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FOREST REHABILITATION IN THE ASIA - PACIFIC REGION: PAST LESSONS AND PRESENT UNCERTAINTIES

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LAMB, D. & TOMLINSON, M. 1994. Forest rehabilitation in the Asia - Pacific region: past lessons and present uncertainties. This paper summarises the discussions at the Workshop on Rehabilitation of Degraded Tropical Forest Lands held in Brisbane in November 1991. Methods of reforesting certain kinds of degraded lands already exist but these are not sufficient for all cases, and also rely heavily on exotic species. Some of these techniques are reviewed and issues requiring resolution are discussed. Potential measures of likely success or failure of forest rehabilitation programmes are outlined.

Key words: Rehabilitation - degraded lands - reforestation - plantations - rural development - agroforestry - Asia-Pacific

LAMB, D. & TOMLINSON, M. 1994. Pemulihan hutan di rantau Asia Pasifik: pengajian lampau dan ketidakpastian kini. Kertas kerja ini meringkaskan perbincangan di Bengkel Pemulihan Tanah Hutan Tropika Ternyahgred yang telah diadakan di Brisbane pada November 1991. Kaedah-kaedah menghutan semula tanah ternyahgred yang tertentu sudah wujud tetapi kaedah-kaedah ini tidak memadai untuk semua kes dan terlalu bergantung kepada spesies eksotik. Sebahagian daripada teknik-tektik ini diulas dan isu-isu yang memerlukan resolusi dibincangkan. Langkah-langkah yang berpotensi untuk menjayakan atau menggagalkan rancangan pemulihan digariskan.

Introduction

Foresters have traditionally seen plantation establishment as the solution to forest degradation. Large areas of plantation are currently being established in the Asia-Pacific region (see, for example, World Bank 1991, WRI/UNEP/UNDP 1992), although it must be said that some of these plantations follow the clearing and burning of existing forests. Traditional methods of plantation establishment are not appropriate to all situations. In some cases the human population density is too high to allow the occupation of large areas of land for long periods for the sole purpose of producing timber. In these situations food production and cash crops with much shorter harvesting cycles are needed. In other cases lands are simply too degraded for normal production forests to be economically viable.

Traditional reforestation methods have also relied heavily on exotic species. It is clear that there are certain species such as teak (*Tectona grandis*) or genera such as *Acacia, Eucalyptus* and *Casuarina* that are extremely useful in many situations because of their simple or well-developed silviculture or because of their ability to grow rapidly in infertile soils. But it is equally clear that it may be unwise to rely too heavily on such exotics. The nature of future markets alone suggests it might be more prudent to include a greater diversity of species in reforestation schemes. There are also ecological advantages in avoiding extensive monocultures of a limited number of species.

Reclamation was defined earlier as meaning reforesting with an exotic species to stabilise a degraded landscape and increase its productivity (Lamb 1993). Many traditional reforestation schemes fall into this category. Landscape rehabilitation has a broader objective. Put simply, it is to increase productivity on degraded lands but to do so using native species wherever possible. It includes reforesting for wood production but may also involve agroforestry and nature conservation.

This report gives an account of a Workshop held at the University of Queensland, Australia in 1991 to discuss the Rehabilitation of Degraded Lands. The workshop sought to share experiences in forest rehabilitation in the Asia-Pacific region with a view to, firstly, identify what lessons had emerged from past experiences and, secondly, highlight those issues where uncertainties still remain.

We begin this account of the discussions by outlining what were generally agreed to be some necessary pre-conditions for the success of any rehabilitation programme. We then report on sessions dealing with requirements for tree planting at degraded sites, the silviculture of "high-value" indigenous trees, methods of rehabilitating severely degraded land, whether there are techniques for rehabilitating large areas of degraded land cheaply and, finally, methods of integrating forest rehabilitation and rural development. We then review some of the research problems deserving further study and conclude by considering possible criteria that might be used to assess the likely success or failure of a rehabilitation programme.

