2.2. Flagship 2. Enhancing how trees and forests contribute to smallholder livelihoods

2.2.1 Flagship Project Narrative

2.2.1.1 Rationale, scope

Our central hypothesis is that food security, nutrition and income for 100 million people in smallholder households in Africa, Asia and Latin America can be significantly increased through better management of the tree and forest resources underpinning their livelihood systems. Recent global assessments suggest that there is 10% or more tree cover on over 43% of agricultural land (about 1 billion ha) that is home to 900 million people[1] and that 28% of household income is derived from forest resources by smallholders living at the forest margin[2]. This Flagship Project (FP) will increase the contribution that trees and forests make to smallholder livelihoods (Sub-IDO 3.2) by developing more productive tree management options (Sub-IDO 9.2), helping smallholders capture more value from the sale of products (Sub-IDO 3.3) and ensuring more equitable management of tree and forest resources (Sub-IDO 9.1) – especially by and for women (Sub-IDO B.1) and young people. This will increase access to diverse, nutrient-rich foods (Sub-IDO 5.2) and increase livelihood opportunities for people in smallholder households, with a focus on those who are socially and economically marginalized (Sub-IDO 3.2).

Research on tree management options and associated markets is combined with work on policy and institutions to ensure impact at scale. Our central focus is at the household level and we develop and apply a 'research in development' (RinD) paradigm together with development partners, to tailor options to suit the highly variable range of contexts in which smallholders can benefit from better tree and forest management (Figure 1). The challenge of addressing a wide range of beneficiaries is discussed in Section 2.2.1.4. While the elements of this paradigm are all individually familiar, bringing them all together in a coherent framework and applying them on a large scale to agroforestry, with our development partners, is a new approach. Options may comprise combinations of technologies, market and extension interventions, and policy instruments, which often interact with one another in achieving livelihood improvements.

The FP has been reorganized from Phase 1 into five research clusters (Section 2.2.1.6). This enables integrative research to be carried out on livelihood systems analysis, synthesis and scaling, so as to structure the work across four major types of tree production that underpin smallholder livelihoods. These are: timber, food and fuel production and marketing; tree-crop commodities (e.g. coffee, cocoa, oil palm and rubber); trees in support of sustainable intensification; and silvopastoral systems. The integrating research adopts a transdisciplinary systems approach, including a focus on institutions and policy conditions for success and scaling. This allows us to tackle major challenges through focused research, to close yield gaps and sustain productivity gains in specific production practices, while facilitating system intensification by managing interactions at the livelihood level and in the enabling environment that conditions it.

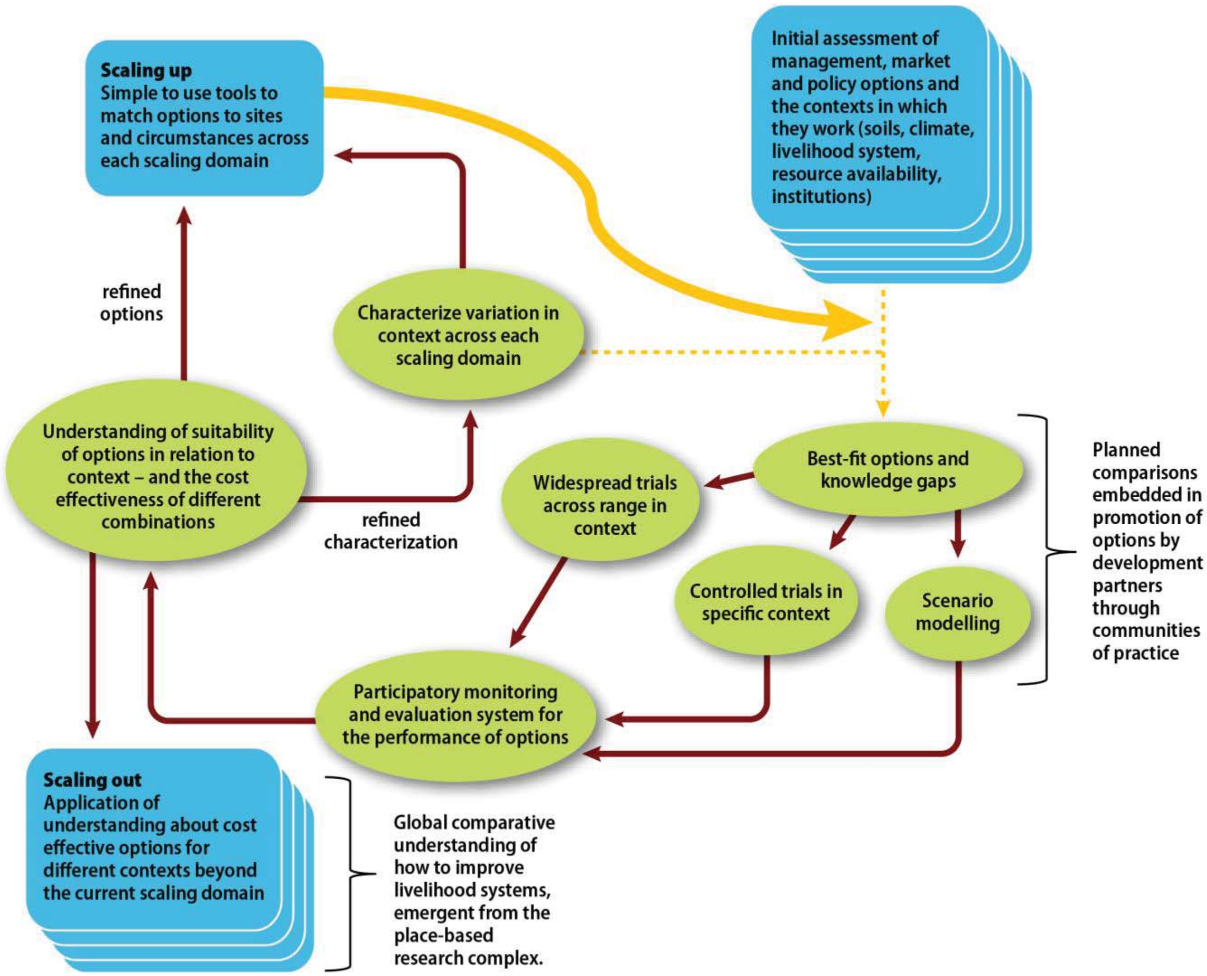

Figure 1. The research 'in' development (RinD) approach (adapted from Coe et al. 2014[3]) that embeds research within development practice by considering options in relation to context[4] and systematically evaluating options across ranges in context by coupling planned comparisons with innovations in data collection from widespread farmer trials.

In terms of major challenges, our focus is on the nexus of meeting rising livelihood requirements for food, water (including that required to produce food) and energy (including that required to cook food) as populations increase, while halting and reversing the widespread land degradation that threatens future productivity, in the knowledge that avoiding degradation is much less expensive than restoration. Trees are pivotal resources in addressing these multiple and interacting goals. We tackle the fundamental production and environmental protection issues in the context of needing to increase smallholder income through better market access and function, enabling households to make exits from poverty. Both production and market options are constrained and can be enabled by socially differentiated access to resources mediated by policies and institutions, with particular requirements to increase women's power over decisions about natural resource management, marketing and income. In this way, we simultaneously address hunger, poverty and environmental protection with a focus on managing trade-offs and synergies amongst them.

2.2.1.2 Objectives and targets

The FP aims to develop forest and agroforestry options, comprising innovations in management, markets and policy associated with the tree cover utilized by smallholders. We anticipate that this will lead to greater and more resilient food security and income for 100 million people, representing about 11% of the population living in our target area i.e. it will benefit people in targeted developing countries living in areas where tree cover on agricultural land is 10% or more or at the forest margins. A key innovation in our approach is the application of systems research at the scale of the proposed impact that we intend to make. This results in operating across large scaling domains by embedding research within development through strategic partnerships with development organizations (Figure 1, Section 2.2.1.1).

