MODELLING DEFORESTATION CAUSED BY THE EXPANSION OF SUBSISTENCE FARMING IN THE PHILIPPINES

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ABSTRACT

The forest area of the Philippines declined in twenty years, during 1970 - 1990, from about one third to about one fifth of the total land area, i.e. from 10 to 6 million hectares. The relative significance of the various direct and indirect causes of deforestation obviously have changed over the course of time. It has been suggested that during the last decades, the expansion of subsistence or small-scale cultivators into the previously forested upland areas has been the major human activity leading to deforestation. The indirect causes of deforestation include economic, political, demographic, and environmental factors. In this paper, it is hypothesised that the indirect causes increasing the expansion of agriculture into the uplands include factors like population density, conditions on farms in the lowlands, as well as poverty and lack of non-farm employment opportunities. The aim is by no means to present a comprehensive causal model but rather to analyse and understand one part of the complexity related to deforestation.

Deforestation or forest cover changes in the Philippines are analysed using multiple regression with pooled data from 55–64 provinces and from two years, 1969 and 1990. In the empirical models, the dependent variable is the logit-transformation of the forest cover of each province, and the independent variables include population density, the share of small farms, and the tenancy rate of each province. First, a model with pooled data and a common intercept is analysed using the ordinary least squares (OLS) method. In addition, the data are analysed using the so-called fixed effects (FEM) and random effects models (REM). According to these estimated models, forest cover is negatively related to all of the three independent variables used, i.e. the bigger the population density and the larger the shares of small and tenant farms, the smaller the forest cover in each province. Unfortunately, omitting some theoretically relevant variables due to the lack of data may have caused bias in the models, and bivariate correlations make the interpretation of the results difficult.

Keywords: Deforestation, fixed effects model, modelling, Philippines, pooled data, random effects model.

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INTRODUCTION

At the beginning of this century, forests still covered about 70 % of the total area of the Philippines, i.e. more than 20 million hectares (Wernstedt & Spencer, 1967). By 1970, the

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area of forests had declined to about 10 million hectares, and by 1990, further to about 6 million hectares, or about 20 % of the land area (DENR, 1990). According to FAO (1993), the relative rate of deforestation in the Philippines between 1980–1990 was more than 2.5% per year, one of the highest rates of deforestation in the world. Over half of the total land area is classified as “uplands”, having slopes of at least 18% (National Economic and Development Authority, 1992). Most of the remaining natural forest exist in these uplands.

The problems related to deforestation in the Philippines have extensively been discussed by Kummer (1992a), but so far little has been published on modelling deforestation in the Philippines. Kummer (1992a), further revised by Kummer & Sham (1994), used cross-sectional data across the provinces for the years 1957, 1970, and 1980. The dependent variables used were the absolute forest area in each year concerned, and the change in the absolute forest area in each province from 1970 to 1980. According to Kummer (1992a), forest area was negatively related to road density in 1957; in 1970 and 1980, forest area was negatively related to both road and population density. In addition, the larger the number of logging licensees in 1970, and the larger the change in agricultural area during 1970–1980, the larger the change in forest area.

In this paper, an attempt has been made to use multiple regression to emphasize one part of the deforestation process in the Philippines, i.e. the expansion of subsistence cultivators into the uplands, and the factors leading to this expansion. It has been assumed that during the last decades, the expansion of the subsistence or small-scale cultivators into the previously forested upland areas would have been the major human activity leading to deforestation in the Philippines. The real or “indirect” causes of deforestation would include those economic, political, demographic, and environmental factors driving or forcing people to expand their farms into the uplands. The discussion on deforestation has often emphasized the role of shifting cultivators or other upland farmers as the causal agents of deforestation when in fact they can be thought of having both the incentive (e.g. Horne, 1996) and the necessity (e.g. delos Angeles & Bennagen, 1993) to expand their farms and thus, cause deforestation.