Some preconditions for successful rehabilitation

Degradation may have many causes and may take many forms. Before embarking on a rehabilitation programme it is essential that the initial causes of degradation be identified and corrected. Steps should then be taken to ensure that further disturbances leading to degradation do not recur during the rehabilitation process.

The first of these preconditions may be easy to achieve but the second will always be difficult. Socio-economic factors are often at the root of land degradation whatever the immediate cause might be. Technical agencies such as government Forestry Departments are often ill-equipped to deal with these. Such agencies should seek to involve specialists from the social sciences as well as silviculturalists and ecologists when it seems likely that socio-economic factors are responsible for land degradation. Fire is a particular problem and is only likely to be solved when local residents see it as being in their self interest to help prevent it.

Requirements for tree establishment on degraded sites

Irrespective of the species used, degraded sites are, by definition, difficult sites to reforest. In most cases it is necessary to modify the site in some way to achieve success. Extensive field experience in many situations has proven that, apart from the need for good planting stock, the single most important activity is early weed control. This must be maintained for at least several years until trees are well established. Other site modifications might include changing soil structure (by ploughing or ripping) or changing soil fertility (by fertilizers). Research is no longer needed to establish whether or not these factors are of importance, but adaptive local research will always be necessary to develop prescriptions and guidelines for local practice.

Cover crops have sometimes been used to facilitate the establishment of preferred tree species. These might be used to remove weeds, fix nitrogen, improve soil organic matter or change the microclimate to prevent insect attack. For example, certain of the Meliaceae (e.g. *Swietenia, Toona*) sometimes appear to be attacked less by the tip moth *Hypsipyla* when grown in shade than when grown in the open (Newton *et al.* 1993). A variety of cover crops have been used in different circumstances. In some tea plantations *Artocarpus* and *Erythrina* have been used as cover crops while *Leuceana* has been widely used in coffee plantations. There is much less agreement on the choice of species as cover crops in forest plantations. *Paraserianthes falcataria* has been used with some success in many situations. In Malaysia, *Peltophorum* and *Adenathera* appear to have been also useful. Species such as *Macaranga, Alphitonia* and *Acacia* are usually thought to be too fast growing to be good cover crop species and in north Queensland, Australia, a cover crop of *Acacia* seemed only to inhibit the growth of the timber species planted beneath. Similar results have been obtained in Malaysia. This is despite the fact that some *Acacias* occupy the early stages in many Australian rainforest successions.

An added difficulty is in knowing at what density the cover crop should be planted. The initial density might be high to "gain control of the site" and remove weeds. Thereafter wider spacings are probably necessary to allow the principal crop species to develop. There is little data, however, describing just what these initial subsequent spacing might be or how long the cover crop is required. One of the few published accounts concerns *Toona australis* (Meliaceae) under-planted beneath logged forest (Cameron & Jermyn 1991). These authors quoted recommendations that the basal area of the overstorey should be maintained at 30-35 m^2 ha^{-1} until four to eight years of age when it could be reduced to about 20 m^2 ha^{-1}. *Toona australis* is attacked by the tip moth *Hypsipyla robusta* and this schedule was believed to minimise these attacks and to allow a satisfactory log length to develop.

There is also no clear indication of whether it is better to plant the cover crop before the principal crop tree or at the same time. Much depends on the relative growth rates of the cover crop and under-planted species. Successes (and failures) have been achieved using both approaches.

Instead of altering sites it may be better to take more care to match species to sites. That is, instead of uniform monocultures covering entire landscapes it may be useful to partition the landscape more carefully and use more than one species, planting each in its most appropriate site. This will require methods of distinguishing and mapping site differences. Spatial modelling techniques using digital elevation models are now becoming available and may assist in this process (e.g. O'Loughlin 1986). These models use contour maps and soil data to construct three dimensional maps that show soil "wetness" and soil "fertility" (via indices) at any selected position. These can be used to choose appropriate species and optimum tree densities for various locations.

