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SELECTING TREE SPECIES FOR RESTORING DEGRADED FORESTS IN NORTHERN THAILAND

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SUMMARY

This paper proposes a system to score the suitability of tree seedling species for planting, to accelerate natural forest regeneration on degraded sites within protected areas in northern Thailand for biodiversity conservation and watershed protection. The criteria considered are seedling performance; ease of seedling propagation; ability to shade out weeds; ability to foster regeneration of other tree species; inhibited natural seed dispersal and rarity. Measurement methods and indices are suggested to quantify each criterion with minimum values of zero and maximum values of one. The scores are then weighted according to the objectives of tree planting activities and the weighted scores summed to give an overall suitability index. Questions raised for discussion include: Is this level of quantification justified or practically achievable? Are there alternative, rough "rules of thumb" that could achieve similar results more economically? Are all the criteria discussed really necessary? Should any other criteria be added? Is the scoring system mathematically sound and practically useful?

DEFORESTATION IN THAILAND

Deforestation remains the most serious threat to biodiversity throughout Thailand, despite a ban on commercial logging since 1989. It also plays a significant role in exacerbating rural poverty and degrading watersheds. The official estimate of current forest cover is 134,910 km^2 or 26% of the country, down from 53% in 1961 (Bhumibamol, 1986). However, unofficial estimates put Thailand's natural forest cover at less than 20% (Leungaramsri & Rajesh, 1992). Between 1981 and 1990 the annual deforestation rate was 3.3% - the highest rate in SE. Asia. After the logging ban, the deforestation rate dropped by an estimated 84% to about 40,000 hectares per year. Illegal logging remains a serious cause of deforestation, although clearance of forests for agriculture, establishment of fast-growing tree plantations and tourism and infrastructure development are also significant causes (Leungaramsri & Rajesh, 1992).

Of particular concern, has been deforestation of the mountainous northern region. Not only are the northern forests a significant repository of the region's biodiversity, but they are also the country's most important water catchments, supplying water for the rapid agricultural, industrial and urban development in and around Bangkok and central Thailand. Furthermore, they provide a range of forest products and ecological services to rural communities. However, in the single northern province of Chiang Mai, satellite images revealed that the deforested area more than doubled in just ten years from 3,235 km^2 in 1975 to 6,513 km^2 in 1985 (GRID, 1988).

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CHANGING ATTITUDES TOWARDS REFORESTING PROTECTED AREAS

Following the logging ban, many former logging concessions were designated national parks or wildlife sanctuaries. As of 31/3/96, 63 terrestrial national parks and 38 wildlife sanctuaries had been gazetted covering a combined total area of 64,117 km^2 (12.66% of the country) (Parr, 1996) or more than half of the total forest area (Boontawee *et al.,* 1995). Furthermore, it is proposed to expand the protected areas system by gazetting 42 new national parks and 31 new wildlife sanctuaries (Parr, 1996). Large parts of many of the current or proposed protected areas are therefore deforested. If such areas are to fulfill their functions of conserving biodiversity and protecting watersheds, they must be reforested. In the past reforestation, even within protected areas, meant establishing single-species plantations, mostly pines and eucalypts, which are of little value for wildlife conservation and watershed protection. Recently, however, the idea of accelerating and complementing natural forest regeneration to recreate original complex forest ecosystems has rapidly gained ground. Some senior Royal Forest Department officials are actively promoting "enrichment planting", using a wide range of native tree species and a random planting pattern, as the main reforestation method within protected areas (Chatwiroon, personal communication, 1996). In 1993 a nation-wide project, involving the government, NGO's and the private sector, was launched to replant 8,273 km^2 of deforested land, as part of celebrations marking His Majesty King Bhumibol Adulyadej's Golden Jubilee, at an estimated cost of about US$ 600 million. The project stipulates use of a wide range of native forest tree species and that restored forests are to be preserved for conservation.

