TREE DOMESTICATION BY THE WORLD AGROFORESTRY CENTRE
AND PARTNERS IN THE PERUVIAN AMAZON:
lessons learned and future prospects

Jonathan P. Cornelius

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Tel: +254(0)20 7224000, via USA +1 650 833 6645
Fax: +254(0)20 7224001, via USA +1 650 833 6646
Email: icraf@cgiar.org
Internet: www.worldagroforestry.org

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About the author

Jonathan P. Cornelius Jonathan Cornelius is a forester with special interests in smallholder (agro)forestry and tree domestication. He has worked principally in Latin America (most recently as leader of ICRAF's work in Peru) and the Pacific. He currently leads James Cook University's Agroforestry and Novel Crops Unit (Queensland, Australia), where he is involved with agroforestry and tree domestication projects in Papua New Guinea and Far North Queensland.

Summary

Background

1. The World Agroforestry Centre (ICRAF) has been active in the Peruvian Amazon since 1991. In spite of changes in emphasis, organizational structure, and its collaborative arrangements, the broad focus of its work during this time has remained constant, i.e. the generation (through biophysical research) and facilitation (through biophysical and social science research and training) of means of preventing, mitigating, or reversing resource degradation.
2. The Amazon region makes up around 60% of Peru's terrestrial area. Much of the Amazonian population of around 3.85 million lives in poverty or extreme poverty. This situation is associated with a process of land degradation linked to increasingly short fallow periods, illegal coca cultivation, and conversion of forest to unproductive grasslands. The original forest cover has been lost from about 90,000 km². Of this area, 55,000 km² are considered to be degraded or abandoned. Degradation processes are most advanced in terms of magnitude and intensity in the *Selva Alta* (rainforest in the altitudinal belt 400-2600 m a.s.l.).
3. Although ICRAF's work has targeted resource-poor farmers, the underlying justification, implicit or explicit, of this work has been environmental: to slow or halt deforestation and associated environmental degradation. For this reason, ICRAF research in Peru has focused on the Amazon rather than the principal concentrations of extreme poverty and tree scarcity (i.e. parts of the Andes).
4. Until 2003, a broad programme of research was conducted, i.e. across ICRAF's research programmes. Subsequently, due to increasingly scarce funds, research concentrated almost exclusively on continuation of the Tree Domestication Project (TDP) begun in 1995.
5. From 2003, as a response to diminishing funding, ICRAF also led the development of the Amazon Initiative Consortium. This process led to the approval in 2007 by the Consultative Group on International Agricultural Research (CGIAR) Science Council of the Amazon Initiative Eco-regional Program (AI-EP).
6. With the approval of the AI-EP and its associated thematic agenda, and due to the advanced state of the TDP, and also taking account of the new CGIAR structure and the "MegaPrograms" associated with it, ICRAF-Amazon decided to review its tree domestication activities in Peru. Accordingly, the present report, based partly on field visits and interviews in Peru in July 2009, was commissioned.

Status quo ante relevant to the future of the TDP: AI-EP and ICRAF-global agendas

7. The AI-EP's four "innovation foci" can be distilled to three essential components:
 - identification of profitable products (tangible goods, environmental services, etc.);
 - development of sustainable production systems for these products;
 - creation of a favourable policy environment, potentially both in terms of removing constraints and of instituting positive innovations.

Overall, the AI-EP agenda appears similar to the agenda that ICRAF and partners have pursued in the Peruvian Amazon since 1991, but with different institutional arrangements.

8. ICRAF's Global Research Program 1 (Domestication, utilization and conservation of superior agroforestry germplasm) has two research outputs:
- “improved agroforestry tree germplasm available with associated information on potential use, benefits and conservation while considering climatic constraints and risks of invasiveness” (GRP 1.1);
 - “prototypes available for sustainable tree seed and seedling supply systems that promote the use of diverse and productive germplasm by smallholder farmers in different social, economic and cultural settings” (GRP 1.2).

ICRAF considers one or both of these outputs to be relevant to six of the eight CGIAR MPs: MP1 (Agricultural systems for the poor); MP2 (Enabling agricultural incomes for the poor); MP4 (Agriculture, nutrition, and health); MP6 (Forests and trees); MP7 (Climate change); MP8 (Agricultural biodiversity).

Status quo ante relevant to the future of the TDP: agroforestry practice and research in the Peruvian Amazon

9. Traditional agroforestry is practised commonly in the Peruvian Amazon, particularly by indigenous and *ribereños* (long-established mestizo and deculturated indigenous farmers of riverside lands). By contrast, tree planting or nurturing on a large scale by colonist farmers seems to be less usual.
10. Fruit trees are the species most likely to be planted by small farmers. Trees are also highly valued for timber, fuelwood, and construction, but are rarely planted for these purposes because of their high abundance in secondary and primary forests.
11. Illicit coca is one of the most important perennial crops in the Peruvian Amazon, particularly in the *Selva Alta*. This is due to factors that outweigh the disadvantages of illegality: (a) relatively high, relatively stable prices; (b) ready markets; (c) key agronomic advantages; (d) ease of processing, value-adding, and transport; (e) the real or perceived lack of alternative livelihood options.
12. “Project agroforestry” (agroforestry promoted by development projects, typically consisting of practices novel to the target farmers) has been promoted by various development agencies, particularly in *Selva Alta*, but to date there have been few independently documented cases of clear livelihood benefits or widespread adoption.
13. By contrast, one form of traditional or semi-traditional agroforestry, cacao or coffee agroforestry with shade trees, is well established and associated with important export crops and important livelihood contributions.
14. Other more recently introduced or developed perennial crops, usually cultivated in monoculture, have also been associated with significant positive impacts on livelihoods, e.g. oil palm, camu-camu (*Myrciaria dubia*).
15. There is no reason in principle why species that conventionally are profitably cultivated as monocultures should not contribute to the positive economic, environmental or social impacts of “agroforestry landscapes”.
16. Smallholder farmers, with the exception of relatively prosperous landowners in the *Selva Central* (a zone located within 5-6 hours road access of Lima), have not adopted to any notable extent the plantation-based production of either fast-growing or high-value timber.
17. ICRAF studies have shown that in traditional agroforestry, the main sources of germplasm for farmers tend to be their on-farm trees, neighbours, fruit markets, and local remnant high forests. Farmers' germplasm sourcing practices for fruit and timber trees are different: the former tend

to be planted from seed, often with conscious selection, whereas seedlings for timber trees tend to be sourced as wildlings in neighbouring forest or crop fields. Physical shortage of germplasm is said not to be a constraint on traditional agroforestry practices.

18. Traditional germplasm supply systems are inadequate to supply the germplasm needs of development projects. In Peru there is no formal germplasm supply system for timber trees, so NGOs and other agencies are likely to experience difficulties in germplasm sourcing. For many native timber species of interest, and for exotics of interest, such as teak, there are no recognized seed sources. The situation in fruit species parallels that of timber trees. Although, for a few species, either traditional or breeders' varieties are available, for the majority of species of possible interest there are no improved sources or cultivars available.
19. Agroforestry research in the Peruvian Amazon can be classified in two categories that sometimes overlap: research published in peer-reviewed publications, often carried out by foreign researchers, and research, often unpublished, carried out by national research organizations such as the *Instituto de Investigaciones de la Amazonía Peruana* (IIAP) or the *Instituto Nacional de Innovación Agraria* (INIA)
20. With the exception of ethnobotanical studies of traditional agroforestry systems, the greater part of published research on agroforestry in the Peruvian Amazon has been carried out by ICRAF or under the aegis of ICRAF or other CGIAR institutions (including the Alternatives to Slash-and-Burn system-wide program (ASB)). In total, there are around 35 published studies, of which 20 are in international journals and 15 are in regional journals. Several of the latter summarize, draw upon, or are translations of internationally published research. These data exclude the many papers published by Tree Domestication Program personnel.
21. ICRAF-ASB research in Peru has demonstrated substantial environmental benefits of agroforestry (in comparison with alternative land-uses), but has generally not been directed at demonstrating financial feasibility or livelihood impact. Like much other agroforestry research, it has been directed at novel systems, with a strong international public good (IPG)-generation element, rather than at supporting and improving existing agroforestry practice.
22. Research by national agricultural research organizations takes place within a somewhat different institutional culture, with less emphasis on publication. As a result, their research productivity is more difficult to evaluate. However, at least in the case of fruit species such as camu-camu, such research has produced significant livelihood impacts. It has also generated useful information on site requirements of a number of timber species.
23. Both agroforestry development projects (i.e. "project agroforestry") and agroforestry research has frequently centred on agroforestry or the "SAF" ("sistema agroforestal", i.e. agroforestry system) as in itself a product worthy of extension or promotion. By contrast, work that has led to positive livelihood impacts has tended to focus on particular species, their products, and their markets. An alternative, perhaps more fruitful, approach would entail development of a product and its market chain, after which, or concurrently to which, environmentally responsible production systems, possibly involving classic agroforestry systems such as multistratas, could be refined and promoted.
24. A similar approach could be used with existing crops. To date, ICRAF-Peru has had little or no engagement with the smallholder-based oil palm industry located close to Pucallpa. However, the apparent (qualified) success of this initiative raises issues that ICRAF could usefully address. First, there appear to be no hard data on either the financial returns to oil palm growing in Ucayali or on the industry's environmental impact. Second, there have been no attempts at developing and demonstrating the feasibility of more environmentally friendly production techniques.

25. The importance of *Inga edulis* and its congeners—as a widely planted fruit and fuelwood species, as a common component in cacao and coffee agroforestry, and due to renewed interest in its role in rehabilitation of degraded sites— was recognized long ago by ICRAF and collaborators, but this is not reflected in current research agendas.
26. A comparison of location of research activities and development activities seems to suggest a significant dislocation between the two: agroforestry research in the Peruvian Amazon has been carried out mostly in the Lowland Rainforest (“Selva Baja”), whereas agroforestry development activities have taken place mostly in the High Altitude Rainforest (“Selva Alta”). This reflects, on the one hand, the predominant location of research institutions and units in the former and, on the other hand, the graver environmental problems and concentration of illicit coca production in the latter.

Status quo ante relevant to the future of the TDP: development and results of the TDP

27. The Tree Domestication Program (TDP) was conceived as a component of ICRAF’s contribution to the ASB program. It was aimed at improving livelihoods of small farmers involved in deforestation through increasing their access to high quality tree germplasm for use in agroforestry systems. It also had environmental objectives: conservation of within-species biodiversity, as well as contributing to overall ASB aims.
28. The principal component of the TDP is a network of on-farm progeny tests / seed orchards of two timber species (*Calycophyllum spruceanum*, *Guazuma crinita*) and one fruit species (peach palm, *Bactris gasipaes*), established between 1998 and 2000. Many of these are now producing seed and in some cases have been thinned on phenotypic or genotypic criteria.
29. Although the priority species were selected through a participatory prioritization process, some aspects of the approach, together with information from other studies, suggest that the species chosen were not those most likely to be planted by farmers. In spite of these reservations, which apply particularly to the selection of *Calycophyllum spruceanum* and *Guazuma crinita*, it is not clear which alternatives, whether fruit or timber species, might have been better choices. In large measure, the difficulty of selecting species is a reflection of the current state of development of agroforestry in the Peruvian Amazon. As few tree species are being planted on a commercial scale, prioritization of species for specific research activities or to illustrate specific approaches is necessarily subject to error or, at least, to suboptimal decisions.
30. The TDP was instrumental in the establishment of the Aguaytia Valley High-quality Seed and Timber Producers’ Association (“Asociación de Productores de Semilla y Madera de Alta Calidad de la Cuenca del Aguaytia”, PROSEMA). PROSEMA has around 50 members, distributed over a large geographic area (lower to upper parts of Aguaytia watershed). With the support of ICRAF, PROSEMA has been able to sell agroforestry germplasm (seeds and seedlings) to various institutional clients.
31. In large measure, the continued existence of PROSEMA would have been impossible without constant support from ICRAF personnel. At least in its present form, PROSEMA does not constitute a replicable model for agroforestry germplasm supply.
32. As yet, the development objectives of the TDP have not been fully achieved. This is because
 - improved germplasm (i.e. with better agronomic or end-product qualities) has not yet been produced, due largely to species biology and the (sexual) improvement strategies chosen;
 - smallholders at present show little interest in planting the two timber species, or in improved varieties of peach palm;

- the preconditions for reversing smallholders' lack of interest have not occurred, e.g. effective development of markets for agroforestry products, and coalescence of the efforts of institutions, budgets, and disciplinary specialists around particular species and products.
33. Due to ICRAF's activities, "domestication" is now a relatively familiar word to many Peruvian agroforesters. However, there has been no real uptake of the ICRAF-Peru domestication approach by ICRAF's partners or other organizations. Rather, improvement work by INIA and IIAP with *Myrciaria dubia*, *Mauritia flexuosa*, and *Plukenetia volubilis* has followed conventional plant improvement methods.
 34. Tree Domestication Program personnel have produced a relatively large number of scientific articles (at least 15 in peer-reviewed journals), including valuable information on genetic variation and site requirements of *C. spruceanum* and *G. crinita*.
 35. The on-farm progeny trials / seed orchard constitute a highly valuable genetic resource which, together with the information generated to date, would permit the relatively rapid and production of highly improved material.
 36. From at least the early 2000s, the TDP's core activities were implemented substantially in isolation from national partners. From 2005, this tendency has been alleviated through new, collaborative projects, but, even taking these developments into account, the core activities have remained ICRAF activities. To a large degree, ICRAF-Peru's mode of engagement has resembled that of a local, independent organization rather than an international institution aiming at generation of international public goods. This mode of engagement has had a negative effect on ICRAF's impact in Peru, as both national and international personnel have been heavily occupied in execution of project administrative and research activities, with little time for mentoring and coordination activities.
 37. The question of inter-institutional collaboration is of profound importance to the domestication enterprise. Effective domestication requires the collaboration of a wide range of actors, including, potentially, producers, researchers, wholesalers, retailers, export promotion agencies, exporters, importers, importing country regulators, and consumers.
 38. The wider concept of domestication is not fully expressed in the ICRAF-Peru TDP program and, to date, does not appear to be fully shared by ICRAF's partners, whose domestication programs tend to focus on genetic improvement or "pre-improvement". However, since at least the mid-1990s, this expanding concept of domestication has been a pillar of ICRAF-Global's approach to agroforestry-based development.
 39. A fundamental cause of this lack of significant progress has been the failure of institutions effectively to collaborate on and coalesce around specific research problems and opportunities. Coalescence of institutional efforts around particular species/products is also the key to effective prioritization and selection of species: selection of species is not so much a matter of choosing "winners" and avoiding "losers", but of mobilizing the human, institutional, and financial resources to bring about the conditions that make success probable.

Foundations of a strategy for the TDP

40. Tree domestication aims at enhancing the benefits of agroforestry, particularly, but not exclusively, its capacity to generate income. For this reason, directions for the future development of ICRAF's TDP depend at least partly on the role of agroforestry itself in the AI-EP and in the Peruvian Amazon. It also depends partly on general principles for ICRAF's intervention in tree domestication, which stem from its mission as a CGIAR centre.

41. In identifying the role of agroforestry in the Peruvian Amazon, a useful question to answer is: “which agroforestry tree species/product/service, employed/produced in which system and practice, offer real potential of simultaneously generating socioeconomic and environmental benefits” and of thereby ‘transforming lives and landscapes’”.
42. The answer to this question is also a broad one: there are many tree species of current economic value in the Peruvian Amazon, and many of them have the potential to be cultivated profitably in agroforestry systems, provided that certain conditions apply.
43. The wider concept of domestication provides an ideal framework for the institutional coalescence needed to bring about such conditions, particularly in the context of the AI-EP, as the domestication concept encompasses a substantial part of the agroforestry interventions under all four innovation foci.
44. ICRAF’s broad role in tree domestication within the AI-EP is implicit in its status as a CGIAR centre and, in particular, its mission of producing international public goods (IPG). There are three obvious IPG associated with agroforestry domestication:
 - First, the domestication concept, as articulated by ICRAF-Global, is a potentially valuable IPG.
 - Second, approaches to domestication, if systematized and supplemented by decision tools, and illustrated by successful examples, are also valuable potential IPGs.
 - Third, specific technical research outputs of the domestication process can be valuable IPGs. One of these, in spite of some difficulties surrounding the feasibility of its international availability, is improved germplasm (i.e. as distinct from approaches to developing it).
45. The above considerations, together with the *status quo ante* summarized above, constitute an adequate basis for identifying appropriate strategies, future actions and specific options for the development of the TDP’s activities in Peru. These options should be consistent with the role outlined above, should take account of specific lessons identified by this study, and, if possible, should build on the activities to date of the TDP—not because of a feeling that “what is started must be finished”, but because the considerable investment made to date means that valuable results can be achieved with relatively little additional investment.

Recommendations for future development of the ICRAF TDP in Peru

46. The three classes of domestication-related IPG mentioned above— the Domestication Concept, Models and Approaches to Domestication, and IPG Research Products— provide a convenient and appropriate framework for exposition and strategic planning of the TDP’s role within the AI-EP.
47. This structure and conceptualization of ICRAF’s engagement should be both understood clearly by ICRAF staff at different levels and communicated clearly to research partners.
48. To date, the wider domestication concept has not been well articulated by ICRAF-Peru, nor adequately expressed in its own work. This is a missed opportunity that should be rectified. The domestication concept is a useful approach for achieving a more integrated approach to a substantial part of the overall agroforestry research agenda, particularly when associated with a broad conception of agroforestry.

49. ICRAF-Peru researchers, including those who are not necessarily closely involved with the TDP or aware of tree improvement techniques, need to become familiar with the wider domestication concept and able to articulate it to current and potential partners and to decision-makers in government and elsewhere.
50. At present, the TDP does not constitute a complete or replicable model suitable for wider uptake. ICRAF-Peru needs to work urgently in order to convert the potential of the TDP into results that will inspire imitation and emulation with other species and regions. Research with palpable results is needed. Preferably this should be based on eye-catching innovation, although tried-and-tested techniques with high impact should never be eschewed solely to fulfill donors' or others' preference for innovative approaches.
51. In the case of *G. crinita* and *C. spruceanum*, the obvious way to do this is through the identification and demonstration of superior clones.
52. Parallel with this activity, ICRAF and partners should take advantage of work done to date by preparing short, high quality technical/extension manuals describing the methodology used, showcasing the excellent growth of the species on suitable sites, and summarizing what is known to date of both species' silviculture, genetics, and processing.
53. The domestication approach, even if articulated clearly as suggested above, will not be implemented adequately, except by ICRAF itself, without clear guidelines. Ideally, these guidelines should be presented as decision-tools, aimed at facilitating and promoting integrated and appropriate approaches, based on explicit decisions, to prioritization (of species/products and target zones) and to planning of technical and other interventions.
54. ICRAF-Peru is a relatively small organization. As a principle of intervention, it is suggested the involvement of ICRAF-Peru in research implementation—as opposed to coordination and facilitation—should be limited to (a) specific actions related to current activities and (b) research actions, preferably of limited duration, with significant potential for generation of IPGs.
55. The TDP should become increasingly involved in coordination and mentoring, as opposed to implementation of research. One aim of this role should be to encourage and, where appropriate, give technical assistance in publication of local research with IPG elements.
56. Domestication is almost necessarily a multi-institutional enterprise. Accordingly, priorities and needs should be determined collaboratively.
57. A collaborative approach by no means removes the need for clear vision and leadership. ICRAF, as a leading agroforestry research organization, should be in a position to supply such leadership. There are a number of research activities that ICRAF could pursue in collaboration with its national partners:
 - Development of a network of seed sources of acceptable quality of priority timber species.
 - Measures to ensure the adequate use of the peach palm genetic resources developed by the TDP.
 - Preparation of a collaborative proposal for domestication work with *Inga edulis*.

- Safeguarding of genetic resources of *C. spruceanum* and *G. crinita* and establishment of demonstration blocks.
- Engagement with the oil-palm industry located in Pucallpa, with a particular view to examining both its financial impact on smallholders and possibilities for agroforestry-based mitigation of any negative environmental impacts.
- The TDP's association with PROSEMA should be reviewed, primarily with a view to identifying lessons of broad interest.
- Preparation of a proposal for domestication work cedar or mahogany or both, aimed at generation of a technological package covering appropriate planting configurations, site selection, silviculture and, ideally, genetic material.
- Commissioning of one or more literature reviews for publishing in peer-reviewed journals, summarizing key findings from the Peruvian "grey literature" on agroforestry.

