

INTRODUCTION

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The two main objectives of the workshop on Forest Restoration for Wildlife Conservation were:

1. To prepare an agenda for the advancement of research on forest restoration for wildlife conservation in Southeast Asia's seasonally dry tropical forests.
2. To establish a protocol for the exchange of information on forest restoration research throughout Southeast Asia.

These objectives were achieved by dividing workshop participants into 3 small discussion groups (comprising 15-20 persons each), which simultaneously considered each main workshop topic, following presentation of the papers printed in parts 2-6 of these proceedings. The discussion groups were provided with guidance in the form of lists of questions (see appendix) to help them to i) identify gaps in knowledge concerning each of the main workshop topics, ii) prioritise the most important areas requiring urgent research and iii) suggest outline research ideas to fill those gaps in knowledge considered to be of highest priority. Discussion group chairpersons presented the research suggestions from each group to the whole assembly for feedback. A total of 136 topics were suggested for further research. Several of these were similar in nature and have been amalgamated or grouped together in this report.

On the final day of the workshop, participants were asked to nominate 10 topics they considered were the most important and 3 requiring further research most urgently. The most important topics that the majority of workshop participants nominated for urgent attention were **plantation design** (species composition, size, positioning etc.), **seed dispersal** and **fire management**. Masakazu Kashio cautioned workshop participants on the inadequacies inherent in ranking research priorities by rapid simple vote. Therefore, the detailed research proposals presented below cover not only those topics nominated as urgent and/or important by vote, but also those that may have received fewer votes but had strong consensus across all discussion groups (revealed when discussion group chairs presented their conclusions).

Based on notes taken during discussion and feedback sessions, members of the editorial committee drafted the outline research proposals presented below. Inevitably, to make the proposals complete, the editorial committee had to add some essential details that were not fully worked through in the limited time of the workshop. However, members of the editorial committee have been in constant contact with the primary advocates of each proposed topic and we feel that the agenda is a true representation of the consensus reached at the workshop. Other topics of lower priority suggested by some (but not all) of the discussion groups and those that did not receive many votes, are briefly listed at the end.

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1. PLANTATION DESIGN

Introduction

Plantation design is a broad concept that first arose during the workshop in the session on accelerated natural regeneration (ANR) and in nearly every plenary session and discussion group thereafter. It was felt that a greater understanding of the conditions under which ANR could contribute towards forest restoration was needed (1.1), so that plantations could be designed to maximise the combined benefits of both ANR and tree planting.

In planted plots, plantation design includes which tree species are selected and their relative proportions in the planting mix, planting density, the number of different tree species planted in each plot and the positioning of plots relative to nearest forest. Whilst planting too many trees or too many species is a waste of resources, planting too few could result in poor quality, low diversity habitat for wildlife or ultimately plantation failure. The need to establish a series of experimental plots to examine the costs and benefits of these various aspects of plantation design was seen as an urgent priority (1.2).

Enhancing the value of plantations as wildlife habitat by providing specialised resources, such as refuges, nesting sites etc. could be an effective technique to ensure that newly established plantations are more rapidly colonised by plants and animals. Although such techniques have been developed for temperate countries, very little work has been done on this in Southeast Asia. Further experiments on this approach were therefore considered highly useful (1.3).

Although many tree-planting programmes are underway in Southeast Asia, almost no monitoring of wildlife in restored forest areas is being undertaken. This means that the relative success or failure of plantation designs currently in use is not adequately assessed in terms of wildlife conservation. Therefore, the benefits of restored forests for wildlife are often undervalued or ignored because they are not quantified. In order to assess the effects of the various aspects of plantation design, more efficient monitoring of wildlife was seen as essential (1.4)².

Stephen Elliott

² See also TUCKER in Part 5 of these proceedings.

1.1 Assessing the potential of degraded sites for restoration by accelerated natural regeneration (ANR)

Rationale

Accelerated natural regeneration (ANR) is a cost-effective approach to forest restoration, based on encouraging natural plant succession. However, it is only appropriate where sufficient woody regeneration already exists or where a source of seeds exists nearby. This research project is proposed to develop protocols and indices to rapidly assess sites for their potential for restoration by ANR.

Objectives

1. To determine the maximum distance from the nearest forest seed source at which ANR will be effective.
2. To determine which soil and vegetation parameters predict the potential of a site to be successfully restored by ANR.
3. To develop site assessment indices based on these parameters.

Methodology

Establish long-term sample plots within cleared areas at exponentially increasing distances from the nearest forest edge up to a distance of several kilometres. Replicate to include different levels of disturbance. In each plot, measure the number of tree seeds and species in the soil seed bank and seed rain to establish the maximum distance that seeds are dispersed from the forest. Within that distance, measure the following variables in sample plots:

1. Density and species composition of the tree seedling community; mean seedling heights (absolute and relative to weed canopy) and basal areas.
2. Soil: horizon depths, organic matter, field capacity, maximum daytime temperature, selected "indicator" micro-organisms.
3. Species diversity of wildlife and population density of key wildlife species.

Repeat seed and seedling measurements in sites of different known ages or, where possible, in consecutive years to create a dynamic model of regeneration over time. Compare seedling and soil variables to see which best predict regeneration outcome.

Expected Outputs

1. Guidelines relating ANR potential with distance to nearest seed source.
2. A protocol for surveying site vegetation (e.g. number and size of plots, variables to be recorded).
3. Interpretive index to predict regeneration rate (e.g. time to canopy coverage) from site vegetation and soil data.
4. Identification of tree species unable to establish by ANR and recommendations for enrichment planting.

Drafted by Kate Hardwick

1.2 Establishing experimental plots to determine optimal plantation design

Rationale

Many aspects of plantation design are arbitrary or inherited from commercial forestry and their effects on wildlife have not been adequately researched. For example opinions at the workshop about planting density varied from the traditional 4x4m spacing, often used in commercial forestry, to 3 trees/m² for the intensive Miyawaki method. Many participants felt that the basis for these densities was obscure and their effects on wildlife had not been adequately tested. Planting too densely wastes resources, whilst planting too sparsely delays canopy closure and might lead to reclamation of areas by weedy vegetation. The number of species that should be planted was also debated. Producing large numbers of tree species in nurseries is expensive, but planting too few might result in poor wildlife habitat. There was a strong consensus that all these aspects of plantation design and others should be tested by a large series of experimental plots.

