WHERE SCIENCE MEETS COMMUNITIES: DEVELOPING FOREST RESTORATION APPROACHES FOR NORTHERN THAILAND

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ABSTRACT

This paper contrasts lessons learned from two forest restoration research projects in Doi Suthep-Pui National Park, near Chiang Mai City, northern Thailand, which combined science with community needs. Collaborating with the Hmong community of Ban Mae Sa Mai (BMSM) in the upper Mae Sa Valley, Chiang Mai University's Forest Restoration Research Unit (FORRU-CMU) established plots from 1997 to 2013 to test the framework species method. The project developed successful restoration techniques and gained insights into the factors that influence villagers' participation in forest restoration. Biodiversity recovery and carbon accumulation exceeded expectations. Villagers appreciated improved water security and a better relationship with the park authority. Recently, however, tree chopping and a breakdown in fire-prevention measures (perhaps symptoms of "project fatigue") have threatened the sustainability of the plot system. Since 2015, the nearby Thai community of Ban Pong Khrai (BPK) has also embraced the framework species method, to restore the watershed above their village. FORRU-CMU provided technical support to LEAF (Lowering Emissions from Asia's Forests) to establish a model payments-for-ecosystem-services (PES) agreement between the community and Tipco Food PCL, whose Aura Water bottling plant depends on the integrity of the watershed to maintain water purity. Remarkably, the BPK villagers opted to forego payments for their labour in favour of funding a community nursery, to sell tree seedlings to the project in subsequent years. This project benefited from the support of a high profile multi-national project as well as the maturity of restoration techniques and community engagement protocols, previously developed by FORRU-CMU. These projects demonstrate the importance of a sound scientific basis for forest restoration projects, long-term institutional support and appropriate funding mechanisms, to achieve sustainability.

Keywords: forest restoration, framework species method, payments for ecosystem-services, PES

INTRODUCTION

In the early 1990s, just as we were establishing Chiang Mai University's Forest Restoration Research Unit (FORRU-CMU), the idea that damaged tropical forest ecosystems could actually be restored, to near their original condition, was little more than the pipedream of a few ecologists. Opposition to the concept came from unexpected sources. Many conservationists saw restoration as unnecessary competition for funds needed to secure remaining primary forest within protected areas. Several even felt that, if restoration were to become practicable, it might encourage a "destroy now – restore later" mentality that would allow developers to

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downplay the destructive environmental impacts of development projects. Some ecologists even regarded tropical forest restoration as a non-starter, because the intricate networks of species inter-relationships, typical of such ecosystems, were too complex to be reconstructed.

In stark contrast, two decades later we now find ourselves in the midst of what could be described as a global forest restoration frenzy, with the UN calling for the return of forests to 350 million hectares of degraded land by 2030—an area larger than India (UNITED NATIONS, 2014). Forest restoration is now regarded as complementary to protecting primary forests, and biological complexity often returns via natural mechanisms, once the recovery of ecosystem structure has been kick-started. The main reasons for this dramatic about-turn are: 1) global recognition of the role that forests play in mitigating climate change, 2) the creation of international funding mechanisms (e.g. REDD+[2]), 3) development of effective, scientifically-based restoration methods and 4) development of incentives and community engagement methods that build social acceptance of restoration projects (e.g. payments for ecosystem services PES [WUNDER, 2015]).

The science of tropical forest restoration has progressed considerably over the past few decades, creating greatly improved techniques that are capable of restoring diverse forest ecosystems to tropical sites at all stages of degradation (ELLIOTT *ET AL.*, 2013, Chapters 3 and 5) such as:1) protection and assisted natural regeneration (on moderately degraded sites) (SHONO *ET AL.*, 2007), 2) planting framework tree species, to boost incoming seed dispersal, where natural regeneration is insufficient (GOOSEM & TUCKER, 2013), 3) maximum diversity methods, where lack of natural seed dispersal limits recovery of tree species richness (e.g. GOOSEM & TUCKER, 2013) and 4) nurse plantations to improve soil conditions, where soil degradation precludes planting other species (SIDDIQUE *ET AL.*, 2008). Research on the design, size and placement of restoration plots has also progressed, showing that planting forest corridors (TUCKER & SIMONS, 2009) and applied nucleation (ZAHAWI *ET AL.*, 2013) maintain genetic diversity and catalyze widespread forest recovery, respectively, with minimal effort.

