17. Environmentally sound timber harvesting

Logging guidelines, conservation reserves and rehabilitation studies

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Abstract. Timber harvesting guidelines formulated for north Queensland rainforests allowed economically viable harvests with minimal ecological impact. Harvesting procedures sought to minimize soil erosion, silting and turbidity in streams, destruction of trees in the residual stand, and disruption of natural habitats and processes. Forest officers selected the trees to be harvested, indicated the direction of felling, and supervised the design, construction and drainage of roads.

The long-term impacts of harvesting are not certain, so it is desirable to reserve some areas for conservation and monitoring. Existing data may help to indicate priority conservation areas, but errors and anomalies may be misleading. Some strengths and weaknesses of such data and techniques are discussed.

Degradation by soil erosion and weed infestation can be difficult and expensive to rectify. Without intervention, such areas may revert to high forest only after several decades, resulting in lost timber production. Reduced floristic diversity and inferior habitat for wildlife also imply substantial non-tangible losses. Rehabilitation may not be financially viable unless industrial plantations are feasible. Thus degradation should be avoided by adopting harvesting practices suited to the silvicultural characteristics of the forest, and by minimizing soil loss and invasion by weeds. In short, prevention is better than cure.

Introduction

Tropical forests are being exploited at an unprecedented rate, and deforestation now approaches 17 million hectares annually (Lanley et al. 1991). Often this exploitation is associated with conversion to other land uses, but sometimes the land remains within the forest estate. Such lands may be degraded by inappropriate harvesting operations which may cause soil erosion and weed infestation. This study looks at ways to minimize the impact of harvesting, and at some consequences of degradation caused by negligent logging and other disturbance. The prospects for rehabilitation are also considered.

Any logging, even environmentally sound logging, may cause changes in the forest, and it is desirable to set aside some areas for conservation, recreation and scientific study. Although guidelines for the design of such reserves are well established, procedures to resolve their placement are rather subjective, and this paper considers a number of objective ways to plan the location of such reserves.

The present study does not examine the merits of conserving tropical forests, or the consequences of harvesting them, as these aspects are covered adequately elsewhere (e.g. Poore and Sayer 1991). Rather, it examines ways to reduce the impact of timber harvesting and considers some of the resulting implications.

Harvesting guidelines

Natural forest management should be ecologically sustainable, economically viable and socially acceptable. Here I shall consider only the ecological aspects of timber harvesting. Any harvest (timber, fibre, fruit or exudates) from any forest (tropical or temperate) should be gathered in a way which minimizes environmental impacts. Four basic principles are necessary, but not always sufficient, to achieve this. These are to minimize soil loss, minimize silting and pollution of streams, minimize destruction of trees in the residual stand, and minimize disruption of natural habitats and processes. Of course, if the forest is to be converted to some other land use, only the first two of these principles are relevant. Thus an important prerequisite is a carefully formulated land use plan indicating the tenure,

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capability and proposed use for all land in the region.

Soil erosion can be reduced relatively easily, by not logging steep slopes, by locating and constructing extraction tracks with easy grades and adequate drainage, by minimizing soil disturbance, and by ceasing operations during periods of heavy rain. Tracks of exposed mineral soil should not be made to each log. Rather, the organic material of the soil surface (and any understorey plants) should be disturbed as little as possible. Winches, grapples and logging arches to lift the leading end of the log clear of the ground may help to minimize soil disturbance during extraction. Whilst these provisions are easy to define in principle, they are more complex to implement in practice. Blanket rules fail to take into account differences in soils and equipment, and a worse-case provision may be impractical. In the seasonal tropics, a wet season cessation of logging operations may be beneficial, but only if drains and culverts are maintained before and during the wet season. Soil erosion occurs not only during logging operations, but also following the cessation of logging. To minimize this erosion, it is essential to check drains and culverts on completion of logging, and to install cross-drains to intercept water running down roads and tracks. Silting of streams will also be reduced by these provisions, and can be further reduced by maintaining buffer strips along streams, and by using bridges and culverts (designed to cope with expected peak flow) rather than fords. Trees should not be felled into streams, and any obstruction to stream flow caused by logging should be cleared on completion of logging.

