild meat to millions of people, especially rural communities and Indigenous Peoples, and the integral and complex role of wild animals in the economies and ecologies of many countries across the globe. More importantly, BRI has been able to shift the global discourse on the importance of wild meat through strategic engagements at key national and global policy fora.

Clearly, forests, trees, and agroforestry have an important role to play in enabling the world to address one of the most pressing challenges of our times: the rapid rising demand and need for nutritious food for current and future generations. As illustrated above, and despite there being a less than ideal portfolio of evidence, FTA has made considerable headway in rising to this challenge. That said, our retrospectively constructed ToC has highlighted some key gaps and reflecting upon it to inform a strategy going forward is strongly encouraged.

We conclude with the following three lessons, which can be considered for building upon this body of work and enhancing its impact potential:

1. *Improving food security and nutrition outcomes through tree-based solutions has considerable potential but requires context-specific, inter-disciplinary, and iterative research and adaptive scaling with implementing partners, local communities, and other stakeholders*. This is already inherent to the FTCP concept but should also be embraced by other efforts to promote tree foods, as well as other complex agroforestry innovations such as fertilizer tree systems and fodder tree technology. Practical tools are needed for appraising local contexts to identify locally relevant food security issues, nutrition gaps (including drivers), and potential options to sustainably address these. This should not only consider the farm context but also the wider landscape, including local forests and other common pool resources. In many cases, options will be more likely adopted if there are financial incentives for pursuing them, thereby requiring that value chain considerations be addressed simultaneously. Finally, given that such work is inherently long-term and involving, it may be necessary, from a cost-effectiveness perspective, to pursue such approaches in the context of broader community development initiatives—including those designed to address one or more of the other four challenges referenced above—where the costs of long-term community engagement are already being catered for or, at least, can be shared.

2. *Given the inherent complexity of bolstering nutrition, carefully thinking through impact pathways and the assumptions that need to hold true for one step in the causal chain to proceed to the next is critical for informing research and intervention design*. From the impact pathways presented above, we have seen that improved household food security and nutrition does not automatically happen following the adoption of an innovation that could potentially contribute to the realization of such impacts. Other complementary changes and/or conditions need to be in place. The consumption of the right foods in the right quantities at the right times by those most in need (e.g., under five children) is key, for example, in improving nutritional outcomes. It is therefore critical to complement such interventions with nutrition-related behaviour change communication, capacity development, gender analysis, and research on cultural preferences, given that, as noted above, facilitating access to nutritious food alone does not necessarily translate into its appropriate and impactful consumption.

3. *Integrating ex-ante impact modelling approaches in research and scaling efforts vis-à-vis tree-based options for enhancing food security and nutrition is useful for both informing these efforts and estimating longer-term potential impacts.* A key role for research is to appraise the local context and work with communities, implementing partners, and other stakeholders to identify locally relevant and viable options for improving food security and nutrition outcomes. There are likely to be multiple options available. The potential impacts of such options (or option combinations) can be modelled vis-à-vis the key food security and nutrition gaps associated with the context, thereby helping to inform decisions on those likely to generate the most impact. Such modelling may also be useful in attracting investment,

particularly when comparisons are made with non-tree-based intervention options. Given that the full potential impacts of such efforts are unlikely to manifest within the timeframe of a donor-funded project cycle, such modelling efforts can be updated based on what participating households have put in place, thereby generating updated estimates of potential impacts. This, too, can be complemented with more conventional approaches for assessment food security and nutritional impacts where feasible.

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APPENDIX A: Cluster-Level TOCs

Cluster 1: Scaling the Production of Food Trees on Farms

Cluster 1 Narrative:

The TOC for this cluster is presented in Figure 12. This cluster of research projects focuses on the contribution of agroforestry and food trees for improving nutrition directly through increased availability and consumption of nutrient-rich foods. Indirectly, the work aims to achieve improved nutrition outcomes through diversification of livelihood opportunities for smallholder farmers in order to attain long-term benefits for families and communities.

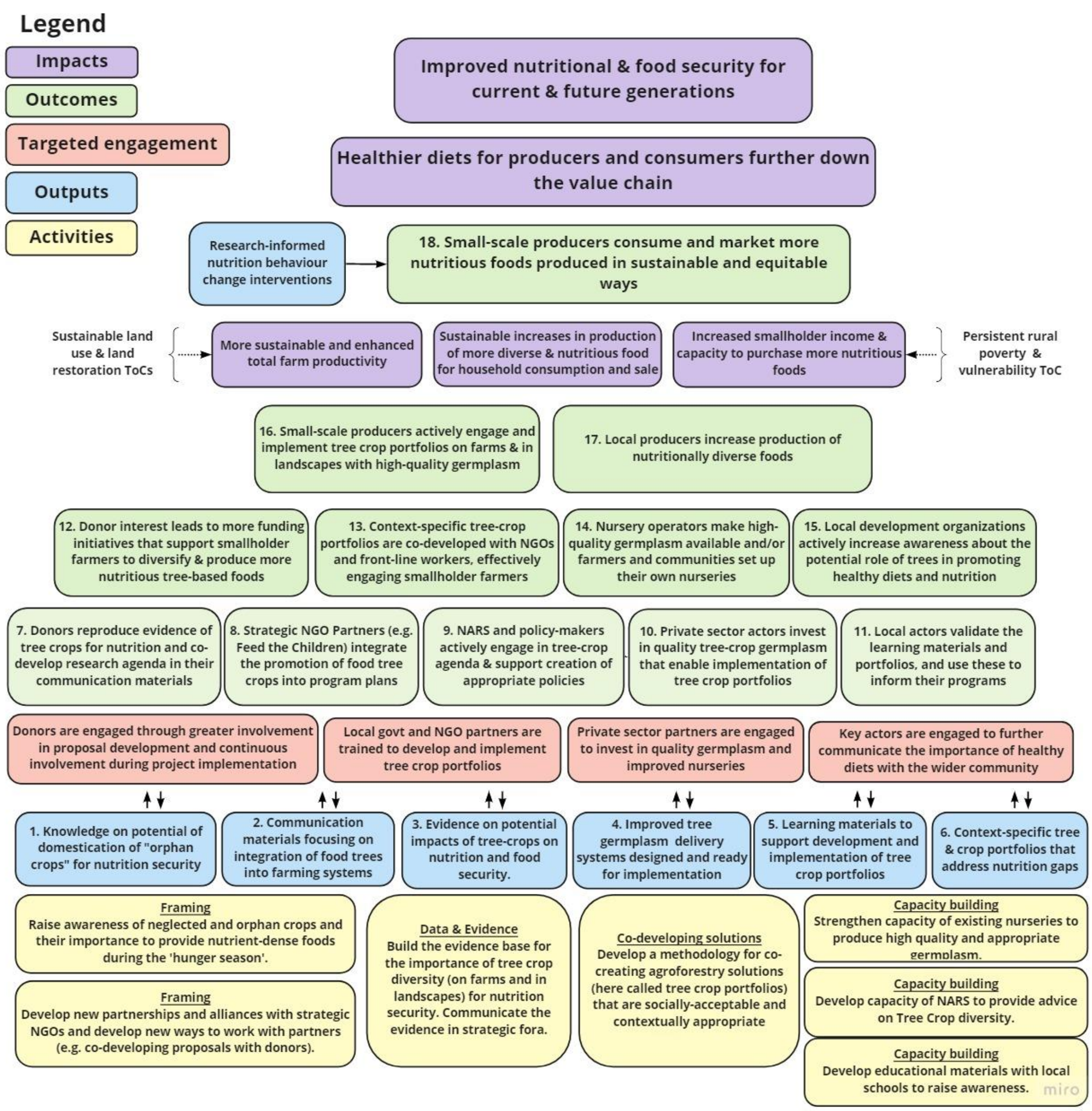

Figure 12. Sub-TOC for Challenge 5 cluster on scaling the production of food trees and crops on farms.

The approach relies on the identification of ecologically suitable and socio-economically relevant food tree and crop portfolios through in-debt consultation with communities combined with desktop analyses. Based on the co-created portfolios, projects make available the material, technical training and capacity to strengthen national partners' and smallholder farmers' engagement in integrating these portfolios into farming systems and restoring landscapes for increased food security and improved nutrition. Diet diversification is thus achieved by implementing climate smart agroforestry approaches and integrating food trees that provide nutrient-dense foods (fruits and nuts, seeds for protein and oils, leaves as vegetables etc.) into the existing mixed crop farming systems. In addition to nutrition security, this approach aims to contribute to landscape restoration by harnessing ecologically suitable food tree and crop portfolios in ways that enhance livelihood and landscape resilience while addressing food insecurity and improving nutrition.

Note that the different pathway arrows have been removed from the four Sub-TOC figures for sake of clarity. The online versions show these pathways correctly and are interactive. They are located at https://miro.com/app/board/o9J_km-ljg4=/?moveToWidget=3074457351846551697&cot=14.

Cluster 2: Integrating trees in cropping fields for sustainable staple food production.

Cluster 2 Narrative:

The TOC for this cluster is presented in Figure 13. This research cluster includes projects that demonstrate the potential contribution of agroforestry to food security and carbon sequestration under climate change in households practicing agroforestry. Specifically, communities of smallholder farmers are encouraged to adapt and target fertilizer, fruit, fodder and timber trees to appropriate niches where they can improve crop and livestock productivity and resilience to risks. Other site and farm-specific interventions include farm-level water and soil management; watershed restoration; agricultural commodity production and value chain and institutional development. These projects employ a unique approach to community-led local development planning, co-learning and integration of solutions from better soil and water conservation, climate-smart production, building local governance/capacity, stronger stakeholder engagement to create the necessary market linkages and policies.

