Tropical Deforestation, Timber Concessions, and Slash-and-Burn Agriculture — Why Encroachment May Promote Conservation of Primary Forests

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Abstract

Conversion of forests for agricultural lands is the most important cause of deforestation in the tropics. For this reason it is often argued that conservation of tropical forests can only be successful if drastic measures are undertaken to protect the forest area from encroachment by shifting cultivators. In this paper we show that under certain conditions encroachment may also have beneficial effects for the conservation of primary forests, because the threat of encroachment acts as a "natural brake" on the pace at which concessionaires open up primary forest areas. Hence, while encroachment may inflict severe ecological damage on secondary forest areas, it may also promote conservation of virgin forests. The net effect of encroachment may be either beneficial or detrimental, depending on society's preferences with respect to conservation of primary and secondary forests.

Keywords: Agricultural conversion, conservation of primary and secondary forests, encroachment, timber concessions, tropical deforestation.

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Introduction

The rate of deforestation and forest degradation in tropical countries caused by human interference has been high and increasing over the past two decades. According to FAO (cited in Amelung & Diehl, 1992), deforestation, defined as the total removal of tree cover, has increased from 0.6% per year in the second half of the 1970s to 0.8% in the 1980s. This would indicate an increase in the deforestation rate of 30% in a decade. Myers (1994) states that the deforestation rate reached 1.8% in 1991, and he also asserts that the deforestation rate in 1994 must be even higher.

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Several types of economic activities are important causes of the depletion of forest resources: agriculture (shifting cultivation, permanent agriculture, cattle ranching), logging, mining and generation of hydropower. Of these causes, the agricultural sector is generally believed to be the single most important contributor to tropical deforestation: shifting cultivation alone is probably responsible for about 40 to 60% of total deforestation (Lanly, 1982; Brünig, 1989). Myers (1994) claims that shifting cultivators were responsible for 61% of total deforestation in 1989 and that this share appears to be rising over time. The timber industry is responsible for about 10% of total deforestation (Lanly, 1982; Brünig, 1989). As one course of action, many authors have concluded that encroachment must be stopped if efforts to combat deforestation are to be successful. Myers (1994) elegantly summarizes:

> *"A broad based approach is needed to overcome the economic, social, political and institutional marginalization of the shifted cultivator which would involve the redistribution of existing farmlands, reform of land tenure systems, build up of agricultural extension services, improvement of credit facilities and provision of agrotechnologies. ... The source problem is an amalgam of non-forestry problems, ... hence the overall problem [of deforestation] must be tackled largely through non-forestry measures" (Myers, 1994, p. 40).*

In this paper we analyse the differences between conservation of secondary and conservation of primary forests.[1] We demonstrate that a trade-off may exist between the two issues. The paper is organised as follows. In section 2 we briefly discuss the relation between encroachment and logging. We develop a model of encroachment in section 3, providing a numerical solution to illustrate the relation between the harvesting of primary forests and encroachment. The conclusions follow.

[1] Primary forests are forests which have not yet been touched by economic activity, while secondary forests are forests which have been disturbed at least once, for instance by selective logging.

The Relation between Encroachment and Logging

It is widely acknowledged that the issues of encroachment and commercial logging are not independent. Logging, for instance, increases the attractiveness of agricultural activity in the tropical forest area by providing access to previously inaccessible areas. The existence of a road network facilitates travelling into the forest and increases potential agricultural rents because of the increased possibilities to transport agricultural surpluses to local and regional markets (Grut, 1990; Grut *et al.*, 1991; Horta, 1991; Jepma, 1993; Southgate *et al.*, 1991). Furthermore, land clearing costs are lower on logged-over forest lands, because loggers have already removed some of the larger trees (Panayotou & Sungsuwan, 1994). For these reasons, some authors argue that logging encourages forest destruction through encroachment. In the words of Amelung & Diehl (1992):

> *The opening up by the forestry sector can only be regarded as the main source of forest disturbance, if it was clear that otherwise potential users face prohibitive costs of entering virgin forests. ... In countries, in which the share of shifting cultivators in deforestation is high, logging can be considered as a necessary first step of destruction by opening up forest areas (Amelung & Diehl, 1992, p. 120).*