Productivity may be lost, not only through the physical loss of soil by erosion, but also through changes in soil structure caused by compaction, impeded drainage and destruction of the soil profile (e.g. bringing subsoil and rocks to the surface). Obviously, soil disturbance should be minimized, but it is not always clear if tracked or rubber-tyred machinery is preferable. Smaller specialist machines are preferable to general purpose heavy earth-moving machinery, and it is important that the blade be no bigger than necessary. However, in practice, it is usually not the machine but the operator who determines the extent and nature of disturbance, and training and incentives may do much to reduce impacts. Blanket rules are not sufficient. Rather, it is necessary for operators to understand the principles and intent of the guidelines, and to have the motivation to do a good job. This implies effective supervision, penalties for noncompliance, and performance clauses for contractors and purchasers. The harvesting guidelines used in north Queensland (available from the author) were based on these principles, were effective in these seasonally wet forests, and provided the basis for the ITTO Guidelines of Best Practice (ITTO 1990a; Bruenig 1991).

Tree felling and extraction also requires the skill and the will of operators to minimize destruction of trees in the residual stand. However, some blanket guidelines can be given. In Queensland, trained Forest Service staff marked and sequentially numbered all trees to be removed, and indicated the direction in which these trees were to be felled. The direction of felling was chosen so as to concentrate the crowns of felled trees into groups, and to avoid damaging trees required for the residual stand. The system of numbering trees and logs helps ensure that no merchantable logs are overlooked, and the sequential numbering makes it easier to find these logs. The CELOS system (Jonkers and Schmidt 1984) also required the preparation of maps showing the location of logs, to assist relocation and to minimize unnecessary travel by the skidder. In Malaysia, climber cutting a year or more prior to felling has also been shown to reduce damage to trees required for the residual stand. Care in extracting logs is necessary to avoid damaging the bark of trees in the residual stand, since such damage assists entry of disease and decay. Extracting short log lengths rather than tree-length sections helps reduce soil disturbance and damage to the residual stand. It is false to assume that shoddy logging operations are more profitable. On the contrary, good logging practices may reduce costs by US $8 per cubic metre harvested and reduced damage to the residual stand may yield a 30% increase in value of the next harvest (ITTO 1990b).

Whilst it may be a desirable aim to "minimize disruption to natural habitats and processes", this is perhaps the most difficult provision to satisfy. It is inevitable that any logging will alter the stand structure and likely that the relative species composition may be affected transiently if not permanently. The art of silviculture is to minimize the impact of such changes, and to promote the rapid development of a new stand with desirable characteristics similar to the original stand. Many "weeds" (I refer to exotic and indigenous plants capable of multiplying rapidly and dominating a site where previously absent or present only in small numbers; not to economic importance) including bamboo, some palms and many vines, are light-demanding, and too much disturbance may favour invasion and infestation by such weeds. These may form a stable subclimax and impede regeneration of tree species for many decades. Thus in many cases, minimal disturbance is the safest approach.

In parts of Africa, a "do nothing" approach has worked well. This method allowed logging of a single species with minimal disturbance and then protected the forest from all human disturbance until the canopy had recovered and the market sought a new species. However, this system was only successful where protection of the forest was assured, and adequate time elapsed between harvests.

