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The Science and Sociology of Restoring Asia's Tropical Forest Ecosystems

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Abstract

Thirty years ago, reforestation in the tropics meant planting monocultures of economic trees. Ecosystem restoration was rarely practised, due to lack of effective techniques. Since then, ecologists have devised ways to: i) assist natural forest regeneration (ANR), ii) plant the right trees in the right places and iii) ameliorate soils on severely degraded sites. Such techniques can maximize recovery of i) biomass, ii) structural complexity, iii) biodiversity and iv) ecological functioning on sites at all stages of degradation. Forest restoration has now become a global priority, with the UN calling for restoration of 350 million hectares by 2030 (the Bonn Challenge). However most of the area pledged to the initiative will become monoculture plantations (45%) or agroforests (21%), even though ecological restoration sequesters 40 and 6 times more carbon respectively and supports far higher biodiversity. Whilst scientists have overcome the technical barriers to restoration, social "scientists" have yet to develop effective tools to overcome the socio-economic barriers, such as poor governance, inadequate stakeholder motivation and ineffective funding mechanisms and science-policy interface. Scientists have delivered the technical tools for restoration – now the social scientists, economists and politicians must deliver the socio-economic tools.

Keywords: Tropical Forest Restoration, Community Forestry, REDD+

1. Introduction

Thirty years ago, tropical reforestation mostly involved establishing monoculture tree plantations, often of exotic economic species (particularly *Eucalyptus* species) on degraded land, even within protected areas. Such plantations provide poor wildlife habitat, have relatively low carbon sequestration capacity (Lewis *et al*, 2019) and often fail to prevent soil erosion and landslides. The idea of restoring tropical forest ecosystems, with biomass, structure, biodiversity and ecological functioning similar to those of the original native forest was often regarded as naïve idealism. Even some conservationists were against the idea. They considered that the development of restoration techniques would divert attention and funding from the priority of protecting remaining primary tropical forest. Several ecologists regarded tropical forests as far too complex to be reconstructed and thought that research on restoration was a waste of time. They also pointed out that techniques to propagate, plant and maintain the thousands of tree species that comprise tropical forest ecosystems were largely unknown, as only a few tropical tree species had been massproduced in nurseries at that time (mostly commercial plantation species).

2. Research for Restoring Evergreen Forest in Northern Thailand

Chiang Mai University's Forest Restoration Research Unit (FORRU-CMU) was established to address this last issue in 1994. We started by developing techniques to restore upland evergreen forest in northern Thailand. The herbarium collection and plant database, established by J. F. Maxwell at CMU's Biology Department Herbarium (Maxwell & Elliott, 2001), enabled us to identify the tree species we worked on and provided distribution data. A phenology study of evergreen forest tree species *in situ* in Doi Suthep-Pui National Park determined optimum seed collection times with observations of flowering and fruiting trees at 3-week intervals over 5 years. In a research nursery in the former national park HQ compound at 1,000 m elevation, experiments determined the optimal methods to grow hundreds of tree species for testing in field trials. The nursery research resulted in production schedules, detailing the most efficient treatments and timings required to produce healthy, vigorous trees (30–50 cm tall) of each species, by the optimal planting time (mid-June in northern Thailand), despite large differences among species in fruiting periods, length of seed dormancy and seedling growth rates (Blakesley *et al.*, 2002). The research included germination trials to test 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).

Every rainy season from 1996 to 2013, experimental plots (1.4 to 3.2 ha/y) were established on degraded land at about 1,300 m elevation in the upper Mae Sa Valley to discover which trees indigenous to evergreen forest acted as "framework species" i.e. had high rates of survival and growth, dense crowns that shade out weeds and produced resources (e.g. fleshy fruit) that attract seed-dispersing animals early in life. Combinations of 20–30 candidate framework tree species were planted, in collaboration with the Hmong community of Ban Mae Sa Mai (BMSM). The objectives of these field trials were to i) compare how well the candidate species performed as framework species, ii) determine the silvicultural treatments that boost performance, and iii) determine 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 existing natural regenerants. Trees were planted randomly and subjected to various fertilizer, mulching & weeding treatments. A spacing experiment revealed that 1.8 m between trees was optimal (Sinhaseni, 2008). Fire breaks were cut every January and fire prevention patrols worked throughout the dry season. Samples of every tree species were monitored after planting and at the end of subsequent rainy seasons. Biodiversity surveys were also carried out, before planting and at various intervals thereafter in planted plots, non-planted controls and remnant forest.