In the models, pooled data from the (55–64) provinces and the years 1969 and 1990, have been used. The ordinary least squares (OLS) method has been used to estimate a model with pooled data and a common intercept. In addition, the so-called fixed effects model (FEM) and the random effects model (REM) have been used. The aim of this paper is by no means to present a comprehensive causal model for deforestation in the Philippines but rather to analyze and understand one part of the complexity related to deforestation, i.e. issues related to the expansion of subsistence farmers into the uplands.

THE CAUSES OF DEFORESTATION IN THE PHILIPPINES

Deforestation has usually been defined as a conversion process, a change of land cover from forest to something else. Forest degradation should be differentiated from deforestation since, even if it can be detrimental to, for example, biodiversity, it can be defined as a modification process happening within a forest (e.g. Palo *et al.*, 1987; Turner & Meyer, 1994). When trying to explain land-use changes, several authors have made a distinction between the human actions that directly alter the physical environment and the causes behind these actions. The human actions causing deforestation are commonly listed as: logging, clearing for permanent agriculture, and shifting cultivation. The extent, timing and place of the changes are affected by a range of economic, political, demographic, and environmental factors (Figure 1; McNeill *et al.*, 1994; Turner & Meyer, 1994). Correspondingly, Kant & Redantz (1997) make a distinction between direct (first-level) and indirect (second-level) causes, and group the first-level causes into two categories: the demand for forest products and the demand for forest land for an alternate land use.

As in other countries, there presumably have been various interacting direct and indirect causes for the land-use changes in the Philippines. The relative significance of the various causes of deforestation obviously has changed over the course of time (see also Lambin, 1994). Population growth and economic opportunities have stimulated the conversion of forest land to agriculture. The various governments of the Philippines have also deliberately adopted policies or “non-policies” that have accelerated the conver-

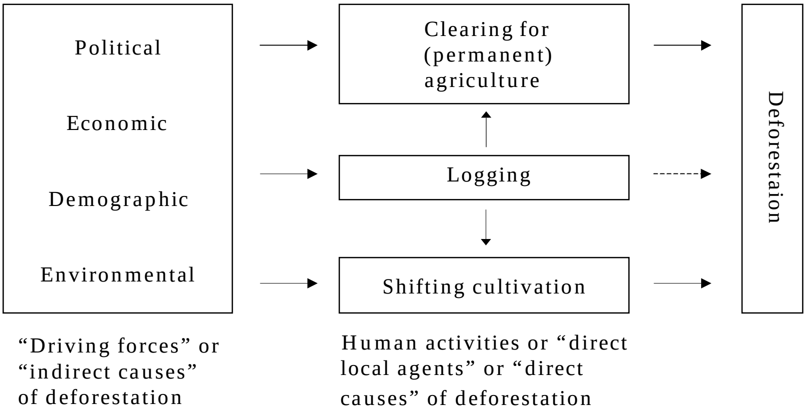

FIGURE 1. THE HUMAN ACTIVITIES CAUSING DEFORESTATION, AND THE FACTORS AFFECTING THESE ACTIVITIES. *The human activities causing deforestation, and the factors affecting these activities (based on the models and ideas of Grainger, 1990; Panayotou & Sungsuwan, 1989; 1994, McNeill et al., 1994; Palo, 1994; Turner & Meyer, 1994 and Kant & Redantz, 1997 (an earlier version of the figure has been presented in Uitamo 1997)).*

sion of forest land (Ganapin, 1987; Saastamoinen, 1996). From the 1500s to the beginning of the 1900s, it was mainly the expansion of commercial agriculture that decreased the forest area (e.g. Uitamo, 1996). In addition, as the population increased and more and more of the lowlands were turned into plantation crops, shifting cultivators were pushed into the uplands, onto more vulnerable soils (Westoby, 1989). The topography, the sensitivity of upland soils to erosion, as well as the large number of small islands have made the Philippines vulnerable to human impact (Ganapin, 1987).

