Title: Public Forest Resource Management in the Philippines: Timber Production, Externalities, and Agricultural Expansion

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Abstract. A model of deforestation and agricultural expansion in the Philippines is developed to elucidate the economic factors driving current land use trends and to determine the efficacy of prevailing public forest management regulations and enforcement. Results from the simulation model indicate potential gains to reforestation, longer harvest cycles, and improved enforcement of property rights.

Background

Tropical forests are destroyed at an alarming rate of 10 to 20 million hectares annually. Without increased public intervention, deforestation will likely continue which could result in near decimation of the remaining forests in the next 50 years (Myers 1993). The rate of deforestation in the Philippines is among the highest in the world. In 1955 nearly half of the Philippines land area was covered in forests. After four decades of intensive timber harvest, today, Philippine forests are found on less than 20% of the country's acreage. Since 1955, the country's forested area declined by 58%, falling from 14.00 million to 5.79 million in 1993, of which 3.65 million hectares were converted to agricultural and other uses. During the same period, alienable or disposable land area increased by 0.8% annually, and was estimated at 14.12 million (47% of the national land area) in 1993.

Large tracts of publicly held forest land were heavily logged and cleared for agriculture and resettlement, in response to population growth, poverty, hunger, and demand for tropical hardwood. Remaining dipterocarp forests, the dominant family of timber trees and the most valuable commercial forest type found in the

tropical forests of the Philippines, contributing more than 90% marketable forest product revenues, were reduced to only 3.85 million hectares (66% of forested area) in 1993, of which only 804,900 (21%) were primary forests (Agaloos 1984, Kummer 1991, Ooi 1993, Grainger 1993, Asian Development Bank 1994). The loss of some 4.65 million hectares of dipterocarp cover between 1970 and 1993 corresponds to an annual loss of approximately 141,000 hectares. This study focuses on two primary threats to forest conservation, the profitability of tropical hardwood logging and the demand for agricultural land.

Forests provide many important benefits (e.g., timber and non-timber products, ecological functions, etc.). However, their benefits are often limited to mature timber values and ignore residual timber and non-market values. Management decisions based solely on timber revenues, may underestimate the value to the community from standing forests such as erosion and flood control, fuelwood, forage, fodder, improved water quality, recreation, biological diversity, etc. Prevalent public ownership of forests underscore the importance of government policies in influencing management, protection, investment, and the terms by which private users gain access and exploit public forest land. Property rights of private owners are likewise governed by public regulations, charges, and taxes, and returns to such an investment that involves a longer production period, are likewise affected by economic factors that are highly sensitive to government policies (Repetto 1988, Hyde and Newman 1991).

Philippine forest land is under government ownership and is predominantly managed for timber production. Usufructory rights to timber resources have been awarded to the private sector primarily through leasehold contracts called concessions or timber license agreement. Concessions are limited to a 25-year tenure and can be renewed once. Concession tracts range from 10,000 to 100,000 hectares and are heavily regulated through a myriad of fiscal devices (e.g., tax instruments, charges, fees, etc.), standards, and restrictions. Timber harvest is governed by a selective logging system which is based on an annual allowable cut (AAC) or diameter limit of trees that may be felled and retained as residuals or maternal stock, as well as the time between successive harvest cycles.

Incomplete enforcement of property rights, insecure tenure, distorted tax policies, and poor monitoring and enforcement of regulations encourage rapid destruction, excessive waste, and conversion to other uses rather than efficient and sustainable use of forests. The result is severe depreciation of the forest resource base, which diminish the contributions of the forestry sector to the economy and cause serious environmental damage, notably soil erosion. Monetary gains from forestry, especially during the 1950s through the 1970s when the Philippines dominated the tropical timber trade, were temporary and at the expense of permanent reduction in future income (Repetto et al. 1988). To this end, an economic model of forest land management is developed.

This paper extends the Faustmann (1849), Hartmann (1976), and other forest rotation studies by modeling the management of publicly held forest lands for an

entire country, including land/acreage in forestry as an endogenous variable, and conversion to agriculture as an alternative use of forest land. A 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 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 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 L that is homogeneous in terms of its biological and physical properties, and is an input in forest and agricultural production. Forests generate income from timber when trees are harvested and sold, and nonmarket benefits from standing trees which occur annually and increases with the age of trees, e.g., soil retention, visual aesthetics, recreation, etc. When the land is planted in crops, agricultural benefits accrue annually. Efficient long-term management of forest resources for national uses can be determined by maximizing the discounted sum of net social returns W from the set of productive activities that can be carried out on the land. Thus, the social planner must determine the optimal allocation between forest and agricultural uses, and furthermore dictate the harvest age of trees. The objective function is

$$W = Y + E + Z - X \tag{1}$$

where Y is the discounted sum of timber net benefits, E is the discounted sum of forest amenity net benefits, Z is the discounted sum of agricultural net benefits, and X is the discounted sum of transition costs involved when switching from forestry to agriculture or from agriculture to forestry.