Objective

To determine optimum designs that will maximise the value of restored forest areas as wildlife habitat under various conditions.

Methodology

1. Establish a series of control and experimental plots replicated in different vegetation types and in different countries. Within the treatment plots, vary the following characteristics:
 - a) Tree planting density
 - b) The number of tree species planted
 - c) The species composition of planted trees
 - d) Distance from nearest forest

This would result in a very large set of treatment combinations and it was accepted that not all variables could be tested at every location.

2. Within the plots, monitor the following variables to assess the successfulness of the various treatments in creating wildlife habitats:
 - a) Performance (growth and survival) of the planted trees.
 - b) Recruitment of non-planted trees and diversity of ground flora.
 - c) Species diversity of wildlife and population density of key wildlife species.
3. Compare results from treatment plots with those from non-planted control plots, to assess the effects of the various treatments.

NB: The experimental design would be very similar to that proposed to study ANR (1.1). In fact the ANR plots could function as control plots for this research. Thus the two experiments could be combined into one set of plots.

Expected Outputs

Practical recommendations to improve plantation design and ensure that tree planting provides optimal habitat for wildlife.

Drafted by Stephen Elliott

1.3 Enhancing habitat diversity in plantations

Rationale

Most restoration methods involve tree-planting to establish a habitat matrix, in anticipation that wildlife will colonise planted areas. This can result in uniformity of habitat in the early years. To maximise the potential of plantations to attract wildlife, it is often necessary to artificially increase habitat diversity. Whilst knowledge of habitat requirements for most tropical wildlife is sparse, certain ecological principles can be used to artificially construct and introduce suitable habitat features to attract wildlife into planted sites. Such techniques are more developed in temperate habitats and may be suitable for adaptation to the seasonally dry tropics. Target wildlife species will vary geographically but will usually have high conservation value or fulfil key ecological functions.

Objectives

1. To identify habitat requirements of target wildlife species and features that could be artificially introduced into planted sites to attract wildlife.
2. To test the practicability of constructing such features under field conditions and their effectiveness in attracting target wildlife species.

Methodology

1. Identify target wildlife species and analyse available data on their habitat requirements.
2. Literature search of habitat reconstruction techniques, to identify those that can be adapted for the target species. The following suggestions might be investigated:
 - a) Artificial constructs, e.g. rock-piles, perches and hibernacula.
 - b) Acceleration of natural ageing processes, e.g. woodpiles, excision of bark to create rot-holes.
 - c) Provision of topographical features to increase micro-climate diversity, e.g. damp hollows, basking platforms.
3. Construct and test the habitat features in new plantations by:
 - a) Baseline monitoring of existing wildlife species in treatment and control plots
 - b) Addition of the habitat features to treatment plots.
 - c) Repetition of wildlife monitoring in the plots with particular observations of the use of habitat features.
 - d) Using initial results to modify and manipulate the habitat features, followed by repeat monitoring.

Expected Outputs

1. Information on which habitat features are most effective at attracting target wildlife species into sites in the early stages of restoration.
2. A protocol for adapting techniques from other geographical areas, using ecological principles.

Drafted by Janice Kerby

1.4 Wildlife monitoring in new plantations

Rationale:

Despite a consensus on the importance of forest restoration for wildlife conservation, very little monitoring has been undertaken of colonisation of restored sites by plants and animals. Species that can be used as indicators of success for forest restoration projects have not yet been identified. Without such monitoring, it is not possible to assess and improve restoration techniques, or to justify work to funders. Identification of species that might indicate successfulness of forest restoration projects will vary among countries, but the general principle should be applicable everywhere.

Objectives:

1. To identify indicator organisms of forest health and successful restoration.
2. To improve assessments of forest restoration trials (such as those outlined in 1.1 and 1.2), by refining wildlife monitoring methods

Methodology:

1. Identify indicator organisms of forest health in different functional groups (e.g. producers, consumers, decomposers). These may include generalists, specialists and rare species.
2. Review the literature to identify and refine suitable methods to survey the identified indicator species.
3. Undertake comparative surveys in intact forest and sites subjected to different restoration regimes to test different wildlife monitoring techniques and assess the following:
 - a) Plant and animal species movement into restored sites; population composition and demographics, using genetic markers.
 - b) Animal behaviour when colonising new sites, including movement between intact and restored forests and interactions with existing populations.
 - c) Patterns of succession in colonising flora.
 - d) Whether restored forest ecosystems become fully functioning e.g. productivity, nutrient cycling, reproduction etc.
 - e) Whether faunal populations are sufficiently well established to breed in the restored sites or are just utilising the area for food or shelter.
 - f) Whether certain animals exist as isolated populations or as part of functioning meta-populations.
 - g) Whether key seed-dispersers establish and facilitate forest regeneration.

Expected Outputs:

1. A list of indicator organisms that can be used to compare the effectiveness of different techniques to restore forests for wildlife conservation.
2. Improved techniques for wildlife monitoring in forest restoration experiments leading to improved forest restoration methods for wildlife conservation.

Drafted by Janice Kerby

2. SEED DISPERSAL

Introduction

Seed dispersal was a recurrent theme throughout the workshop, attracting particular attention in the sessions on accelerated natural regeneration (ANR) (see Part 3 of these proceedings), tree species selection for planting (Part 4) and wildlife (Part 5). In the session on ANR, seed dispersal was identified as an essential factor influencing natural regeneration. In increasingly fragmented landscapes, forest regeneration depends on dispersal of seeds, over long distances, from remnant forest fragments into cleared areas. Research on the effect of distance from a seed source on site regeneration potential was covered in research proposals on plantation design (see proposals 1.1 and 1.2). However, it was also felt that not enough was known about the mechanisms of seed dispersal, in particular the ecology of animal seed-dispersers. This research need was reiterated in the session on wildlife. The first step would be to identify important indigenous animal seed-dispersers (proposal 2.1). Research would then focus on relevant aspects of the ecology of these animals; such as the impact of habitat degradation on population levels and the likelihood that particular species would use and traverse degraded habitats.