Silviculture of high value indigenous trees

Plantations established to replace natural forest areas are commonly composed of exotic species such as *Eucalyptus, Pinus* or *Acacia*. It is likely that the availability of many species presently supplied by natural forests will decline in future as their place is taken by species mostly suitable for the lower end of the market, such as those supplying structural timbers, fuelwood or pulpwood. It is possible, of course, to grow exotic high-value species such as *Swietenia macrophylla, Khaya* or *Tectona grandis* in plantations. But what of some of the native species currently commanding good prices in the market place? These species include some of the so-called cabinet species used for furniture or veneers, as well as food trees such as some of the nut trees (e.g. *Shorea macrophylla, Canarium* spp.). The identity of these higher value species will vary from place to place depending on local markets and local socio-economic conditions as well as on the international timber trade.

In the past there has not been a large incentive to use such species in plantation programmes because of the availability of further supplies from the remaining natural forests. In fact, in the case of timber trees the high rate of logging often meant that prices for these species have not changed much over the years. In addition, when these species were first tried in experimental plantations the growth rates were commonly much less than those of the exotics mentioned above. (It should be noted, however, that many of these early trials were established and maintained using techniques that would be regarded as sub-standard today.) But as the natural forest estate shrinks and the likelihood increases that yields from future cutting cycles will be less than those from initial cutting cycles, it seems probable that any disadvantage these species suffer in volume increment will be more than compensated for by an advantage in price increment as markets react to diminishing supplies.

The identity of many of these species is known, but much less is known about their autecology and silviculture, or about ways of incorporating these species into plantation systems. To that extent we have no lessons from past experience. It may be that these trees are no different than any other species; but it is likely some at least will require a more sophisticated silviculture than do *Eucalyptus, Pinus* or *Acacia*, including careful matching of species to site and perhaps also the use of cover crops or even mixed species plantings.

Although comparatively little work has been done on these species (but see Cameron & Jermyn 1991, Appanah & Weinland 1993), it is clear that there may be considerable genetic variability among them, and, at the very least, scope for exploring provenance differences as has been done for *Acacia, Pinus* and *Eucalyptus*.

Rehabilitation of severely degraded sites

When a severely degraded site is to be rehabilitated, a common objective is to stabilise the site to prevent further erosion and to increase its productivity, ideally to the point where it yields a commercially valuable product. This requires the diagnosis of limitations to plant growth (e.g. by soil analyses, pot trials or foliar analyses) and their correction as far as financial circumstances will allow. Species tolerant of the amended site should then be introduced. Past experience shows that various nitrogen fixing tree species often have an especially valuable role in this process. *Acacia* such as *A. mangium, A. auriculiformis* and *A. leiocalyx* have been successfully used in a number of situations. *Casuarina* such as *C. equisetifolia* and *Paraserianthes falcataria* may also be useful. These can be grown to stabilise the site or improve soil fertility. After harvesting, the improved site might be replanted with a more commercially valuable species, or the original nitrogen fixing species might be re-established in a second rotation. A common approach in many degraded sites has been to establish trials using a variety of species to determine which performs best under the prevailing circumstances.

In the particular case of sites degraded by mining there is overwhelming evidence that the task of rehabilitation can be made easier if rehabilitation is planned during the initial designing of the mine, i.e. before mining commences. In this way topsoils can be stripped and stockpiled ahead of mining, the disposal of any toxic tailings can be planned and the need to move large volumes of soils or tailings can be minimised. Topsoil conservation is especially important because these horizons contain most of the soil organic matter and a significant proportion of the readily available soil nutrients. A typical topsoil conservation practice is to strip off and save the top 15 - 30 cm. This can then be respread on the site when mining is complete. Ideally, the whole process of site rehabilitation becomes part of the mining process and is included in any cost/benefit analyses that are carried out to assess the commercial viability of a particular mine.

While rehabilitation of mine sites is often carried out in order to make productive use of the degraded land there are sometimes situations where the costs of this are simply too high. In such cases it may be preferable to aim at ecological stability rather than commercial viability. This has been the situation in a number of mine sites in geographically isolated parts of Australia. Under these circumstances reasonably successful rehabilitation has been achieved using broadcast sowing of native seeds immediately after cessation of the mining operation. These can be supplemented by planting seedlings of native species not easily established by direct sowing. Empirical trials are usually required to determine appropriate species and techniques. The significant seed pool of mostly native species contained in the re-used topsoils provide an additional conservation benefit.