The main achievement of this work was an effective procedure to rapidly restore evergreen forest ecosystems to degraded upland sites. Best-performing framework tree species (Elliott *et al.*, 2003) and optimal silvicultural treatments were determined, to maximize tree survival and growth rates after planting (Elliott *et al.*, 2000). Canopy closure can now be achieved routinely 2–3 years after planting and biodiversity recovery is rapid. The species richness of the bird community increased from about 30 before planting, to 88 after 6 years, representing about 54% of bird species recorded in nearby mature forest (Toktang, 2005); and the birds brought in tree seeds. Sinhaseni (2008) reported that 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, fruit bats and civets. More recently, Kavinchan *et al.* (2015) and Jantawong *et al.* (2017) demonstrated 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 returned to levels, typical of old-growth natural forest, within 14–16, 21.5 and 16 years, respectively.

Although, the science of restoration is now well understood, its implementation is hindered by the remote locations of restoration sites and high labour requirements. Consequently, FORRU-CMU is now researching the use of drones to carry out some restoration tasks such as i) locating seed trees, ii) aerial seeding (as an alternative to tree-planting) and iii) monitoring restoration progress.

3. Upsurge in Restoration Science

In contrast to 30 years ago, restoration science has now become a respected field of study. Research by many scientists, has greatly improved methods of restoration planning, site assessment, species selection, seed collection and genetic conservation, tree propagation, planting and direct seeding, as well as maintenance of planted trees (weeding and fertilizer application regimes etc.) and monitoring forest recovery, from canopy closure to carbon storage and biodiversity recovery (Mansourian *et al*., 2005; Lamb, 2011; Elliott *et al*., 2013; Bozzano *et al*., 2014).

Such research has enabled ecologists to devise reliable procedures, to restore diverse forest ecosystems on sites at all stages of degradation (Lamb, 2011) from simple protective measures (Chazdon, 2014) and assisted (or accelerated) natural regeneration, on moderately degraded sites (Shono *et al*., 2007), to the framework species method and maximum diversity methods of Goosem & Tucker (2013), where natural regeneration is lacking; and nurse-tree plantations, to improve the soil on severely degraded sites (Siddique *et al*., 2008). The design, size and placement of restoration sites have also received considerable attention, from corridors, to facilitate dispersal of wildlife and the seeds they carry (Tucker & Simmons, 2009) to "applied nucleation" (i.e. planting small forest patches to catalyse more

Figure 1. A. Upper Mae Sa Valley, May 1998 before restoration; B. same site, left of the track, restored forest 15 years old, planted 2001; right, 9 years old restored forest, planted 2007 (photo September 2016). C. Inside the restored forest (10 years old), a dense understorey develops beneath the canopy of the planted trees, with up to 70 recruit tree species represented by seedlings and saplings in the ground layer.

widespread forest recovery (Zahawi *et al*., 2013). Such techniques have been adapted to many different circumstances, from providing local communities with foods and materials (e.g. rainforestation farming [Schulte, 2002]) to rehabilitating open-cast mines (Parrotta *et al*., 1997). Such effective, science-based techniques have contributed greatly to the practicability of "forest landscape restoration" (FLR) — how to integrate forest restoration with other land uses, to maximize overall ecological and economic benefits (Reitbergen-McCraken *et al*., 2007). So, lack of technical know-how no longer impedes effective restoration of tropical forests.

4. Global Restoration Initiatives

Attitudes towards restoration at the highest level have also undergone a paradigm shift over the past 10 years. The "can't/shouldn't-do-it" attitude of 30 years ago has become "must do it, now, fast and on a global scale". The Bonn Challenge was launched in 2011 to restore 150 million hectares, globally, by 2020; and in 2014, the United Nation's (UN) New York Declaration increased the target to 350 million hectares by 2030 (United Nations, 2014). It is estimated that the initiative will generate US$170 billion/y in net benefits. Furthermore, the UN recently declared a "Decade of Ecosystem Restoration" (2021-2030). Such global initiatives have prompted regional and national projects on vast scales, such as AFR100 (100 million hectares in Africa by 2030) and Initiative 20x20 (20 million hectares in Latin America by 2020). The Bonn Challenge website lists 58 national commitments to restore a total of 170 million ha i.e. 20 million above the 2020 target, but this area must be doubled to meet the 2030 target. Total commitments from tropical Asia amount to 23.65 million hectares or 14% of global pledges so far, with India contributing by far the most (Table. 1).

