2. Flagship Projects

2.1. Flagship 1 Tree genetic resources to bridge production gaps and promote resilience

2.1.1 Flagship Project Narrative

2.1.1.1 Rational and Scope

The effective use of tree genetic resources (TGR) to bridge production gaps, ensure profitability and for the essential global diversification of production options as highlighted by GAPAD[1] provides important opportunities to improve livelihoods and sustain ecosystems, and is a crucial part of reversing current cycles of land degradation and deprivation (Dawson et al. and Thomas et al. in[2]). However, the role of TGR in the provision of tree products and services has often been undervalued (Loo et al. in[2]). This has resulted in the cultivation of trees not matched to context, with poor yields and low-quality traits. Opportunities to prevent deforestation and landscape degradation, and to stop narrow agricultural intensification and dietary homogenization, have therefore been lost.

Flagship 1 addresses the under-recognition of the importance of TGR for productive and sustainable landscapes; the lack of coordination and appropriate investment in relevant research; and the inadequate models, tools and support mechanisms for effective testing and upscaling. Activities on **safeguarding** genetic diversity, **domestication** and planting material **delivery** are newly located within a single Flagship, whereas they were previously spread across different components of FTA Phase I, which resulted in a lack of effective integration. Safeguarding research ensures the proper characterization and continued availability of the fundamental resources – the trees – that support agroforestry and restoration planting, while protecting the utility of existing tree populations through their proper genetic management. Domestication research is concerned with the use of large gene pools to support significant genetic gains in tree traits that are important for product and service provision, matched to the production systems and landscapes of growers (Table 1). Research on delivery systems ensures that high quality, needs-matched, tree planting material reaches growers efficiently, to support wide-scale adoption of product and service options. By together drawing on recent methodological advances in each of these three areas, effective coordinated approaches are mainstreamed to provide a route to greater impact.

The enabling environment for coordinated research on TGR has recently become more favorable. First, the findings of the first *State of the World's Forest Genetic Resources* report (SOW-FGR)[3] brought the importance of TGR safeguarding for the 3000+ trees used by humans to wider attention. Awareness was reinforced by recent Action Plans for TGR conservation[4], and by prominent concerns of the pitfalls of small founder tree populations for disease susceptibility under climate change (Alfaro et al. in[2]). Second, recent community genetic research has revolutionized our understanding of the role of TGR in environmental service provision, showing that genetic diversity can be as important as species diversity[5]. This research has provided insights into species interactions that can be used to force positive relationships between genetic diversity and yield in agricultural systems not achievable naturally[6]. Third, greater awareness of climate change has reestablished the importance of resilience that can be supported by diversity breeding and decentralized participatory domestication approaches which consider production traits enhanced by genetic variation, and which use local landscape-level deployment to maintain planting material diversity[7]. Fourth, a greater focus on dietary quality has raised the profile of 'orphan' crops including nutrient rich tree foods in food production[8]. If the massive extant genetic variation of these crops is translated through increased recommended investments in domestication[9] into productivity, quality and profitability gains, they can compete with crop staples (Figure 1). Fifth, renewed investments in forest restoration[10] rely for success on access to site-matched tree planting material, and provide new opportunities to realign existing suboptimal delivery systems. Recent landscape research has also indicated the tree traits that can be manipulated at the genetic level to improve restoration success[11].

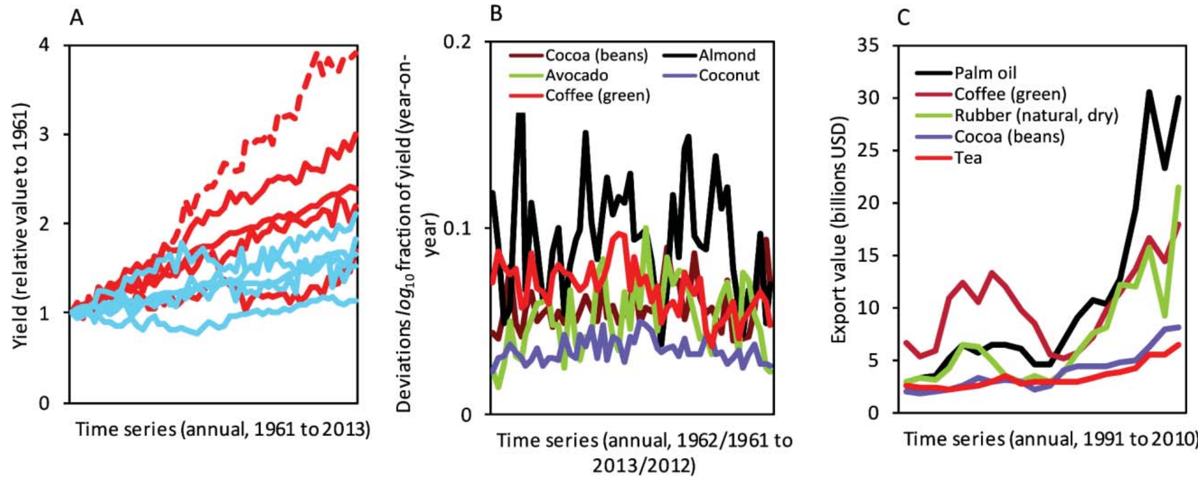

Figure 1. Supporting data for Flagship 1, extracted from FAOSTAT databases. A, 50-year yield time series for 10 crops with large increases (red) or decreases (blue) in their relative contributions as human foods[9]. The red dashed line is the exceptional case of oil palm. Most crops with a large increase in relative importance have doubled in yield over the period. With suitable investment, such gains should be readily achievable for new and orphan tree crops, allowing them to successfully compete in agricultural landscapes; B, Yield stability time series (as A) for five fruit tree crops with > 10% dependence on animal pollinators. Year-on-year instability can be high, but can be reduced by appropriate breeding/selection, choice of propagule type and system- and landscape-matching; C, 20-year export value time series for five formally-bred tree commodity crops. Data indicate high and increasing values, justifying investment in new, and further investment in existing, tree crops.

Table 1. Supporting data for Flagship 1, compiled from indicated sources (Sections 2.1.1.1 and 2.1.1.2)

Topic	Data
Trait improvement through domestication	(Section 2.1.1.1) Level of improvement depends on trait, propagule, production context and method of evaluation. Genetic gains can be high because of large gene pools and limited histories of domestication of many trees. Timber yields have been raised by a factor of two for several trees[12], with similar gains possible for fodders[13]. Significant gains in growth form for timbers and palatability and protein content for fodder trees are also attainable. High yield and food quality (e.g. vitamin, fiber) variation is observed in indigenous fruit trees and in tree commodity crops, although gains in yield are particularly sensitive to production context (e.g. because of pollination requirements)[14]. Cost: benefit analysis shows that investments in genetic improvement can be greatly outweighed by the extra value of the gains achieved (e.g. the case of acacia improvement in Vietnam, where a ratio of 1: >50 was estimated[15]).
Immediate beneficaries Flagship 1	(Section 2.1.1.2) Conservative numbers for beneficiaries draw on experiences among others with: the Mars-funded Vision for Change project to rehabilitate cocoa production with improved planting material in Cote d'Ivoire that, to date, has reached > 10,000 farmers[16]; rural resource center activities that support domestication and market access that serve > 10,000 households in Cameroon (and raise revenues for tree nursery practitioners); scalability projections for the Technologies for African Agricultural Transformation initiative (TAAT) for particular tree crops; and the experiences of the AgFor project in Indonesia, where > 15,000 individuals were trained in tree nursery management and propagation, and where > 500,000 residents benefited from improved access to quality tree seedlings produced in farmers' nurseries[17].
Long-term indicative economic value of domestication and delivery	(Section 2.1.1.2) Value represents an estimate for an extended 10-year intervention period, based on: an assumed year zero economic value of a range of tree commodity crops/products and other existing and new perennial crops/products/services that the program works on directly or influences of 200 billion USD annually (reasonable considering Figure 1C); a baseline of 1% year-on-year increases in productivity/quality of these tree crops/products/services is increased to 1.2% through program intervention, starting in the 1st year and being sustained (and accumulating) over the period (based on large gene pools from which selection can take place and improved technologies for capturing variation; larger gains are frequently attainable); and a baseline of a 1% yearly farmer replacement rate of improved tree planting materials that result from domestication activities is improved year-on-year by 0.5% over the intervention period, starting in year 1 and accumulating. Replacement rates are currently low in part because of ineffective delivery systems as well as the long time to maturity and longevity of many trees, which gives scope for considerable improvement, although effective intervention faces many challenges
Economic value of safeguarding	(Section 2.1.1.2) There are few economic analyses of the value of safeguarding TGR. Of the cases available, coffee is the best example[18]. Analysis of the value of wild coffee genetic resources in Ethiopian forests for three future breeding purposes indicated a net present value of 420 million USD, based on 30-year discounting period, a discount rate of 10%, a 15-year period for successful breeding into cultivars and a 20% adoption rate for improved cultivar planting. Similar analyses although not currently available are required for other tree gene pools, especially of high value species. An obvious candidate is cacao, with its high market value, the need to upgrade production to respond to low yields and pest and disease losses, and current reliance on a relatively narrow genetic base in breeding

2.1.1.2 Objectives and targets

Objectives

Availability and access to quality tree-planting materials suited to location and purpose are serious global constraints to tree planting. Narrow agricultural intensification coupled with loss and degradation of natural forests leads to ecologically impoverished landscapes with low productivity, as well as lost opportunities, besides threatening TGR. Flagship 1 research addresses these challenges by co-developing effective and affordable methods, technologies, gender-responsive guidelines, decision-support tools and proofs of concept in partnership with relevant institutions and networks. By applying optimal combinations of TGR safeguarding measures specific to ecological, geographical and societal contexts, by combining new and already available tree domestication approaches, and by developing context-specific delivery systems for the best available planting materials, livelihoods, and productive and resilient ecosystems, are supported – and current declines are reversed.

Outcomes and Targets

By 2022, Flagship 1 will increase capacity, share data and make recommendations for positive change or improvement in policies and institutions. Allocation of the three main Flagship 1 outcomes to funding windows is shown in Table 2. These outcomes contribute to Sustainable Development Goals 2, 13 and 15. Targets for Flagship 1 by 2022 are shown in Table 3.