Queensland foresters were fortunate to have valuable tree species which were relatively light-demanding and regenerated readily, and to have few problems with bamboo, vines and other weeds. Even in these forests, the minimal disturbance approach seemed to be the most reliable, and logging guidelines stipulated that not more than 50% of the canopy was to be removed in harvesting. In practice, canopy disturbance was often much less than this permitted maximum (e.g. Crome et al. 1992). The timber harvesting guidelines formulated for Queensland rainforests provided for (Vanclay 1990):

a) logging guidelines sympathetic to the silvicultural characteristics of the forest, providing for adequate regeneration of commercial tree species and discouraging invasion by weeds (principally climbing vines);
b) treemarking by trained staff who specified trees to be retained, trees to be removed and the direction of felling so as to retain vigorous advance growth, to harvest mature and defective trees, and to minimize destruction of the residual stand;
c) incentives for logging contractors to be trained and for appropriate logging equipment to be used, so as to minimize soil compaction, disturbance and erosion;
d) prescriptions to protect adequate stream buffers and steep slopes from logging;
e) sufficient areas for scientific reference, feature protection and recreation to be identified and excluded from logging;
f) for deficiencies in an evolving system to be recognized and remedied, leading to an improved system.

Many studies of the effects of logging in these forests have been published and collectively provide a unique demonstration of one possible approach to sustainable timber harvesting. These studies have investigated the effects on fauna (e.g. Crome and Moore 1989), flora (Crome et al. 1992; Nicholson et al. 1988, 1990), hydrology (Gilmour 1971) and soils (Gillman et al. 1985), and indicate that timber harvesting in accordance with the guidelines is probably benign and that any environmental effects are transient and localized. Simulation studies suggest that timber harvesting based on these guidelines would probably be sustainable in the north Queensland rainforests (Vanclay and Preston 1989; Vanclay 1990).

This silvicultural system is one approach which may be successful, but other alternatives also exist. The Malaysian Uniform System involved complete removal of the overstorey canopy in lowland dipterocarp forests, and where adequate regeneration existed, it provided good recovery and canopy closure by the commercial dipterocarp species (Wyatt-Smith 1963). Secondary forest may also regenerate satisfactorily after shifting cultivation, and this suggests another possibility. The success of regeneration following such cultivation seems to depend upon the same two factors: preventing soil loss and overcoming weed problems. Thus successful forest management will depend more on an understanding of stand and weed dynamics than on blanket prescriptions.

Conservation reserves

It is inevitable that timber harvesting will change the stand structure of the forest, and likely that the relative species composition may also be affected. These changes may be transient or permanent, and it is desirable to provide a monitoring capability to gauge the nature and effect of these changes. Reserves protected from harvesting provide an important benchmark for assessing the nature and extent of such changes. Such reserves are also important in providing a habitat for plants and animals detrimentally affected by logging, and may also provide a wilderness area for recreation. Whilst stream buffers and steep slopes may constitute a considerable area of forest estate from which logging is excluded, such a haphazard allocation of reserves is inadequate. Many reserves have been allocated on the basis of scenic beauty (i.e. waterfalls, viewpoints, etc.). This may be good from a recreational perspective, but is inadequate for conservation and monitoring. It is preferable to explicitly provide for the reservation of a representative area of each habitat.

This raises several questions: how do you define a habitat; what constitutes a representative area, and how big should it be? There are several established guidelines for the design of conservation reserves: for example they should be large, contiguous, with the perimeter small relative to the area (e.g. Diamond 1975). However, it is not easy to resolve where to put reserves, or how much of a forest should be reserved in this way. In practice these issues may be of little consequence, as practicalities such as effective management and protection may be the deciding factors. Prescribed percentages of each vegetation type may fail to consider the total area involved. For example, a tract of 50 000 ha of type Y forest has a different conservation need than the only (or last remaining) 50 hectares of type Z forest. Similarly, the area required is larger when the reserve is surrounded by intensive agriculture, than when it is the core area within a biosphere reserve surrounded by selectively logged forest. The only effective way to preserve species and habitats may be to create carefully located protected reserves within a large matrix of managed forest.