There is empirical evidence supporting the claim that shifting cultivators use the logging sector to gain access to primary forest areas. Although the rate of deforestation caused directly by the logging sector is generally believed to be small (as indicated above), logging is the primary cause of forest modification.[2] More than 70% of the primary forest areas brought under exploitation are first degraded by the commercial logging sector (Amelung & Diehl, 1992). Furthermore, according to the FAO (cited in Sun, 1995), deforestation rates due to agricultural conversion are eight times greater in logged-over forests than in undisturbed forests. Barbier (1994) reports that in many African countries around half of the area that is initially logged

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2 Forest modification is defined as the conversion of virgin forests into productive closed forests or other forms of land use (Amelung & Diehl, 1992). Forest modification may be due to selective logging.

is subsequently deforested, while there is little, if any, deforestation of previously unlogged forest land.[3]

Tropical commercial logging typically involves a contract between the government, as the owner of the resource, and a private firm. The firm is granted the right to harvest and manage a certain parcel of forest for a specific period of time, a "concession". In principle, the concessionaire has the sole right to use the resource. In practice, however, control and monitoring costs to safeguard the area from encroachment are high. This implies that, once shifting cultivators have gained access to the forest, they will share its use. The effect of encroachment on logged-over forest areas is that under-aged trees or tree species that are currently not commercially interesting but potentially valuable, are removed. This implies that the forestry sector is confronted with a much younger, less valuable collection of trees for succeeding rounds of logging. For the concessionaire, this can be considered as a cost of opening up an area. Recognition of this will influence decision making. This effect will be illustrated more formally in the next section using a simple model.

THE MODEL

In order to highlight the effect of encroachment on degradation of secondary and primary forests, we make several assumptions. First, we assume that the impact of encroachment on the logger's decision can be adequately analysed by evaluating the optimal depletion time of the primary forest (T_1) and the secondary forest (T_2), respectively. The interpretation is that extending the depletion period is beneficial for nature conservationists because society can enjoy the stock and flow services provided by the forest for a longer time. Likewise, reducing the optimal depletion period corresponds with a less desirable situation. Obviously T_1 must be smaller than T_2. The specification of the objective function of the logger is as follows:

$$\text{Max}_{y_1 y_2}\, W = \int_0^{T_2} \left[P_1(t)\, y_1(t) + P_2(t)\, y_2(t)\right] e^{-rt}\, dt \qquad (1)$$

[3] For this to be true, woodlands must be excluded from the sample of African forests as access to these areas is relatively easy.

where P_i, i = 1,2 indicates the price of wood from primary and secondary forests respectively, and y_i represents the quantity harvested in forest type i. In the model, harvesting of primary forests is expressed in hectares whereas harvesting of secondary forest is expressed in biomass units. Our focus is on the size of area of primary forests, whereas incorporating the growth potential of secondary forests makes representing this stock in terms of biomass more logical. Apart from the fact that P_1 is a price per hectare and P_2 is a price per biomass units, prices for wood from primary and secondary forests may also differ due to, for instance, different species composition (Grainger, 1993). We assume that prices are exogenous to the individual logger, and that a maximum price exists. The discount rate r is assumed constant.

The equations of motion of the model will be explained next. With respect to harvesting primary forest, for which net growth is negligible, the model is an extension of the standard mining model (Hotelling, 1931; Dasgupta & Heal, 1979). It is assumed that all harvesting takes the form of selective logging,[4] and that encroachment is induced by commercial logging. No encroachment is possible unless the forest is first subjected to selective harvesting so there is no encroachment on primary forests.[5] Thus, the equation of motion of the stock of primary forest is simply:

$$\frac{dx_1(t)}{dt} = -y_1(t) \tag{2}$$

where $x_1(t)$ is the stock of primary forest, measured in hectares, and $y_1(t)$ is the area of primary forest selectively logged, also measured in hectares. Now turning to the

[4] As mentioned above, the share of the logging sector in deforestation is relatively small. Since the forestry sector is by far the most important source of forest modification, the explanation must be that after the first round of logging there is still some sort of tree cover present. Grut (1990) even asserts that selective logging is "a regime not much more interventionist than the regime of nature itself".