The realization that recovering tropical forest ecosystems can sequester huge quantities of atmospheric CO_2 (and thus help to mitigate global climate change) has resulted in the UN's REDD+ scheme. Originally conceived as a mechanism merely to reduce the rate at which CO_2 from forest destruction enters the atmosphere, the scheme was subsequently expanded to include "enhancement of carbon stocks" (UNITED NATIONS, 2007) i.e. removal of CO_2 from the atmosphere by forest expansion. This has created international funding mechanisms for restoration that were inconceivable in the 1990s, e.g. the Green Climate Fund, carbon credits etc. However, to qualify for REDD+, restoration projects must be carried out with the "full and effective engagement of … indigenous peoples and local communities". This means that restored forests must provide the same range of forest products and ecosystem services, as the original forest once did. Secondly, actions must be "consistent with the conservation of natural forests and biological diversity … and … incentivize the protection and conservation of natural forests and their ecosystem services and enhance other social and environmental benefits" (UNITED NATIONS, 2010, safeguards [d] and [e]). Neither of these conditions is achieved by conventional plantations of fast-growing tree species. Consequently, forest restoration must recreate the "look and feel" of primary forest ecosystems with the maximum biomass, structural complexity, biodiversity and ecological functioning that are sustainable, within the limits imposed by the climate and soil.

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[2] Reducing Emissions from Deforestation and Forest Degradation in developing countries, including conservation, sustainable management and enhancement of carbon stocks – policies and incentives, developed under the UN Framework Convention on Climate Change (UNFCCC).

This approach also demands effective community engagement and the provision of appropriate incentives. Although FORRU-CMU is a scientific and technical research unit, we inevitably had to engage with local communities, as soon as we began to establish field trials, in and around the densely populated Doi Suthep-Pui National Park in northern Thailand. This involved developing negotiation skills and sharing both scientific and indigenous knowledge among villagers and scientists. Over the years, these activities provided FORRU-CMU with observational insights into how to combine both the scientific and socio-economic aspects of forest restoration; a process that varies considerably, with ethnic group, cultural background, economic status and previous experiences of the communities involved. Therefore, here, we share our experiences, both positive and negative, from working with two neighbouring, but very different, communities in upland northern Thailand.

STUDY SITES

Ban Mae Sa Mai[3] (BMSM) and Ban Pong Khrai (BPK) are both located in the upper Mae Sa Valley, in or beside Doi Suthep-Pui National Park (DSPNP) (see Fig. 1). An overview of the two communities is provided in Table 1.

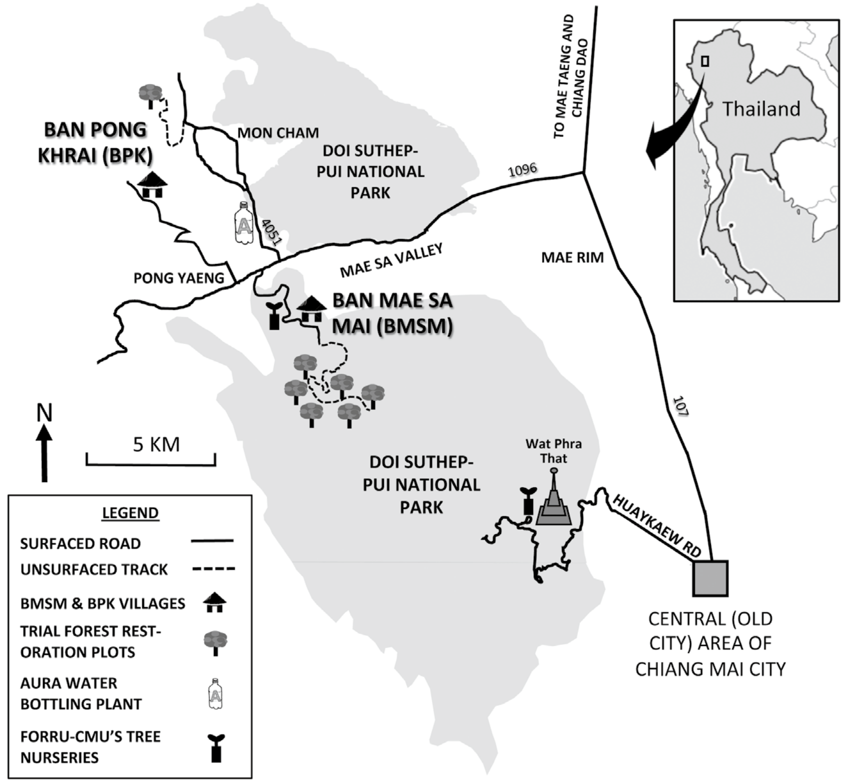

Figure 1. Map showing location and access to the study sites.

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[3] Ban = village. BMSM has since been split into two administrative units, one of which retains the original name, whilst the other is Ban Mae Sa Noi. Noi = little.

