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Producing Framework Tree Species for Restoring Forest Ecosystems in Northern Thailand

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Abstract Since 1994, the Forest Restoration Research Unit of Chiang Mai University's Biology Department (FORRU-CMU) has been developing methods to restore forest ecosystems to deforested sites within protected areas, for biodiversity conservation and environmental protection in northern Thailand. With support from WWF Greater Mekong Thailand Country Programme and corporate sponsor King Power Duty Free, the unit is working with Hmong hill tribe villagers from Baan Mae Sa Mai, in Doi Suthep-Pui National Park, to expand a demonstration site for the "framework species method" of forest restoration. The technique entails planting 20 to 30 indigenous forest tree species, capable of rapidly shading out weeds and attracting seed-dispersing animals from nearby forest remnants. This results in rapid increase in tree species richness, progressing towards the species composition of the original forest, as well as overall biodiversity recovery. FORRU-CMU operates a research tree nursery, where innovative tree propagation techniques are developed, and a community-based nursery and education centre, where the practicability of those techniques is tested by local villagers. The nurseries and the demonstration field trials have become a popular training facility where visiting foresters and conservationists, both from Thailand and neighbouring countries, can learn effective forest restoration methods. FORRU-CMU provides a model for formulating a strategy to apply the framework species method to restore larger degraded sites within Thailand's protected areas system.

Keywords Tropical forest · Restoration · Framework species · FORRU · Thailand

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Introduction

Since 1961, forest cover in Thailand has declined by nearly two thirds, falling below 25% for the first time, during the past decade (Bhumibamon 1986; FAO 1997, 2001). Although commercial logging in primary forest has been banned since 1989, the annual rate of deforestation remains about 0.5% (of remaining forest), mostly as a result of land clearance for agriculture and illegal logging (Fig. 1).

The consequences of deforestation have been losses of biodiversity and environmental degradation (flash floods in the rainy season, droughts in the dry season, soil erosion and siltation of water courses), as well as increased rural poverty, where villagers now have to purchase those products formerly gathered from forests, at no monetary cost.

In Doi Suthep-Pui National Park, where the project described here is located, Hmong hill tribe villagers have been the main agents of forest destruction, having converted about 17% of the park's area to agriculture (Thailand Development Research Foundation 1997), including vegetable production (cabbages, carrots, maize and so on), small areas of upland rice and expansive lychee orchards. In recent years, there has been a strong shift away from subsistence agriculture towards cash crops for export abroad, particularly cabbages and lychees.

In the upper Mae Sa Valley of the park, the original Hmong community ran out of water about 40 years ago, due to deforestation around the spring, which supplied the village with water. This forced the villagers to move their village down from 1,300 m elevation to its present location at 1,000 m elevation. Construction of a government-funded primary school and other facilities helped to consolidate the community and discouraged further movement. However the relocation event left the villagers with a strong sense of the link between deforestation and loss of water sources. Consequently, forest above the new village (Ban Mae Sa Mai = 'village river Sa new'), was declared as 'community forest' to protect three springs, which

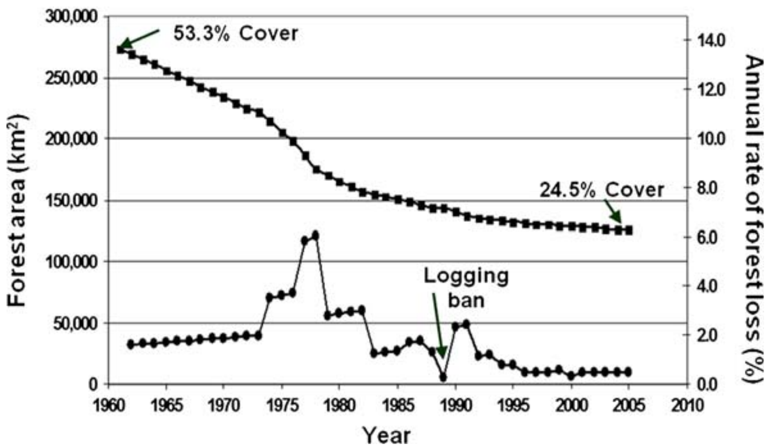

Fig. 1 Forest loss in Thailand since 1961—data from the Royal Forest Department (with extrapolation between years when data were published), -■-, forest area; -●-, rate of loss

provide water both for domestic use and to irrigate fields and lucrative lychee orchards below the village. A small number of villagers formed the Ban Mae Sa Mai Natural Resources Conservation Group and began tree planting to restore the upper watershed. However, early tree planting efforts (in the mid 1980s) mostly involved establishing single-species plantations of exotic eucalypts or native pines, which were widely available from Royal Forest Department nurseries at that time. Such plantations did little to conserve the watershed and failed to provide viable habitat for wildlife.