On a more applied level, several discussion groups highlighted the need to manage sites in order to maximise seed dispersal into cleared areas. In the discussion on ANR, it was felt that more information was required on the use of isolated trees as perches to encourage bird visitation (2.2). Knowledge of the circumstances under which perches can accelerate natural regeneration was considered useful, as the effect may vary in relation to certain site conditions, such as weed cover and distance from the nearest forest.

The role of bats as seed dispersers received particular attention in several sessions. Workshop participants considered that knowledge of bats as seed dispersers was less well advanced, compared to that of birds. Therefore, it was proposed that further research on the ecology of bats and the management of sites to promote their visits was an urgent priority (2.3). In the session on tree species selection, the focus was more on the need to identify mixtures of tree species that are attractive to seed dispersers. Important traits of tree species selected for planting include regular and prolific production of fruit that are attractive to wildlife, the production of fruit at an early age and structural diversity.

Kate Hardwick

2.1 Identifying major seed dispersers

Rationale

Forest restoration projects can plant only a limited number of tree species, resulting in a planted forest with low species richness compared with primary forest. Natural seed dispersal must be encouraged (especially of those tree species which cannot be grown in nurseries and planted), to complete the restoration process to re-establish a more diverse forest ecosystem³. Identification of important seed-dispersing animal species is critical for forest restoration, so that such species can be encouraged to colonise newly planted sites. Each animal migrating from remnant natural forests will potentially carry seeds into forest restoration sites. Many bird and mammal species are involved in seed dispersal and it would be impossible to design a planting scheme that attracts them all. Thus, major seed-dispersers that feed on a wide range of forest trees or on keystone tree species vital to ecosystem function, need to be identified.

Objectives

1. To identify plant species critical to ecosystem function, but not suitable for nursery propagation and planting.
2. To determine which animals have the greatest potential to disperse the seeds of such plant species into forest restoration sites.

Methodology

1. Review literature to identify species or families of trees that play a critical role in the full functioning of natural forest ecosystems.
2. Study intact forest to determine which indigenous tree species fall into the above category.
3. Identify which of those tree species cannot easily be propagated for planting, then determine which animals are potential seed-dispersers of such tree species.
4. Study the behaviour of the animals identified as potential seed dispersers, to detect behavioural traits which affect their efficiency as seed dispersers, e.g:
 - a) presence and viability of seeds in their faeces
 - b) seed burying for storage
 - c) prolonged retention of seeds in gut or externally
 - d) propensity to travel long distances between forest and open degraded areas
 - e) rejection of seeds once the fruit has been eaten

Outputs

1. A greater understanding of which animals are critical seed dispersers for forest restoration and their seed-dispersing behaviour.
2. The potential to improve plantation designs to attract such animals into deforested areas undergoing restoration.

Drafted by Janice Kerby

³ See TUCKER and CORLETT & HAU in Part 5 of these proceedings.

2.2 Isolated trees as perches

Rationale

Forest regeneration on degraded sites dominated by herbaceous weeds can be limited by a diminished seed rain caused by a scarcity of birds, as a result of low structural complexity of the vegetation. The presence of bird perches might reduce this problem⁴. Although there is strong evidence that isolated trees in degraded landscapes provide perches for birds and increase the seed rain, the effects of tree species and architecture, landscape variables (vegetation structure, distance and amount of forest in the surrounding landscape), weed competition and seed predation on seedling recruitment beneath perch trees are less well-known.

Objectives

1. To evaluate the effects of different tree species and tree architecture on the seed rain and seedling recruitment beneath isolated perch trees in degraded areas.
2. To assess the influence of vegetation type and landscape variables around perch trees on their capacity to attract birds and enhance tree seedling recruitment.
3. To maximise tree seedling recruitment beneath perch trees by testing the effects of different weed control methods and seed predator exclusion.

Methodology

1. Identify isolated perch trees in various vegetation types, with different amounts of forest at different distances in the surrounding landscape.
2. Monitor bird species that perch in the trees, their behaviour, and their diet, by direct observation and analysis of faeces. Attempt to germinate seeds found in faeces.
3. Monitor the quantity and species composition of the bird-dispersed seed rain (with seed traps) and survey seedling recruitment beneath perch trees, compared with control points with no perch trees.
4. Analyse results to determine the effects of tree species and architecture, vegetation structure and the amount and distance of forest in the surrounding landscape on seedling recruitment.
5. Test the effects of different weeding methods and seed predator exclusion on seedling establishment.

Expected Outputs

1. Knowledge of which tree species are most effective at enhancing seed-dispersal.
2. A better understanding of how vegetation structure and landscape variables influence the capacity of perch trees to increase the bird-dispersed seed rain, leading to more efficient ANR techniques.
3. Improved plantation designs and silvicultural methods to maximise tree seedling recruitment beneath perch trees.

Drafted by Kevin Woods and George Gale

⁴ See SCOTT *et al.* in Part 5 of these proceedings.

2.3 Investigating and enhancing the role of bats as seed-dispersers

Rational

It was generally accepted at the workshop that ANR or tree-planting could restore relatively few tree species to any particular site and that wildlife is essential to disperse the seeds of a much wider range of tree species into sites undergoing restoration. All major groups of seed-dispersers require more research, but it was felt that bats had been least researched and were a top priority. Bats have a great potential to assist forest restoration, due to their high species diversity, high biomass, and their capacity to transport both small and large seeds over long distances⁵.

Objective

1. To quantify the effectiveness of bats as seed-dispersers from forest into deforested areas undergoing restoration.
2. To develop methods to encourage bats to disperse seeds into deforested areas undergoing restoration.

Methodology

1. Review literature and assess indigenous knowledge of bats in deforested areas, by interviewing local people.
2. Collect bats' faeces in seed traps and determine which seeds germinate from them.
3. Carry out surveys to identify bat species that travel between forest and deforested areas.
4. Determine which species of planted trees are most attractive to bats as food sources or roosting sites.
5. Carry out test plantings of tree species that are attractive to bats, to see if bat populations can be increased.
6. Erect bat boxes in forest restoration areas to determine if they are effective at attracting bats. Assess the effects of different box designs or positioning on the attractiveness of the boxes to bats (could be included in proposal 1.3).

Expected Outputs

1. A better understanding of the role of bats in dispersing seeds into areas undergoing forest restoration.
2. Practical techniques to encourage bats to disperse seeds into areas undergoing forest restoration.

