Participatory domestication of agroforestry trees: an example from the Peruvian Amazon

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Farming communities in the Peruvian Amazon depend upon more than 250 tree species for construction material, fence posts, energy, fibres, resins, fruits, medicines, and service functions such as soil conservation and shade (Sotelo Montes and Weber 1997). However, because of deforestation, forest fragmentation, and overlogging, the diversity and the quality of valued tree species are declining around many rural communities. The resultant loss to local communities in income, self-reliance, and nutritional security is often severe. In addition, national and global environmental benefits of forests are reduced.

Most farmers practise traditional slash-and-burn agriculture in the Peruvian Amazon (Denevan and Padoch 1988). Because the typically acidic soils lack sufficient nutrients for sustainable, repeated harvests of annual crops, farmers cut and burn the forest to release accumulated nutrients in the woody biomass. This allows one to three years of cropping (rice, maize, cassava) before the fields are left to fallow or are converted to pasture. A 20-year forest fallow is considered necessary to restore soil fertility for a sustainable three-year cropping phase (J.C. Alegre, personal communication). Since an average farm is only 30 hectares (ha), and 2–3 ha are typically cleared annually for crop production, a 20-year rotation is not an option for most farmers. So most farmers decrease the fallow period to five years or less, resulting in degraded soils and low crop yields.

Slash-and-burn agriculture fragments and alters the forest habitat, resulting in poor natural regeneration of many valuable tree species. In addition, farmers and loggers cut the best timber trees in their forests, without leaving high-quality trees to produce seed for natural regeneration (Weber *et al.* 1997). In time, farmers no longer have access to high-quality tree seed for their agroforestry systems. When crop yield and forest value decrease, farmers often migrate to open up more land, thereby repeating the cycle of deforestation, forest fragmentation, soil degradation, and poverty.

The International Centre for Research in Agroforestry (ICRAF) and its partners are working to counter this cycle and to help ensure that farming communities and the global community continue to derive the benefits that trees provide. In this paper, we describe a tree domestication project underway with farming communities in the Peruvian Amazon. Domestication is defined as an iterative process involving the identification, production, management, and adoption of desirable tree germplasm. The project aims to provide increased productivity and long-term sustainability for farm forests, while also empowering farming communities to conserve tree genetic resources.

Principles of farmer-driven tree domestication

Farmers domesticate trees by bringing them into cultivation, adapting them to their needs and environmental conditions by deliberately or inadvertently selecting for certain characteristics, and applying particular management strategies (Leakey and Simons 1998). To develop and implement an effective domestication strategy, farmers and researchers should collaborate from the outset. This is because farmers, who are the principal beneficiaries of tree domestication, can best identify their needs in a research programme. Farmers also have valuable knowledge about tree species that can guide the research programme.

Identifying farmers' preferences for agroforestry trees is the first step in participatory tree domestication. Following guidelines developed for priority setting (Franzel *et al.* 1996), we conducted farmer-preference surveys and solicited advice from experts in forest products, markets, and other disciplines. We learned that farmers would like to cultivate more than 150 tree species, and we identified 23 of these as high priority for domestication (Sotelo Montes and Weber 1997). Domestication projects have begun for four of the species that figure significantly in the farm economy (Labarta and Weber 1998): *Bactris gasipaes* Kunth, *Calycophyllum spruceanum* Benth., *Guazuma crinita* Mart., and *Inga edulis* Mart.

Documenting farmers' knowledge about variation within a tree species is an essential component of participatory tree domestication. The documentation provides testable hypotheses for research that can accelerate the delivery of improved tree planting material to farmers.

For example, *Bactris gasipaes* (peach palm) is an under-utilised food crop that many farmers cultivate on a small scale. Some farmers prefer a starchy fruit for flour, while others prefer an oily fruit for cooking oil. Farmers have learned to use visual identification to tell which palms are better for these products. In their experience, fruits with red, waxy coats have higher oil content than fruits with red or yellow, non-waxy coats. This hypothesis about variation in fruit traits is being tested experimentally, and if proved correct, will allow farmers and researchers to select the best genetic material for multiplication quickly and inexpensively.