Tree production for reforestation in Thailand is mainly undertaken by the Royal Forest Department (RFD), which has built large-scale nurseries in all four main regions of the country. For example, the RFD nursery near Chiang Mai (Mae On) produces about 1 million trees a year, but mainly of economic timber species, with more than 50% of the trees produced being teak (*Tectona grandis*). The nursery employs 67 staff, and has a tissue culture laboratory for teak. The plants are potted into polybags and are then used as a source of cuttings. About 20 cuttings are obtained from each clonal plant over three years. These are established in mist chambers and are then grown in polybags and Rex tubes in the nursery, with regular hose watering. About 60% of the trees are used for government plantations, the remainder being distributed to private landholders. The landholders, who must provide evidence of property title, are interviewed and place orders in advance for trees. At present, demand exceeds supply. Government subsidies are available to landholders to obtain trees. The nursery also produces *Eucalyptus* spp., *Pterocarpus macrocarpus* (Red Sandalwood), and various fruit trees.

The Forest Industry Organization (FIO) is a state enterprise, concerned with industrial production of fast growing species (notably teak), and operates many plantations in forest reserves throughout Thailand. It operates large nurseries, and uses tissue culture to produce teak trees. FIO nurseries do not distribute trees to private growers.

In general, the RFD and FIO nurseries produce a narrow range of tree species, dominated by teak and other mainly commercial species for timber production. However, prompted by the growing environmental movement in Thailand in recent years, a greater variety of species are now grown, including some indigenous forest tree species for ecological restoration. Some large private nurseries also operate in Thailand, but in general, the availability of free, high quality trees from RFD nurseries hinders development of the private sector.

In this situation, a need exists for nurseries to produce planting stock of a wider range of indigenous forest tree species for forest restoration. Chiang Mai University's Forest Restoration Research Unit (FORRU-CMU) has established two model nurseries in Doi Suthep-Pui National Park, in northern Thailand to fill this niche; a research nursery and a community nursery. The nurseries not only produce trees for small-scale restoration plantings, but they are also used as a research facility to determine how best to grow a wide selection of the forest tree species, indigenous to northern Thailand.

With the support of WWF Greater Mekong Thailand Country Program and King Power Duty Free Co. and in collaboration with the Hmong community of Ban Mae Sa Mai and the national park authority, the unit is expanding a trial plot system in the upper watershed of the Mae Sa Valley in Doi Suthep-Pui National Park to demonstrate the framework species method of forest restoration. This involves planting 20–30 indigenous forest tree species, capable of shading out weeds and attracting seed-dispersing animals. The planted trees rapidly restore forest structure and ecological functioning, whilst seeds, brought in by animals from nearby forest remnants, gradually re-establish the tree species composition of the original forest ecosystem, when they germinate. Fundamental to this project's success has been participation by all stakeholders at every stage of the project, from site and species selection to planting and taking care of planted trees, as well as monitoring. Stakeholders have included the Hmong villagers from Baan Mae Sa Mai, educational institutes (particularly Chiang Mai University), government (Doi Suthep-Pui National Park), non-governmental organizations (the Forest Resources Management Unit of WWF Greater Mekong Thailand Country Program) and the business sector (King Power Duty Free Co.).

Forest Restoration Principles Adopted

FORRU-CMU rejects the adage, adopted by many conservation organizations, that 'tropical forests, once destroyed, are lost forever'. The unit bases its work on the more optimistic view that it is possible to transform largely deforested landscapes into lush tropical forests, in a few years. Forest restoration is seen as just one, highly specialized, form of reforestation, which balances use of the forest by both humans and wildlife (Elliott 2000).

The methods adopted by FORRU-CMU for forest restoration and for working with communities have evolved and been refined over a period of about 14 years. The unit's work has been complemented by a wide range of research projects by Chiang Mai University, Biology Department students and collaboration with tropical forest biodiversity specialists from various countries. The principles adopted have been recently documented by the FORRU-CMU team in a comprehensive training manual 'How to Plant a Forest' (FORRU 2006), which was funded by the UK's Darwin Initiative. The book can be freely downloaded from http://www.forru.org.