Shafer (1990) gave a comprehensive review of conservation design principles. Petocz (1989) considered the practical application of these principles in the preparation of an integrated conservation strategy for Irian Jaya. He summarized several key principles for the placement of conservation reserves:

- The entire altitudinal spectrum should be covered;
- All known centers of endemism should be protected;
- Representative cross-sections of each habitat should be included;
- Substantial tracts of lowland rainforest may be required to accommodate their rich floristic diversity and to provide for species occurring infrequently;
- Species requiring large areas should be accommodated by creating protected areas within a larger matrix of managed forest;
- Special consideration should be given to the protection of mangroves, vegetational transition zones, and commercial forest types;
- Habitats for migratory species require explicit attention;
- Breeding and feeding sites (including offshore islands and beaches) should also be considered.

It is important that attention is not confined to undisturbed or large tracts. Many habitats have been extensively disturbed, and some of these habitats now exist only as small, disturbed and degraded areas. Past disturbance may not reduce the conservation importance of a habitat, but rather may increase the importance of protecting the habitat to prevent further degradation, and to protect these remnants within the reserve system.

What information can be used to define habitats, representative areas and conservation reserves? Mackey et al. (1988) argued that three components were relevant: the biota (plants and animals), the habitat (environmental factors), and the niche (responses of the biota to these factors). Nix (1982) argued that complete niche specification was not necessary, and that it was sufficient to consider primary responses to the dominant environmental regimes; namely radiation, thermal, moisture, mineral nutrient and biotic. Thus Mackey et al. (1988) employed a digital elevation model, 23 bioclimatic attributes inferred from weather records, and geological survey maps to define bioenvironments in north Queensland. Their approach allowed objective identification of habitats without additional field survey work, but the design of reserves remains subjective. This approach does not utilize large amounts of prior information which commonly exists. Such data can be efficiently manipulated by Geographic Information Systems (GIS), and in theory, expert system principles could be used to objectively identify both the size and location of conservation reserves. Unfortunately, computer technology does not solve all the problems, and creates some new ones. Prior information is usually patchy, giving good coverage in some parts, and poor coverage in others, and this limits the inferences that can be drawn from such data.

One such source of prior information commonly available includes herbarium records (of flora, and equivalently, museum records of fauna). These may indicate locations of high species richness and of rare and/or endangered species. Unfortunately, most herbarium records are obtained by serendipity rather than from systematic surveys, and this negates the value of this data source. Reliable herbarium records could help to identify "hot spots", either specially rich in the number of species collected or with many records of a single rare or endangered species, but in practice may indicate more spurious locations than true hot spots. False hot spots of the first kind may occur when the recorded location indicates a place name (e.g. the nearest post office) rather than the actual site of collection. Other anomalies of this kind occur when collectors record latitude and longitude to the nearest degree rather than to degrees, minutes and seconds or precise grid coordinates. False hot spots of the second kind (i.e. many specimens of a rare plant) may occur at picnic areas and at easily accessible and well-known locations of "special" plants (e.g. monotypic endemic genera). These anomalies may occur when field trips are arranged for visiting botanists and taxonomists to show them places and plants of interest, and specimens are collected for both the visiting and host institutions, leading to (over time) multiple specimens in the local herbaria. If these anomalies are not rectified, the herbarium records may provide misleading inferences (e.g. may indicate hot spots outside the forested area). Forestry department and nature society records provide one possible avenue to verify official herbarium records, but pose another problem. State Forests may appear to exhibit richer flora than National Parks, and this may be attributed to the relative ease of access and of obtaining permits to collect specimens. But how much subjective editing of the herbarium database can be done before the database itself is no longer an objective record, but rather a subjective artifact of the editing process? What do you do with areas that remain uncollected? Clearly, if herbarium labels are to provide a useful database for inferring conservation significance, the reliability of each record must be encoded into the database. Thus the database must indicate if the specimen was collected during a systematic survey or otherwise, and must indicate the precision and reliability of the recorded location.