Better management of trees by smallholders acts on livelihoods through increased production of food and products that are sold, system intensification through producing fuel and fodder close to home, freeing up cash and labor for other intensification options and avoiding and reversing land degradation by maintaining and restoring soil health and increasing the efficiency of water and nutrient use. This is coupled with improving value capture by producers from as-yet poorly developed markets for many forest and agroforestry products, and is enabled through policy reforms to remove barriers to people (especially women) deriving benefit from and controlling production and income from, trees and other forest resources. These impacts of trees on livelihoods interact strongly, so that understanding and addressing trade-offs and synergies associated with the adoption of innovation options is fundamental to successful development outcomes.

Making impact at scale by enhancing smallholder tree and forest management requires innovation in the ways that research and development address fine-scale variation in context. Context includes social, economic and ecological factors that determine the suitability of different innovations. The FP therefore, devotes a quarter of the budget to the development and application of novel methods for conducting research across large scaling domains in cooperation with development partners (Table 1). These resources have huge leverage as they act upon the development funds of partner organizations, which are an order of magnitude (typically a ratio of around 1:100) larger than those available for research (see Section 2.2.1.6) and are the only way sufficient resources can be mobilized to conduct research at scale[50]. We refer to this as a co-learning approach because researchers, extension staff, farmers and private sector actors come together in multi-stakeholder platforms and learn together. Local knowledge is seen as a resource largely complementary to global scientific knowledge[51]. We refer to these collectively as ‘communities of practice’ but they may take different forms, such as value chain innovation platforms[52] or land-care groups[53] to suit different contexts. This involves recognizing that we are dealing with innovation systems comprising actors with different knowledge, attitudes and interests who interact through various formal and informal institutional channels. This approach ensures that research outputs can be scaled up and out to affect 11 selected Sub-IDOs (Table 2) elaborated further in relation to each CoA in Section 2.2.1.6. A further quarter of the budget is devoted to research on system intensification, including the role of trees in sustaining soil health, leading to higher productivity and greater food security for 20 million people (Outcome 2.4). This involves close collaboration with other agri-food system CRPs because trees have an impact on the yield of staple food crops and livestock (see Figure 3, Section 2.2.1.3). About 20% of the budget focuses on research aimed at increasing production and value capture from smallholder tree-crop commodities (e.g. cocoa, coffee, rubber and oil palm), targeting a 25% higher income for 20 million people (Outcome 2.3). The remaining 30% of the budget is equally focused on: improving diets and increasing income from smallholder production and sales of food, fuel, timber and other products targeting 5 million people (Outcome 2.2): improving productivity and animal welfare of silvopastoral systems across 15 million ha; and, avoiding or reversing the degradation of over 5 million ha (Outcome 2.5). We adopt a gender-transformative approach across the FP research portfolio (Table 2) with about 10% of the budget focused specifically on increasing the control that women have over production and income from trees and forests (Outcome 2.2).

Examples of current research and past achievements that evidence the plausibility of all the outcome targets are tabulated in Annex 3.12 .

Table 1. Outcomes by windows of funding.

Outcomes	Amount needed (million USD)	W1/W2 (%)	W3 (%)	Bilateral (%)
1. Improved food security and livelihood opportunities for 100 million people in smallholder households and more productive and equitable management of natural resources over an area of at least 50 million ha. This outcome integrates some outputs from other research clusters through their scaling.	25	24	0	76
2. Improved livelihood opportunities involving timber, fruit and NTFPs contributing a 25% increase in income for over 5 million people and more equitable management of natural resources, including a 25% increase in women's participation in decisions involving tree and forest management and utilization and improvement in substantive representation of women in community forest management institutions	15	24	0	76
3. Diversified tree-crop production systems covering 5 million ha and improving diets and livelihood opportunities for 20 million people in smallholder producer households	20	24	0	76
4. Increased access to diverse, nutrient-rich food for 20 million people by closing yield gaps by trees in agricultural systems, improving and maintaining soil health, intensifying system interactions (fodder and fuelwood), directly contributing to production, reducing and reversing land degradation, and increasing the resilience of smallholder livelihoods	25	24	0	76
5. Closing yield gaps through improved pasture management and animal husbandry on over 15 million ha and 1 million animals and contributing to reducing and reversing land degradation on over 5 million ha	15	24	0	76
Total	**100 million**	24	0	76

Table 2. Investments by sub-IDOs.

Sub-IDOs	Amount needed (million USD)	W1/W2 (%)	W3 (%)	Bilateral (%)
3.2 Increased livelihood opportunities	15	24	0	76
3.3 Increased value capture by producers	7	24	0	76
5.2 Increased access to diverse, nutrient-rich food	10	24	0	76
8.1 Land degradation minimized and reversed	10	24	0	76
9.1 More productive and equitable management of natural resources	10	24	0	76
9.2 Agricultural systems intensified and diversified in ways that protect	12	24	0	76
10.1 Increased resilience of agroecosystems and communities	6	24	0	76
B.1 Gender-equitable control of productive assets and resources	10	24	0	76
C.3 Conducive agricultural policy environment	10	24	0	76
D.3 Increased capacity for innovation in partner research organizations	5	24	0	76
D.4 Increased capacity for innovation in partner development organizations and in poor and vulnerable communities	5	24	0	76

2.2.1.3 Impact pathway and theory of change (for each individual FP)

The ultimate beneficiaries of livelihood systems research are the 100 million smallholders who take up options generated by the research to improve their livelihoods. Our theory of change (Figure 2) rests on three main tenets: (i) that current management of tree cover on farms and at forest margins can be improved to achieve higher and more sustainable yields, leading to better food and nutrition security; (ii) that smallholders and particularly women, can achieve higher returns from tree and forest products by better marketing and processing, thereby increasing their income; and (iii) that people (especially women, young people and other marginalized groups) can participate more in, and benefit more from, using tree and forest resources, if policies, legislation and institutions affecting their use are geared towards this. The development of international public goods (IPGs) associated with specific options is outlined in Section 2.2.1.6, which describes the clusters of activity.