Drafted by Stephen Elliott

⁵ See CORLETT & HAU in Part 5 of these proceedings.

3. FIRE ECOLOGY AND MANAGEMENT

Introduction

Fire is a serious, but little understood, problem throughout the tropics, requiring substantial research to reduce its damaging impacts. Workshop participants recognised that fire kills vast numbers of both planted and naturally established young trees throughout the region and agreed that it was the most common cause of forest restoration failure. Many participants described essential fire prevention measures (e.g. firebreaks, patrols, education programmes etc.) to protect forest restoration sites from fire⁶. Such measures often constituted the most expensive part of forest restoration schemes.

Although the disastrous effect of fire on young trees was recognised as a major silvicultural issue, its effects on other plants and animals are largely unknown. Participants briefly discussed the likely impacts on soil micro-organisms. It was concluded that the effects of a slow burn would be particularly damaging and could degrade the soil biota. It was unknown how long it might take the soil ecosystem to recover, but it was suggested that study of land subject to rotational slash and burn systems might yield useful data. Fire also affects other plant and animal communities essential for successful forest restoration, such as seed-dispersing birds and mammals, both through direct mortality and habitat loss. Loss of vegetation also exposes animals to hunting. Indeed, this is one of the main reasons why fires are deliberately started in the region. The relationship between fires and local communities was also discussed, in relation to the causes of fires and fire prevention.

Considerable anecdotal evidence was contributed on the effects of fires, on young trees. It was observed in Thailand that pines had the highest survival after fire, as their leaf buds are so tightly wrapped that they exclude oxygen around them and so do not burn; thus they readily re-sprout after fires. Many participants recognised that coppicing after fire was common in many tree species, but that little was known about regrowth from stumps and how this affected the structural stability of the tree⁷. Whereas trees may recover by coppicing after a single fire, repeated fires deplete energy reserves, so that coppicing no longer occurs. Participants recognised that the limited research that has been undertaken to identify fire-tolerant tree species was inadequate and recommended further studies (3.1).

Several participants suggested that controlled (or prescribed) burning could prevent accumulation of dead vegetation that provides fuel for fires and thus reduce damage by uncontrolled wildfires, but research to develop effective and safe controlled burning techniques was considered inadequate or non-existent in some areas (3.2). If a site burns every year, the fuel load will be low, but tree seedlings will be killed. With longer intervals between fires, many seedlings might have grown large enough to resist fire, but the fuel load would be greater and fires would be more damaging. The issue of timing of controlled burns in relation to the dry and wet seasons was also discussed, as was the cost of effective fire-prevention versus the value of the damage caused by a fire.

Janice Kerby

⁶ See especially SVASTI in Part 2 of these proceedings.

⁷ See HARDWICK *et al.* in Part 3 of these proceedings.

3.1 Identification of fire-tolerant tree species for forest restoration

Rationale

In seasonal Southeast Asia, forest restoration often fails because planted trees are destroyed by fire during the dry season. In most areas, fire is an annual hazard that cannot be completely prevented. However, intensive fire prevention measures during early establishment of forest restoration plots, combined with use of fire-resistant tree species can maximise success. Research is needed to identify native species that are fire-resistant or resilient.

Objective

To identify native tree species, which can resist burning or rapidly recover after fire damage (subsequently referred to as fire-tolerant).

Methodology

1. Review literature to identify tree species with the following fire-tolerant characteristics:
 - a) high growth rate (i.e. the canopy is quickly elevated above low-level flames);
 - b) thick, insulating bark;
 - c) insulated or protected buds;
 - d) the capacity to resprout from burnt stumps or produce root suckers.
2. Interview local people to review indigenous knowledge of which tree species might be fire-tolerant.
3. Draft a list of species most likely to be fire-tolerant.
4. Establish field trials of such tree species in a non-protected area. Test the response of planted trees to fire at different ages, comparing different intensities and frequencies of fire.
5. Replicate study across different vegetation types and fire regimes to ensure that results generated are locally relevant
6. Subsequently, extend field trials to test the fire-tolerance of species about which there is no prior knowledge.

Expected Outputs

1. A ranked list of fire-tolerant species for each region, detailing the age and/or size at which each species becomes resistant or resilient to fire.
2. A greater understanding of the responses of trees to different frequencies and intensities of fire.
3. A greater understanding of the mechanisms of fire-tolerance in trees.

Drafted by David Blakesley and Kate Hardwick

3.2 Assessing the feasibility and effects of prescribed burning as a fire prevention method

Rationale

One way to prevent fire destroying forest restoration schemes is to reduce accumulation of dead plant material that constitutes fire fuel. Prescribed burning has been advocated as a method to reduce fuel accumulation, when weather conditions and moisture in the vegetation can minimise damage. Little research has been done on how prescribed burning might be used most effectively. More information on the impacts of the timing and frequency of burns is needed. All fires damage trees and wildlife to some extent, but it may be possible to minimise damage by careful development of this technique. Field experiments with fire will be controversial. Experimental sites must be carefully selected and experiments must be fully explained to local people, to prevent misunderstandings.

Objectives

1. To determine if prescribed burns reduce long-term fire damage to restored forests by preventing larger, uncontrolled wildfires.
2. To determine the optimal frequency and timing of prescribed burns.

Methodology

1. Identify sites, where prescribed burns can be conducted safely, which include a range of different weedy vegetation types. Establish forest restoration trials (or use existing ones); delineate treatment plots and create firebreaks around control plots.
2. Undertake baseline monitoring of planted and naturally established trees, ground flora, seed-dispersing animals, pollinators, soil invertebrates and micro-organisms.
3. Carry out controlled burns at various times of the dry season and at different frequencies in replicated treatment plots.
4. Repeat monitoring to determine the effects of the prescribed burns.
5. Allow plant biomass to accumulate for periods of 3 months to 2 years and then carry out uncontrolled burns across both treatment and control plots.
6. Repeat monitoring to determine differences in the damage caused by the uncontrolled burns between the treatment and control plots.

Expected Outputs:

1. Data on the relative impacts of controlled and uncontrolled burns on tree seedlings, ground flora and keystone animals.
2. Clarification of whether controlled fire can be used as a tool for protecting restoration sites from wildfire and if so, identification of the most effective methods to achieve this.