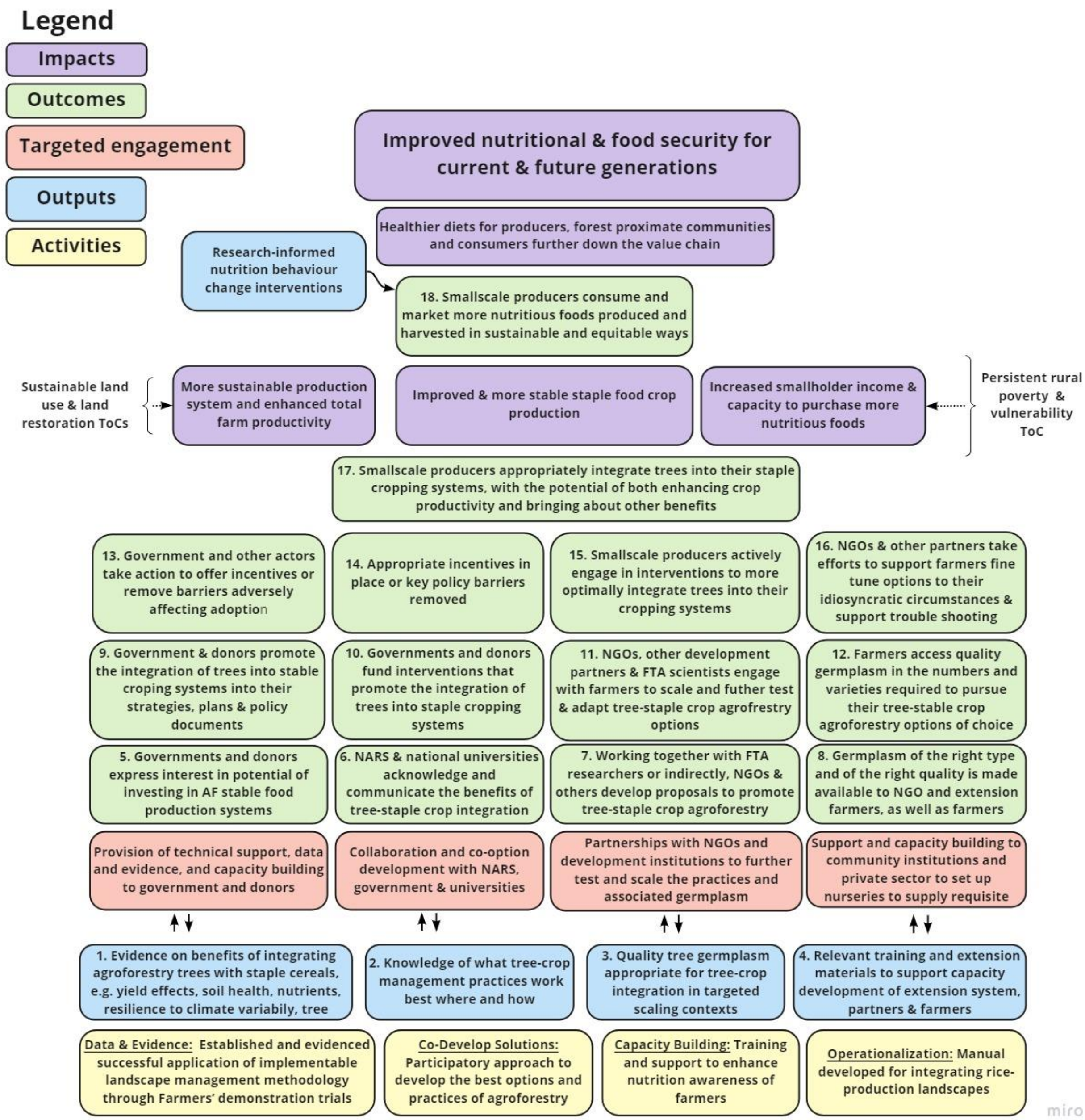

Figure 13. Sub-TOC for Challenge 5 cluster on integrating trees in cropping fields for sustainable staple food production.

Cluster 3: Improving smallholder dairy production through tree fodder

Cluster 3 Narrative:

The TOC for this cluster is presented in Figure 14. This body of work is designed to sustainably improve food security and increase income for smallholder farmers through greater access to a competitive, inclusive dairy industry. the goal is to develop improved market access in a wealth-

creating, robust dairy value chain. Projects that support this body of work develop evidence and guidelines to assist government agencies, international donors and NGOs to invest in scaling up value chain innovation platforms (VCIP)s in select regions. Insights on the role of market information delivery systems are researched ti improve VCIP effectiveness. Recommendations are developed to enhance policy instruments, regulations and investment incentives to support retail linkages with smallholders, especially women and the younger generation of farmers. Communication and outreach programs are developed to enhance coordination and policy engagement with VCIPs. Lastly, the project enhanced capacity of partners in developing institutional arrangements, market access and development of effective VCIPs.

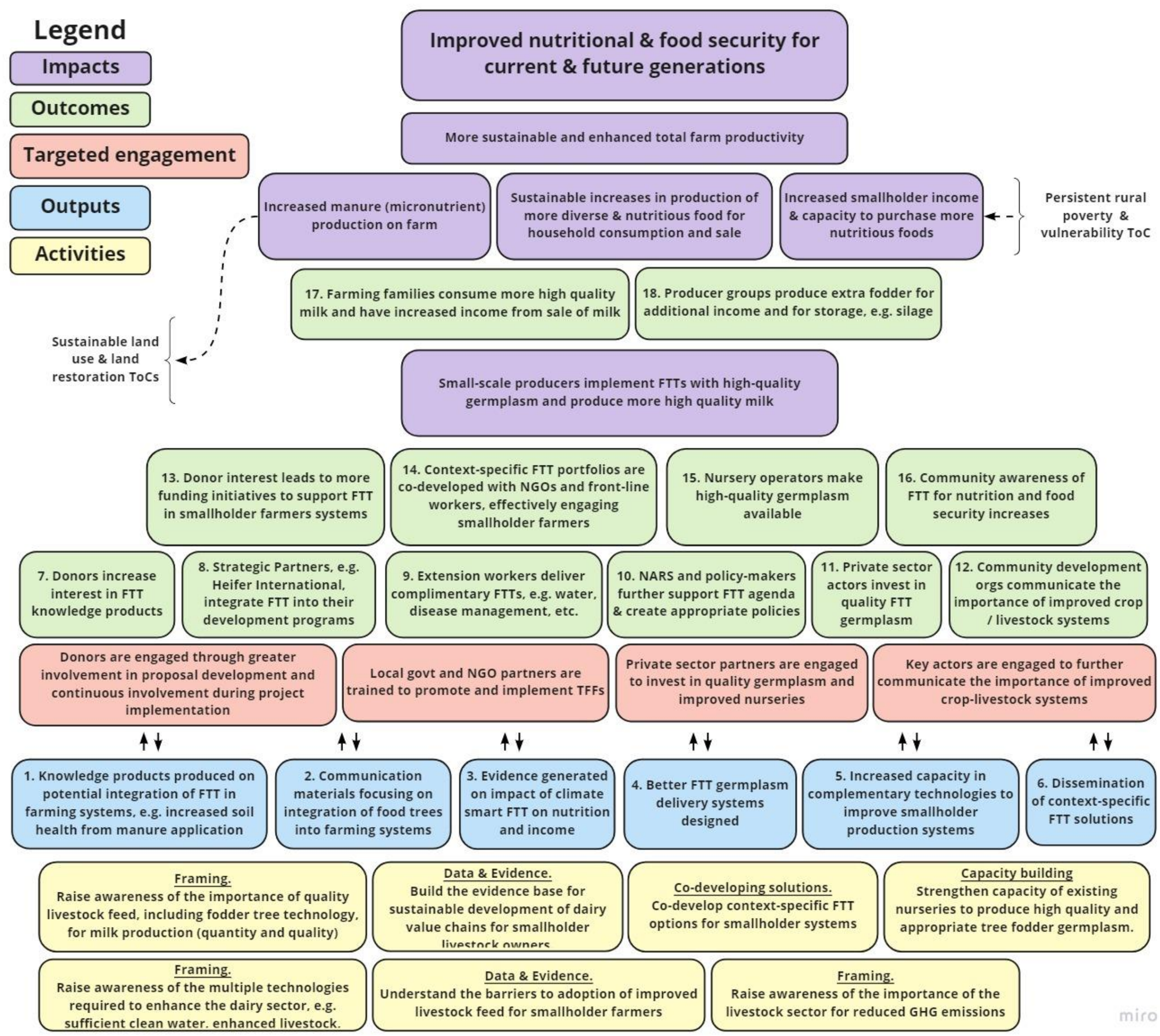

Figure 14. Sub-TOC for Challenge 5 cluster on improving smallholder dairy production through tree fodder.

Cluster 4: Understanding the relationship between forest resources and the food security and nutritional status of forest proximate communities

Cluster 4 Narrative:

The TOC for this cluster is presented in Figure 15. FTA researchers have undertaken primary research to evidence the contribution of forests to meeting the food and nutritional requirements of forest proximate communities at the global level (Rowland et al., 2017), as well as in Indonesia (Ickowitz et al., 2016; Purwestri et al., 2019), Cameroon, the DRC, Ethiopia (Baudron et al., 2017), and Zambia. This includes the administration of household surveys.