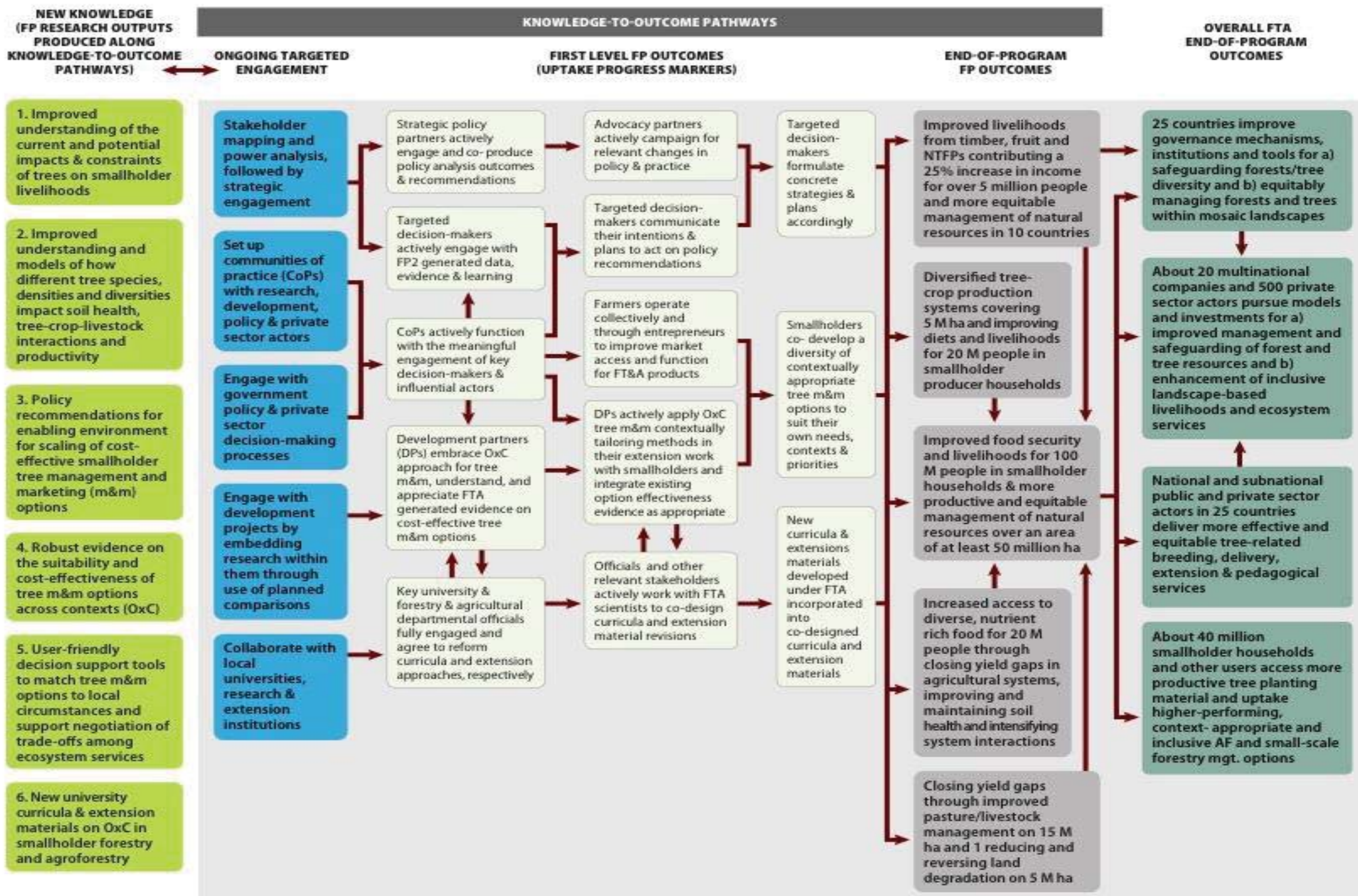

Figure 2. Flagship 2 theory of change (ToC).

Analysis of development practice reveals that current forest and agroforestry options available for smallholders, while benefitting some people, are: (i) not comprehensive in terms of the contexts they cover (leaving some people without appropriate options for improvement); (ii) are often promoted outside their appropriate contexts (revealing gaps in our understanding about matching options to context); and (iii) require an appropriate enabling environment, especially for marginalized people to benefit from them (and for perverse outcomes to be avoided). Research can address these constraints and therefore, improve smallholder livelihoods through better use of tree and forest resources, if the research is conducted in a way that ensures its relevance across contexts.

A major route to facilitating smallholder uptake is via embedding research within development through multi-stakeholder communities of practice (Figure 3). This involves both research and development partners changing the way that they work, to use planned comparisons of ranges of options across ranges in context to efficiently learn, with smallholders, about what works where and for whom (Figure 1). It uses knowledge-based system methods to combine high-end science with local knowledge[5]. This is a major shift (from promoting what is considered the best-bet option in any instance) and requires new capacity among development partners in identifying options for different contexts and designing and learning from planned comparisons (PCs). PCs provide rigorous evaluation of the costs and benefits of alternatives, more usefully and iteratively than simply comparing performance against a baseline. We combine this with outcome mapping and process tracing to understand and verify causal connections along anticipated impact pathways. Options include market, policy and institutional interventions that are also taken up directly by private and public actors with whom we engage. Specific research areas and outcomes are elaborated in Sections 2.2.1.2 and 2.2.1.6.

Achieving change requires us to forge and sustain new partnerships with development organizations, the private sector and policy-makers (Section 2.2.1.7). We have identified and sought to manage the risks associated with these interfaces that are critical for our research outputs to deliver impact (Table 3). We start from a sound basis of partnerships established in Phase 1 and manage the risks associated with partners failing to either engage or deliver through the following six-point strategy that involves:

- ongoing communication with and monitoring of, communities of practice to identify potential problems before they emerge and to avoid them developing in the future
- operating with a diversity of partners and partnership models (thereby "avoiding having all our eggs in one basket") and creating space for learning which forms of partnership work best
- focusing on the quality of partnerships that we establish in terms of their reciprocity, efficiency and effectiveness
- selecting some quick-win routes to impact at the outset, so that early successes , as achieved in Phase 1 piloting, will sustain the partnerships that are established
- persisting and continuing to innovate where challenges in establishing and sustaining partnerships arise, learning from experience and trying new approaches where necessary
- linking innovation in partnerships with development organizations and the private sector, to policy processes and publicity, creating incentives around success.

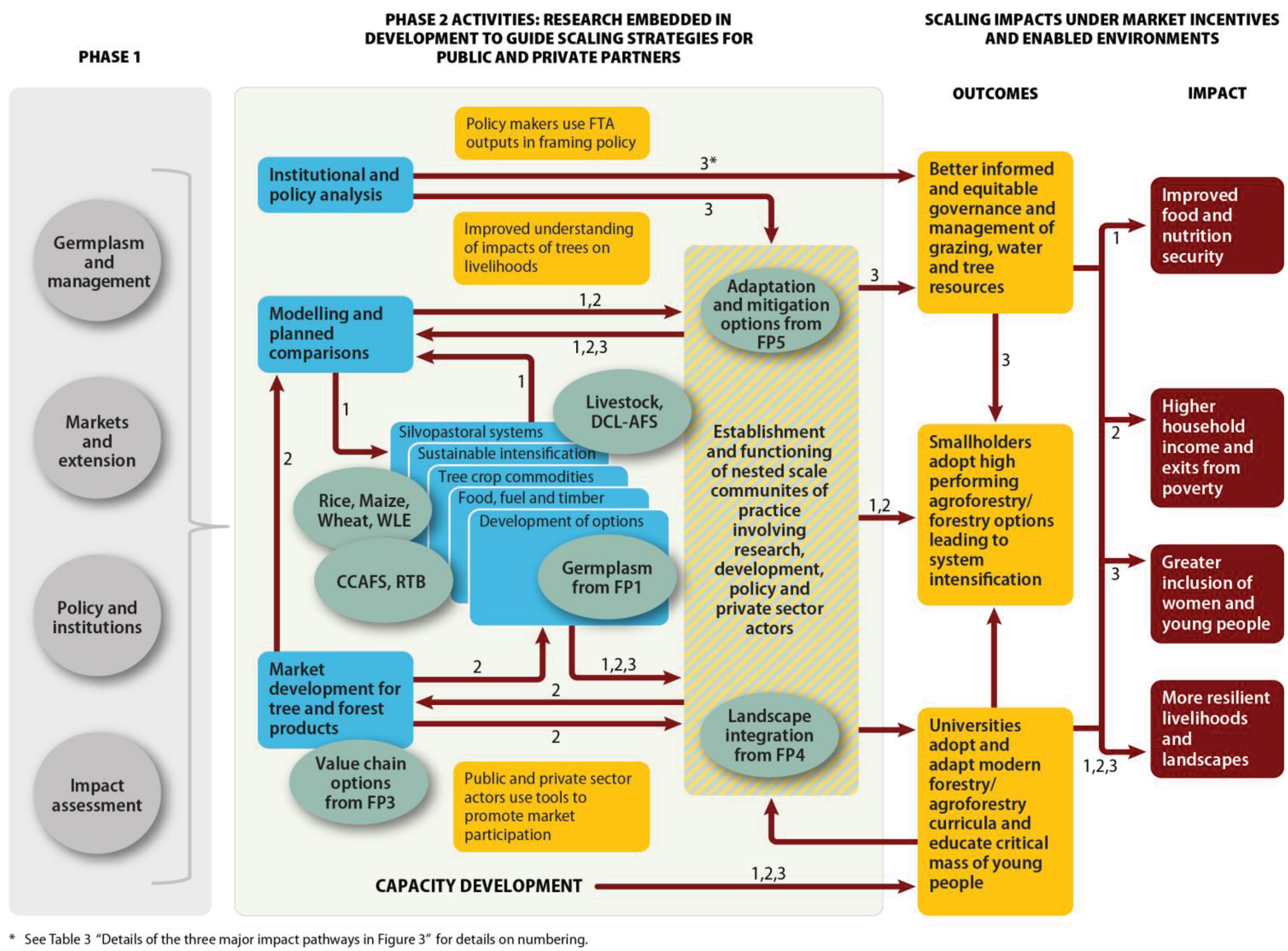

Figure 3. Diagrammatic representation of three major livelihood systems impact pathways (details, including risks and assumptions and their relationship to research activity are given in Table 3.