The Framework Species Method

Low intensity methods for restoration, such as accelerated natural regeneration (ANR), can achieve rapid canopy closure where populations of naturally established trees are dense, but the result is usually a secondary forest with low biodiversity (FORRU 2006). FORRU-CMU complements ANR with the framework species method of forest restoration to achieve more complete and rapid biodiversity recovery and return the tree species composition to that of the original primary forest ecosystem more rapidly than would occur naturally. The framework species method of forest restoration accelerates biodiversity recovery, because the species chosen for planting are grown from seeds from original, remnant forest and they produce fleshy fruits, have nectar-rich flowers or provide other resources that attract seed-dispersing animals from remaining forest into planted areas. Seeds dropped by those animals provide the basis for accelerated recovery towards the original tree species composition.

With support from Thailand's Biodiversity Research and Training Program, FORRU-CMU scientists successfully developed a framework species approach to restore evergreen forest, above 1,000 m elevation in Doi Suthep-Pui National Park. Planting 29 framework tree species resulted in more than 70 "recruit" (non-planted) tree species re-colonizing the plots within 8 years (Sinhaseni 2008) and bird species richness rose from 30, before planting, to more than 80, within 6 years (Toktang 2005). High-performing framework tree species were successfully identified from amongst the indigenous tree flora (Elliott et al. 2003).

This approach to forest reforestation is based on local knowledge and environmental circumstances. It begins with research into the tree species composition of the 'target' forest ecosystem (i.e. a nearby remnant of the original forest ecosystem); to determine which tree species might act as framework tree species and to identify seed sources. Phenology studies are carried out to determine optimal seed collection times and, eventually, seeds are collected for germination in a nursery.

Species Choice and Seed Collection for FORRU-CMU's Research Nursery in Doi-Suthep-Pui National Park

Previous work had established the rich botanical diversity of Doi Suthep-Pui National Park (Maxwell and Elliott 2001), so FORRU-CMU began with the herbarium collection and database of the park's flora, established by J. F. Maxwell, which provided preliminary taxonomic and distribution information for 654 tree or treelet species indigenous to the area (including 341 found in evergreen forest).

The unit first established an office and a research nursery at the national park's former headquarters compound, conveniently located at 1,000 m elevation, on the boundary between evergreen and deciduous forest types. Two years later, a community nursery and field plots were established at Ban Mae Sa Mai in the Ma Sa Valley in the north of the national park. The research nursery employs a manager and three staff, and produces about 20,000 trees a year. Shading is provided from trees planted around the nursery, rather than by netting. A research and display area is housed under a plastic roof and a seed-storage and germination area is protected by wire mesh to prevent entry of squirrels or other pests.

The unit's work began with phenology studies to determine optimal seed collection times. About 5–10 individuals of each of 100 species were identified and labelled along foot paths, leading through relatively undisturbed evergreen forest from the unit's research nursery. From 1995 to 1998, the trees were observed, at 3-week intervals, for flowering and fruiting phenology and they served as the initial seed collection trees.

Seed Collection

All seeds were collected from as many trees as possible and bulked before sowing. This procedure ensured that maximum genetic diversity was retained in the planting stock and that the trees being grown were all genetically suited to local conditions, the objective being to restore biodiversity rather than grow trees of good form and timber production. In fact, selecting seed trees for good form would run counter to the objectives of the project, since trees with good form are more likely to be cut down for timber. Seed collection is a major task of the nursery, and must be done throughout the year, as seeds of the various species come into season. Seeds are collected with a 10 m pole, tree climbing and from the ground, depending on the species.

Raising Trees in FORRU-CMU's Research Nursery

More than 420 tree and treelet species (about two thirds of the indigenous tree flora) have been experimented with in FORRU-CMU's research nursery. At any one time, at least 50 species may be growing there. Growing such a wide variety of species creates major challenges. Although species differ greatly in seed collection time, length of dormancy and seedling growth rates, all tree species must be ready for planting (i.e. about 30–50 cm tall) at the beginning of the rainy season (May–June in northern Thailand), the optimal planting time. A substantial research program has been carried out to develop methods for dealing with this complexity of seedling production (Blakesley et al. 2002). This research has included germination trials, testing various methods to break dormancy (including scarification, heat treatment, and soaking in water or acid), seed storage experiments and seedling growth trials (testing various media, containers and fertilizer regimes). Germination experiments are carried out in replicated modular trays, with data collected weekly (Fig. 2).