Reforesting large areas of degraded land cheaply

Unfortunately there appears to be few examples of successful rehabilitation of large areas of formerly forested land at low cost. In all cases where large areas have been used the costs have been high. Direct seeding has been tested in some locations but its use is limited (e.g. to revegetate recently mined sites where plant cover is absent). In some situations the involvement of non-government organisations (NGOs) is important. The best option is to encourage the cooperation of rural communities actually living in the area and having a vested interest in the success of the operation. This is discussed further below.

A key approach is to make better use of naturally occurring secondary successions. This might be done by enrichment planting. Much degraded land is occupied by some form of secondary forests. The composition, biomass and productivity of these vary considerably but it is frequently the case that little is known about them or the rates at which they are developing. The issue is also discussed further below.

Integrating rehabilitation and rural development

Rehabilitation of degraded land requires recognition of the place of forests in the culture of each society, as well as awareness of the pressure for agricultural land. Grasslands, even *Imperata* grasslands, are not always viewed as wastelands (see, for example, Sherman 1980, Potter 1987). If the place of forests in the culture is not conducive to rehabilitation then some way must be found to overcome this if reforestation via plantations is still deemed preferable to, say, agroforestry. Heavy-handed attempts by government agencies to step in and rehabilitate degraded lands can often be counter-productive especially if rural populations believe they are unlikely to benefit directly and may even lose ownership or use of the land. In some cases further disturbances (e.g. wildfires) may occur which prevent rehabilitation.

A corollary of this is that rehabilitation objectives should be established in consultation with the rural communities. Some more traditional societies may prefer to continue with traditional land use practices. Other communities may have abandoned some of their traditional practices and be more inclined to consider a wider range of options. In the Solomon Islands, for example, some island communities have begun to develop cash economies based on crops such as copra, coffee or cocoa while others have decided to maintain subsistence economies with strict controls on tourism and little cash crop development.

In truly degraded lands the real difficulty may not be that the rural population is suspicious of government agencies or that their objectives are different from those of the government agencies, but rather that the whole process of degradation has left them in a situation from which it is difficult to escape unaided. For example, many of the able bodied men may have migrated from the area looking for work leaving behind a population of women, children and older people, often in poor health. This residual population may also have come to believe that their lands are totally unproductive and incapable of rehabilitation. That is, there may be little capacity or will to improve the situation. In these situations the role of silviculturalists must be to offer options for consideration and, where possible, to establish demonstration plots to show what might be done. Certain incentives may also be required such as the granting of land tenure, access to finance or help with marketing of crop produced on the formerly degraded lands. Where possible village institutions encouraging cooperation between individuals should be strengthened.

In all cases the rehabilitation process must yield economic or other benefits at a comparatively early stage and these benefits must be apparent and flow directly to the rural community. Benefits such as watershed protection (which primarily benefits downstream communities) or a timber harvest at some date, perhaps many decades away, are unlikely to be attractive solutions. In some cases it may be possible to use species having a traditional economic value or even religious significance (e.g. *Ficus*). Government agencies are often unaware of these species or their significance. Species used should also be suitable for existing or potential markets. Multipurpose trees may have an especially important role in these situations. Where the areas being rehabilitated are isolated from markets the harvested products should be of sufficient value to permit long distance transport. Some nut trees may be particularly useful in this respect. Not only does the tree remain after the harvest but the nuts have a high value to weight ratio and they are sufficiently robust to not require any special storage conditions, unlike, for example, certain fleshy fruits.

Agroforestry is the usual practice adopted when trying to satisfy the needs of a rural community as well as establish woody plants in a particular landscape. This term covers a very wide range of activities ranging from those where the tree component is small and scattered or is used as a temporary fallow to those where trees are a dominant feature and other plants such as food crops are temporarily present during the early establishment period or are an understorey component in a plantation forest. The choice of approach will be dictated by the degree of degradation present as well as the socio-economic circumstances. More work needs to be carried out to explore the many options available. This will be discussed further below.