Drafted by Janice Kerby and Stephen Elliott

4. SPECIES SELECTION, NURSERY AND PLANTING TECHNIQUES

Introduction

Although topics under the heading of species selection, nursery and planting techniques were not strongly nominated for further research by participants in the final vote, they are an essential prerequisite for most of the other research proposals advocated in this agenda. For example, although the general principles of the framework species method of forest restoration found wide support amongst the participants, identification, propagation and field trials of framework species has only been carried out in northern Thailand⁸ and Queensland, Australia⁹. Before experimental plots can be established region-wide, to test plantation design (see 1.2), it is first necessary to select appropriate tree species for each area of the region and learn how to propagate and plant them. Such basic research has not been done in most countries in the region. Neglecting to do it would severely constrain future forest restoration research efforts. Therefore it is included in this agenda (proposal 4.1).

Forest geneticists at the workshop stressed that genetic considerations are of paramount importance, if forest restoration for wildlife conservation is to be scaled up from experimental plots to nation-wide or region-wide programmes. Participants acknowledged that in most forest restoration experiments, seeds are usually collected from a few trees that are well known to project staff. Participants acknowledged the risks of such practices, in narrowing the genetic base of future large-scale plantations. It was recognised that the low number of votes in favour of genetic research was due to low representation of forest geneticists at the workshop, but that genetics is a critical issue for the long-term viability of forest restoration programmes. A written submission, after the workshop was therefore accepted for inclusion in the agenda (proposal 4.2).

Of all the nursery and planting techniques, it was felt that direct seeding was least understood and had most potential for reducing the costs of forest restoration programmes. The results of direct seeding have been highly variable in different parts of the region and very little research has been done to refine the technique. Further research on direct seeding, therefore, was strongly endorsed by workshop participants (proposal 4.3).

Stephen Elliott

⁸ See ELLIOTT *et al.* in Part 4 of these proceedings.

⁹ See TUCKER in Part 5 of these proceedings.

4.1 Identification of framework species in different bio-regions

Rationale

Natural forest can be restored by planting mixtures of “framework tree species” to complement natural regeneration. Framework tree species attract seed-dispersing wildlife and catalyse tree recruitment, by suppressing weeds and ameliorating soil and microclimate conditions. This technique has been tested only in Queensland, Australia and Chiang Mai, Thailand¹⁰. Whilst the basic principles of the method are applicable throughout Southeast Asia, further research is needed to identify appropriate framework tree species for each part of the region, develop suitable propagate techniques and appropriate planting and silvicultural methods to suite the various ecological and socio-economic conditions that exist in various parts of the region.

Objectives

1. Define bio-regions within participating countries.
2. Identify appropriate framework tree species within each bio-region.
3. Develop nursery production and silvicultural methods for such framework species.

Methodology

1. Review climate, topographic and vegetation data to define bio-regions. Identify host institutions within each bio-region. Establish field stations with nurseries, forest study plots and potential restoration sites.
2. Review literature and indigenous knowledge to develop lists of potential framework species by considering:
 - a) seed availability and ease of propagation,
 - b) field performance and canopy structure,
 - c) provision of wildlife resources (e.g. fruit, nectar, perches, etc.) at a young age.Identify gaps in coverage of secondary data.
3. Carry out phenology studies and nursery trials to develop efficient propagation methods for potential framework species e.g. germination treatments, fertiliser, pruning and watering regimes etc.).
4. Carry out field trials as described in proposal 1.2. Also test silvicultural techniques such as fertiliser application, mulching and weeding methods and record time to flowering/fruitletting and drought- and fire-tolerance of the planted trees.
5. Expand the study to test species that do not feature in the literature or indigenous knowledge.

Expected Outputs

1. Reference data and lists of framework tree species suitable for planting for each bio-region investigated in Southeast Asia.
2. Ultimately more successful forest restoration programmes throughout the region.

Drafted by Kate Hardwick and David Blakesley

¹⁰ See papers by TUCKER in Part 5 and ELLIOTT *et al.* in Part 4 of these proceedings.

4.2 Maintenance of genetic diversity within plantations

Rationale

The 1992 Convention on Biodiversity emphasised the importance of maintaining intraspecific genetic diversity and evolutionary potential. When planting native forest trees, adaptability and maintenance of a broad genetic base must be ensured. Forest restoration is usually initiated using small populations of planted trees derived from few parent trees. Genetic variation in this founding population is critical, particularly if restored areas are far from pollen sources. Molecular techniques provide a valuable tool for measuring the genetic diversity of trees, thus enabling better genetic management for forest restoration.

Objectives

1. To establish guidelines based on current literature, to reduce genetic erosion when collecting seed or cuttings of tree species used for forest restoration.
2. To assess intraspecific genetic diversity in selected framework tree species by microsatellite (SSR) marker analysis.
3. To use SSR data to select parent trees that have maximum genetic diversity.

Methods

1. Review literature on best forestry practices and conservation biology, related to genetic maintenance. Draft genetic guidelines for forest restoration, considering:
 - a) seed collection (forest floor vs. tree; seed distribution on a selected tree);
 - b) distance between parent trees (seed and pollen dispersal distances);
 - c) minimum number of parent trees and
 - d) location of parent trees (genetic diversity within and between local populations, selection from appropriate ecotype).Information currently available will allow some of these questions to be answered, to immediately improve current seed collection practices.
2. Select framework tree species (see 4.1) and develop polymorphic SSR markers; identify and characterise SSR's or use suitable markers identified from the literature.
3. Collect plant material from a minimum of 25 trees in each sub-population under investigation.
4. Examine levels of genetic diversity within and among sub-populations.
5. Examine levels of genetic diversity within seed progeny to give an estimate of pollen donors.
6. Analyse data to identify groups of parent trees with maximum genetic diversity.

Outputs

1. Guidelines for the selection of parent trees for seed collection and vegetative propagation of species used for forest restoration.
2. Application of SSR's to select parent framework trees for forest restoration.