Table 2. Outcomes by windows of funding

Outcomes	Amount needed (million USD)	W1/W2 (%)	W3 (%)	Bilateral (%)
1. (Safeguarding) Managers and policy-makers adopt effective monitoring methods, tools and practices to mitigate threats to valuable TGR, and implement suitable safeguarding strategies in line with international initiatives, such as the Global Plan of Action for Forest Genetic Resources and the Global Strategy on Conservation and Use of Cacao Genetic Resources	23	19	0	81
2. (Domestication) Agricultural and horticultural research and development partners adopt cost-effective domestication approaches for priority tree species, based on impacts and maximizing efficiency, and considering trade-offs involved in intensification, while paying attention to smallholder breeders' rights	23	19	0	81
3. (Delivery) National governments, extension services and private partners adopt cost-effective and equitable tree-planting material delivery approaches, with attention to appropriate international and national policies governing material transfer/use agreements and using the most appropriate decision support tools, to supply high-quality site-appropriate tree-planting material to smallholders and other growers	23	19	0	81
Total	**69 million**	19%	0%	81%

Table 3. Targets by 2022

Activities	Targets
Safeguarding	Support for implementation of global and regional strategies for TGR conservation in Latin America and Africa; support for *circa situ* safeguarding of TGR of 10 globally-important and 100 regionally-important food or income-generating tree species; tools and approaches for reducing the impacts of threats such as illegal logging and over-grazing in place in five key countries; on-line status and threat assessment tools for 100 species in Latin America and 100 in Africa used by managers to develop national conservation strategies; effective, efficient and equitable approaches and policy recommendations for TGR conservation developed for 10 priority species in target countries in each of three continents; training materials, characterization methods, policies and indicators of status and threats adopted in 10 countries
Domestication	Guidelines and decision-support tools on domestication approaches adopted by national research partners in at least 10 countries, with national and private sector breeders, on user-prioritized species; genomic data and assembled germplasm collections/panels fully developed and used in breeding strategies for five important food tree crops; stakeholders testing at least 10 more potential 'varieties' of trees across agro-ecological zones; public and private partners engaged in tree domestication activities to reach identified needs with incipient cultivars for at least three more tree species
Delivery	National extension partners, private companies and others involved in agroforestry and restoration initiatives in 10 countries have adopted best practices for sourcing planting material; national partners, on protected public land, have established new breeding/production seed orchards for 20 tree species globally; policy-makers have incorporated appropriate certification standards into delivery systems in five countries; farmers have adopted user-friendly online and mobile phone decision support tools to support tree planting choices in conjunction with market information services in five countries; national extension partners have determined and adopted improved context-specific delivery approaches for priority tree species in 10 countries, with the roles of the various actors involved properly aligned; changes in policies and strategies by national governments and implemented by national extensions services have resulted in entrepreneurial suppliers becoming more engaged in delivery (supplying at least 20% more material than 2016 levels) in five countries

Within the timescale of FTA Phase II, we estimate the number of smallholders benefiting directly from Flagship 1 activities due to improved access to resources through safeguarding as more than 500,000, with more than 1 million additional community beneficiaries (such as forest harvesters). We estimate the numbers positively affected directly by domestication activities that extend beyond smallholders to wider rural stakeholders to be similar. We anticipate the numbers of smallholders benefiting directly from Flagship improvements in planting material delivery systems to be 2 million or more, while more than 10 million will benefit from more effective restoration supported by improved delivery (Table 1). A longer-term (after 10 years) indicative value of interventions in economic terms and with effects amplified through wider adoption of the theory of change is estimated as an annual benefit following program intervention of ~USD 230 million in today's prices (Table 1). This does not account for reduced losses in genetic diversity through safeguarding that support options for future production by TGR incorporation into breeding and selection programs, which would increase the value of the intervention further, as illustrated by an analysis of wild coffee genetic resources in Ethiopia that indicated a net present value of ~USD 420 million (Table 1).

Links to IDOs and SDGs

Three Clusters of Activity (CoA) constitute the research program of Flagship 1. The CoAs contribute to the CGIAR's SRF sub-IDOs as follows:

- CoA 1.1 (safeguarding): sub-IDOs **4.4**, 5.2, **8.2**, 8.3, 9.2, **9.3**
- CoA 1.2 (domestication): sub-IDOs 1.2, 2.2, 3.1, 3.2, 3.4, **4.3**, 4.5, **5.2**, 8.3, **9.1**, **10.2**
- CoA 1.3 (delivery): sub-IDOs 1.2, 3.1, 3.2, **3.4**, **4.5**, **8.3**, 9.1, 10.1, 10.2, 10.3.

Bold indicates sub-IDOs of highest importance, described in Table 4 along with allocations of Flagship 1 investments.

Table 4. Investments by sub-IDOs

Sub-IDOs	Amount needed (million USD)	W1/W2 (%)	W3 (%)	Bilateral (%)
4.4 Increased conservation and use of genetic resources	6,9	19	0	81
8.2 Enhanced conservation of habitats and resources	4,1	19	0	81
9.3 Enrichment of plant and animal biodiversity for multiple goods and services	2,8	19	0	81
4.3 Enhanced genetic gain	6,8	19	0	81
5.2 Increased access to diverse nutrient-rich foods	2,8	19	0	81
9.1 More productive and equitable management of natural resources	2,1	19	0	81
10.2 Enhanced adaptive capacity to climate risks	2,1	19	0	81
3.4 More efficient use of inputs	6,8	19	0	81
4.5 Increased access to productive assets, including natural resources	3,5	19	0	81
8.3 Increased genetic diversity of agricultural and associated landscapes	3,5	19	0	81
A.3 Improved forecasting of impacts of climate change and targeted technology development	3,45	19	0	81
A.4 Enhanced capacity to deal with climatic risks and extremes	3,45	19	0	81
B.2 Technologies that reduce women's labor and energy expenditure developed and disseminated	3,45	19	0	81
B.3 Improved capacity of women and young people to participate in decision-making	3,45	19	0	81
C.1 Increased capacity of beneficiaries to adopt research outputs	3,45	19	0	81
C.3 Conducive agricultural policy environment	3,45	19	0	81
D.4 Enhanced institutional capacity of partner research organizations	3,45	19	0	81

2.1.1.3 Impact pathway and theory of change

Flagship 1's theory of change is illustrated in Figure 2. Through co-research and co-development of decision support tools and by capacity building, stakeholders are better able to define priorities, select methods and improve and implement practices and policies for TGR safeguarding within and in addition to wider forest, woodland and tree conservation measures. These stakeholders include national agricultural, forestry and horticultural research institutions, policy-makers, national planning agencies, global conservation organizations, community forestry groups, local authorities, and the private sector. Through similar approaches and the adoption of model domestication pathways and decision support tools, stakeholders are able to more widely and effectively promote and apply new approaches to tree genetic improvement in combination with well established existing methods to realize faster, more targeted and better sustained genetic gains for a wide range of tree species during domestication, suited to production and landscape contexts. More efficient and inclusive tree planting material delivery options and support tools, developed through co-research and through engagement with policy-makers, the private sector, government extension services, national tree seed centers and business development NGOs, enable the upgrading and commercialization of input suppliers, including women and youth enterprises. These suppliers are then able to more effectively provide growers with a range of more productive, diverse and/or site-matched tree planting materials that provide better options than existing materials. These measures support incomes that encourage a general reinvestment in farming and forest management. Through co-research with national partners, a better understanding of how, when and where domesticated resources and otherwise appropriately chosen planting material contribute to the provision of environmental services leads to more sustainable TGR management guidelines for adoption through national policy-makers. This knowledge also reveals important traits that inform domestication. Improved planting material inputs increase the range, yield and quality of tree products available for rural women and men and their households, supporting their incomes and diets, and enhancing the success of restoration initiatives. As farmers and traders further integrate improved tree products into value chains with the support of small and medium enterprises (SMEs) and larger commercial companies, peri-urban and urban consumers benefit through increased availability at reduced unit production costs and hence at lower consumer prices, enhancing the range of accessible products. Among other benefits this supports dietary diversity. Central to the theory of change is the assumption that all stakeholders are able to recognize the value of TGR, and therefore support pathways to impact. An important role of Flagship 1 is therefore to characterize and demonstrate this value, which is often not immediately apparent, and how it can be captured and mobilized.