The Delphi survey technique provides a formal procedure to draw on, and collate the knowledge of experts in many disciplines (e.g. Schuster et al. 1985), and this approach may be used to identify areas of particular conservation importance. However, this too is not a panacea, but is subject to many limitations. Typically, respondents will vary from those with an intimate knowledge of a few specific areas to those who have an overview of the whole area, and even "experts" may find it difficult to reconcile other interests as diverse as their favourite study site or holiday location, to fears that publicizing sites would lead to exploitation (in particular, illegal collecting of orchids). This leads to the same problem: that of incomplete and incompatible data sets. Typically, the union of all key conservation areas so identified may encompass the entire region under consideration, whilst the intersection may be null. A workable compromise may require considerable subjective input.

Published maps of vegetation or forest types, of geology or soils, and of land tenure or disturbance may be available and should be considered in conservation planning. However, these different sources normally involve different scales, projections and editions of base maps, and introduce new problems in the form of "slivers" in the GIS. These slivers may indicate unusual transitional habitats important for conservation and research, or they may be anomalous and indicate the accumulation of small errors in the GIS. Anomalous slivers most commonly arise with vector-based GIS such as the popular ESRI Arc/Info system. Layers of information captured from independent sources may contain small errors in mapping or digitizing, and when these are overlaid or intersected, lines which should in reality form common boundaries do not line up in the GIS, but form these slivers. There is no way of knowing which of these slivers are real, and which are artifacts of the GIS. Some sensible decisions can be based on the width and area of these slivers, but these decisions are subjective and at best, repeatable but not objective. So do not get bogged down in technology, but use whatever medium is most readily available. If digital data and GIS are available, they will certainly be very helpful. However, if digital data are unavailable, it may be better and quicker to use transparent overlays than to try to digitize all the necessary data. Collate as much information as possible, but be critical of possible errors, especially with locations.

It seems that there is no objective and automated procedure to identify an optimal biosphere zoning for the conservation reserves, and it may be impossible to avoid subjective decisions, political expediency and gut feelings. However, this is not necessarily bad. Our ability to quantify ecology and habitat characteristics remains rather limited, and the subjective opinion of well-informed local experts, after careful consideration of the best available information, may provide a quicker, cheaper and better basis for conservation zoning than the most sophisticated computer technology which gives no guarantee of a good solution. It is also important to have a good understanding of what is possible; there is little point in proposing grand but impractical schemes which cannot be adopted, and it may be better to stick with the possible and strive for quick and effective implementation. There is little doubt that any proposal which satisfies Petocz's principles (1989), includes any remaining large areas still undisturbed, includes those areas with maximum topographic diversity, and encompasses as many habitats as possible in a single contiguous core area, will provide a good basis for a conservation system.

Rehabilitation

For much of the tropical forest, it is too late to pontificate on how to identify areas to set aside, and on how to harvest the forest in an ecologically acceptable way. For many forests, the damage has already been done. What can be done to help these forests? Some studies on rehabilitation have been made, and provide some guidance for rehabilitation of degraded forests. However, it is necessary to consider the scale of such rehabilitation projects. In Australia, volunteers have rehabilitated several small remnants (i.e. less than 100 ha) of rainforest by replanting and controlling weeds (especially vines, repeatedly until canopy closure). Restoration of a dipterocarp forest in Sarawak involved considerable inputs over only 50 ha (Miyawaki 1991; Mori 1991). At the FRIM Campus in Kepong (Malaysia), dipterocarps and other rainforest species have been re-established on mining spoil and abandoned vegetable gardens (Barnard 1954; Appanah 1991). Whilst these examples have been successful, these procedures cannot readily be applied to large tracts of forests in more remote areas. In many tropical countries, taungya systems (e.g. Evans 1982) which combine agricultural production with tree crops may be more feasible, but may not recreate a natural forest.