Table of Contents

Summary	4
Background	4
Status quo ante relevant to the future of the TDP: AI-EP and ICRAF-global agendas	4
Status quo ante relevant to the future of the TDP: agroforestry practice and research in the Peruvian Amazon.....	5
Status quo ante relevant to the future of the TDP: development and results of the TDP	7
Foundations of a strategy for the TDP	8
Recommendations for future development of the ICRAF TDP in Peru	9
1. Introduction: objective, approach, and structure	18
2. The <i>status quo ante</i>: context and state of advance of the ICRAF Tree Domestication Program.....	19
2.1 Introduction.....	19
2.2 Poverty and resource degradation in the Peruvian Amazon	19
2.3 ICRAF Research directions in Peru: objectives and approaches, 1991-2009	21
2.3.1 <i>The “Yurimaguas years”: 1991-1995</i>	<i>21</i>
2.3.2 <i>Pucallpa and ASB: 1996-2003.....</i>	<i>22</i>
2.3.3 <i>The Amazon Initiative: 2003-2009.....</i>	<i>22</i>
2.4 The Amazon Initiative Eco-regional Program	23
2.4.1 <i>Objectives and thematic agenda.....</i>	<i>23</i>
2.4.2 <i>Comment and analysis</i>	<i>25</i>
2.5 ICRAF Global Research Projects and CGIAR Mega-Programs.....	25
2.6 Agroforestry research in the Peruvian Amazon	26
2.6.1 <i>Peer-reviewed research</i>	<i>26</i>
2.6.2 <i>Agroforestry research by national institutions</i>	<i>29</i>
2.6.3 <i>Comment and analysis: agroforestry research in the Peruvian Amazon</i>	<i>31</i>
2.7 Agroforestry practice in the Peruvian Amazon	33
2.7.1 <i>Traditional indigenous and smallholder agroforestry.....</i>	<i>33</i>
2.7.2 <i>Cacao and coffee agroforestry.....</i>	<i>35</i>
2.7.3 <i>“Project agroforestry”</i>	<i>35</i>
2.7.4 <i>Potential monospecific components of agroforestry landscapes.....</i>	<i>36</i>
2.7.5 <i>Germplasm use and issues in agroforestry practice.....</i>	<i>41</i>
2.7.6 <i>Agroforestry practice in the Peruvian Amazon: comment and analysis, including research implications.....</i>	<i>42</i>
2.8 The Tree Domestication Program	44
2.8.1 <i>Objectives and target group</i>	<i>44</i>
2.8.2 <i>Approach and activities.....</i>	<i>45</i>
2.8.3 <i>TDP Scientific Results</i>	<i>56</i>
2.8.4 <i>TDP Development results.....</i>	<i>59</i>
2.8.5 <i>TDP Conservation results.....</i>	<i>59</i>
2.8.6 <i>The TDP: comment and analysis</i>	<i>60</i>
3. Foundations of a strategy for the TDP: the role of agroforestry and tree domestication in the AI-EP and in the Peruvian Amazon, and general principles for ICRAF intervention.....	66
3.1 Potential contribution of agroforestry to the goals of the AI-EP	66
3.2 Role of tree domestication in the AI-EP	69
3.2.1 <i>Concepts of tree domestication</i>	<i>69</i>
3.2.2 <i>Tree domestication in the AI-EP.....</i>	<i>69</i>
3.3. ICRAF’s role in tree domestication within the AI-EP.....	71

4. “Roadmap” for future development of the ICRAF TDP in Peru.....	72
4.1 Structure and conceptualization of ICRAF’s intervention.....	72
4.2 Guidelines for implementation of an IPG-oriented agenda	72
4.2.1 IPG: <i>The Domestication concept</i>	72
4.2.2 IPG: <i>Working models and approaches</i>	72
4.2.3 IPG <i>Research products</i>	73
4.3 Summary of recommendations	76
References.....	79
Appendix 1: List of interviewees and other contacts during visit to Peru, July 2009	86

List of Tables

	Page
Table 1. Principal findings of agroforestry research by ICRAF and others in Peru, excluding tree domestication research	27
Table 2. Research initiatives on agroforestry systems listed by Meza <i>et al.</i> (2006)	30
Table 3. Agroforestry development initiatives listed by Meza <i>et al.</i> (2006)	36
Table 4. Reforestation development initiatives listed by Meza <i>et al.</i> (2006)	39
Table 5. The species prioritization process used in ICRAF's Tree Domestication Program in the Peruvian Amazon	47
Table 6. Species prioritized by the ICRAF Tree Domestication Program for agroforestry research in three zones of the Peruvian Amazon	50
Table 7. Species selected for domestication activities as a result of a priority-setting process by ICRAF in the Peruvian Amazon	51
Table 8. Location and current status of progeny-trial blocks established by the ICRAF Tree Domestication Program in the Aguaytía Valley	52
Table 9. Location and environmental characteristics of test sites used by the TDP in the Peruvian Amazon	54
Table 10. Principal scientific results of ICRAF's Tree Domestication Program in Peru	57
Table 11. Two-way classification of potential target productive practices with respect to environmental and livelihood impacts	67
Table 12. Possible types of agroforestry interventions by two-way livelihoods / environment impact classification	68
Table 13. Relationships between the current ICRAF concepts of agroforestry domestication and the AI-EP Innovation Foci	70

List of Figures

	Page
Figure 1. Distribution by Region (in ‘000s) of the Amazonian population of Peru	20
Figure 2. The four Innovation Foci of the AI-EP: interrelationships and contributions to the AI-EP’s objective.	24
Figure 3. INIA and IIAP research with native fruits and nuts	30
Figure 4. SFM/BAM forest estate near Pucallpa	41
Figure 5. Objectives of ICRAF’s Tree Domestication Program in the Peruvian Amazon	45
Figure 6. ICRAF experimental blocks in the Aguaytía watershed.	55

Abbreviations and acronyms

AI	Amazon Initiative Consortium
AI-EP	Amazon Initiative Ecoregional Program
ASB	Alternatives to Slash-and-burn CGIAR System-wide Program
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical
CIFOR	Center for International Forestry Research
CONCYTEC	Consejo Nacional de Ciencia y Tecnología
FOB	Free on board
GDP	Gross domestic product
ICRAF	International Centre for Research in Agroforestry (World Agroforestry Centre)
IF	Innovation Focus
IIAP	Instituto de Investigaciones de la Amazonía Peruana
IIRSA	Iniciativa para la Integración de la Infraestructura Regional Suramericana
INCAGRO	Innovación para el Agro Peruano
INIA	Instituto Nacional de Investigación Agraria
IVITA	Instituto Veterinario de Investigaciones Tropicales y de Altura
LA	Latin America
NARO	National Agricultural Research Organization
NPV	Net present value
OLAMSA	Oleaginosa Amazónica S.A.
MP	MegaProgram
PES	Payment for environmental Service
PROSEMA	Association of Aguaytía Watershed Producers of High Quality Seed and Wood
REDD	Reduced emissions from deforestation and degradation
SLUS	Sustainable land-use systems
TDP	Tree Domestication Program
TISA	Traditional Indigenous and Smallholder Agroforestry
UNALM	Universidad Nacional Agraria La Molina
UNAP	Universidad Nacional de la Amazonía Peruana

Scientific and common names of plant species

Scientific name	Common name	Common name	Scientific name
<i>Amburana cearensis</i>	ishpingo	Achiote caspi	<i>Bixa platycarpa</i>
<i>Aspidosperma vargasii</i>	quillobordón colorado	African oil palm	<i>Elaeis guianensis</i>
<i>Baccharis floribunda</i>	sachahuaca	aguaje	<i>Mauritia flexuosa</i>
<i>Bactris gasipaes</i>	peach palm, pijuayo	arazá	<i>Eugenia stipitata</i>
<i>Bixa platycarpa</i>	Achiote caspi	arrocillo	<i>Rottboellia cochinchinensis</i>
<i>Calycophyllum spruceanum</i>	capirona	bolaina blanca	<i>Guazuma crinita</i>
<i>Caryodendron orinocense</i>	metohuayo	caimito	<i>Pouteria caimito</i>
<i>Cedrela odorata</i>	Spanish cedar, cedro	camu-camu	<i>Myrciaria dubia</i>
<i>Cedrelinga catenaeformis</i>	tornillo	capirona	<i>Calycophyllum spruceanum</i>
<i>Colubrina glandulosa</i>	shaina	Caribbean pine	<i>Pinus caribaea</i> var. <i>hondurensis</i>
<i>Croton draconoides</i>	sangre de grado	cashupsha	<i>Imperata brasiliensis</i>
<i>Dipteryx micrantha</i>	shihuahuaco	Cat's claw, uña de gato	<i>Uncaria</i> spp.
<i>Elaeis guianensis</i>	African oil palm	cocona	<i>Solanum sessiliflorum</i>
<i>Eucalyptus x urograndis</i>	Hybrid of <i>E. grandis</i> and <i>E. urophylla</i>	cumala	<i>Virola calophylla</i>
<i>Eugenia stipitata</i>	arazá	estoraque	<i>Myroxylon balsamum</i>
<i>Guazuma crinita</i>	bolaina blanca	guaba	<i>Inga edulis</i>
<i>Imperata brasiliensis</i>	cashupsha	huayruo colorado	<i>Ormosia schmuckei</i>
<i>Inga edulis</i>	guaba	Hybrid of <i>E. grandis</i> and <i>E. urophylla</i>	<i>Eucalyptus x urograndis</i>
<i>Juglans</i> spp.,	Walnut, nogal	ishpingo	<i>Amburana cearensis</i>
Lauraceae (<i>Aniba</i> , <i>Cinnamomum</i> , <i>Nectandra</i> and others)	Moena	kudzu	<i>Pueraria phaseoloides</i>
<i>Mauritia flexuosa</i>	aguaje	macambo	<i>Theobroma bicolor</i>
<i>Myrciaria dubia</i>	camu-camu	Mahogany, caoba	<i>Swietenia macrophylla</i>
<i>Myroxylon balsamum</i>	estoraque	marupa	<i>Simarouba amara</i>
<i>Oenocarpus bataua</i>	ungurahui	metohuayo	<i>Caryodendron orinocense</i>
<i>Ormosia schmuckei</i>	huayruo colorado	Moena	Lauraceae (<i>Aniba</i> , <i>Cinnamomum</i> , <i>Nectandra</i> and others)
<i>Pinus caribaea</i> var. <i>hondurensis</i>	Caribbean pine	pashaco blanco	<i>Schizolobium amazonicum</i>
<i>Plukenetia volubilis</i>	Sacha inchi	peach palm, pijuayo	<i>Bactris gasipaes</i>
<i>Pollalesta discolor</i>	yanavara	quillobordón colorado	<i>Aspidosperma vargasii</i>
<i>Poraqueiba sericea</i>	umari	sachahuaca	<i>Baccharis floribunda</i>
<i>Porouma cecropiifolia</i>	uvilla	Sacha-inchi	<i>Plukenetia volubilis</i>
<i>Pouteria caimito</i>	caimito	sangre de grado	<i>Croton draconoides</i>
<i>Pueraria phaseoloides</i>	kudzu	shaina	<i>Colubrina glandulosa</i>
<i>Rottboellia cochinchinensis</i>	arrocillo	shihuahuaco	<i>Dipteryx micrantha</i>
<i>Schizolobium amazonicum</i>	pashaco blanco	Spanish cedar, cedro	<i>Cedrela odorata</i>
<i>Simarouba amara</i>	marupa	tahuari amarillo	<i>Tabebuia serratifolia</i>
<i>Solanum sessiliflorum</i>	cocona	teak	<i>Tectona grandis</i>
<i>Spondias mombin</i>	uvos	tornillo	<i>Cedrelinga catenaeformis</i>
<i>Swietenia macrophylla</i>	Mahogany, caoba	umari	<i>Poraqueiba sericea</i>
<i>Tabebuia serratifolia</i>	tahuari amarillo	ungurahui	<i>Oenocarpus bataua</i>
<i>Tectona grandis</i>	teak	uvilla	<i>Porouma cecropiifolia</i>
<i>Terminalia oblonga</i>	yacushapana	uvos	<i>Spondias mombin</i>
<i>Theobroma bicolor</i>	macambo	Walnut, nogal	<i>Juglans</i> spp.,
<i>Uncaria</i> spp.	Cat's claw, uña de gato	yacushapana	<i>Terminalia oblonga</i>
<i>Virola calophylla</i>	cumala	yanavara	<i>Pollalesta discolor</i>

1. Introduction: objective, approach, and structure

During the period 2003-2009, the institutional context of ICRAF's work in Latin America underwent important changes: initially, with the formation of the Amazon Initiative Consortium (AI) (Porro *et al.* 2005) and, subsequently, with the approval in 2007 of the Amazon Initiative Ecoregional Program (AI-EP). At the same time, ICRAF maintained continuity with its previous work in the Peruvian Amazon, chiefly through implementation of the Tree Domestication Program (TDP) initiated in 1995 (Weber *et al.* 2001).

The present report reviews ICRAF's tree domestication activities in Peru, with the general objective of outlining possible future directions consistent with (a) the thematic priorities of the AI-EP and (b) the objective of relevant ICRAF Global Research Programs (GRP) and CGIAR MegaPrograms (MP). The report is based on analysis of relevant literature, a field visit to Peru (July 2009, see Appendix), and views formed during the author's tenure as leader of ICRAF's TDP from 2003-2007.

The report has three principal chapters. Chapter 2 consists of an overview of the *status quo ante* relevant to future development of the TDP, including ICRAF research directions, AI-EP priorities, the state of advance of agroforestry in Peru, the state of advance and results to date of the TDP itself, and the wider national and regional context. In Chapter 3, foundations of a strategy for the TDP are set out, based on the *status quo ante*, the role of agroforestry and tree domestication in the AI-EP, and suggested general principles for intervention by ICRAF-Peru. Emphasis throughout, and particularly in Chapter 3, is on ICRAF's core business, i.e. research for development. Chapter 4 outlines suggested future strategy and activities, and includes a summary of recommendations.

2. The *status quo ante*: context and state of advance of the ICRAF Tree Domestication Program

2.1 Introduction

The future development of the TDP in Peru depends principally on the possible contribution of tree domestication in Peru to CGIAR and ICRAF objectives, as expressed in the AI-EP's agenda, ICRAF GRP, and CGIAR MP, as well as on ICRAF's ability to deliver this contribution. However, the role of tree domestication in the AI-EP and the Peruvian Amazon is itself dependent on a wider agroforestry context, i.e. current and possible agroforestry practice, particularly as informed by research. In addition, the experience to date and state of advance of the TDP is of obvious relevance to its future development. These considerations, which, together with the wider regional, national, and international context, constitute the *status quo ante* relevant to future development of the TDP, are reviewed in the present chapter.

In Section 2.2, current levels of poverty and land degradation in the Peruvian Amazon are briefly described. Section 2.3 reviews ICRAF research directions in Peru (and the wider Amazon) from 1991 to the present, with emphasis on objectives and approaches, excluding the TDP itself. This is followed by a description of the AI-EP (Section 2.4). In Section 2.5, relevant ICRAF and CGIAR priorities are briefly described. In Section 2.6, the results of formal agroforestry research in the Peruvian Amazon are summarized, whereas Section 2.7 describes current agroforestry practice in the Peruvian Amazon. Finally, in Section 2.8, the TDP itself is described, including its objectives, approach, activities, and results.

In general, ICRAF's current definition of agroforestry as "a form of land use that integrates trees on farms and in agricultural landscapes for economic, social and environmental benefits" is adhered to here, particularly in the context of the contribution of agroforestry to the AI-EP. However, research by ICRAF and partners in the Amazon from 1993 has, implicitly or explicitly, in general defined agroforestry more conventionally—typically, as a spatial or temporal combination of trees and crops or animals. This more conventional concept of agroforestry is reflected in the description of agroforestry research in Section 2.6 and in other sections of this report.

2.2 Poverty and resource degradation in the Peruvian Amazon

The Peruvian Amazon makes up around 60% of the country's terrestrial land area, including virtually all of the Regions of Loreto, Madre de Dios, San Martín, and Ucayali, as well as extensive areas of Amazonas, Cajamarca, Huánuco, and Junín (Figure 1). Much of the Amazonian population of 3.85 million, particularly the rural population, lives in conditions of poverty or extreme poverty. For example, in 1999, 40% of rural children of 6-9 years old had chronic malnutrition, while 42-51% of the rural population of Loreto and Ucayali was living in extreme poverty (Ministerio de Educación 1999). This situation, deplorable in itself, is associated with a vicious circle of land degradation caused by increasingly short fallow periods, illegal coca cultivation, and conversion of forest to unproductive grasslands, driven partly by immigration from the coastal and Andean zones (itself a means of escape from extreme poverty), and, at times, government policy (White *et al.* 2005; Meza *et al.* 2006). The original forest cover has been lost from about 90,000 km². Of this area, 55,000 km² are considered to be degraded or abandoned, with forest recovery inhibited by artificial burning, low soil fertility, soil compaction, and competition from native grasses, *Pteridium* ferns, and other herbaceous vegetation (Meza *et al.* 2006). Degradation processes are most advanced in terms of magnitude and intensity in the *Selva Alta*¹ (Meza *et al.* 2006).

¹ *Selva Alta* (literal translation is "high jungle") is an altitudinal rather than canopy-height classification, referring to rainforest in the 400-2600 m a.s.l. altitudinal range (Meza *et al.* 2006). Similarly, *Selva Baja*, literally "low jungle," refers to lowland (<400 m a.s.l.) rainforest.

Figure 1. Distribution by Region (in '000s) of the Amazonian population of Peru (Sources: Law 27307 for Promotion of Investment in Amazonia (listing of departamentos, provinces and districts considered Amazonian); X National Population Census (<http://inei.inei.gob.pe/inei/RedatamCpv2005.asp?ori=C>))

Illegal coca cultivation remains one of the principal economic activities in the Peruvian Amazon², in spite of a fall in prices in the early-mid 1990s due to an increase in production in Colombia³. In 2008 there were around 54,000ha of illegal coca in Peru, principally in the *Selva Alta*. Farm-gate value of coca leaf production in 2008 was an estimated \$292m, equivalent to 0.4 per cent of GDP (UN Office on Drugs and Crime 2008). Illegal coca production has been a “success” in terms of adoption and local livelihood impact because of (a) a lack, perceived or real, of viable alternatives; (b) relative ease of value-adding (coca leaf transformed to *pasta básica de cocaine* (PBC)⁴) (c) relatively stable, relatively high prices for coca leaves and PBC; (d) the high value; weight/volume ratio of PBC; (e) coca leaves can be harvested up to six times a year, from as young as six months from planting; (f) robustness and ease of cultivation (Dávalos *et al.* 2009; Dion and Russell 2008).

Historically, road-building has been associated with increased deforestation (White *et al.* 2005). However, it remains a key national and international development policy instrument, expressed in the ongoing IIRSA initiative⁵, which has led to improvement of the Yurimaguas-Tarapoto and Pucallpa-Lima roads and associated waterways, and construction of the “Interoceanic Highway” from the Brazilian state of Acre, through Madre de Dios, to the Peruvian coast. Although the adverse environmental effects of such developments are widely recognized, they are often supported by local populations, who value improved access to the facilities—hospitals, schools, other government services, markets, etc.—available in larger towns and cities. A key policy concern is to ensure that the advantages of improved infrastructure, including improved market access, can facilitate sustainable land-use, rather than lead to increased deforestation.

² In the agricultural sector, probably second only to coffee (see 2.7.2).

³ Due to the dismantling by the Fujimori government of the “air-bridge” to Colombia (Angrist and Kugler 2007).

⁴ An intermediate stage in the production of cocaine hydrochloride, and the active ingredient in “crack”.

⁵ www.iirsa.org.

2.3 ICRAF Research directions in Peru: objectives and approaches, 1991-2009⁶

2.3.1 The “Yurimaguas years”: 1991-1995

Between 1972 and 1991, the National Institute for Agrarian Research (Instituto Nacional de Investigación Agraria, INIA⁷) San Ramón Experimental Station (Yurimaguas, Alto Amazonas Province, Loreto) was the site of TropSoils, a major research program in agriculture for the humid tropics, implemented by North Carolina State University (NCSU) and national partners. ICRAF’s involvement in Peru dates from the end of this period, when, following NCSU’s withdrawal from Yurimaguas, it essentially took over NCSU’s role⁸, although with a stronger emphasis on agroforestry than previously (other areas of TropSoils research included rice, maize, oil crops, pastures, and soils). During this period, ICRAF’s main office in the Amazon was located in Yurimaguas, with activities also in Iquitos and Pucallpa. TropSoils research on agroforestry—ICRAF’s “prehistory” in Peru—was summarized in a compendium (IIAP 1996), and included work on silvopastoral systems, improved fallows, peach palm agronomy, alley cropping, and genetic resources (*Inga*, peach palm and other native fruit species).

During the 1991-1994 period, ICRAF’s work was largely focused on continuation of the research begun by NCSU. It was apportioned between three of ICRAF’s (then) global programs: Multipurpose Tree Improvement (P2), Component Interactions (P3), and Systems Improvement (P4). Program 2 continued with TropSoils work on *Inga* genetic resources and also managed a peach palm (*Bactris gasipaes*) collection assembled during the NCSU period. Program 3 took over two major TropSoils experiments: a contour hedgerow intercropping trial begun in 1987, and experiment Y4/12, which addressed soil changes under alternative systems to slash-and-burn⁹. By 1994, the hedgerow intercropping work was considered not to be of high priority, “because of lack of farmer interest and adoption” and because “other research has shown that such labour-intensive technologies are more suitable when land is scarce, which is not the case in this area” (ICRAF 1994)¹⁰. Program 4’s work was carried out in the framework of the Alternatives to Slash-and-Burn CGIAR System-wide Program (ASB). Work in Yurimaguas was to be centered on improved fallows and development of economically sound multistrata systems. Multistrata systems were also considered of high priority in Iquitos, with emphasis on fruits for the local market, whilst work at Pucallpa was to stress silvopastoral systems and living fences to increase productivity and diversity of pastureland.

By 1995, ICRAF-Latin America had identified five major research components: characterization (concerned with assessment of socioeconomic and biophysical processes leading to deforestation), policy, tree domestication, “agroforestry interventions”, and capacity building. The overall focus was on

“generating agroforestry technologies for alternatives to slash-and-burn agriculture at the forest margins that lead to poverty alleviation, improve household food security and provide global environmental benefits — such as ameliorating global warming and conserving biodiversity ... revolving around ...one key hypothesis:

⁶ Based partly on ICRAF 1993, ICRAF 1994, ICRAF 1995, ICRAF 1995.

⁷ Currently the National Institute for Agrarian Innovation, Instituto Nacional de Innovación Agraria.

⁸ TropSoils Executive Director, Dr. Dale Bandy, became ICRAF’s Regional Coordinator.

⁹ Results from both experiments were published by present and former staff of both NCSU and ICRAF (Section 2.6.1.).

¹⁰ This change reflected a wider shift in opinion and disillusionment with alley cropping (Sanchez 1995). However, Elkan (2005) reported massive adoption of *Inga* alley cropping in tropical wet conditions in northern Honduras, due largely to its efficiency of weed control. Similar work, begun in collaboration with Hands, the researcher behind the work in Honduras, is currently being implemented by UNALM in Peru (Carlos Reynel, UNALM, pers. comm. 16th July 2009).

intensifying land use as an alternative to slash-and-burn can reduce deforestation and poverty” (Izac 2002).

2.3.2 Pucallpa and ASB: 1996-2003

In 1996, ICRAF shifted the location of its main Amazon office to Pucallpa. At least three reasons played a part in this decision: the risk to personal safety due to political violence in Yurimaguas, the unacceptable isolation of the latter site, and the argument that the fast-expanding area around Pucallpa was more representative of Amazonian forest margin sites (and therefore of more relevance to the ASB program)¹¹. In the 1996 report, all of ICRAF’s work in the humid tropics of Latin America was presented as “constituting our institutional commitment to the...ASB Program.” Work continued on species prioritization for tree domestication, studies of germplasm use and tree management, comparative nutrient dynamics in “best-bet alternatives” to slash-and-burn, work on silvopastoral and multistrata systems, and training.

By 1997, ICRAF-LA’s stated agenda was a more explicitly environmental one:

“our research addresses poverty alleviation and food security, but its major focus is on the integration of environmental considerations in the agricultural productivity agenda of small farmers cultivating at the forest margins. The objective is to reduce environmental degradation and to rehabilitate already degraded lands through the introduction of more sustainable land-use systems (alternatives to slash-and-burn practices).”

Program 3’s work concentrated on validation in Pucallpa of the multistrata technology developed in Yurimaguas (involving the establishment of demonstration plots and, in San Alejandro (upper Aguaytía watershed) and elsewhere, further experiments), work on improved fallows, and research on approaches to introducing trees in pastureland¹². The varied work within the ASB framework included research on use of medicinal plants (Clavo *et al.* 2003), local ecological knowledge (Joshi *et al.* 2004), carbon stocks and greenhouse gas emissions, a proposal on intensified secondary forest management¹³, collaborative work on ASB site characterization¹⁴, collaborative work with CIFOR on plant biodiversity assessment using functional attributes (Gillison and Alegre 2000), a report on the market for products of secondary forests¹⁵, and impact of kudzu fallows on deforestation (Yanggen 2000).

2.3.3 The Amazon Initiative: 2003-2009

From 1997-2001, both restricted and core funding of the ICRAF Latin America budget decreased markedly, and by 2002 even the reduced 2001 levels of funding were considered to be unsustainable (Izac 2002). In response, a new strategy was conceived. In thematic terms, this strategy was based on the proposition that

“the principal challenges confronting LA [Latin America] are to slow down, if not stop, the processes of land and natural resources degradation, while enhancing livelihoods...in a context of very low

¹¹ Julio Alegre, Roger Leakey, Julio Ugarte, personal communications, various dates (2003-2009).

¹² Four approaches, informed by the reluctance of farmers to remove cattle in order to plant trees, were identified: spot fencing, cattle repellents, late transplanting (3-4 year old saplings), thinning of abandoned pastureland (Julio Alegre, personal communication, 16th July 2009).

¹³ Faminow, M.D. 2001. ICRAF Concept for Intensified Management of Secondary Forests (draft). ICRAF, Lima (cited in White *et al.*, 2005).

¹⁴ Led by Centro Internacional de Agricultura Tropical (CIAT).

¹⁵ Guevara R., Faminow M., Toledo E. 2001. Cited in White *et al.* 2005.

rural population densities, geographic isolation of this population and large remaining forest resources.¹⁶”

In organizational and institutional terms, the strategy, informed by the difficulty that had been experienced in securing adequate sustained funding, was to pursue a “new mode of engagement”, i.e. the creation of an “inter-institutional and interdisciplinary team of scientists...who work on the big research questions facing the Amazon” which would “function as a ‘distributed network’ of scientists” (Izac 2002). Within this framework, ICRAF and partners would “address policy questions with a direct bearing on the adoption of agroforestry practices by farmers as these have been demonstrated to be barriers to adoption” while, “to ensure that the policy agenda is well rounded and grounded in biophysical work”, it would be complemented by tree domestication activities (led by ICRAF) and “work on other essential dimensions of appropriate technology development and scaling up of adoption” (Izac 2002).