When documenting farmers' knowledge and perceptions about variation within tree species, it is essential to recognise potential gender differences, because men and women may value different tree species. For example, many women cultivate trees in home gardens for fruit, medicines, and other products that they use in the household and sell in local markets. In one case study (Potters 1997), women recognised six varieties of *Inga edulis*, which they would cultivate specifically for fruit, shade, or firewood. They distinguished the varieties based on pod size and on the size, shape, and colour of the leaves. According to their experience, certain varieties have tastier fruits, while others are better for shade. The women also perceived a correlation between seed colour and fruit production. In their experience, trees that develop from black seeds produce many fruits, but trees from yellow seeds do not produce much fruit. Men, on the other hand, dedicate considerable time to land clearing, charcoal production, house construction, and fence building. With experience, they learn which species are best for different uses, and recognise variation within some of their most valued species. For example, they cultivate *C. spruceanum* for timber and charcoal in secondary forests. In their experience, *C. spruceanum* trees with dark reddish-brown bark and few knots on the stem have dense wood and are best for sawn timber, whereas the wood of trees with light-coloured bark is not dense, is easy to split with an axe, and is best for firewood and charcoal.

Selecting improved tree planting material with farmers

Through appropriate selection strategies, farmers can achieve improvement in timber-tree form, fruit quality, and other commercially important traits (Simons *et al.* 1994). Most tree species include considerable genetic variation, which provides opportunity for selection and improvement. The challenge is to determine efficient methods for characterising variation and for selecting the best genetic material with farmers for agroforestry systems that are often complex and vary from farm to farm. Non-traditional approaches, which involve farmers as collaborators throughout the research process, are generally required.

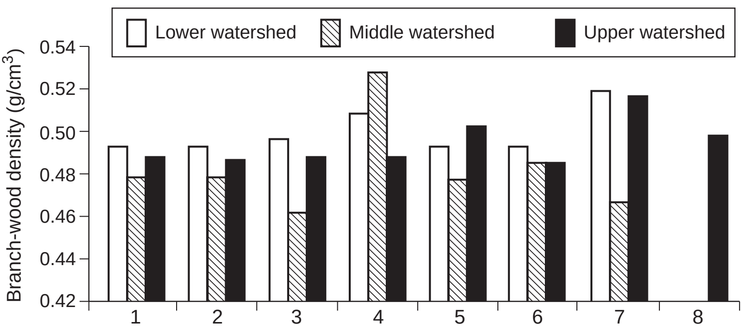
An example of a non-traditional approach to improvement is illustrated by on-farm provenance trials of two timber-tree species, *Calycophyllum spruceanum* and *Guazuma crinita*. The former is also valued for firewood, charcoal, and construction poles. Both species are relatively fast growing, and can be harvested in 3–20 years, depending on the product desired. Researchers and farming communities over a large geographic area identified 11 extensive natural populations (provenances) of each species in the Peruvian Amazon and then collected seed from these populations in 1996. Trees were not selected based upon their physical appearance; they were sampled following a 'systematic collection' strategy (35 trees collected at random in each population, with a minimum distance of 100 m between trees) designed to ensure a representative sample of the variation within natural populations (Dawson and Were 1997). The seed was used to establish on-farm provenance trials in the Aguaytía watershed in 1998. The principal objective of the ongoing trials is to identify the most promising provenances for different products under various rainfall and soil conditions in the watershed. The Aguaytía is representative of many watersheds in the western Amazon basin; in general, soils are more fertile and rainfall is higher in the upper portion of the watershed. The study area extends over a distance of approximately 80 km. Along this 80 km, elevation increases from approximately 180 to 300 m, and annual rainfall increases from approximately 1800 to 3500 mm. Temperature data are not available, but average annual temperature is approximately 26°C.

