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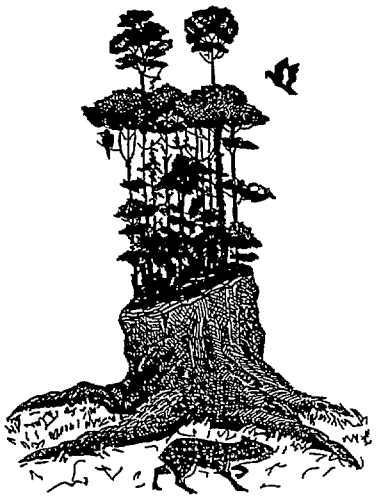

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LIMITATIONS OF LOW-INTENSITY SELECTIVE LOGGING FOR SUSTAINABLE TROPICAL FORESTRY

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Limitations of Low-Intensity Selective Logging for Sustainable Tropical Forestry

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EXECUTIVE SUMMARY

Low-intensity selective harvesting systems, especially those based on diameter limits are often attractive to foresters and conservationists because they maintain a high degree of forest cover while theoretically providing a sustainable flow of harvestable wood However, as currently practiced, highly selective harvesting requires human intrusion into large areas of undisturbed forest, gradually resulting in the drastic reduction of the most highly-valued species and often neither provides conditions appropriate for regeneration nor protects biological diversity Instead of evaluating the success or failure of harvests by their selectivity or loss of canopy cover, it would be more appropriate to evaluate the success of harvesting based on measurable standards of sustainability These standards may include the quantity and quality of regeneration produced and projections of future economic value that also predict the likelihood of areas staying in forest cover or being converted to non-forest uses

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SECTION I

INTRODUCTION

SECTION I
INTRODUCTION

Tropical forests contain more than half of the world's species and play important roles in stabilizing meteorological and nutrient cycles These same forests are also sources of highly valued products and the lands that they occupy are often under heavy demand for alternative uses In nearly all parts of the world, tropical forests are currently under intense exploitation and/or development pressure with a net deforestation rate currently exceeding 150,000 km^2 per year (Whitmore 1997) In response to this problem, forest managers, ecologists, and conservationists are struggling to provide answers to complex questions regarding how to protect forest biodiversity and the critical functions of these forests while maintaining a sustainable and financially profitable flow of forest products for human use

To date, the strategies most often employed to manage and protect natural tropical forests in many tropical countries include 1) identifying and setting aside areas (such as national parks and ecological reserves) where little or no human exploitation or disturbance is permitted and 2) practicing "minimum impact" logging, such as single-tree selection or selective harvesting often according to diameter limits on forests lands used for commodity production

There is little argument that setting aside a part of undisturbed forestland is important for the conservation of tropical forests, although the amount and specific areas necessary to be set aside is often in dispute (Frumhoff 1995) Ecological reserves can protect organisms sensitive to human disturbance and serve as indicators of natural and human impacts on ecosystems However, some believe that it is unlikely that sufficient land will be set aside in reserves in order to adequately protect biodiversity and maintain a sufficient level of other ecological services such as carbon sequestration (Johns 1985, Hanson et al 1991, Samson 1993 Frumhoff 1995) Therefore it will be important to depend upon lands managed for forest products to complement the functions of biological reserves

Management of tropical forests for wood and other products has involved a wide range of techniques including monoculture plantations clearcutting followed by natural regeneration agroforestry systems and single tree selection (Redhead and Hall 1992) However except for forests in the process of conversion to other uses low-intensity selective logging is the most common harvesting technique employed This technique typically involves harvesting only a few highly valuable species with selection often based on some minimum diameter limit (Buschbacher 1990) If logging is to occur in an area selective logging is often favored by foresters and conservationists because of its relatively low disturbance impact where a large amount of forest overstory cover is always maintained (Johns 1985 Frumhoff 1995 Rice et al 1997)

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It is important to note that most silviculturists differentiate between "selection" and "selective" silvicultural systems In selection systems, individual trees are selected for harvesting with the intention of maintaining sustained yield over time, which is the goal of natural forest management In contrast "selective" harvesting involves cutting selected trees based on economic considerations of stem size and/or quality without respect to sustained yield This type of harvesting is also referred to as "high-grading" and "creaming" (Redhead and Hall 1992) or "liquidation logging" (Dickinson et al 1996)