By late 2002, this new strategy, in the form of the Amazon Initiative concept, had been adopted as ICRAF’s new strategy for the region. ICRAF’s regional coordinator, from 2003 based in Belém, Brazil, led the development of the Amazon Initiative (initial stages of which were documented by Porro *et al.* (2005)), while ICRAF’s research activities in Peru from 2003-2008 were limited essentially to continued implementation of the TDP¹⁷ and complementary support of rural enterprises¹⁸, with other activities “phased-out” and handed over to national collaborators¹⁹. By 2007, substantial additional funding had been secured for tree domestication research in Peru and Bolivia (Porro 2009), partly as a direct consequence of the closer institutional links facilitated by the Amazon Initiative. Since 2008, activities in Peru have widened to include research on cacao-based agroforestry systems and climate change impacts (Porro 2009).

2.4 The Amazon Initiative Eco-regional Program

2.4.1 Objectives and thematic agenda²⁰

The AI-EP’s essential aim is to contribute to the development and uptake of sustainable land-use systems “that avoid further deforestation and support governments and civil society in their goals related to human welfare, environmental services, and improved governance.” That is, the AI-EP’s objective is essentially a dual one: to halt, reverse, or mitigate resource degradation, while improving living standards of the Amazonian rural poor. In large measure, the “resource” in question is the land and forest resource and its capacity for producing goods and services.

The essential strategy adopted is to promote and facilitate smallholder adoption of sustainable land-use systems on forested and deforested land, including, but not limited to, degraded land. The AI-EP addresses the complex and, to date, intractable problems that must be overcome for this apparently simple aspiration to be fulfilled. These problems are to be approached through production of four “outputs”, which also provide the thematic structure (“Innovation Foci”) of the AI-EP: mitigation of and adaptation to climate change; adoption of sustainable land use systems in deforested and degraded areas; enhanced benefits from forests for livelihoods and the environment; fair, financially attractive market value chains for Amazon products. These outputs both feed into each other and into the AI-EP objective (Figure 2). The four outputs are further described below.

¹⁶ The context appears to reflect Amazonian rather than “Latin American” conditions.

¹⁷ Now under the “Trees and Markets” theme, following the dissolution of the “programs” of the previous structure.

¹⁸ Principally through the project “Empowerment of farmers through organization and enterprise-building” (2002-2004), financed by the Tinker Foundation.

¹⁹ In practice, Program 3 research was discontinued; multistrata plots and experiments near Pucallpa were “handed over” to INIA, but there have been no further published outputs from these experiments. Some areas have been maintained by INIA as demonstration plots.

²⁰ Source: CIAT Medium-term plan, 2010-2012.

Figure 2. The four Innovation Foci of the AI-EP: interrelationships and contributions to the AI-EP's objective.

2.4.1.1 Innovation Focus 4: Fair, financially attractive market value chains for Amazon products

IF4 is central to the AI-EP's objective of improving Amazonian livelihoods. It aims principally at removing constraints and identifying opportunities for the development — particularly, the profitable sale of — agricultural and forest products, including both established and novel products. As such, its results will largely determine the financial viability and sustainability of the production systems to be developed through the other three IFs. IF4 includes product identification, germplasm development, integration of the products in sustainable land-use systems (SLUS) and market chain development.

2.4.1.2 Innovation Focus 3: enhanced benefits from forests for livelihoods and the environment

IF3 addresses the need to realize the value of existing forest; in effect, it proposes to secure public benefit — environmental protection and enhancement — by facilitating private benefit, i.e. income from forest products. The strategy is based on the construction of approaches to implementation of Multiple-use Forest Management. It will also work on developing the potential of underutilized species, including both production and dissemination of germplasm, and marketing. Finally, it will work to improve land tenure systems and arrangements for resource access.

2.4.1.3 Innovation Focus 2: adoption of sustainable land use systems in deforested and degraded areas

IF2 will work to overcome constraints to the adoption of ecologically and agronomically sustainable land-use systems such as improved, legume-based pastures, multistrata agroforestry systems, small-scale timber plantations, silvopastoral systems, secondary forest management, and improved fallows. The constraints define the nature of the proposed work, and might include poor targeting of technologies, lack of germplasm of sufficient quantity and/or quality or at accessible prices, market limitations (including but not limited to the lack of development of markets for environmental services), the combination of free access to forest frontiers and insecure land tenure, and the lack of supporting systems (technical support, credit).

2.4.1.4 Innovation Focus 1: Mitigation and adaptation to climate change

IF1 aims at ensuring that the production systems (including the germplasm employed) developed in IF3 and IF2 are resilient to climate change and that they contribute to carbon capture. As well as intersecting with IF3 and IF2, work will include development of practical methods for assessing carbon footprint of different SLUS, and development of payment for environmental services (PES) schemes, including reward for reduced emissions from deforestation and degradation (REDD).

2.4.2 Comment and analysis

The four IF can be distilled to three essential components. First — and note that, due to positive and negative feedbacks, these three components could be listed in any order—profitable products (tangible goods, environmental services, etc.) must be identified. Second, sustainable—in all its dimensions, and in conditions of climate change and climatic instability—production systems for these products must be identified. Third, a favourable policy environment, potentially both in terms of removing constraints and instituting positive innovations, needs to be created²¹.

Overall, the AI-EP agenda appears similar to the agenda that ICRAF and partners have pursued in the Peruvian Amazon since 1992. Given that the agenda is based on a wide-ranging process of consultation at various levels of civil society, this is a strength of the AI-EP, as it means that it is in a position to benefit from the results and lessons of previous research and experience. However, in its emphasis on markets and market access, the AI-EP agenda represents a departure from previous ICRAF approaches in the Amazon.

2.5 ICRAF Global Research Projects and CGIAR Mega-Programs

ICRAF's GRP1 (Domestication, utilization and conservation of superior agroforestry germplasm) has two research outputs:

- “improved agroforestry tree germplasm available with associated information on potential use, benefits and conservation while considering climatic constraints and risks of invasiveness” (output of GRP 1.1);
- “prototypes available for sustainable tree seed and seedling supply systems that promote the use of diverse and productive germplasm by smallholder farmers in different social, economic and cultural settings” (output of GRP 1.2).

ICRAF considers one or both of these outputs to be relevant to six of the eight CGIAR MP:

- MP1 (Agricultural systems for the poor: 1.1 Diversified crop-livestock systems in dry areas; 1.2 Intensified smallholder systems; 1.3 Coastal-aquatic system; 1.5 Maize systems);
- MP2 (Enabling agricultural incomes for the poor: 2.1 Priority value-chains);
- MP4 (Agriculture, nutrition, and health: 4.1 Nutritious and diversified diets; 4.4 Human health and climate change; 4.5 Targeted nutrition/health agricultural interventions);
- MP6 (Forests and trees: 6.3 Interactions between agriculture, forestry and biomass; 6.4 Mitigation of climate change with forests and trees);
- MP7 (Climate change: 7.4 Adaptation for seasonal risk);
- MP8 (Agricultural biodiversity: 8.1 In situ conservation; 8.2 Ex situ agricultural collections; 8.3 IP and policies).

The concept of domestication expressed in the work program of GRP1 appears to be a relatively narrow one (e.g. in comparison with that espoused by Simons and Leakey (2004). A wider concept, taking in agronomic, product development, and marketing aspects of tree crop domestication,

²¹ In the AI-EP structure, policy is a crosscutting theme, present in all the Innovation Foci.

would also take in elements of GRP2 (Enhancing productivity of agroforestry systems) and GRP3 (Improving tree product marketing for smallholders) and would make a correspondingly larger contribution to the CGIAR MP.

2.6 Agroforestry research in the Peruvian Amazon

Agroforestry research in the Peruvian Amazon can be classified in two categories that sometimes overlap: research published in peer-reviewed publications, often carried out by foreign researchers, and research, often unpublished, carried out by national institutions such as the Peruvian Amazon Research Institute (Instituto de Investigaciones de la Amazonía Peruana, IIAP) or INIA. Both types of research form part of the context of ICRAF's engagement in the Peruvian Amazon.

2.6.1 Peer-reviewed research

With a number of notable exceptions²², the greater part of published research on agroforestry in the Peruvian Amazon has been carried out by ICRAF or under the aegis of ICRAF or other CGIAR institutions (including the Alternatives to Slash-and-Burn system-wide program (ASB)). As, throughout this period, ICRAF's agenda—particularly as formulated in 1997²³—was similar to that of the AI-EP, research results should be of key relevance in the present context. The principal findings of this research, including that done by researchers from other institutions, are summarized in Table 1.

²² Particularly the contributions by ethnobotanists and others on traditional agroforestry systems (Section 2.7).

²³ See Section 2.3.2

Table 1. Principal findings of agroforestry research by ICRAF and others in Peru (i.e. research published in international peer-reviewed publications, excluding research on tree domestication research and traditional agroforestry practices)

Research area / finding	Source
Alley cropping and contour hedging	
Contour alley cropping is an effective way of controlling soil erosion on sloping ground: mean annual soil loss was 34-57 times greater under continuous cropping than under contour alley cropping with <i>Inga</i> ("hedgerows" trap soil, while the mulch reduces raindrop impact)	Alegre and Cassel 1996; Alegre and Rao 1996
Soil physical properties, particularly bulk density and hydraulic conductivity were also better under <i>Inga</i> contour alley cropping than under conventional continual cropping on sloping land	Alegre and Cassel 1996; Alegre and Rao 1996
Although soil chemical properties were significantly better under alley cropping, in 12 of 15 cases there were no yield increases (rice/cowpea) (partly because 22% of the land was under hedgerows)	Alegre and Cassel 1996; Alegre and Rao 1996
On more fertile, alluvial soils, <i>Leucaena</i> , <i>Erythrina</i> and <i>Inga</i> all had a negative effect on growth of rice.	Salazar, Szott and Palm 1993
Multistrata systems	
Physical soil properties, N mineralization, and biomass/density of soil macrofauna were superior to those in low and high input continuous cropping	White <i>et al.</i> 2005, Alegre and Cassell 2001
Over 10 years, organic C accumulation was greater than under low input cropping, as was N accumulation. P, K, Ca, and Mg accumulation were similar to or inferior to low input cropping.	White <i>et al.</i> 2005
Multistrata systems maintained more and a greater proportion of P in plant-available form than annual cropping and alley cropping	Szott and Meléndez 2001
Returns to land (NPV ha ⁻¹) for the multistrata system were much lower than short- or long-fallow shifting agriculture (\$18-60 ha ⁻¹ v. \$262-591 ha ⁻¹). Returns to labour (wage at which NPV = zero) were more similar (\$2.9-\$3.6 for multistrata, \$4.1-\$4.62 for shifting agriculture).	White <i>et al.</i> 2005
The Yurimaguas multistrata system had relatively low above ground biodiversity species richness (11 species), although an extensive multistrata system in Brazil had much higher species richness (47) (species richness was 66 for a logged forest in Ucayali). Soil macrofauna species richness was higher in the multistrata system than all other land uses (degraded pasture, improved pasture, shifting agriculture, low or high input cropping, peach palm orchard, secondary forest), as was biomass of soil macrofauna.	White <i>et al.</i> 2005
Above ground C stocks in a multistrata system (<i>C. catenaeformis</i> / <i>B. gasipaes</i> / <i>Colubrina</i> / <i>Inga</i> / <i>Eugenia stipitata</i> / Coffee / Centrosema) were 59 T ha ⁻¹ , compared to 294 T ha ⁻¹ in a forest that was moderately logged 40 years ago. A logged forest in Ucayali had 123 T ha ⁻¹ . Stocks in annual crops were 3-17 T ha ⁻¹ , 44 T ha ⁻¹ in a five year old fallow and 126-185 T ha ⁻¹ in a 15 year old fallow. N ₂ O fluxes in the multistrata system were similar to secondary forest and less than those in swidden fallow; those in cropping systems were 2-3 times higher. Methane fluxes were negative for the multistrata system and other tree-based systems. They were positive only for high input cropping.	White <i>et al.</i> 2005 and references therein

Table 1 (continued). Principal findings of agroforestry research by ICRAF and others in Peru (i.e. research published in international peer-reviewed publications, excluding research on tree domestication research and traditional agroforestry practices)

Research area / finding	Source
Silvopastoral systems	
In a silvopastoral system with <i>Centrosema</i> forage planted under peach palm at 600 trees ha ⁻¹ on a degraded site, average live-weight gain of cattle (2.3-3.3 animals ha ⁻¹) was substantially greater than under traditional grazing systems. Peach palm production was low, but was not affected by grazing. As there was no treatment of grazing without trees, elucidation of the effect of the trees on the animals was not possible. Soil physical properties improved over time.	Arévalo et al, 1998
Improved fallows	
In a comparison of six fallow systems (natural, planted <i>Inga</i> , <i>Inga</i> + <i>Centrosema</i> , planted <i>Colubrina</i> , <i>Colubrina</i> + <i>Centrosema</i> , pure <i>Centrosema</i>) followed by a cropping phase with three successive annual crops of maize, cowpea, rice), <i>Centrosema</i> alone gave the highest yields. Yield after tree fallows were similar or inferior to natural fallows (because of removal of poles and fruits). Financial performance of the different fallows would depend on the possibility of sale of tree products.	Alegre et al. 2005
In a comparison of seven fallows (natural, <i>Centrosema macrocarpum</i> , <i>Pueraria phaseoloides</i> , <i>Stylosanthes guianensis</i> , <i>Desmodium ovalifolium</i> , <i>Cajanus cajan</i> , <i>Inga edulis</i>) grown for 53 months after one year of rice cropping, the fallows with <i>Inga</i> and <i>Desmodium</i> (both woody leguminous species) outperformed the others in terms of N, P and K stocks. All fallows depleted stocks of Ca and Mg.	Szott and Palm 1996
<i>Inga</i> / <i>Desmodium</i> fallows during and after a maize-cassava sequence effectively controlled herbaceous weeds, both species contributing. Yields of cassava were not reduced by the fallow, and plantain yields possibly increased. <i>Inga</i> was the main source of biomass accumulation. However, the system requires more labour, may be more pest-susceptible, and reduces growth of other potentially useful species.	Staver 1989
In a modeling-based comparison of an improved fallow (3 years <i>Inga</i> fallows followed by 2 cassava crops) with a system currently practiced near Pucallpa (3 years <i>Imperata</i> , followed by 1 cassava crop), the improved fallow was less profitable in the short-term, but became more profitable after about 10 year.	Lojka et al. 2008

2.6.2 Agroforestry research by national institutions

Typically, research carried out by the national institutions is organized in semi-permanent programs or projects, with formal annual work plans, and is largely internally funded, with some modest quasi-external funding such as that provided by the INCAGRO²⁴ program. Although relevant to agroforestry and consistent with ICRAF's broad definition of agroforestry, the research in question may or may not be identified as agroforestry research by the institution and researchers concerned²⁵. Publication, particularly in peer-reviewed literature, is not necessarily an explicit goal of the research, and, internally, may be less important than the completion of planned activities and the full execution of planned budgets²⁶. However, in spite of not being oriented towards publication, national agricultural research projects in Peru have made major impacts on livelihoods of Peruvian farmers. Some examples of relevant agroforestry research, rather than a comprehensive survey, are presented here.

2.6.2.1 IIAP and INIA work with Native Fruits and Nuts²⁷

IIAP maintains an active program of research on fruit and nut species, implemented by its Sustainable Use of Biodiversity (USB) and Terrestrial Ecosystems (PET) Programs. The former program carries out botanical, agronomic, and pre-improvement work with *Porouma cecropiifolia*, *Theobroma bicolor*, *Mauritia flexuosa*, and *Caryodendron orinocense* (Figure 3). The PET program works with both *aguaje* (*M. flexuosa*) and *camu-camu* (*Myrciaria dubia*). IIAP has also carried out work with *Oenocarpus bataua* and *Spondias mombin*, financed by CONCYTEC²⁸.

To date, the research of both programs has been carried-out on-station, although in recent years IIAP has begun also to "return" evaluated germplasm of *T. bicolor*, *M. flexuosa*, *Theobroma grandiflorum* to farmers²⁹.

IIAP's work on fruit species is most advanced in the case of *aguaje* and *camu-camu*. In the former, work has included market studies (García Mauricio and Pinto Arévalo 2002), identification and collection of seed from dwarf phenotypes, and establishment of progeny tests. In the case of *M. dubia*, work has included extensive germplasm collections in different watersheds, establishment and maintenance of germplasm collections, clonal testing, development of vegetative propagation techniques, studies of variation in ascorbic acid concentration, product development, and market chain studies (Farronyay 2006).

INIA maintains extensive collections of *camu-camu* in its experimental stations near Iquitos and Pucallpa (Figure 3), but appears to be less active in agronomy and genetic improvement. Recently, INIA and IIAP have been collaborating on improvement of *camu-camu* within the framework of FRUTAMAZ, an ICRAF-coordinated project (see Section 2.7.2.3). INIA-Iquitos also maintains a semi-moribund germplasm collection of peach palm and a collection of native and exotic fruits (Figure 3) in the El Dorado Experimental Station near Iquitos.

²⁴ "Innovación para el Agro Peruano", a World Bank sponsored program coordinated from within the Ministry of Agriculture.

²⁵ IIAP, in particular, has not stressed agroforestry research as such (Angel Salazar, IIAP, personal communication, 13th July 2009), although some of the institution's work relates to purposeful deployment of trees of farms and in the landscape.

²⁶ One former head of INIA remarked that the reluctance of some researchers to publish (particularly those whose first language is Quechua) may be due to lack of confidence in writing skills, and to reluctance to expose deficiencies to colleagues and supervisors (Ricardo Sevilla, pers. comm., 9th July 2009).

²⁷ Sources: meetings of 13th July 2009 with IIAP staff, also IIAP (2000).

²⁸ National Council for Science and Technology.

²⁹ Agustín López, IIAP, personal communication, 13th July 2009.

2.6.2.2 Research on “agroforestry systems”

Meza *et al.* (2006) list three national research initiatives on agroforestry systems (Table 2). The results of these studies are not easily accessible; according to Meza *et al.* (2006), the most notable findings have been the general ones of improved knowledge of degradation processes and improved knowledge of soil requirements of different species. Ricse (2003) also presented a financial analysis of a proposed multistrata agroforestry system, based on projected values of costs and income. He reported an internal rate of return of 58%.

Table 2. Research initiatives on agroforestry systems listed by Meza *et al.* (2006)

Initiative	Executing agencies, location
Improved fallows in contour plantings for sustainable planting of annual crops	INIA; Irazola, Ucayali
Sustainable Amazonian Systems (silvopastoral systems)	Tropical and Highland Veterinary Research Institute (<i>Instituto Veterinario de Investigaciones Tropicales y de Altura</i> , IVITA; Coronel Portillo, Ucayali
Economic evaluation of agroforestry systems	National University of the Peruvian Amazon (<i>Universidad Nacional de la Amazonia Peruana</i> , UNAP); Maynas, Loreto

Figure 3. INIA and IIAP research with native fruits and nuts: IIAP researcher Agustín López with fruits from different varieties of *Theobroma bicolor* (top left); INIA germplasm collection of *Myrciaria dubia* during flood season (top right); INIA germplasm collections of *Bactris gasipaes* (bottom left) and tropical fruits (bottom right).

2.6.2.3. Research on plantation forestry

Smallholder-oriented research on plantation forestry, particularly species trials, has been carried out by a number of institutions, including the Tropical and Highland Veterinary Research Institute (*Instituto Veterinario de Investigaciones Tropicales y de Altura*, IVITA), IIAP, INIA, and ICRAF itself. Ara (1999) looked at growth of *Guazuma crinita* in three one-year old plantations located on “upland”³⁰ sites near to Nueva Requena. He found a significant positive relationship between Ca content of soil samples from the top 10cm soil and growth rate. Castillo Quiliano (2003) reported on plantation performance of the same species on sandy “upland” and periodically flooded sites in Ucayali. He found that commercial volume production at 4 years on the floodable site was more than double that on the upland site.

Soudre *et al.* (2001) reported on growth of six native species (*Amburana cearensis*, *Calycophyllum spruceanum*, *Cedrelinga catenaeformis*, *Schizolobium amazonicum*, *Terminalia oblonga*, *Tabebuia serratifolia*) on degraded sites along the Campo Verde-Nueva Requena road close to Pucallpa. All sites were abandoned swidden fields, dominated by *Imperata brasiliensis*, *Rottboellia cochinchinensis* and *Baccharis floribunda*. *S. amazonicum* had the highest growth rate, i.e. about twice the mean dbh of other species at 13 months, but survival was 75-80%. Survival was > 90% in the case of *C. spruceanum*, *T. oblonga*, *T. serratifolia*, but less than 20% in the case of *C. catenaeformis*. Ricse (2007) reported the results of species trials of *Aspidosperma Vargasii*, *Calycophyllum spruceanum*, *Dipteryx micrantha*, *Myroxylon balsamum*, *Ormosia schmuckei*, *Swietenia macrophylla* and *Tabebuia serratifolia*, located on highly acidic degraded soils in Ucayali. At six years, the average height and dbh of *D. micrantha* planted with earthworm compost were respectively 11.0m and 13.7cm, with 100% survival. Other species had average heights between 3.3m (*S. macrophylla*) and 6.3m (*T. serratifolia*).

2.6.3 Comment and analysis: agroforestry research in the Peruvian Amazon

In their review of the work of the Alternatives to Slash-and-Burn program in Peru, White *et al.* (2005), referring largely to the work presented in Table 1, commented that “in Peru, land uses that store more carbon and have greater biodiversity also have lower returns to labor and land”. However, the validity of this generalization is questionable—principally because few alternative land-uses were considered by ASB-Peru, and partly because each seems to be presented as a “given” without any possibility of modification. In the specific case of multistrata agroforestry, two “representative” systems were analyzed: a *G. crinita* plantation with *Centrosema* understorey and annual crops in the first year, and one that “contains *Inga*, annual crops, and *Centrosema*”. Neither seems typical or representative of most researchers’ concepts of multistrata agroforestry, and both lack higher value fruits and timber. In the case of fallow-based systems, White *et al.* (2005) stress how farmer innovation can move systems towards both financial and agronomic sustainability:

“for fallow-based agricultural systems, one may be tempted to state that they are neither financially attractive nor sustainable. Results ... refute such a claim. Although such agricultural systems can demonstrate productivity losses from weed invasions and soil fertility decreases, management practices of farmers can help maintain and even enhance the financial viability of such systems. For older, degraded areas, farmers often use fast-growing leguminous plants, such as kudzu, to increase soil fertility and organic matter. Farmers are also experimenting with crops such as cotton, beans and tropical fruits.”

There is, however, no reason why such farmer innovation could not be equally important in the case of other systems such as multistrata systems, which may in any case be components of long-fallow systems. If anything, research to date (Table 1) suggests that there are production systems that can be more environmentally benign than shifting cultivation, whose returns to land or labour

³⁰ i.e. non-flooded.

are comparable to shifting cultivation, and which might be made more profitable with further farmer- or researcher-led innovations.

Such comparison of agroforestry systems with alternative land-uses also suffer from an additional, more serious weakness: they have been designed with an essentially environmental focus, with little or no attempt to maximize profitability, so it makes little sense to compare their returns with other, profit-oriented land-uses. This in turn suggests the need to go beyond research into agronomic and environmental sustainability if agroforestry systems are to stand any chance of massive adoption. Although there is certainly a need to establish that agroforestry systems do exhibit greater environmental sustainability than alternatives, it is also important to recognize that, once this is demonstrated, there is a need to focus in on species and their products, whether they are worth producing, and, if so how to produce them in sufficient quality and quantity.

By contrast, the research on fruits and nuts described in Section 2.6.2.1 is largely product-oriented and, indeed, would probably not be identified as agroforestry research by the scientists involved. Although the camu-camu industry has recently suffered set-backs, and in spite of the absence of independent evaluation of its impact, research by IIAP and INIA into this species appears to have had clear positive impacts on livelihoods (see Section 2.7.4.2). A challenge that remains might be seen as the mirror image of that facing the “agroforestry systems” research discussed above: i.e. the need to ensure that camu-camu production contributes to mitigation or prevention of land degradation.