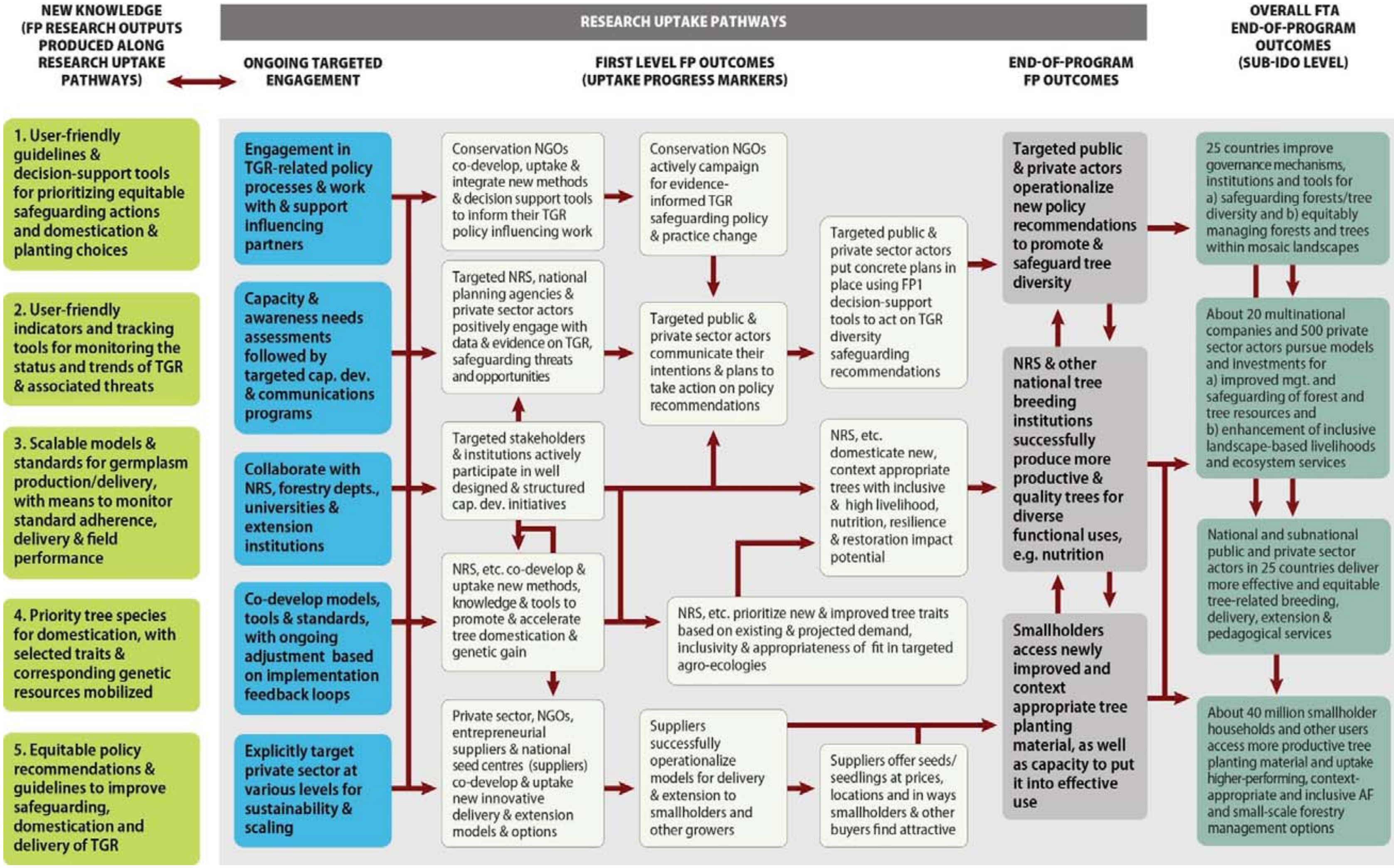

Figure 2. Theory of change for Flagship 1

Reaching impact through linkages with other Flagships, CRPs and platforms

The research of Flagship 1 targets, develops and ensures appropriate delivery options for the most basic input – tree planting material well matched to production and landscape contexts – that is promoted by other FTA Flagships. Each of the three elements of Flagship 1 are therefore clearly represented in all four of FTA's key end-of-program outcomes. Interactions between Flagship 1 and other FTA Flagships are summarized in Table 5 and Figure 3. Flagship 1 impacts are determined primarily through close interaction and research co-investment with Flagships 2 and 4; these relay positive effects to Flagships 3 and 5, respectively (Indicated in Table 5 in bold). Interactions with other CRPs and platforms requiring further exploration within FTA Phase II are also indicated.

Table 5. Summary of interactions with other FTA Phase II Flagships, CRPs and platforms

Component	Contributions of FP1 to…	Contributions from Flagship, CRP, platform to FP1…
FTA Flagships		
FP2 (livelihood systems)	**Improvements in tree characteristics that support sustainable intensification in a range of production systems and at various spatial/temporal scales, e.g. through enhancing mixed species LER**	**Development of appropriate planting material delivery options for different production contexts; effective/equitable approaches for up-and out-scaling TGR interventions (e.g. participatory domestication); joint testing of domestication traits in multi-species systems**
FP3 (value chains; mediated through FP2)	A range of planting material options for higher-quality tree products and more useful services with greater market value, suitable for incorporation into, and the diversification of, value chains	Selection/prioritization of market-determined species and traits for tree domestication; options to integrate tree-planting material into product/service markets, including public-private partnerships/SMEs; market-based certification approaches for safeguarding TGR
FP4 (land-scapes)	**Planting material options better matched to a range of landscape/ ecological niches, supporting restoration; more optimal (genetic) management of landscapes to support products, services and resilience**	**Development of appropriate planting material delivery options for different landscape configurations; joint testing of different/evolving landscape configurations on TGR across scales, and the effectiveness of particular environmental service rewards for TGR safeguarding; prioritization of tree traits to support landscape resilience**
FP5 (climate change; mediated through FP4)	Site-matched, 'future-proofed' tree-planting material, with high adaptive capacity and greater mitigation opportunities (e.g. carbon sequestration and biofuels)	Important tree traits for adaption and mitigation, including new trait combinations for novel environments; climate models to indicate planting domain shifts under future climates
SP (impact & inclusion)	Indicators, tools and capacity training to monitor and evaluate FTA II success from the context of the value of TGR in supporting productivity and sustainability	Development of key indicators for measuring impacts and demonstration of value of TGR to stakeholders; adaptive learning to guide future research directions and support TGR mainstreaming within the wider FTA

Component	Contributions of FP1 to…	Contributions from Flagship, CRP, platform to FP1…
CRPs		
A4NH (with FTA II Flagship 4)	More nutritious, productive and production system- and site-matched tree foods aligned with the prioritized needs of communities	Prioritization of relevant traits for food tree domestication to support nutritional quality and diversity, within tree food and annual food crop portfolios
CCAFS	Tools for tree-site matching under future climates, based on key tree traits	Models to help FP1 study tree distributions and determine tree-planting material delivery systems to meet future site-specific climates
PIM	Key adoption, impact and policy concerns for TGR and related technologies	Framework for TGR tenure, ownership and governance issues; effective and cost-efficient policies, strategies and extension approaches for facilitating uptake of planting material
Livestock	Cross-transfer of domestication tools and delivery systems, especially for animal forages	Important tree traits to maximize positive interactions in mixed livestock production systems; threats to TGR safeguarding
All AFS CRPs	Nexus for FTA II-wider AFS CRP learning; models for genome-environment marker-assisted selection and focused trait identification using natural plant populations; lessons for annual 'orphan' crops delivery; information on tree-crop interaction traits (with FTA II FP2)	Models for domestication and planting material delivery to be adapted to the specific context of tree species, key traits, products and services; opportunities for exploring positive tree-crop interactions by focusing on key interaction traits (with FTA II FP2)
Platforms		
Big data	Tree genomic data, for exploration of synteny with crops (e.g. legumes); geo-referenced species, vegetation and risk assessment maps; modeling approaches to support analytical capability	Methods for comparative analysis of genomes, distributions and interactions, supporting safeguarding priorities, trait capture and climate-smart delivery approaches
Genetic gains	Models for genome-environment association analysis based on natural plant populations (as under 'all AFS CRPs'); case studies where large gains possible through platform use	Links with experienced scientists, outsourced services and range of tailored solutions for the use of advanced genomic methods in TGR domestication, especially relevant for the African Orphan Crops Consortium (AOCC)[19]
Genebanks	Context-specific information on the relevance of complementary safeguarding approaches, exploring positive and negative interactions between methods; identify gaps in *ex situ* collections; feedback, perspectives and context for ABS arrangements (Policy Module)	Characterization of TGR supports the prioritization of safeguarding *in* and *circa situ* and of candidate material for domestication; raw material for domestication; phytosanitary support to tree-planting material delivery systems; framework for dealing with ABS of domesticated and wild tree resources (Policy Module)

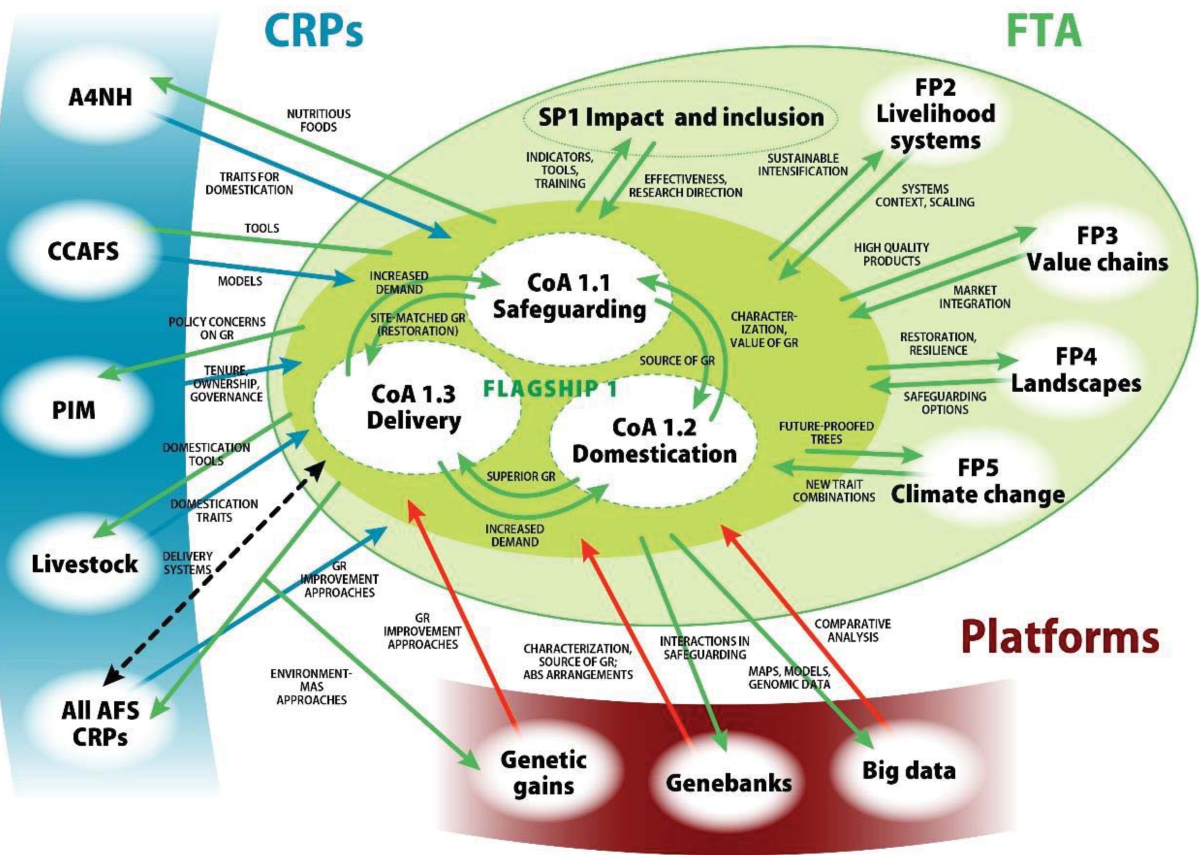

Figure 3. Linkages with other FTA Flagships, CRPs and platforms, including nested linkages between Flagship 1 clusters. Major impacts for Flagship 1 within FTA are mediated through Flagships 2 and 4.