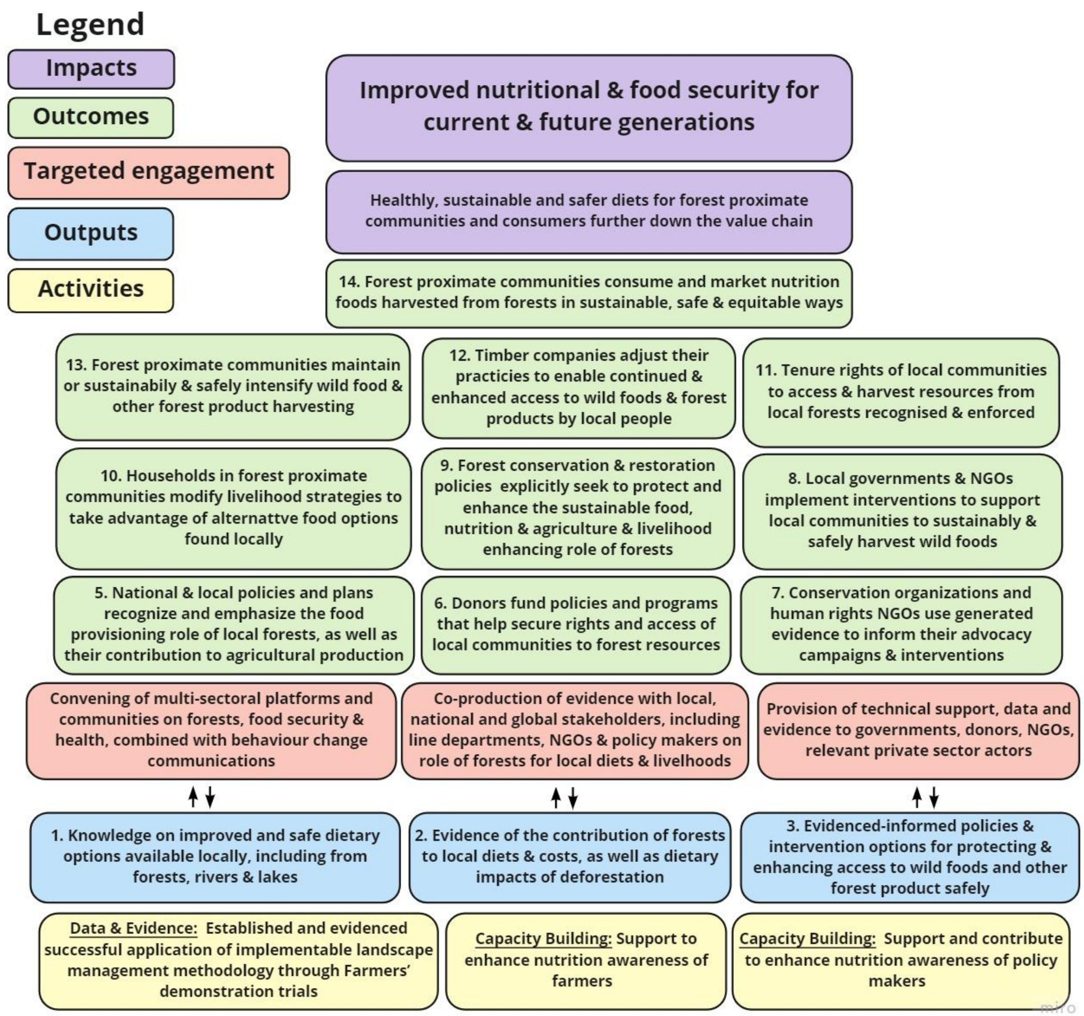

Figure 15. Sub-TOC for Challenge 5 cluster on understanding the relationship between forest resources and the food security and nutritional status of forest proximate communities.

Key findings have been disseminated and shared through multi-stakeholder platforms and focus group discussions, with the aim of raising awareness among policymakers and other relevant

stakeholders on the contribution of forests to local diets. In Indonesia, for example, recommendations were co-developed with local communities, informed by evidenced food consumption patterns among traditional and oil palm households. In Ethiopia, Uganda, and Burkina Faso, a total of 1,750 stakeholders participated in such platforms, complemented with approximately 200 focus group discussions with communities where data were presented for participatory validation and further qualitative interrogation. At the global level, FTA has sought to raise awareness of and provide policy options for enhancing the food and nutrition provisioning function of forests by providing inputs to (a) the International Union of Forest Research Organization's (IUFRO) Global Forest Expert Panel (GFEP) process; (b) the International Conference on Forests for Food Security and Nutrition; and (c) the high level of panel of the CFS.

APPENDIX B: Project Objectives and Impact Pathway Evidence

Evidence Collected for Cluster Impact Pathways

Reading the tables. The "box" numbers in the tables (Tables 10, 11, 12 and 13) below correspond to the numbers in the Sub-TOC boxes in Appendix A. This allows the reader to follow the chain of evidence through each impact pathway for a research cluster. The chronology of evidence recorded in the tables follows the order of listed projects. For example, Cluster 1 comprises four projects and each row in the Cluster 1 table of evidence has four paragraphs, matching the project in the list. If no evidence was found in the project documents to support a specific box in the ToC, the row says "No evidence" for that project. Each row thus has four paragraphs or "no evidence" statements for Cluster 1. Lastly, where subsequent projects have no evidence reported, spaces between lines are removed to improve readability.

Cluster 1 Projects - Scaling the Production of Food Trees on Farms

1. Agrobiodiversity and Landscape Restoration for Food Security and Nutrition in East Africa
2. Food Trees for Diversified Diets, Improved Nutrition, and better Livelihoods for Smallholders in East Africa
3. Fruiting Africa: Tree Crops Development in Africa to Benefit the Poor
4. Machakos Fruit Tree Development Project

Combined Project Objectives:

This project focused on the contribution of agroforestry and food trees for improving nutrition directly through increased availability and consumption of nutrient-rich foods. A secondary objective was to contribute to landscape restoration by harnessing the ecological benefits of suitable food tree and crop portfolios in ways that enhance livelihood and landscape resilience. These projects identified ecologically suitable and socio-economically relevant food tree and crop portfolios and make available the material, technical training and capacity to strengthen national partners' and smallholder farmers' engagement in integrating these portfolios into farming systems and restoring landscapes for increased food security and improved nutrition. Specifically, nutrition improvement comes through diversification of livelihood opportunities for smallholder farmers to attain long-term benefits for communities. Diet diversification is achieved by implementing climate smart agroforestry approaches and integrating food trees that provide nutrient-dense foods (fruits and nuts, seeds for protein and oils, leaves as vegetables etc.) into the existing mixed crop farming systems.

Over 16,000 people were engaged, of which 8,500 smallholder farmers were engaged in project activities from data generation, participatory action research, knowledge exchange events, cross-site learning visits, and targeted training on cultivation of prioritised food tree and crop species

and varieties, establishment of multiplication gardens (for crop species), and nurseries (for food tree species).

Table 10. Project-level evidence supporting the Cluster 1 Sub-TOC.

Box	links to Box …	Collected evidence from project reports
1	7	This project produced multiple International Public Goods (IPGs), including training materials, scientific publications, databases and datasets. Technical materials included two articles, one book chapter, one working paper, one background paper, and one manual were developed relevant to the context of the project, and the approaches used, including portfolio development, the use of agricultural biodiversity, and the importance of under-utilised (orphan) crops for addressing food and nutrition, and supporting climate-smart agriculture. Completed suitability maps for 7 priority species developed, 3 indigenous fruit tree species (Adansonia digitata, Tamarindus indica, Balanites aegyptiaca) and 4 exotic fruit trees species (Carica papaya, Mangifera indica, Moringa oleifera and Persea Americana) covering Ethiopia and Uganda under multiple climate scenarios. Farmer-researcher managed evaluations on pest and diseases completed for Durum wheat in Ethiopia, and for groundnuts, cassava and food trees in Uganda. Knowledge products focus on quantification of the contribution of trees for providing fruits (globally), and on the nutritional value of tree foods - specifically indigenous/ underutilised tree species compared to other food crops. The project produced five journal articles, three book chapters, one working paper. Learning materials were produced on portfolio development and importance of biodiversity and underutilised (orphan) crops for addressing food and nutrition, and supporting climate-smart agriculture. The project has a further three publications (two book chapters and one journal article in preparation), one journal article (under review), and two InfoBriefs are currently being finalized. Four data generation tools developed. Tool 1: farm diversity survey – food production, Tool 2: food consumption and nutrition survey, Tool 3: Priority setting for species selection, and Tool 4: validation FGDs. The project produced 59 publications of various types, and two value studies were completed. Project publications are available from the project website No evidence
2	8	Communication materials were developed for sensitisation of the communities. Over 10 diverse sets of communication materials including Calendars, posters, flyers etc. developed and disseminated during the National Agricultural show and farmer field days (Uganda and Ethiopia). Over 6,000 individual print materials (info-sheets, booklets/ guidelines, banners etc.) were produced and distributed during the project lifecycle to communicate projects objectives, achievements and partnerships. These communication tools were used to create awareness on the importance of integrating a diversity of nutrient-dense food tree and crop species and varieties into existing farming systems to contribute to year-round food and nutrition security, resilience of farming systems and ensuring productive landscape restoration through improved soil cover and microclimate, among other benefits. Two radio programmes broadcast by Buruuli and Musana FM in Uganda. Listenership for Musana FM covered Nakaseke district, Luweero, parts of Wakiso and Kiboga districts, while Buuruli FM covered Nakasongola district, Luweero, parts of Masindi, Kiryandongo and Nakaseke districts. The project worked directly with eight different partners: national research partners, academic and training institutes, local NGO's and CBO's, and local authority and government offices). Partners were engaged based on their operating procedures for participating in research for development activities, and for accessing and interacting with the communities. Other partners included: National Forestry Resources Research Institute (NaFoRRI), National Agricultural Research Organization (NARO),

		Uganda Bukalasa Agricultural College (BAC), Uganda Our Lady of Lourdes, Catholic Parish, Nakasongola, Uganda, Ethiopian Biodiversity Institute (EBI), Ethiopian Institute of Agricultural Research (EIAR) and Mekelle University, Ethiopia. Bioveristy International was the co-lead ICRAF. Information, Education and Communication (IEC) tools were developed that focus on customised portfolios. IEC tools developed include training/promotional videos (English and Swahili versions), presentations made at international events, and blogs/ media pieces. The project reached schoolchildren and community members through the Healthy Learning Programme (HLP). In addition, the project collaborated with popular TV program Shamba Shape Up (TV programme) which has a potential (national) viewer audience of 3,782,000. Project developed a training video. The nursery establishment and management "Do It Yourself" video is 26 minutes long.
3	9	The project developed On-Farm Demonstration Plots and On-Station Demonstration Plots. On-Farm: Two hundred and ninety-seven (297) full and partial food tree and crop species portfolio demonstration plots have been established across the sites in Uganda and Ethiopia. Crops - 160 demonstration plots were established in Nakaseke (n=99) and Nakasongola (n=61). Food tree species – 137 food tree portfolios (full or partial) were established on individual farms in Uganda (n=38) and Ethiopia (n=99) project sites. On-Station: For food tree species, four main on-station demonstration plots were established, two in each country (Nakaseke and Nakasongola in Uganda, and Ziway and Meki in Ethiopia. Additionally, two community seedbanks for common bean, groundnut and cassava were established, as well as a central demonstration garden (Nakaseke) in Uganda. Evidence is partially generated through establishment of Agroforestry and Nursery Innovation Hubs and On-farm demonstration plots. Priority species were identified through the participatory community priority setting FGDs and feature in the African Orphan Crop Consortium (AOCC http://africanorphancrops.org/) list which comprises of prioritized crops by African countries. No evidence No evidence
4	14	29 nursery operators participated in stakeholder workshops for the development of the nursery certification guideline which involved multiple Ministries. 47 nursery operators received training on nursery management and operation (Uganda and Ethiopia). Genetic resources were made available in the project sites. Crop Seed varieties: 35 varieties of common bean, 24 varieties of groundnut, 17 varieties of cassava and three vegetables species were made available to beneficiary farmers, through national partners. Food Tree Seedlings species + varieties: 8 species and 15 varieties. Seed and Seedling Distribution are established and tested. The project also supported the transfer of improved species and varieties to Ethiopia and Uganda for similar on-station, and on-farm trials (See Section IV IPGs). KALRO further supported project activities through the propagation and multiplication of species for distribution to project farmers and nurseries. Seven species (11 varieties) were multiplied resulting in over 1,200 seedlings: Musa spp., Guajava psidium (TSG 2), Citrus sinensis (Washington navel, Caracara navel), Citrus limon - lemon (Lisbon, Genoa), Citrus Limon - mandarin (Tambor, Empress), Citrus Limon – grapefruit (Marsh, Star Ruby), Citrus limon – lime (Bears lime, Thai lime). Rural Resource Centers (RRCs) are proven to be effective in making germplasm available while serving as community training centers. The project established four RRCs, 14 satellite nurseries, and two motherblocks of improved varieties of selected fruit species.