It is notable that agroforestry research by ICRAF and others in the Peruvian Amazon has been carried out very largely in the Amazonian lowlands of Loreto and Ucayali. This is perhaps due to historical reasons — i.e. ICRAF-Peru’s roots in the TropSoils program based in Yurimaguas— more than an explicit decision based on specific criteria. There are at least five reasons why a greater emphasis by ICRAF and partners on the *Selva Alta* could be appropriate:

- more critical problems of degradation, implying more palpably beneficial effects of agroforestry interventions;
- better access to markets;
- greater pressure on remaining forest, implying greater need for intensification;
- the *Selva Alta* includes prime cacao and coffee producing zones, both of which offer opportunities for agroforestry diversification;
- presence of longer-established colonist populations with more diverse local knowledge, derived from more consolidated, locally adapted livelihood strategies.

Finally, and in spite of some encouraging results, the paucity of published research on agroforestry in Peru is striking. In total, and excluding work on tree domestication (see 2.8.3) there are around 35 published studies, of which 20 are in international journals and 15 are in regional journals (Meza and Cornelius, 2005). Several of the latter summarize, draw upon, or are translations of internationally published research. In spite of ICRAF’s sometime prioritization of silvopastoral systems, there is almost no published research on this theme, and, in general, much of what has been published is based on a few experiments established by the TropSoils Program. While the widespread adoption of agroforestry in the Peruvian Amazon does not depend purely or even principally on locally implemented research, it does require a certain critical mass of locally validated findings. The relative scarcity of substantive results from research to date implies funding deficits, excessive workloads, or inefficient use of resources. In order to increase future research productivity and achieve the agroforestry outputs outlined in Section 2.4.1, the AI-EP will clearly need to plan carefully its use of resources.

2.7 Agroforestry practice in the Peruvian Amazon

In examining agroforestry practice in the Peruvian Amazon, it is useful to distinguish four types of agroforestry³¹ that are of some current importance: traditional indigenous and smallholder agroforestry, cacao and coffee agroforestry, “project agroforestry”, and potential monospecific components of agroforestry landscapes. The latter would not be considered agroforestry by more restrictive definitions; whether they can be considered agroforestry according to the broader, ICRAF definition, depends on various factors, including management practices and, presumably, their degree of dominance in the landscape. Each of these is examined below, with emphasis on income-generation potential and environmental impact. Germplasm issues in current agroforestry practice are also considered (Section 2.7.5).

2.7.1 Traditional indigenous and smallholder agroforestry

2.7.1.1 Prevalence

The existence in the Peruvian Amazon of domesticated or partially domesticated tree species such as *Bactris gasipaes* and *Theobroma bicolor* suggests strongly that indigenous Amazonians have been planting trees for generations³². Colonist (Hoch *et al.* 2009), indigenous (Denevan and Treacy 1987) and riverine (De Jong 2001) farmers continue to do so, whether in home gardens (Padoch and de Jong 1991; Oré Balbin and Llapapasca Samaniego 1996; Potters 1997; Coomes and Ban 2004), managed fallows (Denevan and Padoch 1987; Coomes, Grimard and Burt 2000), planting in crop fields (Brodie *et al.* 1997; de Jong 2001), or other less easily categorized ways.

There is some evidence that colonist farmers are less likely to practise agroforestry, particularly fallow management. Fujisaka *et al.* (2000) reported that fallow management by colonist upland and riparian farmers near Pucallpa was limited to leaving selected plants in swidden fields, but of a limited set of naturally regenerated species, and at most half of the farmers did so. Furthermore, settlers had limited knowledge of local plants beyond the most common species such as *Calycophyllum spruceanum*, *Guazuma crinita*, *Tabebuia serrata*, and *Inga edulis*. Similarly, in studies of dynamics of fallows on settlers’ farms near Pucallpa, Smith *et al.* (1999) found that there was no tree planting. Denevan and Padoch (1987) observed that, in the case of indigenous Bora communities, there was no clear transition between swidden and fallow, and no real abandonment of swidden fields, whereas Flores Paitan (1987) notes that in colonist shifting agriculture the fields are abandoned after a short period (2-3 years).

In contrast to these results, Brodie *et al.* (1997) found that farmers in four communities near Pucallpa, whether colonist or indigenous, practised fallow management, including tree planting (timber trees, fruit trees). This inconsistency with the reports of Fujisaka *et al.* and Smith *et al.* may be partly due to an oversimplification of the ethnic classification of the four communities. Brodie *et al.* only mention indigenous and colonist groups³³, i.e. they may have confounded colonist and riverine groups. Furthermore, ICRAF staff report that each of the communities studied (Shambo Porvenir, Porvenir, San Martín and Yanamayo, the last three of which are referred to as settler communities) is composed of more than one of these three groups (Julio Ugarte, personal communication, August 2009). Although ICRAF staff also report that colonist farmers in the Neshuya-Curimaná direct-sow and maintain *I. edulis* in swidden fields (Abel Meza, personal communication, 12th August 2009), this practice is closer to an improved fallow than a traditional managed fallow, i.e. it aims at faster recuperation of the site rather than production during the

³¹ i.e. using the broad ICRAF definition of agroforestry

³² Generations of trees or humans. Although preferential consumption of fruits of certain types and their subsequent germination in middens is also thought to be a cause of the genetic changes associated with domestication, there seems little doubt that deliberate sowing or planting was also involved.

³³ “Ribereños” are mentioned, but defined as “people who live by a river or lake” rather than as a culturally distinct group.

fallow period (as do similar practices with kudzu). Similarly, Castillo's (2009) report of producers with "a certain level of knowledge and capital" planting *G. crinita* intercropped with maize, i.e. essentially a taungya system, seems to refer more to a case of sporadic adoption of a system promoted by researchers and extension workers rather than a traditional agroforestry system. In summary, it seems that, to date, there are no unambiguous reports of intensive, traditional-type fallow management by colonist farmers in the Peruvian Amazon.

2.7.1.2 Tree species in traditional indigenous and smallholder agroforestry

There is strong evidence that fruit-trees are more commonly planted than timber trees or than trees used for poles or firewood (Brodie *et al.* 1997; Lamont, Eshbaugh and Greenberg 1999; Coomes and Ban 2004; Potters 1997). For example, Brodie *et al.* (1997) collected 205 instances of tree use on 59 sampled farms. Of these, 49% were fruit trees, principally *Inga edulis*, oranges, and mango. Most of the remaining 51% were neither tended nor planted. After fruit trees, the most common uses were firewood (13.6%) and poles (15.1%), but trees used for these purposes were not planted or cultivated because of their abundance in secondary forests. Similarly, in random samples of 30 smallholders in near Iquitos, Pucallpa, and Yurimaguas, Labarta and Weber (1998) reported that the timber trees *Calycophyllum spruceanum* and *Guazuma crinita* were produced by management of natural regeneration, while in an intensive study of the hamlet of Trancayacu, Potters (1997) found that of five species studied, only peach palm was planted (*Inga* seed was sown essentially casually, while *C. spruceanum* and the timber-trees *Cedrelinga catenaeformis* and *Pollalesta discolor* were neither planted nor sown).

Brodie *et al.* (1997) commented that "farmers' ideal tree growing venture is one that provides a cash income in the short-term and has a low labour requirement." Although this may be a reasonable explanation of the trends mentioned above, two additional observations are necessary. First, the benefits of tree growing may include own consumption as well as cash income. Second, the lack of interest in planting trees for poles and firewood may reflect not so much "time preference"—because poles and firewood can be produced as quickly as fruit—but the high natural abundance of the former products.

Finally, it should be noted that species used are also likely to reflect market access. This is one determinant of species richness in home gardens (Lamont, Eshbaugh and Greenberg 1999), and presumably in other planting configurations.

2.7.1.3 Economic impact of traditional indigenous and smallholder agroforestry

Traditional agroforestry practices can make substantial contributions to livelihoods. Padoch (1987) reported the percentage income derived from crops and forest products in 13 villages located in the Iquitos region. Although intensively managed crops were in many cases the single most important category, fruit trees also produced >10% of income in six of the villages, and many villages relied on produce from agroforestry plots for >50% of their cash income. Income from medicinal plants was negligible or nil. Similarly, in the riverine community of Tamshiyacu, the bulk of income came from cultivation and harvesting of production of fruits such as *B. gasipaes*, *Poraqueiba sericea*, and *Pouteria caimito* cultivated in "cyclic agroforestry plots" (Padoch *et al.* 1985).

Labarta and Weber (1988) reported income from agroforestry products and staple crops in smallholder communities. The mean proportions of total income that were derived from agroforestry products (*B. gasipaes* fruit, *Inga* fruit, firewood, timber of *G. crinita* and *C. spruceanum* was 32%, 48% and 15% in respectively Yurimaguas, Iquitos, and Pucallpa; fruit sales (chiefly *B. gasipaes*) made up respectively 61%, 88%, and 52% of the totals for agroforestry products.

2.7.1.4 Environmental impact of traditional indigenous and smallholder agroforestry

Traditional systems are essentially environmentally benign. Managed fallows offer a potentially profitable alternative to conversion of swidden fields to pastureland. Also, if land (i.e. for annual crops) is not limiting, then production of saleable products in fallows may make longer fallows advantageous. Bora fallows are still in their most productive period at age 12 (Denevan and Treacy 1987), long after short fallows would already have been cleared for a further cycle of cultivation.

Smith *et al.* (1999) contrast the environmental impact of improved fallows, which they expect to lead to less forest (because secondary forest will have no chance to develop), with that of enriched fallows, which they consider to be a more effective approach to securing environmental, soil, and economic benefits.

2.7.2 Cacao and coffee agroforestry

There are more than 313,000 ha of coffee plantations in Peru³⁴ and more than 64,000³⁵ ha of cacao plantations, many of them consisting of associations with *Inga edulis* or other shade-trees. In 2008 these agroforestry systems were responsible for respectively 2.1%³⁶ and 0.05%³⁷ of the value of Peruvian exports. Coffee agroforestry in Peru is concentrated in the higher parts of the *Selva Alta*, and is therefore located outside of the main area of interest, at least to date, of ICRAF and, perhaps, the AI-EP. Cacao production in Peru is concentrated in areas of greater interest to the AI-EP (e.g. the Aguaytia Valley, Tingo Maria, Tarapoto). In these regions, considerable resources have been and will likely continue to be invested in promotion of cacao as an alternative to illicit coca production (e.g. DEVIDA 2004). Cacao agroforestry systems constitute working examples of sustainable, potentially (or actually) profitable Amazonian land-use systems and therefore are directly relevant to the AI-EP's central goals.

Returns to land (NPV ha⁻¹, 15% discount rate) from cacao were the best (with citrus) of “upland” land-uses examined by the ASB consortium in Peru (White *et al* 2005 and references therein), although returns to labour were relatively low. Research also suggests that shade-tree components can make substantial contributions to livelihoods, although not necessarily to income. Rice (2008) found that in coffee farms in Peru, 28.5% of “value” of production came from firewood or (principally) fruits. However, only 3% of *income* (including valuation of self-consumption) of coffee farm production came from fruits, while sale of firewood was “inconsequential”. Rice found an average of 43.45 *Inga* trees ha⁻¹. The “technological package” promoted by DEVIDA (2004) prescribes shade-tree spacing of 6-19m (higher shade density is used in areas of lower precipitation and higher temperature). Suggested species include various *Inga* species, some timber species (*G. crinita*, *A. cearensis*, *Cordia*), but no fruit species, in part because of possibly increased pest and disease risk.

With respect to environmental impacts, similar arguments apply as for managed fallows. Although conversion to cacao may result in forest degradation or deforestation, shaded cacao is generally regarded as environmentally preferable to other non-forest land-uses (Donald 2004 and references therein).

2.7.3 “Project agroforestry”

The term “project agroforestry” is used here to describe specific, named agroforestry systems, often based on on-station research or demonstration plots (in-country or abroad), but also on existing practice (e.g. coffee with shade trees), typically promoted as part of development projects. In Peru

³⁴ Ministerio de Agricultura [Ministry of Agriculture] 2010a.

³⁵ Ministerio de Agricultura [Ministry of Agriculture] 2010b. Area harvested in 2008.

³⁶ Ministerio de Comercio Exterior y Turismo [Ministry of External Trade and Tourism] 2010. The value of coffee exports (unroasted grain) in 2008 was US\$ 643.80 million, exceeded only by gold, copper, fish meal, zinc, molybdenum and lead.

³⁷ Ministry of Agriculture [Ministerio de Agricultura] 2010c.

and neighbouring countries (notably, Brazil), the term “agroforestry system” (or simply “SAF”) has come to be virtually synonymous with multistrata systems, particularly, in Peru, those developed in the San Ramón Experimental Station in Yurimaguas. Although few farmers have adopted multistrata systems or other researcher-generated practices (e.g. silvopastoral systems, improved tree-based fallows, alley-cropping), they have been promoted in development projects implemented by government and non-government organizations and have been implemented by farmers under the aegis of such projects. Meza *et al.* (2006) list 16 development initiatives of this type (Table 3). They do not analyze in detail the individual results of these initiatives³⁸. However, they do comment that those projects that have resulted in increased income have tended to do so either due to sales of products such as coffee or cacao, or as a result of direct project subsidies. From the perspective of executing and financing agencies, all of these projects were aimed partly or wholly at restoring tree or forest cover on degraded land and were in some degree successful in meeting this objective, at least temporally.

Meza *et al.* (2006) also list a number of factors that impeded the success of the initiatives: ecological factors (extremely poor soil, ignorance of site requirements of the species used), socioeconomic factors (unwillingness to participate in non-subsidized activities, poor organization), and institutional factors (lack of coordination between institutions, uncertain land tenure).

Table 3. *Agroforestry development initiatives listed by Meza et al. (2006)*

Type of Initiative	Executing agencies, location
	Selva Alta
Agroforestry systems with coffee and cacao	Reforestation Committee, Satipo-Chanchamayo: Oxapampa, Pasco
Agroforestry systems with coffee and cacao	Municipality of Mariano Dámaso Beraún
Agroforestry systems with coffee and cacao	Consorcio Foresta 5: Leoncio Prado, Huánuco
Agroforestry systems with pineapple, coffee and <i>Solanum sessiliflorum</i>	Huallaga Central Reforestation Committee: Huánuco, San Martín
Agroforestry systems with coffee, timber trees, fruit trees	CEDISA (Centro de Desarrollo e Investigación de la Selva Alta): Lamas and San Martín, San Martín
Native timber trees and <i>Inga edulis</i> associated with annual crops	FUNDAM (Fundación para el Desarrollo Agrario del Alto Mayo): Rioja, San Martín
Agroforestry systems with coffee, fruit trees and annual crops	PEAM (Proyecto Especial Alto Mayo): Moyobamba, San Martín
<i>Inga edulis</i> as coffee shade	INRENA: Jaén and San Ignacio, Cajamarca
Agroforestry systems with coffee, timber trees, and <i>Inga</i> spp.	GTZ: Jaén, San Ignacio, Bagua
Agroforestry systems with coffee	PRONAMACHCS: Bagua
	Selva Baja
Agroforestry (unspecified)	Camara Forestal Nacional: Padre Abad, Ucayali
Agroforestry systems with <i>bolaina blanca</i> , cat’s claw, and annual crops	ADES (Asociación para el Desarrollo Sostenible de la Selva)
Agroforestry systems with annual crops	Reforestation Committee, Pucallpa
Agroforestry systems with timber and non-timber species	Reforestation Committee, Madre de Dios: Tambopata
Agroforestry systems with timber and non-timber species	INRENA: Tambopata, Madre de Dios
Agroforestry systems with species of economic value (coffee, cacao, fruits) and <i>Inga edulis</i>	FADEMAD (Federación Agraria Departamental de Madre de Dios)

2.7.4 Potential monospecific components of agroforestry landscapes

The current ICRAF definition of agroforestry is a landscape level definition, such that monoculture at plot level may be considered as part of an “agroforestry landscape”. A number of established and emerging perennial crops, generally cultivated in monoculture, are therefore potential components of agroforestry landscapes, i.e. are being or could be integrated into agricultural landscapes in ways

³⁸ Due to the temporary nature of the activities, poor documentation, and personnel changes, such an analysis would probably be possible only through direct survey of a sample of beneficiaries.

that increase social, environmental and economic benefits. Three crops or crop types are considered below.

2.7.4.1 African oil palm

Currently, the most important legal perennial monoculture crop in the Peruvian Amazon is African oil palm (*Elaeis guianensis*), with 5900ha in production in Ucayali, and 3900ha “installed”, i.e. planted but not in production³⁹. These plantations feed processing plants in Neshuya (OLAMSA) and Aguaytía. There is another processing plant, with associated plantations, located near Tocache in San Martín (Palmas del Espino). The Ucayali initiatives were established with external funding as “alternative development”⁴⁰ projects.

Around four hundred of the 500 or so palm growers in the Neshuya area are OLAMSA shareholders, who receive a share of profits at the end of each year. The price per fresh raceme is set to 15.5% of the Indonesian FOB price. The price in July 2009 was US\$95 T⁻¹, higher than the 2009 low of \$65, but much lower than the \$285 T⁻¹ at the beginning of the year⁴¹. OLAMSA technical personnel report current average production at 18.7 T fresh raceme ha⁻¹ yr⁻¹, and costs of about \$2200 in first year, then \$1400-\$2100 ha⁻¹ yr⁻¹ thereafter⁴².

Although White *et al.* (2005) report that net present values from oil palm production in Ucayali equate to returns to labour below the minimum wage, appearances (e.g. TV satellite dishes) and anecdote (e.g. aggressive marketing to cooperative members by credit card companies⁴³) suggest that the establishment of the OLAMSA plant near Pucallpa has had a transformative effect on incomes of at least some smallholders in its zone of influence. This impression was reinforced by conversations with Nemesio Damian, a long-time ICRAF collaborator and current president of the Aguaytía Watershed High Quality Seed and Wood Producers’ Association (Asociación de Productores de Semilla y Madera de Alta Calidad de la Cuenca del Aguaytía, PROSEMA) (see Section 2.8.2.3). Mr. Damian has 11ha of oil palm plantation, of which 5ha are in production. He reports income of S/.1000-S/.1500 every 15 days from the 5ha. He expressed no reservations with regard to oil palm, other than commenting (in response to questions) that the OLAMSA technical personnel tend to be inflexible with regard to departures from the standard “technological package”⁴⁴.

2.7.4.2 Camu-camu

Camu-camu (*Myrciaria dubia*) is a native myrtaceous shrub or small tree, whose fruits have exceptionally high vitamin C content (up to 3000mg 100g⁻¹, i.e. approximately 30 times that of orange) (Pinedo 2006). It has been heavily promoted by IIAP, INIA, and Regional Governments as an export crop. By 2007 there were around 700ha of camu-camu plantations in Ucayali, and around 1300 families involved in its production (ICRAF 2007). Between January and November 2006 camu-camu exports grew by 130%, with a value of US\$1.86 million (ICRAF 2007). Prices peaked at \$4200 T⁻¹ of pulp in Lima. More recently, the economic downturn, competition from Brazilian-produced acerola (another fruit high in Vitamin C), and product reformulation in Japan (i.e. reduction from 6%-2% camu-camu concentration) have led to a fall in prices (\$1200 T⁻¹) and

³⁹ source: www.regionucayali.gob.pe.

⁴⁰ i.e. alternative to illicit coca production.

⁴¹ Nemesio Damian, PROSEMA, personal communication, 11th July 2009. These fluctuations seem excessively wide and possibly correspond to a longer time-span than that reported.

⁴² S/. 4000-6000 ha⁻¹ yr⁻¹; Pedro Seijas Cárdenas, OLAMSA, personal communication, 15th July 2009.

⁴³ Pedro Seijas Cárdenas, OLAMSA, personal communication, 15th July 2009

⁴⁴ He recounted that his wife had had to insist on retaining a particularly productive aguaje (*Mauritia flexuosa*) tree that the OLAMSA personnel has asked her to eliminate from the oil palm plantation.

demand (zero demand from Japan in 2008 and 2009 to date)^{45,46}. However, in the medium-term it seems likely that camu-camu will remain a viable production option. IAP researcher Mario Pinedo (admittedly a camu-camu enthusiast) commented “those who have persisted with camu-camu are not millionaires, but they have transformed their economic situation...whereas the extractivist producer remains in the same situation”⁴⁷.

2.7.4.3 Timber tree plantations

The area of monocultural timber plantations in the Peruvian Amazon is negligible. Activity is concentrated in the relatively prosperous *Selva Central*⁴⁸, and there tends to involve medium to large landholders and investment groups rather than smallholders (pers. comm., Julio Ugarte, ICRAF, 8th July 2009; Ymber Flores and Pedro Reyes, INIA, 10th July 2009⁴⁹). ICRAF is already strongly identified with this production system, both because of its work in timber tree germplasm development and because some of the TDP trials have been highly effective as monospecific demonstration plots. However, even in ICRAF’s zone of influence, there has been little uptake of such activities by smallholders. There are several possible explanations for this: low standing timber prices, lack of access of farmers to value-adding equipment, the relatively high investment needed, the demanding soil requirements of the species worked with by ICRAF (*G. crinita* and *C. spruceanum*) (see 2.5.2.3), and the lack of activity in extension and promotion.

It is worth mentioning that ICRAF’s association with timber tree plantations—specifically, small monospecific blocks of *G. crinita* or *C. spruceanum*, planted in association with *Centrosema* ground cover and with heavy soil amendment and fertilization—is in a sense an accident, as the system represents the conditions under which germplasm has been tested, aimed at ensuring reasonably high survival and growth, rather than the systems in which it would necessarily be deployed.

In spite of the low uptake of this technology by smallholders, current activity in timber plantations is of obvious relevance to ICRAF’s tree domestication work. Some notable initiatives are reviewed here.

GEA Forestal, PROSEMA and Pronaturaleza

In 2001–2002, ICRAF became involved in an association between GEA Forestal, a local forestry company, Pronaturaleza, a Peruvian NGO, and PROSEMA (Aguaytía Watershed High Quality Seed and Wood Producers’ Association, Asociación de Productores de Semilla y Madera de Alta Calidad de la Cuenca del Aguaytía), a civil association formed by ICRAF’s farmer collaborators (see Section 2.8.2.3). According to White *et al.* (2005), a framework agreement and individual contracts were signed between GEA and PROSEMA members, establishing that PROSEMA would provide an inventory of members with legalized land rights and with adequate biophysical conditions to plant *G. crinita*, and guaranteeing that GEA would buy the products produced —*G. crinita* roundwood— by PROSEMA. Seedlings were produced on GEA lands as part of a donor-financed project executed by Pronaturaleza, and then planted on smallholder lands. The project “Empowerment of farmers through organization and enterprise-building” (2002–2004), financed by the Tinker Foundation and executed by ICRAF, aimed in large measure at preparing PROSEMA partners to participate in this partnership. However, although some plantations were established by

⁴⁵ Juan Fernando López Menozzi (Palmagro) and Lambert Pie Pau (Selva Industrial S.A.), personal communications, 7th July 2009.

⁴⁶ Mario Pinedo, IAP, personal communication, 13th July 2009.

⁴⁷ Mario Pinedo, IAP, personal communication, 13th July 2009.

⁴⁸ A zone of both lowland and upland rainforest located within 5–6 hours road travel of Lima.

⁴⁹ Characterized by one interviewee as falling into two groups of investor: the speculators (i.e. those interested in acquiring, adding value to, and selling property), and the “for the good of humanity” benefactors.

Pronaturaleza⁵⁰, in practice no commitment was ever made by GEA Forestal to buy the timber produced, and the proposed partnership never reached fruition.