In this article, the literature regarding the impact of selective and selection logging of natural forests on sustainable wood supply and conservation of biological diversity in the tropics is reviewed, with a focus on studies conducted in the neotropics Although sustainability goals of selection and selective harvesting are quite different, both types of logging typically involve the clearing of individual trees without extensive removal of canopy cover The purpose of this article, however, is to point to real and potential problems with the nearly unilateral use of selective logging in the neotropics including frequent regeneration failures, deterioration of stumpage value increased access to post-logging human disturbance, and other negative implications for sustainability that may eventually result in increased deforestation due to conversion to more short-term profitable non-forest uses Modifications of, and potential alternatives to currently-used methods of harvesting are discussed

SECTION II

SELECTIVE HARVESTING IMPLICATIONS FOR REGENERATION AND SUSTAINED YIELD

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SELECTIVE HARVESTING IMPLICATIONS FOR REGENERATION AND SUSTAINED YIELD

In much of the neotropics, harvesting has been highly selective, focusing on the extraction of a few individuals of the most valuable species Most of this logging has taken the form of high-grading without attempting to maintain long-term sustainability of the harvested species The most common method is to locate large individuals of highly valuable tree species such as mahogany (*Swietenia macrophylla*), with tree finders who cut trails to individual trees which are then cut and skidded to the nearest logging road Secondary damage from these operations such as injury to surrounding trees and erosion due to poorly installed logging roads has been common (Uhl and Vieira 1989, Johns et al 1996) Eventually, marketable trees of valuable species are exhausted and loggers look for new less-valuable species to harvest in the area or move on to other yet unlogged areas There are many cases where this system of harvesting may prove to be unsustainable due to creation of conditions unfavorable for regeneration and gradual deterioration of forest stumpage value because of high-grading

A number of important neotropical tree species appear to have life histories that are incompatible with selective harvesting These include valuable timber species like mahogany, species important for wildlife, and non-wood product species Mahogany is a late successional gap-phase species that attains its most rapid growth with overhead sun and lateral shade (Lamb 1966) While intolerant of shade, seedlings can remain suppressed in the forest understory for many years In Central America the species is apparently adapted to large disturbances such as fire and hurricanes (Snook 1996) probably because mature trees of this species survive these disturbances better than other species Minimum cutting diameters are used throughout the range of mahagony to regulate cutting but despite their inherent appeal, they are not likely to be sustainable because of failure of recruitment into larger size classes (Snook 1996) The removal of large seed trees lack of seedbed preparation, and the failure of selective harvesting to provide sufficiently large gaps have apparently led to regeneration failure

Likewise in the Chimanes forest of Bolivia, Gullison et al (1996) studied the selective harvesting of mahogany which also resulted in relatively small gaps and little soil disturbance Very little regeneration was found except in areas which were flooded or where there was previous erosion of high terraces They concluded that with a proposed 30-year cutting cycle even if the companies obeyed the current 80 cm diameter limit set for the species and left 10% unharvested as seed trees harvesting would still result in eventual elimination of harvestable individuals of the species since commercial trees take an average of 105 years to reach 80 cm (Gullison and Hubbell 1992)

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In northern Belize, Whitman et al (1997) found that disturbance was relatively low at a site recently harvested for mahogany Canopy cover declined by only 2% and compacted soils covered only 3 8% of the area In addition, just 4 8% of trees and 1 9% of saplings were damaged for the whole area Despite this low damage, however, they concluded that this harvesting was not likely to be silviculturally sustainable because disturbance was probably insufficient to promote adequate mahogany regeneration