Table 1. Basic community information

	Ban Mae Sa Mai	Ban Pong Khrai
Ethnic group	Hmong	Northern Thai
Population	1,800[a]	463
Main income sources	Agriculture, selling handicrafts, Queen Sirikit Botanical Gardens	Tourism, agriculture, Aura Water
Village location	18°52′07.24″N 98°51′08.47″E	18° 54′51.93″N 98°48′12.53″E
Village elevation (m)	1018	1018
Plots locations	18°51′46.62″N 98°50′58.81″E	18°55′50.04″N 98°48′22.12″E
Plots elevation (m)	1200–1325	1400
Original forest type[b]	Evergreen	Evergreen
Protected status	Village & plots inside national park	Village & plots just outside national park
Project started	1996	2015

[a] BMSM and Ban Mae Sa Noi combined (at the start of the project).
[b] Using the forest classification system of MAXWELL & ELLIOTT (2001)

DEVELOPING EFFECTIVE RESTORATION PRACTICES

Like most of upland northern Thailand (>1000 m altitude), the Upper Mae Sa Valley is characterized by formerly evergreen forest land, at stage-3 degradation (*sensu* ELLIOTT *ET AL*., 2013, Chapter 3). Such areas are dominated by herbaceous weeds that suppress natural regenerants[4]. The latter are present at densities too sparse to close canopy within two years (i.e. <3,100/ha). Seeds of most forest tree species continue to be dispersed into the restoration sites, because both seed sources (i.e. nearby remnant trees and forest patches) and viable populations of seed-dispersing birds and mammals remain in the surrounding landscape (most evergreen forest tree species are animal-dispersed). Restoring forest ecosystems to stage-3 degraded landscapes requires a combination of 1) protection (e.g. fire prevention), to eliminate the factors that originally caused or perpetuate the degradation, 2) assisted natural regeneration (SHONO *ET AL*., 2007) to ensure the survival of remaining natural regenerants and accelerate their growth (e.g. weeding and fertilizer application), and 3) complementary tree-planting to increase overall stocking density to at least 3,100 per hectare – the level required to initiate canopy closure within two years.

Upland evergreen forest in the study area comprises at least 340 tree/treelet species (FOREST RESTORATION RESEARCH UNIT, 2005). It is not necessary to grow and plant them all, since many species can re-colonize deforested sites via natural seed dispersal from nearby remnant forest patches. So, the question becomes: which species should be planted to re-initiate and accelerate natural mechanisms of forest succession?

[4] Includes remnant mature seed trees, live tree stumps capable of coppicing, tree saplings and tree seedlings, taller than 50 cm.

In 1997, FORRU-CMU began developing a "framework species" approach, after having studied the concept in Australia where it was first conceived (GOOSEM & TUCKER, 2013). The framework species method involves planting 20–30 tree species to rapidly restore forest structure and function, whilst animals, attracted to the planted trees, disperse the seeds of many other tree species into the restoration site. Framework tree species are selected from amongst the indigenous forest tree flora. They are native, non-domesticated forest tree species with high survival and growth rates when planted out into exposed, weedy deforested sites. They have dense, broad crowns, which shade out herbaceous weeds and are thus capable of bringing about rapid site recapture[5]. Framework tree species also produce fleshy fruits, nectar-rich flowers or other resources, which attract seed-dispersing animals, particularly frugivorous birds and bats. The planted trees, therefore, act as "bait", enticing such animals to drop seeds from nearby forest trees into the restoration sites. Mixtures of framework tree species should include both pioneer and climax species. Crowns of the fast-growing, light-loving, pioneer trees form an upper canopy and attract seed-dispersers at an early age, whilst those of slower-growing, shade-tolerant, climax tree species form an understory, ready to replace the pioneers, as the latter begin to die (around 15–30 years after planting). Amongst the ground flora, seedlings of many non-planted forest tree species establish from the seeds brought in by birds and mammals. Thus, the mechanisms of natural forest succession are re-established (FOREST RESTORATION RESEARCH UNIT, 2005). FORRU-CMU's initial research program focused on identifying, propagating and trialing framework tree species for restoring evergreen forest above 1000 m altitude, since such forest has the highest conservation value, compared with the region's other forest types (MAXWELL & ELLIOTT, 2001).

The herbarium collection and database of the local tree flora, established by J. F. Maxwell at CMU Biology Department Herbarium (MAXWELL & ELLIOTT, 2001), provided an invaluable species identification service, as well as information about species' distributions for most evergreen forest tree species. FORRU-CMU established a research nursery at 1000 m altitude in the former headquarters compound of the national park. We first studied the reproductive phenology of forest trees, by tagging 5–10 individuals of each of 100 identified species, along paths from the unit's tree nursery through undisturbed evergreen forest. Observations of flowering and fruiting trees at 3-weekly intervals over five years, determined optimal seed collection times and provided seed-collection opportunities.