During this century, resettlement projects and migration, as well as the expansion of the export crop area, have contributed to an increase in the area of agricultural lands. After the Second World War, logging accelerated, peaking in the 1960s and 1970s (Boado, 1988). The area under state timber concessions doubled in ten years, from 4.5 million hectares in 1960 to about 10 million hectares in 1970. There were still about 8 million hectares under concessions in 1980 (Boado, 1988; Forest Management Bureau, issued annually). The indirect role of logging seems to be much more important than the direct one. According to Kummer (1992a), deforestation in the Philippines is a two-step process involving the conversion of primary forest to secondary forest by logging; followed by the subsequent removal of this secondary forest by the expansion of agriculture, mainly by subsistence or poor small-hold cultivators (see also Palo & Lehto, 1996).

In this paper, it is assumed that the major human activity causing deforestation, or the major direct cause of deforestation in the Philippines during the last two to three decades, has been the expansion of agriculture, mainly by subsistence or poor small-hold cultivators. A part of this expansion presumably has been caused by traditional shifting cultivators. However, especially due to the lack of forest areas large enough for traditional shifting cultivation, a significant share of the expansion must have been caused by the expansion of those cultivators who have migrated into the forested areas from other areas, maybe from nearby lowlands or from adjacent, already eroded uplands. These people maybe cannot be regarded as "traditional" or "shifting" cultivators in the strictest meaning of the term but they nevertheless may have to move and cultivate new areas once the over-used areas have become too eroded for agricultural production. In fact, the distinction between sedentary and shifting cultivation may be disappearing and instead, it might be better to use the tenure status as an operational definition of land use in the uplands (Kummer 1992b, Cornista *et al.* 1986, see Horne 1996). Even stating that the expansion has mainly been due to "subsistence" agriculture is difficult since the distinction between "subsistence" and "commercial" agriculture may not be very clear, even if they are often used as opposite terms to each other.

Due to the confusion in the terms, in this paper the use of the term "shifting cultivation" is avoided. The term "subsistence agriculture" is used here instead to refer to the expansion of both traditional shifting cultivators and other poor farmers into (former) forest lands, which most probably officially belong to the state. The expansion of subsistence (or small-scale) agriculture has been possible because of an open-access situation in the uplands (delos Angeles & Bennagen, 1993), possibly combined with the easy access due to the "opening" of the forests by logging activities (Kummer, 1992a). Since few migrants moving into the uplands obtain secure tenure rights, they have little incentive to invest in soil conservation, but instead use short-sighted farming practices (Cruz *et al*., 1992). Thus, while cultivation has possibly been on a sustainable basis in the past, several things, including the adoption of low-land cultivation methods not suitable for uplands, have led to more exploitative patterns of land use (e.g. delos Angeles & Bennagen, 1993; Horne, 1996).

According to delos Angeles & Bennagen (1993) the conditions in the agricultural lowlands, including population pressure, poverty, and landlessness are among the factors leading to the migration into the uplands and thus, to deforestation there. Rudel & Roper (1997) present two theories on the causes of deforestation, one of which is called the "immiserization theory". According to them, a classic example of this type of deforestation occurred in the Philippines in the 1980s. This theory attributes most deforestation to the expansion of peasants and shifting cultivators, who have few other opportunities for finding a source of livelihood than clearing additional land for agriculture. Low levels of economic activity and the fiscal austerity associated with a large foreign debt prevent the creation of non-farm jobs. The absence of alternative economic opportunities and increasing population pressure compel people to cultivate marginal lands.

The Philippines is one of the most densely populated countries in the world with a population density of more than 200 persons per km^2 in 1990 (National Statistical Coordination Board 1992). Cruz & Cruz (1990) studied population pressure in the Philippine uplands. Their conclusion was that, even if it was not properly reflected in the statistics, about one third of the country's population resided in the uplands where the remaining natural forests exist. The upland population has grown even more rapidly than the country's population as a whole, due to in-migration as well as the high birth rates in the uplands.