Although mahogany is a classic case, a large number of other valuable timber species appear to have similar ecological requirements as mahogany they need enlarged forest openings often accompanied by fire or soil scarification for seedling establishment For example, in the selectively-logged semi-dry forests of Lomerio, in eastern Bolivia, most of valuable timber species, including *Amburana cearensis*, *Cedrela fissilis*, *Centrolobium microchaete*, *Anadenanthera macrocarpa*, and *Machaerium scleroxylon*, only appear to regenerate well in more highly disturbed areas with higher light availability, such as on the borders of logging roads (Proyecto Bolfor, unpublished data) Meanwhile, in neighboring secondary forests, where indigenous peoples historically have cut large clearings in the forests and prepared crop sites for several years with the use of fire, abundant regeneration of many of these same forest species is typical (Proyecto Bolfor unpublished data) Indeed, tropical forests are resilient to disturbances on a much larger-scale than those produced by single treefalls, including shifting agriculture, hurricanes, fires and flooding (Brown and Lugo 1990, Attiwill 1994, Lugo 1995) Regeneration on more intensively logged areas is often excellent (Budowski 1988, Finegan 1992) For example, even areas which have been completely cut and subsequently abandoned are now regenerating into secondary forests Although often less diverse and aesthetically appealing than primary tropical forests secondary forests often contain valuable timber species and offer many of the same ecological services, including watershed protection, carbon sequestration, and habitat for wildlife (Budowski 1988 Brown and Lugo 1990, Finegan 1992) More intensive use of secondary forests may be a viable option for reducing pressure on primary forests (Bawa and Seidler 1998)

In addition to timber tree species fig trees (*Ficus*), considered to be a keystone resource for wildlife in undisturbed forests (Leighton and Leighton 1983, Terborgh 1986, McKey 1989 Lambert and Marshall 1991 Terborgh 1992) are likely to be dependent upon more intensive disturbance for regeneration than that provided by single tree selection Densities of many fig species increase in early successional forests where light availability appears to enhance regeneration (Milton et al 1982 Gautier-Hion and Michaloud 1989, McKey 1989) In a recent study of fig densities and regeneration in eastern lowland forests of Bolivia (Fredericksen et al in review), the highest rate of regeneration of four forest types was found on the most heavily harvested site and in locations characterized by high to moderate light availability and recent soil disturbance

Growing in the Amazon forests of Peru Bolivia, and Brazil, the Brazil nut tree (*Bertholletia excelsa*) is much valued for its edible nuts and provides nearly the sole source of livelihood for many local populations during the wet season (Mori 1992) Although there is evidence that indigenous peoples were responsible for its current distribution it is clear from several studies that there is a general lack of regeneration of brazil nut trees throughout its range

(Mori and Prance 1990 Richards 1993, Boot and Gullison 1995) However, a study by Boot and Gullison (1995) indicated that regeneration was more abundant in disturbed areas with higher light availability Myers (1997) also found that regeneration of Brazil nut trees, especially for saplings, was proportionally much higher in gaps > 30 m^2 Although not logged itself it appears that this species is also dependent upon larger areas of disturbance for successful regeneration and is not likely to regenerate in forests subjected to selective logging

It is likely that a lack of regeneration and the probable disappearance of valuable timber and non-timber species in many naturally managed forests in the tropics will not allow for the practice of low-intensity selective harvesting to continue indefinitely as the dominant type of logging At some point, these forests will likely lose too much of their value and will be converted to other non-forest uses In temperate forests, the long-term financial profitability of selective harvesting with low diameter limits (25-30 cm dbh) has been lower than monocyclic systems (Dwyer and Kurtz 1991, Lu and Buongiorno 1993) However it is uncertain if these results are applicable to tropical forests where diameter limits are currently much larger (40-70 cm dbh) Minimum diameter-limit cutting is likely to be less degrading if diameter limits are set high (Buschbacher 1990) However it is arguable that any system which specifically selects against the largest and best-formed individuals of the best species is prone to loss of economic value through negative selection

In spite of this, diameter-limit, selective logging systems are often used in developing countries, such as is the case in Bolivia, in order to control for sustainability of wood resources There are a number of reasons why these systems are attractive to forest managers in the neotropics Minimum diameter limits are easily understood by loggers as well as easily implemented and enforced by forest managers Moreover, they are perceived by some as producing a natural sustained flow of wood, large trees are harvested as they come into maturity leaving more growing space for smaller trees that will be harvested in the future In general single-tree selective systems, whether based on diameter-limits or not are perceived as emulating natural disturbances in tropical forests because selectively-harvested forests look more like natural forests than most other types of harvesting The forest remains more or less dominated by tree cover and trees felled by harvesting create clearings and somewhat similar in size and shape to those produced by natural treefalls The high percentage of canopy cover also protects watersheds from erosion, especially on steep slopes (Redhead and Hall 1992) From a vegetation management perspective, minimizing the size of clearings is important to discourage the proliferation of lianas and other weeds that might prevent or delay tree regeneration (Putz 1983 Lawton and Putz 1988, Buschbacher 1990, Webb 1997) Finally, selection harvesting is amenable to situations in tropical countries that focus on the supply of large-diameter high-quality sawtimber and where markets for small-diameter material are non-existent