Developing a theory of place for Flagship 1

The development of Flagship 1's theory of place (Figure 4) involves Flagships 2 and 4 in particular. Geographic foci of CoA 1.1 are genetic diversity hotspots where important TGR exist and where resources are threatened, within the range of landscape configurations of Flagship 4. CoA 1.2 activities focus on priority tree species determined by local women and men, market needs and other important factors such as 'researchability' and tend ot be more localised in distribution. CoA 1.3 locations are chose for their value in 'proof of concept' testing for up and out-scaling according to Flagships 2 and 4, in addition to cognizance of the locations of other large-scale agroforestry/restoration initiatives. For CoA 1.3, Flagship 4 provides a framework of landscape configurations for different planting material delivery systems. CoA 1.3 not only considers the priority species of CoA 1.2, but a diverse portfolio of species for production and restoration.

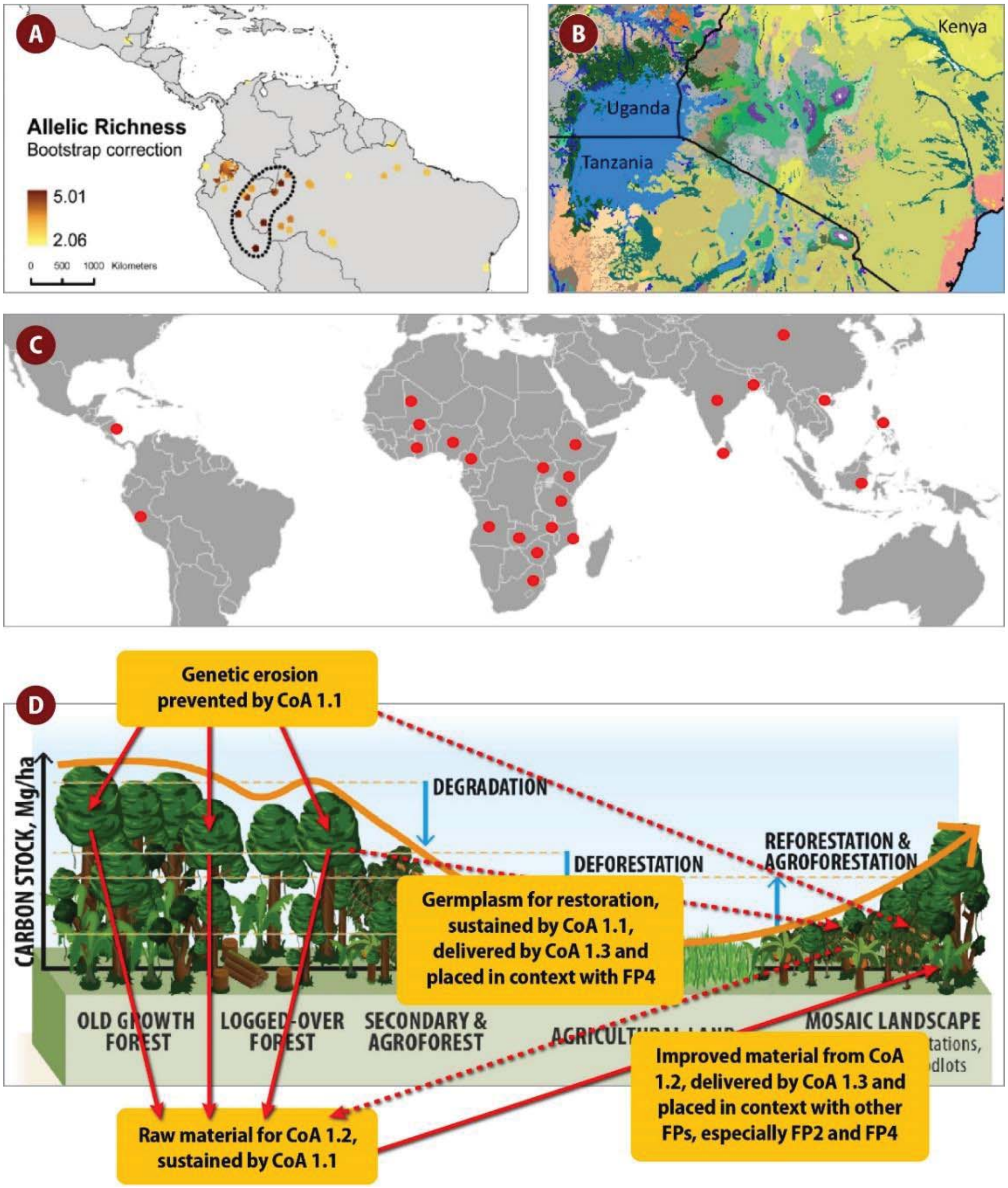

Figure 4. Elements of the theory of place for FP1. A, Genetic diversity hotspots in cocoa in the Amazon, based on molecular markers, indicating priorities for safeguarding purposes (dashed enclosure; CoA 1.1); B, High resolution vegetation map for eastern Africa (extracted snapshot) informing what trees should be planted where in the region for delivery purposes (different colors indicate different vegetation types; CoA 1.3), guiding plantings initiatives. Superimposed on other spatial data sets, maps such as A and B support the 'when' as well as the 'where' of the up- and out-scaling of plantings relevant for other FTA Flagships; C, Countries with tree domestication activities (CoA 1.2) under FTA Phase I are indicated by red circles. Species worked on, with common names, example countries and their key use(s), include: *Allanblackia parviflora* (allanblackia, Ghana, fruit for edible oil), *Allanblackia stuhlmannii* (allanblackia, Tanzania, fruit for edible oil), *Dacryodes edulis* (safou, Cameroon, fruit), *Docynia indica (son tra, Vietnam, fruit), Gliricidia sepium* (madre de cacao, Indonesia, shade and soil fertility replenishment), *Guazuma crinita* (bolaina blanca, Peru, timber), *Prunus africana* (African cherry, Cameroon, medicine) and *Sclerocarya birrea* (marula, Malawi, fruit); D,

Placing the three Flagship 1 CoAs within the context of the forest transition curve of FTA illustrates the linkages between them.

2.1.1.4 Science quality

Flagship 1 is concerned with salience, combining novel with well-established methods where this advances the ability to address strategic issues for TGR, particularly in bridging knowledge gaps for key bottlenecks to reach improved development outcomes and impacts. We start with a range of important tools and the knowledge framework generated under FTA Phase I. For safeguarding, for example, a number of innovative spatial datasets were derived, including MAPFORGEN[20] and vegetationmap4africa[21]. Work on genetic diversity indicators also revealed more practical and affordable measures (Graudal et al. in[2]), while a greater understanding of the possible interactions between TGR safeguarding options and past and contemporary land- and resource-use patterns was obtained, which guide conservation and sustainable use practices across different settings within the context of wider conservation actions[22]. For domestication, a wealth of experience in methods for different product and service requirements was obtained. Allanblackia, a new fruit tree domesticate that reached the market with food oil, was an important case study that involved the development of a novel public-private collaborative platform to support domestication with market integration. The approach is currently being applied to other indigenous fruits such as safou in Central Africa and son tra in Asia. Considerable new experience was also gained in decentralized participatory tree domestication approaches, especially in Central Africa[23], that achieve positive outcomes for livelihoods, nutrition and the social standing of participants, their households and communities, and which encouraged the development of new enterprises to undertake domestication and deliver new fruit tree varieties[24]. For delivery, innovative characterization of current delivery systems has led to the development of more effective approaches to allow different stakeholders to align their objectives and to work together positively to reduce the costs for suppliers and growers in sourcing planting material, with particular emphasis given to the role of small entrepreneurial suppliers[25].

In FTA Phase II, earlier outputs and outcomes will be extended in scope based on lessons learned (Section 2.1.1.5) and newly developing approaches and knowledge. Innovative tools and approaches will be applied and improved in the following ways (relevance to particular CoA indicated):

- By the application of new thinking on appropriate TGR safeguarding approaches that challenge 'conventional wisdom' on the benefits of cultivation and the linkages between safeguarding settings in different contexts (CoA 1.1)[26].
- By mainstreaming of advanced, geo-spatial methods of threat mapping and gap analysis in combination with local 'gendered' knowledge, to support partners in determining safeguarding priorities for TGR (CoA 1.1, building on Phase I maps[20,21]).
- By further development and testing of novel hand-held media tools of vegetation and other map resources to support both safeguarding (CoA 1.1) and planting material delivery for trees with the right products/services for particular production systems/landscapes (CoA 1.3)[27].
- By the application of in-house next generation sequencing facilities working in collaboration with other institutions, breeder networks and global bioinformatics support to facilitate new approaches to the domestication of priority trees, through the AOCC initiative (CoA 1.2)[19].
- By the application of new statistical methods to combine genomic and interpolated environmental information to test potential and limits for marker-assisted selection for environmental adaptation, including with regard to anthropogenic climate change (CoA 1.2).
- By further exploring the production system and landscape contexts of up and out-scaling of decentralized participatory domestication approaches for tree products and services that consider consumer and private sector concerns (CoA 1.2)[28].
- By integrating genomic-environmental data sets with participatory domestication, to facilitate the deployment of TGR more closely adapted to a wide range of different production and landscape contexts (CoA 1.2 and 1.3).

- By option testing of new, inclusive and context-tailored entrepreneurial support models for tree-planting material delivery systems for smallholders and restoration practitioners, with the use of innovative Before-After-Control-Impact experimental designs that have not yet been applied to the sector (Graudal et al. in[2]) (CoA 1.3).
- By applying new ensemble climate modeling approaches that determine probability-based delivery/suitability domains for tree planting to a much greater range of trees (CoA 1.3), making available the developed packages to the ecological research community for wider application.
- By further developing flexible and resilient approaches for tree planting material supply in the context of anthropogenic climate change effects for landscape restoration[29], based on considerations of both genetic and species suitability, phenotypic plasticity and emerging knowledge on current practice (CoA 1.3).

Competitive advantage

Endnote-listed references that include the Flagship 1 team indicate that the program brings together leading global researchers. A recent publication highlight was a special edition of *Forest Ecology and Management* on TGR edited by Flagship 1 staff, with many co-authored contributions, which contained some of the most downloaded articles for the journal in the following year[2]. Another recent highlight was the SOW-FGR[3], which was supported by Flagship 1 staff at FAO's request in the form of data collection, advice, review, writing of chapters and of thematic studies[11]. This last initiative was illustrative of the ability of Flagship 1 to bridge research, development and policy concerns, with a 'research for development' team that deliberately integrates science with practice, and which is capable of large program management and delivery (see appended CVs and Table 6).