The discounted sum of timber net revenues over N rotations can be expressed as

$$Y = \begin{cases} \sum_{i=1}^{k} \left[\dfrac{(P-C)V(h_i) - D\rho^{h_i}}{\rho^{h_i}} \right] F_i \text{ in transition} \\ \left[\dfrac{(P-C)V(\bar{h}) - D\rho^{\bar{h}}}{\rho^{\bar{h}} - 1} \right] \left(\dfrac{1}{\sum_{i=1}^{k} \rho^{h_i}} \right) \bar{F} \text{ at steady state} \end{cases} \tag{2}$$

where i indexes rotation sequence, P is timber price, C is timber harvesting cost per hectare, $V(h_i)$ is timber yield per hectare, h_i is stand age or $(T_i - T_{i-1})$, where T_i is harvest date, $h_i = \bar{h}$ for $i \geq k+1$, D is timber planting cost per hectare, F_i is forest area planted with trees, $F_i = \bar{F}$ for $i \geq k+1$, and $\rho = 1 + r$.

Timber P price and harvesting C and planting costs D, are constants. Timber yield $V(h_i)$ is assumed to have the following properties with respect to its partial derivatives: $V_{h_i} > 0$ and $V_{h_i h_i} \leq 0$.

Nontimber benefits from forested acreage are defined in terms of erosion control ε, which is expressed as a function of agricultural A_i and forest areas F_i and yield volume $V(j_i)$. Amenity yields are produced at no additional cost, other than what would have been incurred from timber production. In addition, since amenity yields are not transacted in markets, prices are imputed based on the opportunity cost of soil erosion from agricultural production. The discounted sum of nontimber net benefits over N rotations is

$$E = \begin{cases} \sum_{i=1}^{k} \left[\dfrac{\sum_{j_i=1}^{h_i} \phi\, \varepsilon\left(A_i, F_i, V(j_i)\right) \rho^{h_i - j_i}}{\rho^{h_i}} \right] F_i \text{ in transition} \\ \left[\dfrac{\sum_{\bar{j}=1}^{\bar{h}} \phi\, \varepsilon\left(\bar{A}, \bar{F}, V(\bar{j})\right) \rho^{\bar{h} - \bar{j}}}{\rho^{\bar{h}} - 1} \right] \left(\dfrac{1}{\sum_{i=1}^{k} \rho^{h_i}} \right) \bar{F} \text{ at steady state} \end{cases} \tag{3}$$

where j_i indexes age during rotation, $j_i = \bar{j}$ for $i \geq k+1$, ϕ is forest amenity price, $\varepsilon\left(A_i, F_i, V(j_i)\right)$ is soil retention capacity of forests, and A_i is land area devoted to palay production, and $A_i = \bar{A}$ for $i \geq k+1$.

The production function for erosion control benefits is increasing in F_i and $V(j_i)$ and decreasing in A_i. Constant or diminishing marginal returns are assumed on the

second order partial derivatives. Mathematically, the following first and second partial derivatives are implied: $\varepsilon_{A_i} < 0$, $\varepsilon_{F_i} > 0$, $\varepsilon_{V_i V_{j_i}} > 0$, $\varepsilon_{A_i A_i} \leq 0$, $\varepsilon_{F_i F_i} \leq 0$, and $\varepsilon_{V_i j_i} \leq 0$.

Palay is used as a proxy for agricultural production. The discounted sum of agricultural net receipts over N rotations is

$$Z = \begin{cases} \sum_{i=1}^{k} \left[(B-G) Q(\mathcal{L}, \mathcal{K}, \mathcal{F}, A_i) \right] \left[\frac{\rho^{T_i} - 1}{r\rho^{T_i}} - \frac{\rho^{T_i - 1} - 1}{r\rho^{T_i - 1}} \right] A_i \text{ in transition} \\ \left[\frac{(B-G) Q\left(\mathcal{L}, \mathcal{K}, \mathcal{F}, \bar{A}\right)}{r} \right] \left(\frac{1}{\sum_{i=1}^{k} \rho^{T_i}} \right) \bar{A} \text{ at steady state} \end{cases} \tag{4}$$

where B is palay price, G is palay production cost, $Q(\mathcal{L}, \mathcal{K}, \mathcal{F}, A_i)$ is palay yield per hectare, $\mathcal{L}$ is labor input in terms of real wages, $\mathcal{K}$ is capital input in terms of tractor use, and $\mathcal{F}$ is fertilizer input.