In the nursery, a wide range of experiments determined the optimal methods to grow hundreds of tree species for testing in field trials. The aim was to produce containerized trees of a suitable size for planting (30–50 cm tall) by the optimum planting time (the start of the rainy season, mid-June), despite large differences among the species in fruiting periods, length of seed dormancy and seedling growth rates (BLAKESLEY *ET AL.*, 2002). The research included germination trials, testing various techniques to break dormancy (SINGPETCH, 2002), seed storage experiments and seedling growth trials (testing various media, containers and fertilizer regimes) (ZANGKUM, 1998; JITLAM, 2001). CMU research students tackled more detailed options for planting stock production, such as propagation from cuttings (VONGKAMJAN *ET AL.*, 2002), the growing-on of wildlings (KUARAK, 2002) and the application of mycorrhizal fungi (NANDAKWANG *ET AL.*, 2008). This resulted in "production schedules", detailing the most efficient treatments and timings required to produce healthy, vigorous planting stock, of each tree species, by the optimal planting time.

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[5] The point at which planted trees overcome competition with herbaceous weeds, and canopy closure becomes inevitable.

Every rainy season from 1996 to 2013, experimental plots, ranging in size from 1.4 to 3.2 ha/y were planted with various combinations of 20–30 candidate framework tree species, in collaboration with the Hmong community of BMSM, in Doi Suthep-Pui National Park at about 1300 m altitude. The objectives of these plots were to 1) assess the potential of the planted tree species to perform as framework species, 2) test the responses of the trees to various silvicultural treatments, and 3) determine the rates of recovery of biodiversity and carbon storage compared with non-planted control plots and natural remnant forest. Before tree-planting, plots were cleared of weeds by slashing and spraying with glyphosate, taking care not to damage any existing natural regenerants. Trees were planted randomly across the plots, averaging 1.8 m apart (or the same distance from a natural regenerant). Various fertilizer, mulching and weeding regimes were tested during the first two rainy seasons after planting. Fire breaks were cut every January and fire prevention patrols worked throughout the dry season.

Samples of the planted trees were labeled and monitored two weeks after planting and at the end of each subsequent rainy season. Surveys of naturally established trees and birds were also carried out before planting and at various intervals thereafter in the planted plots, non-planted controls and remnant forest.

The main technical achievement of all this work has been an effective procedure to rapidly restore evergreen forest ecosystems to stage-3 degraded uplands (Fig. 2). Best-performing framework tree species have been identified (ELLIOTT *ET AL.*, 2003) and optimal silvicultural treatments identified, to maximize survival and growth rates after planting (ELLIOTT *ET AL.*, 2000). With those species and treatments, canopy closure can now be achieved routinely within 2–3 years after tree-planting and biodiversity recovery is rapid. The species richness of the bird community increased from about 30 before planting, to 88 after six years, representing about 54% of bird species recorded in nearby mature forest (TOKTANG, 2005), and the birds brought in tree seeds. SINHASENI (2008) reported 73 species of non-planted trees re-colonized the plot system within 8–9 years, most having germinated from seeds dispersed from nearby forest by birds (particularly bulbuls), fruit bats and civets. The species richness of mycorrhizal fungi and lichens also increased dramatically, often exceeding that of natural forest (NANDAKWANG *ET AL.*, 2008; PHONGCHIEWBOON, 2008, respectively). Most recently, KAVINCHAN *ET AL.* (2015a and b) and JANTAWONG *ET AL.* (2017) demonstrated remarkably rapid recovery of ecosystem carbon dynamics. Net inputs of carbon into the soil from litterfall, overall accumulation of soil organic carbon and accumulation of above-ground carbon in the trees return to levels that are typical of old-growth natural forest within 14–16, 21.5 and 16 years, respectively.

Just over 20 years ago, lack of knowledge, about how to propagate, plant and care for native forest tree species, was one of the most often-quoted constraints to the success of tropical forest restoration. FORRU-CMU's work has largely removed this constraint, at least for upland evergreen forests in northern Thailand. Our research has established 1) which species to plant, 2) optimum seed collection times, 3) optimum treatments for seed storage and germination, 4) time and treatments needed to grow saplings to optimum size by the optimum planting time, 5) optimum planting techniques and spacing, 6) optimum fertilizer application and weeding methods and frequency, 7) how fast biodiversity returns, and 8) how much carbon forest restoration can sequester (ELLIOTT *ET AL.*, 2013).

CONNECTING WITH A COMMUNITY: ECOLOGISTS LEARN SOCIAL SCIENCE

Trial plot establishment was the point at which we, as scientists, had to develop social science skills since, in a heavily populated park, the only sites available for forest restoration are on abandoned (or fallow) agricultural land. Consequently, for forest restoration to be successful, the local community must agree with, and actively collaborate in, tree planting and aftercare to encourage a sense of stewardship over the resulting forest. In 1996, the national park authority recommended that we work with the Hmong community of BMSM, above which lay about 100 ha of deforested and degraded land, much of it uncultivated. BMSM is the largest Hmong community in northern Thailand. The village was originally founded at 1300 m altitude, but was moved down to its present location in 1967, after deforestation caused the water supply to dry up (according to village elders). Construction of a government-funded school at the new site discouraged further movement. However, the relocation event left the villagers with a strong sense of the link between deforestation and watershed services.