Farmers were selected in the lower, middle, and upper parts of the watershed to participate in the on-farm provenance trials. We selected 20 farmers based upon their interest in the project, experience in tree management, and standing in the community as innovators and leaders. Each farmer has one replication of the trial. The farmers participate actively in evaluating tree growth, and they provide useful information about selection criteria, such as the hypothesis mentioned above concerning bark and wood characteristics of *C. spruceanum*. If results from the provenance trial prove this hypothesis correct, farmers will be able to select rapidly the best trees for sawn timber or for charcoal, and multiply the seed for personal use and sale.

Preliminary results of the trials illustrate potential gains that farmers can realise from selection. After one year in the field, the local provenance of *G. crinita* from the Aguaytía watershed was significantly taller than the other provenances, suggesting that seed from the Aguaytía watershed would be best for reforestation in that watershed and in other watersheds with similar environmental conditions (Sotelo Montes *et al.* 2000). However, wood density and other traits should also be evaluated before recommending the best seed source. In *C. spruceanum*, for example, wood density varies greatly among provenances and environments, and no single provenance performs best in all environments (see Figure 1: there were only eight provenances in the trial). Some provenances have higher wood density in the upper watershed, with more favourable growing conditions, while others perform better in the middle and lower watershed where soils are less fertile and drier. This indicates that different provenances of *C. spruceanum* are likely to be better adapted to different parts of the watershed.

An ideal provenance for timber and energy would grow rapidly and produce wood of high density and high heat content. Identifying this provenance requires evaluating growth and wood traits together. We illustrate this with *C. spruceanum*, using a statistical technique that summarises variation in growth and wood traits into component 'traits' (principal component analysis). Provenance means for two component traits are plotted; the horizontal axis summarises branch-wood density and heat content, while the vertical axis summarises growth, which

Figure 1: Variation in branch-wood density at 18 months among provenances of *Calycophyllum spruceanum* tested in the Aguaytía watershed, Peru



Provenance: 1 Lagunas, 2 Barranca, 3 Pastaza, 4 Jenaro Herrera, 5 Tamshiyacu, 6 Mazan, 7 Pevas, 8 Von Humboldt (tested only in upper watershed) includes tree height, stem diameter, number of stem nodes and branches. In this case, the best provenances fall in the upper right quadrant of the plot. In the lower watershed, one provenance showed a 'win–win' response with the best growth and wood characteristics (see Figure 2). In the upper watershed, several provenances expressed these characteristics and could be considered as seed sources for reforestation (see Figure 3).

Figure 2: Plot of component traits of *Calycophyllum spruceanum* provenances tested in the lower Aguaytía watershed, Peru

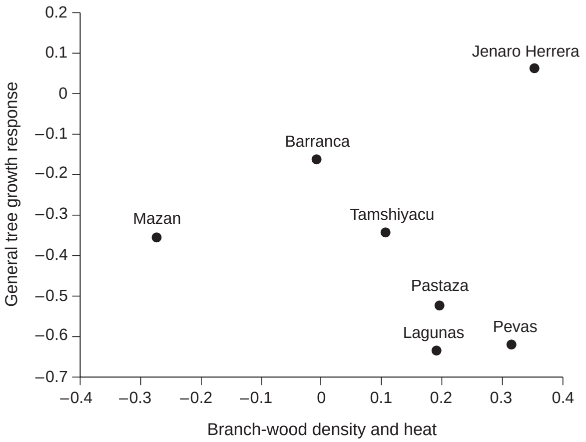
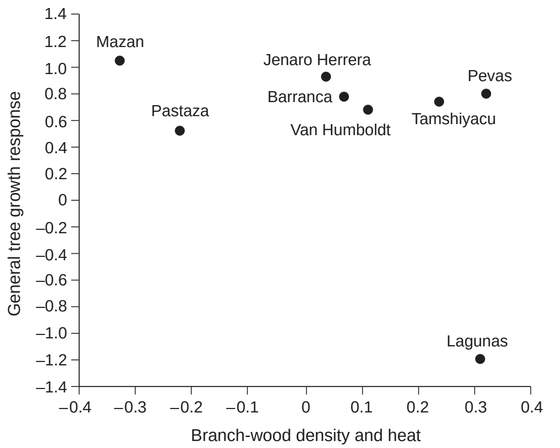