However, implementing such an abrupt change in policy has been considerably constrained by lack of knowledge of how to grow and plant seedlings of the wide range of native tree species needed. Of particular concern is the lack of knowledge about which tree species are the most suitable for planting in the hot, dry, sunny and weedy conditions found in most deforested areas. Some fundamental questions include: which tree species are most able to compete with and eventually shade out herbaceous weeds; which can foster the establishment of seedlings of other tree species and which can be propagated and planted easily?

THE FOREST RESTORATION RESEARCH UNIT

The Forest Restoration Research Unit (FORRU) was established in November 1994 to investigate some of these questions (Elliott *et al.,* 1995). It is a joint initiative between Chiang Mai University (CMU) and the Headquarters of Doi Suthep-Pui National Park (under the Royal Thai Forest Department (RFD)), which adjoins the university campus. The project is generously sponsored by Riche Monde (Bangkok) Ltd. and Guinness-United Distillers' Water for Life Project.

FORRU is situated at the Headquarters of Doi Suthep-Pui National Park, northern Thailand (18° 50' N, 98° 50' E) at about 1,000 m elevation in a transitional zone between mixed evergreen-deciduous forest and evergreen forest (Maxwell, 1988). The area experiences a monsoonal climate, with a marked dry season from December to April, followed by a rainy season which peaks in August. Annual rainfall is usually about 1,000 at the base of the mountain and about 2,000 mm near the summit (1,685 m elevation). There is a cool season from November to February, during which mean daily temperatures are 20.2-24.2°C, after which temperatures rise sharply, peaking at about 30°C in April.

Although an estimated 40-50% of the park is deforested, it retains an exceptionally rich vascular flora (CMU's Herbarium Database has records for 2,139 species from the national park). As a result, the park was recently listed by the IUCN as a "centre of plant diversity" (Elliott and Maxwell, 1995). Six hundred and twenty-six species of tree or treelet have been recorded within the national park, of which about 400 grow in the habitats and at the elevation range around FORRU (CMU Herbarium Database, 1996). The work of the first 3-year phase of the FORRU project (1994-97) is cataloging and describing the fruits, seeds and seedlings of the large number of tree species found in the park. Seed germination trials and preliminary seedling planting trials in deforested areas have also been carried out. Seedlings of around 50 species have been planted randomly at two sites within Doi Suthep-Pui National Park (near Mahidol Waterfall and near Ban Mae Sa Mai). At the end of each major season (dry season, rainy season and cool season) the seedlings are monitored. The Mahidol Waterfall site was first planted in September 1995, with additional planting in August 1996. Ban Mae Sa Mai was planted in June 1996, so the oldest seedlings have been planted out for only just over 1 year at the time of writing.

About 300 tree species have been examined, at least to some extent, by the project so far. However the second phase of the project will concentrate on 20-30 tree species which are most useful in complementing natural regeneration in deforested areas. The aim will be to develop efficient mass propagation systems for them and carry out more extensive planting trials testing different planting methods and post-planting management systems. The project must therefore develop rational for selecting 20-30 such tree species from the 300 or more examined so far. This paper discusses how species might be selected and identifies gaps in the existing data collection program.

CHARACTERISTICS OF DEFORESTED AREAS

The FORRU project is concentrating on deforested areas above 1,000 m elevation, where evergreen forest was the original vegetation type, since such areas are the most important for both biodiversity conservation and watershed protection. They are normally dominated by herbaceous vegetation, typically including grasses (*Pennisetum polystachyon* (L.) Schult., *Imperata cylindrica* (L.) P. Beauv. var. *major* (Nees) C.E. Hubb. ex Hubb. & Vaugh., *Thysanolaena latifolia* (Roxb. ex Horn.) Honda, *Phragmites vallatoria* (Pluk. ex L.) Veldk. etc.), bracken fern (*Pteridium aquilinum* (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try.) and the herb/shrub *Eupatorium odoratum* L. and ubiquitous herbs such as *Commelina diffusa* Burm. F, *Bidens pilosa* L. var. *minor* (Bl.) Sherf and *Ageratum conyzoides* L. By the end of the rainy season, such vegetation often exceeds head height and is practically impenetrable, although many species die back in the dry season. Frequent fires are primarily responsible for perpetuating such dense herbaceous vegetation.