Table 3. Details of the three major impact pathways in Figure 3.

ToC pathway	Key assumptions	Key risks	Behavioral change required	Capacity development required
1	Management options are generated that increase yield (and total factor productivity) sufficiently to significantly improve food and nutrition security Development partners will collaborate in trialing a sufficient range of options across a sufficient range of contexts so that options can be matched to appropriate contexts A generic understanding of how contextual factors and combinations of them will affect the suitability of options can be derived from planned comparisons	Development partners fail to engage across a sufficient range of context for a sufficient time for context specific results to be produced	Development partners to embed planned comparisons in their development practice and learn from monitoring and evaluating their performance	Awareness that current best bets are not always appropriate Design and analysis of planned comparisons Use of evidence in decision-making
2	Market development (including adding value through processing) results in sufficiently higher smallholder income for people to exit from poverty Private sector partners are willing to engage in market development Appropriate conditions exist or can be developed for smallholders to cooperate in leveraging markets	Private sector partners do not sufficiently engage in market development with smallholders	Smallholders to operate collectively to leverage market opportunities Private sector partners to engage with smallholders in market development	Skills to develop and run institutions amongst smallholders Market information and development skills amongst smallholders How to develop and sustain positive linkages with smallholders among private sector actors
3	Barriers to access to critical resources (e.g. land, trees and their products) by marginalized groups exist and can be removed or eased by policy reform Smallholders can be incentivized to adopt more sustainable management of resources Long-term improvements in environmental impact of agriculture can be achieved without reducing short-term productivity	Policy changes are not made despite evidence of their effectiveness because of vested interests	Policies are implemented at a resolution fine grained enough to reconcile trade-offs between production and other ecosystem services Policy-makers use evidence in negotiating policy formation and implementation	Spatially explicit evaluation of trade-offs and synergies among impacts of land-use change on ecosystem services by policy-makers and implementers

2.2.1.4 Science quality

The science quality of the FP arises from our commitment to innovation. We adopt a novel RinD paradigm (Section 2.2.1.1) and will deliver high-impact journal papers coupled to blogs, policy briefs and development action that translate high-impact science into high-impact outcomes on the ground. In this proposal, we illustrate science quality mainly through the articulation of the research clusters (Section 2.2.1.6), which innovate on the basis of a clear articulation of past developments in each field and partner with advanced research organizations, including a number of universities and CSIRO, to ensure that we continue to harness frontier research during implementation (Section 2.2.1.7). In articulating the research clusters, we use previous FP outputs, so that we build our new research on a sound foundation of past success, coupled with important learning – from Phase 1 and the wider research community – that informs the innovations that we propose to take forward into Phase II (Section 2.2.1.5). We expose our science to scrutiny not only through peer-reviewed publication and by presenting ideas and results at international meetings, but also by adopting a co-learning approach (Section 2.2.1.2) through which we obtain iterative feedback from stakeholders on the saliency and legitimacy of our research from its early stages.

The key areas of innovation include the development and application of the RinD approach that addresses fine-scale variation in context across large scaling domains (CoA 2.1)[6]. This involves the use of planned comparisons with large sample sizes requiring novel data collection methods that make use of recent developments in ICT[7], including increasingly sophisticated remote sensing products, crowdsourcing of data from large samples of famers and real-time two-way communication with farmers and extension staff which is becoming increasingly viable through development of smartphone apps. Together with CSIRO, we have developed the capacity to model tree-crop interactions within the Agricultural Production Systems sIMulator (APSIM) modeling framework[8] and will extend this from the few tree species (*Eucalyptus* sp., *Grevillea robusta* and *Gliricidia sepium*) and crops (maize and wheat) initially built into the simulator in Phase 1, so as to embrace tree diversity, as well as a broader range of crops, including rice and dryland cereals (CoA 2.4) across a broad range of conditions in collaboration with the maize, wheat, rice and DCL-AFS CRPs. This will address the increasingly clear preferences of farmers to have more trees and more tree diversity on their farms[9] and in their farming landscapes[10] that can confer higher productivity and resilience[11]. Meta analysis has shown that across sub-Saharan Africa, fertilizer trees produced a mean maize yield increase of 1.3 and 1.6 t ha^{-1} for non-coppiced and coppiced trees, respectively[54] but with different performances across different soil types, climatic conditions and fertilizer inputs[55]. More than 160,000 Zambian farmers now grow food crops under *Faidherbia* fertilizer trees and more than 200,000 farmers in Malawi have adopted tree–maize intercropping systems[56]. In an impact survey across Burkina Faso, Mali, Niger and Senegal, farmers managing natural regeneration of trees in their fields achieved 15–30% higher crop yields (depending on tree species, location and crop type) than other farmers, with benefits positively correlated with the density and maturity of trees. Households practicing FMNR derived an average income of USD 200 from tree products, despite only selling 10–25% of their harvested tree products (leaves, pods, fruits and wood)[57]. The variability of performance of different agroforestry options amongst farmers presents a major challenge because mean increases are not useful for generating advice for any particular farmer, since they may experience much higher or lower performance than the mean. Where the variation about mean performance can be explained by context, the precision with which options can be offered to farmers increases and the risk the farmer faces in adopting a new practice is reduced[58].

A major challenge is that the FP has a wide range of beneficiaries, from subsistence farmers focused on increasing the yield of staple crops in East and Southern Africa, through often migrant cocoa and coffee smallholders who want to commercialize in conditions of uncertain land tenure and prices in West Africa, smallholders marketing timber and other products at forest margins in the Amazon and Indonesia, to cattle-keepers in Central America. These different people face different barriers to adopting better tree management and marketing practices, and there is a need to involve them in adapting options to suit their variable contexts. We have found that structured stakeholder engagement, starting with systematic acquisition of local knowledge, that is then used to organize discussion of options in multi-stakeholder workshops, leads to the emergence of more diverse and inclusive options and to changes in knowledge, attitudes and behavior as participants share knowledge amongst groups that might not often do so[59]. For example, in the Virunga landscape in Eastern Democratic Republic of the Congo, structured stakeholder engagement led to a profound shift from development organizations promoting a few exotic species in woodlots, largely benefiting men wealthy enough to allocate land exclusively to trees, to more than 70 tree species being identified, more than half of them native, to be used in 15 distinct agroforestry practices[60], with different people interested in different options. Women wanted early-maturing fruit trees that they could add value to by processing into jam or juice as well as fertilizer trees, while the marginalized, indigenous Batwa people were interested in melliferous species to boost their honey production and livestock owners wanted windbreaks in their pastures. Similar results were obtained in the Lake Tanganyika catchment, where combining satellite image analysis to identify erosion hot spots with local knowledge of trees that had once grown there, led to WWF engaging with farmers to plant over 2 million trees in 2012, including 16 native species that had never before been promoted. Simple spreadsheet tools to match different species to field, farm and landscape niches were developed so that extension staff could interact with farmers to decide on appropriate tree-planting strategies that suited their context. These tools were simple matrices of options and contexts, so that it was easy to identify what species were likely to be suitable for different people and places[61]. More sophisticated knowledge-based systems tools have similarly been used to allow extension staff to enter contextual information and obtain information about suitable options, based on both local and scientific knowledge. ICRAF has developed a smartphone tree finder app[62] that shows potentially suitable trees for different locations, as well as decision-support tools that use the analysis of farmer ranking of tree attributes to suggest suitable companion trees for coffee and cocoa in different contexts[63].