		The support to the nurseries (both project established and expanded) included fencing, supply of basic nursery management tools and supplies such as potting papers, wheelbarrows, watering cans and irrigation horse pipes.
5	11	Technical materials consisted of the location specific customised portfolios with the calendar of prioritized food tree and crop species, along with nutritional information, and food production and consumption indicators representative of the communities. Two Technical booklets developed, one Grafting and one tree planting manual translated into Amharic, with pictorials and distributed to farmers (Ethiopia). Four customised Portfolio Info-Sheets developed for each of the sites. Six research tools developed for data collection (three surveys - farm diversity and socio-economic, and food consumption and nutrition, Rapid Market Survey, two FGDs schedules, farm mapping tool). One sampling strategy guideline developed. Three diversity fairs were organized in Uganda (with over 4000 participants). In addition, four farmer exchange visits organized in Uganda and Ethiopia. Quality Declared Seed Guideline developed and validated with 53 multi-stakeholder participants in an expert meeting. Learning materials were produced: a characterization of the local food systems in the project sites looking at short and long food chains, and engage smallholder farmers in the co-development of recommendations that are ecologically suitable, and that responded to the needs of the communities for seasonal food availability, nutrition, and priority food tree and crops species for income generation. Capacity building includes: Trainings on tree planting and management, nursery trainings, nutritional education training, trainings on nutritious food portfolios, and trainings on enterprise development. One guidebook for developing fruit tree portfolios was published. Capacity building and skill endowment among fruit producers: 4 trainings benefitting 40 (20 Female and 20 Male) trainees
6	11	Customized portfolios were developed based on data collected from households through surveys and FGDs. In total, 609 households were surveyed for socio-economic and farm diversity assessment (included tree and crop survey). An additional 304 households were surveyed for food consumption and diets for a total of 607 respondents (women and children prioritized as most vulnerable). In addition, 26 FGDs with 360 participants (180 men, 180 women) were completed. Over 2,000 (1,119 women, 985 men) involved in targeted, intensive training on portfolios, tree cultivation and management, nurseries, multiplication gardens, community seed banks. A further 604 participants visited the project information stand during the national agricultural show organized at Jinja in Uganda. Nine site-specific tree crop portfolios were completed (eight in Kenya and one in Uganda). The portfolios were customized based on evidence generated from the following: four site specific need assessments, four data generation tools developed and deployed to 613 smallholder farming households (Tool 1 farm diversity survey – food production), 1,184 women and children (Tool 2 food consumption and nutrition survey – on-farm, and off-farm – access to markets), 52 FGDs completed (Tool 3 Priority setting for species selection). Thirty validation FGDs (Tool 4) completed with 311 smallholder farmers, 152 women – age disaggregated 70 older, and 82 younger participants, and 159 men – age disaggregated, 83 older and 76 younger participants. Three site specific tree crop portfolios were established in Kenya (Machakos, Kakamega and Siaya). No evidence
7	12, 13	No evidence No evidence No evidence

		No evidence
8	13	No evidence Feed the Children piloted an integrated agroforestry and nutrition programme in three schools in Kenya, two in Machakos County and one in Laikipia County Shamba Shapeup promoted the tree crop portfolio approach on their regular programming. No evidence
9	10, 13, 14	No evidence NARS stakeholders engaged include: Ministry of Agriculture, Ministry of Health, and Ministry of Education. This collaboration has been unique in the delivery of the programme for bringing together and demonstrating the link between agriculture and nutrition to the wider community, using schools/education platforms as an effective community entry point. KALRO responsible for propagation and multiplication of prioritized 15 varieties of 15 food tree species. The motherblock established (at Thika, the HRI HQ) now provides an important genetic resource base for future material distribution. No evidence No evidence
10	14	Two private nurseries in Ethiopia (Ziway and Meki) have been established and upgraded for the supply of quality planting materials. No evidence 20 female group representatives were trained in micro-processing. An additional 20 farmers were trained in business development. No evidence
11	15	Four customized portfolios completed, one for each site. Validation of these portfolios was done by over 700 participants (farmers, national partners, extension actors) in Uganda; In Ethiopia, the validation exercise involved nine government and woreda extension officers, and nearly 200 community members. Feed the Children piloted an integrated agroforestry and nutrition programme in three schools in Kenya, two in Machakos County and one in Laikipia County 2,360 farmers were reached through Training of Trainers 165 Group representatives trained on nutrition, healthy foods and diets. No evidence
12	16	IFAD-1187 (see below) was funded based on the success of this project (IFAD-1200). No evidence No evidence No evidence
13	16	Four customized portfolios completed, one for each site. Nine site-specific tree crop portfolios were completed (eight in Kenya and one in Uganda). Three site specific tree crop portfolios were implemented. No evidence

14	16, 17	Four mother blocks for improved planting materials were established. Six community nurseries were upgraded, two in Ethiopia and four in Uganda. Seedling distribution systems delivered over 10,000 seedlings of 15 prioritized food tree species were distributed during the project. The following numbers were distributed for each species: Carica papaya (900), Casimoroa edulis (450), Citrus limon (920), Citrus sinensis (970), Macadamia integrifolia (100), Mangifera indica (1150), Balanites aegytiaca (100), Passiflora endulis/ flavicapa (450), Persea Americana (1365), Psidium guajava (1360), Syzygium cuminii (400), Solanum betacea (220), Tamarindus indica (405), Annona reticulata (520), Erybotyra japonica (80), Moringa oleifera (515). No evidence Thirty six (36) farmers and nursery operators (15 Male and 21 Female) were trained on value chain analysis and development, record keeping, business financing and financial management alongside development and actualization of agro-business plans. Establishment and /or expansion of 11 tree nursery hosting a total of 195,274 fruit tree seedlings and 92,945 non fruit tree seedlings
15	17	No evidence The project supported the establishment of two agroforestry innovation hubs to serve as convergence points for trainings and distribution of materials (planting and communication), and upgraded six community nurseries to ensure availability and access to increased diversity of quality food tree seedlings and associated technical knowledge on tree planting and management, and nursery establishment and management. No evidence No evidence
16	18	Food tree species index increased in Ethiopia from 3.7 to 4.9 Food tree species index decreased in Uganda from 7 to 5 A total of 453 demonstration plots were established with at least 10,005 individual food tree seedlings (16 species) distributed to farmers using a phased approach to ensure the best chance for seedling survival. No evidence No evidence
17	18	Households experiencing food insecurity in Ethiopia decreased from 34 to 18%. Households experiencing food insecurity in Uganda increased from 52 to 70. No evidence No evidence No evidence
18	n/a	Household Dietary Diversity in Uganda increased from 6.7 to 6.9. Household Dietary Diversity in Ethiopia decreased from 6.6 to 6.3 No evidence No evidence No evidence

Cluster 2 Projects - Integrating trees in cropping fields for sustainable staple food production

1. Agroforestry Food Security Programme - Phases I & II

2. A Regional Programme in the Sahel and Horn of Africa, enhancing Food and Water Security for Rural Economic Development (DRYDEV)
3. Enabling Small Holders in Odisha to Produce and Consume More Nutritious Food through Agroforestry Systems
4. Trees for Food Security - Phase II: Developing Integrated Options and Accelerating Scaling up of Agroforestry for Improved Food Security and Resilient Livelihoods In Eastern Africa

Combined Project Objectives

These projects aimed to demonstrate the potential contribution of agroforestry to food security and carbon sequestration under climate change in households practicing agroforestry. Specifically, communities of smallholder farmers were encouraged to adapt and target fertilizer, fruit, fodder and timber trees to appropriate niches where they can improve crop and livestock productivity and resilience to risks. Other activities include site and farm-specific interventions, such as farm-level water and soil management; watershed restoration; agricultural commodity production and value chain and institutional development. Specifically to DRYDEV, the project's unique approach encompasses community-led local development planning, co-learning and integration of solutions from better soil and water conservation, climate-smart production, building local governance/capacity, stronger stakeholder engagement to create the necessary market linkages and policies. These projects generally also used the "Option by Context" approach which was developed by ICRAF researchers, as well as farmer-led participatory approaches to cater to specific needs of local communities.

These projects aimed to improve local and national tree germplasm supply and delivery systems to enable farmers to access high quality tree seed and seedlings in a timely manner. This includes strengthening capacity of national and local institutions, NGOs and CBOs in scaling up agroforestry to achieve Evergreen and climate-smart agriculture. These projects aimed to reach over 500,000 people and benefit nearly 2,000,000 people in smallholder farming communities.

Table 11. Project-level evidence supporting the Cluster 2 Sub-TOC.

Box	links to Box …	Collected evidence from project reports
1	5	The project developed evidence that was aligned with several government and donor initiatives, including: Malawi Growth and Development Strategy (MGDS) II; Agriculture Sector Wide Approach Programme (ASWAP); and Irish Aid strategy in Malawi. DryDev had a consistent communications strategy as time and resources were dedicated to thoroughly document and promote to a large audience, the learnings of what worked, what did not work during the numerous co-learning processes in each site, as well as at the country and overall programme coordination levels. In Kenya, farm pond technology emerged as a game changer in terms of improving production, income and livelihoods. The preferred pond size in semi-arid lands was 250 m3 which costs about US$3,000. Kenyan farmers from Makueni, Machakos and Kitui counties demonstrated they could pay back such ponds in less than two years.