A summary of various online resources involving the current Flagship 1 team produced under FTA Phase I is given in Figure 5, illustrating high annual use of products and indicating the visibility of the staff involved in research and development communities. A co-authored statistical software suite (vegan), for example, has been cited more than 8,400 times in the scientific literature[30], and has had more than 350,000 installations. Staff have wide experience of research in different geographic areas and at various scales, and in working with a wide range of stakeholders, collaborating with well-established key partners globally (see Section 2.1.1.7). The ability to bridge communities provides context and realism to research, and supports progression into impacts, as do important contributions and leadership in policy discussions globally on TGR[4]. Of key importance, the teams' researchers have the detailed understanding of tree biology needed to underpin effective research.

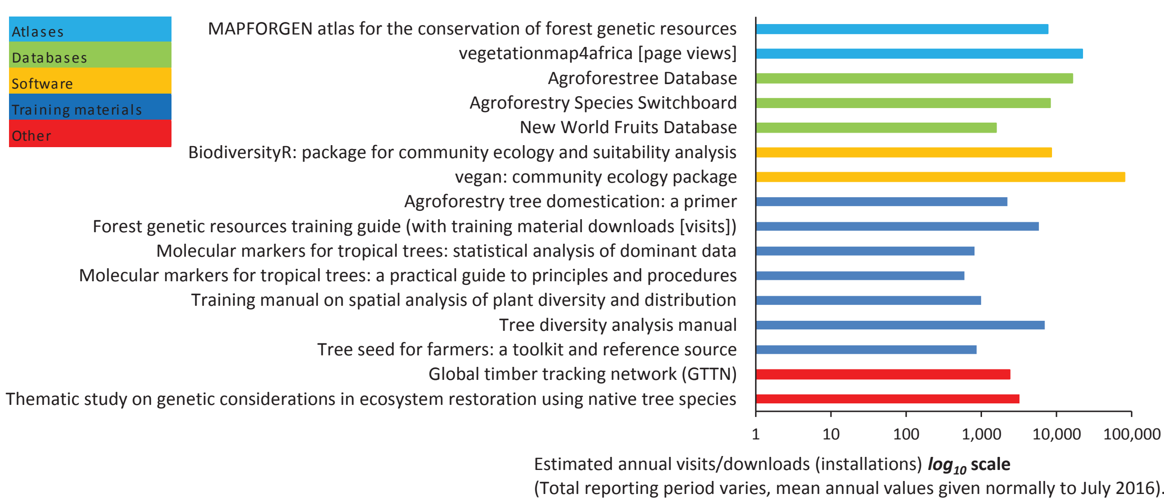

Figure 5. Annual reads and downloads/installations of various online outputs of the Flagship 1 team. Note the log_{10} scale on the *x* axis.

Table 6. Key scientists and development practitioners for Flagship 1 (alphabetic **surname** order)

Name, institution	**Specific skills**	**H**	**Total Citations**	**Rank CGIAR** (if CGIAR)	**Position in FP1**	**FTE**
David **Boshier**, Univ. Oxford	Conservation ecologist	19	2,070	-	CoA 1.1 support, conservation	0.20
Richard **Coe**, ICRAF (ILRI, Reading)	Statistical expert	27	3,899	55	FP1 support, statistics	0.20
Jonathan **Cornelius**, ICRAF	Forest genetics and management	20	1,837	120	FP1 support, strategy	0.3
Ian **Dawson**, ICRAF (& JHI)*	Genetics and genetic resource specialist	26	2,003	101	FP1 support, strategy	0.65
Jerome **Duminil**, Biover. Int*	Forest geneticist	12	1,168	139	CoA 1.1 (sci.)	0.20
Steve **Franzel**, ICRAF	Agricultural economist	35	4,745	45	FP1 support, economics	0.20
Lars **Graudal**, Univ. Copenhagen (& ICRAF)*	Development practitioner, ex-Director Danida Seed Centre	10	586	-	CoA 1.3 lead	0.80
Rhett **Harrison**, ICRAF	Conservation, forest ecologist	22	2,242	95	CoA 1.1 (senior sci.)	0.30
Chris **Harwood**, CSIRO	Tree breeder	20	2,076	-	CoA 1.2, 1.3 support, domestication, delivery	0.20
Ramni **Jamnadass**, ICRAF*	Genetic resources specialist	20	1,838	119	FP1 Leader	0.80
Wanjiru **Kamau-Rutenberg**, AWARD*	Gender expert, AWARD Director	n/a	n/a	-	FP1 support, gender issues	0.15
Roeland **Kindt**, ICRAF*	Ecologist	23	12,053	12	CoA 1.3 lead support	0.80
Roger **Leakey**, ITF	Domestication expert, ex-Director research ICRAF	48	7,350	-	CoA 1.2 support, domestication	0.20
Judy **Loo**, Biover. Int.*	Forest geneticist	16	914	171	CoA 1.1 lead	0.75
David **Neale**, Univ. California Davis **	Tree genomics expert	n/a**	> 10,000	-	CoA 1.2 support, genomics	0.10
Jim **Roshetko**, ICRAF	Delivery specialist	18	1,389	130	CoA 1.3 (senior sci.)	
Zac **Tchoundjeu**, ICRAF*	Domestication specialist	32	3,478	64	CoA 1.2 lead	0.90
Evert **Thomas**, Biover. Int.*	Ethnobotanist	15	580	234	CoA 1.1 (sci.)	0.70
Barbara **Vinceti**, Biover. Int.*	Conservation specialist	16	2,629	87	CoA 1.1 lead support	0.50
Jianchu **Xu**, ICRAF	Agroforestry-landscape ecologist	33	8,290		CoA 1.1, 1.3 (senior sci.)	0.30

*Scientific leaders for FP1 whose CVs have been provided. ** Not on Google Scholar.

2.1.1.5 Lessons learned and unintended consequences

Combining safeguarding, domestication and delivery research into a single Flagship is a means to effectively apply lessons from FTA Phase I. These include:

Safeguarding: combining varied information sources allows rapid out-scaling of spatially explicit safeguarding tools. Calculating 'option values' for TGR is crucial and these need to be combined with genetic diversity indicators, perceived values, and threat and distribution information, to prioritize safeguarding. Interactions between TGR safeguarding methods for *in*, *circa* and *ex situ* environments need to be explored further in a range of landscapes, to develop environmental reward systems specifically targeted to TGR.

Domestication: Experience in domestication methods, including the decentralized participatory approach, shows that such interventions are most successful when part of a suite of measures that encourage general upgrading of farm practices, including support for soil fertility replenishment[31]. Domestication approaches shared with public and private partners including SMEs can be applied to a wide range of tree products and services. Specifically considering the role of women allows skewed benefits to be more effectively addressed.

Delivery: Planting material delivery approaches for annual crops require specific adaption for application to trees. Lessons on effective stakeholder interactions need to be appropriated to realize 'proofs of concept' and impacts. Integration of delivery models into value chains with tree product markets is required, working with SMEs[32] through approaches such as participatory domestication, which requires scaling out from Central Africa. Particular attention is needed to strengthen weak extension services that are a bottleneck in adoption.

Placing TGR in context: TGR must be considered in the context of inter-specific diversity. Appropriate safeguarding systems for TGR enhance, and ameliorate loss, of inter-specific diversity as well as of genetic variation. Better domestication approaches can support, maintain and enhance positive interactions between species. More optimal delivery systems result in a wider range of tree species being planted, which supports overall diversification. Understanding the interactions between intra- and inter-specific diversity is important for placing TGR in the context of all other FTA Flagships.

We seek to avoid the following key potential unintended consequences of TGR research:

- That policy measures put in place to safeguard TGR, including access and benefit-sharing (ABS) arrangements to benefit local communities, and high option values for TGR, result in limited access to TGR for research and hinder the distribution of superior material for use by farmers and other tree growers.
- That domestication and market expansion result in a trend to monoculture in production, rather than desired diversification, reducing service provision and increasing production risks.
- That enhanced delivery for planting material results in new species assemblages that interact negatively in production systems (e.g. introducing weeds and diseases), causing declines in productivity and resilience rather than gains.
- That the increased profitability of production resulting from domestication and improved planting material delivery leads to the clearance of forests for tree cultivation and/or reduced attention to the management of natural resources, as a less-important source of product.

Examples of collaboration to avoid these potential consequences include: encouraging open ABS arrangements that support communities but do not unduly hamper innovation; and resisting trends to monoculture by exploiting genetic resources to maximize land equivalence ratios in mixed production systems.

2.1.1.6 Clusters of activity (CoA)

Formulated based on global and national priorities, the CoA of Flagship 1 on safeguarding (CoA 1.1), domestication (CoA 1.2) and delivery (CoA 1.3) research represent the core interdependent elements in effective management and use of TGR. Progress in each is needed to reshape current suboptimal mainstream practice that negatively affects development. The priority for safeguarding research stems from the recent SOW-FGR recommendations; for tree domestication research from levels of improvement and the high investment returns possible with the proper use of gene pools that increase production options (Table 1); and for delivery research from the widespread failure of current delivery mechanisms to support tree planting matched to site and purpose, along with the recognition that institutional reorientation and other measures can result in much improved practice, as demonstrated in the crop sector. The purpose of research in Flagship 1 is to address the key 'need to know' strategic elements of research to improve current outcomes (W1/W2 funding), providing lessons that can then be tested and applied more widely through development in practice that feedbacks to strategy (W3 funding).

