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Silvicultural intensification for tropical forest conservation

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Abstract. Minimizing the deleterious environmental impacts of logging and other silvicultural treatments is the primary conservation goal in tropical forests managed for timber production. While it is always environmentally beneficial to minimize unnecessary damage, more intensive silviculture should not be discouraged in tropical forests in which regeneration and growth of commercially valuable timber species requires such treatments. Failing to regenerate commercial species may render forests more susceptible to conversion to other, more lucrative land uses. Increasing the intensity of silviculture may also decrease the total area of forest exploited for timber, thereby reducing the impacts of over-hunting, timber theft, wildfires, colonization, and conversion, which are facilitated by the increased accessibility of logged areas.

Introduction

As long as there is demand for timber and profits to be made, logging will continue in the majority of tropical forests outside protected areas. Given that there are limits to the area of forest that can be totally protected, conserving tropical forest biodiversity will depend a great deal on strategies for protecting biodiversity in areas where timber is harvested (Boyle and Sayer 1995; Sayer et al. 1995; Dickinson et al. 1996; Mason and Putz 2001).

Excessive pre-occupation with minimizing the direct impacts of logging can inadvertently promote deforestation, at least where regenerating commercially valuable tree species requires more substantial disturbances than those typically caused by light selective logging. We recognize that many factors influence deforestation rates (see Kaimowitz and Angelsen (1998) and Wunder (2000) for reviews), but the presence or absence of substantial stocks of rapidly growing commercial trees must influence decisions about forest protection or destruction. And while not diminishing the direct effects of logging on tropical forest biodiversity, we also contend that the indirect or secondary impacts of over-hunting, timber theft, wildfires, colonization, and conversion, which result from the increased accessibility of logged areas, are even more threatening.

These observations lead us to recommend that conservationists insist that forest managers apply the least destructive silvicultural treatments needed to promote the regeneration and growth of the commercially valuable tree species being harvested. This recommendation may seem like no more than a familiar call for sustaining timber yields, but the required silvicultural interventions for meeting this goal may be of an intensity that makes some environmentalists uncomfortable.

The goal of minimizing impacts

The principal goal of most conservation efforts is to protect ecosystems and their components in their historical, classical, or pre-intervention states, hereafter referred to as 'natural', with full recognition of the substantial roles that humans have played in the shaping of most forests. Given this objective, it is not surprising that conservation guidelines for tropical forests managed for timber production emphasize the importance of minimizing the intensity and frequency of interventions so as to minimize deviations from the natural range of states of forest ecosystems. Guidelines for conservation-oriented tropical forest management that have been endorsed by environmentalists and conservation biologists have included minimizing changes in canopy cover, strict adherence to diameter cutting limits, minimizing damage to residual trees, and restriction of intrusive post-logging silvicultural treatments (Terborgh 1992; Frumhoff 1995; Grieser Johns 1997; Reid and Rice 1997; Rice et al. 1997; Bawa and Seidler 1998; Bowles et al. 1998; Frumhoff and Losos 1998). The assumption behind this minimal intervention approach to forest management appears to be that the more harvested forests retain the conditions observed immediately prior to harvesting, the more biological diversity and ecosystem functions will be retained. For example, if gap-phase dynamics typify a forest's disturbance regime prior to logging, then logging should mimic this process (e.g., Landres et al. 1999).

Management for minimum impact is unfortunately sometimes at odds with sustainable forest management (management of the forest for all goods and services, as well as maintenance of ecological functions), or at least with the more specific goal of sustaining timber yields. It is generally accepted that in addition to conserving biodiversity, conscientious forest managers should strive to ensure the sustained flow of timber and other forest products demanded by society. Sustaining yields requires that commercial species regenerate prior to or soon after timber harvests and that the trees grow rapidly enough to permit equal harvests of the same species in the future. For forests with abundant seedlings, saplings, and poles of commercial tree species present prior to logging, reducing the impacts of logging on the residual stand may be enough to sustain future timber yields. In contrast, regenerating many valuable timber-producing tree species in some forests requires larger disturbance than is typically created when minimal impact logging techniques are used and logging intensities are low (Gullison et al. 1996; Hall 1996; Snook 1996; Whitman et al. 1997; Fredericksen 1998; Dickinson and Whigham 1999; Dickinson et al. 2000; Fredericksen and Mostacedo 2000). Familiar examples include *Swietenia macrophylla* and *Cedrela* spp. in the Americas, *Entandrophragma* spp. in Africa, and *Shorea leprosula* in Asia. Additionally, some non-timber product species, such as Brazil nut (*Bertholletia excelsum*), appear to regenerate best in large gaps and other disturbed areas (Myers et al. 2000). On the basis of these observations it appears that forest managers are often presented with a dilemma: maintain pre-intervention forest structure (and presumably biodiversity) or sustain timber yields.