Agricultural area A_i is the only variable input to palay production Q, other inputs such as labor $\mathcal{L}$, capital $\mathcal{K}$, and fertilizer $\mathcal{F}$ are assumed constant. The relationship between Q and A_i is summarized as follows: $Q_{A_i} > 0$ and $Q_{A_i A_i} \leq 0$.

There are costs involved in transitioning acreage from forestry to agriculture and vice versa. The basic idea being that one cannot move costlessly from one land use to another. In this model, a one year fallow period, which is equivalent to deferring the future stream of net returns for one year, is used to capture the lower bound transition costs per hectare S_{F_i} for forestry and S_{A_i} for agriculture. Thus, in equilibrium, the first

rotation will be different from subsequent rotations. The discounted sum of transition costs over k rotations can be written as

$$X = \sum_{i=1}^{k} \frac{S_{F_i}}{\rho^{\sum_{m=1}^{i} T_m}} F_i + \frac{S_{A_i}}{\rho^{\sum_{m=1}^{i} T_m}} A_i \tag{5}$$

where m indexes i .

Two constraints are imposed on the maximization problem. The equality constraint which states that the sum of forest F_i and agricultural acreage A_i should not exceed the total stock of land L

$$F_i + A_i \leq L \tag{6}$$

and the yield volume constraint for second growth dipterocarp stands adopted from Ramoran (1985)

$$\log V(h_i) = 1.03 + 0.28(h_i) * ba_0 + 0.49 \log(site) * \log(ba_0) \tag{7}$$

where ba_0 is the initial stand basal area and $site$ is site quality or mean total height of dominant and co-dominant dipterocarp species (40-80 cm in dbh).

Data and Methods

Data used in the empirical model of this paper was derived exclusively from secondary sources. Economic factors of forest production such as timber price, planting and harvesting costs were based on a report by Bote (1991). Regional forestry area accounts from 1970-1993 were derived from various statistical yearbooks by the Forest

Management Bureau. Volume and soil erosion rates for secondary dipterocarp forests were from Revilla et al. (1989) and Francisco (1994), respectively.

Palay prices and costs from 1985-1995 were obtained from PhilRice and Bureau of Agricultural Statistics (1994) and the Department of Agriculture (1996). Time-series data from 1970-1993 on crop yield and acreage were obtained from PhilRice and Bureau of Agricultural Statistics (1994), tractor use were from Food and Agriculture Organization (FAO) Production Yearbook (various years), and fertilizer use were from the International Rice Research Institute (various years). Labor costs and 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 growth rates of past values. Agricultural and forestry prices and costs were deflated to 1988 constant values.

Alternate plausible production functions (linear, semi-log, log-log, and quadratic) were estimated with least squares to test the responsiveness of erosion to land use and timber yield, palay yield to production inputs, and fertilizer use to cumulative erosion. Nonnested procedures were used to test specification and selection among alternative production functions. Test results were evaluated at 10%, 5%, and 1% significance levels. An empirical model of the optimal path of forest harvest and conversion in the Philippines was solves using Gams/Minos software on the personal computer.

Empirical Results

Nonnested test results on alternate functional forms (linear, log, semi-log, and quadratic) for the amenity, palay, and fertilizer use functions indicate that the linear, log-

log, and quadratic forms were adequate empirical specifications, respectively. The regression equations are as follows

$$\begin{aligned}\varepsilon\left(A_i, F_i, V(j_i)\right) &= 49.750 + 32.646A_i - 28.542F_i - 0.251V\left(j_i\right)\\ &\quad (9.371)^{***}\ (2.041)^{**}\ \ (-1.809)^{**}\left(-5.036\right)^{***}\\ &\quad R^2 = 0.926\ \ \bar{R}^2 = 0.915\end{aligned} \tag{8}$$

**,***Significant at the 0.05 and 0.01 probability levels.

$$\begin{aligned}\ln Q\left(\mathcal{L},\mathcal{K},\mathcal{F}\right) &= 2.754 + 0.113\ln\mathcal{L} + 0.209\ln\mathcal{K} + 0.506\ln\mathcal{F}\\ &\quad (3.946)^{***}(0.644)\quad (5.172)^{***}\quad (7.751)^{***}\\ &\quad R^2 = 0.887\quad \bar{R}^2 = 0.870\end{aligned} \tag{9}$$