The positionings and inter-linkages between CoA were outlined earlier in Figure 3 and, with reference to the forest transition curve of FTA, in Figure 4D. In more detail, the safeguarding research of CoA 1.1 helps to describe, and support the availability of, the TGR that are the raw material for tree domestication activities in CoA 1.2. Similarly, well-described and safeguarded TGR are important sources of site-matched planting material for restoration activities, supported through the delivery pathways developed by CoA 1.3 research. At the same time, the domestication research of CoA 1.2 helps characterize important genetic traits and patterns of intra-specific variation important for safeguarding activities in CoA 1.1. Domestication research defines the values of particular TGR for providing important products and services, supporting safeguarding and defining priority areas for conservation based on a utilitarian justification of use value. With regard to CoA 1.3, CoA 1.2 research supports the devleopment/selection of superior planting material that is then delivered by the cluster. Finally, the realization of impact through the delivery of site-matched and/or genetically improved planting material to growers through CoA 1.3 supports the importance of domestication research in CoA 1.2 and of the TGR retained through the safeguarding of Cluster 1.1. The relationships between CoA 1.2 and CoA 1.3 in addressing production- and ecosystem service-provision gaps through both up-scaling and out-scaling are illustrated in Figure 6.

The hypotheses and assumptions behind research for each of Flagship 1's CoA are given in Table 7.

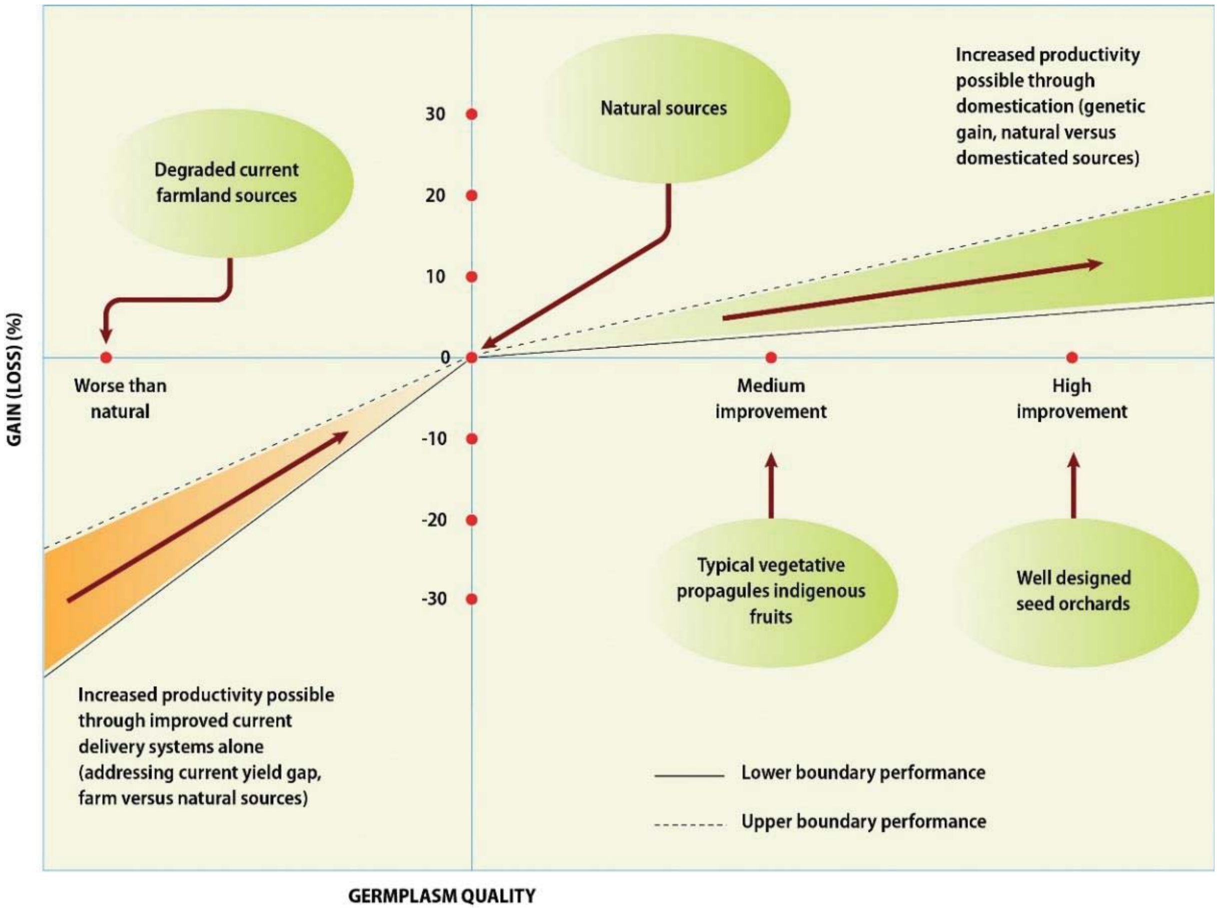

Figure 6. Schematic illustrating the gains in performance available through changes in the planting material sources used by smallholders. Initial productivity gains are frequently possible just by improvements in delivery systems that allow sub-optimal degraded material (compared to existing natural, unimproved) sources to be replaced on farmland. Further gains are supported by domestication activities, with the possible gains varying by domestication approach and intensity. The diagram illustrates that all productivity gains depend on having appropriate planting material delivery systems in place.

CoA 1.1 Safeguarding diversity

CoA 1.1 is concerned with safeguarding TGR vital for the sustainable future of humankind. The important roles of these TGR in supporting landscape resilience and productivity have been neglected, due in part to the often cryptic nature of variation (hidden to the naked eye), and inadequate valuation. In a reversal of the adage "can't see the forest for the trees", the focus of development has been at the landscape, forest or ecosystem level, often to the detriment of the trees themselves – "can't see the trees for the forest". In fact, TGR provide important environmental services to support production and enhance resilience, while they are an essential resource to support new domestications for tree products and services, as well as for enabling progress in ongoing domestications of important existing tree commodity crops such as cocoa, coffee, coconut, timber and other products. Furthermore, access to diverse, site-matched TGR is necessary to respond to important initiatives in landscape restoration, including the concept of a 'land degradation neutral world'.

At the same time as providing resources for domestication, however, the dynamics of tree domestication potentially support a trend either to landscape diversification (via successful integration) or to commodity crop monoculture (via displacement), and these different trajectories complicate safeguarding. Conventional methods that remain essential have been *in situ* conservation, needed because many tree species still exist primarily in the wild, and *ex situ* seed/planted 'genebanks' for species that have been the subject of cultivation and some improvement. But, new and more holistic approaches that include on-farm *circa situ* methods are required, considering possible synergies and likely trade-offs with *in* and *ex situ* techniques, depending on species, production context and landscape.

The research of CoA 1.1 builds upon existing knowledge and current TGR safeguarding initiatives. It does so with innovative methods to develop and disseminate appropriate and efficient conservation and sustainable use approaches for TGR that benefit women, men, and their households, in different ecosystems, and in various national and regional settings. Research includes analyzing, spatially characterizing and mapping patterns of tree genetic diversity and threats that affect the well-being of rural people in forest and farm landscapes. Research seeks to resolve questions regarding mainstream theory on TGR conservation practice, such as the assumption that the cultivation of timber and tree commodities is sufficient to safeguard their genetic resources. Research determines the conditions when such wisdom holds, based on production systems, landscapes and tree biologies, and through synthesis integrates this information with the wider concerns of production system and landscape conservation. Economic analyses of the options provided by TGR are crucial to compare the value of land use for genetic safeguarding with alternatives, for example where wild relatives of tree crops are conserved compared to clearance and agricultural use.

Key research questions:

1. Indicators and methods: What are the most cost-effective indicators and methods to determine the extent, trends/threats and value (current and option, for productivity and resilience) of TGR in natural and restored forest, farm and other settings, to identify the location and intensity of threats to valuable TGR and support the development and implementation of appropriate safeguarding partnerships and activities?

2. Safeguarding combinations: What are the minimum requirements and optimal combinations of safeguarding approaches for TGR, considering synergies and trade-offs between them in specific contexts, including in particular geographic regions, production systems, landscapes, and policy environments, and considering different users' needs, to support sustainable resource management?

3. Stakeholder engagement: How can stakeholders be convinced and supported (e.g. through payments for ecosystem services) to develop, implement and monitor cost-effective conservation plans and strategies for safeguarding TGR in different contexts (forest, farm, etc.), taking into consideration conservation status, trends and threats for target species, and local knowledge and experience?

Deliverables

1. Effective and affordable methods and decision-support tools, including status and threat assessment maps and appropriate option value methods for the prioritization of safeguarding actions, which consider landscape, production systems, biodiversity (genetic diversity) hotspots, protected area or other assigned conservation status, TGR availability and value, and specific users' needs; 2. Nationally and regionally endorsed actions plans and networks for TGR safeguarding, with minimum requirements defined at the regional level; 3. User-friendly characterization methods and indicators with practical guidelines for their application in monitoring the status and trends of TGR and associated threats, with case study applications; 4. Case studies on the utility/limitations of ABS in supporting the characterization of TGR and for safeguarding; and 5. Policy briefs, reward systems, strategies and guidelines for appropriate safeguarding of TGR in various political, socioeconomic and environmental contexts, at different scales, and based on the biology of the species concerned.

CoA 1.2 Tree domestication to enhance products and services

CoA 1.2 focuses on the domestication of tree species identified as priorities by producers and consumers to enhance production, profitability and farm-level resilience. Large gene pools support the domestication of new tree species, of continued domestication of incipient domesticates, and of already domesticated tree commodities, although the value of these gene pools has often been ignored in the past except for a few high value trees. The variation from within gene pools can be deployed 'as is' (for example, choosing the best existing provenances for restoration planting) for immediate impacts or can be incorporated into more formal breeding/improvement programs for longer-term gains in productivity and production stability. Greatly accelerated and better targeted genetic gains are achievable by combining traditional methods for selection such as multi-locational field trials with novel genomic, phenomic and modeling approaches that can now be applied to previously little-researched trees because of the lower costs of approaches, providing opportunities to revisit the use of these species in farming systems. Since wild trees tested in genomic studies evolved *in situ*, environmental datasets based on their sample locations are of particular value in genome-environment association studies to identify markers linked to adaptive traits.

Diversity breeding and decentralized participatory domestication approaches also support impact while maintaining resilience through the deployment of genetic diversity, with the participatory approach being gender-responsive. Research is concerned not only with traits directly connected to tree products, but with those that contribute to environmental service provision, and with the 'interaction traits' between components of production systems. Our research is concerned with two levels of activity in domestication. The first is to provide a limited number of worked examples of domestication ('spear' species that forcibly demonstrate the value of domestication, such as allanblackia; see legend to Figure 4C) as strategic models that can be adopted by others to domesticate further tree species. Work here focuses on currently underutilized species. The second level of activity is to provide a range of guidelines, training tools, online databases and maps, which through promotion networks for information exchange, spread best domestication practice globally.