We submit that in many ways this dilemma is false and that the goals of sustaining timber yields and maintaining biodiversity in managed forests are not incompatible if there are judicious compromises between retaining forest structure and providing the microsite conditions necessary for regenerating commercial species. Furthermore, implementing this compromise does not imply a drastic shift from current forest management practices or unrealistic costs.

It is always important to minimize unnecessary perturbations during logging. Low-impact timber harvesting techniques, which are well known but unfortunately not often applied in the tropics (Putz et al. 2000), typically include directional felling of trees to minimize damage to future crop trees and to increase the efficiency of yarding operations, planning of logging roads and skid trails to minimize their length and width and to reduce erosion, and pre-logging vine cutting to reduce collateral damage caused by intertree vine connections. Typical logging, in contrast, is unplanned and carried out by untrained crews; the results include unnecessary damage to the soil and residual stand. These damages to the residual stand and soil also result in reduced future yields of merchantable timber (Pinard and Putz 1996).

The importance of minimizing the deleterious impacts of logging on tropical forests notwithstanding, it is sometimes necessary to create disturbances of substantial size and intensity to promote seedling establishment and to enhance growth of light-demanding commercial species. Additional silvicultural treatments such as weed control might also be required after logging. Under some conditions, even logging roads, skid trails, and log landings do not have adverse affects on regeneration. Although compaction of wet soil by logging machinery substantially impedes regeneration on skid trails (Malmer and Grip 1990; Pinard et al. 1996), where soils are dry during logging, skid trails are often densely colonized by commercial tree species (e.g., Snook 1998; Dickinson and Whigham 1999; Dickinson et al. 2000; Fredericksen and Mostacedo 2000). Soil compaction may in the future impede sapling growth in our study area in lowland Bolivia, but natural regeneration on skid trails in this area continued to grow well 4 years after logging (personal observation). Similarly, in logged areas of miombo woodlands in Zambia, colonizing farmers actually prefer log landings for planting crops (F.E. Putz, personal observation). Experimental studies in Bolivian humid forests also demonstrate better regeneration of commercial tree species in logging gaps after soil scarification by skidders compared to equally open unscarified areas (Jackson et al. 2002).

While enlarged logging gaps, soil disturbance, and post-logging silvicultural treatments are inimical to some species, the abundance and diversity of many wildlife taxa in Bolivia tend to increase in logging gaps up to 1000 m^2 compared to unlogged forest (Fredericksen et al. 1999; Fredericksen and Fredericksen 2002).

Similarly, Fragoso (1991) reported that in Belize, species such as Baird's tapir (*Tapirus terrestris*) use skid trails and logging roads relatively more frequently than trails through forest understories. At larger scales, such as the forest stand and landscape, it is still unclear what real ecological damage results directly from carefully conducted selective logging up to 50–80 m^3/ha, given the rapid rate of vegetation recovery in the tropics and the varied response of the many plant and animal species to logging disturbances (e.g., Cannon et al. 1998; Manokaran 1998). For example, although population densities of insectivorous understory birds typically decline after even low-intensity logging (Johns 1988; Thiollay 1992; Mason 1996), a wide array of other species increase after logging if hunting is controlled.

Examples of species that appear to benefit from logging include: tapirs (Fragoso 1991); frugivorous, nectivorous, and flycatching birds (Fredericksen et al. 1999), and even some primates (Johns and Skorupa 1987; for reviews see Grieser Johns 1997; Putz et al. 2001). At a larger scale, concerns about changes in regional biodiversity due to the proliferation of disturbance-adapted species (Frumhoff 1995) are probably only valid for landscapes where disturbance is already common. In landscapes with large tracts of undisturbed forest, regional species diversity is more likely to increase, not decrease, after logging due to increases in disturbance-adapted species that were relatively rare prior to intervention. Admittedly, disturbance-adapted species are often considered to be less desirable for conservation purposes than forest interior species. In any event, qualitative assessments of which species need to be conserved need to placed within the framework of local and regional conservation needs. All disturbance-adapted species are not necessarily weeds or otherwise undesirable for conservation purposes. Furthermore, many tropical forests, such as those in much of Amazonian Bolivia, do not resemble the tall and closed-canopied stands envisioned by many environmentalists. Instead, their canopies are somewhat open, they have recent histories of disturbance (fires and clearing for agriculture), and little difference in species composition can be detected between logged and unlogged areas (Mostacedo et al. 1998; Toledo et al. 2001). In general, there often appears to be a disconnection between what forest conservationists want to conserve and the histories of the forests under consideration.