Reforestation-based development initiatives listed by Meza *et al.* (2006)

Meza *et al.* (2006) list a number of development and land rehabilitation initiatives based on reforestation with timber trees (Table 4). As mentioned in connection with agroforestry systems (see 2.7.3), financial benefits to farmers from these projects have generally been limited to direct subsidies from the projects themselves⁵¹. In spite of the indifferent socioeconomic result of these activities, similar projects continue to be implemented. For example, the Regional Government of Ucayali currently is implementing seven reforestation projects in Coronel Portillo and Atalaya, with an area of 3000 ha, whilst local governments (municipalities) in Curimaná, Aguaytia and Nueva Requena are devoting 1-3% of their budgets to reforestation, principally with *G. crinita*, *C. spruceanum*, *D. micrantha*, *T. serrata*, *Cedrela odorata*, and *S. macrophylla*.⁵²

Table 4. Reforestation development initiatives listed by Meza *et al.* (2006)

Type of Initiative	Executing agencies, location
	Selva Alta
Block and shelterbelt reforestation with native (mahogany, walnut) and <i>Eucalyptus</i> spp.	Reforestation Committee, Satipo-Chanchamayo: Oxapampa, Pasco
Reforestation with native species of land degraded by coca production	Programa de Naciones Unidas para Fiscalización Internacional de Drogas (PNUFID): Huamalies and Leoncio Prado, Huánuco
Reforestation with <i>bolaina</i> , Spanish cedar, <i>moena</i> and <i>tornillo</i> in blocks and shelterbelts	Municipality of Mariano Dámaso Beraún
Reforestation with <i>ishpingo</i> , <i>achiote caspi</i> , Spanish cedar, <i>bolaina</i> , mahogany	Huállaga Central Reforestation Committee: Huánuco, San Martín
Reforestation with native (<i>capirona</i> , <i>Inga edulis</i> , <i>pashaco</i> , <i>shaina</i>) and exotic species (<i>Albizia</i> , <i>Eucalyptus</i>)	INRENA: Moyobamba and Rioja, San Martín
Reforestation in degraded grasslands with native ((<i>capirona</i> , <i>Inga edulis</i> , <i>pashaco</i> , <i>shaina</i>) and exotic species (<i>Albizia</i> , <i>Eucalyptus</i>)	PEAM (Proyecto Especial Alto Mayo): Moyobamba and Rioja, San Martín
Forest plantations for energy and construction	PEAM (Proyecto Especial Alto Mayo): Moyobamba and Rioja, San Martín
Reforestation with <i>pashaco</i> and <i>Eucalyptus</i>	INRENA: Jaén y San Ignacio, Cajamarca
	Selva Baja
Reforestation in shelterbelts and blocks with Spanish cedar, <i>marupa</i> , <i>tornillo</i> and <i>cumala</i>	Iquitos Reforestation Committee: Maynas, Loreto
Reforestation with <i>bolaina</i> , mahogany, <i>tornillo</i> , <i>sangre de grado</i>	Reforestation Committee, Pucallpa
Reforestation with mahogany, <i>pashaco</i> , Spanish cedar, <i>tornillo</i>	Reforestation Committee, Madre de Dios: Tambopata
Reforestation with mahogany, <i>pashaco</i> , Spanish cedar, <i>tornillo</i>	INRENA: Tambopata, Madre de Dios

FONDEBOSQUE⁵³

FONDEBOSQUE is a “quango” set up in 2002, aimed at capturing and channeling funds for the development of the Peruvian forest industry, with a strong emphasis on plantation forestry⁵⁴. Since 2004, it has been promoting reforestation following highly technified, intensive methods, based on southern Brazilian practice, i.e. clonal eucalyptus (8 clones of *Eucalyptus x urograndis* and *E.*

⁵⁰ In some cases, in close proximity to ICRAF progeny trials.

⁵¹ Benefits from sale of cacao and coffee (see 2.7.3) do not apply in the present context.

⁵² Manuel Soudre, IIAP, personal communication, 10th July 2009.

⁵³ Martin Retamoso Inuma, FONDEBOSQUE, personal communication, 9th July 2009.

⁵⁴ See fondebosque.org.pe.

urophylla), mechanized site preparation, containerized planting stock). Currently, FONDEBOSQUE is producing 600,000-900,000 plants per year in three nurseries. In 2007, 1200 ha of plantations were established in Oxapampa, *Selva Central*. In spite of emphasis on the “Brazilian system”, 70% of current seedling production is of native species (*G. crinita*, *C. spruceanum*, cumala, *Juglans* spp., *Simarouba glauca*, *C. catenaeformis*).

REFORESTA-Peru⁵⁵

REFORESTA-Peru S.A.C. is a private company formed by Enrique Toledo, founder and ex-CEO of FONDEBOSQUE. At present, REFORESTA-Peru is active principally in the Tarapoto area. The company markets a complete service in design, establishment, and maintenance of agroforestry and forestry farms, using a technological package similar to that of FONDEBOSQUE, but also influenced by approaches developed by TropSoils, ICRAF, and CIAT.

Mr. Toledo describes one investment option as the “cacao pension fund”; he explains that a landowner wishing to establish such an asset would require about 20ha of coffee or cacao, with *Centrosema* ground cover and *C. spruceanum* and *S. macrophylla* timber component. On already-purchased land, REFORESTA-Peru’s charges would be about \$1800 ha⁻¹ for installation, \$1300 ha⁻¹ yr⁻¹ for maintenance over the first three years, and \$600 ha⁻¹ yr⁻¹ thereafter. Installation would involve mechanical site preparation, with ripping to 40cm, application of a minimum of 1T dolomite ha⁻¹ (to reduce pH to 4.5-5.5), and application of rock phosphate.

Another model involves conversion or diversification of cattle farms with teak (*T. grandis*). After pasture improvement on part of the property (ensuring no net loss of cattle production), *T. grandis* would be planted on the remainder. Mr. Toledo projects value of standing timber of \$60,000 ha⁻¹ at age 14, presuming sale of timber as processed sawn timber. REFORESTA-Peru is negotiating the purchase of a state-of-the-art portable sawmill, at a cost of around €100,000, which would enable them to offer milling services.

For the Tarapoto region, REFORESTA-Peru has prioritized eight native timber species (*S. macrophylla*, *C. odorata*, *G. crinita*, *C. spruceanum*, *Colubrina*, *S. amazonicum*, *S. amara*, and bamboo (*Guadua* spp.)) and three exotics (*Tectona grandis*, *E. x urograndis*, *Pinus caribaea* var. *hondurensis*).

SFM / BAM (Sustainable Forest Management / Bosques Amazónicos)⁵⁶

SFM / BAM is a Peruvian-British afforestation consortium. Its initial business model was based on sale of future wood production. The company’s current focus is on carbon sequestration and sale, to be complemented eventually by sale of certified processed wood products. SFM /BAM’s forest estate is located on a highly degraded former cattle-farm near Pucallpa (Figure 4), and is managed in collaboration with AIDER, a Peruvian NGO. Essentially, the aim is to establish a high value, high C-stocked plantation consisting of *Dipteryx micrantha*, a high-density hardwood, mixed with mahogany (10-20 trees ha⁻¹). Initially, *Inga edulis* is planted, with the main aim of reducing soil compaction and fixing nitrogen. Fertilizer is added to the planting hole. After 1 year, *Simarouba amara* and *D. micrantha* are planted at 833 stems ha⁻¹, along with the mahogany. *S. amara* is a lighter hardwood, expected to be harvested at 10 years. Mechanized site preparation is used when possible. Weeds are controlled chemically, although pests are mostly removed manually. To date, 815ha have been established, of a planned estate of 2500ha. The company currently employs 35 fulltime workers, plus 470 workers per planting season. This is expected to fall to about 50-60 workers once planting is complete, who will work on tending operations (pruning, weeding). Growth to date of both *D. micrantha* and *S. macrophylla* appears impressive, considering the poor soils. The principal problems encountered to date appear to be pest infestations on *Inga edulis*, the

⁵⁵ Source: Enrique Toledo, REFORESTA-Peru, personal communication, 17th July 2009.

⁵⁶ Source: Jorge Chávez Rodríguez (AIDER), personal communication, 11th July 2009; Alejandro Llaque S. (Bosques Amazónicos) and Jorge Chávez Rodríguez, personal communications, 15th July 2009.

need for intensive pruning of *I. edulis* (in order to allow sufficient light for growth of the other species), high variability and the need for lower stature genotypes of *I. edulis*, and seed sourcing and quality problems in *S. macrophylla* (high incidence of albinism).

In theory, the SFM / BAM “package” is available for adoption by local smallholders. However, SFM/BAM staff mention impediments to such adoption: their own stipulation of 5ha minimum block size, and the difficulty of ensuring appropriate use of herbicides (i.e. avoiding human health risks as well as herbicide drift to the crop trees).

Figure 4. SFM/BAM forest estate near Pucallpa (top left: typical soil profile; top right: soil penetration by *Inga edulis* roots; bottom left: view from fire tower of reforested areas; bottom right: interior of one-year old plantation).

2.7.5 Germplasm use and issues in agroforestry practice

2.7.5.1 Traditional indigenous and smallholder agroforestry

Germplasm used in traditional agroforestry systems is not generally purchased. Brodie *et al.* (1997) found that the main sources of germplasm for farmers were their on-farm trees, neighbours, fruit markets, and local remnant high forests. Consistent with this, it is known that home gardens of farmers from larger kin groups tend to be more diverse (Coomes and Ban 2004), suggesting that germplasm is sourced by exchange or gift rather than purchase. Home gardens may also serve as experimental areas (Hamlin and Salick 2003) or temporary storage areas, i.e. pending planting of material in forest fallows (Padoch and de Jong 1991; Coomes and Ban 2004).

Brodie *et al.* (1997) found that approaches to sourcing germplasm of timber and fruit trees were quite different. In the former case, seedlings were sourced as wildlings in neighbouring forest or crop fields, whereas fruit trees were planted predominantly (87%) from seed. There was no conscious selection in the case of timber trees, whereas farmers selected fruit tree germplasm prior to planting based on fruit characteristics.

Brodie *et al.* (1997) also reported that:

“physical shortage of germplasm, except in the case of S. macrophylla, is not a limiting factor in tree cultivation among farmers of the case study communities.”

It should be noted that this comment refers to germplasm for traditional planting practices, including some practices that farmers aspire to (e.g. mahogany cultivation). Clearly, it is not necessarily or probably valid for all possible tree planting activities.

2.7.5.2 Timber species in “project agroforestry” and pure plantations

Traditional germplasm supply systems (2.7.5.1) are likely to be inadequate to supply the germplasm needs of development projects such as those listed by Meza *et al.* (2006), whereas in Peru there is no formal germplasm supply system for timber trees. As a result, NGOs and other agencies are likely to experience difficulties in germplasm sourcing. For example, SFM / BAM has resorted to sourcing mahogany seed from one parent tree. ICRAF’s work has largely resolved such problems in the case of *C. spruceanum* and *G. crinita*, but there are no recognized seed sources for the many other native species of interest, nor of potentially important exotic species such as teak. Furthermore, some agencies (e.g. some personnel within the Regional Government of Ucayali⁵⁷) remain unaware of the availability of *C. spruceanum* and *G. crinita* seed from PROSEMA and of the existence of genetic improvement projects with these species.

2.7.5.3 Fruit species in “project agroforestry” and pure plantations

The situation in fruit species parallels that of timber trees. Although, for a few species, either traditional varieties / landraces (*Theobroma bicolor*, *Bactris gasipaes*) or breeders’ varieties (major fruits such as avocado, *Citrus*, mango) are available, for the majority of species of possible interest (e.g. *Oenocarpus bataua*, *Mauritia flexuosa*, *Caryodendron orinocense*, *Pouteria caimito*, *Poraqueiba sericea*, etc), there are no improved sources or cultivars available. However, national institution research with “new” fruit trees (e.g. *M. dubia*, *M. flexuosa*), unlike that with timber trees, tends to be explicitly focused towards cultivar development. This difference perhaps reflects the much higher awareness of the importance of genetics amongst agronomists than amongst foresters.

2.7.6 Agroforestry practice in the Peruvian Amazon: comment and analysis, including research implications

Hoch *et al.* (2009) have suggested that “project” tree planting (whether in agroforestry systems or smallholder timber plantations) has largely failed because, rather than supporting farmers’ traditional tree planting activities, it has concentrated on alternatives with unrealistic cost and labour demands. While it may be true that development projects have not given adequate consideration to existing tree planting practices, and that researchers or extensionists may even be unaware of them, it is worth pointing out also that, by and large, such activities —encompassing both sporadic tree planting and more formal traditional practices—are part of a production system and livelihood strategy associated with poverty and extreme poverty, whereas development projects, although sometimes ill-conceived, poorly planned, or poorly executed, usually aim at

⁵⁷ Pers. comm., Edgar Manuel Inga Pérez, Rubén Munarris Norreses, Grober Panduro Pisco, Róger Vargas Simplicio, Regional Government of Ucayali, Division of Natural Resources and Environment, 14th July 2009.

significant improvement or transformation of living conditions. The real question of interest should not be:

“how can development (and research) projects support traditional indigenous and smallholder tree planting?”

but, rather:

“how can agroforestry development projects, perhaps based partly on traditional indigenous and smallholder tree planting, effect transformation in the lives of the rural poor?”

The clearest lesson from the experiences described above is that market access is an important and probably ineluctable condition for such transformations to occur. This is shown or suggested by, for example, the relative success of agroforestry projects associated with coffee or cacao production, the keen awareness of markets shown by private sector investors such as the management of REFORESTA-Peru, the apparent, if qualified, success of the oil-palm enterprise in Ucayali, frequent disillusionment of smallholders with projects that fail to generate increased income (Meza *et al.* 2006), the (qualified) success of camu-camu, and the widespread adoption of illicit coca cultivation. It is also, it might be added, a matter of common sense.

One implication is that agroforestry development and research activities in Peru need to be both product/market- and environmentally-driven, and need to leave behind the idea that an “agroforestry system”, in itself, is a research or extension product of particular interest or value to smallholders: in reality, the simple “installation” of an agroforestry system will not have any transformative effects on livelihoods. The potential, rather, is in development of products and their market chains. Once these are established, or concurrently, then environmentally responsible production systems, possibly involving classic agroforestry systems such as multistratas, can be developed and promoted as a research product that can have the desired transformative effect.

Smallholders express, by their actions, a clear preference for planting fruit trees rather than timber trees. It seems likely that this preference is motivated at least in part by market opportunities. However, it would be a mistake to conclude that the products prioritized for development should therefore necessarily be native fruits. This is largely because smallholders are likely to be unaware of some markets and uses, and particularly of those export markets and associated products that offer a genuine possibility of “transforming lives”. This principle is illustrated both by camu-camu (a native fruit, but one marketed largely on the basis of characteristics initially unknown to smallholders, i.e. vitamin “C” content) and oil-palm.

FONDEBOSQUE and REFORESTA-Peru publications and personnel make a persuasive, although familiar, case for plantation forestry in the Peruvian Amazon: a trade deficit in wood products, the much greater potential productivity of plantations v. natural forest, reduced forest to mill transport costs, suitability for forestry, rather than agriculture, of many Amazonian soils, possibility of reducing pressure on natural forest, etc. This potential is real, but its realization in a way that will benefit smallholder farmers will obviously require coordinated action, rather than isolated “reforestation” campaigns involving distribution of seedlings to farmers. In the case of site-sensitive species such as *G. crinita*, such campaigns are likely to be counterproductive, as, without intensive site preparation and maintenance (as espoused by REFORESTA-Peru), such plantations are likely to fail on many “upland” farms.

In the product-centred approach suggested above, the implication is that agroforestry tree products will be the principal income-generating components of production systems. However, an alternative entry-point for agroforestry development is available, i.e. the diversification and sustaining of existing systems. This may involve marketable or service-providing agroforestry species. The obvious example is the enhancement of cacao and coffee monoculture (or simple coffee/cacao agroforestry systems) with diversified or improved shade trees.

Diversification of oil palm farms and plantations could be another opportunity. To date, ICRAF-Peru has had little or no engagement with the smallholder-based oil palm industry located close to Pucallpa, even though several of the farmers involved in the TDP are *palmicultores*. Essentially, the industry has been treated as being of little or no relevance to ICRAF's agenda, or, at least, of no more relevance than off-farm income sources. However, the apparent (qualified) success of the OLAMSA initiative raises two issues that ICRAF could usefully address. First, there appear to be no hard data on either the financial returns to oil palm growing in Ucayali or on the industry's environmental impact. Second, although criticism of the environmental impact of the industry is commonplace in the Pucallpa area, there have been no attempts at quantifying environmental impact or at developing and demonstrating the feasibility of more environmentally friendly production techniques, for example incorporation of fruit trees, including *Inga*, between rows and in fence lines. There may be both agronomic and social constraints to such practices; here the intention is only to point out that there is a need at least to establish what scope there may be for such modified oil palm production practices. The same might apply to other monocultures.

Inga edulis is of particular interest in this and other regards. The importance of this species (and its congeners) was recognized long ago by TropSoils and ICRAF, but this importance—as a widely planted fruit and fuelwood species, as a common component in cacao and coffee agroforestry, and due to renewed interest in its role in rehabilitation of degraded sites—is not reflected in current research agendas.

Finally, a comparison of location of research activities and development activities seems to suggest a significant dislocation between the two: research activities in Amazonian agroforestry, including timber plantations, tends to be carried out in the *Selva Baja*, whereas development initiatives appear to be more common in the *Selva Alta*. This likely reflects a number of factors: on one hand, the influence of the TropSoils program and the location of both ICRAF and INIA's agroforestry section in Pucallpa, and, on the other, the development imperatives caused by extensive land degradation and, perhaps, the more acute need for alternatives to coca production in the Highland Rainforest. Although understandable, this apparent dislocation is undesirable and, insofar as the AI-EP seeks to have an impact in the *Selva Alta*, should be of concern to it.

2.8 The Tree Domestication Program

2.8.1 Objectives and target group

The Tree Domestication Program was begun in 1995 (ICRAF 1995)⁵⁸. There appears to be no single, definitive, complete description of the objectives of the Program. However, they are stated explicitly or implicitly in the various documents describing initial activities and intentions (Sotelo Montes and Weber 1997; Weber *et al.* 1997; Weber *et al.* 2001). The program's development and environmental objectives, based on these sources, are summarized in Figure 5. Essentially, the TDP was aimed at improving livelihoods of smallholder farmers by facilitating their access to high quality germplasm that would result in both higher and more stable production of tree products, particularly in silvopastoral systems, multistrata systems, and improved fallows, i.e. ICRAF's priority systems at that time. The program was to secure environmental goals both directly (because the domestication activities would entail conservation of genetic resources) and indirectly (because intensification with improved material “may” lead to reduced deforestation). The activities, located principally in the Aguaytía Valley, were conceived as model or pilot activities, which, based on the results achieved with individual farmers, would then be scaled-up both locally and, through “institutionalization” of the approach, throughout the Peruvian Amazon. Sotelo-Montes and Weber (1997) state that, for the initial priority-setting process (see 2.8.2.1) “resource-poor farmers

⁵⁸ Previous to this, work had been restricted to continuation of research on *Inga* and *Bactris gasipaes* begun by the TropSoils Program.

Figure 5. Objectives of ICRAF's Tree Domestication Program in the Peruvian Amazon

involved in deforestation" were selected as "clients", i.e. as the group targeted by the research-for-development intervention.

The scientific objectives are in general implicit in or clear from the activities and experiments implemented (see 2.8.2), i.e. elucidation of patterns of genetic variation, estimation of genetic parameters, quantification of effects of seed movements, etc.

2.8.2 Approach and activities

The TDP can be most easily presented as being composed of a core program of tree improvement (described in 2.8.2.2), with a number of specific supporting or complementary activities (2.8.3.3). The activities were directed principally at four species, selected using a participatory priority-setting procedure. As this procedure underlies the TDP and influences its usefulness, it is described first.

2.8.2.1 Priority-setting

The justification and broad approach of the priority-setting process is clearly stated by Sotelo Montes and Weber (1997):

“Before beginning an extensive program of agroforestry research it is necessary to prioritize species. This prioritization should consider the present and future needs of the farmers, the tree species that satisfy their necessities, those biological characteristics and attributes relevant to research, and the present and future markets available for the farmers.”⁵⁹

The prioritization process used, based on one developed by ICRAF and ISNAR (Franzel *et al.* 1996), consisted of a number of stages (Table 5), including identification of farmers’ “most important” or “highest priority” species, evaluation of these species’ suitability for specific priority uses, expert consultation, and consideration of other factors such as feasibility of research and adoption potential.

⁵⁹ “Antes de iniciar un extensivo programa de investigación agroforestal se debe hacer la priorización de especies. Esta priorización debería considerar las necesidades presentes y futuras de los agricultores, las especies arbóreas que satisfacen sus necesidades, características biológicas y atributos en la investigación de estas especies, así como el presente y futuro mercado disponible para los agricultores.”

Table 5. *The species prioritization process used in ICRAF's Tree Domestication Program in the Peruvian Amazon (based on Sotelo Montes and Weber 1997)*

<i>Stage</i>	<i>Methods</i>	<i>Notes</i>
0. Identification of priority agroforestry systems	Collaboration with national institutions, universities and NGOs	Multistrata systems, silvopastoral systems and improved fallows were selected. Although system prioritization was not, as such, a part of the species prioritization process, Sotelo Montes and Weber (1997) state that "the prioritized species must be easily applicable to these systems." ⁶⁰
I. Selection of study zones and target groups (i.e. for prioritization study and, by implication, for subsequent domestication studies)	Based on contemporary ICRAF research priorities	Target group: resource-poor farmers involved in deforestation for agricultural activities Sites: Iquitos, Pucallpa and Yurimaguas
II. Evaluation of the clients' needs for trees	<p>Surveys of farmers in Iquitos (n=64), Pucallpa (n=49), and Yurimaguas (n=20)</p> <p>Each farmer selected the 15 most-used species on her / his farm</p> <p>Each farmer selected and ranked the 10 highest priority species according to their importance to her / him; value of 10 given to the "most important" species, nine to the next (etc.)</p> <p>Mean importance of each species was calculated by study zone. The species with the highest mean was assigned a "relative importance" of 100% in the zone, others receiving a proportionally scaled lower relative importance.</p> <p>The percentage of surveyed farmers that used each species included in the lists of 15 most-used species and 10 highest -priority species was calculated.</p>	<p>Sampling scheme not specified (random, stratified by gender, etc)</p> <p>Meaning of "highest priority" and "importance" not clear, but presumably refers to importance in farmers' livelihood strategies, or at least in the agriculturally based components of these.</p> <p>Peach palm is used by Sotelo Montes and Weber (1997) to illustrate the process. In Yurimaguas, the "most important" species had a mean importance of 4.75, whereas peach palm attained an importance of 3.75, i.e. its relative importance was 64%. 75% of the farmers used peach palm, and 50% of them named it as one of their 10 priority species.</p>
III. Evaluation of the farmer-prioritized species	"Using the survey on products and services of the prioritized species and combining surveys of researchers, extension workers, marketing experts, etc., priority species were identified (10 in Yurimaguas, 10 in Pucallpa, 12 in Iquitos; 23 in total in the three zones) and the potential capacity of each species in each zone to supply a given product was determined (values of 1, 2 and 3 indicating respectively low, medium, and high potential)."	This step seems to have involved first construction of a consensual list of priority species, followed by evaluation of their capacity to supply specific products.

⁶⁰ "...las especies que se priorisen deben ser facilmente aplicables a estos sistemas."