Key research questions:

1. Domestication approaches: What are appropriate, cost-effective domestication approaches for priority trees, and how can impacts in providing products and services be effectively assessed among possible domestication options, to maximize efficiency in bridging production gaps and in enhancing profitability?

2. Trade-offs in domestication: How can domestication approaches be developed and implemented that fully consider the trade-offs involved across the intensification gradient (polycultures-monocultures), and support higher levels of species and genetic variation in production landscapes, to strengthen their resilience?

3. Smallholder involvement: What are appropriate measures to put in place (e.g. the protection of intellectual property) to support the wider participation of smallholders and local communities in developing new and unique 'cultivars' of a wide range of tree species, that supports impact by out-scaling?

Deliverables:

1. Dynamic (producer- and consumer-sensitive) lists of priority tree species for domestication, with key traits for production, including those that support positive agroecosystem interactions, identified; 2. Gender-responsive guidelines, and decision-support and practical tools, for tree domestication; 3. Public-private consortia engaged in tree domestication; 4. Improved 'varieties' of priority tree foods and for other tree products, with value visible for growers in comparative demonstration plots/trials; 5. Genetic resources mobilized through the genotyping of appropriately assembled germplasm collections, combined with public databases of genomic, phenotypic and environmental information; and 6. Appropriate ABS models for farmer-developed tree varieties.

CoA 1.3 Delivery systems for tree-planting material

CoA 1.3 focuses on research to support the development of trustworthy and efficient delivery systems for best quality tree planting material, for farmers and other growers including large restoration projects, addressing the consistent constraint of poor planting material availability that has been unaddressed in large part because of inadequate attention to appropriate institutional roles and stakeholder interactions. The research of CoA 1.3 bridges the knowledge to action gap on existing delivery systems, incorporating development-based experience in working with tree nurseries, seed dealers and other input suppliers. Research is concerned with exploring the utility and implementation of appropriate systems and the constraints that must be addressed to reach impact. This includes adapting annual crop delivery approaches to trees, with adjustments based on tree uniqueness (time to maturity, fecundity, range of species, level of domestication, 'cryptic' gains, etc.). It also involves adapting the few successful existing delivery systems for tree commodities to a wider range of trees.

There are businesses opportunities for smallholders and other local entrepreneurs and SMEs, including women and youth, in the establishment and upgrading of tree nurseries, and in the provision of logistical services and agronomic advice, boosting rural economies where agroforestry initiatives are underway. Increasing commitments to restoration also provide new opportunities for planting material supplier businesses. Special effort to include women-preferred species enhances their participation. A range of innovative decision-support tools links planters with appropriate planting material, based on available sources, site and the purpose of planting.

Key research questions:

1. The baseline of delivery systems: what are the most effective ways to characterize, evaluate and monitor ultimate success of the current tree-planting-material delivery systems to smallholders and other growers, including of the sources, pathways, actors (collectors, producers, traders, other distributers, NGOs, government agencies, etc.) and policies involved, in order to provide a baseline from which to make improvements?

2. Appropriate delivery systems: what are the most cost-effective and equitable tree-planting-material multiplication and delivery systems for smallholders and other growers, to supply high-quality, site-appropriate material, taking into account: the required scale and reach; the appropriate division of costs and benefits among stakeholders; the need to provide complementary options to buffer production risks; and the existing policy environment?

3. Information and regulation: what decision-support tools, policy measures and regulatory frameworks are required to allow growers to match and anticipate production requirements and restoration objectives with suitable, available tree-planting material, taking into consideration changes in climate, markets, social diversity, quality of natural regeneration and other important trends?

Deliverables:

1. Delivery system models for tree-planting material that support and reinforce the needs and interests of different users, including for both women and men smallholders and (other) landscape restoration practitioners; 2. Community-based and entrepreneurial multiplication and delivery enterprises e.g. seed orchards and rural resources centers; 3. Appropriate quality standards (e.g. accreditation schemes) developed and promoted to actors in the germplasm production and delivery sector; 4. Measures to ensure these standards are mainstreamed by policy-makers, extension services and the private sector, including manuals, policy briefs, and other capacity and extension materials on delivery systems; 5. User-friendly decision-support tools to inform planting choices in conjunction with market information services and restoration requirements; and 6-8: Indicators to monitor the performance of delivery pathways with regard to models (6), to standards including the performance and viability of planting (7), and to evaluate quality and the needs for management (including enrichment) of natural regeneration (8).

Table 7. Hypotheses and assumptions behind the three CoA of Flagship 1's research

Cluster		Assumptions
CoA 1.1	Genetic diversity can be monitored by cost-effective development and application of adequate tools, with methods for safeguarding being adjustable in response to suitable indicators; an optimal combination of TGR safeguarding measures can be identified in specific ecological, geographical and societal contexts, considering the positive and negative interactions between the measures applied; regulatory frameworks and incentive schemes in favor of integrated TGR safeguarding can be designed	Demonstrating the value of TGR for improved livelihoods, restoration and domestication supports safeguarding activities in collaboration with farmers and other stakeholders; more efficient tools and approaches to support TGR safeguarding, including through the sustainable extraction of products, can be devised from an understanding and description of model species and the contexts of systems; policies and legal instruments implemented to provide for ABS can be compatible with the characterization of germplasm that supports TGR safeguarding priorities
CoA 1.2	It is possible to apply a range of context-specific domestication approaches and to determine their relative cost-effectiveness for different production systems and landscapes; appropriate domestication approaches are available to contribute effectively to farm- and landscape-level resilience through the adequate management and deployment of TGR, maintaining or enhancing diversity; the protection of small farmers' intellectual property enhances the local development of tree 'cultivars' of documented quality, and facilitates their diffusion through formal and informal channels (facilitated by CoA 1.3)	A key factor that supports the integration of new tree crops in agricultural production systems is an increase in productivity and/or product quality; sufficient genetic diversity is present within tree species to realize large genetic gains (and hence production gains, once material is delivered to growers through CoA 1.3); communities have already or can obtain land and tenure rights that allow them to reap the benefits from improving their production systems through better quality tree planting material inputs; policies and legal instruments implemented to provide for ABS do not need to prevent access to TGR to support genetic improvement activities
CoA 1.3	Context-specific characterization of planting material delivery systems can be undertaken for trees to allow for an adequate assessment of their efficiency; among the wealth of differently organized input supply systems that are currently applied it is possible to identify those that work best in a given context; it is possible to produce context- and tree biology-specific recommendations for tree planting material delivery systems, enabling high potential for increasing productivity and farm- and landscape-level resilience	Smallholders and other tree planters will demand higher-quality planting stock when its benefits have been demonstrated to them and/or when appropriate certification/traceability schemes are in place, increasing adoption and providing market opportunities for germplasm suppliers; better institutional organization of stakeholders involved in delivery can reduce transaction costs for farmers and other growers in obtaining suitable material; policies, legal instruments and certification schemes, implemented to provide for ABS, to protect breeders' and farmers' rights and to control planting material quality, provide a supportive environment for delivery and do not significantly increase transaction costs

2.1.1.7 Partnerships

Important partners include agricultural, forestry and horticultural research institutions of global and national excellence, as well as development agencies and practitioners, and private companies, as outlined below. To develop improved methods and action plans for TGR safeguarding in CoA 1.1, partnerships operate with conservation organizations and networks that work at regional and global levels, including APFORGEN, LAFORGEN, CacaoNet, COGENT, INGENIC and ICCO. To co-develop, inform and implement policy change in CoA 1.1, partnerships operate with government agencies including Treaty-competent authorities and inter-governmental actors, including FAO, CBD and the secretariats of the International Treaty on Plant Genetic Resources for Food and Agriculture and the Nagoya Protocol, along with their national focal point in target countries. To further integrate CoA 1.1's activities on TGR into a global context, Flagship 1 participates in the Global Tree Assessment led by Botanic Gardens Conservation International and the IUCN Global Tree Specialist Group. To set domestication priorities, access genomic and informatic resources, and help drive impact in new (and reinvigorated old) tree product markets in CoA 1.2, partnerships operate with the private sector at global and regional levels, including with Mars Inc., Nestle and Unilever and, to understand application at the local level, with SMEs and organized farmer groups, including women's self-help groups. To facilitate the development of tree domestication methodologies, partnerships operate with national and international forestry and horticultural research centers and foundations such as the World Vegetable Center and the International Tree Foundation (ITF), public and private breeders, and regional research hubs such as BECA. To develop domestication strategies and access newly developing methods including genomic approaches, CoA 1.2 partners with the advanced research organizations UC Davis (USA) and JHI (UK). To develop and understand the implementation of appropriate planting material delivery options in CoA 1.3, partnerships operate with a range of national tree seed centers, national and international development NGOs including CONCERN, VI and World Vision, government extension services and commerical companies such as Mars Inc.. Partnerships also operate directly with SMEs to understand and develop their role in delivery systems. To develop and implement policy changes supportive of tree planting material delivery, partnerships are in place with FAO and the OECD. To specifically support delivery options for restoration programs, partnerships operate with IUCN and WRI. To provide strategic research direction, facilitate negotiations with inter-governmental actors on policies and certification, and to develop key decision support tools for delivery systems, Flagship 1 includes scientists from the University of Copenhagen, the center of expertise globally on tree-planting material delivery approaches among international advanced research organizations.

With respect to the overall impact pathway (Figure 7), many partners, and many different interactions between them, are required to bring about change, and options are needed to minimize possible negative interactions between public (e.g. government agencies, research institutions, NGOs) and private sector actors (e.g. large companies, local entrepreneurs, community enterprises), and support the equitable distribution of benefits and costs in safeguarding, domestication and delivery activities between them. An important component of partnerships with different stakeholders, therefore, is the joint definition of problems for the co-development of appropriate solutions and roles in their implementation. Close and open collaboration with farmers is also required to understand the relevance of research and devised options, based on the different perceptions of women and men, and rich and poor, farmers of the appropriate role of TGR in supporting the availability of products and services, through direct and indirect provisioning.