Together with universities in the UK and the US, we will apply the latest advances in genomics to better understand how trees improve soil health by enhancing the abundance and activity of soil organisms (CoA 2.4)[12]. We will do this by applying advances in DNA sequencing of soil microbial populations[13] to test hypotheses about non-responsiveness in soils and how trees affect soil health through fostering functionally balanced soil biota. We address a key implementation gap in relating land-use decisions at field and farm scale to impacts on ecosystem service provision at local landscape scales[14], by developing and applying spatially explicit negotiation support tools. Building on the Polyscape[15] approach developed in Phase 1, we couple this with sustainable agricultural intensification dashboards designed to be used to bring evidence to bear in multi-stakeholder platforms where policy decisions are made[16]. We plan to continue to innovate in using systematic approaches for local knowledge acquisition, building on recent advances in statistical analysis of farmer rankings of tree attributes[17] to combine local and scientific knowledge in developing more diverse and inclusive agroforestry options[18]. We will apply a new, unified theory of empowerment[19] together with advances in understanding vulnerability[20] and equity[21] to address constraints in realizing effective and equitable governance of tree and forest resources.

2.2.1. 5 Lessons learned and unintended consequences

In Phase 1, we pursued research along disciplinary lines (management options, markets, policy). We found that these interact strongly and need to be combined to achieve livelihood gains at scale. In Phase II, we reconcile place-based research with the production of generalizable IPGs, using a novel RinD paradigm (Figure 1). We found in Phase 1 that conventional approaches to prioritizing tree species and management practices for scaling did not address the inclusive needs of socially differentiated actors or fine-scale variation in conditions and led to narrowing tree diversity at larger scales. In Phase II, we adopt an 'options-by-context' approach that recognizes variation among people and places, and develops context-specific and locally adaptable options that reach a broader range of people while conferring resilience at landscape and livelihood scales. Our systems characterization informs FP1 in defining field, farm and landscape niches for tree species and priorities for improvement. We jointly evaluate tree germplasm from FP1 across contexts (Figure 3) and embed innovations in tree seed and seedling delivery from FP1 within tools for promoting tree diversity that combine local knowledge with high-end science (including suitability mapping of tree species from FP1). We feedback learning from large-scale, planned comparisons of tree promotion approaches to inform FP1 research.

In Phase 1, we identified a need for hard evidence on the cost-effectiveness of intervention options to inform investment decisions in scaling. We address this in Phase II through nested-scale planned comparisons. In Phase 1, we established that trees on agricultural land are associated with larger abundances of soil organisms[22]; we build on this in Phase II using genomic approaches to understand how different tree species, density and diversity affect the functional profiles of soil organisms and affect soil health.

In Phase 1, we analyzed how tree product markets, culture and policies have differential effects according to gender[23]; we will build on this in Phase II by pursuing gender-transformative research and greater engagement with the private sector in developing market access for smallholders. In Phase 1, we identified a key implementation gap in linking farm-level decisions to impacts on ecosystem service provision at local landscape scales[24]; addressed in Phase II by developing novel GIS applications at resolutions that can inform negotiation support. In Phase II, we expand our research on silvo-pastoral systems in line with recommendations of the independent evaluation of FTA during Phase 1 and the huge land area over which these systems are relevant, together with the expanding demand for sustainable livestock products.

Intended and unintended consequences: Improving smallholder livelihoods involves dealing with complex systems behavior rather than linear, deterministic outcomes. While we have defined specific desirable outcomes that we aim to achieve in overall terms, this is done by guiding emergent practice through iterative cycles, within and beyond the research domain. During this process, we take steps to manage the risks inherent in the partnerships involved (see Section 2.2.3) and to monitor the winners and losers. A significant part of our research portfolio looks at who benefits from innovations in terms of policy and practice and what can be done to ensure that intended beneficiaries are reached. Examples from Phase 1 include understanding the impacts of forest policy on regenerating trees on farm and of partial devolution of forest authority on vulnerability[25] and empowerment[26] of smallholders. We have also explored issues of equity in distribution of benefits from carbon payment schemes and the requirements for social safeguards that will result in positive outcomes for smallholders[27]. We now direct the program at producing research outputs that can support negotiation of desirable outcomes by bringing evidence to bear on them.

2.2.1.6 Clusters of activity (CoA)

The FP comprises five research clusters. An integrating cluster on livelihood systems analysis, synthesis and scaling, structures and integrates work across four other clusters; each cluster focuses on a major set of tree production practices that underpin smallholder livelihoods (Figure 4). We operate active portfolio management to focus the research on priority issues and geographic areas and to ensure critical mass where we do work to make a difference (Table 4). Primary priorities are represented by the choice of the four research clusters (2.2–2.5) focusing on key ways in which trees contribute to smallholder livelihoods, based on their potential for impact on system-level outcomes (SLOs), as outlined in the description of each cluster. Within each cluster, specific focal geographies were selected by applying the following criteria:

- demand from national and regional organizations evidenced by willingness to engage in policy reform and/or significant expenditure on development action (> USD 100 million over the phase 2 duration, nationally)
- potential for impact on SLOs evidenced by the importance of trees to livelihoods and landscapes and prospects for improved management of tree cover, resulting in a focus on forest margins where tree crops are expanding and agricultural land with >10% cover and locally high population density
- prospects for site integration by co-locating research amongst partners within the Flagship, with other Flagships in the CRP (focusing on the FTA sentinel site network) and with other CRPs (collaborating on key crops: rice, maize, wheat, legumes, dryland cereals and tree crops).

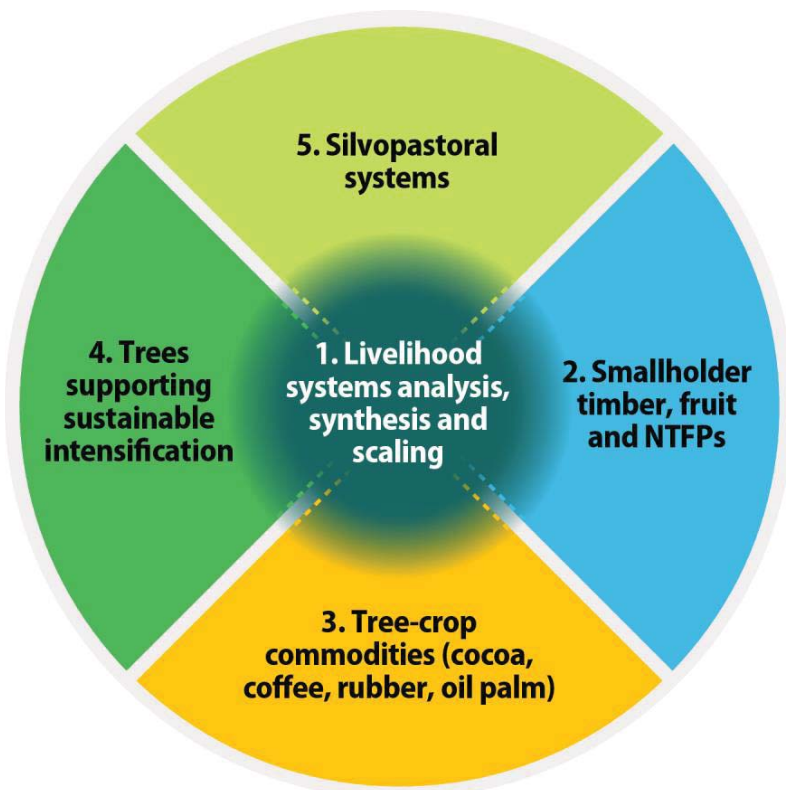

Figure 4. The five research clusters in the FTA livelihood systems FP.