Figure 3: Plot of component traits of *Calycophyllum spruceanum* provenances tested in the upper Aguaytía watershed, Peru



Improved performance is clearly important when selecting tree populations for cultivation, but we must also consider genetic diversity. Diversity is needed to enhance the capacity of planting material to adapt to changing user requirements and environmental conditions (Simons *et al.* 1994). Moreover, most tree species do not tolerate inbreeding; if inbreeding during cultivation significantly reduces their genetic diversity, the next generation will be less vigorous and less productive.

Tree domestication practices can have a conservation function if they ensure that planted material is productive, adapted, and genetically diverse. Provenance and progeny trials are useful for selecting more productive and adapted tree planting material for different environmental conditions, but sophisticated molecular techniques are required to assess overall genetic diversity. Using these techniques, we identified the most diverse provenances of *C. spruceanum* (Russell *et al.* 1999) and recommended that farming communities manage them for *in situ* conservation and seed production (Sotelo Montes *et al.* 2000). In *Inga edulis*, we are concerned that domestication has reduced genetic diversity on farms, compared with wild populations. Preliminary results confirm this hypothesis (T. Pennington, personal communication) and warrant introducing germplasm to increase the genetic diversity on farm and the participatory management methods needed to maintain the diversity.

Demonstrating the risk of poor tree adaptation to farmers

In most tropical countries, few mechanisms control the source of seed used for tree-planting projects. Seed may be collected in one region and used in another with different environmental conditions, without any knowledge of its potential adaptation. Seed zones and transfer guidelines based upon ecological and sometimes genetic criteria have been proposed as ways to minimise the risks of disappointing tree performance. Normally, it is assumed that transferring seed from one environment to another imposes some degree of risk and that seed from local sources is generally better adapted to local environmental conditions than seed from foreign sources.

To test questions of adaptation, it is important to select an appropriate 'field laboratory' so that results can be extrapolated over larger areas. As mentioned, the Aguaytía watershed is representative of many others in the Peruvian Amazon. In 1998, farmers selected 200 trees each of *C. spruceanum* and *G. crinita* that had been sampled throughout the lower, middle, and upper parts of the Aguaytía watershed. These were 'targeted collections' (Dawson and Were 1997), in which farmers selected their best trees based upon desirable timber characteristics (straight bole without bifurcation, few knots, thin branches, relatively small canopy). Progeny of the 200 trees were established in progeny trials on 15 farms in the lower, middle, and upper parts of the same watershed in 2000-1. The results of these trials will allow us to quantify the effect of a hypothetical seed transfer from one part of the watershed to another. For example, we hypothesise that progeny of trees collected in the upper part of the watershed will grow best in the replications located in the upper watershed and least well in the replications located in the lower watershed. The relative differences in progeny performance in the lower, middle, and upper watershed will allow us to estimate potential production losses associated with a given seed transfer from one part of the watershed to another. Farmers and development workers will then be able to decide if the risk is acceptable, when balanced against other factors. Conclusions drawn from the trials can also be extrapolated to other watersheds with similar environmental conditions.