Drafted by David Blakesley

4.3 Direct Seeding

Rationale

Direct seeding could be a much cheaper method of establishing mixed plantations of framework tree species than planting saplings grown in nurseries. The technique could be used on its own or to complement ANR or conventional tree planting. However, the effectiveness of direct seeding might be limited due to seed predation, low germination rate or seedling mortality in the harsh conditions prevalent in deforested areas. Workshop participants agreed that direct seeding had not been adequately tested by controlled field trials and that further research in this area could substantially reduce the costs of forest restoration projects.

Objectives

1. To determine which tree species can be established by direct seeding.
2. To determine the site conditions under which direct seeding is most successful.
3. To develop and test pre-treatment and sowing techniques to reduce seed predation and maximise seed germination and seedling establishment after direct seeding.

Methodology

1. Select a range of tree species with different seed characteristics so that generalisations can be made as to which seed types are suitable for direct seeding.
2. Establish experimental plots to test the effectiveness of direct seeding. Replicate plots in different locations to test the effects of site conditions (e.g. vegetation, climate, seed predator populations etc.) on the outcome of direct seeding.
3. Test various treatments that might increase the effectiveness of direct seeding such as :
 - a) Pre-treating the seed to accelerate germination after sowing, to reduce the time available for seed predators to attack the seeds.
 - b) Pre-treating the seeds with chemicals that deter seed predators.
 - c) Burying the seeds at different depths.
 - d) Sowing the seeds at different densities.
 - e) Weeding to remove cover for seed predators and reduce competition.
4. It was suggested that direct seeding might be particularly useful for establishing large-seeded, shade tolerant tree species, beneath the canopy of previously planted trees to enhance biodiversity. Experimental plots could be established to test the effectiveness of this hypothesis.

Outputs

1. A better understanding of the conditions under which direct seeding is successful and cost-effective.
2. A better understanding of tree species or types of seeds suitable for direct seeding.
3. Development of effective techniques to increase success of direct seeding.

Drafted by Stephen Elliott

5. SOCIAL AND COMMUNITY ISSUES

Introduction

The subject of community forestry recurred in several sessions during the workshop, highlighting its multi-disciplinary nature. The results of voting reflected the importance of social and community issues in forestry, with more research proposals arising from this session receiving a significant number of votes than from any other session. This indicates a need to develop greater understanding and skills to increase involvement of communities in the implementation of forest restoration projects. Each major category of social and community issues contained at least one sub-topic that received many votes, reflecting the need to address a diverse array of community issues, in order to work more effectively with local people. Although most participants did not consider any social and community topics as urgent, three areas of research were nominated as important: determining the factors which motivate villagers to become involved in forest restoration; the effects of forest restoration on water supplies and sustainable harvesting of forest products.

Throughout the workshop, integration of forest restoration for wildlife conservation with local community needs was stressed. Providing incentives for local people to become involved in forest restoration was seen as essential, but many participants felt not enough was known about the factors that motivate villagers to become involved in forest restoration. Many motivating factors were suggested, such as increasing income through employing paid labourers, improving food security, security of land tenure, reducing erosion and bringing value and pride back to communities. Further study of these and other incentives was considered important (proposal 5.1).

Several speakers identified improved water resources as one of the most important advantages of forest restoration for local communities. The issue of watershed conservation was raised throughout the discussions as it encompasses many components of forest restoration, but participants considered that the relationship between forest restoration and water supply had been poorly researched and that further research in this area would be useful (5.2).

The right to harvest products from the forest was also seen as a strong incentive for local people to become involved in forest restoration. However, the need to ensure that harvesting is sustainable and does not impact on wildlife was also considered to be important. Ascertaining the carrying capacity of restored forests was voted as the third most important topic of the workshop, but it was recognised that little work has been done on this (5.3).

Kevin Woods

5.1 Motivating local people to become involved with forest restoration

Rational

Most areas where forest restoration for wildlife conservation has been implemented are small and experimental. Once suitable technologies to restore forests for wildlife have been developed, it will be necessary the scale-up activities to cover large areas. This will involve enlisting the support of local communities, if forest restoration is ever to significantly increase wildlife. Restoring forests for wildlife conservation might appear to offer few rewards to local communities and might even conflict with the requirements of rural villagers for agricultural land. However, workshop participants identified a wide range of reasons why local people become involved in forest restoration programmes, from the provision of water and forest products to the development of ecotourism, new employment opportunities and greater political recognition. There was general consensus that these needed further study, to determine which incentives created greatest motivation and whether incentives that worked in some countries might be transferable to others.

Objective

To identify the most important incentives and disincentives for local communities to accept or reject forest restoration projects in their vicinity.

Methodology

1. Select communities throughout Southeast Asia that actively participate in forest restoration programmes and those that have rejected such programmes.
2. Identify the main incentives and disincentives for local people to become involved in forest restoration programmes through participatory appraisal.
3. Transfer incentives from communities that participate in forest restoration to those that have rejected it.
4. Monitor changing attitudes within the selected communities as a result of the introduction of new incentives.

Expected Outputs

1. A better understanding of the factors that motivate or deter local communities from becoming involved in forest restoration.
2. Ultimately a greater acceptance and understanding of forest restoration for wildlife conservation in more communities throughout the region

Drafted by Stephen Elliott

5.2 The effect of forest restoration on seasonal yield of water

Rationale

Emphasising the link between forest restoration and reliability of water supplies provides a strong incentive for communities to support forest restoration. However, there is much controversy over the effects of reforestation on seasonal water yield in the seasonally dry tropics. One argument is that forest restoration increases the water-holding capacity of soil and prevents soil erosion, thus increasing infiltration and storage. This results in increased flow during the dry season. Another view is that tree-planting increases net evapo-transpiration, which decreases yield in all seasons. More quantitative evidence from the seasonal tropics is required to resolve this debate. The problem requires broad-based studies of water yield in areas that have already undergone forest restoration as well as in-depth analyses of how water yield changes as forest restoration progresses.

Objectives

To test the hypothesis that forest restoration decreases catchment water yield during the rainy season, but increases yield during the dry season.