***Significant at the 1% probability level.

$$\begin{aligned}\Im(M) &= 0.035 + 2.34E-09\,M - 1.38E-17\,M^2\\ &\quad (3.180)^{***}(5.097)^{***}\quad (-3.884)^{***}\\ &\quad R^2 = 0.702\quad \bar{R}^2 = 0.673\end{aligned} \tag{10}$$

***Significant at the 1% probability level.

where ε is the erosion rate and M is cumulative erosion. Since ε in equation (8) is defined in terms of erosion, the signs of its coefficients are the opposite of the expected signs of nontimber amenity yields given earlier. Also, palay yield Q in equation (9) was normalized on A_i and expressed on a per hectare basis. Thus, the coefficient of A_i is equal to 1.

Estimated parameters for the fertilizer function were used to derive the average opportunity cost of soil retention benefits from forestry, which was valued at P3.47E-5/ton between 1970-1990.

Results of the base model indicate that optimal rotation for the transition period is 2.52 years (beginning with 30 year old trees) and 31 years during steady

state. In all cases, convergence to steady state was achieved after the first transition period. Solutions for the optimal land allocation favored agriculture (14.93 million hectares) over forestry (4.98 million hectares). The optimal amounts are 6 and 14 percent off the observed allocation for agriculture and forestry. However, since 4.98 million hectares or 25% of the combined actual allocation for agriculture and forestry was an arbitrary lower bound, an even smaller amount may result from a smaller lower bound.

Sensitivity analysis during the transition period for different timber prices and harvesting costs, palay prices and costs (+10, +20, +30, -10, -20, and -30 percent of initial levels) and interest rates (10 and 20 percent) yielded small variations in rotation length compared to the base model, and remained unchanged with changes in timber planting costs (+10, +20, +30, -10, -20, and -30 percent of initial levels) and land area (30 million hectares). In contrast, rotation lengths were extremely responsive to changes in the price of nontimber amenity yields. For example, increasing the amenity price to 10, 100, and 150 percent of timber profits resulted in optimal rotations of 214.02, 227.76, and 227.97 years. At steady state, none of the changes in the variables affected the optimal rotation length. This suggests that because of discounting and the long production period involved in forestry, changes in variables affect the initial rotation lengths more than the steady state rotation length (Newman, Gilbert, and Hyde 1985).

In general, the land allocation result in the base model was supported in the sensitivity analysis. The same proportion was maintained when the stock of land

to be allocated between the two competing uses was increased to cover the Philippines' total land area of 30 million hectares. The only exceptions were obtained with a 10 percent discount rate (15 percent was used in the base model), an increase of 20 and 30 percent in timber base price, a reduction of 10, 20, and 30 percent in palay price, and an increase of 10, 20, and 30 percent in palay base cost, which increased the amount of forest land at steady state from 4.98 to 14.93 million hectares.

When prices and costs were allowed to change simultaneously based on historical growth rates, the optimal transition period rotation length was 6.22 years and 33.73 years at steady state, and the optimal allocation between agriculture and forestry is 4.98 and 14.93 million hectares, respectively. This indicates that national income accounts in Philippine forestry could be improved by increasing the forest rotation length by 6-9 years and converting agricultural land to forestry uses from approximately -141,000 to 271,000 hectares annually.

Win-win scenarios in terms of amenity benefit and social welfare gains were achieved in several cases. Increasing timber price by 20% and 30% resulted in amenity gains valued at $984.04 and $981.17, respectively and social welfare gains of $8.15 billion and $12.52 billion, respectively. Modest amenity gains of less than $100 were obtained when palay price increased by 10% and 20% and palay cost decreased by 10%, 20%, and 30%. Social welfare gains ranged from $1.45 billion to 4.25 billion. Increasing amenity price to equal timber profits dramatically increased amenity benefits by $195.55 billion and social welfare by

$169.01 billion. When amenity price was further increased to 150 percent of timber profits, amenity benefit and social welfare gains of $293.32 billion and $266.79 billion, respectively, were posted. Finally, when prices and costs were adjusted to reflect historical trends, amenity and social welfare gains were $776.77 and $9.37 billion, respectively.

Conclusion

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 (e.g., commercial loggers) or subsistence (e.g., migrant farmers, fuelwood gatherers, landless lowlanders, and poor population), and are valued exclusively for their extractive component, will be used at a rate that exceeds the social optimum.

More efficient resource use can be achieved through more complete specification of property rights and stricter monitoring and enforcement of regulations. For example, restricting concessionaire rights to certain forest benefits fosters inefficient economic behavior that maximized over those benefits for which rights can be claimed instead of the aggregate benefits from multiple use forest production.

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