CMU student projects have tackled some of the more detailed options for planting stock production, such as the role of mycorrhizae (Nandakwang et al.

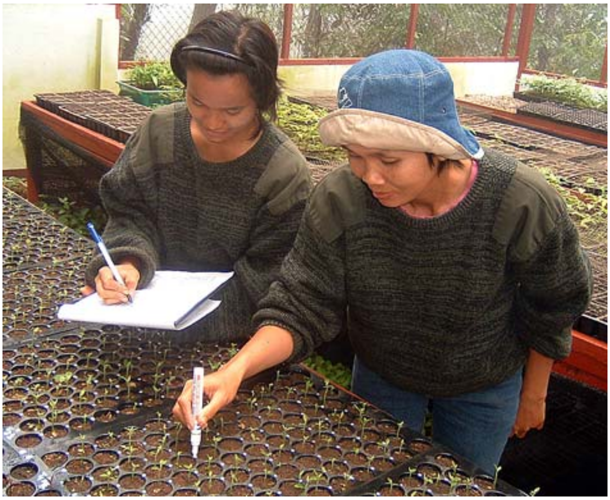

Fig. 2 FORRU-CMU staff monitoring a germination trial in the research nursery

2008), propagation from cuttings (Vongkamjan et al. 2002) and the growing on of wildlings to produce planting stock (Kuarak 2002). Experiences, gained and protocols developed from this extensive research program, have now been written up as a technical manual (FORRU 2008), to support other researchers who want to develop their own research programs for propagating potential framework tree species.

Choice of Pot Type and Formulation of Potting Mix

Experiments were conducted to determine the best container type and potting medium to use (Zangkum 1998; Jitlam 2001). Polybags, 9 × 2½ inches, are usually suitable for most species. They are tall enough to accommodate a long tap root by planting time, although root spiralling can be a problem for species that have to be kept in the nursery for longer than 1 year.

REX pots with multiple cells (produced in Thailand and similar to hiko trays) have also been used with some success (Zangkum 1998). These solve the problem of root spiralling by diverting root growth along vertical grooves and they allow aerial root pruning. Twenty-four saplings are conveniently carried in one tray, but the tray system does not allow for grading saplings.

Containers are usually placed on the ground, with manual root pruning carried out if needed (Fig. 3). Root pruning encourages root branching and removes the risk of transplantation shock when the saplings are lifted for planting. Some saplings, if not planted out during the first planting season, are carried forward to the next year, but with culling of the weaker ones and continued root pruning.

Experiments have confirmed that forest soil is a critical ingredient of the potting mix because it contains mycorrhizal fungi and possibly other microbes that are necessary to promote seedling growth (Nandakwang et al. 2008). Research showed that the most suitable mix is 50% forest soil, 25% peanut husks and 25% coconut husk. Charcoalized rice husk can also be used, but present a health hazard, such that nursery workers need to wear a mask when dealing with this ingredient.

Fig. 3 Root pruning of saplings in tall polybags

Fertilizer application and Watering

Current fertilizer application and watering practices (illustrated in Fig. 4) have been arrived at through research and observation. Osmocote (about 10 grains applied every 3 months) has been the most effective fertilizer treatment for most species. Watering by hand is preferred, because different species have different watering requirements. Labelling all the trees in the nursery is essential for good research projects and also allows the nursery to be used for education and training.

Plant Protection

In general, insecticides are not used in the nursery. Instead, multiple beds of the same species are spaced widely apart in the nursery, so that if one is attacked by insects another may be pest free. Damping off of young seedlings in germination trays is sometimes controlled with fungicide (Captan or Thiram).

Production Schedules

The ultimate aim of nursery research at FORRU-CMU is clear and concise production schedules for each framework tree species. For each tree species being grown, a production schedule is a concise description of the procedures for producing planting stock of optimum size and quality from seed (or wildlings) by the optimum planting out time. The production schedule is most clearly represented as an annotated timeline diagram, which shows when each operation should be performed and which treatments should be applied to manipulate seed germination and seedling or sapling growth. A production schedule combines all available knowledge about the reproductive ecology and horticulture of a species including: optimum seed collection date; natural length of seed dormancy; how seed dormancy might be manipulated with

Fig. 4 Fertilizer application and watering practices in FORRU-CMU's research nursery

pre-sowing treatments or seed storage; length of time required from seed sowing to pricking out; length of standing down time required to grow saplings to a plantable size and how standing down time can be manipulated with fertilizer application and other treatments. A production schedule is a working document, which changes as more experience is gained from growing multiple batches of each species. Preparation of production schedules also enables identification of areas requiring further research and appropriate treatments to test in subsequent experiments.