Table 5 (continued). The species prioritization process used in ICRAF's Tree Domestication Program in the Peruvian Amazon (based on Sotelo Montes and Weber 1997)

<i>Stage</i>	<i>Methods</i>	<i>Notes</i>
IV. Prioritization of uses of trees and, simultaneously, species for specific uses	<p>Based on a two-way table (product/service v. species). Each species was assigned a weight based on its potential “in relation to its possible use” (“en relacion con su posible uso”), and a score based on its potential as source for the product or service in question.</p> <p>Each species was assigned a relative value, with the highest performing species receiving a value of 100%.</p>	Peach palm is again used as an example; if needed moderately often for use in fences it would be assigned a weight of 2. However, as the species is not well suited to this use, its score would be 1. The overall evaluation for each species is then derived from the sum of the weighted scores for each use.
V. Final prioritization of the species in each zone and for the <i>Selva Baja</i> in general	<p>Based on results of the previous stages (relative importance assigned by researchers and farmers), feasibility of research, adoption potential (ease of establishment, age of first harvest, commercial potential, use with “different technologies”, adaptability in different regions and socioeconomic groups) and special characteristics (“possibility of equitable use, conservation of basic resources, regional distribution⁶¹”).</p> <p>The 15 species with high total scores in at least two of the three zones were then selected, and the total relative scores of each of these species in the <i>Selva Baja</i> were calculated, incorporating also the results of Stage 4 and the within-zone score (see previous paragraph).</p> <p>Finally, five priority species were selected based on total scores and ease of use in agroforestry systems.</p>	

⁶¹ “Posibilidad de uso equitativo, conservacion de recursos básicos, distribución regional”

A large number of species were identified by farmers as being among their 15 most important or 10 “high priority” species. That is, there was relatively little agreement among farmers on which species were most important. In Yurimaguas (n=20), only 15% of the 58 species mentioned were considered as important by more than half of the farmers, whereas in Pucallpa and Iquitos less than 2% were selected by more than half. Sotelo Montes and Weber (1997) note a “marked preference for species that supply wood, followed by energy and food.” The 23 highest priority species are listed in Table 6. Of these, five species were initially selected as priority species, easily adaptable to agroforestry systems (Table 7). However, *C. catenaeformis* was subsequently dropped from the list of priority species because of its unsuitability to the soils in much of ICRAF’s target zone in the Aguaytía Valley. In spite of its high ranking, *Cedrela odorata* was not adopted as a priority species because of its susceptibility in the establishment phase to “pests and diseases” (i.e., presumably, *Hypsipyla grandella*, the mahogany shoot-borer).

In the case of *Inga edulis*, although 35 mother-trees were selected with farmers in 1997 for two selection criteria (fruit characteristics, shade/biomass) and a random control, and tests were established with this material near Pucallpa, no further work was done until 2006, when a small conservation plantation consisting of material collected from the tests was established on INIA land in Pucallpa.

2.8.2.2 Core tree improvement activities of the TDP⁶²

Participatory selection of mother-trees

The centrepiece of the TDP is a network of on-farm progeny tests of *Bactris gasipaes*, *Calycophyllum spruceanum*, and *Guazuma crinita*. Seed collections for these were carried out between 1997 and 1999, with direct involvement of farmers. In the case of peach palm, the collaborating farmers selected mother-trees of the spineless Pampa Hermosa landrace, primarily based on fruit characteristics (quantity, exocarp colour, oiliness and starchiness, texture, size). Open-pollinated seed was collected from 100 mother-trees in 1997 (four localities along the Cuiparillo River, east of Yurimaguas) and 302 in 1999 (12 localities along the Paranapura River, west of Yurimaguas). For bolaina, 209 mother-trees in 14 Aguaytía Valley localities were selected in 1998. Selection criteria included stem and crown form. In the same year, 208 selected trees and 75 randomly selected trees were selected, again from 14 Aguaytía Valley localities, using similar selection criteria as for bolaina. For all the species, selection intensities were kept low (≈ 1 in 20) to ensure relatively high genetic variation in all traits at program inception⁶³.

Progeny test / seed orchard establishment and maintenance

Progeny from the above collections were raised in replicated nursery experiments, and then outplanted in progeny tests *cum* seed orchards (Table 8). The blocks were located discontinuously on different smallholdings, with groups of three blocks nested within the zones-in-regions described in Table 9. One experiment was established in the case of bolaina, and two each for capirona and peach palm. Each progeny test of *C. spruceanum* and *G. crinita* consisted of nine randomized blocks: three in the upper Aguaytía watershed, three in the central watershed, and three in the lower watershed, i.e. closest to Pucallpa. A similar approach was used for *B. gasipaes*, except that two tests were established (corresponding to the 1997 and 1999 seed collections), in both the Aguaytía Valley and close to Yurimaguas. The capirona trial established in 2001 (Table 8) differs from the other experiments, in that it is aimed specifically at quantifying the effect (if any) of the mild phenotypic selection used in mother-tree selection, i.e. by comparing the performance of progeny of selected and random trees.

⁶² Based partly on Cornelius *et al.* (2005).

⁶³ In multitrait selection, the best overall tree (or best one-in-20) is very unlikely to be the best in all traits, and selection in at least some traits will have been zero or even negative (Cornelius *et al.*, in preparation).

Table 6. Species prioritized by the ICRAF Tree Domestication Program for agroforestry research in three zones of the Peruvian Amazon (after Sotelo Montes and Weber 1997, Cuadro 1)

Species	Family	Products	Relative importance			% of farmers identifying the species as being important			Total relative score			
			Y ¹	P ²	I ³	Y	P	I	Y	P	I	SB ⁴
<i>Bactris gasipaes</i> (peach palm)	Arecaceae	food, wood, fences, fibre	64	33	100	75	20	67	100	100	100	100
<i>Cedrelinga catenaeformis</i> (tornillo)	Fabaceae	wood, shade, energy	35	15	33	30	10	34	82	8	79	84
<i>Cedrela odorata</i> (Spanish cedar)	Meliaceae	wood, medicine, energy, shade	47	97	49	70	49	38	83	85	81	82
<i>Inga edulis</i> (ice-cream tree)	Fabaceae	shade, energy, food, fences, wood, medicine	33	37	95	70	36	67	NU ⁵	89	96	73
<i>Calycophyllum spruceanum</i> (capirona)	Rubiaceae	Wood, energy, fences	75	100	21	45	55	14	99	92	NU	67
<i>Guazuma crinita</i> (bolaina)	Sterculiaceae	wood, energy, fences	34	77	4	55	42	3	91	98	NU	66
<i>Mauritia flexuosa</i> (aguaje)	Arecaceae	food, energy, fibre, wood	22	32	40	25	14	31	NU	84	85	60
<i>Phytelephas macrocarpa</i> (vegetable ivory)	Arecaceae	fibre, food, wood	77	NU	54	75	NU	31	74	NU	63	43
<i>Bertholletia excelsa</i> (Brazil nut)	Lecythidaceae	food, wood, energy, shade	NU	NU	7	NU	NU	6	NU	NU	79	39
<i>Poraqueiba sericea</i> (umari)	Icacinaceae	energy, food, wood	4	13	51	15	8	27	NU	NU	84	38
<i>Pouteria caimito</i> (caimito)	Sapotaceae	food, energy, wood, medicine	5	43	75	25	36	55	NU	NU	85	37
<i>Tabebuia</i> spp. (tahuari)	Bignoniaceae	wood, medicine	9	56	NU	25	20	NU	NU	80	NU	34
<i>Spondias mombin</i> (uvos)	Anacardiaceae	fences, food	NU	5	12	NU	6	13	NU	NU	72	33
<i>Ficus anthelmintica</i> (oje)	Moraceae	medicine, shade	40	9	3	90	10	8	73	NU	NU	32
<i>Sheelea</i> spp. (shebon)	Arecaceae	fibre, food	13	44	26	30	18	17	NU	78	NU	30
<i>Euterpe precatoria</i> (huasaí)	Arecaceae	medicine, food, wood, fibre, energy	13	1	27	10	2	31	NU	NU	72	
<i>Pollalesta discolor</i> (yanavara)	Asteraceae	wood, energy, fences	100	NU	32	75	NU	20	69	NU	NU	
<i>Croton matourensis</i> (ciprana)	Euphorbiaceae	wood, energy	77	NU	NU	70	NU	NU	65	NU	NU	
<i>Caryodaphnopsis foste</i> , <i>Ocotea</i> spp. (moena)	Lauraceae	wood, energy	NU	92	NU	NU	37	NU	NU	63	NU	
<i>Lepidocaryum tesmannii</i> (irapay)	Arecaceae	fibre, wood	5	NU	53	5	NU	34	NU	NU	61	
<i>Minguartia guianensis</i> (huacapu)	Olacaceae	wood, energy, medicine	5	3	89	5	2	42	NU	NU	59	
<i>Apuleia leiocarpa</i> (anacaspi)	Fabaceae	wood, energy	43	NU	NU	60	NU	NU	58	NU	NU	
<i>Hetempsis jenmanii</i> (tamshi)	Araceae	wood, fibre, fences	NU	NU	69	NU	NU	48	NU	NU	39	

¹Yurimaguas; ²Pucallpa; ³Iquitos; ⁴Selva Baja; ⁵NU=not used by the farmers in the zone in question.

Table 7. Species selected for domestication activities as a result of a priority-setting process by ICRAF in the Peruvian Amazon

Species	Uses and possible planting systems
<i>Bactris gasipaes</i>	Fruit from fifth year, heart-of-palm from second year. Can be planted in association with annual crops for two growing seasons, then with a leguminous cover crop for weed control.
<i>Cedrelinga catenaeformis</i>	Timber. Possible component of multistrata systems on poor soils, or for use in enriched fallows, for harvesting in the fortieth year.
<i>Inga edulis</i>	Can be planted on soils with high Al saturation as a short-term fallow, with firewood or charcoal production in the second year and fruit in the third year. Also excellent in alley cropping for N-fixation and its abundant green manure.
<i>Calycophyllum spruceanum</i>	Flooded areas; production of firewood and charcoal in the fourth year, construction posts in the eighth year.
<i>Guazuma crinita</i>	Upland areas; production of firewood and charcoal in the fourth year, construction posts in the eighth year.

Planting sites were selected by farmers and ICRAF personnel based on soil characteristics and distance to potential sources of extraneous pollen (minimum accepted distance was 100m). Each block consisted of 50-200 families, each represented by a two-tree plot (experimental unit), planted at 2.5m square spacing for peach palm and 3m square spacing for the other species. In the case of the capirona selection study, there were two large main plots per site (random v. selected), each consisting of 75 two-tree individual progeny subplots. This non-contiguous design was chosen partly for essentially pragmatic reasons: the area of each block (about 0.5ha) was considered small enough to be manageable by individual farm families. However, it also has specific advantages, particularly (i) that it might allow sampling of a wider range of conditions, including varying farmer practices, than if blocks-within-zone were concentrated on one site and (ii) it permits the implementation of different selection criteria and intensities in different individual blocks, so that different tests may be converted to seedling seed orchards with different emphases on genetic gain versus genetic conservation and different emphases on different traits.

The trials have been weeded by the landowners, typically every two to three months, for which they have received payment from ICRAF (approximately \$4-\$8 per month⁶⁴, paid quarterly). These payments have been important in ensuring relatively consistent levels of maintenance between blocks.

In many cases, growth and development in the experimental blocks have been impressive. In other cases, there have been problems due to inappropriate site selection and, in general, productivity of peach palm in the Aguaytía Valley blocks has so far been disappointing (Figure 6).

⁶⁴ i.e. Peruvian S/.12.50-22.50

Table 8. Location and current status of progeny-trial blocks established by the ICRAF Tree Domestication Program in the Aguaytía Valley

Species	Experiment	Region	Block and owner	Status ¹
<i>Bactris gasipaes</i>	1997 seed collection	A-I	4 (Carlos Baras)	A
			5 (Jorge Grandez)	A
			6 (Máximo Romucho)	A
			7 (Glicería Pascal de Alva)	A
		A-II	8 (Juan Rengifo)	A
			9 (Jhonny Lino)	T
			10 (Román Barrionuevo)	A
		A-III	1 (Luis Tuesta)	A
			2 (Alfredo Bardales)	U
			3 (Silensario Romero)	A
	1999 seed collection	A-I	1 (Enrique Inuma)	U
			2 (Máximo Romucho)	A
			3 (Ludeño García)	T
			5 (Glicería Pascal de Alva)	T
		A-II	6 (Jhonny Lino)	T
			7 (José Trigos)	T
			8 (Amancio Espinoza)	T
			9 (Victoria Carrera)	A
			10 (Marcelino Rojas)	A
		A-III	11 (Estela Nieves)	T
			12 (Magbis Pinedo)	U
			13 (Nelson Izquierdo)	U
			15 (Carlos Trinidad)	A
<i>Calycophyllum spruceanum</i>	Phenotypic selection trial	A-I	1 (Enrique Inuma)	A
			2 (Ludeño García)	A
			3 (Vidal Inocente)	A
		A-II	4 (José Trigos)	A
			5 (Giter del Aguila)	U
			6 (Marcelino Rojas)	A
		A-III	7 (Estela Nieves)	T
			8 (Magbis Pinedo)	T
			9 (Gregorio Mejía)	T
			10 (Franco García)	A

Table 8 (continued). Location and current status of progeny-trial blocks established by the ICRAF Tree Domstication Program in the Aguaytía Valley

Species	Experiment	Region	Block and owner	Status¹
<i>Calycophyllum spruceanum</i>	Progeny trial / seed orchard	A-I	1 (Enrique Inuma)	A
			2 (Jorge Grandez)	A
			3 (Ludeño García)	A
			4 (Vidal Inocente)	A
			5 (Glicería Pascal de Alva)	A
		A-II	6 (Jhonny Lino)	T
			7 (José Trigos)	A
			8 (Nemesio Damian)	T
			9 (Giter del Aguila)	T
			10 (Marcelino Rojas)	A
		A-III	11 (Estela Nieves)	T
			12 (Magbis Pinedo)	T
			13 (Felix Chasquibol)	T
			14 (Gregorio Mejía)	T
			15 (Carlos Trinidad)	T
<i>Guazuma crinita</i>	Progeny trial / seed orchard	A-I	1 (Jorge Grandez)	A
			2 (Ludeño García)	A
			3 (Máximo Romucho)	A
			4 (Vidal Inocente)	A
		A-II	5 (Marcelino Rojas)	A
			6 (Juan Rengifo)	A
			7 (Justina Ramírez)	T
			8 (Nemesio Damian)	T
			9 (Lelis Portocarrero)	A
		A-III	10 (Máximo Romero)	A
			11 (Estela Nieves)	T
			12 (Lenin Avila)	T
			13 (Agustín Noriega)	T
			14 (Javier Castillo)	A
			15 (Franco Garcia)	A

¹A=abandoned;
T=thinned,
active;
U=unthinned, active.

Table 9. Location and environmental characteristics of test sites used by the TDP in the Peruvian Amazon

Region ¹	Zone ² and species tested ³	Environmental characteristics
Ucayali	A-I (Nueva Requena (lower Aguaytía watershed)) (B,C,P)	Highly acidic sandy soils, well to excessively drained, annual rainfall $\approx$ 1600mm, pronounced dry season
Ucayali	A-II (Curimaná (middle Aguaytía watershed)) (B,C,P)	Soils acidic, various textures (clayey loams, silty loams), moderate drainage, annual rainfall $\approx$ 2600mm)
Ucayali	A-III (San Alejandro (upper Aguaytía watershed)) (B,C,P)	Soils acidic, various textures (clayey loams, silty clays, clayey silts), drainage poor to moderate, annual rainfall >3000mm)
Loreto	Y-I (Along Yurimaguas-Munichis road) (P)	Soils slightly acidic, various textures (sand to clayey loam), moderately to well-drained, annual rainfall >2000mm)
Loreto	Y-II (Along Yurimaguas-Tarapoto road) (P)	Soils slightly acidic, various textures (sand to silty clay), moderately to well-drained, annual rainfall >2000mm)

2.8.2.3 TDP Supporting and complementary activities

Provenance-testing

Provenance tests were carried out in the case of *G. crinita* and *C. spruceanum*, using a similar design in each. Ten (*C. spruceanum*) or 12 (*G. crinita*) provenances were included, sampling a wide geographic area with quite variable conditions (4°S to 10°S latitude, 71° to 77° W longitude, 1800-4000 mm yr⁻¹ precipitation, 100-300 m a.s.l.). Trees were selected randomly in each collection area. A randomized complete block experimental design was used, with 36-tree and 16-tree plots respectively in *G. crinita* and *C. spruceanum*. The blocks were planted separately from each other on farmers' lands in the Aguaytía watershed (as described above for the progeny tests). The trials were maintained by farmers under the same arrangements as for the progeny tests / seed orchards. Final measurements of the provenance trials were carried out in the 3rd-4th year of growth, after which maintenance was discontinued.

PROSEMA and agroenterprise-building

From early in development of the TDP, ICRAF staff saw the involvement of farmers in multiplication and dissemination of planting material as an alternative strategy for germplasm delivery, and it was suggested that seed production could be a potentially remunerative commercial activity for farmers:

“the production of improved germplasm on farm is a new type of small-business enterprise, which generates additional income and employment for farming communities. Farmers can earn annually at least USD1000 per hectare from the sale of unimproved seed, and much more from the sale of selected seed” (Weber et al. 1997)

Figure 6. ICRAF experimental blocks in the Aguaytía watershed. Top: successful blocks of *G. crinita* (left), *C. spruceanum* (right). Bottom left: relatively productive *Bactris gasipaes* block; bottom right: remnant trees of failed *G. crinita* block (foreground)

Accordingly, from 1999, collaborating farmers in Ucayali were assisted in forming a civil association, the Aguaytía Watershed High-Quality Seed and Wood Producers' Association (Asociación de Productores de Semilla y Madera de Alta Calidad de la Cuenca del Aguaytía, PROSEMA), aimed at commercial sale of tree seed and other products. PROSEMA has received assistance from ICRAF since 1999. As well as two specific donor-funded projects⁶⁵, this assistance has included substantial ongoing support from ICRAF, e.g. in organizing and providing transport for association meetings (needed because PROSEMA membership is dispersed between the lower, middle, and upper Aguaytía watershed), providing administrative and secretarial support, provision of office space and computer facilities, resolution of conflicts between members, locating customers and securing payment for PROSEMA seed sales, etc.

⁶⁵ The Tinker Foundation project "Empowerment of farmers through organization and enterprise-building" (2002-2004) and the USA Fund for the Americas project "Use of select germplasm of bolaina, capiróna, *Inga* and peach palm for increasing smallholders' incomes in the Peruvian Amazon" (2007-2009).

PROSEMA has been selling seed of *G. crinita*, *C. spruceanum*, and *B. gasipaes* since 2007. From 2008-mid 2009, PROSEMA sold about 5.8kg of bolaina seed, 1.3kg of capirona seed, and 80kg of peach palm seed to a small number of NGOs and GOs. In addition, over the same period it also sold around 30,000 seedlings of these and other species. Total receipts over this period were more than \$US16,000, equivalent to about \$332 per PROSEMA member (Cornelius *et al.* 2010).

Molecular analyses

Three studies of molecular genetic variation have been carried out under the aegis of or with support from the TDP. Adin *et al.* (2004) sampled DNA from 203 progeny plants derived from the two peach palm collections. They then estimated population genetic parameters using AFLP markers in order to estimate levels of genetic diversity, to test for differences in populations located in colonist and indigenous communities, and to test for the presence of isolation-by-distance effects on genetic structure. Russell *et al.* (1999) sampled DNA from 89 individuals from the provenance collection of capirona. Genetic parameters were estimated using AFLP markers in order to assess the partitioning of genetic variation within and among populations and to examine whether downstream populations were more genetically variable than upstream populations. Finally, Hollingsworth *et al.* (2005), using SSR markers, looked at diversity in planted and natural stands of *I. edulis*, in order to test for effects of domestication on genetic diversity.

Recent activities with fruit species

From 2005, ICRAF begins to expand its work with fruit species, with two principal strategic objectives. First, to complement existing TDP work with peach palm. Second, to further Amazon Initiative aims and approaches through enhancing coordination both between ICRAF and its Peruvian research partners, and between the Peruvian institutions themselves. From 2005-2008, ICRAF and partners (IIAP, INIA) implemented the INCAGRO-financed project FRUTAMAZ (“Management, conservation, and use of genetic resources of Amazonian fruit species through interinstitutional cooperation and coordination in the framework of the Amazon Initiative”), focusing on *B. gasipaes*, *M. dubia*, and *M. flexuosa*. Subsequently, from 2007 to date, it has coordinated the multilateral (Peru / Bolivia) FONTAGRO-funded project FRUTAM (“Improvement of the competitiveness of production chains of Amazonian fruit species”), focusing on the same species, plus *Oenocarpus bataua* (ungurahui) and *Theobroma grandiflorum* (cupoasú).

2.8.3 TDP Scientific Results

The principal scientific results to date of the TDP are summarized in Table 10. Provenance and progeny tests have revealed significant genetic variation at provenance and family-within-provenance level in both *G. crinita* and *C. spruceanum*. Furthermore, the magnitude of variation at both levels is both of economic significance and indicative of potential for genetic improvement.

To date, no results are available on quantitative genetic variation in peach palm, although Cornelius *et al.* (2009) have published information on between-trait phenotypic associations.

Table 10. Principal scientific results of ICRAF's Tree Domestication Program in Peru

Topic	Principal Results	Reference
<i>Provenance studies of C. spruceanum, based on wide collections within the Peruvian Amazon</i>		
Variation in stem-growth and branch-wood traits at 18 months among seven provenances	Significant differences in stem height and number of nodes, but little differentiation between provenance means No significant variation in density or heat content of branchwood No evidence of local adaptation	Sotelo Montes <i>et al.</i> 2003
Variation in coppice-shoot growth among seven provenances	Significant differences between provenances in coppice-shoot height and number of new coppice shoots	Boivin-Chabot <i>et al.</i> 2004
Variation in stem growth and wood traits among seven provenances of capirona between 30 and 42 months	Significant variation in stem height, but not in other traits. At age 42, the “tallest” provenance was approximately 17% taller than the “shortest”	Weber and Sotelo Montes 2005
<i>Provenance-progeny studies of C. spruceanum based on collections within the Aguaytía watershed</i>		
Genetic variation and correlations between growth and wood density	Significant variation between provenances in height and diameter at 39 months Significant variation between families within provenance in height and diameter at 39 months Significant variation between provenances in wood density at 39 months Significant variation between families within provenance in wood density at 39 months For growth and density traits, variation between families-within-provenances was greater than that between provenance Values of heritability at 39 months for height, diameter and basic density were typical of values found in forest trees (Cornelius 1994) Phenotypic correlations between growth rate and density were positive	Sotelo-Montes <i>et al.</i> 2006
Genetic variation in wood shrinkage	Significant genetic variation in wood shrinkage between families-within-provenances	Sotelo-Montes <i>et al.</i> 2007
Genetic variation in wood colour	Significant variation between families-within-provenances in wood colour, uncorrelated with growth rate or density	Sotelo Montes <i>et al.</i> 2008
<i>Provenance studies of bolaina, based on wide collections within the Peruvian Amazon</i>		
Variation in tree growth and wood density between 11 provenances	There was significant variation in 30-month height between provenances at each of three zones, but not across zones (i.e. there was significant zone-provenance interaction). In the best growth conditions, the best provenance was about 30% taller than the worst. Diameter variation was significant in the lower watershed, where growth was also slowest. The local provenance was the fastest or second fastest growing in all three sites There was significant variation in mean basic density in the upper watershed and in the across zone analysis	Weber and Sotelo Montes 2008

Table 10 (continued). Principal scientific results of ICRAF's Tree Domestication Program in Peru

Topic	Principal Results	Reference
<i>Molecular studies</i>		
AFLP variation in capirona	Molecular variation was concentrated at the within-population level, but Fst levels were moderate (0.118) and variation between populations was highly significant	Russell <i>et al.</i> 1999
AFLP variation in peach palm	Little variation between populations, suggesting human-mediated gene flow through seed transfer	Adin <i>et al.</i> 2004
SSR-variation in <i>Inga edulis</i>	Significantly lower variation in planted stands of guaba than in natural stands. However, variation in both groups was still relatively high.	Hollingsworth <i>et al.</i> 2005

2.8.4 TDP Development results

The TDP's principal development objective is to improve smallholder livelihoods, principally through providing smallholders with access to higher-quality agroforestry germplasm. Ex-post evaluation of its effectiveness in this regard would be premature, as seed production from the Aguaytía Valley and Yurimaguas seed orchards has only begun in the last 2-3 years. In addition, virtually no selection has as yet been applied and, consequently, there is no reason to believe that ICRAF/PROSEMA seed is genetically superior, except in comparison to seed from inbred or otherwise unsatisfactory sources.