5. Climate Change as the Main Driver of Global Restoration

The main driver behind this upsurge in global restoration initiatives has been the realization that forest restoration, could play a major role in mitigating global climate change.

The Intergovernmental Panel on Climate Change (IPCC) suggests that around 199 gigatonnes of carbon (GtC) must be removed from the atmosphere by 2100, to limit global warming to <1.5˚C, of which 57 should be taken up by new forests (Lewis *et al*., 2019). The importance of forests as carbon sinks resulted in the UN's REDD+ initiative. 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 encouraged the creation of international funding mechanisms to support restoration 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 a similar range of forest products and ecosystem

Table 1. Pledges to global forest restoration targets by tropical Asian countries. Area in millions of hectares

Country	Date pledged	Area	By
Asia Pulp, Indonesia	2015	1.00	2020
Bangladesh	2017	0.75	2020
India	2015	13.00	2020
	2015	8.00	2030
Pakistan	2017	0.10	2020
Pakistan KPK	2015	0.35	2020
	2018	0.25	2030
Sri Lanka	2017	0.20	2020
TOTAL		23.65	

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]). Conventional plantations of fast-growing tree species meet neither of these conditions. 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.

Nevertheless, plantations comprise 45% of the area currently pledged for "restoration" under the Bonn Challenge, according to Lewis *et al.* (2019). They point out that such plantations are very shallow carbon sinks. Planting all 350 million hectares, under the Bonn Challenge with tree plantations would sequester just 1 GtC, and agroforestry would sequester just 7 GtC. In contrast, restoration of natural forest ecosystems over the same area would sequester 42 GtC, well on the way to meeting the target of 57 GtC mentioned above. According to Lewis *et al.* (2019), natural forests are 6 times better than agroforestry and 40 times better than plantations at storing carbon (sequestering 12, 1.9 and 0.3 GtC per 100 Mha respectively by 2100), and they provide more habitats for biodiversity recovery.

6. The Failure of Social Sciences

In 1994, I attended a conference entitled "Biodiversity and Community Forestry", run by the Regional Community Forestry Training Centre in Bangkok. During the conference, the most important limitations to more effective forest management for biodiversity conservation were identified as: poor governance, failure to engage communities effectively, lack of long-term funding mechanisms and an ineffective science-policy interface. Twenty-one years later, I was shocked to see almost identical take-home bullet points presented at the end of a conference on "Forestry-related Policy and Governance", run by the International Union of Forest Research Organizations (IUFRO) (Elliott, 2018). It seemed that little had changed. Since the 1994 conference, ecologists had delivered many tried and tested tools to overcome the technical barriers of restoration, but apparently social scientists had made little progress with delivering effective tools to overcome the social, political and economic barriers.

REDD+ is a case in point. It was meant to provide financial incentives for forest conservation and restoration, by placing a value on the capacity for forests to absorb atmospheric carbon dioxide. However, papers on REDD+, at the IUFRO conference were far from encouraging. Several speakers presented studies showing that REDD+ subverts local forest management practices to meet global demands, at the expense of local needs; impinging on traditional community rights, whilst failing to deliver appropriate payments to villagers. Old familiar problems such as unclear land tenure, land conflicts, poor governance, inadequate payments and unpalatable tradeoffs – were regurgitated as reasons why REDD+ was failing, without any sound tools suggested to address them. The ultimate test of REDD+, however, is to detect a decline in forestry-related CO_2 emissions. At the IUFRO conference Maria Brockhaus (CIFOR) reported that REDD+ had failed to reduce forestry-related CO_2 emissions in 13 out of the 14 countries that she had studied (2001–2014). Only Brazil had achieved a slight reduction, whilst remaining by far the highest forest-CO_2-emitter in the study. According to Brockhaus, "the transformational changes needed are being hindered by powerful "business-as-usual actors". She stated that Governments should regulate the behaviour of large investors, but "only an empowered civil society can hold businesses and states accountable. From rhetoric to actually reducing emissions seems to be a very long way. I hear a lot, but I don't see much".