Critical issues still remaining unresolved

The foregoing suggests that successful rehabilitation programmes could be achieved more cheaply and quickly if some of the existing knowledge was more widely used, but also that rehabilitation will improve with further research. Some of this research must deal with locally relevant topics such as methods of handling particular species' seeds and raising these species in nurseries, or dealing with particular weeds. There are also, however, a number of more generic problems that will continue to limit forest rehabilitation in the Asia-Pacific region. Some of these are listed in Table 1.

A key issue is species choice. Economic and ecological circumstances usually require that the species should be both commercially valuable and tolerant of often unfavourable conditions. If possible these species should also be easy to raise in large numbers in nurseries, should grow rapidly, be capable of coppicing and nitrogen fixation, tolerant of heavy pruning or pollarding, and resistant to fire, pests and diseases. A number of exotic species are widely used in rehabilitation programmes because they have many of these attributes. But ecological caution suggests it is unwise to continue to rely on such a limited species mix for all future rehabilitation efforts. The region contains some of the world's more diverse floral communities and it is inconceivable that there are not many indigenous species that might be usefully included in future rehabilitation programmes. Not only should these be identified and tested but efforts should be made to identify their environmental tolerances so that these species can be matched with the most appropriate sites.

A second critical issue is how to establish these species on degraded sites. In many situations traditional plantation establishment techniques might be satisfactory. But in some highly degraded sites a nurse crop might be necessary to ameliorate the site to allow the target species to be established. Certain trees may even require such a nurse crop in less degraded sites. Which species require such nurse crops and under what circumstances is this the case? Some argue that all species from late successional stages need some early shade to become established. Others argue that there is ample field evidence that this is not true. Are there certain physiological attributes that might be quickly evaluated to decide? Or are empirical field tests required? If some amount of cover is required, then the next question is how this should be provided and how should it be managed? There is much anecdotal evidence bearing on the question although not enough to devise guidelines or rules for any particular species. There may be considerable scope here to use a modelling approach based on models of tree growth that use simple physiological data.

An alternative to using temporary mixtures such as target trees beneath a short lived nurse crop might be to use permanent plantation mixtures. These are obviously more difficult to manage (how does one deal with species that grow at different rates? Will this mean one species is harvested before another leading to excessive damage to the residual species?). But mixtures may have some biological advantages especially in matters such as nitrogen fixation, pest and disease control. In an area containing naturally diverse forest ecosystems it is a topic deserving much more research.

One situation where some of the necessary research is already underway is in the related issue of establishing understorey crops such as pineapples, spices or rattans beneath a timber tree plantation. Much of this has been based on trial and error testing. Perhaps more work is needed to explore the ecological processes involved so that a more diverse range of species can be utilised.

Table 1. What don't we know? Issues deserving further research

Which species to use?	How to establish these species at degraded sites?	How to manage secondary forests?
(a) What indigenous species might be useful?	(a) Which species need nurse crops and why?	(a) What are the dominant species in these forests?
(b) Which provenances of these are best?	(b) How should this be provided?	(b) Which of these are economically useful?
(c) What are their precise habitat requirements?	(c) How much should be provided?	(c) What ecological services do these forests provide?
	(d) How long should it persist?	(d) How can these economic and ecological benefits be increased?
	(e) Should permanent plantation mixtures be used? If so, why?	(e) How might these secondary successions be hastened and biodiversity increased?
	(f) Under what circumstances might direct seeding be useful?	
	(g) What economically valuable plants might be used beneath a plantation canopy?	
	(h) How might these be established?	
	(i) Under what circumstances should new mycorrhiza be introduced in rehabilitation programmes?	

Mycorrhizae are common in forest soils in the region and are sometimes lost or depleted when degradation occurs. Little is known about the extent to which this happens and, hence, the need for reinoculation of mycorrhiza to ensure forest regeneration. Nor is much known about which mycorrhizae are the most appropriate species to use or how long these persist after a seedling is planted in the field. The topic is obviously one deserving much more research.