Accelerating the delivery of high-quality planting material to farmers

Once appropriate planting material has been identified, what is the most efficient way to produce and disseminate it? Farmers consistently cite the lack of high-quality tree seed as a major constraint to diversifying and expanding their agroforestry practices (Simons 1996). Providing farmers with high-quality tree seed in a timely manner, therefore, is one of the principal objectives of tree domestication. A traditional approach to tree improvement involves a number of sequential steps – species selection trials, provenance trials to identify the best seed sources of a species, progeny tests to identify the best mother trees within a selected seed source, collection of germplasm from the best mother trees to establish seedling or clonal seed orchards, and, finally, the production of high-quality seed from orchards for dissemination to users. This process is too time consuming and expensive to undertake for most tree species, and the work, if not carefully planned, may seriously reduce the genetic diversity in tree-planting material. Furthermore, the formal sector of governmental and non-governmental organisations that produce and disseminate tree seeds cannot meet the growing demand for quality planting material.

An alternative approach is to involve key farmers not only in selecting the most promising planting material, but also in multiplying and disseminating it. This approach reduces the number of steps to the end user, while measures are taken to maintain genetic diversity and quality. For example, on-farm provenance or progeny trials of *C. spruceanum* and *G. crinita* can be converted into seed orchards after approximately three years, thereby dramatically shortening the time required to deliver selected planting material to farmers. Farmers and researchers will thus be able to select the best trees to retain for seed production and can then cut the other trees in each replication. Farmers can use or sell the cut trees for construction poles, firewood, and other products, and manage stump sprouts for future harvests. The orchards themselves can satisfy the entire demand for planting material in the watershed and have a decentralised, *circa situ* conservation function on farm. Participating farmers are being organised into networks to produce and sell high-quality seed, seedlings, and timber to organisations involved in tree planting projects and to timber companies. This will be a new form of small-business enterprise in Peru. The earnings will depend on the scale of production, but it is estimated that farmers will be able to earn at least US$1000 per year from the seeds, seedlings, and timber in a 1 ha lot of *C. spruceanum* or *G. crinita*.

Adoption of the tree domestication methodology

National and local institutions, non-governmental organisations, and private enterprise in Peru are becoming increasingly aware of the need to conserve tree genetic resources and manage them sustainably. We are working with several institutions and selected timber companies to promote the use of improved seed and certified timber production for the international market. We are also working with the National Institute for Natural Resources (INRENA) to institutionalise tree domestication in the Peruvian Amazon. Through INRENA's extensive network for reforestation, it will be possible to reach thousands of farmers in the next five years. Through INRENA's lobbying efforts in the Peruvian government, policy changes are being introduced in the forestry laws to promote the sustainable use and conservation of tree genetic resources for future generations.

Lessons learned and conclusions

Farmers are frustrated with the low prices for traditional food crops and the unstable prices for perennial crops like coffee and cocoa. From past experience, they are sceptical of new 'boom' crops like palm hearts for the gourmet market. They are eager for alternatives in which they have a comparative advantage in production, and many now see tree crops for timber, fruit, energy, medicine, and seed as a good investment.

Farmers should have a strong vested interest in conserving tree genetic resources, since they are the first to suffer if these resources decline in value. But they will become encouraged to conserve only if they see tangible economic benefits. The challenge, therefore, is to engage key farmers in tree domestication research, quantify the economic benefits, and use the farms to demonstrate the economic potential to others in the community. This is not easy, because most farmers in the region lack a 'tree-planting culture' and think in the very short term. Getting most farmers to think ahead for a longer term may require generations. It may ultimately depend on the success of the national educational system and non-governmental conservation organisations.

There is a clear need to use genetic resources sustainably and conserve valuable tree species for the future economic development of resource-poor farmers in the Peruvian Amazon. We believe that the best way to achieve this goal is by promoting participatory tree domestication and conservation-through-use, where farmers themselves manage the resources, with technical assistance from international and national institutions (O'Neill *et al.* in press).

We cannot scale this project up to the national level with our limited resources. But we can train and motivate national and local institutions and private enterprise to adopt these methods and scale up tree domestication. The major challenge is to demonstrate the short, medium, and long-term economic potential that can be realised by domesticating trees and conserving tree genetic resources through wise and careful use of them.

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