		A total of 26 nutri-gardens were introduced and evidenced the provision and access of year-round nutritious food. Enhanced water infiltration for 90,000 sapling plants. A cover crop (grasspea), a biofortified short legumes for capturing rice fallows, was established on 400 acres. An AgriVoltaic System (AVS) was installed in 3 villages. No evidence
2	5, 6	Capacity and skills of extension staff and farmers strengthened, and agroforestry widely practiced. Guidelines for the development of a coherent agroforestry policy established. The programme supported smallholder farmers to pursue contextually appropriate options that were their priorities, informed by the realities of the local context whilst integrating local and expert knowledge (Options by Context approach). The choice of technology, farming practice or other development intervention like the creation of market and financial linkages and governance or institutional arrangements in each site was guided by seven scaling principles (Box 1): co-learning, context-specific both in terms of location and type of farmers targeted, cost-effectiveness and scalability, inclusiveness, low environmental and social impact, climate-smartness and sustainability. A total of 219,694 farmers were reached (participated in training and applied new technologies or farming practices), as follows: Burkina Faso: 41,772; Ethiopia: 43,922; Kenya: 35,363; Mali: 46,437; Niger: 52,200, 35 Training of Trainers were delivered in integrated crop management and seed production in Paddy. 284 village level trainings were provided in package and practices of paddy and fruit crops. 10 publications (Working paper, country reports, peer review publications, policy briefs). One (1) decision support tool to select investment options.
3	7	Options for quality tree seed and seedling supply appropriate to different circumstances developed and quality tree germplasm made available to suppliers. No evidence Introduction of biofortified varieties; 50MT of paddy seed procured for distribution. Distributed to 1,782 selected farmers, two of its improved rice varieties rich in protein and zinc. 5 MT of pulses seed procured for distribution. Introduced high yield lower toxic varieties. More than 47,000 horticultural plants procured for distribution. These are short legumes in rabi season to capture fallow. 2,000 timber plants seedings supplied. Improved rice varieties: Protein contains increased from 5-6% to 10%. 38 Nursery established under training and regular guide (2 for QPM + 36 small nurseries) More than 5,400 farmers enabled to plant backyard gardens No evidence
4	7, 8	2,962 farmers were trained in fruit tree and nursery management technologies, and fodder management. Guidelines for the Voluntary Germplasm Certification were developed for private nursery operators by the department of seed certification at department of research and technical services A total of 4,625,878 trees planted in the project countries (Burkina Faso: 328,332; Ethiopia: 3,320,895; Kenya: 164,658; Mali: 182,211; Niger: 629,782) Training of trainers: total trainers trained: 1,618; total farmers trained: 18,542. 360 trainings at village level. Enabled convenient access to agroforestry information for knowledge poor extension workers; Mobile based monitoring & App developed and applied which resulted in geotagging of more than 80% plants, crops.

		Network of farmer trials established: 3,500. One database developed (crop productivity, tree products and services under different agroforestry practices from the farmers trials). 5,000 Households implementing water management technologies. 50,000 Households implementing agroforestry practices. 83,00 ha of land was impacted. There was a food security impact on 222,000 people. 1,500 Women and youth farmers trained. 5,000 Tertiary students trained in agroforestry courses (ONGOING). Improved business skills of traders (30% women): 200 direct and 5,000 indirect.
5	9	Irish Aid adopted the project's practices. In Mali, the success of the DryDev approach has inspired the World Bank to design a project titled 'Mali Drylands Development Project' (PDAZAM). DryDev organized a side-event entitled during the 2019 World Water Week in Stockholm called 'From Success to Scale: Improving rainfed agriculture in Africa'. The lessons were used to shape the Transforming Investments in African Rainfed Agriculture (TIARA) initiative being developed by Stockholm International Water Institute (SIWI) and partners. Dubar India (private sector) expressed interest in integrating medicinal tress in the project, with provision of training and improved planting materials, and promising output marketing strategy. No evidence
6	5	At least 100 extension staff use improved methods to match tree options to sites and farmer situations. No evidence No evidence No evidence
7	11	Research services generate and share information on what tree options work best in different circumstances. No evidence No evidence No evidence
8	12	Tree germplasm suppliers produce quality tree seeds and seedlings for farmers. Amount of germplasm of fertilizer trees supplied: 30,408 kg. Amount of germplasm of fuelwood trees supplied: 958 kg. Amount of germplasm of fodder trees supplied: 382 kg. Nursery operators implement the Guidelines for the Voluntary Germplasm Certification. No evidence No evidence No evidence
9	10, 13	Policy makers formulate and implement appropriate policies to mainstream agroforestry nationally. Project staff worked with the district councils to formulate district by-laws to curb bushfires and reduce livestock damage to the Agroforestry trees. Project lobbied for inclusion of Agroforestry seed germplasm in the draft Seed Act In Ethiopia, most of DryDev's integrated approach of the eight WPs are well aligned to Ethiopian national and regional governments' key policies and strategies. This alignment has helped with resource leveraging (i.e. technical, financial & material) and created strong coordination with key government sectors. No evidence No evidence
10	7, 11	No evidence

		County governments in Kenya use DryDev trainers of trainers (ToTs) to provide extension services to farmers engaged in projects in Kitui, Machakos and Makueni counties. The Kenya government, through the Kenya Irrigation Act of 2019, a water harvesting authority was established to oversee future efforts aimed at increasing water storage per capita in the country. In March 2019, the Government committed to construct 125,000 ponds by 2022, which is part of support to the irrigation authority, which already plans to excavate farm ponds across Kenya. No evidence No evidence
11	8, 15	No evidence No evidence No evidence No evidence
12	15	No evidence No evidence No evidence No evidence
13	14	No evidence No evidence No evidence No evidence
14	15, 17	No evidence A total of 16,481.68 ha of land was put under irrigation for greater crop intensity and yields: Ethiopia: 70%; Burkina Faso, Kenya: 13%. No evidence No evidence
15	17	No evidence A total of 122,850 ha of land was rehabilitated: Ethiopia: 50,711 ha; Kenya: 13,472 ha; Niger: 50,917 ha. 90,058ha of farmland was put under improved soil and water conservation practices. Climate smart production options were applied to 52,994 ha. No evidence No evidence
16	8, 15, 17	No evidence No evidence No evidence No evidence
17	18	42.1% of respondents reported that their staple food lasted between 7 and 9 months after harvest compared to a baseline figure of 28.8% for the same period (n=450; 150 households in each district). 79.6% of households perceived that food production was better over LOP compared to the baseline. 79.6% of households perceived improved food production compared to year 1 of project. Income increased by 95% from US$76 to US$147. Change in average milk yield per cow per day increased from 8 to 10.6 litres. Additional income from mangoes was MK 4850.34 (750 Malawian Kwacha = 1 USD). Unexpected benefit: Carbon sequestered from Gliricidia-Maize systems was 38,990 tonnes in Mzimba, 36,016 tonnes in Dedza, and 63,142 tonnes in Thyolo. Carbon mitigated from Tephrosia-maize systems was 131,594 tonnes in Mzimba, 48,588 tonnes in Dedza, and 48,310 tonnes in Thyolo. Increase of 1% for men and 15% for women in the households (HH) consuming 5 or more of the Minimum Dietary Diversity food groups. Increase of 3% of households scoring

		positively on 2/3 of weighed indicators of the Resilience index. Farmers are now adopting high yielding dairy cows and there is renewed interest in animal fattening as a business. Milk production per cow increased from 2.5 L/day to 7 L/day. No evidence No evidence
18	n/a	No evidence No evidence No evidence No evidence

Cluster 3 Projects - Improving smallholder dairy production through tree fodder

1. East Africa Dairy Development (EADD) - Phase II
2. Developing Value Chain Innovation Platforms (DVCIP) to Improve Food Security in East and Southern Africa

These projects employed multiple strategies simultaneously. The EADD project, for example, was designed to sustainably improve food security and increase income for 216,000 smallholder farmers through greater access to a competitive, inclusive dairy industry. Based on Heifer's multiplier of 5.36 people affected indirectly for every person affected directly, it means that EADD had a goal to reach 1.22 million people directly and indirectly. The project was implemented in Uganda, Kenya, Tanzania and Ethiopia. The vision of success for EADD is to transform the lives of resource-poor farming families through improved market access in a wealth-creating, robust dairy value chains. The project aimed to reach smallholder farmers: 43,000 in Uganda, 58,000 in Kenya, 50,000 in Tanzania, 65,000 in Ethiopia.

The DVCIP project aimed to develop evidence and guidelines to assist government agencies, international donors, and NGOs to invest in scaling up value chain innovation platforms (VCIP)s. The goal was to provide insights on the role that market information delivery systems play in promoting more effective VCIPs. Recommendations were developed to enhance policy instruments, regulations and investment incentives to support retail linkages with smallholders, especially women and the younger generation of farmers. Communication and outreach programs were developed to enhance coordination and policy engagement with VCIPs. Lastly, the project enhanced capacity of partners in developing institutional arrangements, market access and development of effective VCIPs. The target reach was 5,000 farmers.

Combined, these projects aimed to increase income and improve food security for smallholders as follows: more profitable women producers, traders, processors and retailers; improved productivity and quality products; more efficient and competitive value chains; more jobs for rural landless wage earners from expanding local rural enterprises; higher daily wages for rural workers; more diversified income sources for small producer households; and more spending in local communities, increasing the non-farm rural economy. The expected social impacts are:_more women and rural households lifted out of poverty; less outward migration from rural zones; new

management and organizational skills for IP participants; more disposable income for spending on children's education. The expected environmental impacts are: improved watershed management enabled by more profitable farming; stronger agroforestry related environmental benefits; improved soil nutrient and erosion outcomes linked to requirements of higher value products; and improved on farm management practices gained through farmer networking.

Table 12. Project-level evidence supporting the Cluster 3 Sub-TOC.