Despite these positive aspects there are many difficulties inherent in low-intensity selective logging systems, especially for those based on diameter limits The biggest problem with selective systems is that they often degenerate into high-grading (Smith 1986) This felling system demands a high degree of skill to maintain species composition and size class distributions, especially in the tropics where light-demanding and shade-tolerant trees are often intermixed (Redhead and Hall 1992) High grading often results after successive rotations of

harvesting the largest trees (based on diameter-limits) of the best species In pure stands, high-grading may just eliminate the best individuals of one species, but in species-diverse stands, such as tropical moist forests elimination of species is often the result (Smith 1986) Diameter limit harvesting can also increase the possibility of eliminating seed sources for regeneration (Putz 1993) Seedling density is often correlated with the density of large-diameter seed trees and diameter-limit harvesting removes seed input unless special care is taken to leave seed trees (Plumptre 1995)

Other problems with selective harvesting include increased costs and incidental damage Because logging is spread out over a wide area, logging costs per m^3 harvested are increased over similar-scale operations that are more area-intensive (Redhead and Hall 1992) In addition, felling of mature trees needs to be skillfully applied to avoid damage to neighboring individuals Studies of logging damage caused by selective harvesting have varied considerably For example, Uhl and Vieira (1989) found that although only 2% of harvestable trees were logged, 26% of the remaining trees were destroyed or damaged and significant other damage was caused by skidding and logging road construction However, Whitman et al (1997) found that mahogany logging only directly affected < 13% of a recently harvested area in Belize It has also been shown that logging in tropical forests often increases their susceptibility to damaging fires due to increased fuel loads and increased human incursion (Uhl and Buschbacher 1985 Uhl and Kauffman 1990) Application of reduced impact logging methods will likely reduce the incidence of secondary harvesting damage, including damage to regeneration, in tropical forests in the future (Fox 1976 Heinrich 1995 Pinard and Putz 1996) However damage from selective harvesting is unlikely to be ever completely eliminated The question then arises whether to distribute this damage over large areas of forest, as in low-intensity selective or selection harvesting, or to confine damage to smaller patches of more intensively harvested forests Studies of biodiversity responses to harvesting appear to indicate that while logging is not necessarily incompatible with conservation goals, intrusion into undisturbed forests should be limited whenever possible

SECTION III

SELECTIVE HARVESTING IMPLICATIONS FOR BIODIVERSITY

SECTION III
SELECTIVE HARVESTING IMPLICATIONS FOR BIODIVERSITY

Studies of wildlife responses to logging have shown that a significant number of wildlife taxa or species, especially insectivorous birds (Johns 1985, Thiollay 1992 Mason 1996) decrease in abundance or disappear from forests following harvesting Because there are some species that are sensitive to even minor disturbances, the optimal method of biodiversity conservation would be to permit no intervention in forests (Terborgh 1992, Bawa and Seidler 1998) Indeed some disturbance-sensitive species are probably prone to any form of logging and their conservation will depend on the success of ecological reserves and not on the intensity of logging However, for areas under natural forest management, deciding how to carry out harvesting should depend on priorities for the conservation of locally important species Since not all plant or animal species require undisturbed or minimally disturbed habitats it is necessary to define what level of disturbance is permissible to retain species of management concern Unfortunately very little is known about logging disturbance thresholds for most plant and animals species

Evidence exists that harvesting may not always be inimical to most biodiversity conservation goals (Reid 1992 Sayer et al 1995) In fact, abundance and diversity of some wildlife groups may actually increase following logging (Johns 1985, Fragaso 1991) Although wildlife may flee areas during the actual period of logging, this loss may only be temporary provided that there are areas nearby to serve as sources of recolonization (Wilcox 1980) Once harvesting is completed many species of wildlife increase in harvested stands due to an increase in food availability, increases in structural diversity, and facilitation of movement through the use of trails and roads that constructed during logging In addition, increased light in disturbed areas may increase the availability of prey, fruit, or palatable foliage for many types of wildlife (Johns 1988)