Table 4. Funding model for research-in-development.

Research project	Development leverage
AD/EU Land restoration project. Receives USD 5 million for 5 years to work in five countries (Ethiopia, Kenya, Mali, Niger and Tanzania) – approximately USD 1 million per country. Aim – to develop successful land restoration approaches for different contexts to effect scaling-up through IFAD development investments. Rationale – embedding RinD approach will accelerate development impact by understanding what land restoration will work where and for whom.	In Kenya, the work informs the IFAD/FAO/WFP investment of USD 116 million in the KCEP–CRAL project across eight counties over 5 years and is embedded in the Netherlands DryDev investment (USD 10 million in Kenya) that co-locates in three of these countries. The KCEP–CRAL investment aims to reach 100,000 farmers and sustainably lift 80,000 of them out of poverty by 2022. Similar connections to development investments are made in the other four countries. Leverage 1:126
IFAD is contracting FTA researchers to the value of USD 2.8 million to coordinate a regional hub project to scientifically underpin a twelve-country GEF program to foster resilient food security in Africa.	The value of the regional hub project is USD 10 million and the GEF program is USD 96 million. This initiative is expected to attract more investment. Essentially this acts as a conduit (impact pathway) for FTA outputs. Leverage 1:42
Our experience of FTA research projects in technology development indicates that without development leverage, it costs on average USD 80–120 per household reached. For example, the FTA Trees4FoodSecurity project in Burundi, Ethiopia, Rwanda and Uganda was funded at USD 4 million and reached over 30,000 farm households with improved technology in its first phase, and is funded at USD 3.7 million to reach a further 50,000 households (benefiting approximately 250,000 people) in its second phase.	Where we embed RinD (roughly half our research fund spending) and achieve 1:100 leverage with that, it would be consistent for USD 100 million of research funds in FP2 from 2017–2022 to impact up to 50 million households (summing our country estimates we have conservatively estimated reaching 16.67 million households with technology, benefiting 100 million people) and assuming development spend targets are met, we expect to lift 4.61 million people (around 1 million households) out of poverty.
A key feature of the RinD approach is addressing both technology development and innovation in the enabling environment simultaneously and policy interventions that remove barriers to people benefiting from better management of trees, often facilitates wide-scale adoption of technologies.	In Peru, a change in the definition of agroforestry legalized smallholders selling timber from managed fallows at the forest margin (affecting 4.5 million ha and well over a million people). The National Agroforestry Policy in India aims to remove barriers to adoption of agroforestry for over 15 million smallholder farmers. FTA's participatory farm trials in Vietnam led to Decision No 27/2015/QD_UBND, to provide farmers in Yen Bai with incentive of VND 1 million ha^{-1} to grow grass strips to prevent soil erosion, increase maize yields and provide feed for livestock, and a subsidy of VND 6 million ha^{-1} for planting *son tra* (*Docynia indica*) fruit trees in Tram Tau and Mu Cang Chai districts. Typical farm income (once the trees start fruiting) is USD 2000 ha^{-1}.

CoA 2.1 Livelihood systems analysis, synthesis and scaling.

This cluster provides connections across research clusters, including comparative analysis and ongoing prioritization amongst clusters, facilitated through using common approaches and methods developed in this cluster but used across the other clusters in FP2.

We hypothesize that making impact at scale for smallholders through improved management and marketing of trees and their products requires addressing the fine-scale variation in context that conditions suitability of options. Where trees are incorporated in agricultural systems, gains from system intensification are likely to be greater than from tree products and outcomes will be derived from emergent practice amongst complex groups of stakeholders that can be guided through negotiation support rather than determined by prescriptive approaches.

Research questions: How can we most efficiently, effectively and equitably co-develop design principles for matching options that improve the use of trees and forests by smallholders (comprising technologies, extension methods and market interventions, and policy and institutional instruments) to the fine-scale variation in the context of smallholder livelihood systems? This requires us to understand how contextual variables condition the suitability of options and to embed participatory action research within a systematic frame. How can scientific information be used to support negotiation among stakeholders, bridging farm to local landscape scales to manage the impacts of land-use change on ecosystem service provision? What are the political and institutional conditions that allow for household and smallholder success in terms of livelihood improvements, including ways to scale-up the results from interventions? How can tree crops help to build critical livelihood assets (e.g. human, social, natural, physical and financial capital), and how do asset endowments and dynamics vary across and within households according to gender and age? How can access to and control over these assets by women and young people be improved?

The opportunities for livelihood benefits from better management of tree and forest resources vary. Rural livelihoods generally comprise agricultural and nonagricultural elements and forest elements at the forest margin, which all need to be understood in developing appropriate options to improve food security and income. This cluster develops and applies approaches, methods and tools aimed at identifying opportunities for change, trade-offs and negotiation among them (e.g. Polyscape[28]). This includes specific attention to social inclusion with a focus on gender and young people. We focus on household livelihood systems and how they interact with one another at local landscape scales, while recognizing that expanding livelihood options often requires action at larger scales. We consider issues of local knowledge, labor availability, migration and rights as key factors, and provide a framework for modeling interactions in and among livelihood systems[29]. We use anthropological and survey approaches to analyze key issues such as land tenure, power relations in market access, the role of government in responding to and supporting smallholders and communities, collective action, community organization and governance. We partner with development organizations to enable systematic research on options across variations in context within large-scale domains (Figure 2). Planned comparisons, using trials with large sample sizes and crowdsourcing of data, using recent advances in information and communication technology, are combined with controlled trials and modeling. This will contribute to smallholders getting increased access to diverse, nutrient-rich foods and livelihood opportunities, as well as to more productive and equitable management of natural resources (Sub-IDOs 5.2, 3.2 and 9.1).

CoA 2.2 Smallholder timber, food and fuel production and marketing

We hypothesize that smallholder income can be increased and made more equitable by better connecting smallholders to markets and developing markets for key tree and forest products. Future timber supplies will increasingly come from farm-grown sources and farmers can benefit from this by improving silviculture, harvesting and marketing. Demand for charcoal from growing urban populations will increase and developing sustainable production is more viable than imposing controls that are rarely effective and if so, tend to displace the problem. Markets can be developed for a range of non-timber tree and forest products, including fruit that women can particularly benefit from.

Research questions: How can barriers be removed to smallholders accessing markets for tree and forest products, allowing them to capture more of their value, especially for people who are socially or economically marginalized (including women and young people)? What types of products and markets are most suitable and what interventions are most cost effective to realize these outcomes? How can smallholders profitably produce and market quality timber on a small scale? How do different approaches to forest management impact smallholder livelihoods at the forest margin?

Timber, fruit and other NTFPs grown on farms or cultivated in, or gathered from, forests by smallholders often have potential for value to be added locally (e.g. in furniture manufacturing, drying fruit, or making jam and juice) and contribute substantially to many smallholders' incomes and food security. In this cluster, we examine the prospect of enhancing smallholder livelihoods by better production and marketing of these products on farms and investigate the impacts of different forms of forest management on livelihood outcomes[30]. This contrasts with FP4, which looks at forest management from the perspective of managing, maintaining and regenerating 'forests' for multiple purposes. We collaborate across Flagship Projects to deliver on integrated timber production (combined analysis of farm and forest supply) and design of community forestry interventions that combine livelihood and forest management outcomes. Often, land and tree tenure create barriers to people (often women) obtaining benefits from trees and associated products[31]. Forest legislation often mitigates against farmers exploiting timber in managed fallows at forest margins or regenerating trees on farms. Trees on farms are an increasingly important source of timber, with huge potential for productivity and profitability gains through better management practices and market development. We are researching how smallholders can get improved access to lucrative and legal timber[32] and fruit markets through opportunities for expanding sustainable harvest of a diversity of NTFPs, as well as ways to increase income from trees by incorporating quality germplasm (in collaboration with FP1) and appropriate tree management in farming and smallholder forest systems[33]. A major thrust of research surrounds the social aggregation of smallholders in various institutions and the associated private-sector engagement that can improve market opportunities by smallholders accessing financing and inputs to intensify their livelihoods, and through more lucrative arrangements for selling products. We experiment with alternative ways of catalyzing value-chain innovation platforms that can achieve these outcomes. This research contributes to increasing livelihood opportunities and more productive and equitable management of natural resources (Sub-IDOs 3.2 and 9.1).