7. Why Are Social the Sciences So Ineffective?

7.1 Subjective objectives

In the many social science theses and papers that I have reviewed over the years, the objectives often reflect the idealistic pre-conceptions of the authors and presuppose the studies' results. For example, a typical social science objective might be: "To demonstrate that community forestry conserves biodiversity", whereas a scientist would write: "To determine the effects of community forestry on biodiversity". The former subjectively seeks to reinforce a preconceived ideal (that communities can remain living in protected areas), whilst the latter objectively seeks the truth, regardless of any socially inconvenient outcomes.

7.2 Baselines, controls and replication

At the 1994 meeting on community forestry and biodiversity, I was concerned by the lack of rigor in many of the studies presented. Speaker after speaker presented lists of plant and animal species and diversity indices as evidence that community forests conserve biodiv-ersity. However, none showed how biodiversity had changed since before implementing community forestry (no baseline) and none had compared such changes with those in nearby conventionally managed forest, growing under similar conditions over the same period (no controls). Furthermore, none of the studies had been replicated. The notion that "community forestry conserves biodiversity" was therefore unfounded. The most that could be concluded was that some biodiversity survives in community forests, even though it might be declining from previous higher levels and it may be lower than in conventionally managed forest (Elliott, 1994).

A truly objective study of the effects community forestry on biodiversity would require: i) establishment of paired sites in various forest types and under various socio-economic conditions, with one site of each pair becoming the control site (where the management regime remains unchanged), whilst in the other, the treatment is applied (in this case conversion to community forestry); ii) baseline surveys of biodiversity and socio-economic indicators in both sites; iii) application of the treatment for a suitable period and iv) identical biodiversity and socio-economic surveys afterwards. Over the study period, biodiversity may rise or fall in both control and treatment sites, but the ultimate question is: "At the end of the study, is biodiversity higher in the community forest plots relative to the control plots and has it increased or declined since the baseline survey?"

To my knowledge, such experiments have never been used to objectively test community forestry or any of the other socio-economic constructs proposed, since the 1990's, to combine economic development with forest restoration and conservation (REDD+, FLR, PES [Payments for Ecological Services] etc.). The logistical difficulties of setting up landscape-wide, paired, experiments are of course enormous, particularly finding similar control and treatment sites, replication across landscapes and securing long-term funding. Such studies would also require cooperation among many disparate organizations, which can be difficult. But since the conservation of tropical forests is of such global importance, one would think that over the past 20-30 years, such difficulties would have been addressed and the resources made available to implement these essential experiments. So why haven't they been performed? Maybe it is a fear of negative "inconvenient" results. If properly-executed, landscape experiments were to show that community forestry, REDD+, FLR, PES etc. do not deliver the promised increases in both environmental and social benefits that form the basis of such initiatives, it would mean that combining development with environmental protection and biodiversity conservation doesn't work. That would necessitate removal of development projects and communities from protected areas and geographical separation of conservation and development: in effect, a return to the original concept of protected areas, as being inviolate and conserved in perpetuity for biodiversity conservation and environmental protection. So rather than risk the potential emergence of such inconvenient truths, the definitive studies are simply not done.

8. Conclusions

Over the past 30 years, ecologists have transformed the concept of forest ecosystem restoration from a disparaged dream into an achievable goal and it is now accepted as an urgent global priority by the UN and many national governments. However, social scientists and economists continue to struggle with providing proven effective tools to overcome the socio-economic and political barriers to its implementation. We need to put the science back into social science, with carefully planned, replicated, controlled experiments at the landscape level, to objectively test the effectiveness of existing socio-economic constructs, such as community forestry REDD+, FLR, PES etc. and, if necessary, modify or replace them. Scientists have delivered the tools needed to overcome the technical barriers to forest restoration - now the social scientists, economists and politicians must deliver the tools needed to overcome the socio-economic and political barriers.

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