The third issue concerns secondary or regrowth forest about which surprisingly little is known. It is possible to generate lists of so-called secondary species that occur in the region (e.g. *Macaranga, Trema, Mallotus*, etc.) but much less is known about the relative proportions of these or the densities of those that have economic utility. Many of these forests provide considerable economic benefits to local populations but these often go unrecognised by government agencies and are rarely managed to ensure their continuance. Many secondary forests also provide a variety of ecological services such as watershed protection or species conservation. Again these are commonly unrecognized. Research needs to quantify these matters and examine how the economic and ecological value of these areas might be enhanced.

Finally, what is the role of animals in forest rehabilitation? How can they be used to facilitate increased biological diversity at degraded sites? In what situations can they inhibit successful rehabilitation? And what modifications to rehabilitation programmes are needed to create suitable habitats for a larger range of animals than might normally occupy a monoculture? Might comparatively small changes to reforestation schemes driven by economic imperatives give a disproportionate benefit in terms of maintaining regional animal diversity?

Measuring success

Much of the experience reported at the workshop was of the first attempts at land rehabilitation in new or difficult situations. A great deal remains to be learned about all phases of the rehabilitation process. This progressive change in management strategies requires great skill on the part of managers and silviculturists, and depends on accurate reporting on the condition of the forest at each stage of development. Because of the exploratory nature of much current work, it is unrealistic to expect a manager to be able to justify every action by reference to past scientific research. Therefore it is important that managers and silviculturalists spend sufficient time in the field observing the development of trees and crops, and also observing the way in which local people are able or prefer to interact with these new ecosystems.

It follows from this that methods of measuring likely success or failure are needed so that early adjustments or corrections are made to current practice if it seems likely that the defined objectives will not be met. The most obvious measures of success are that further disturbances cease and that the rehabilitation programme achieves its objective(s). Whether the objective is a tree monoculture, an agroforestry system or even a diverse, species-rich forest resembling the original ecosystem, this normally also involves a certain level of stability and sustainability. But most rehabilitation programmes may take some considerable time to achieve these end points. What is needed, therefore, is a set of criteria or targets appropriate for different stages of the programme, against which progress can be assessed. These criteria might be quantitative, such as a certain survival rate among planted trees, or they might be more qualitative and expressed as an index of some kind, for example that topsoil erosion is "low" (i.e. compared with that in undisturbed forest). Ideally these criteria should be simple to assess.

Some possible criteria are given in Table 2. These have been arranged in three groups: silvicultural or production indicators; ecological indicators; and socio-economic indicators. The specific form of these indicators should be tailored to specific sites or conditions. The indicators thus take the form of questions, the answer to which will indicate present conditions or trends.

The most critical of the silvicultural indicators is the extent to which planted seedlings survive. This is commonly measured within months of planting but might be also assessed at some later date (say after two years) which takes account of the ability of seedlings to persist in the face of weed competition. If this survival rate is acceptable, attention may then shift to growth rates, stocking levels, weeds, pests and diseases. Precise levels of each of these factors will depend, of course, on local circumstances and objectives.

Ecological indicators monitor a related but different set of factors. In this case the focus is more to do with biological diversity and ecological processes. The former is more important if some form of restoration is being sought while the latter might be of interest irrespective of the objective. Surface soil stability and the absence of erosion are of common concern in many situations, as may also be the levels of soil organic matter and soil fertility. In some situations the prime objective may be, in fact, to simply improve these to the point where some more production-oriented land use is possible. Target species are included because these alone can sometimes be indicators of success since their presence depends on many other conditions being appropriate. For example, a particular bird or plant may require a forest with a certain structure and species composition. In some cases these species may even be one of the objectives of rehabilitation.

Many of these silvicultural and ecological criteria may have relevance to the rural communities living in the vicinity of rehabilitation projects. Thus a vigorously growing forest on a formerly degraded hill slope may mean less erosion and fewer landslips affecting farming communities in lower valley floors. But dense tree plantings that may have been appropriate at an early stage of rehabilitation may be inappropriate at a later stage when the trees have more extensive root systems and are using more water. In many places the establishment of exotic tree plantations has resulted in water tables declining with obvious consequences for domestic, crop and irrigation water supplies.