The degree of natural forest regeneration (in terms of the density and species diversity of naturally-established tree seedlings) in such areas is exceedingly variable due to variability in history of disturbance, topography, micro-climate, soil, distance from nearest forest etc. but at least some natural forest regeneration is usually present. For example, in Doi Suthep-Pui National Park Karimuna (1995) recorded an average density of naturally-established seedlings or saplings (5-250 cm tall) of 1.34 m^{-2} of 18 species at one deforested site at about 1,400 m elevation. During a survey in a 1,600 m^2 plot above Ban Mae Sa Mai (1,260 m elevation), 174 naturally-established seedlings or saplings (>30 cm tall, gbh< 10 cm) were recorded (0.12 m^{-2}) of 36 species.

It is unlikely that the soil seed bank plays a major role in tree regeneration. The maximum tree seed dormancy period recorded so far in germination experiments on more than 300 tree species at the FORRU nursery is 253 days (for *Euodia meliifolia* (Hance) Bth, Rutaceae). Therefore, within a year after removal of mature trees from a site, it is probable that no tree seeds from the original seed bank remain germinable (Figure 1.). Therefore, most regeneration is derived from the incoming seed rain and especially from vegetative growth, mostly coppicing shoots from surviving tree stumps, which grow much faster than seedlings germinating from seeds. They can rapidly shade out weeds and create conditions favourable for germination of incoming seeds. During the survey near Ban Mae Sa Mai (mentioned above) 80% of seedlings recorded were coppicing.

Any attempts to restore forest ecosystems on such areas must take account of what seedling species are already present. To propagate and plant tree species which can successfully colonize such areas naturally is a waste of resources. Therefore, it is recommended that surveys are carried out before planning tree planting programs to determine which tree seedling species are present and which should be propagated and planted to increase tree density (to enable rapid canopy closure and shade out weeds) and to enhance tree species diversity. To assist with such surveys, the FORRU project is working on an illustrated tree seedling handbook, which should enable rapid identification of seedlings in the field.

SELECTING TREE SPECIES

Matching commercial plantation tree species with specific site conditions has been extensively researched. However, the selection of tree species to accelerate re-establishment of diverse tropical forests for environmental protection has only recently received attention. In Brazil, Knowles and Parrotta (1995) devised a semi-quantitative scoring system to rank 160 tree taxa in order of their suitability for mixed tree species plantings to restore open-cast bauxite mines, based on 3 criteria: seed germination treatment requirements, alternatives for the production of planting stock and early growth and survival.

In Queensland, Australia Goosem and Tucker (1995) developed the "framework species method" of re-establishing rain forest ecosystems. Framework tree species are those which "capture the site" by rapidly shading out weeds and attract birds and bats, which bring in the seeds of a wide range of additional tree species. Experimental plots established with 30 framework species attracted an additional 68 species of naturally establishing tree seedlings within 6 years (Tucker, pers. comm.). The criteria listed for the selection of framework species included ease of propagation, tolerance of the harsh conditions in deforested sites, regenerative ability, growth rate, canopy density, attractiveness to wildlife and limited seed-dispersal mechanisms. Lists of 12 groups of framework species were provided for planting in the 12 ecological mapping units of the Queensland Wet Tropics World Heritage Area defined by altitude, climate and geology.

Being very much influenced and inspired by both the above publications, we started to think about designing a quantitative system to score tree species for their suitability for planting in deforested sites in northern Thailand, using the existing data of the FORRU project as much as possible.

SELECTION CRITERIA

1. Seedling Performance

Seedling performance can be considered in terms of both survival and growth rate. FORRU is collecting such data during routine monitoring of randomly planted seedlings. Undoubtedly the most important characteristic for selecting tree seedling species for planting in deforested areas is that they can survive in the predominantly hot, dry, sunny and weedy conditions in such areas. Knowles and Parrotta (1995) ranked performance in the first two years after planting as good (>75% survival, sun tolerant, vigourous leading shoots), fair (50-75% survival rate require partial shade, active shoot growth) and poor (<50% survival rate, sun intolerant, stagnant shoot growth).