Like all tree improvement programmes, the direct financial impact of the TDP is dependent on three principal factors: the area of plantation established, product value, and the increase in quantity or value of production due to genetic improvement. At present, it is unrealistic to look for any major direct financial impact of the TDP, both because of the modest amounts of planting currently going on and because of the probably rather low degree of improvement exhibited by PROSEMA seed. Although TDP seed may also be more genetically diverse than some other potential seed sources (see also 2.8.5), it is unclear what financial impact this might have.

The TDP was conceived of as a model approach, and therefore the question of further uptake of the approach is also of relevance to its impact. Here too, effects have been limited. Although "domestication" is now part of the vocabulary of Peruvian agroforesters, and at least one project with "domestication" in its title has been carried out (an INCAGRO-financed project executed by IIAP), there has been no uptake of the particular approach used by ICRAF. Rather, approaches used have essentially been those of conventional plant improvement and pre-improvement, rather than participatory domestication.

Nevertheless, there is little doubt that ICRAF's work with *G. crinita* and *C. spruceanum* has had a significant impact on the Peruvian forestry sector. The impressive growth exhibited by a number of highly accessible and visible experimental blocks (Figure 6) has contributed to a wider appreciation of the potential of both species and has without doubt played a part in placing such options on the national and regional forestry agenda. It is due in part to the TDP's activities that *G. crinita* and *C. spruceanum* play such a prominent role in the activities listed by Meza *et al.* (2006) (Tables 3 and 4) and in the agenda of organizations such as FONDEBOSQUE and REFORESTA-Peru. However, the TDP's contribution to the growing momentum of plantation forestry is difficult to separate from that of other actors.

Finally, PROSEMA members have derived some benefit from their involvement with the TDP, due to seed sales, payments for trial maintenance, and training. However, like the TDP as a whole, the justification for ICRAF's work with PROSEMA has lain in the possibility of future scaling-up than in the local benefits to PROSEMA members themselves. To date, neither detailed evaluation nor scaling-up of this initiative has been attempted.

2.8.5 TDP Conservation results

The genetic resource conservation impact of the TDP is difficult to assess, as there is no baseline assessment of the condition of genetic resources of the three species. However, it is likely that, as accessible natural forest supplies of timber grow scarcer, there will be increasing pressure on natural stands of bolaina and capirona. It would,

therefore, be unwise to assume that the natural forest genetic resources of these common species are necessarily safe, suggesting that the TDP plantings are fulfilling a valuable genetic conservation role. However, medium- to long-term conservation of the genetic resources currently located in the on-farm tests will probably require the establishment of replicates on institutional land, e.g. of INIA⁶⁶ or IIAP.

2.8.6 The TDP: comment and analysis

2.8.6.1 TDP Prioritization

In spite of previous findings that smallholders in the Peruvian Amazon tend to prefer fruit trees to species used principally for construction, fuelwood and sawntimber (see 2.7.5.1), four of the six highest priority species identified by the TDP were timber species; as mentioned above (2.8.2.1), the farmers surveyed tended to prefer wood-producing species.

Explanation of this apparent inconsistency would require detailed examination of the survey methodology. However, it seems likely that the explanation lies in the type of questions asked of the farmers, who were asked to identify their “most important” species. Undoubtedly, farmers place a high value on species they use frequently for important purposes such as house construction and fuel. However, for such uses there is a high degree of substitutability between species, leading to a multiplicity of species being selected (see 2.7.2.1), i.e. a given farmer’s opinion regarding which species are most important is likely to depend on which are available on her or his farm. For the same reason, the species chosen by a given farmer are likely to be among the most abundant—an unhelpful result as abundant species, or those which, if absent, can easily be substituted by other species, are less likely to be planted by farmers, and, therefore, are probably relatively unpromising candidates for domestication.

Potters (1997) noted this problem in her study of a community near Yurimaguas, where the prioritization process found that the timber species *Pollalesta discolor* was the species with highest “relative importance”. She noted that it was identified as important essentially because it was amongst the most common species and was therefore the most used for construction and poles, an important tree use. However, there was no interest in planting *P. discolor*, because of its abundance in secondary forest. She commented: “It should be seriously questioned whether this is the most relevant species for improvement research.” It seems reasonable to suggest that the prioritization process should have emphasized more strongly the need to identify species that farmers were interested in planting, rather than those they considered to be “important”.

The prioritization process produced some other unexpected and perhaps anomalous results: the prioritization of two timber species that require sites of relatively high quality or, alternatively, high investment in soil amendments (*G. crinita*, *C. spruceanum*), when farmers often don’t have access to such sites (resources), or would rather use them for food production; the high prioritization of a species exotic to and rarely planted in the three survey zones (Brazil-nut); the absence from the list of mahogany, in spite of farmers’ common expressions of interest in the species (Brodie *et al.* 1997).

⁶⁶ Any such initiative would need to take into account the security also of institutional landholdings; some of INIA’s holdings in the Von Humboldt Experimental Forest are subject to regular land invasions.

In spite of these reservations, which apply particularly to the selection of *G. crinita* and *C. spruceanum*, it is not clear which alternatives, whether fruit or timber species, might have been better choices. The selection of peach palm appears to have been highly appropriate, at least in terms of farmer interests, but if anything the TDP's work with peach palm has, to date, had less impact than the work with bolaina and capirona. In large measure, the difficulty of selecting species is a reflection of the current state of development of agroforestry in the Peruvian Amazon. As few tree species are being planted on a commercial scale, prioritization of species for specific research activities or to illustrate specific approaches is necessarily subject to error or, at least, to suboptimal decisions.

2.8.6.2 TDP Improvement strategies

In a sense, it might be argued that the particular species chosen for the TDP are not as important as the overall process of demonstrating a viable approach that is suitable for replication elsewhere. However, in this regard, the TDP might have been more effective. Scaling-up and -out require both that approaches be feasible for GOs and NGOs, and that they are sufficiently effective, in terms of palpable impact, to stimulate uptake. The impact pathway of the TDP (Figure 5) is dependent on production and use of more productive germplasm, yet the quickest route to achieving this outcome, i.e. vegetative propagation and clonal testing, was not used in the case of bolaina and capirona, and is not feasible in the case of peach palm.

Although concerns surrounding clones and the conservation of genetic diversity are valid, these do not imply that farmers should not have access to highly improved material, including clonal material. The TDP's conservative and, in terms of adoption potential, rather unwieldy approach to genetic improvement contrasts with that used in other ICRAF regions, e.g. West Africa, where vegetative propagation techniques for selection of superior clones have been stressed.

Low-technology vegetative propagation techniques are available for tropical timber trees (Leakey *et al.* 1990). With the use of clonal selection, there is every possibility that impressive gains in productivity and quality of both species, or indeed, of other timber species, could have been achieved with lower expenditure than what was necessary to establish and maintain the extensive network of progeny-tests established in Ucayali and Yurimaguas. Similarly, in the case of fruit species such as *P. sericea*, *P. caimito*, *I. edulis*, or for that matter *M. dubia* (which is absent from the list of priority species), conventional horticultural techniques (vegetative propagation by grafting and air-layering), allied with both phenotypic and genotypic selection, could by now have led to the development of local cultivars of demonstrable superiority, i.e. the sort of result likely to stimulate wider uptake and application to other species and zones.

2.8.6.3 TDP Participatory aspects

The participatory element of the activities implemented has been much stressed (Weber *et al.* 1997; Weber *et al.* 2001; Cornelius *et al.* 2006). Essentially, farmer participation has taken three forms: extensive farmer involvement in the prioritization process, farmer involvement in mother-tree selection (both in the period 1996-1998), and remunerated farmer participation in the maintenance of the experimental blocks (see 2.8.2.2), according to a schedule designed by ICRAF staff.

The involvement of end-users in prioritization is clearly indispensable. However, the case for siting of trials on farmers' land is not so clear-cut. Particularly in the case of

the small block sizes used, this involves high marginal cost (relative to alternatives) without any obvious marginal benefit. Siting of genetic resource collections on **individual** farmers' lands is somewhat arbitrary and in itself is insufficient to secure the avowed goal of wider community access to these resources. The testing of genetic material in on-farm conditions is important, but in practice testing has been carried out under rather standardized conditions similar to those in experimental stations, with high-intensity maintenance and fertilization⁶⁷. The objective of ensuring that eventual selections are suitable for the conditions in which they will be used could be secured more efficiently, for example using on-station trials with differing management intensities and planting configurations, probably combined with experimental designs more efficient than the highly traditional randomized complete block design used by the TDP. Finally, involvement of a representative group of farmers in selection decisions cannot be made simply by involving individual farmers with the management of the trial(s) on their lands. Rather, it will require a process of broader consultation more similar to the prioritization process, and could be done as easily in conjunction with on-station trials as on-farm trials. This is not to say that on-farm trials have no place in participatory tree domestication, but rather to point out that they are not an indispensable element, and that on-station trials may also play a role.

It is easy to presume that participatory tree domestication is simply an application to agroforestry of participatory genetic improvement methods used with staple crops. However, particularly in the context of the Peruvian Amazon, there are fundamental differences. First, farmers are to a large degree unfamiliar with cultivation of many of the species that are candidates for domestication, in contrast to their often expert knowledge of cultivation of staple crops. This means that they will be unable to give the same kind of expert feedback possible in the case of participatory improvement of staple crops. Second, many tree crops, particularly timber trees, do not require the same intensity of management that is required by most agricultural crops. This means that, for much of the rotation or testing period, a "participatory" on-farm trial requires or needs no particular attention (i.e. participation) from the farmer, so that, to a degree, it might as well be located on a research station as on farmers' land. It could therefore be argued that participatory approaches could be more effectively used at a later stage in development of both agroforestry practice and germplasm development – for example, in the evaluation of clones of a species for which a profitable market had already been established.

Given farmers' unfamiliarity with cultivation of many species and their lack of engagement with non-traditional agroforestry (and, in many cases, with traditional and indigenous smallholder agroforestry, the TDP trials also fulfill a useful extension and training function. However, the establishment of a relatively small number of dispersed, relatively (from a demonstration viewpoint) large plots, seems an inefficient means of securing this objective.

2.8.6.4 Tree improvement and tree domestication

Although the TDP has engaged to a degree in marketing research (e.g. studies of markets for peach palm fruit and seed within the "Tinker" project) and silvicultural research (e.g. various theses on site and soil effects on growth of priority species

⁶⁷ Here ICRAF's approach contrasts with the approach successfully used by the CATIE Tree Improvement Program (Mesén *et al.* 1993), in which lower-intensity management was used, i.e. trial cleaning at most every three months, and post-establishment fertilizer use limited to cases of apparent deficiency problems.

carried out by undergraduate and postgraduate students), in large measure, it has been a tree improvement program, based largely on traditional forest tree improvement approaches.

Tree improvement, as such, is obviously an insufficient response to the challenges and opportunities posed by agroforestry in the Peruvian Amazon, or to the opportunities presented by specific species or products. By contrast, tree domestication, with its wider connotations of agronomic and silvicultural research, product development, and marketing, as well as genetics (Simons and Leakey 2004) represents a more satisfactory, integrated approach—both in disciplinary terms and in its potential to engage, motivate, and concentrate the efforts of research partners.

2.8.6.5 Partner institutions, collaboration, and domestication

From at least the early 2000s, the TDP's core activities were implemented substantially in isolation from national partners, with little or no participation of INIA or IIAP in day-to-day operation or even in specific major activities. From 2005, this tendency has been alleviated through new, collaborative projects, but, even taking these developments into account, the core activities have remained ICRAF activities, implemented by ICRAF personnel in collaboration with its smallholder partners. To a large degree, ICRAF-Peru's mode of engagement has resembled that of a local, independent organization rather than an international institution aiming at generation of international public goods. Other considerations apart (see below), this mode of engagement has had a negative effect on ICRAF's impact in Peru, as, given the institution's low level of staffing, both national and international staff have been heavily occupied in execution of project administrative and research activities, with little time for mentoring and coordination activities.

Independently of wider considerations on appropriate modes of engagement for CGIAR institutions, ICRAF TDP personnel, who have been exclusively foresters or forest geneticists, have never possessed the breadth of expertise to implement a full domestication program, particularly one involving fruit trees. In the short-to-medium term, it is unlikely that ICRAF-Peru's staffing will include the full range of expertise relevant to tree domestication. For this reason, and for others, factors responsible for the lack of collaboration on tree domestication between ICRAF and its local partners need to be identified and, where possible, overcome. These factors likely include the following:

- the presence of strong NARO institutional agendas, formulated independently from ICRAF's, or actively avoiding duplication of ICRAF's work;
- unfamiliarity of INIA's agroforestry staff (exclusively foresters) with genetic improvement methods;
- arguably, stronger engagement of INIA with the work of the former Programs 3 and 4, rather than Program 2, and consequent disengagement on termination of Programs 3 and 4;
- INIA genetic improvement specialists' lack of awareness of ICRAF's work;
- institutional and personnel instability within both ICRAF and INIA;
- unwillingness of specific individuals within INIA to dedicate institutional, human or material resources to work considered by them to reflect ICRAF's rather than INIA's agenda.

The question of interinstitutional collaboration is of fundamental importance to the domestication enterprise. Effective domestication requires the collaboration of a wide

range of actors, including, potentially, producers, researchers, wholesalers, retailers, export promotion agencies, exporters, importers, importing country regulators, and consumers⁶⁸. Coalescence of institutional efforts around particular species/products is also the key to effective prioritization and selection of species: if there is not adequate institutional critical mass behind a specific project (species), then satisfactory results will not be achieved, even if the species/product choice has been optimal in terms of potential. That is to say, selection of species is not so much a matter of choosing “winners” and avoiding “losers”, but of mobilizing the human, institutional, and financial resources to bring about the conditions that make success probable.

2.8.6.6 PROSEMA

There is little doubt that PROSEMA owes its continued existence to the constant support of ICRAF staff and ICRAF resources. Its members are too geographically dispersed, its focus is too narrow and remote from members’ core livelihood concerns, and its financial income is too small to allow long-term independent survival. Even with the support of ICRAF staff, organization and transport of members to PROSEMA meetings is a major undertaking; without this support, it would be virtually impossible. However, the PROSEMA experience has demonstrated that smallholders can be motivated and organized to sell germplasm. In the context of development of germplasm supply systems for smallholders, what is now needed is detailed assessment of smallholder demand and willingness to pay for agroforestry germplasm (Cornelius *et al.* 2010). It is possible that, with the current state of advance of agroforestry in Peru, and particularly non-traditional agroforestry, the win-win concept of smallholder production of germplasm is one whose time has not yet come and should only be pursued when agroforestry tree planting is more widely adopted.

2.8.6.7 Clients and target systems

Formally, the TDP targets smallholders involved in slash-and-burn agriculture and aims to produce germplasm selected for use in silvopastoral systems, multistrata systems, and managed fallows. However, the approach to genetic testing has essentially disregarded these objectives, as genetic treatments are being tested in conventional, monospecific blocks, with the implicit assumption that genotypes superior in these conditions (including relatively intensive site preparation, fertilization, and maintenance regimes) will also be superior in these agroforestry systems. This suggests strongly that any selections made under these conditions should be provisional selections, which will need to be tested at a later date in actual conditions of use.

The targeting of resource-poor slash-and-burn farmers remains valid. However, targeting of clients for tree improvement and domestication research also implies targeting of geographical areas (because environmental conditions, and therefore suitability of germplasm, are correlated with geographical location). In addition, targeting needs to take into account not just the degree of poverty of smallholders and the environmental impact of their activities, but also the feasibility of their engaging

⁶⁸ The importance of a thorough approach to domestication, encompassing marketing and regulatory barriers, is well illustrated by the cases of camu-camu and sacha-inchi (*Plukenetia volubilis*). The former, like other Peruvian products, is blocked from entry to the European Union due to the Novel Food Regulation (Juan Fernando López (PALMAGRO), Lambert Pie Pau (Independent / CIRAD), personal communications, 8th July 2009.). Sacha-inchi (source of an omega-3 oil) is the latest boom-product to have captured attention in Ucayali, but various farmers in the Curimaná area have been unable to sell their produce (Nemesio Damian, PROSEMA, personal communication, 15th July 2009).

in profitable agroforestry activities. This, in turn, is likely to depend on factors such as market access, population density, and farmers' current productive activities and specializations (i.e. whether cacao producers, oil palm producers, etc.). This suggests that selection of target groups needs to be more rigorous than, for example, simply specifying slash-and-burn farmers in Ucayali or in the Peruvian Amazon as a whole, particularly for purposes of generating working pilots suitable for uptake elsewhere. In this respect, the concentration of research in the *Selva Baja* is questionable (see 2.6.3)

2.7.6.8 Prospects of achieving development goals

Many of the points made above imply that the TDP has been suboptimally designed and implemented, in the sense that its objectives could have been furthered both more effectively and more cheaply using more efficiently alternative methods. However, past costs, as in all economic decisions, are irrelevant to the future of the TDP: they imply neither that the TDP activities should be continued nor that they should be discontinued. At this juncture, the important question is what can be achieved now and at what cost, given the work that has already been completed.

The TDP has endowed Peruvian agroforestry with a highly valuable, structured genetic resource for three species with high potential for use in agroforestry, forestry, and horticultural production systems. In addition, data analyses to date have generated valuable information on strategies for using this resource, while additional information can be readily gleaned from existing and future measurements. The existing genetic and information resources are sufficient to permit the development of highly improved genetic material of *G. crinita*, *C. spruceanum*, and *B. gasipaes*, with marginal benefits that, because of past expenditure, are very likely to exceed marginal costs. Whether the availability of such material can contribute to improving livelihoods depends on whether these genetic improvement activities can be effectively complemented by wider domestication activities.

3. Foundations of a strategy for the TDP: the role of agroforestry and tree domestication in the AI-EP and in the Peruvian Amazon, and general principles for ICRAF intervention

Tree domestication aims at enhancing the benefits of agroforestry: particularly, but not exclusively, its capacity to generate income. For this reason, the future development of ICRAF's TDP depends at least partly on the role of agroforestry itself in the AI-EP. It also depends partly on general principles for ICRAF's intervention in tree domestication, which stem from its mission as a CGIAR centre.

3.1 Potential contribution of agroforestry to the goals of the AI-EP

ICRAF's current definition of agroforestry as "a form of land use that integrates trees on farms and in agricultural landscapes for economic, social and environmental benefits" is broad; it would be difficult to envisage a situation in which agroforestry, so defined, would **not** form a part of sustainable land-use at a landscape level. At the same time, a definition of this breadth is not helpful in indicating the sort of agroforestry practices or systems that might constitute or form a part of the sustainable land-use systems whose adoption is sought. Possibly, in an eventual set of priority systems or practices, those consistent with more traditional definitions of agroforestry⁶⁹ will figure prominently, in large measure because research by ICRAF and partners in the Amazon from 1993 has in general implicitly or explicitly defined agroforestry in these terms and because, in general, ICRAF's partners still understand agroforestry in these terms. Nevertheless, the broader definition is useful. It serves both as a reminder of the landscape scale and as a way of ensuring that potentially useful tree-based options that don't correspond with the meaning of agroforestry as generally understood are not eschewed.

Rather than seeking to answer a broad question such as "what is the role of agroforestry in the AI-EP", a more useful question to answer—echoing the ICRAF definition of agroforestry, and the comments above (2.6.3, 2.7.6) on the need for a product- or species-centred approach—might be:

"which agroforestry tree species/products/services⁷⁰, employed/produced within which systems and practices, offer real potential of simultaneously generating socioeconomic and environmental benefits and of thereby 'transforming lives and landscapes'".

The answer to this question is also a broad one: there are many tree species of current economic value in the Peruvian Amazon, and many of them have the potential to be cultivated profitably in agroforestry systems, provided that certain conditions apply.

In order to explore more fully the type of agroforestry interventions that might further the aims of the AI-EP, it is useful to identify four classes of target productive activity,

⁶⁹ i.e. as a spatial or temporal combination of trees and crops or animals.

⁷⁰ The species / product / service terminology reflects the importance of service functions of species such as *Inga edulis*, in which case the commercial product may be an established agricultural commodity (cacao, coffee, beef), rather than an "AFTP"

distinguished by their contributions to livelihoods and environmental services⁷¹ (Table 11). Activities classified as 0+ are sustainable agronomically and environmentally, but generate little or no income and are associated with a condition of poverty rather than with escape from poverty, e.g. some traditional agroforestry systems. 0- systems would include shifting cultivation in conditions of unsustainable population pressure. +- systems generate significant income, but contribute to environmental degradation (for example, unsustainable exploitation of valuable NTFP or TFP, or some industrial agriculture), whereas ++ production systems both generate significant income and contribute to resource rehabilitation or avoidance of degradation. Obviously, the AI-EPs objectives are advanced by shifts towards ++ conditions. ICRAF's slogan asserts that agroforestry will "transform lives and landscapes". However, the required shifts are not necessarily shifts that are obviously paradigmatic, or of a "silver bullet" character. Palpable impact may require no more than modifications of traditional agroforestry practices, or of institutions or policy, sometimes in only one of the two dimensions of Table 11.

Table 11. Two-way classification of potential target productive practices with respect to environmental and livelihood impacts

		Contribution to environment	
		Negative	Non-degrading or rehabilitative
Contribution to transforming livelihoods	Little or none	0-	0+
	Substantial	+-	++

Productive practices classified "++" systems are possible candidates for wider adoption in other regions and are obviously also the type of outcome that new systems, whether farmer-designed or researcher-designed, will aim for. To shift 0+ systems to ++ systems will require higher profitability (e.g. through better marketing or higher quantity / quality of production), but without risking environmental values. Systems 0- require either improvement through significant institutional or technical modification, or perhaps elimination, via policy innovation, to render them "--" and therefore unattractive to smallholders. Systems +- may be consistent with AI-EP objectives if technical innovations that neutralize negative environmental effects can be introduced (many +- systems draw on natural capital in order to generate their positive benefits, implying that ways must be found to substitute natural capital in order to shift such systems to ++).

An example of application of this two-way classification is illustrated in Table 12, which gives examples of specific actions or classes of actions that might move individual productive activities towards "++" status. Such an approach would facilitate identification both of "lines of least resistance" for agroforestry interventions and of specific roles for individual institutions and technologies, including tree domestication.

⁷¹ Disregarding, for the present, the possibility that, through payment for environmental services, provision of such services may contribute directly to livelihood enhancement.

Table 12. Possible types of agroforestry interventions by two-way livelihoods / environment impact classification

Classification (see Table 11)	Example	Possible actions to achieve ++ (see Table 11)	
		Livelihoods	Environment
0-	Unsustainable harvesting of <i>Mauritia flexuosa</i>	Improved fruit quality More remunerative value chains	Agronomic / management interventions for sustainable management Policy interventions (tenure, forest frontier)
0+	Fruit production in managed fallows	Improved quality Better market access	None
+ -	Oil palm monoculture	None	Agronomic / management interventions
++	Cacao agroforestry	Supporting systems, germplasm... (++ systems are not necessarily self-sustaining)	Policy interventions (tenure, forest frontier)

3.2 Role of tree domestication in the AI-EP

3.2.1 Concepts of tree domestication

Identification of the role of domestication in achieving these shifts requires clarification of the meaning of the term, which, like “agroforestry”, has tended over time to acquire a broader meaning. Foresters have been aware for some time that the species they work with are wild and that, therefore, their genetic improvement is a form of domestication, in the standard sense used in agricultural science and palaeobotany (Libby 1973). In a seminal ITE/ECTF Conference held in 1992, domestication of a tree species was “taken to encompass the identification and characterization of its germplasm resources; the capture, selection and management of its genetic resources; and the regeneration and sustainable cultivation of the species in managed ecosystems” (Leakey and Newton 1994), a central idea here being that domestication is more than another word for genetic improvement. Over the subsequent decade, the concept of domestication, at least as promoted by ICRAF, expanded to take in also market identification and development, and has been regarded as a continuous process, such that domesticated species such as peach palm can also be said to be under (further) domestication (Simons and Leakey 2004).