[5] This assumption is perhaps somewhat heroic, but it facilitates the formal analysis. The results will not be affected qualitatively if we would mitigate this assumption and assume instead that there is a difference in the speed at which slash-and-burn cultivators encroach upon primary and secondary concession lands.

specification of the second equation of motion, we need to make the translation from the area of primary forests to quantity of biomass in secondary forests. For this purpose we multiply the area harvested in primary forests by a conversion factor γ.[6]

To incorporate encroachment in the model we arbitrarily assume that encroachment can be represented as a destructive process beyond the control of the forestry sector that devastates β% of the stock of secondary forest in every period. This is an uncommon assumption, for which no empirical support exists. However, since encroachment is restricted to secondary forest area (x_2), damage due to agricultural conversion (S) is likely to be linked to the size of the forest that has been opened up for access. For any other model specification with $\partial S/\partial x_2 > 0$ similar results can be obtained. The current specification is chosen for mathematical convenience. The second equation of motion of the model is:

$$\frac{dx_2(t)}{dt} = \gamma y_1(t) - y_2(t) + (\rho - \beta)x_2(t) \tag{3}$$

where $x_2(t)$ is the stock of secondary forest measured in biomass units. Depleting the stock of primary forest implies accumulating a stock of secondary forest as is evident from the first term on the right hand side of (3). Next, $y_2(t)$ is the quantity of biomass harvested in the secondary forest and ρ is the (constant) growth rate of secondary forests.

Invoking the maximum principle and assuming an interior solution gives the following first order conditions:

$$P_1(t) + \gamma\mu(t) = \lambda(t) \tag{4}$$

$$P_2(t) = \mu(t) \tag{5}$$

[6] The constant is derived as follows. Assume that the biomass per hectare of undisturbed forests equals ψ_1 units, and that by law or custom yields per hectare are restricted to ψ_2 units. Now, γ is given by $((\psi_1 - \psi_2)/\psi_2)$.

$$\frac{\dot{\lambda}(t)}{\lambda(t)} = r \tag{6}$$

$$\frac{\dot{\mu}(t)}{\mu(t)} = r - \rho + \beta \tag{7}$$

In these equations, $\lambda(t)$ and $\mu(t)$ are the costate variables, akin to Lagrange multipliers, that measure the shadow price of the associated state variable, and $\dot{\lambda}(t)$ and $\dot{\mu}(t)$ represent the derivatives of these shadow prices with respect to time. The interpretation of (4) is that the marginal benefits of harvesting a unit of primary forest, measured as the sum of direct revenues and future harvests as a secondary forest, are equal to the foregone future timber benefits from leaving it as primary forest. Equation (5) states that marginal timber benefits from secondary forest should equal marginal cost of foregone future timber benefits. Equations (6) and (7) are non-arbitrage conditions: (6) is simply the Hotelling rule and (7) is an extended version of this rule that accommodates the growth of the resource (ρ) and encroachment damage (β). When we assume that the inverse demand functions are linear, i.e. $P_i(t) = \overline{P}_i - \alpha_i y_i(t)$, then substituting (6) and (7) in (4) and (5) and solving the differential equations, we get:

$$P_1(t) - \left(\overline{P}_1 + \gamma \overline{P}_2 e^{(r-\rho+\beta)(T_1 - T_2)}\right) e^{r(t-T_1)} + \gamma P_2(t) = 0 \tag{8}$$

$$P_2(t) - \overline{P}_2 e^{(r-\rho+\beta)(t-T_2)} = 0 \tag{9}$$

where $\overline{P}_i$, i = 1,2, is the backstop price for wood extracted from forest type i, which will be reached at $t = T_i$ because by definition at time T_i forest type x_i must be depleted and subsequently $y_i(T_i)$ equals zero. This also means that by integrating (2) and (3) and evaluating them at T_1 and T_2 respectively, we find:

$$x_1(0) = \int_0^{T_1} y_1(t)dt \tag{10}$$

$$e^{(\rho-\beta)T_2} \int_0^{T_2} \left[\gamma y_1(t) - y_2(t)\right] e^{-(\rho-\beta)t} dt = 0 \tag{11}$$

Note that by definition $x_2(0)$ equals zero. Substituting the linear inverse demand function in (8) and (9) and solving for $y_i(t)$, the optimal depletion periods can be derived (see Appendix 1).