Box	links to Box …	Collected evidence from project reports
1	7	The specific technology supported by FTA are Fodder Trees that are designed to work alongside other technologies. One supporting technology is a dairy hub for bulking milk at one central location, to access markets and/or access training and services (such as veterinary supplies, breeding supplies and nutrition supplements for their cattle). Six value chains analyzed in total. Dairy and coffee value chains developed in Uganda, and village chicken value chain developed in Zambia. While some value chains are not specifically focusing on dairy, they are considered income generating and thus will contribute to household income and food security. Two publications focusing on strategies for empowering women in selected value chains (Odoul et al and Kimaiyo et al)
2	8	No evidence Project produced: Evidence updates & briefs, options for enhanced policy instruments, online videos & blogs, Newspaper reports, Televised news coverage, and Publications. Stakeholder network mapping identified key stakeholders for targeted communication. ICRAF, NaFORRI, Makerere University and University of Adelaide developed partnership arrangements with NUCAFE, National Coffee Resources Research Institute (NaCORRI), and Uganda Coffee Development Authority (UCDA) for continuation and expansion of the specialty coffee initiative in Uganda.
3	9, 10	Four technologies were identified namely water recharging valley tanks, rainwater recharging dam-lined tanks with and without roofs and shallow wells (shadoofs). The project subsidized the installation of all four types of facilities, paying for 35% of the installation costs of unroofed dam-lined tanks, 45% of the cost of the roofed dam-lined tanks, 50% of the cost of shallow wells and 85% of the cost of the valley tanks. As a result of this initiative, 53 valley tanks (38 in SW & 15 in NE) with capacity of each to hold 1,500 cubic meters, 35 rainwater recharging dam-line tanks (all in SW) with capacity to hold 40 cubic meters each, 63 shallow wells (all in NE) have been constructed. A total of 906 farmers are benefitting directly. However, these initiatives are expected to benefit more than 20,000 farmers across the two clusters. Several outputs: systematic review of approaches to value chain IP development in Africa. Analysis of variables for cross sites institutional analysis. Spatial correlation in household choices across levels of aggregation analyzed and maps produced. Report on social networks. Drivers of institutional strengthening identified and characterized, and rural institutional capacity needs identified and development strategies defined. Training manual developed on picking of quality coffee beans. Recorded voice calls (robocalls) to 450 selected households to remind farmers to pick quality coffee beans. Capacity building of students: Four (4) PhD and eight (8) MSc students were supported by this project.
4	11	No evidence No evidence
5	12	Complementary technologies that support FTT varied widely. In Uganda, 2,189 farmers were trained to make silage. Across all sites, 133,938 farmers utilized crop residues. 53 rainwater recharging valley tanks, each with a storage capacity of over 1.5 million litres of

		rain water, each capable of supporting 143 heads of cattle for 3 months. Each valley tank benefits 8 dairy farms. 35 dam-lined tanks each benefit a single farmer. 63 shallow wells, each benefiting 10-15 farmers. Business planning and marketing training was undertaken for the two flagship value chains - village chicken in Zambia and coffee in Uganda. Overall, over 4,950 smallholder farmers were reached. 1,900 were trained and mentored on specialty coffee production involving improved quality of coffee cherries and post handling processes.
6	12	No evidence No evidence
7	13	No evidence No evidence
8	14	Project worked through Volunteer Farmer Trainers (VFTs). 664 VFTs were deployed in the NE Cluster POs, reaching 14 farmers per VFT per year. Strategic partnerships were established with Conserve Nature, Youths for rainwater harvesting (RWH) and other development organizations to increase water availability to farmers. Strategic partnerships include Kenya Dairy Farmers Federation (KDFF), Southern Agricultural Growth Corridor of Tanzania (SAGCOT), Enhanced Dairy Sector Growth in Ethiopia and (Netherlands Development Organization) SNV. The IP model was taken up in Zambia for large scale production of village chicken, beans and soy.
9	10, 14	Uptake of climate smart agricultural practices varied considerably. Rainwater harvesting increased from 43% in the baseline to 52% in 2015 and to 59% in 2017. Tree planting rose from 23% to 37%. In contrast, organic manure applications declined from 20% to 6%. No evidence
10	15	Government of Uganda program called Operation Wealth Creation (OWC) resulted in registering 19,190 farmers for conserving feeds. 3,159 acres of Rhodes grass were established, and 537,560 bales of hay have been harvested. 7 POs (Nyamitsindo, Ishongororo, Kyakabunga, Kanyaanya, Sanga, Nyabuhikye & Bukanga) were given access to machinery in form of tractors, ploughs, harrows, trailers to aid fodder production. No evidence
11	15	The project worked with Service Providers Entrepreneurs (SPEs) networks. Through SPEs, 5,196 farmers have were supported to conserve 3.9 Million tons of silage while 2,189 farmers were directly trained to make silage through demonstrations. Youths have taken up the fodder production and conservation services as business earning them a total of $US 3647. SPEs in the 2 clusters produced 26,135 bales of hay. The project worked with Agriculture, Environment and Ecosystem (AGRENES) - a water-for-production private company. The IP model was taken up in Zambia for large scale production of village chicken, beans and soy.
12	16	No evidence No evidence
13	17, 18	No evidence No evidence
14	17, 18	Strategic partnership resulted in training of 23,068 farmers in 16 POs in RWH for livestock production. Other key outcomes of these linkages are included in the draft paper on water. Rainwater harvesting increased from 43 to 52% (relative to baseline, tree planting increased from 23 to 37%, manure application decreased from 20 to 6% No evidence
15	17, 18	No evidence

		No evidence
16	17, 18	386 demonstrations related to livestock feed have been set up, and 10,479 tons of silage and 31,438 bales of hay (Boma Rhodes, Brachiaria mulato hybrid II) have been made on 639 farms. 133,938 utilized various types of crop residues including maize stovers, rice straw, bean straw and groundnut haulms. No evidence
17	n/a	No evidence In Uganda, 1,900 farmers produced improved quality of coffee cherries. 1,300 farmers adopted improved dairy feeding. 100 beehives were established.
18	n/a	Planting of fodders increased from 28.9% of farmers in the 2014 baseline survey to 36.3% in 2017. Concentrate use was reported to increase from 14% to 73.5% of farmers between 2015 and 2017. Beneficiary farmers increased from 168 to 456 farmers who have established over 5,000 (5,426) acres of improved forage grasses mainly pure and mixed stands of Rhodes grass, Desmodium & Brachiaria) No evidence

Cluster 4 Projects - Understanding the relationship between forest resources and the food security and nutritional status of forest proximate communities

1. From Growing Food to Growing Cash: Understanding the Drivers of Food Choice in the Context of Rapid Agrarian Change in Indonesia
2. Scaling up Data on Non-wood Forest Projects in Zambia
3. Yangambi, pôle scientifique au service de l’homme et des forêts (YPS)
4. Improving the way Knowledge on Forests is Understood and Used Internationally (DFID KNOW-FOR Phase 1 & 2)
5. Governing Multifunctional Landscapes (GLM) in Sub-Saharan Africa: Managing Trade-Offs between Social and Ecological Impact

Recognizing a need for a paradigm shift, one that changes the narrative from emphasizing trade-offs between food security and conservation, to one that acknowledges the essential contribution that forests make to the sustainability of the world’s nutritionally balanced food and agriculture systems, these projects are contributing to a new discourse and knowledge on the interplay between forests, nutrition and food security. The work focuses on increasing food security and building upon outcomes and knowledge-sharing related to forests, food security and nutrition. The body of work represents a consolidation of research into both policy and practice. Examples of this approach include establishing district-level multi-stakeholder platforms on forests, food security and nutrition, and health.

Table 13. Project-level evidence supporting the Cluster 4 Sub-TOC.

Box	links to Box …	Collected evidence from project reports
1	5, 6, 10	One info brief and one article summarizing the project's findings and recommendations produced - Community (especially mothers) awareness of food and nutrition increased

		No evidence A total of 1,750 stakeholders from the community members to policy makers attended meetings in Ethiopia, Uganda and Burkina Faso that focused on the linkages forests and food security 68 community focus group discussions conducted to obtain qualitative data, receive feedback and engage community members. 3 stakeholder meetings completed in 3 countries. Gender relevant nutritional survey conducted (with 13 local coordinators trained to lead qualitative and quantitative data collection, 50 local enumerators trained to conduct household nutritional surveys), completed a total of 3,077 household nutrition surveys 5 countries. 50 Community meetings at project sites (engagement and qualitative data) - Six communities engaged and participated in participatory data collection (household mapping and wealth ranking, focus group discussions, historical trends and pebble distribution games). Three workshops conducted with project partners and researchers First round meeting with key stakeholders held as district level multi-stakeholder platforms on forests, food security and nutrition, and health established in Cameroon and DRC to bring together those working in health, forestry, conservation, fisheries and nutrition
2	5, 6	Different dietary patterns and outcomes of oil palm vs traditional households with a big emphasis on the sources of the different food groups for each sector. The drivers of the changes in staple consumption from sago to rice and the implications Methodology for the household survey on quantities of wild foods consumed are developed and tested. Regionally, informant interviews and household survey on food frequency conducted CIFOR were a contributor to the report (through the involvement of our post-doc Name Sakana) by the Africa Rising partnership on "The Impact of Sustainable Intensification on Landscapes and Livelihoods in Zambia". Completion of a special issue on Global Dry Forests with accompanying blogs and other dissemination. Published book on "Agrarian Change in Tropical Landscapes" based on research in seven tropical countries currently being undertaken by graduate students. Comparative study of Nutrition and trees in sub-Saharan Africa. Agro-industrial expansion, integrated landscape management and impacts of the food security of forest dependent livelihoods: A study of the southwest region of Cameroon. Exploring the dynamic interplay between food security, commodity production, and land-use in tropical forest landscapes. The Role of Smallholder Agriculture Food Security and Deforestation. Two survey protocol developed: (1) Data set on mother and child daily nutrition and food source available and (2) Data set on agricultural expansion developed (livelihood, income, food security, agriculture practices) Established piloting sites in DRC and Cameroon, and the first round of health surveys has taken place. Studies on Nutritional Status, food security, WASH behaviors, and dietary diversity, infection, and fisheries is on-going (Nov. 2020) in order to prepare ad-hoc engagement strategies in both countries at local and (where relevant) national levels.
3	5, 6, 7	National and district stakeholder meetings conducted National workshop, district FDG, market survey conducted No evidence CIFOR was a key contributor to the IUFRO High Level Expert Panel report on: "Forests, Trees and Landscapes for Food Security and Nutrition – A Global Assessment Report",

		which was launched at the UNFF in May 2015. Facilitate multilevel stakeholder engagement that contribute to the policy process to achieve global food security, where CIFOR continues to Chair the High Level Panel of Experts report on “Sustainable forestry for food security and nutrition” for the World Committee on Food Security. Produce recommendations on forestry’s role in “Making a Difference in Food Security and Nutrition”, the theme of its 44th Session High Level of Panel, the World Committee on Food Security (CFS) No evidence No evidence
5	6, 9	National and sub-national governments express their interest to take up the project's results and its recommendations The workshop participants (Universities, the National Food and Nutrition Commission, Ministry of health, Ministry of Livestock and Fisheries, Zambia Statistics Agency, the World Food Program, SNV, the National Institute of Science and Industrial Research) express their interest and enthusiasm for the study and indicated their interest for future collaboration on the topic No evidence With policy influence from CIFOR's works on forests and trees on nutrition and dietary diversity led the government of Ethiopia to formulate recommendations for the inclusion of nutrition-sensitive interventions in their government's nutrition program. Based on IUFRO Panel recommendation, CFS recognized that forests and trees must also be at the core of integrated policies and action on food security and nutrition across the agricultural sectors. Engagement with IUFRO GFEP process. Created awareness of forest and trees contributing to food and nutrition security in global level; reported in report “FAO Declaration on Forests, food security and nutrition” at The International Conference on Forests for Food Security and Nutrition. CIFOR’s Food Security project has generated large amount of interest and engagement from national and international policy makers, research institutions, and international NGO’s. The fact that CIFOR are now regarded as a major player in the sphere of forests and food security is indicative that its have had influence in the wider policy and practitioner arena. No evidence
6	5, 8	No evidence No evidence CIFOR’s work is being integrated into global development practices. As evidence, Ten Principles for a Landscape Approaches is served as the implementation framework for the USAID’s USD 47 million project, LESTARI. No evidence No evidence
7	6, 8, 11	No evidence No evidence No evidence No evidence No evidence
8		No evidence No evidence No evidence No evidence No evidence