In 1981, the village and surrounding farmland were included within the boundaries of the newly declared Doi Suthep-Pui National Park. This meant that the villagers faced a legal threat of eviction, since under Section 16 of the National Park Act (proclaimed in 1961): "Within the national park, no person shall: (1) hold or possess land, or clear or burn the forest;" and the villagers had no land-ownership titles. To avoid possible enforcement of this law, a few villagers formed the "The Ban Mae Sa Mai Natural Resources Conservation Group" in the early 1990s, to demonstrate to the authorities that they were responsible custodians of the environment. They declared a remnant of degraded primary forest above the village as their community forest, because it protected three springs that supplied water to the village and the agricultural land below it. They also formulated a system of self-imposed penalties to deter tree-felling and hunting in the community forest. Furthermore, in 1996 the villagers decided to contribute to a national project to celebrate His Majesty King Bhumibol Adulyadej's Golden Jubilee, which aimed to restore forest to more than 8,000 km^2 of deforested land nationwide. They agreed to phase out crop cultivation on 50 ha of the upper watershed and reforest the area, whilst intensifying agriculture on the more fertile lower valley by installing an irrigation system. The Royal Forest Department provided them with eucalyptus and pine trees to reforest the watershed, but the villagers were disappointed with the limited species choice and poor results.

When FORRU-CMU approached the village Conservation Group in 1996, to discuss planting framework species trial plots, they readily agreed, recognizing an opportunity to improve their previously unsuccessful efforts to reforest the 50-ha watershed area, which they had already decided to contribute to the Golden Jubilee Project. This partnership provided FORRU-CMU with three important resources: 1) indigenous knowledge, 2) an opportunity to test the practicability of research results with local people and 3) a supply of local labour. In addition to the environmental benefits of restoration, the partnership provided the BMSM community with 1) technical expertise, 2) funding and 3) positive publicity, which helped to transform the public image of the Hmong, at that time, from forest destroyers to forest saviours. The villagers provided information on which tree species colonize abandoned fields, which are attractive to wildlife and which seed-dispersing animals survived in the valley. Discussions revealed that they had traditional uses for nearly all the candidate framework tree species proposed for planting.

Observing the success of an initial tree planting event in 1996, the villagers asked FORRU-CMU to sponsor construction of a community tree nursery on the edge of the village, so that funding for planting stock production flowed through the village economy. We agreed and trained villagers in basic tree propagation methods and nursery management. Since then, FORRU-CMU has continued to employ villagers fulltime to collect seeds and grow about 20,000 trees per year (salaries currently sponsored by the Rajapruek Institute Foundation) and also pays them target-related bonuses. In 2006, when one of the villagers reclaimed the nursery site for house construction, a bigger and better nursery was built on the main access road north of the village, on a site donated by the watershed office, sponsored by World Wildlife Fund and King Power Duty Free.

Villagers provided their labour for all aspects of the project, from nursery work to planting, maintenance and monitoring of the planted trees, as well as fire prevention. The village committee declared tree-planting to be a community activity, which meant that every household in the village was obliged to send one family member to join the work (or pay a fine of 150 THB to the community fund). At the end of each planting event, FORRU-CMU presented a donation to the village community development fund. These donations were mostly used to improve the water system and roads in the village.

Following devastating fires in 1998, fire prevention was also declared to be a community activity. The villagers cut fire breaks in mid-January (at the start of the hot-dry season) and from then until mid-April (the start of the rainy season), fire prevention teams of 16 persons manned a fire station in the upper watershed, 24 hours a day, to detect any fires approaching the area and extinguish them. Each household provided one family member every 11 days to join this activity. At the start of each fire season, an animistic ceremony was held, to ask the village guardian spirit for successful fire prevention. If fires did not burn the planted plots, a pig was sacrificed at the end of the fire season to thank the spirit. This provided a social event, at which the villagers, FORRU-CMU staff and national park officers could meet informally, strengthen their partnership and plan where to plant trees next. FORRU-CMU paid for labour to cut the fire breaks, meals for the fire prevention teams and for the pig. The village committee organized teams to weed around the planted trees and apply fertilizer. FORRU-CMU paid regular daily labour rates to those who did the work. This combination of payments and voluntary inputs increased support for the project at the community level. Frequent meetings were held with the villagers, to share project tasks and particularly to decide on the positioning of the plots so as not to conflict with existing land use. In addition, the head of the family, appointed to take care of the nursery and founding member of the Conservation Group, Mr. Naeng Siwapattarapong, acted as the main liaison, relaying information between FORRU-CMU staff and the village committee. As outside interest in the project grew, villagers also became involved in presenting the project to visitors and to the media, thus helping to build a positive public image of the community.