The model is complicated and analytically solving it in order to illustrate the relation between T_i and β proves to be extremely cumbersome. Therefore, we resort to a numerical solution. Representative results are presented in Figure 1. The optimal time of depletion is on the vertical axis and β is on the horizontal axis.

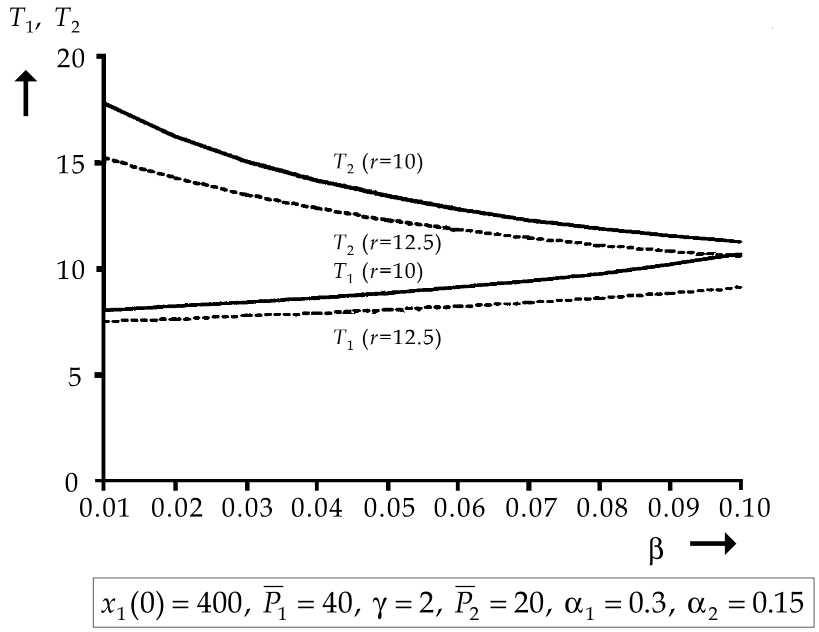

FIGURE 1. OPTIMAL DEPLETION TIMES OF PRIMARY AND SECONDARY FORESTS AS A FUNCTION OF ENCROACHMENT, FOR TWO DIFFERENT DISCOUNT RATES (r = 10% AND r = 12.5%).

The following observations apply. First, high discount rates (r) correspond with enhanced depletion of both primary and secondary forests. As is evident from Figure 1, optimal depletion periods for a high discount rate are always lower than for a lower discount rate (i.e., the T_i curve for r = 12.5% is located below the T_i curve for r = 10%). More importantly, however, is the trade-off between conservation of primary and secondary forests as encroachment increases: the higher β, the higher T_1 and the lower T_2. The T_1 path is an upward sloping function of β whereas the T_2 path is downward sloping.

The interpretation is that concessionaires want to avoid losing part of their stock to shifting cultivators. Encroachment thus can be considered as a sort of property tax on "owning" logged-over forest areas. Cutting back on encroachment losses can be achieved in two ways. First, by reducing the "supply" of secondary forest by harvesting less primary forest. Encroachment acts as a "natural brake" on the rate of harvesting in primary forests: supply is postponed such that encroachment damage is discounted (hence, $\partial T_1/\partial\beta > 0$). Second, by intensified harvesting of secondary forest areas in order to outrace the shifting cultivators.