So what are the objectives of rehabilitation? Objectives may include enhancing timber production, preventing further soil erosion, restoring scenic quality, or restoring a natural ecosystem, and these may be conflicting. The most common forms of rainforest degradation include soil erosion on old extraction tracks, and the invasion and domination by exotic or indigenous weeds such as bamboo, palms and climbers. Procedures for ameliorating soil erosion are well documented and relatively easy to effect. Earth works to slow the speed of the water and to retain particulate matter can do much to alleviate soil erosion. However, weed control may require major intervention and the use of chemicals or heavy machinery, both of which may contribute other detrimental effects. In areas with good access, one financially viable option for bringing degraded forest back into timber production is to convert it into industrial plantations, but this introduces two problems: (1) substantial areas of bare soil may be exposed and liable to erosion during plantation establishment; and (2) most industrial plantations are monocultures, often exotic monocultures, which provide less diversity, and create a habitat for fewer plant and animal species than does the degraded forest. Mixed species plantations and agroforestry schemes may offer greater environmental and economic benefits, but may be financially less attractive for investors. Thus before embarking on a major programme of rehabilitation, the objectives and implications should be carefully examined.

In some instances, rehabilitation may be effected relatively easily if commenced sufficiently soon after logging. In Vanuatu and other areas in the Pacific, the vine *Merrimia peltata* is a serious problem following canopy disturbance, forming climber towers and impeding tree growth. However, it provides good cattle fodder, and grazing following logging can control the vine, provided that grazing pressure and duration are monitored to avoid damage to regenerating trees. Another means of control effective in trial plots of industrial tree plantations was to plant sweet potato, which occupies the site more quickly than *Merrimia*, displacing the latter, but which does not climb trees and is itself eliminated following canopy closure. Other short-lived pioneer shrub species may offer similar potential for controlling weeds through rapid canopy closure without excessive impairment of tree growth. Other species may also offer potential suppressing weeds, provided that they exhibit fast growth, small stature and do not climb the regenerating trees. Some legumes may be suitable, and offer the added advantage of nitrogen fixation.

A study of extensive areas of degraded hill dipterocarp forest in Peninsular Malaysia indicated that the opportunities for intervention were rather limited once woody or aggressive weeds were established (Silviconsult 1990). The most prevalent weeds were bamboo and bertam palm which are rather difficult to eliminate or control. Poisoning may not be effective as excessive canopy opening following death of the original weed crop could provide new opportunities for invasion by the same and other weeds. Enrichment planting may help trees to occupy the site more quickly, but the growth of these trees is slow relative to the growth rates of the weed species. Intervention may not be financially viable (Silviconsult 1990), except for industrial plantations on sites with good access and topography, and these may introduce other environmental problems. Where local people can be involved, agroforestry and community forestry may offer greater environmental and economic benefits, but this may not recreate a natural forest.

The moral of this study is that prevention is better than cure. Harvesting operations in forests prone to infestation by bamboo, palms, vines and other weeds should be carefully formulated to be silviculturally appropriate and to cause minimal canopy disturbance. On completion of harvesting in an area, sufficient drainage should be effected on all extraction tracks to minimize the danger of erosion. Careful harvesting is cheaper, more effective and more certain than rehabilitation.

Conclusion

Rehabilitation of degraded forest may be expensive, slow and uncertain. Once degraded, tropical forests may eventually rehabilitate themselves, but this may take many decades during which timber production may be negligible and the habitat value for other flora and fauna may be reduced. Intervention to hasten natural recovery may not be financially viable, and industrial schemes such as plantations may incur environmental costs. Agroforestry and community forestry schemes may offer greater potential where the local community is willing to participate, but should not be seen as a panacea as significant environmental costs may still be incurred. Clearly, prevention is better than cure. Thus harvesting operations should be customized to the silvicultural characteristics of the forest and, unless intensive silviculture has been proven, should strive to minimize soil and canopy disturbance. Drainage work should be undertaken on roads and tracks at completion of harvesting to prevent soil erosion.

It is inevitable that harvesting will change the structure of the forest, and possible that the species composition may also be altered, so it is desirable that some should be set aside as conservation and reference areas. These conservation areas should provide a representative sample of all forest types and habitats.

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