Forest Resource Management and Alternative Incentive Mechanisms: Controlling Deforestation in the Philippines

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Abstract:

A dynamic model of deforestation and agricultural expansion in the Philippines is developed to elucidate the economic factors driving current land use trends and determine the efficacy of prevailing forest regulations, by quantifying trade-offs between status quo and social optimum resource use. Model results indicate intervention areas for improving public forest management.

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Background

The rate of deforestation in the Philippines is among the highest in the world. Since 1950, forested acreage in the Philippines declined by 61%, falling from 15 million to 5.7 million in 1995. The destruction of the country's forest resources has been blamed primarily on two factors, the profitability of tropical hardwood logging and the demand for agricultural land, which diminished the contributions of the forestry sector to the economy and caused serious environmental damage, notably soil.

Philippine forest land is under government ownership. Access, extraction, and management of forest resources have been delegated to the private sector primarily through leasehold contracts called concessions or timber license agreements. Concessions are limited to a 25-year tenure and can be renewed once. Concession tracts range from 10,000-100,000 hectares and are heavily regulated.

The timber licensing system was invoked to regulate utilization and promote sustained yield of forest resources, however, with timber harvesting cycles for dipterocarp[1] forests averaging between 30-40 years, the 25-year tenure

[1] The dominant family of timber trees found in the tropical rain forest of Southeast Asia (Bee 1993). In the Philippines, dipterocarp forests comprised 3.85 million hectares (67% of total forested area) in 1993 and are primarily of the mahogany tree species, which include red lauan, tanguile, tiaong, white lauan, almon, bagtikan and mayapis, the apitong group, and the yakal group (Forest Management Bureau 1994).

arrangement appears to be too short. Concessionaires maximize short-term profits resulting in overharvest. In addition, since the license is specific only to timber harvesting benefits, concessionaires are unable to capture benefits from the land tract beyond timber production. Further, the lease allows migrant farmers, fuelwood gatherers, landless lowlanders, and the poor population to compete with concessionaires for timber resources. Corrupt local officials and forestry personnel profit heavily by overlooking lease violations. These foster individual profit maximization behavior and unsustainable forest management (Hyde and Newman, 1991; Paris and Ruzicka, 1991).

A dynamic model of timber production, land use, and soil erosion is developed to determine the optimal rates of timber harvest, deforestation (or afforestation), conversion to agriculture, and transition time to steady state. Environmental amenities such as the soil retention capacity of forests is expressed as a function of forested acreage, age of the stands, and land use. Production functions are estimated with ordinary least squares. Estimation of the foregone opportunity costs from current forest use is then estimated from simulation of the optimal and status quo paths of forest harvest and conversion using nonlinear dynamic optimization. Model results are discussed in terms of corrective policy measures to increase efficiency in resource use.

Theoretical Model

Consider a region with a fixed area of land Γ that is homogeneous in terms of its biological and physical properties, and is an input in forest and agricultural production. Forests yield marketed benefits from timber Y, which occur periodically when trees are cut and sold, and nonmarketed amenities from standing trees N, which occur annually as a continuous flow of service. Agricultural benefits Z accrue from the annual production of crops. The social planner is faced with the problem of allocating land between these two competing activities.

The discounted sum of net revenues from successive harvest cycles of a single-aged forest stand is

$$(1) \quad Y = \sum_{i=1}^{\infty} \left[\frac{(P-C)V(l_i)(1+r)^{-(l_i)} - D}{(1+r)^{T_i}} \right] F_i$$

where C: harvesting cost

D: planting cost

F_i: forest land area planted with trees on the ith rotation

i : rotation index

l_i: rotation age

P: timber price

r: annual real discount rate

T_i: harvest date of the ith rotation

$V(l_i)$: yield function of marketable timber on the ith rotation

Y: present value of net revenues from timber harvest

Price P, harvesting cost C, and planting cost D, are constants. Timber yield V is assumed to be a quasi-concave function of rotation age l_i . This implies that V increases at a diminishing rate as l_i increases. Formally,

(2) $$\frac{\partial V(l_i)}{\partial (l_i)} > 0 \qquad \frac{\partial^2 V(l_i)}{\partial (l_i)^2} < 0$$