Here we suggest that the proportion of seedlings surviving two years after planting provides a suitable index of survival.

Mean relative growth rate (MRGR yr-1) over two years...

$$\frac{\ln(\text{shoot height after 2 years}) - \ln(\text{shoot height when planted})}{2}$$

...expressed as a proportion of the MRGR of the fastest growing species is suggested as an index of growth.

2. Ease of seedling propagation

Obviously, seedlings which cannot be propagated cannot be planted, so ease of propagation is probably equally as important as post-planting performance. At FORRU seedlings are germinated from seeds collected near the nursery and transferred to black plastic bags for growing on under shade. These experiments are replicated in both deep shade and strong sunlight, so that species dependent upon deep shade can be screened out, since they would be unsuitable for planting in deforested sites.

One obvious index of seedling propagation is therefore proportion of seeds germinating in strong sunlight without any pre-sowing treatments necessary to break dormancy. Although these data are readily available, such an index would not take into account seedling mortality within the nursery. So a better index might be the number of seedlings of plantable size and quality produced per seed sown. It might also be desirable to take into account the length of time needed to grow the seedling to a plantable size. This, of course, can be greatly influenced by nursery management practices.

Raising seedlings by germinating seeds in a nursery is only one option for producing planting stock. Other options include sowing seeds directly into deforested areas and transferring seedlings dug up from the forest (wildlings) directly into deforested areas. Both these options do not require a nursery and could be ranked as easier and cheaper than germinating seeds in a nursery. Direct sowing of seeds, however, is likely to be severely limited to tough-coated seeds, since seed predation in deforested areas is often high (Hau 1996). A fourth option is to transfer wildlings into a nursery for growing on before planting out. Future research at FORRU will compare these options and score their effectiveness.

3. Ability to shade out weeds

The next most important characteristic is a seedling's ability to "capture" a site by shading out weeds. This will be a function of growth rate, lateral spread of the crown and crown density, all of which could be quantified. However, we suggest that it is better to measure weed suppression directly. During monitoring of the FORRU seedling planting trials, weediness around the planted seedlings is routinely scored using a fairly subjective scoring system of 0 = no weeds, 1 = up to 33% weed cover, 2 = 33-66% weed cover and 3 = 66-100% weed cover. One problem of devising an index of weed-suppression using these scores is that weed cover is highly seasonal. Any index, therefore, could either be based on mean weed scores over a complete annual cycle, or on weed scores at the end of the rainy season, when weed density is normally greatest. A suitable index for the weed-suppressing quality of the crowns of each species might therefore be...

$$1 - \frac{\text{Mean weed score at the end of the rainy season}}{3}$$

This index would need to be calculated as a mean of a cohort of seedlings of, say, 20+ individuals, at a given age. However, such an index might not become meaningful until the seedlings are several years old and have had enough time to have an impact on the weeds around them so it is debatable as to what the "given age" should be.

4. Inhibited natural seed dispersal

As mentioned above, it is a waste of resources to propagate and plant those tree seedling species which are already able to colonize deforested areas, by natural seed dispersal. Conversely planting should favour those species, whose absence from regenerating areas is explained by inadequate seed dispersal mechanisms. This is especially so in northern Thailand where most large seed-dispersing vertebrates have become extirpated in many protected areas, mostly due to hunting. Generally speaking, the larger the seed, the less likely it is to be dispersed into deforested areas and therefore the greater the need to include it in tree planting activities. A suitable index of inhibited natural seed dispersal might therefore be...

$$\frac{\text{Mean seed dry mass of species considered}}{\text{Mean seed dry mass of largest seeded species}}$$

An exception to this rule might be wind dispersed species with winged seeds. Since such species can generally disperse over long distances and are unaffected by the local extirpation of seed dispersing animals, it is suggested that they be given a score of zero. At FORRU a database of seed and fruit characteristics including dry mass is being compiled from sub-samples of seeds collected for germination trials, so the required data are readily available.

5. Ability to foster regeneration of other tree species

Although probably less important than seedling performance and propagation, the ability to foster the regeneration of a wide range of tree species should be included in the selection scoring system, if it is desirable for the planted forest to develop greater species richness than that provided by the actual trees planted.