The effects are twofold. First, during the depletion period of the primary forest the area of this type of forest will be greater if the threat of encroachment exists. Hence during this period amenity values will be higher, and biodiversity is greater when compared to logging not constrained by encroachment. The second effect is that the quality and quantity of secondary forest areas will deteriorate if more shifting cultivators move to the area. The shifting cultivators themselves will cause more direct damage and in addition the forestry sector will respond by increased harvesting. This may cause a change in species composition and will reduce biomass per hectare. A trade-off exists between conservation of primary forest and conservation of the quantity and quality of secondary forest. Depending on the preferences of the international community with respect to nature conservation, different weights are given to these effects. This implies that, on balance, the destructive process of slash-and-burn agriculture can be considered either beneficial or detrimental.

CONCLUSIONS

Encroachment by shifting cultivators on tropical forest concessions is generally considered a primary cause of deforestation. Drastic measures have been proposed in the literature to reduce the number of people who appear to depend on forest resources. Here we demonstrate that destructive conversion of forest areas for agricultural purposes is only part of the story. Under the assumption that encroachment is confined to accessible logged-over forest areas, encroachment has similar effects as a property tax on owning secondary forests. If the damage due to encroachment is positively related to the size of the secondary forest area, hence agricultural conversion increases as the area of accessible forest increases, then concessionaires will respond by reducing the rate at which they harvest primary forests. This implies that the net effect of encroachment is theoretically ambiguous and needs to be empirically determined.

Whether the moderating effect of encroachment on harvesting of primary forests described in this paper will be significant in practice remains an open question. The braking power of squatters is probably small relative to the overall desire of logging firms to enter new areas. Also, if loggers do not consider successive rounds of logging, for instance because concession rights are defined for a short period or because primary forests are more profitable to exploit and abundantly available, the "natural brake effect" will be negligible.

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APPENDIX 1:

From the first order conditions, the optimal extraction paths $y_1(t)$ and $y_2(t)$ can be determined:

$$y_1(t) = \frac{1}{\alpha_1}\left[\overline{P}_1 - \left[\overline{P}_1 + \gamma\overline{P}_2 e^{(r-\rho+\beta)(T_1-T_2)}\right]e^{r(t-T_1)} + \gamma\overline{P}_2 e^{(r-\rho+\beta)(t-T_2)}\right] \quad \text{(A1)}$$

$$y_2(t) = \frac{1}{\alpha_2}\left[\overline{P}_2 - \overline{P}_2 e^{(r-\rho+\beta)(t-T_2)}\right] \quad \text{(A2)}$$

The two equations which simultaneously determine T_1 and T_2 are derived by solving equations (10) and (11), using the optimal extraction paths (A1) and (A2). Solving (10) yields:

$$\alpha_1 x_1 = \overline{P}_1 T_1 - \frac{1}{r}\left[\overline{P}_1 + \gamma\overline{P}_2 e^{(r-\rho+\beta)(T_1-T_2)}\right]\left[1 - e^{-rT_1}\right] + \frac{\gamma\overline{P}_2 e^{-(r-\rho+\beta)T_2}}{(r-\rho+\beta)}\left[e^{(r-\rho+\beta)T_1} - 1\right] \quad \text{(A3)}$$

Furthermore, solving (11) yields:

$$\frac{\alpha_1\overline{P}_2}{\alpha_2\gamma}\left[\frac{1}{\rho-\beta}\left(1 - e^{-(\rho-\beta)T_2}\right) - \frac{e^{-(r-\rho-\beta)T_2}}{r-2\rho+2\beta}\left(e^{(r-2\rho+2\beta)T_2} - 1\right)\right]$$
$$= \frac{\overline{P}_1}{\rho-\beta}\left(1 - e^{-(\rho-\beta)T_1}\right) + \frac{\gamma\overline{P}_2 e^{-(r-\rho-\beta)T_2}}{r-2\rho+2\beta}\left(e^{(r-2\rho+2\beta)T_1} - 1\right)$$
$$-\left[\overline{P}_1 + \gamma\overline{P}_2 e^{(r-\rho-\beta)(T_1-T_2)}\right]\frac{e^{-rT_1}}{r-\gamma+\beta}\left(e^{(r-\rho+\beta)T_1} - 1\right) \quad \text{(A4)}$$

By solving these two equations simultaneously in GAMS, the optimal depletion times of primary and secondary forests are determined.