9	8, 10, 11, 12, 13	No evidence No evidence No evidence No evidence No evidence
10	13	No evidence No evidence No evidence No evidence No evidence
11	12	No evidence No evidence No evidence No evidence No evidence
12	13	No evidence No evidence No evidence No evidence No evidence
13	14	No evidence No evidence No evidence No evidence No evidence
14	n/a	No evidence No evidence No evidence No evidence No evidence

APPENDIX C: Methods for DALY Estimation

Predicting ecologically suitable areas for selected fruit tree species

We selected fourteen fruit tree species high in dietary iron and vitamin A contents using the priority food tree and crop food composition database developed at World Agroforestry-ICRAF (Stadlmayr et al., 2019). We modelled the ecological suitability of the selected fruit tree species under climate change using FAO's EcoCrop model[8] in R and the BiodiversityR package (Kindt, 2018). The suitability of individual grid cells for the selected fruit tree species is based on established ecophysiological growth responses to temperature and precipitation thresholds, which we obtained from FAO Ecocrop database[9]. We used existing spatial datasets to predict suitable locations. We extracted baseline climatic data from WorldClim v2.1[10], including variables: mean temperature (BIO1), minimum temperature (BIO6), maximum temperature (BIO5) and mean annual precipitation (BIO12). We used future projected climate data from the AfriClim ensemble dataset (RCP 4.5 and 8.5, 2055)[11]. We modelled each expected species' distribution under two Representative Concentration Pathways (RCP) that represent a medium stabilization scenario (RCP4.5) and high emission scenario (RCP8.5) for 2055. All raster data were resampled to a 1 km resolution using the bilinear method. The synthesized map of climate was reclassified into five equal classes from 0-1 in 0.2 increments representing the following classes: unsuitable, poor, medium, good, and excellent. Then, we subtracted future suitable area (medium, good and excellent) from the baseline to determine the suitable area gained or lost under climate future change for each species using the Raster package in R. This output is used to guide the selection of fruit tree species that constitute a portfolio of species that can be scaled up in each country. Tree species with positive gain in the predicted growing area under the two future climate scenarios were selected. The final portfolio of fruit tree species selected for each country is presented in Table 14. As mentioned above, we estimated DALYs lost for 12 SSA countries with high prevalence of vitamin A and dietary iron deficiencies based on data from Global Burden of Diseases (GBD) 2019.

[8] The link to the Ecocrop database does not seem stable. Explanation is available at https://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1027491/ and the data used in this analysis can be downloaded from GitHub at https://github.com/supersistence/EcoCrop-ScrapeR, see the excel file "cropbasics_scrape" after downloading the Zip file

[9] https://opendata.eol.org/dataset/ecocrop

[10] https://www.worldclim.org/data/worldclim21.html

[11] https://www.york.ac.uk/environment/research/kite/resources/

Table 14. Portfolio of fruit tree species selected for each country and their nutrient content.

Spps name (English)	Scientific name	Iron (mg /100 gm)	Vit A REA (mcg/100gm)	Folate (mcg/100 gm)	Vit C (mg /100 gm)	Ethiopia	Kenya	Uganda	Burkina Faso	Malawi	Mali	Tanzania	DRC	Gambia	Nigeria	Zambia	Mozambique
Wild medlar, pulp, raw	Vangueria infausta	4.30			5.00	x	x		x	x	-	x	-	-	x	-	-
Tamarind, pulp, ripe, raw	Tamarindus indica	3.10			12.00	x	x	x	x	-	-	x	-	-	x	x	x
Papaya, pulp, raw	Carica papaya	0.70	161.00	25.00	58.00	x	x	x	x	-	-	x	x	-	x	x	x
Mobola plum, raw	Parinari curatellifolia	2.80			65.00	x	-	-	-	x	x	-	-	x	x	-	-
Marula, fruit, pulp and skin, raw	Sclerocarya birrea	3.40				x	x	x	-	-	-	x	x	-	x	x	x
Mango, pulp, raw	Mangifera indica	0.70	227.00	25.00	36.00	x	x	-	-	x	x	-	-	x	x	-	-
Loquat, pulp, raw	Eriobotrya japonica		182.00			x	x	x	x	x	x	x	-	-	x	-	-
Japanese persimmon, pulp, raw	Diospyros kaki		200.00		8.00	x	x	x	x	x	x	x	-	-	x	-	-
Guava, pulp, raw	Psidium guajava	0.70	70.00		261.00	x	x	x	-	-	x	x	-	-	x	-	-
Desert date, dried, raw	Balanites aegyptiaca	10.10		50.00		x	-		x	-	x	-	-	-	x	-	-
Bird cherry, raw	Berchemia discolor	2.20			50.00	-	-	-	x	-	x	-	-	-	-	-	-
Baobab fruit, pulp, raw	Adansonia digitata	6.10		50.00	269.00	x	x	x	x	x	x	x	x	x	x	x	-
Azanza, pulp, ripe,raw	Azanza garckeana	4.40				-	-	-	-	-	x	-	-	-	-	-	-
African wild date plum, raw	Phoenix reclinata	7.00				x	x		x	x	x	x	x		x	x	-
Number of spps selected per country						**12**	**10**	**7**	**9**	**7**	**10**	**9**	**4**	**3**	**12**	**5**	**3**

Note: "x" represents the spps. was selected for the portfolio of the respective country and "-" represents the spps. was not selected.

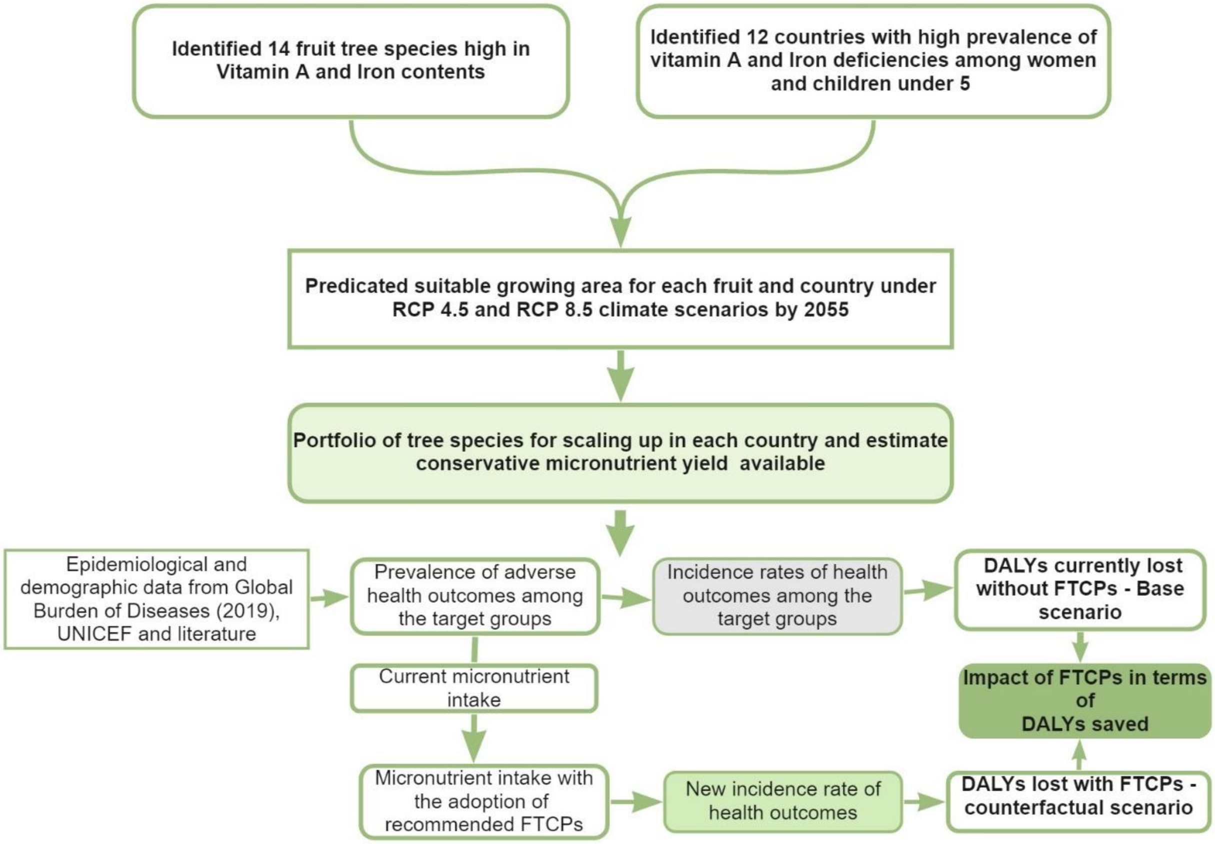

Figure 16. Procedures for predicting ecologically suitable growing area for the selected fruit tree species and DALYs estimation.

The disability-adjusted life years (DALYs)

DALY measures 'healthy life years" that are lost due to a particular condition. It measures both morbidity and mortality in a single index. The burden of a condition is the sum of 'years of life lost" (YLL) due to cause-specific mortality and the sum of "years lived with disability" (YLD) (Zimmermann and Qaim, 2004).

In estimating the DALYs lost due dietary iron and vitamin A deficiencies under the base scenario and with FTCPs, we followed Zimmermann and Qaim (2004) and Stein et al (2005). Here we present the summary of the approach, data used and sources. The detailed data sources and assumptions are provided in the appendix.