The socio-economic indicators listed assess whether the human populations are likely to be sustained by the land and resource use patterns established by the rehabilitation programme. Perhaps the most fundamental of these is whether the populations are stable, decreasing (suggesting that resources are limited and are probably being over-exploited) or are increasing (suggesting that migrants might have been attracted to the area and that over exploitation may begin at some time

Table 2. Potential indicators for monitoring rehabilitation projects

Silvicultural/production indicators	Ecological indicators	Socio-economic indicators
Are seedling survival rates adequate?	Are the desired species present?	Is the local population stable?
Are the growth rates (e.g. basal area, height, volume) sufficient?	Are the numbers and diversity of plants and animal species appropriate?	Are market prices for commodities produced at the site relatively stable?
Are weed species under control?	Is natural regeneration occurring?	Are adequate food and fuel energy supplies available?
Is tree density appropriate for stand age?	Are appropriate nitrogen fixers present in sufficient numbers?	Is there an appropriate balance between food crops, cash crops and protective forest?
Are pests or diseases under control?	Are certain target species present (e.g. indicator species, keystone species, rare species, endemic species)?	Is consumption of fuelwood sustainable?
	Is the plant cover adequate?	Are economic benefits from rehabilitation accruing equitably?
	Is the soil surface stable?	Are external subsidies (e.g. fertilisers, weedicides, finances) still needed?
	Is the amount of soil organic matter adequate?	
	Is the quantity and quality of surface and ground water acceptable?	

in the future). Other sensitive indicators might be price levels for certain key commodities (e.g. rising fuelwood prices may lead to excessive tree felling) or whether external subsidies of finance or other resources are needed. (Successful rehabilitation implies price stability and a reduction in the need for external subsidies.) A particularly useful measure of success is the degree to which land use patterns are stable. In most situations it is likely that a certain part of the landscape should be protected by forest cover to stabilize watersheds and protect steeper slopes. If agricultural prices rise and lead to a replacement of this protective forest by subsistence or cash crops, further degradation may occur.

The indicators listed in Table 2 are not the only ones that might be used and relevant indices can be devised to fit different circumstances. It might be useful, for instance, to devise a measure of the extent to which land users are landowners or some index of the degree to which people have security of tenure. People with such security are likely to have a vested interest in long term measures to improve productivity. Whatever criteria are used they should be capable of giving early feedback to managers to permit adjustments to be made as early as possible.

Conclusion

There is an increasing need to reforest the expanding areas of degraded land that occur in most parts of the Asia-Pacific region. Techniques already exist to achieve at least some kinds of reforestation provided sufficient resources are made available. The problems are that these techniques are not suitable for all situations or all objectives and the necessary resources are not always available. A particular difficulty is that many of the existing reforestation techniques rely on exotic species, and result in plantation monocultures. Whatever economic advantages these offer (and economic benefits are obviously essential) such plantation do little to help conserve regional biodiversity, apart from possibly reducing the rate at which further natural forests are cleared.

More effort is needed to develop methods of rehabilitating the full spectrum of degraded lands that exist in the region and more research is required to make better use of indigenous species, recognizing that certain exotic species will always have a role to play in particular ecological or economic situations. Complete restoration of regional biodiversity may not be possible but plantations of native species, each matched carefully to its own particular site within a landscape, should offer greater benefits than do present practices.

As more carefully designed studies of rehabilitation are carried out in future there will be an increasing need to compile and share databases that record the experiences gained. The PROSEA (Plant Resources of South East Asia) project based at Bogor, Indonesia, is documenting some of the plant species available. What are also needed are more detailed descriptions of how these species perform in particular environmental conditions and management regimes, and more information on the extent to which these new forests provide habitats for other less commercially attractive biota.

Financial and other resources for forest rehabilitation may be a more intractable problem. Governments and private companies may be able to achieve a good deal if they wish. But more can probably be done if ways can be found to enable local communities to-participate and benefit as well. Demonstrations of what is possible and examples of successful approaches may have an critical role to play in this respect.

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