CoA 2.3 Developing and sustaining smallholder tree-crop commodity production

The overarching hypotheses are (i) that appropriate incorporation and management of companion trees in cocoa and coffee production systems, alongside appropriate fertilizer and pest control, can increase and sustain productivity of existing stands and buffer against climate change; (ii) that rubber and oil palm production systems can be made more sustainable through intercropping; and (iii) that smallholders can derive higher income from product sales through improved certification schemes and by exploiting specialist market niches.

Research questions: How can smallholder tree-crop commodity production systems be sustainably managed in the face of climate change, price volatility, declining yield and soil fertility following forest conversion, coupled with constraints on opening new forest areas, and those imposed by the dynamics of migration? What is required in terms of an enabling environment to switch from unsustainable monocultures to more diverse and resilient production practices?

Tree crops produce important globally traded commodities including cocoa, coffee, rubber and oil palm and are the basis of smallholder livelihoods. Cocoa and coffee alone cover 20 million ha and are the mainstay of over 30 million smallholder households. There is a hotly contested debate around the need to intensify production and how to do this without aggravating environmental and social disbenefits, around which a plethora of certification schemes have emerged. In Phase 1, we established the importance of trees in sustaining soil fertility and yield in cocoa as well as in providing diversification options and contributing to the food security of smallholder farmers[34]. Pests and diseases affect yield and are influenced by climate and tree shade – with important opportunities for trees to buffer climate change and contribute to the control of pest and disease spread[35]. Yield gaps for coffee vary at the fine scale in relation to soil conditions and farmer practices, with trees having the potential to buffer anticipated climate change effects[36]. The farming of cocoa and oil palm are competing land uses at forest frontiers, making diversified production systems attractive to policy-makers reconciling production and environmental goals. We have major engagements to develop national schemes for diversified cocoa in Peru and oil palm in Brazil to address these needs. There is a huge area of recently planted rubber, particularly in China. We are looking at developing 'green rubber' production practices that are environmentally benign and sustainable. This research contributes to increasing livelihood opportunities through diversification of monocultures and closure of yield gaps by sustainable intensification focused on agronomic management, including planting materials, pruning and fertilization (Sub-IDOs 3.2 and 9.2).

CoA 2.4 Trees supporting sustainable agroecological intensification

The overarching hypothesis is that the establishment and better management of tree cover in crop fields and farmsteads can increase and sustain soil health and crop yields while contributing to system intensification through provision of fodder and fuelwood on farms.

Research questions: What are the optimum levels of tree density and diversity in different contexts required to increase total productivity of smallholder livelihood systems while conferring resilience at farm and landscape scales? We also need to understand how to effectively promote the desired density and diversity, given a widespread history of removing trees from agricultural land, conflicts between grazing animals and tree regeneration and promoting of a few, largely exotic tree species on farms and in woodlots, rather than more diverse options. What is the relationship between tree cover (density and diversity) and soil health and where are there trade-offs and synergies between production goals and the provision of other ecosystem services?

Trees are an important cornerstone of system intensification in many contexts; they improve and sustain soil fertility by tightening nutrient and water cycling[37], fix nitrogen, control erosion and sustain soil biota[38]. By providing fuelwood and fodder on farms, they free up labor for other tasks and may substitute for other resources, such as fuelwood instead of dung being burnt, which can then be returned to the soil. In Phase 1, we established that farmers typically retain a range of trees on their farmland for different purposes with characteristic profiles of tree use and management, and that farmers have detailed knowledge about tree attributes for a diversity of species that determine their utility for intensification[39,40]. We also established fine-scale variation in the performance of fertilizer trees in relation to landscape position, species, altitude, soil properties, rainfall and agronomic practice[41]. Advances in genomics[42] are allowing us, for the first time, to connect functional profiles of the living soil to different tree species, densities and management. We are now combining high-end science with local knowledge to develop and test species-diverse tree management options to intensify livelihood systems and increase their resilience. We are researching governance options to address tree ownership and control the free grazing of cattle, which often prevents farmers from managing naturally regenerating trees on their land. This research contributes to smallholders getting increased access to diverse, nutrient-rich food, closing yield gaps as trees improve and maintain soil health, and directly contributing to production, reducing and reversing land degradation, and increasing the resilience of smallholder livelihoods (Sub-IDOs 5.2, 8.1 and 3.1).

CoA 2.5 Sustaining silvo-pastoral systems for production, animal welfare and the environment

The overarching hypothesis is that establishment and better management of tree cover on pastures can contribute simultaneously to higher livestock productivity, animal welfare and biodiversity conservation as well as restoring degraded rangelands and avoiding future degradation.

Research questions: What is the relationship between tree cover (density and diversity) and pasture and animal productivity and welfare in silvo-pastoral systems? Where are there trade-offs and synergies between production goals and the provision of other ecosystem services?

FAO[43] estimates that grasslands are by far the largest agricultural use of land (26% of all land globally and >70% of agricultural land) and contribute to the livelihoods of 800 million people. Trees in pastures are ubiquitous in the Sahel and much of Latin America and provide fodder and shade for animals as well as sustaining soil fertility and contributing to biodiversity conservation. It is increasingly realized that while retaining trees on pastures can halt and reverse degradation following deforestation, appropriate species and densities are required to do this profitably and productively. In Phase 1, we established not only the importance of tree cover on pastures for production and biodiversity conservation, but also the sustainability problems that can arise for tree regeneration unless measures are taken to retain sufficient refuges at landscape scales for farm-level regeneration to be possible[44]. As climate change advances, deepening and lengthening dry spells in the seasonally dry tropics, trees and shrubs are increasingly seen as a supplementary fodder source[45]. Loss of production due to heat stress in farm animals has been estimated at over USD 40 billion per year and presents a major animal welfare challenge. We are researching how best to develop multi-strata silvopastoral systems, live fences, windbreaks and fodder banks as key development options to sustain smallholder livelihoods based on pasture use. This research closes yield gaps through improved pasture management and animal husbandry, and contributes to reducing and reversing land degradation (Sub-IDO 8.1).

2.2.1.7 Partnerships

Partnership strategy: We engage with development partners, the private sector and policy-makers from the outset of our research so that the outputs address important issues in a form suitable for uptake and thus generate outcomes and impact (Figure 1). Upstream partners deliver understanding and expertise that underpin the development of new options. These include: Simulistics[46] (software SME) co-developing a proprietary modeling environment; CSIRO collaborating to incorporate trees within their APSIM suite of globally calibrated crop models; Bangor University of Wales, UK researching genomics to understand the functional profiles of soil biota; local knowledge and participatory GIS; and a range of other advanced research institutes (SLU, Sweden; Cornell, Columbia, USA and University of Adelaide, Australia). We have ongoing collaboration with African universities including JKUAT in Kenya (joint long-term research site with many registered postgraduate students), Makerere University in Uganda and the universities of Mekele and Hawassa and Wondo Genet College of Forestry in Ethiopia. We engage with the private sector at a large scale (Mars Inc. on cocoa in Côte d'Ivoire; Unilever on *Allanblackia* in Africa; Clarins on plants for the cosmetic industry in China) and with national SMEs that co-develop novel products such as nonperishable forms of *Docynia indica* in Vietnam[47]. IFAD, ESPA, WWF, ActionAid, CARE and SahelEco are partners for delivery at scale. The Ministries of Environment and of Agriculture in Peru and EMBRAPA in Brazil are engaged with us in developing option-by-context matrices for cocoa and oil palm, respectively. Local governments of three provinces in northwest Vietnam are co-investing in scaling-up the effectiveness of introducing trees on sloping land and we are engaged with three county governments in Kenya (Machakos, Makueni and Kitui) in developing communities of practice around sustainable intensification. The success of our research in development strategy depends on development partners engaging and delivering, so we have developed a six-point plan to manage the risks associated with interactions with our partners elaborated in Section 2.2.3.