Apart from direct impacts of logging on biodiversity, the highly selective logging promoted by many conservationists can place a high toll on the stocking of commercially valuable trees in the residual stand, reducing its value to the point where it may become susceptible to conversion to non-forest uses (Johnson and Carbarle 1993). Restricting harvesting to scattered trees that are larger than some minimum diameter is presumably based on the assumption that growth of small- and medium-sized trees in the small gaps opened by loggers will provide for future harvests. Unfortunately, these diameter limits are too often based on unfounded assumptions about the silvicultural requirements of commercial species. More likely, stand quality will decline following the familiar scenario known as 'high-grading' or 'creaming' (Smith et al. 1997), where large, well-formed, vigorously growing trees of the best species are replaced by the smaller, poorly formed trees of less valuable species that are left to inherit the stand. Apparently, the ‘gap-phase regeneration’ paradigm of tropical forest dynamics that was proposed in the 1930s (Aubreville 1938) and rose to domination in the 1980s (e.g., Brokaw 1982; Hartshorn 1989) is still being invoked by environmentalists concerned about the deleterious impacts of logging. The persistence of this paradigm is disturbing in the light of accumulating evidence for the importance of cataclysmic natural and anthropogenic disturbances in many tropical forests (e.g., Wyatt-Smith 1954; Lamb 1966; Snook 1996; Whitmore 1997). Furthermore, the recognition that many forests once considered ‘pristine’ developed after agriculture (e.g., Deneven 1992; Bush and Colinvaux 1994) should give advocates of a ‘gap-phase’ approach to tropical silviculture reason to reconsider the generalizability of this powerful paradigm.

In addition to a tendency towards dysgenic selection, lower diameter limits often restrict silvicultural and market options, especially when diameter limits are imposed subjectively and across all species. In some dry forests in Bolivia, for example, harvest of the most abundant commercial tree species, *Acosmium cardenasii*, is not economically feasible because trees develop hollow stems before they reach 40 cm in diameter, the minimum for logging.

Primary versus secondary impacts of logging

Regardless of how logging is conducted, its primary impacts often pale in comparison to its secondary impacts. In particular, increased road access invites more serious threats to the forest in the form of timber theft, hunting, colonization, and conversion (Johns 1985; Putz 1994; Frumhoff 1995; Robinson and Bennett 2000; Laurance 2001). Increased human intrusion into logged areas also implies a greater risk of wildfires ignited by humans (Uhl and Buschbacher 1985). Logged forests are also very prone to wildfire because of increases in temperature and fuel loads and decreases in relative humidity (Uhl and Kauffman 1990). Because secondary threats are generally more serious than logging itself, it seems logical that, rather than focusing primarily on minimizing stand disturbance during logging, conservationists should insist that governmental authorities help forest managers to address these secondary threats.

Although the risks of secondary impacts of logging support the importance of reducing the total areas logged and the total length of logging roads, there are other approaches to conservation that do not so strongly diminish the economic viability of forest harvesting or reduce the options available for forest management for timber. It seems reasonable, for example, to propose intensification of forest management in some areas in order to permit the retention of more extensive unlogged reserves. More intensive timber harvesting in smaller areas also increases the efficiency and reduces the costs of timber stand management. There are other ways to reduce secondary logging impacts that remain to be explored, such as gating and more permanently closing roads, using remote sensing to detect invasions by forest colonists, and developing fire protection plans.

Conclusions

Most forest products in the tropics are still derived from natural forests and not from plantations. Some forest products, such as durable and cabinet grade timbers, are unlikely to ever be produced in large volumes in plantations. Despite technical advances in our understanding of how to manage these forests, social, political, and economic forces often frustrate or overwhelm efforts to conduct sustainable forestry and to prevent deforestation (Buschbacher 1990; Boyle and Sayer 1995; Reid and Rice 1997; Rice et al. 1997; Bawa and Seidler 1998; Putz et al. 2001).

Natural forest management has been criticized, sometimes to the point of advocating unsustainable timber harvesting as an alternative; the liquidation of valuable timber to render tropical forests economically unattractive to further logging and available for purchase at low prices (Rice et al. 1997; Bowles et al. 1998; Frumhoff and Losos 1998). It should be noted, however, that the political, social, and economic forces that foster unsustainable forestry decrease the likelihood of effective protection of forests in demarcated reserves.

Because little of the world's tropical forest will be protected in national parks and other reserves, it is essential that conservation biologists strive to help forest managers minimize the primary and secondary impacts of logging (Whitmore 1997). Conservationists should not ask that the goals of sustained timber yield be abandoned in order that forests managed for timber look more like forest preserves. Perhaps a sounder long-term conservation strategy would be to reduce the focus on the short-term impacts of logging and pay more attention to managing commercially productive forests that are protected from wildfires and poaching and that are consequently unlikely to be converted to non-forest land uses. These managed forests will still retain a large proportion of their pre-harvest biodiversity, much more than would be retained if they were to be converted to cattle pastures, agricultural fields, or pulpwood plantations.

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