If we assume that steady state will be achieved in some future time, the above equation may be rewritten in two parts: an initial transition phase, which eventually converges to steady state after k rotations (Hardie, Daberkow, and McConnell, 1984). Prices as well as harvesting and planting costs are also expected to increase at a constant annual rate of g , s and m, respectively. The discounted net benefits from timber production is

(3) $$Y = \sum_{i=1}^{k} \left\{ \frac{\left[P(1+g)^{T_i} - C(1+s)^{T_i} \right] V(l_i)(1+r)^{-l_i} - D(1+m)^{T_i}}{(1+r)^{T_i}} \right\} F_i + \left\{ \left\{ \left[\frac{P(1+g)^T}{(1+r)^T - (1+g)^T} - \frac{C(1+s)^T}{(1+r)^T - (1+s)^T} \right] V(L)(1+r)^{-L} \right\} - \frac{D(1+m)^T}{(1+r)^T - (1+m)^T} \right\} F$$

where $l_i = L$ for $i \geq k+1$

$F_i = F$ for $i \geq k+1$

$T_i = T$ for $i \geq k+1$

Rotation age L, forest area F, and harvest date T, are constants because at steady state, rotations are of equal length and forest area is the same for each rotation.

Environmental amenities N, such as soil retention are specified in terms of age of the stands j_i and forested acreage F_i, as shown below.

$$(4) \qquad N = \sum_{i=1}^{\infty} \sum_{j_i=1}^{l_i} \left[\frac{\phi \eta\left(j_i, F_i\right)(1+r)^{-j_i}}{(1+r)^{T_i}} \right] F_i$$

where ϕ: amenity price

The amenity production function η is positively dependent on j_i and F_i, subject to diminishing marginal productivity. These characteristics are reflected in the first and second derivatives as follows

$$(5) \qquad \begin{array}{ll} \dfrac{\partial \eta\left(j_i, F_i\right)}{\partial\ j_i} > 0 & \dfrac{\partial^{\,2} \eta\left(j_i, F_i\right)}{\partial\ j_i^2} < 0 \\ \dfrac{\partial\ \eta\left(j_i, F_i\right)}{\partial\ F_i} > 0 & \dfrac{\partial^{\,2} \eta\left(j_i, F_i\right)}{\partial\ F_i^2} < 0 \end{array}$$

Following Equation (3), environmental amenities are also expressed in two parts: before and after steady state. Amenity price is also assumed to increase at a constant annual rate of o. The adjusted net present value from non-timber benefits is

$$N = \sum_{i=1}^{k} \sum_{j_i=1}^{l_i} \left[\frac{\phi\ (1+o)^{T_i}\, \eta\left(j_i, F_i\right)(1+r)^{-j_i}}{(1+r)^{T_i}} \right] F_i + \sum_{J=1}^{L} \left[\frac{\phi (1+o)^{T} \eta\left(J, F\right)(1+r)^{-J}}{(1+r)^{T} - (1+o)^{T}} \right] F \quad (6)$$

where $j_i = J$ for $i \geq k+1$

Aggregate net benefits from forestry $\Im$ at any given time is the sum of timber and amenity benefits, which is written as

$$\Im = \left\{ \sum_{i=1}^{k} \frac{\left[P(1+g)^{T_i} - C(1+s)^{T_i}\right] V(l_i)(1+r)^{-l_i} - D(1+m)^{T_i}}{(1+r)^{T_i}} + \sum_{i=1}^{k} \sum_{j_i=1}^{l_i} \frac{\phi\,(1+o)^{T_i}\,\eta(j_i, F_i)(1+r)^{-j_i}}{(1+r)^{T_i}} \right\} F_i$$

(7)

$$+ \left\{ \left\{ \left\{ \left[\frac{P(1+g)^T}{(1+r)^T - (1+g)^T} - \frac{C(1+s)^T}{(1+r)^T - (1+s)^T} \right] V(L)(1+r)^{-L} \right\} - \frac{D(1+m)^T}{(1+r)^T - (1+m)^T} \right\} + \sum_{J=1}^{L} \frac{\phi\,(1+o)^T\,\eta(J, F)(1+r)^{-J}}{(1+r)^T - (1+o)^T} \right\} F$$

Equation (7) shows the discounted sum of forest net benefits from a series of rotations, starting from the sequence prior to the steady state (i^{th} to the k^{th} rotation), and continuing on to steady state, which begins with the $k+1$ rotation.