Following Zimmermann and Qaim (2004), the formula for DALYs lost can be represented as the sum of YLL and YLD:

$$DALYs_{lost} = \sum_{j} T_j \, M_j \left(\frac{1 - e^{-rL_j}}{r}\right) + \sum_{i} \sum_{i} T_j \, I_{ij} \, D_{ij} \left(\frac{1 - e^{-rd_j}}{r}\right)$$

Tj = total number of people in target group *j*
Mj = mortality rate associated with the deficiency in target group *j*
Lj = average remaining life expectancy for target group *j*
Iij = incidence rate of disease *i* in target group *j*
Dij = disability weight for disease *i* in target group *j*
dij = duration of disease *i* in target group *j* (for permanent diseases *dij* equals the average remaining life expectancy *Lj*)
r = discount rate for future life years

Functional outcomes and target groups

In this section we specify the components of the calculations. DALYs lost under the base and counterfactual scenarios calculated separately for different diseases and aggregated to obtain the total burden of disease. Following Stein et al. (2006), we calculate the DALYs for adverse functional outcomes of micronutrient deficiencies as the deficiencies are not diseases as such. Therefore, we calculate DALYs for the following functional outcomes related to dietary iron and vitamin A deficiencies.

Functional outcomes, target groups and data sources for iron deficiency

Iron deficiency remains the largest nutritional deficiency worldwide and the leading cause of anemia. Anemia can also be caused by other factors such as malaria and hookworms. Anemia caused by iron deficiency is iron deficiency anemia (IDA), affecting most women and children in low-income countries. We focus on this subgroup of anemia in our analysis. There are three stages of anemia – mild, moderate, and severe, but adverse consequences exist only for moderate and severe IDA. The adverse functional outcomes attributed to moderate and severe IDA are:

- Impaired physical activity
- Impaired mental development
- Maternal mortality

The target groups chosen for IDA following Stein et al. (2006) are:

1. Impaired physical activity (children under-five and women 15-49 years)
2. Impaired mental development (children under-five)
3. Maternal mortality (women 15-49 years), stillbirth (0 years), and children mortality (<1 year) following mother's death

Functional outcomes and target groups for Vitamin A deficiency

Vitamin A is an essential nutrient required for maintaining immune functioning, eye health, vision, and growth. Two categories of VAD exists – sub-clinical and clinical. Sub-clinical VAD is usually not associated with immediate symptoms. Still, it can reduce immune competence and cause high morbidity and mortality caused by measles, diarrhea, and other infectious diseases, especially among children under five. Clinical VAD involves xerophthalmia, a range of eye conditions from

night blindness and Bitot spot to more severe clinical outcomes such as corneal ulceration, corneal scars, and permanent blindness (Sommer, 1990). For VAD, we considered four adverse functional outcomes. These are Night blindness and Blindness, measles and child mortality. Night blindness and Blindness are clinical manifestations of xerophthalmia. Night blindness the temporary disease and earliest clinical manifestation of xerophthalmia, which is associated with the inability to see in dim light. Blindness is a permanent disease. Measles and VAD-related child mortality are considered independent of eye symptoms as they can already occur at the sub-clinical deficiency level. Our analysis has not considered Bitot's spot, corneal ulceration and corneal scars due to the lack of reliable epidemiological data on these diseases. This may lead to an underestimation of total health costs. But, as Bitot's spot and corneal ulceration were not supposed to lessen functionality (Stein, 2006), although they are associated VAD, the resulting inaccuracy will be relatively small.

The target groups for VAD outcomes are:

1. Children under five for all the four adverse outcomes
2. Pregnant and lactating women (15-49 years) for night blindness

Data sources

The epidemiological and demographic data we used are from the GBD 2019 database (GBD, 2020). These includes target group's size and average remaining life expectancy, the prevalence of moderate and severe IDA among under-five children and women of reproductive age for respective countries. We used the same information as Stein et al. (2006) for disability weight and disease duration in the target group. We also used a 30% social discount rate following Stein et al. (2006).

The mortality rate due to IDA is considered only for maternal mortality, stillbirth, and child death since other impairments are not fatal. For India, Stein et al. (2006) attributed 5 % of all maternal mortality to IDA. This is a conservative estimate, given some studies indicates 22% of maternal death worldwide are associated with IDA (Stoltzfus et al., 2004). We used the 5% attribution as Stein et al. since other reliable data for the countries considered in our analysis were unavailable. For the average national maternal mortality rate in the target countries, we used the 2017 ratio obtained from the UNICEF database[12]. Data is available in terms of the number of maternal deaths per 100,000 live births. To calculate the maternal mortality rate due to IDA, we used the following additional information.

a. The total fertility rate in the entire population (per 1000 people): we used the crude birth rate from the GBD 2019 database.
b. Percentage of all pregnancies that result in live births (%): Reliable national data for each country is unavailable. Therefore, we used an average of Kenya and Uganda as a proxy for other target countries, which is 91.3% based on Waiswa et al. (2020, pp.6)

[12] https://data.unicef.org/country/

c. The above two pieces of information, combined with the total population size, yield the number of live births.

So, the maternal mortality rate due to IDA is computed as a product of the number of live births (c), national maternal mortality ratio, and percentage of maternal mortality ratio attributed to IDA (5%). Maternal mortality leads to other adverse outcomes such as an increased number of stillbirths and child deaths due to the absence of breastfeeding and care caused by the mother's death. We assume stillbirth to be 30% of pregnant women who died due to iron deficiency anemia following Stein et al. (2005) for India. The mortality rate of the surviving 70% of the new-borns during their early childhood is greater due to lack of breastfeeding. We assumed 13% of the under-five mortality rate per 1000 live births (Stein, 2006; UNICEF, 2016). This applies to those children who would otherwise have been exclusively breastfeeding during the early months. Therefore, we used the proportion of children under-five months that exclusively feed on breastmilk obtained from the UNICEF database. We used national under-five mortality rates per 1000 live births from the UNICEF database. Drawing on the above information and assumptions, the percent of new-borns who die later due to a lack of breastfeeding – and ultimately because their mother died due to severe IDA is calculated as the number of maternal deaths*(0.7*0.13*under-five mortality rate*percent of the under-five month exclusively breastfeed).

For VAD, the size of target group was taken from the GBD 2019 database, the number of pregnant women was derived from each country's total fertility rate, which is also obtained from GBD 2019 database. The number of lactating women was estimated using the information on live births and breastfeeding for respective countries. For the prevalence of night blindness due to VAD in pregnant women and children under five, we used WHO data (Ritchie and Roser, 2017). The data is available as a percentage of pregnant women or children under five with night blindness. We used the prevalence of blindness and measles in children under five due to VAD from the GBD 2019. Finally, we assumed mortality due to VAD to be 3% of the total under five mortality rate in each respective country following Stein et al. (2006).

Estimating micronutrient supply with the scaling of FTCPs

To estimate conservative micronutrient (iron and vitamin A) yield potentially made available for consumption due to adopting recommended FTCPs, we assumed adoption of 10%, where the recommended tree fruits are adopted on 10% cropland in each country in an agroforestry system. Based on this, the amount of micronutrient supply per year from the production of FTCPs was calculated for iron and vitamin A using the prioritized tree food composition database by ICRAF (Stadlmayr et al., 2019). The database contains micronutrient content for iron (mg/100g) and vitamin A, expressed in retinol activity equivalent (RAE) (µg/100g) for each of the prioritized and potentially scalable fruit trees in each country.

For the baseline nutrient intake, simulations based on detailed food consumption data from a nationally representative household survey are more demanding in data availability, computing

power, and programming time, even for a single country, let alone 12 countries. So, we relied on estimated micronutrient intake from the global dietary database (GDD)[13], available for 2018 as the current iron and vitamin A intake for the respective target groups and countries. Combined with recommended dietary allowance (RDA) for the two micronutrients, we estimated the amount of micronutrient gaps that can be reduced using FTCPs.

Linking micronutrients to health outcomes

To relate the increased iron and vitamin A with FTCPs, we used the dose-response function explained in Zimmermann and Qaim (2004). The basic concept of dose-response is the nonlinearity and concavity of the association between micronutrient intake and the functional outcomes. As explained in Stein et al. (2005), if two individuals consume the same amount (dose) of bioavailable micronutrient, the one with a higher level of deficiency is expected to show a relatively bigger positive response to his or her health status. This is captured in Figure 17 below, adapted from Zimmermann and Qaim (2004). Given the shape of the curve, the efficacy of FTCPs can be calculated as the ratio of area A divided by the combined area of A + B. Thus, the efficacy "can take any value between zero and one, whereby it is positively correlated with the convexity of the curve" ((Zimmermann and Qaim, 2004), p. 158). We used the formula shown in Zimmarmann and Qaim (2004), applied to the intake data for each target group, and calculated the efficacy for FTCPs.

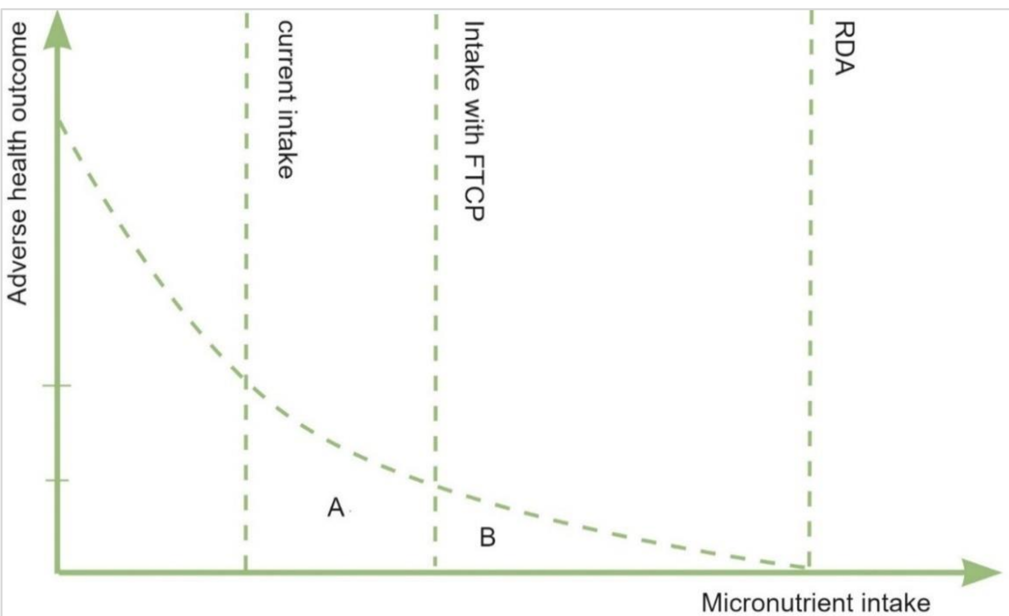

Figure 17. Relationship between micronutrient intake and health outcome, adapted from Zimmermann and Qaim (2004)

[13] https://globaldietarydatabase.org/data-download