From September 2005 to February 2007, structured interviews, with more than 70 community members, revealed that villagers valued the social impacts of the project the most, followed by watershed services. About 80% of respondents said that the project had helped to reduce internal social conflicts over natural resource shortages and improved relationships between the community and authorities. Villagers also highly appreciated that the project had improved their public image. Most interviewees also stated that they had noticed an improvement in water quality, reduced soil erosion, less clogging of water pipes with silt and an increase in the reliability of the water supply during the dry season. A majority recognized that forest restoration had contributed to increased production of forest products, such as bamboo shoots and canes, banana leaves and flowers and wild vegetables and mushrooms, but such products contributed only a small amount towards household economies. Villagers also recognized that the project had boosted eco-tourism in the village, but the revenue from it benefitted only a few families. In general, therefore, most villagers valued intangible benefits from the project more highly than monetary inputs.

However, in recent years, both the numbers and the aspirations of the villagers have grown, increasing pressure on the underutilized and now heavily reforested upper watershed. Members of the Conservation Group are no longer prominent on the village committee and the current village chief is not as favourable towards conservation as his predecessors were. The threat of eviction from the national park has diminished, as the park authority now has a long history of not enforcing national park laws—even degazetting parts of the park that become developed, rather than evicting developers and restoring forest.

FORRU-CMU planted its last experimental plots at BMSM in 2013, because labour to clear a site for planting in 2014 was not forthcoming, despite having secured a generous sponsor for the work. The focus of our research has shifted to long-term studies of biodiversity recovery and carbon accumulation in the existing plots, since the plot system at BMSM spans such a wide range of ages (plots planted annually from 1997 to 2013). However, such studies are now threatened, due to increased disturbance. Since 2010, tree chopping began to change the forest structure of some plots. The system of fines previously imposed by the village committee to deter tree chopping is now clearly inoperative (Fig. 3).

Furthermore, the formerly well-managed fire prevention system has weakened. Fire breaks are cut too late and fire patrol teams no longer man look-out posts in the upper watershed. Consequently, fires in 2015 and 2016 ravaged about 30% of the plots. In 2012, one plot (planted 2009) was cleared to grow cabbages, despite the village committee having selected it for forest restoration just three years previously (Fig. 5A). Such disturbances greatly diminish the scientific value of a chronosequence of restoration plots, planted with trees of known species and ages annually over 16 years (although they also open up opportunities to study the effects of disturbance).

However, the situation is not entirely one of deterioration. In 2014–16, the villagers organized their own tree-planting events and in early 2018, they organized a major public event to renew their commitment to fire prevention and raise awareness and support for it among the wider Hmong community (12 villages in all). The balance in the community between those for or against restoration now appears to be in a state of flux. Part of the problem may be that some of the villagers may no longer be satisfied with the intangible social and environmental benefits of restoration, which a majority stated as their primary motivation 10 years ago. It may be that, to prevent restored forests from suffering the same fate as the original forest, intangible benefits must be converted into monetary benefits.

PAYMENTS FOR ECOSYSTEM SERVICES (PES)

Under PES schemes, users of an ecosystem service (e.g. water consumers) pay those who maintain or improve it (e.g. tree planters who restore watersheds), effectively monetarizing some of the less tangible benefits of forest restoration (Wunder, 2015). In 2015, LEAF

(Lowering Emissions from Asian Forests[6]) invited FORRU-CMU to provide technical support for a model PES scheme, involving the villagers of Ban Pong Khrai (BPK, service provider) and Tipco Foods PCL (service consumer).

Tipco draws mineral water from the Pong Khrai sub-watershed (part of the same Mae Sa watershed within which BMSM is located) for bottling under the Aura brand. Therefore, the company was willing to invest in maintaining the integrity of the watershed, upon which the purity of its product depended. They agreed to invest 200,000 THB (34 THB to the US$ at time of writing) to restore 10 rai (6.25 rai = 1 ha) of forest in the first year and, if successful, to repeat this annually for 10 years.

BPK lies just a few kilometres north of BMSM, yet our experience of working with the Thai community there differed greatly from that of working with the Hmong community of BMSM. BPK is a much smaller community than BMSM is (Table 1) and it is less dependent on agriculture for income. Many of the BPK villagers work at the Aura Water plant and the Flying Squirrel Zip Line. The latter is an eco-tourism venture that depends on maintenance of an intact forest ecosystem, from which every family in the village receives an annual bonus payment. Hence the villagers already had experience of being paid to protect a forest for an environmental service, in this case eco-tourism. The BPK villagers also had a political point to make. About 20–30 years previously, Hmong cabbage-growers had encroached onto some of their communal land. Having successfully evicted the invaders (about 10 years previously), the villagers wanted to deter re-incursions by re-asserting their territorial claim. Since most of the land was not needed for agriculture, a high-profile reforestation project was an obvious option.