This wide concept of domestication is not fully expressed in the ICRAF-Peru TDP program (see Section 2.8.6.4) and, to date, does not appear to be fully shared by ICRAF’s partners, whose domestication programs tend to focus on genetic improvement or pre-improvement. However, since at least the mid-1990s, this expanding concept of domestication has been a pillar of ICRAF’s approach to agroforestry-based development.

3.2.2 Tree domestication in the AI-EP

“Not a single [new or novel] Peruvian product has been successful”

(Ricardo Sevilla, Director of the Peruvian Technical Secretariat for Cooperation with the CGIAR)⁷²

Similar expressions of frustration at lack of progress are commonly heard in Peruvian agroforestry circles. In the case of agroforestry products, it has been argued above (e.g. Section 2.8.6.5) that a fundamental cause of this lack of significant progress has been the failure of institutions effectively to collaborate on and coalesce around specific research problems and opportunities. To a large degree, and on a broader scale, the AI-EP itself is a response to this problem.

Within the field of agroforestry research and development, the wider concept of domestication provides an ideal framework for such institutional coalescence, particularly within the domain of the AI-EP, as the domestication concept encompasses a substantial part of the agroforestry interventions under all four innovation foci (Table 13).

⁷² Personal communication, 9th July 2009. That is, successful in achieving a significant niche on world markets. Ing. Sevilla, a former head of INIA and one of Peru’s most experienced and knowledgeable agronomists, cited a number of examples, including Peru’s varieties of purple maize, which, he reported, are now being produced in Thailand, while exports from Peru remain at the same levels as in the early 1970s.

Table 13. Relationships between the current ICRAF concepts of agroforestry domestication and the AI-EP Innovation Foci

Components of domestication	IF1: Mitigation and adaptation to climate change	IF2: adoption of sustainable land use systems in deforested and degraded areas	IF3: enhanced benefits from forests for livelihoods and the environment	IF4: Fair, financially attractive market value chains for Amazon products
Basic research (genetics, mating systems, etc)		Development of improved agroforestry germplasm		
Genetic improvement and management of diversity	Development of adapted germplasm and land use systems	Development improved agroforestry germplasm		Product development
Propagation and germplasm supply systems	Dissemination of improved (adapted) agroforestry germplasm	Dissemination of improved agroforestry germplasm	Dissemination of germplasm and associated knowledge	Seed / germplasm management
Horticultural and silvicultural research	Development of resilient agroforestry systems	Adaptive research, selection of sustainable land-use systems		
Product development				Product development
Market chains			Marketing of a wider range of forest products	Market identification, development of market chains

Any intervention associated with specific products or service-species and directed at achieving the shifts mentioned previously (Tables 11, 12) *could* be considered to fall within this sphere. At the same time, it is important to clarify that there are interventions that fall outside the “domestication” sphere. For example, it would be highly artificial, and probably counterproductive in terms of partnership-building, to attempt to fit into a domestication paradigm the improvement, marketing or agronomy of cacao or other established crops, even where these are typically grown as main species within agroforestry systems. There are also many cases when not all elements of the domestication “menu” need to be deployed: it is easy to envisage situations where a given species might require work on germplasm availability or silvicultural techniques, but where, for example, marketing work might be unnecessary. Such a situation, indeed, is implied in the approach illustrated in Table 12. However, in such cases, the domestication framework remains a useful one with which to identify priorities and institutional roles.

3.3 ICRAF’s role in tree domestication within the AI-EP

ICRAF’s broad role in tree domestication within the AI-EP is implicit in its status as a CGIAR centre and, in particular, in its mission of producing international public goods (IPG). There are three obvious IPG associated with agroforestry domestication.

First, the domestication concept, as articulated by ICRAF-Global, is a potentially valuable IPG. As outlined above (Section 3.3.2), its importance lies in its implication of an integrated approach to development of new productive options, a process which in many Latin American countries tends to be fragmented into distinct genetic improvement, marketing, and agronomic / silvicultural components. This situation implies that this IPG is underutilized and underpromoted.

Such an integrated approach responds to a number of priorities and deficiencies identified in Chapter 2, including the need to generate substantive locally validated research findings through better use of scarce research funds (2.6.3), and the need to work more closely with NARs (2.8.6.5), and the need to avoid the “agroforestry systems” approach that has to some extent dogged agroforestry research for development and agroforestry development in Peru (2.7.6).

Second, approaches to domestication, if systematized and supplemented by decision tools, and illustrated by successful examples, are also valuable potential IPGs.

Third, specific technical outputs of the domestication process can be valuable IPGs. One of these, with some caveats (see 4.2.3.1) is improved germplasm. Technical IPGs would also include information on specific silvicultural or agronomic management techniques and information on market barriers and opportunities.

The above considerations, together with the *status quo ante* reviewed in Section 2, constitute an adequate basis for identifying appropriate strategies, future actions and specific options for the development of the TDP’s activities in Peru. These options should be consistent with the role outlined in the present section, should take account of specific lessons identified in Chapter 2, and, if possible, should build on the activities to date of the TDP—not because of a feeling that “what is started must be finished”, but because the considerable investment made to date means that valuable results can be achieved with relatively little additional investment. Chapter 4 outlines a strategy for the TDP’s future activity, including proposed activities.

4. “Roadmap” for future development of the ICRAF TDP in Peru

4.1 Structure and conceptualization of ICRAF’s intervention

To a large degree, in recent years ICRAF-Peru has appeared to be focused on generation of research results and products of essentially local interest—even though these may have had some IPG elements—and, to a point, has had a mode of engagement similar to local NGOs and GOs. Even though ICRAF-Peru management has been aware of the mission of producing IPG, this can be easily forgotten in day-to-day project management, particularly given the lack of involvement in the TDP of ICRAF’s national partners. For this reason, the three classes of domestication-related IPG mentioned in Section 3.4—the Domestication Concept, Models and Approaches to Domestication, and IPG Research Products—provide a convenient and appropriate framework for exposition and strategic planning of the TDP’s role within the AI-EP. This structure and conceptualization of ICRAF’s engagement should be both understood clearly by ICRAF staff at different levels and communicated clearly to research partners.

4.2 Guidelines for implementation of an IPG-oriented agenda

4.2.1 IPG: The Domestication concept

To date, the wider domestication concept (Simons and Leakey 2004) has been poorly articulated by ICRAF-Peru, and poorly expressed in its own work. This is an important missed opportunity, as the domestication concept is a useful approach for achieving a more integrated approach to a substantial part of the overall agroforestry research agenda, particularly when associated with a broad conception of agroforestry.

ICRAF-Peru researchers, including those who are not necessarily closely involved with the TDP or aware of tree improvement techniques, need to become familiar with the wider domestication concept and able to articulate it to current and potential partners and to decision-makers in government and elsewhere. This means explaining the nature of domestication as an integrated approach to development of novel agroforestry products (including service trees), addressing genetic, phytochemical, agronomic, marketing, intellectual property, and regulatory aspects. The effective communication of this message will require purposeful and planned activities, with supporting documentation.

4.2.2 IPG: Working models and approaches

4.2.2.1 Demonstration and documentation of successful examples

At present, the TDP does not constitute a complete or replicable model suitable for wider uptake. In particular, it has yet to produce germplasm with any demonstrated or notable degree of genetic superiority. ICRAF-Peru needs to work urgently in order to convert the potential of the TDP into results that will inspire imitation and emulation with other species and regions. Research with palpable results⁷³ is needed. Preferably

⁷³ An aspect stressed by DEVIDA personnel (José Isla, personal communication, 7th July 2009). The experience of DEVIDA and associates in promoting alternatives to illicit coca production—with its advantages of relatively stable, reliable markets, multiple harvests per year, and relatively high profitability—is perhaps underutilized by ICRAF and its partners.

this should be based on eye-catching innovation, although tried-and-tested techniques with high impact should never be eschewed solely to fulfill donors' or others' preference for innovative approaches.

In the case of *G. crinita* and *C. spruceanum*, the obvious way to do this is through the identification and demonstration of superior clones. Low-technology techniques for macro-propagation of forest trees (i.e. by rooted cuttings) have been available for more than 20 years, and work for the great majority of tropical timber trees with which they have been tried (Leakey *et al.* 1990). ICRAF-Peru personnel and partners, including institutions such as FONDEBOSQUE, already have experience with this or similar technology, and specialized technical support is also easily available. Methods for propagating both species could easily be developed in less than 12 months, and clones with varying juvenile growth would be available after 24-36 months. Candidate clones (including inferior clones, for demonstration purposes) would be selected based on genetic analyses of the existing network of progeny trials.

Parallel with this activity, ICRAF and partners should take advantage of work done to date by preparing short, high quality technical/extension manuals describing the methodology used, showcasing the excellent growth of the species on suitable sites, and summarizing what is known to date of both species' silviculture, genetics, and processing. Both manuals should emphasize the domestication concept in both their titles and content (e.g. "Domesticación de bolaina: silvicultura, genética, y procesamiento" ["Domestication of 'bolaina': silviculture, genetics, and product processing"]), and should be designed and written with both international (Amazonian) and domestic readerships in mind. Later editions would add vegetative propagation methods and, eventually, material on characteristics of selected clones.

4.2.2.2 Systematization

The domestication approach, even if articulated clearly as suggested above (Section 4.2.1), will not be implemented adequately, except by ICRAF itself, without clear guidelines. Ideally, these guidelines should be presented as decision-tools⁷⁴. These would facilitate explicit decision-making on aspects such as prioritization (of species/products and target zones), respective roles of and emphases on genetic and agronomic (silvicultural) research, approach to conservation of genetic diversity, role for participatory and on-station research, product development and marketing, regulatory barriers, provision for germplasm supply systems, intellectual property concerns, etc.

4.2.3 IPG Research products

In terms of number of personnel, ICRAF-Peru is a small organization and, in the short- medium-term, seems unlikely to expand significantly. There is no point in ICRAF-Peru expending significant parts of its efforts on executing projects that could be implemented by national partners, particularly as substantial involvement in *implementing* extensive research activities tends to absorb a significant part of researcher time and makes interaction with and influence of national researchers more difficult. As a principle of intervention, it is therefore suggested and assumed here that involvement of ICRAF-Peru in research implementation—as opposed to coordination and facilitation—should be limited to (a) specific actions related to current activities; (b) research actions, preferably of limited duration, with significant

⁷⁴ The dichotomous key approach used by Cornelius (2009) could be one model for such tools.

potential for generation of IPGs, particularly aspects of model approaches or working examples of domestication.

With the integration of the domestication approach within the AI-EP, as envisaged in Section 3.5.2 and facilitated by the products outlined in Section 3.5.3, the TDP should become increasingly involved in coordination and mentoring, as opposed to implementation of research. One aim of this role should be to encourage and, where appropriate, give technical assistance in publication of local research with IPG elements.

Due to its breadth and multidisciplinary nature, domestication is almost necessarily a multi-institutional enterprise. Accordingly, priorities and needs should be determined collaboratively, an approach that characterizes the work to date of both ICRAF-Peru and the TDP. However, a collaborative approach by no means removes the need for clear vision and leadership. ICRAF, as a leading agroforestry research organization, should be in a position to supply such leadership. There are a number of areas, some identified within the scope of the present study, which ICRAF could pursue in collaboration with its national partners. These are described below.

4.2.3.1 Agroforestry germplasm

As briefly noted above, there are some difficulties in the conception of agroforestry germplasm as an IPG.

First, germplasm can only be an IPG if it can be moved internationally. As, in agroforestry, conditions and management are often more variable than in agriculture, there is a possibility that material selected in one country (latitude / longitude / precipitation regime) may not be superior in another⁷⁵. This would detract from the IPG nature of the germplasm.

Second, as yet there are no mechanisms in place for securing the rights of farmers involved in participatory domestication and particularly, in the IPG context, how they would be rewarded for the use of their germplasm in other countries.

Third, there are difficulties involved in free movement of germplasm between some countries.

However, none of these difficulties is insurmountable, and their resolution could be part of ICRAF's construction of germplasm as IPG.

Assuming that these difficulties can be accommodated, there are a number of specific activities that could usefully be carried out. In any case, the activities listed would also contribute usefully as examples of successful domestication-related work (i.e. as provided for in 4.2.2.1).

Timber tree germplasm

As noted above (2.7.5.2), there are no seed sources of a number of timber species of current interest (e.g. *C. odorata*, *T. serratifolia*, *S. macrophylla*, *S. amazonicum*, *D. micrantha*, *T. grandis*). Plantation silviculture can be implemented successfully without highly improved seed sources⁷⁶, and a network of seed sources of acceptable

⁷⁵ i.e. due to genotype-environment interaction.

⁷⁶ In large measure, because final crop trees represent a small proportion of trees initially planted. This, together, with other silvicultural interventions, particularly pruning, means that a good quality final crop can be produced even with unimproved seed. Seed quality becomes more important when higher ratios of initial to final spacing are used, as in some agroforestry systems.

quality of a variety of species could be quickly and easily established. In the particular case of mahogany, the Director-General of the Peruvian *Dirección General Forestal y de Fauna Silvestre* has expressed an interest in developing a collaborative project with ICRAF on seed source development⁷⁷.

Peach palm germplasm

Since 1999, the TDP has invested more resources in peach palm domestication than in any other activity, largely because of the establishment of progeny tests in both Ucayali and Alto Amazonas (Loreto). However, to date, only one publication has been produced (Cornelius *et al.* 2009), and development impact has been limited to the local sale of a small amount of seed. Furthermore, growth and fruit production in the trials, particularly in Ucayali, has often been unsatisfactory.

The peach palm progeny tests constitute a very valuable genetic resource, and are the potential source of the first estimates of genetic parameters for fruit production in peach palm, as well as being potential sources of improved seed for a species widely planted by smallholders in the Amazon and agroindustry in southern Brazil. Four measures need to be taken to ensure the adequate use of this resource. First, there is a need to assess the usefulness of individual trial blocks, particularly those which to date have not been productive. This assessment should be carried out by an expert in peach palm agronomy⁷⁸. Second, the evaluation protocol should be reviewed and a series of definitive trial measurements should be carried out over several years, as single-year productivity measurements are unlikely to be reliable. Third, definitive analyses of the data should be carried out and published. Fourth, the peach palm working group formed in 2006 as a result of the ICRAF-organized peach palm workshop in Lima should be reinvigorated and, if possible, relaunched as a domestication initiative, i.e. as suggested in Section 4.2.1.

Inga edulis domestication

Inga edulis is perhaps the most widely planted agroforestry tree in Peru. As well as being of increasing importance in land rehabilitation, it plays a major role in the valuable coffee and cacao industries. In spite of its identification in the prioritization process as a high priority species, the TDP has carried out almost no work on its domestication. A proposal for domestication of the species, aiming at producing vegetatively propagated cultivars suitable for land rehabilitation, coffee and cacao shade, and, perhaps, fruit production, would have a good chance of attracting cross-institutional and industry support, and should be actively promoted by ICRAF-Peru.

Genetic resources of *G. crinita* and *C. spruceanum*

In addition to the development of improved germplasm, there is a need to safeguard the genetic resources of bolaina and capirona currently located on-farm. Under the recently concluded INCAGRO project SEMFOREST, selected individuals from the trials were to be grafted into clone banks / seed orchards on secure lands in order to ensure their continued availability (in the event of loss of progeny tests) and availability for future improvement work. This work should be completed, and complemented by bulked seed collections from each experimental block. A sample of 50-100 plants derived from each block should then be established at close spacing as a

⁷⁷ Gustavo Suárez de Freitas Calmet, personal communication, 8th July 2009.

⁷⁸ Several specialists from the Peruvian Amazon have provided paid advice to ICRAF on the management of the peach palm trials, but without any noticeable beneficial impact. It may be necessary to recruit an international peach palm expert to review these trials.

gene bank (0.5m x 0.5m, coppiced regularly for easy maintenance). The gene bank would also serve as a source of cuttings for clonal testing. For each species, two to three strategically located blocks with good growth could be retained for demonstration purposes, i.e. through agreement with and possible compensation of the landowner in question.

4.2.3.2 The PROSEMA initiative

The TDP's long association with PROSEMA (see 2.8.6.6) should be reviewed, primarily with a view to identifying lessons of broad interest in the development of agroforestry germplasm supply systems.

4.2.3.3 Mahogany, cedar, and *Hypsipyla*

Peruvian smallholders, like smallholders elsewhere, consistently express interest in cultivating mahogany and cedar. However, the *Hypsipyla* problem—whether real or perceived—often discourages research and development institutions from working with these species. The TDP is a case in point, as cedar, one of the highest priority species, was eliminated from consideration due to the *Hypsipyla* problem. There is growing realization that, with appropriate planting configurations, site selection, silviculture and, ideally, genetic material, cultivation of both cedar and mahogany is feasible. However, to date there is no research-based, technological package for doing so. The generation of such a package, based on financial analysis of candidate silvicultural systems, would be a most valuable IPG.

4.2.3.4 Production of IPG from grey literature

A large amount of agroforestry information in Peru is “buried” in grey literature, particularly theses and project reports (Meza and Cornelius 2005). Much of this information is of relevance to tree domestication, in the wider sense, and there is little doubt that some is of national and international interest. While the enumeration of such information in bibliographies (e.g. Meza and Cornelius 2005) is a valuable step in its rescue and utilization, it is only the first step. The most cost effective way to finish this task would be through the commissioning of one or more literature reviews⁷⁹, which should be published both in peer-reviewed journals and as nationally disseminated technical publications.

4.2.3.4 Opportunities for oil palm diversification

As argued in Section 2.7.6, ICRAF should engage with the oil-palm industry located in Pucallpa, with a particular view to examining both its financial impact on smallholders and possibilities for agroforestry based mitigation of any negative environmental impacts.

4.3 Summary of recommendations

1. The three classes of domestication-related IPG mentioned above—the Domestication Concept, Models and Approaches to Domestication, and IPG Research Products—provide a convenient and appropriate framework for exposition and strategic planning of the TDP's role within the AI-EP.

⁷⁹ Such a task could be carried out by one or more capable graduate students, perhaps in collaboration with an experienced researcher from ICRAF or a partner institution.

2. This structure and conceptualization of ICRAF's engagement should be both understood clearly by ICRAF staff at different levels and communicated clearly to research partners.
3. To date, the wider domestication concept (Simons and Leakey 2004) has not been well articulated by ICRAF-Peru, nor adequately expressed in its own work. This is a missed opportunity that should be rectified. The domestication concept is a useful approach for achieving a more integrated approach to a substantial part of the overall agroforestry research agenda, particularly when associated with a broad conception of agroforestry.
4. ICRAF-Peru researchers, including those who are not necessarily closely involved with the TDP or aware of tree improvement techniques, need to become familiar with the wider domestication concept and able to articulate it to current and potential partners and to decision-makers in government and elsewhere.
5. At present, the TDP does not constitute a complete or replicable model suitable for wider uptake. ICRAF-Peru needs to work urgently in order to convert the potential of the TDP into results that will inspire imitation and emulation with other species and regions. Research with palpable results is needed. Preferably this should be based on eye-catching innovation, although tried-and-tested techniques with high impact should never be eschewed solely to fulfill donors' or others' preference for innovative approaches.
6. In the case of *G. crinita* and *C. spruceanum*, the obvious way to do this is through the identification and demonstration of superior clones
7. Parallel with this activity, ICRAF and partners should take advantage of work done to date by preparing short, high quality technical/extension manuals describing the methodology used, showcasing the excellent growth of the species on suitable sites, and summarizing what is known to date of both species' silviculture, genetics, and processing.
8. The domestication approach, even if articulated clearly as suggested above, will not be implemented adequately, except by ICRAF itself, without clear guidelines. Ideally, these guidelines should be presented as decision-tools, aimed at facilitating and promoting integrated and appropriate approaches, based on explicit decisions, to prioritization (of species/products and target zones) and to planning of technical and other interventions.
9. ICRAF-Peru is a relatively small organization. As a principle of intervention, it is suggested its involvement of ICRAF-Peru in research implementation—as opposed to coordination and facilitation—should be limited to (a) specific actions related to current activities and (b) research actions, preferably of limited duration, with significant potential for generation of IPGs.
10. The TDP should become increasingly involved in coordination and mentoring, as opposed to implementation of research. One aim of this role should be to encourage and, where appropriate, give technical assistance in publication of local research with IPG elements.
11. Domestication is almost necessarily a multi-institutional enterprise. Accordingly, priorities and needs should be determined collaboratively.
12. A collaborative approach by no means removes the need for clear vision and leadership. ICRAF, as a leading agroforestry research organization, should be in a

position to supply such leadership. There are a number of research activities that ICRAF could pursue in collaboration with its national partners:

- Development of a network of seed sources of acceptable quality of priority timber species.
- Measures to ensure the adequate use of the peach palm genetic resources developed by the TDP.
- Preparation of a collaborative proposal for domestication work with *Inga edulis*.
- Safeguarding of genetic resources of *C. spruceanum* and *G. crinita* and establishment of demonstration blocks.
- Engagement with the oil-palm industry located in Pucallpa, with a particular view to examining both its financial impact on smallholders and possibilities for agroforestry-based mitigation of any negative environmental impacts.
- The TDP's association with PROSEMA should be reviewed, primarily with a view to identifying lessons of broad interest.
- Preparation of a proposal for domestication work cedar or mahogany or both, aimed at generation of a technological package covering appropriate planting configurations, site selection, silviculture and, ideally, genetic material.
- Commissioning of one or more literature reviews for publishing in peer-reviewed journals, summarizing key findings from the Peruvian "grey literature" on agroforestry.

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Appendix 1: List of interviewees and other contacts during visit to Peru, July 2009

Date	Name	Institution
7 th July 2009	Carlos González, José Isla, María Mejía, Guillermo Paredes	DEVIDA
	José Dancé	CODESU
	Luis Espinel	Conservation International
8 th July 2009	Juan Fernando López	PALMAGRO
	Lambert Pie Pau	Selva Industrial S.A.
	Gilberto Domínguez	UNALM
	Antonio Guerrero, Gustavo Suárez	DGF
9 th July 2009	Ricardo Sevilla	STC-CGIAR
	Martín Retamoso	FONDEBOSQUE
10 th July 2009	Oscar Barreto, Rory Baldoceda	UNU
	Manuel Soudre	IIAP-Pucallpa
	Ymber Flores, Pedro Reyes	INIA-Pucallpa
11 th July 2009	Jorge Chávez	AIDER
	Nemesio Damian	PROSEMA
13 th July 2009	Dennis del Castillo, Ricardo Farronyay, Carmen Rosa García, Agustín López, Kymber Mejía, Mario Pinedo, Angel Salazar	IIAP-Iquitos
14 th July 2009	Edgar Manuel Inga, Rubén Munarris, Grover Panduro, Jorge Revilla, Róger Vargas	GOREU (Dirección Medioambiente)
15 th July 2009	Alejandro Llaque	SFM BAM
	Jorge Chávez	AIDER
	Pedro Seijas, Jorge Vigo	OLAMSA
16 th July 2009	Julio Alegre, Carlos Reynel	UNALM
	Rubén Guevara	CENTRUM-PUCP
17 th July 2009	Miguel Barandarian, Enrique La Hoz, Juan Risi	INIA-Lima
	Enrique Toledo	Reforesta Peru
	César Cerdan	AIDSEP

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32. Compensation and rewards for environmental services.
33. Latin American regional workshop report compensation.

34. Asia regional workshop on compensation ecosystem services.
35. Report of African regional workshop on compensation ecosystem services.
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58. Assessing the Hydrological Situation of Talau Watershed, Belu Regency, East Nusa Tenggara.
59. Kajian Kondisi Hidrologis DAS Talau, Kabupaten Belu, Nusa Tenggara Timur.
60. Kajian Kondisi Hidrologis DAS Kapuas Hulu, Kabupaten Kapuas Hulu, Kalimantan Barat.
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84. Lesson learned RATA garut dan bengkuntat: suatu upaya membedah kebijakan pelepasan kawasan hutan dan redistribusi tanah bekas kawasan hutan.
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