The other activity in our model is agriculture, which is represented by palay[2] production. The discounted net benefits from palay production is

(8) $$Z = \sum_{i=1}^{\infty} \sum_{t_i=1}^{T_i} \frac{BQ(A_i) - G}{(1+r)^{t_i}} A_i$$

[2] Filipino term for unhusked rice.

where A_i: land area devoted to palay production on the i^{th} sequence (rotation)

B: palay price

G: palay production cost

i: sequence index

$Q(A_i)$: palay yield

r: annual real discount rate

t_i: time

T_i: number of years in the i^{th} sequence which coincides with the harvest date for trees

In this model, palay production Q increases at a declining rate with positive changes in palay land area A_i. Mathematically, this is expressed as

$$(9) \quad \frac{\partial Q(A_i)}{\partial (A_i)} > 0 \qquad \frac{\partial^2 Q(A_i)}{\partial (A_i)^2} < 0$$

This is because A_i increases from a reduction in forest area F_i, which is rich in organic matter and nutrient content, thereby, enhancing palay yield. However, as deforestation proceeds, marginal forest lands are released to agriculture, which adversely affects production (Ehui, Hertel, and Preckel, 1984).

As with forestry investments, revenues from palay production may be expressed as having a transition and steady state sequence. Steady state is achieved if the change in palay land area from sequence $i-1$ to i, A_i' equals zero, such that succeeding land areas devoted to agriculture are the same for each interval. In our model, steady state occurs after the k^{th} sequence. Palay price and cost grow at an annual rate of u and d, respectively. The present value which incorporates these adjustments in growth is

$$Z = \sum_{i=1}^{k} \left\{ \frac{B(1+u)\left[(1+r)^{T_i} - (1+u)^{T_i}\right]}{(1+r)^{T_i}\left[(1+r)-(1+u)\right]} Q\left(A_i\right) - \frac{G(1+d)\left[(1+r)^{T_i} - (1+d)^{T_i}\right]}{(1+r)^{T_i}\left[(1+r)-(1+d)\right]} \right\} A_i + \left\{ \frac{B(1+u)}{(1+r)-(1+u)} Q(A) - \frac{G(1+d)}{(1+r)-(1+d)} \right\} A \qquad (10)$$

The first term on the right hand side of the equation represents the present value of an annuity that terminates after the k^{th} sequence, and the second term represents the present value of a perpetual annuity that begins after the k^{th} sequence.

Efficient long-term management of forest resources for national uses can be determined by maximizing the net social returns from forestry and agriculture, W, where W is defined as the maximum net present value of aggregate benefits.

$$W = \left\{ \sum_{i=1}^{k} \frac{\left[P(1+g)^{T_i} - C(1+s)^{T_i}\right] V(l_i)(1+r)^{-l_i} - D(1+m)^{T_i}}{(1+r)^{T_i}} \right.$$

$$\left. + \sum_{i=1}^{k} \sum_{j_i=0}^{l_i} \frac{\phi\,(1+o)^{T_i}\,\eta(j_i, F_i)(1+r)^{-j_i}}{(1+r)^{T_i}} \right\} F_i$$

$$+ \left\{ \left\{ \left\{ \left[\frac{P(1+g)^T}{(1+r)^T - (1+g)^T} - \frac{C(1+s)^T}{(1+r)^T - (1+s)^T} \right] V(L)(1+r)^{-L} \right\} \right. \right. \right.$$

$$\left. \left. - \frac{D(1+m)^T}{(1+r)^T - (1+m)^T} \right\} + \sum_{J=0}^{L} \frac{\phi\,(1+o)^T\,\eta(J, F)(1+r)^{-J}}{(1+r)^T - (1+o)^T} \right\} F$$

$$+ \sum_{i=1}^{k} \left\{ \frac{B(1+u)\left[(1+r)^{T_i} - (1+u)^{T_i}\right]}{(1+r)^{T_i}\left[(1+r) - (1+u)\right]} Q(A_i) - \frac{G(1+d)\left[(1+r)^{T_i} - (1+d)^{T_i}\right]}{(1+r)^{T_i}\left[(1+r) - (1+d)\right]} \right\} A_i$$

$$+ \left\{ \frac{B(1+u)}{(1+r) - (1+u)} Q(A) - \frac{G(1+d)}{(1+r) - (1+d)} \right\} A \qquad (11)$$

Subject to the following constraints.