Once LEAF had facilitated agreement for the project from Tipco and BPK, FORRU-CMU's first task was to train the villagers to carry out a rapid assessment of the density of natural regenerants in the planting site and to determine both the number and the species of trees to plant to bring about forest canopy closure in 2–3 years. We used a simple survey method, developed at BMSM, based on circular sample plots of 5 m radius (ELLIOTT *ET AL.*, 2013, Chapter 3). The following day, we facilitated a meeting with the villagers, LEAF and Tipco, to calculate the budget needed to plant, maintain and monitor the required number of trees. Having analyzed the rapid assessment data overnight, we presented the results to the meeting and then invited all participants to collaborate on completing a detailed cost-calculation spreadsheet. This "collaborative costing" process combined data from the rapid site assessment (numbers of trees to be planted and natural regenerants to be maintained, plot size and distance from nursery/village etc.) with the villagers' knowledge of local prices (for labor, materials, transport etc.) to cost each project task (site preparation, planting, maintenance, fire prevention, monitoring, training, supervision, accounting and reporting). The comprehensive structure of the spreadsheet was based on FORRU-CMU's many years of experience of costing tree-planting at BMSM. Completing the spreadsheet created a consensus on costs among all the stakeholders and removed any possibility of price gouging. However, this resulted in a bottom line of 230,000 THB for 10 rai (for planting, maintenance and monitoring over two years), which was 30,000 THB more than the limit that the donor was willing to spend. The villagers were then asked to consider three options 1) ask the donor to pay more, 2) reduce the area to be restored or 3) reduce costs. Surprisingly, they elected to reduce costs, by volunteering their labor. Impressed with such generosity, the planting stock supplier (the

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[6] A USAID-funded initiative to reduce forestry-related emissions of greenhouse gases, implemented across SE Asian countries by Winrock International, 2011–2015.

Figure 2. Forest restoration using the framework species method has transformed the landscape of the upper Mae Sa Valley. A, April 1998: fire ravaged the area. B, The bend in the track (yellow arrows) is now over-arched with forest planted in 2001 (left side) and 2007 (right side) (photographed September 2016). The crown of a large tree, which survived the 1998 fires, circled in red serves as a reference point. Photographs by Stephen Elliott.

Figure 3. A desolate site in the upper Mae Sa Valley (A) was planted with framework tree species in 2000. Twelve years later (B) a structurally complex forest with high biodiversity was restored. But tree-chopping by villagers opened the canopy, allowing fire to destroy the understorey and kill many of the adult trees in 2016 (C). Two rainy seasons after the fire, dead standing trees dominate the plot and the understorey has been replaced with invasive herbaceous weeds and banana plants (D). Photographs by Stephen Elliott.

BMSM nursery) reduced the price of saplings by 20% below actual production costs (also contributing to the project "in kind"). This reduced total cash costs to 170,000 THB, freeing up a 30,000 THB underspend. The villagers then opted to invest this in establishing their own tree nursery. Having just learnt about sapling production costs (during the spreadsheet session) and having a potential buyer for 10 years (if Tipco continued with the project), they immediately recognized an opportunity to divert more of the project funding through the village economy in subsequent years. LEAF then offered to hire FORRU-CMU to run a workshop for the villagers in nursery management and tree propagation. Therefore, during the spreadsheet costing process, the villagers effectively agreed to forego payments to individuals (for labor), in favor of investing in a community venture with potential to generate income over many years subsequently, but at some risk (i.e. if TIPCO decided *not* to continue with the project after the first year).

The first tree-planting event went well. Villagers maintained and monitored the trees enthusiastically, even though they had voluntarily foregone payments to do so. By the end of the second rainy season, the performance of most of the planted tree species exceeded that of the same species that had been planted at BMSM, perhaps reflecting improved techniques of planting stock production, planting and aftercare that had been developed over the years (Fig. 4).