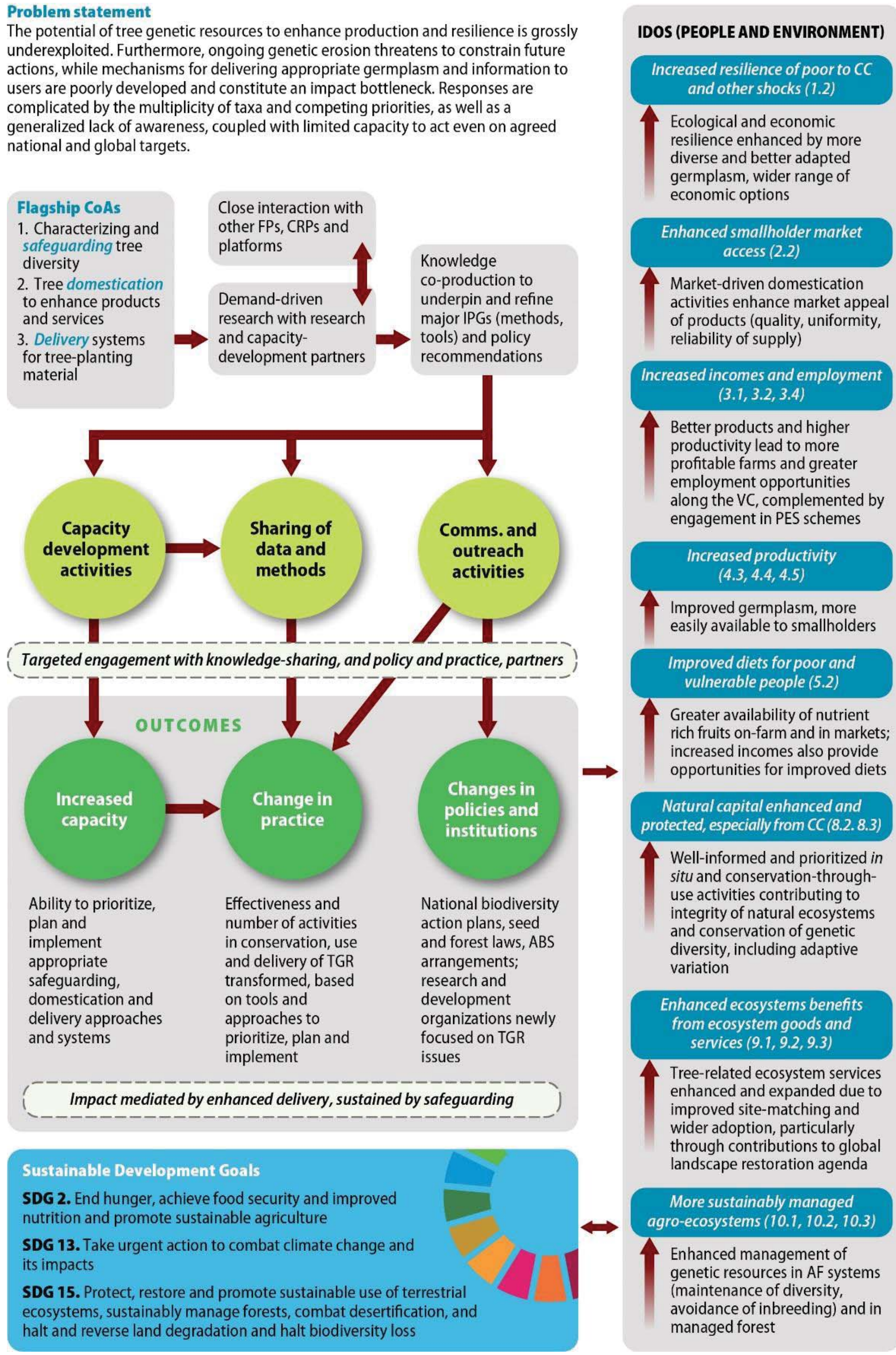

Figure 7. Schematic description of Flagship 1’s pathways to impact

2.1.1.8 Climate change

Flagship 1 has an essential role in responding to anthropogenic climate change in both an adaptation and mitigation context. Predicting and mapping climate risks and safeguarding diverse TGR that have the potential to adapt to changing and possibly new climates provides the option value to respond to change, while diversity breeding and participatory domestication provide more resilient and adaptive tree planting material that is supplied through climate-responsive delivery systems for agroforestry practices. Research within Flagship 1 indicates how tree planting patterns will need to change, and the modifications that will be required to deliver planting material for climate-smart agricultural and restoration-based responses. CCAFS provides models to study plant species distributions that can be used to describe supportive tree planting material delivery systems to meet future location-specific climate-based adaptation and mitigation needs, while the development of new ensemble climate modeling approaches for determining probability-based delivery/suitability domains within Flagship 1 can provide reciprocal benefits to CCAFS (see also Table 5). This research indicates the level of interdependency of countries for appropriate tree planting material for restoration, reforestation and agroforestry under climate change, and for which clear procedures need to be put in place for germplasm exchange of tree species under the Plant Treaty and the Nagoya Protocol.

2.1.1.9 Gender

Operationalizing change through Flagship 1 provides particular opportunities for women. Access to productive TGR as an 'input' may not be as strongly controlled by men as other resources such as land and credit. Commitment to gender begins with a particular focus on recruiting, retaining and building the capacity of woman scientists in the Flagship 1 team through the African Women in Agricultural Research and Development (AWARD) post-doctoral fellowship program, among other initiatives. Flagship 1 is the only FTA Flagship to be led by a woman. Team members are trained in gender-responsive methods in research and practice that are required to achieve equitable and sustainable impacts. In CoA 1.1, the involvement of women (and young adults) in setting safeguarding priorities is based on their particular knowledge, uses and future needs.

Participatory demand-driven research is built on local skills and fosters the inter-generational transfer of knowledge on management practices, ecology and conservation actions, within which context women have an important role in communicating with the next generation. In CoA 1.2, full attention is given to the involvement of women (and youth and elders) in setting values, species priorities and traits for selection, particularly for tree foods that have a clear role in supporting family nutrition and women (and youth) incomes. Full engagement of women (and youth) in participatory domestication approaches and in business opportunities in value addition is supported through tested approaches that address the structural constraints that limit their participation. For CoA 1.3, the involvement of entrepreneurial women (and young entrepreneurs) in delivery systems will be enhanced, seeking specific comparative advantages through understanding their existing knowledge, skills and experiences. Research includes attention to appropriate financing instruments for enabling poorer women to participate individually or in collectives. Key research that cuts across CoA is the identification of gender-responsive arrangements that help women to enhance their roles in NRM decision-making and gain greater control over derived benefits.

2.1.1.10 Capacity development

Engagement with partners to develop research and innovative capacities is essential for Flagship 1, as is outreach to communicate the relevance of TGR and their exchange in supporting agroforestry and restoration programs, to support our theory of change. Through capacity development we seek to strengthen strategic partnerships to support and co-develop TGR conservation strategies, encourage the wide adoption of tree domestication approaches, and establish the infrastructure and approaches required for well-functioning delivery systems. To these ends, Flagship 1 will maintain its good record of capacity development from FTA Phase I, as revealed by relevant outputs (e.g. Figure 5). Building on existing resources, plans for capacity development for CoA 1.1 include developing and delivering training materials for practitioners and university/research institution instructors (CapDev Element 2), and close collaboration with networks and institutions in Africa, Asia and Latin America (including SAFORGEN, APFORGEN and LAFORGEN, respectively) in how to develop plans and networks for safeguarding TGR. For CoA 1.2, specific plans include developing future research leaders by an innovative (post-degree) fellowship program for African breeders through the African Plant Breeding Academy[19] (CapDev Element 4) that supports the integration of new research approaches in breeding programs. Training of scientists and extension workers in organizational approaches and technical methods to support participatory domestication approaches (CapDev Element 2) that are then disseminated to local communities in order to support domestication impacts will also be undertaken. CoA 1.3 supports the development of capacity in national tree seed centers and farmers' networks, and among local entrepreneurs, in methods, processes and decision-support tools for developing appropriate delivery systems (CapDev Element 6). Partnership with AWARD enables the development of capacity on gender-responsiveness (CapDev Element 5). Youth will in particular be engaged through the development of innovative web-based learning tools, decision support platforms and information- and opportunity-sharing applications (CapDev Element 10).

2.1.1.11 Intellectual assets and open access management

The methods, strategies, data and decision support tools generated by Flagship 1, including maps, valuation methods, prioritization procedures, management guidelines, policy briefs, training materials and genomic/phenomic data sets will be made freely available and in a timely manner through open access online databases and portals, and in other formats suitable for different users, including on hand-held consumer devices such as smartphones. Due credit will be given to all the contributors involved in the development of these products. Improved 'varieties' of priority tree products, assemblies of tested germplasm and genetic material in multiplication stands are made available in the context of existing international, national and institutional ABS and IP arrangements such as the Nagoya Protocol and the International Undertaking on Plant Genetic Resources for Food and Agriculture, seeking as far as possible to maximize benefits to a wide range of users, with an emphasis on realizing benefits for local domesticators and smallholders. Working with PIM provides a framework for dealing with tenure, ownership and governance, while the Genebank platform Policy Module provides technical resources for dealing with ABS of domesticated tree resources, including for work undertaken in collaboration with the private sector. In addition, the tree commodity crops such as cacao and coconut that are part of the current safeguarding and delivery programs provide ABS models for newly domesticated trees and lesser-used species whose use is being intensified, indicating pitfalls and advantages of particular arrangements.

2.1.1.12 FP management

The lead CGIAR Centers for Flagship 1 are ICRAF and Bioversity International, but important collaborations within FTA Phase II are required with CIFOR, especially on safeguarding approaches. The main CGIAR partners remain the same compared to research on TGR in FTA Phase I, building on previous close collaborations. Since Flagship 1 is a new entity, however, it requires a new institutional arrangement for its management. Overall management is hosted by ICRAF, with CoA 1.1 led by Bioversity International, CoA 1.2 by ICRAF and CoA 1.3 by the University of Copenhagen, which is a longstanding partner of ICRAF and Bioversity International, with particular expertise in tree planting material delivery systems (see Table 8 and Annex 3.8 for management staff CVs). The arrangement of meetings of team members will take opportunistic advantage of the annual calendar events of individual institutions (e.g. annual Science Weeks) to invite staff from other lead institutions and other key partners to participate in scientific discussion, Flagship coordination and output finalization.