Attractiveness to wildlife, particularly frugivores, is widely accepted as a desirable characteristic of planted trees, since wildlife will disperse the seeds of non-planted trees into the planted site, which, if they germinate and establish, will enhance tree species richness. This effect is probably the most difficult to quantify of the selection criteria considered here. There are three ways in which this effect might be quantified:

i) measure the density and species diversity of frugivores visiting different adult tree species;

ii) measure the density and species diversity of the seed rain, attributable to animal dispersal, beneath the canopies of remnant trees in deforested areas and

iii) measure the density and species richness of animal dispersed tree seedlings, naturally establishing beneath the canopies of remnant trees in deforested areas.

Of these 3 options, measuring the final outcome of wildlife attractiveness on forest regeneration (i.e. iii) seems to be the most logical, but it would require long-term observations beneath isolated trees in deforested areas. If such data were available, standard indices of species diversity, applied to the tree seedlings establishing beneath the canopies, might provide a useful index of each tree species' ability to foster the regeneration of seedlings of other tree species. Likewise, observations of wildlife visitations to different tree species and use of seed traps to measure the seed rain beneath the canopies of different tree species would also require very long-term studies and they are only indirectly related to the numbers and species of seedlings actually establishing beneath the canopies of the various tree species.

In the absence of such detailed data a general rough rule of thumb might be that if tree species produce fleshy fruits which are obviously attractive to generalist frugivores, some kind of positive score is assigned. At FORRU, no detailed studies of the type required for i) to iii) above have been carried out so far, although we hope to set up a sub-project to study seedling establishment beneath the canopies of isolated remnant trees in deforested areas within the next two years.

6. Rarity

If the purpose of forest restoration is to conserve biodiversity, the rarity of the species should also be taken into consideration. Some might argue that deliberately favouring rare tree species in planting activities would create an "unnatural" forest. However, rare species are mostly threatened by man's activities and therefore propagating and planting them would help to reverse an already unnatural situation. Making sure that rare tree species do not become extirpated or extinct is one of the most direct ways to maintain biodiversity.

The entire tree flora of Doi Suthep-Pui National Park has been entered into a computer database system at Chiang Mai University's Department of Biology Herbarium, based on the collections of J. F. Maxwell over the past 9 years. Within that system, species are scored subjectively for abundance on a scale of 0 to 5:

0	Probably extirpated
1	Only a few individuals, in danger of extirpation
2	Rare
3	Medium abundance
4	Common, but not dominant
5	Dominant

A suitable index of rarity might therefore be...

$$1 - \frac{\text{Abundance score}}{5}$$

SCORING SYSTEM

For all the above criteria, the aim has been to create a score with a minimum value of zero and maximum value of 1. However, it is clear that not all the criteria are of equal importance and therefore, before they are combined to give an overall suitability score, weightings must be applied. The exact weightings applied will vary according to the objectives of the tree planting activity. The following weightings are suggested as suitably matching the objectives of the FORRU project.

Criterion	**Weighting?**
Seedling Performance	5
Ease of seedling propagation	5
Ability to shade out weeds	4
Ability to foster regeneration of other tree species	3
Inhibited natural seed dispersal	2
Rarity	1

The final step is to combine the weighted scores. Summation is probably the most appropriate way the achieve this. Multiplication would exaggerate the differences between species and has the disadvantage that if any score is zero, the total score would also be zero, thus ignoring all other positive scores.

QUESTIONS ARISING

When dealing with large numbers of tree species, it seems sensible to attempt to quantify their various characteristics, so that valid comparisons can be made to provide a sound basis for species selection. However, the six-part proposed index outlined above requires a considerable amount of data. Collecting all the data will be a time-consuming, labor intensive and expensive process. So the main questions raised by this paper is:

Is this level of quantification justified or practically achievable?

Are there alternative, rough "rules of thumb" that could achieve similar results more economically?

Are all the criteria discussed really necessary? Should additional criteria be added?

Is the scoring system mathematically sound?

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