(12a) $F_i + A_i \leq \Gamma$

where Γ: total stock of land

Land Constraint. The scope of the land use problem is limited to existing acreage in F and A at time zero.

(12b) $-F_i' = A_{i+1}'$

Land Conversion Constraint. Harvested forest acreage is either replanted or converted to agricultural land in the following period.

Data and Methods

Economic factors of forest production such as stumpage price and costs (planting and harvesting) were obtained from Bote (1991), and projected to their 1993 values. Age of standing trees in 1993 were calculated using Ramoran痴 volume yield equation for second growth dipterocarp forests, and regional forestry area and volume data for 1990 and 1995 by Revilla et al. (1989).

On-site soil erosion rates in agricultural, forest and grassland uses for each of the 13 regions of the Philippines in 1993 were obtained from Francisco (1994). Data on soil erosion were drawn from an earlier study on natural resource accounting by the International Resources Group, Ltd. et al. (1991). Estimates were adjusted by a weighing factor based on the relative size of each land use. The value of nutrients in eroded soil were computed using the replacement cost method, where on-site losses were measured in terms of the inorganic fertilizer equivalent of soil nutrients lost in the process of erosion (e.g., nitrogen to urea (45-0-0), phosphorus to solophos (0-20-0), and potassium to muriate of potash (0-0-60)). Valuation was in terms of the average price of urea, solophos and muriate of potash in 1993.

Average prices and costs of palay production from 1985-1990 were obtained from PhilRice and Bureau of Agricultural Statistics (1994), and from 1991-1995 were from the Department of Agriculture (1996). Time-series data from 1970-1993 on palay yield and land (area harvested) were obtained from PhilRice and Bureau of Agricultural Statistics (1994), capital (tractor use) were from FAO Production Yearbook (various years), and inorganic fertilizer applied (nitrogen (N), solophos (P_2O_5) and muriate of potash (K_2O)) were from the International Rice Research Institute (various years). Labor use (mandays) was computed based on labor costs (hired, operator/family and exchange) and daily nominal wage rates were obtained from the International Rice Research Institute (various years) and PhilRice and Bureau of Agricultural Statistics (1994). Data gaps were estimated based on the annual growth rates of past values.

Alternate plausible production functions were estimated with least squares and compared using nonnested tests. Results were evaluated at 10%, 5%, and 1% significance levels. The dynamic forest harvest-land use model for the Philippines was solved empirically on Gams/Minos software.

Empirical Results

Simulation results from the first rotation sequence of the model indicate that national income accounts in Philippine forestry could be improved by (1) extending the forest rotation length from an average of 30 to 70 years, (2) converting agricultural land back to forestry from approximately -100,000 to 130,286 hectares annually, and (3) intensifying the replanting in harvested forested acreage from an average rate of 41,685 hectares between 1960-1993 to 357,143 hectares annually. Using a 200-year time horizon, succeeding rotation sequences did not result in convergence to steady state.

Results support the theory that undermanaged and publicly-held forest resources in a developing country such as the Philippines, which are under heavy pressure from various users, motivated either by profit or subsistence, and are valued exclusively for their extractive component, will be used at a rate that exceeds the social optimum.

Conclusion

The forest harvest-land use model provides useful insights in evaluating forest management policies in the Philippines. Preliminary results show that currently, trees harvested in the Philippines are too young, replanting efforts are insufficient, and land allocation in agriculture and forestry is suboptimal. An increase in rotation length and forested acreage would increase national annual returns by $539,462. At current prices and costs, indications are that no further deforestation should occur, and in fact, the government would do well to revert acreage of planted agricultural lands back into forestry over the next few decades.

Existing policies disregard the long production period and the non-timber amenity functions of forests. Inclusion of non-timber benefits from forestry and enhancement of their values are important factors in alleviating excessive harvesting and conversion, and premature harvesting of trees in publicly-held forest land in the Philippines.

An additional layer of regulations would likely do little to improve the country's forest resource use. More efficient harvesting rates and sustainable logging practices could be achieved through more complete enforcement of existing regulations. This would go a long way in moving Philippine forest management closer to the social optimum.

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