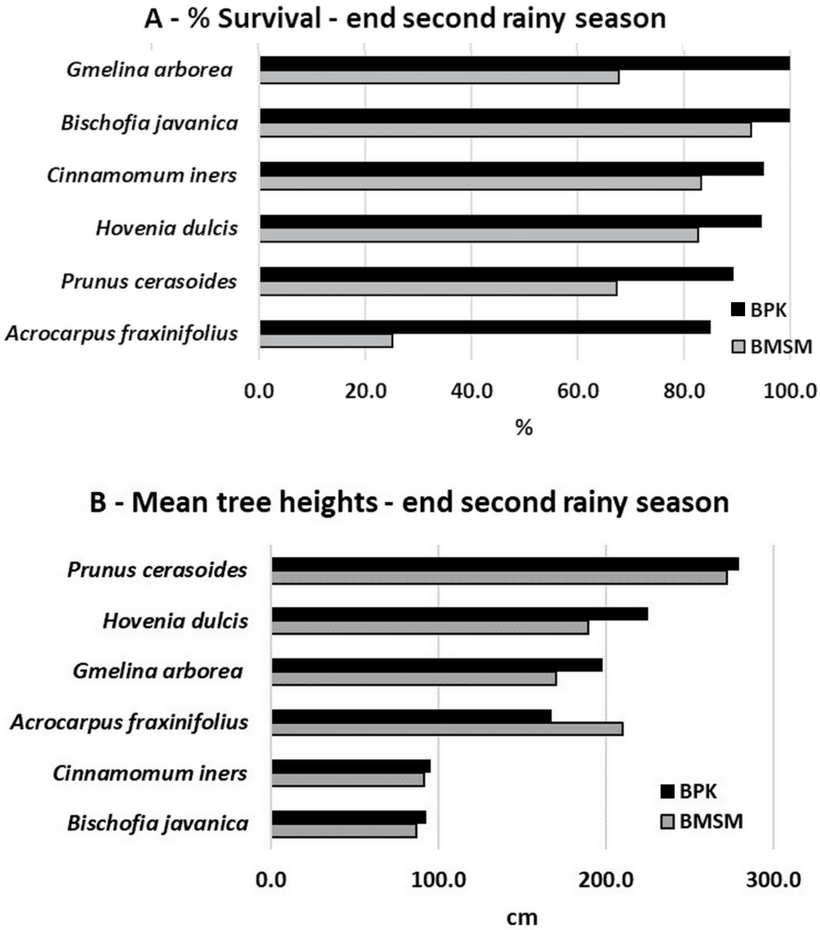

Figure 4. Mean tree survival (A) and growth (B) compared between the BMSM and BPK sites, for species that were planted at both sites. The BMSM data are averaged across plots planted in 1998 and 1999. The BPK data are for trees planted in 2015. Saplings were 30–50 cm tall when planted.

Tipco agreed to fund a further 10 rai in 2016 and, as news of the project spread, other sponsors got involved. In 2016, PUR Projet[7] offered to sponsor an additional 10 rai and the villagers agreed. So, the 2016 plots were expanded to 20 rai. However, since maintenance and monitoring goes on for two years, the villagers then had to tend 30 rai in 2016 and began to realize that they may have overstretched their small community's labor supply. Consequently, they did not plant any trees in 2017. However, planting resumed in 2018 with sponsorship from Aura Water, so continuity and sustainability of the PES relationship appears to be holding for now.

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[7] PUR Projet is a French social business that promotes livelihoods and regenerates ecosystems.

Figure 5. A, At BMSM, a student holds the remains of the 2009 plot sign. Immediately behind him, a few of the planted trees survived, but most of the plot in the background was converted into a cabbage field by 2016, perhaps reflecting waning commitment of villagers ("project fatigue"), as the project enters its 21st year. B, In contrast, the BPK villagers maintained trees, planted in 2015, well. After 15 months, most of the trees had grown taller than 2 m, reflecting enthusiasm at the start of a project. Photographs by Stephen Elliott.

CONCLUSIONS

The two projects shared several similarities. Both used forest restoration partly to make political statements. At the larger Hmong community of BMSM, an ethnic minority used restoration to demonstrate their patriotism, whilst deflecting regulatory pressure from the national park authority. At the smaller Thai community of BPK, restoration was used to re-affirm a territorial claim. Water was also a common key motivating factor; at BMSM to secure irrigation for agriculture, and at BPK as an environmental service to generate funding. Eco-tourism played a role at both communities, although revenue from it was more evenly spread among the households at BPK than at BMSM. Voluntary labor was willingly provided by both communities, following the tradition of "community activities" amongst the Hmong at BMSM and being seen as essential to generate investment in a community-wide benefit at BPK (the tree nursery). Lastly, early during project development, both communities recognized that establishing a community tree nursery and growing saplings themselves would divert more project funding into their village economies.

Although, restoration of the sub-watershed above BMSM undoubtedly transformed the landscape (Fig. 2), "project fatigue" now threatens its long-term sustainability. Despite FORRU-CMU having continuously provided the community with financial and technical support over more than two decades and developed inclusive methods of collaboration, even such intensive inputs have not been enough to deter some villagers from damaging the plot system (Figs. 3, 5A), despite the project having originated from within the community itself. The PES model offers hope that such a negative outcome may not be inevitable (Fig. 5B), by converting intangible benefits into long-term funding from private-sector companies with a vested interest in sustained restoration. However, such opportunities to link businesses with forest restoration are limited and not all restoration sites can generate income from eco-tourism or water.

Whether restoration projects succumb to the ever-increasing demands of a growing human population or are sustained by innovative funding mechanisms (e.g. PES), could determine the ultimate success of the UN's call to reforest 350 million hectares around the world by 2030 (United Nations, 2014).

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