An example of a seedling production schedule is provided in Fig. 5. This is the schedule for the fast-growing pioneer species, *Prunus cerasoides*, which fruits in April–May. Its seeds have short dormancy and seedlings grow rapidly during the rainy season, so that by December their roots have penetrated deep enough into the soil to supply the shoot with water during the high temperatures of the dry season. In the nursery, saplings which grow to a plantable size by December would have to be kept for a further 6 months before the next planting season (the following June) and would require root pruning to prevent them from out-growing their containers. In the nursery, the production schedule, therefore, involves storing the sun-dried pyrenes (i.e. seed enclosed within the woody fruit endocarp) at 5°C until January,

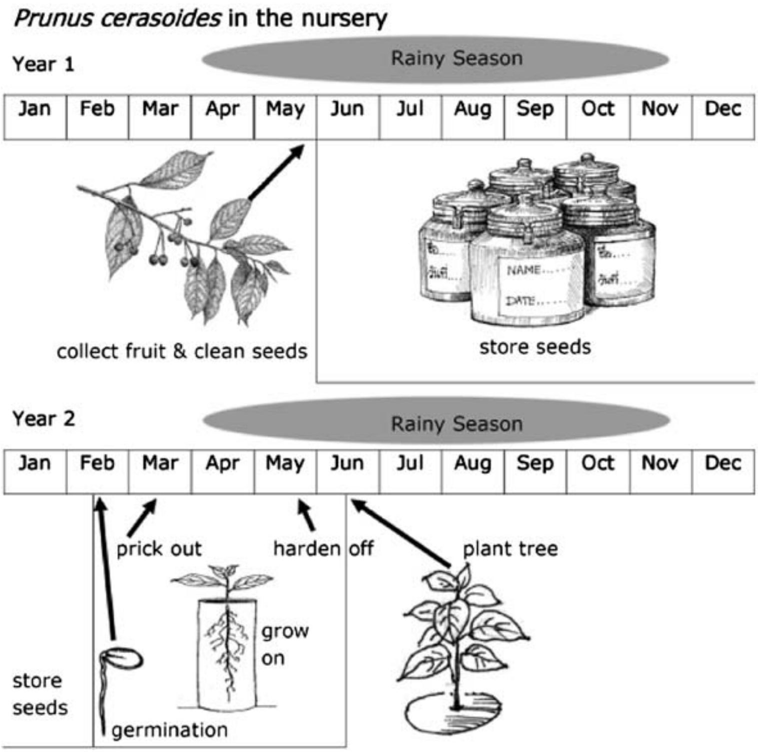

Fig. 5 Production schedule for *Prunus cerasoides* (artwork and design by Surat Plukam and Jenny Schabel)

when they are germinated (by cracking open the endocarp). Plants grow to the optimum size, just in time for hardening off and planting-out, in June. Development of this production schedule involved research on phenology, seed germination, seedling growth and seed storage.

Distribution of Trees

One of the main objectives of the nursery is to produce trees for field trials to determine which species satisfy the criteria of framework tree species outlined above. Since 1996, the nursery has provided more than 87,000 trees for field experiments covering about 28 ha. Trees are labelled, subjected to various silvicultural treatments and then monitored annually to determine survival and growth rates as well as attractiveness to seed-dispersing wildlife (for results see Elliott et al. 2003 and FORRU 2006). In addition, thousands of trees have been supplied to community groups, NGOs and to the RFD and other government organizations, to promote forest ecosystem restoration throughout northern Thailand.