Methodology

1. Broad based studies of existing forest restoration plots.
 - a) Identify water catchments that have already undergone forest restoration in a broad range of environmental conditions.
 - b) Identify suitable paired control plots, which have remained deforested.
 - c) Measure hydrological parameters that affect water yield. Analyse data to determine differences between restored forest plots and deforested plots.
2. In depth study of the mechanisms by which forest restoration affects water yield over time.
 - a) Select paired deforested catchments in various locations with different environmental conditions.
 - b) Measure hydrological parameters that affect water yield for several years to determine baseline conditions.
 - c) Carry out forest restoration by tree planting or ANR in one catchment of each pair, whilst leaving the other one to regenerate naturally.
 - d) Continue monitoring hydrological parameters for several years to determine changes in water yield as the canopy closes.

Expected Outputs

Statistical evidence of the effect of forest restoration on seasonal water yield in the seasonal tropics and how this varies according to factors such as bedrock and forest type.

Drafted by Kate Hardwick and Stephen Elliott

5.3 Sustainable harvest of products from restored forests in non-protected areas

Rationale

Restored forests in buffer zones or other areas outside national parks and wildlife sanctuaries can both support wildlife and provide products for local people. However, in order to maintain a healthy forest ecosystem that will continue to provide products in the long term, it is essential that harvesting of forest resources be carefully managed within sustainable limits. Local managers will need to develop methods to assess the productivity of forest resources, devise ecologically and socially acceptable harvesting strategies, monitor and evaluate levels of product extraction and implement a system of disincentives for those who over-harvest. The research proposed here aims to develop the knowledge that would be needed to implement such schemes.

Objectives

1. To identify target products.
2. To identify the type and age of restored forest that can support each product.
3. To determine the effects of product extraction on the ecology of restored forest.
4. To develop sustainable harvesting methods.

Methodology

1. Review existing literature and use participatory rural appraisal to identify target products that are desired by local communities but cannot be cultivated.
2. In restored forests outside protected areas, select study sites, which vary in age and species composition and are subject to low or no usage.
3. Survey the sites to determine
 - a) initial condition of the forest and status of wildlife and
 - b) productivity of the products to be harvested.
4. If absent or slow to establish, introduce the products to the sites.
5. Develop sustainable harvesting strategies with local people, by further participatory rural appraisal.
6. Implement experimental harvesting regimes for several years, to determine the sustainable yield.
7. Monitor the effects of product extraction on the forest and wildlife.

Expected Outputs

1. Best practice guidelines for product introduction and extraction in restored forests, which could be adapted by local managers to suit their particular natural and social environment.
2. Practical indices by which the sustainability of harvesting could be judged.

Drafted by Kate Hardwick

OTHER RESEARCH SUGGESTIONS

Accelerated natural regeneration

Effects of fire on wildlife habitats

Research to assess the affects of fire on the wildlife habitat value of sites undergoing forest restoration was suggested.

Effects of different weeding regimes on fire risk in forest restoration

Prolific growth of weeds in deforested areas provides fuel for fires. Weeding is necessary not only to reduce competition with planted trees, but also to reduce fire risk. The effects of different timing and methods of weed control on fire risk should be investigated.

Interactions between weeds and other wildlife

Weeds provide habitat for many wildlife species, but weeding is essential to maximise performance of planted trees and reduce fire risk. Experiments should be conducted to minimise any deleterious effects of weeding on wildlife.

Edaphic factors that limit forest regeneration

Forest regeneration is often limited by the hot, dry sunny conditions prevalent in deforested areas. Identification of the main limiting factors could lead to the development of better site management techniques to accelerate natural regeneration or improve the performance of planted trees. More research on light and soil factors was suggested with emphasis on soil moisture. Participants also suggested experiments to test new management techniques to overcome the identified limiting factors.

Disturbance

Forest restoration is often limited by disturbances such as fire, chopping and browsing. Experiments were suggested to determine how much disturbance could be tolerated before forest restoration would be inhibited.

Keystone species

Keystone tree species provide essential resources to wildlife, especially seed-dispersers and pollinators, in seasons of shortage. Research to determine the minimum viable populations of keystone tree species was suggested.

Fragmentation

Forest fragmentation was recognised as a major factor limiting pollination, seed dispersal and causing inbreeding in isolated wildlife populations. More research on the effects of fragmentation on forest restoration was suggested. Determination of the minimum viable size of restored forest patch, to minimise edge effects and maintain viable populations of wildlife, was also suggested for further study.

Soil seed bank

Research to assess the contribution of the soil seed bank to forest restoration and to develop management techniques to minimise damage to the soil seed bank and encourage germination was considered important by some workshop participants.

Existing vegetation

The existing vegetation on any restoration site can facilitate or hinder restoration efforts. More research on the interactions between planted trees and existing weeds or naturally established trees was suggested. Identification of plant species that might be antagonistic to forest restoration was suggested. The relationship between the age of a site and species diversity could be used to indicate the potential for restoration by ANR. This research would yield more effective weed control methods and improved ANR techniques.

Stump propagation

Tree stumps can be an important source of natural regeneration in forest restoration projects. Treatments to encourage tree stumps to sprout and grow well should be developed.

Models of forest regeneration

Develop models to predict the rate of natural regeneration based on soil factors, the seed bank and seed rain and the demography and species richness of naturally established trees.

Seed dispersal mechanisms

For many tree species, seed dispersal mechanisms remain unknown. Knowledge of seed dispersal mechanisms and distances can help to assess the likelihood of a tree species dispersing naturally into deforested areas and hence the need to plant it. Simple observational studies on seed dispersal mechanisms were suggested.

Species Selection

Criteria for species selection

Many characteristics were suggested as criteria for the selection of tree species for propagation and planting for forest restoration. Most of these characteristics are not known for the vast majority of forest tree species native to Southeast Asia. Therefore research to assess these characteristics for a wide range of species would be useful. The characteristics suggested included:

Drought tolerance – after fire, seasonal drought is the main cause of mortality of planted trees.

Multiple uses – tree species that provide products for local communities, as well as habitat for wildlife. The inclusion of domestic fruit trees in the planting mix was suggested for testing.

Species that provide specific food resources for wildlife¹¹.

¹¹ See also proposal 2.3.

Rapid maturation –tree species that flower and fruit at a young age.

Keystone species – trees that provide a reliable supply of food for wildlife during seasons of shortage

Limited seed dispersal –tree species with large seeds or those for which seed dispersal agents (e.g. large mammals) have become extirpated.

Resilience –species most able to regrow after damage (e.g. fire, chopping or browsing etc.).