A much more serious threat to biodiversity than periodic logging is permanent forest conversion that results in large-scale habitat elimination and forest fragmentation (e g Johns 1985, Uhl and Buschbacher 1985, Buschbacher 1990, Terborgh 1992 Bierregaard et al 1992) Wildlife and other forest products, such as palm hearts tend to disappear only after access is gained into forests by hunters and/or other extractors via logging roads Likewise habitat becomes unsuitable for forest-obligate wildlife not because of the mosaic of temporary forest clearings created by logging but when forest sections become isolated from one another by large areas that are kept clear of forest for crop agriculture, cattle-ranching, and human settlements If it is true that biodiversity is most threatened by human intrusion that is secondary to logging it may be preferable to attempt to reduce the rate at which new areas are logged by practicing more intense logging in areas currently being harvested

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SECTION IV

ALTERNATIVES TO SELECTIVE LOGGING

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There are many alternatives to low-intensity selective logging, many of which have proven successful in providing abundant regeneration One potential method of logging used in natural tropical forests to increase regeneration has been strip clearcutting This system has been applied experimentally in Brazil (Pitt 1961) and Peru (Hartshorn 1989, Ocana-Vidal 1992) where all trees are harvested in strips from 20-50 m wide Only a small fraction of the forest is strip cut each year, allowing the gaps to close The potential harvest cycle is 30 years The clear-felling in strips allows for adequate light to induce growth from advanced regeneration and adjoining uncut areas serve as sources of seed for additional recruitment of regeneration However, strip-cutting may sometimes promote proliferation of weeds (Putz 1993) and/or excessive regeneration of species with minimal commercial value at the expense of commercial regeneration Gorchov et al (1993) found that strip cutting in Peru led predominantly to the recruitment of *Cecropia* sp and other low value pioneers

Other alternative harvesting systems that may encourage regeneration and diminish species degradation are seed tree and shelterwood systems In these systems, a portion of the canopy is temporarily retained after harvest to provide additional seed to harvested areas while providing some shelter for species intermediate in their tolerance to shade After advanced regeneration is established, the remaining trees are harvested to provide additional light to regenerating trees The Trinidad Shelterwood System (Baur 1964) is one example that has been applied with some success One problem with clearcutting and shelterwood systems is that they are often inefficient and wasteful of resources in areas where markets are only available for a few species and where limited markets exist for small diameter material However, whether utilized or not, it may be desirable to fell or otherwise kill some unmarketable species to prevent them from obtaining dominance in the future stand

Finally selection harvesting can be implemented in ways that result in larger openings than single tree gaps Group selection appears to have been underutilized in the neotropics particularly in areas where market limitations discourage the use of monocyclic systems Group selection may retain the benefits of selective harvesting while providing the increased light to the forest floor and reduced root competition needed to stimulate regeneration Research is needed to test the feasibility of group selection systems as well as what other silvicultural treatments might be needed to prevent weed infestations in enlarged clearings

SECTION V

CONCLUSIONES

SECTION V
CONCLUSIONS

Low-intensity selective harvesting and diameter-limit systems are often attractive to foresters and conservationists because they retain a high degree of forest cover While appropriate under some circumstances, these harvesting systems should not be looked upon as the only option for natural forest management in the tropics As currently practiced, highly selective harvesting necesitates human intrusion into large areas of undisturbed forest, gradually resulting in the elimination of the most highly-valued species, and often neither provides conditions appropriate for regeneration nor protects biological diversity Despite their apparent low impact, it may also make little ecological or economic sense to encourage the widespread use of such systems if they compromise the future economic value of forests Instead of evaluating the success or failure of harvests by their selectivity, it would be more appropriate to evaluate harvesting based on measurable standards of sustainability These standards may include the quantity and quality of regeneration produced and projections of future economic value that predict the likelyhood of forests staying in forest cover or being converted to non-forest uses

Given that uncontrolled selective logging causes extensive residual damage and leads to the loss of disturbance-sensitive plant and animal species, it might be more ecologically attractive to practice more intensive forestry on a smaller land base, thus preserving more undisturbed forestland for use by wildlife A shift away from land-extensive selective harvesting will reduce forest access to poachers and settlers and may thereby mitigate damages to wildlife populations on more intensively harvested forestlands Under many circumstances, economic savings are also likely to be significant because logging costs will decrease dramatically with more land-intensive harvesting systems due to reductions in logging road construction and transportation costs

SECTION VI

BIBLIOGRAPHIC REFERENCES

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