Training Courses and Education Activities for School Groups

FORRU-CMU's research nursery is also used for training and education. Workshops and other education events are carried out for various target groups, including school children and their teachers, villagers and government officials. With sponsorship from the United Kingdom's Eden Project, FORRU-CMU has supported establishment of tree nurseries in 12 communities and provided training and technical support in four northern provinces. The aim is now to try to transfer the concepts and research techniques that have been developed by FORRU-CMU to other countries. Therefore, the nurseries and plot system have been used intensively to train foresters from China, Laos, Cambodia and Vietnam and the training texts produced by the unit ('How to Plant a Forest' and 'Research for Restoring Tropical Forest Ecosystems') have been translated into the languages of each of those countries. Consequently, plans have been written to replicate the work of FORRU-CMU in China, Laos and Cambodia, supported by the UK's Darwin Initiative, and to devise appropriate restoration techniques for the various forest ecosystems of those countries.

Motivation for Villagers to Restore Forests

Since tree planting takes land out of cropping, the question arises as to why local people should participate in the project. The area being planted is marginal land in the upper watershed, where access is difficult. The villagers had already decided to take this land out of agricultural production and to allow it to be replanted with forest trees to mark the Golden Jubilee of Thailand's monarch—His Majesty King Bhumibol Adulyadej—in the mid-1990s. Therefore, land conflicts were minimal.

Securing water supplies is a major motivation for this village with a history of water shortage. Villagers have no land tenure rights in the national park. Therefore, by becoming major participants in forest restoration, the villagers are strengthening their right to remain living in the park, by demonstrating to the authorities that they are responsible stewards of the environment. They have improved their relationship with the park and other local authorities and improved their public image, since the project has been featured in many news articles and several TV documentaries. Thus, they are helping to change the public image of hill tribe people from being forest destroyers to that of being forest protectors. More obvious utilitarian benefits, such as collection of forest products, are seen as less important, since the Hmong at Ban Mae Sa Mai are not heavily dependent on them for subsistence and collection of such products is illegal in a national park.

In summary, the primary incentives for the villagers to join the forest restoration project are (i) a more secure supply of water and (ii) a stronger position for the Hmong in Thai society.

Discussion

With large areas within Thailand's protected area network requiring restoration for biodiversity recovery, the question is: how can the concepts and methods, successfully developed by FORRU-CMU, be scaled up and applied to larger areas? Rather than planning large-scale restoration programs (which have been the standard approach of government agencies thus far), FORRU-CMU recommends simply replicating the small-scale work that the unit has pioneered, over many communities. Many small-scale projects, continuing over many years, would be more effective than a single, large-scale project implemented over a few years.

It is essential that local communities are involved right from the planning stage onwards, particularly in selecting which sites will be planted each year (to enable adjustments in agricultural areas to be gradual), and in assigning seed collection and nursery management responsibilities. Basing seed collection programs and community nurseries in villages generates a sense of community ownership of the project and thus reduces the risk that planted trees will be cut or burnt later. The forest authority should then buy trees from the villagers for planting events and thus generate a source of income for the villagers.

If villagers are the main source of labour for the project, the area planted each year should not be larger than can be weeded and maintained by the available labour force. Consequently annual planting events should be continued over the number of years required to completely cover the total area targeted for restoration. This has the advantage of creating a patchwork of restored plots, of many different ages, which is ideal for maximizing habitat diversity for wildlife, since some wildlife species prefer smaller trees with sparse cover, whilst others prefer larger trees providing dense cover. A single, large-scale planting event creates a more uniform, even-aged forest and may fail if the labour available is insufficient to carry out the frequent weeding and fertilizer application needed for the framework species method, in the first two rainy seasons after planting. The number of labourers required for weeding and fertilizer application averages about 20–25 per hectare. If the activity is declared a community activity, then each household usually provides one person per day of work. Hence, the maximum area that should be planted and maintained per year can be calculated by simply dividing the number of households in the community by 20–25.

The main problem with this approach to scaling up is the amount of training and education required to provide villagers with all the technical skills needed to collect seeds of the right species and grow trees to a suitable size and quality by the planting date. FORRU-CMU's education team of four persons has been stretched to provide training frequently enough and of a sufficiently high standard to service the needs of 12 community tree nurseries and associated planting projects, funded by the Eden Project, over three years. So scaling up, by replicating many community-based projects, would require a large number of trainers and educational activities.

Another problem is often the reluctance of national forestry agencies to hand over responsibility for tree production, as well as planting and maintenance of planted plots, to local villagers and provide them with adequate payment. However, local people, with local knowledge of the fruiting patterns of indigenous tree species, may be better equipped to grow the wide range of framework tree species needed for forest restoration, than staff of national forest agencies that tend to concentrate on mass production of a small number of commercial timber trees.

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