Tree propagation

Fruiting phenology

More studies of the reproductive phenology of tropical tree species were suggested to help plan seed collection programmes.

Seed storage

Seed storage could greatly increase nursery efficiency and is essential for the distribution of tree species useful for forest restoration. It was recognised that little information is available on which species can be stored and for how long, before viability declines. More research in this area was recommended.

Seed Germination

More research on germination of native tree species that are difficult to germinate was considered to be useful. Testing of mechanical, chemical and thermal treatments to break dormancy was suggested.

Vegetative propagation

For all but a few commercially valuable tree species, vegetative propagation techniques have not been developed. Research to develop vegetative propagation techniques was considered important for species that cannot be propagated from seed. Research to establish hedges as sources of material for vegetative propagation was also seen as a priority.

Wildling propagation

Transplantation of tree seedlings from forests into nurseries or directly into forest restoration sites may provide a cheap alternative to raising planting stock from seed. However, transplantation methods have not been tested. Such factors as the optimum size of wildling for transfer and pruning methods, to reduce the shock of transplantation, need to be developed.

Improving the quality of planting stock

Various nursery techniques to improve seedling propagation were considered to be in need of further research. Determining optimum container size, potting medium, and regimes for watering, fertiliser application and root pruning were all identified as requiring further studies. The efficacy of using mycorrhizae to improve seedling growth was considered to be a priority. Improved nursery hygiene should also receive attention. Cost-benefit analyses were seen as an essential counterpart to the scientific research.

Planting and aftercare

Weeding methods

Weeding is one of the most costly aspects of forest restoration programmes. Research aimed at developing and evaluating simpler cheaper weeding techniques (such as flattening weeds with boards) should be carried out.

Effects of herbicides on soil micro-organisms

Non-residual herbicides (e.g. glyphosate) can provide a cost-effective method to control weeds in planted areas. Concern was expressed that such chemicals might inhibit soil micro-organisms (e.g. mycorrhizae) beneficial to trees or interfere with nutrient cycling. Research to monitor such effects should be initiated.

Evaluate impacts of pests and diseases in the field

Almost no information is available about the effects of pests and diseases on the performance of the vast majority of native forest tree species after they are planted out in deforested areas. Identification of pest or disease problems, assessment of their potential impact and, if necessary, the development of control methods was suggested for further research.

Community and Social Considerations

Forest restoration to reduce crop pests

In some circumstances, provision of forest habitat reduces the incidence of crop damage by wild animals. The potential for this effect in Southeast Asia should be investigated.

Markets and financial gains

The ability of local communities to make use of restored forest areas might depend on market conditions. Social research to identify interactions between local communities, forest use and financial gains should be implemented.

Information exchange

One of the main reasons why forest restoration programmes fail to be accepted by local communities is lack of communication between project implementers and key local people. Research to develop and test better methods of communication should be carried out.

Government policies

The effects of various government policies on forest restoration and how local people might benefit from them are not fully understood and are constantly changing. Continual research to provide feedback to governments on the effects of their policies on local communities and on wildlife conservation was seen as a necessity.

Zoning

It was felt that existing land zoning systems do not provide adequately for forest restoration areas and often disenfranchise local people. Further research to re-evaluate current zoning systems and develop improved systems was suggested.

Monitoring

Develop appropriate criteria and indicators to assess the results of community forest restoration programmes.

Drafted by Stephen Elliott

Appendix – guiding questions to assist discussion groups to identify important or urgent areas needing further research

SESSION 3 - THE ECOLOGY AND MANIPULATION OF NATURAL REGENERATION

1. What are the main ecological factors limiting natural forest regeneration in seasonally dry forests in SE Asia?
2. How can these ecological constraints be reduced or removed to accelerate regeneration of original forest ecosystems?
3. What experiments have already been carried out to manipulate natural regeneration or remove limiting factors? What techniques have been successful or unsuccessful?
4. For which of the processes of natural regeneration (seed production, dispersal, seed predation, germination, seedling establishment etc.) is knowledge least advanced?
5. Of those processes, which ones require further research most urgently or would result in the greatest advance in forest restoration programs? What would be the most useful experiments to establish in the near future?

SESSION 4 - SPECIES SELECTION AND TECHNOLOGIES FOR GROWING SEEDLINGS

1. What criteria should be used to select tree species for wildlife conservation?
2. What further work is required on species selection?
3. What methods of seed collection should be used to maintain genetic diversity within tree species being planted?
4. What techniques have participants used and found to be most effective at growing native forest trees in nurseries for planting in restoration projects? Discussion could consider different methods of seed collection, germination, potting techniques, fertilisers, pest control etc.
5. What nursery propagation techniques for native forest trees are least developed or least understood?

6. For which of those techniques, identified in 5, is further research most urgent or important?

SESSION 5 - PLANTING TREES AND SILVICULTURE

1. Which methods of tree planting and silviculture have participants used for forest ecosystem restoration; which ones work best and which have failed? This could include consideration of size at which saplings are planted, spacing, methods and frequency of weed control, fertilizer application, mulching, pruning, thinning etc.
2. What are the most important gaps in our knowledge of the ecological factors determining the performance of planted trees?
3. What would be the most useful scientific experiments to establish to fill these gaps in knowledge?

SESSION 6 - INTERACTIONS BETWEEN WILDLIFE AND FOREST RESTORATION

1. What are the positive effects of wildlife on forest restoration programs? How can these effects be encouraged?
2. What are the damaging effects of wildlife on forest restoration programs?
3. How can forest restoration programs be designed to provide habitats for wildlife?
4. What might be some adverse effects of forest restoration programs on wildlife?
5. What methods should be employed to monitor wildlife in restored forests and what key plants or animals should be monitored?
6. What experiments should be established to investigate interactions between wildlife and restored forests?

SESSION 7 - COMMUNITY INVOLVEMENT IN FOREST RESTORATION FOR WILDLIFE

1. How can information exchange among scientists, practitioners and local communities be facilitated?
2. How do forest restoration programs benefit or disadvantage local communities?
3. Why do communities become involved in forest restorations programs?
4. Why do local communities sometimes oppose or destroy forest restoration programs?
5. What further research is required to investigate inter-actions between local communities, areas of restored forest and the wildlife they contain?

Stephen Elliott