Comparative advantage: Livelihood systems are at the heart of the new SRF, as it is here that poverty reduction and food and nutrition security manifest. Trees have been undervalued components of fields, farms and agricultural landscapes, often eliminated as more intensive agriculture has developed and then later reintroduced when sustainability challenges become acute. Hence, there are huge gains possible from research on developing and promoting tree options to enhance smallholder livelihoods. Institutions tend to separate agriculture and forestry, so that new approaches are necessary to address the farm–forest interface. CGIAR is in a unique position to broker this engagement, both because it involves novel methods, tools and approaches, and because it demands profound change in the way that national and regional bodies do business. FTA can also influence these issues because it has a unique combination of partners, from upstream research to development practitioners, covering a broad combination of disciplines, applied across a carefully selected geographical range, that typifies the challenges that are faced globally. We collaborate as shown in Figure 3, with CCAFS and RTB on developing tree-crop commodity production systems (CoA3), with maize, rice, wheat, DCL-AFS and WLE in addressing sustainable intensification (CoA 4) and with livestock in silvo-pastoral systems (CoA 5).

2.2.1.8 Climate change

Enhancing smallholder livelihoods requires explicit consideration of global change, with climate change as one of several key drivers that affect longer-term productivity and resilience. Climate change is more important for some of the production systems we are working on than for others. For example, some tree-crop commodities such as coffee are particularly sensitive to climate change and we work collaboratively with CCAFS on integrating climate change predictions about areas likely to be suitable for growing coffee in the future, into our intervention options, as well as the potential for using shade trees to buffer these effects. Similarly, climate change is likely to have larger implications for smallholder forestry and agroforestry in some geographies more than in others, with some of the most severe issues relating to combined rainfall and temperature effects in already dry and highly variable climate zones within which population is increasing at an alarming rate (e.g. some parts of the Sahel). Since trees are generally long-lived, we factor climate change into the development of options more generally, collaborating with FP1 on appropriate germplasm for climate proofing in different contexts and with FP5 on mitigation and adaptation options. From a livelihoods perspective, while mitigation initiatives present opportunities to enhance income, they often have differential effects across social groups. Thus, we focus on developing carbon finance initiatives that are positive rather than negative in terms of equity, vulnerability and empowerment of marginalized groups such as women and ethnic groups that are constrained in their access to land.

2.2.1.9 Gender

Gender-focused research comprises over 20% of our research portfolio. This is driven both from the need to achieve greater gender equity as a goal in its own right and from the hypothesis that natural resource management (NRM) that is more inclusive of women will be more effective. We do a gender audit across each research cluster, each year and interact with gender specialists to explore the extent to which we are asking relevant and sufficient gender research questions and are using appropriate and comparative methods and tools. The emphasis of our gender research is shifting from understanding gender differences to exploring the means of achieving more equitable NRM and reduced labor requirements for women (gender-transformative outcomes). In Phase 1, we found that a numerical representation of women in NRM institutions did not necessarily confer better NRM outcomes for issues important to women who were shaping the decisions[48]. In Phase II, we will address substantive representation in institutions and broader research on gender to encompass the changes in the enabling environment required to achieve gender equity.

2.2.1.10 Capacity development

The co-learning paradigm (Figure 1) embedded within our ToC (Figure 2) and key impact pathways (Figure 3) places capacity development center stage, requiring a profound shift in the way research, development and private-sector organizations operate. Specifically, we recognize the transaction cost involved in getting a critical mass of people within partner organizations to a level of awareness, understanding and with an appropriate skill set for 'research in development' to become self-sustaining. We are confident that this is possible because of early successes in Phase 1, through which initial engagements were sustained because of positive feedback resulting from adopting new approaches[49]. In Phase II, we will ramp up this co-learning by careful assessment of capacity needs followed by addressing the capacity development needs that are identified (CapDev Element 1). This will result in improving the innovation capacity of research (D.1.3) and development (D.1.4) organizations/or partners, and the private sector. The adopted co-learning paradigm moves away from a top-down approach to knowledge transfer in favor of co-production – and hence ownership – of new knowledge and experience. We explicitly deliver learning materials and delivery approaches (Element 2) and by strengthening communities of practice (that include innovation platforms), we contribute to Element 10. We partner with a number of universities and have built in PhD and MSc studentships as a key element of the FP (Element 4).

2.2.1.11 Intellectual asset and open access management

Intellectual assets (IA) produced under FTA are in compliance with the CGIAR principles on the management of intellectual assets (CGIAR IA principles) and CIFOR IA management policy for effective dissemination of research outputs and maximizing global impact. The following CGIAR IA principles shall be adopted as guidance on IA management of FTA:

- FTA research results and development activities are regarded as international public goods for the maximum possible access.
- Partnerships are critical to ensuring access to the best knowledge and innovation to achieve maximum impact.
- There will be sound management of intellectual assets (IA) and intellectual property rights (IPR) with integrity, fairness, equity, responsibility and accountability.
- All IAs produced under FTA are managed in ways that maximize global accessibility.

In line with the CGIAR open access and data management policy and CIFOR OA policy, FTA outputs will be made available under the least restrictive licensing to describe the legal rights to information products and encourage their use and adaptation. It will be published in a format that can be downloaded, indexed and searched by commonly used web applications. The outputs will be disseminated through open access repositories to ensure it is archived and shared systematically with other Centers and made accessible as IPG.

A specific narrative on FTA IA management and open access implementation is available in Section 1.0.12 and 1.0.13 of the Full FTA Proposal, including a detailed strategy for IA management in Annex 3.10 and OA/OD implementation in Annex 3.9.

2.2.1.12 FP management

The FP is led by Fergus Sinclair at ICRAF who has navigated the Flagship through the first phase, creating an effective program across participating institutions and a broad range of upstream and development partnerships to deliver high science quality with development impact. Cluster leaders have been nominated from across the partners within FTA and have two out of five (40%) as women. Cluster leaders will be financially supported to organize research within their cluster across partners within FTA as well as, where appropriate, with other CRPs. Patricia Masikati, a very practical, outcome-orientated system modeler at ICRAF will coordinate upstream inputs from CSIRO at field and Simulistics at farm and livelihood scales in CoA1 and work with Tim Pagella on evaluating ecosystem service trade-offs and synergies at local landscape scales. She will also interact with ICRAF's modeling team in Bogor, Indonesia (Betha Lusiana and Adrian Dwiputra) to develop in-house capacity to adapt and develop APSIM sub-models. The Flagship has strong links from CoA 3 with CCAFS and RTB, from CoA 4 to maize, wheat, rice, DCL-AFS and WLE and from CoA 5 to livestock. The cluster leaders will form a management team for the Flagship, while inclusivity across partners will be achieved through the use of a Yammer group, which has proved successful in keeping a critical mass of scientists engaged at both the proposal and pre-proposal writing phases. The nominated cluster leadership is organized as follows:

1. Systems analysis, synthesis and scaling. Tim Pagella, Bangor University, UK.
2. Timber, food and fuel production and marketing. Peter Cronkleton, CIFOR
3. Tree-crop commodities. Philippe Vaast, CIRAD
4. Sustainable intensification. Catherine Muhturi, ICRAF
5. Silvo-pastoral systems. Adriana Chacon, CATIE.