Even if the per capita income has increased during the last several years in the Philippines, the problem of poverty seems to have at least remained or even worsened. In fact, it would appear that the inequality of income and absolute poverty have increased in the Philippines since the 1950s (Oshima,1987; see Kummer, 1992a). The inability of the manufacturing sector to create a significant number of jobs in urban areas has meant that the burden of job creation and poverty alleviation has fallen to the agricultural sector, which, like in most other developing countries as well, plays a major role in the Philippine economy (Kummer, 1992a).

The tenancy rate in the Philippines has been one of the highest in South East Asia (Bellow *et al.*, 1982; see Hurst, 1990). Tenancy in the lowlands is believed to contribute to the increasing pressures to clear more land for cultivation in the uplands. The average tenancy rate of the Philippines has declined from 27% to 17% between the 1971 and 1991 censuses (NSO, 1995a) but it is not clear whether this trend is diminishing the pressures on forests. Due to the lack of other employment opportunities, former tenants may often become cultivators in the uplands (Lacuna-Richman, pers. com.). Another factor describing the conditions in the agricultural lowlands is the increasing share of small farms. The average share of farms having the size of less than one hectare has increased from 14% in 1971 to 37% in 1991 (NSO, 1995a). Obviously, such small farms cannot be divided further between all of the descendants of the cultivator families and thus, a part of those descendants not able to find work elsewhere try to make their livelihood by clearing farmland from forest.

The causes of deforestation presented in Figure 2 are in accordance with the ideas presented earlier in Figure 1, but including the expansion of subsistence agriculture as the only direct cause of deforestation. Obviously, clearing land for “permanent”, “commercial” or “large-scale” agriculture

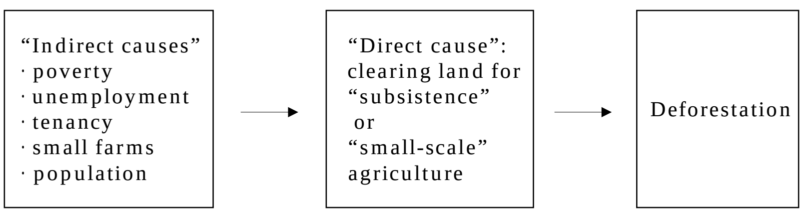

FIGURE 2. EXPANSION OF SUBSISTENCE AGRICULTURE.
The expansion of subsistence agriculture as the only direct cause of deforestation, and the indirect causes affecting this expansion.

was also still significant during, at least, the 1970s but that part of the land-use changes will not be analyzed here. The indirect causes affecting the expansion of subsistence agriculture are assumed to include the factors driving or forcing people to expand their farms into the uplands, as described earlier, i.e. population pressure, poverty, lack of other, non-farm employment opportunities, tenancy in the lowlands, and the inadequate size of the existing farms.

DATA AND METHODS

The Sources of Data

Provincial data were used in the analyses. There are 12–15 regions divided into about 70 provinces in the Philippines. Thus, choosing provincial level data meant that the number of cases was sufficient for regression modelling purposes but, on the other hand, the quality and availability of data was a much bigger problem at the provincial than at the regional level.

In this study, as well as in several others on deforestation, forest cover was used as the dependent variable since reliable data on deforestation itself were not available. In the models, data from two points of time were used, 1969 and 1990. Data on forest cover were obtained from two different sources. The 1990 forest cover data were obtained from the consolidated forest cover data of NAMRIA (1990), which combines the data of the two most recent and reliable inventories (Forest Management Bureau, 1988, and Swedish Space Corporation, 1988). The consolidated data of NAMRIA (1990) are considered to be more reliable than either of the original data sets (Holmgren, 1989; Basa & Dalañgin, 1991). The 1969 data were reported by the Philippine-German Forest Resources Inventory (Forest Management Bureau, 1988). The data were calculated by remeasuring almost all of the so-called forest resource condition maps of the forest inventory conducted in 1965–1972. The inventory itself was based on the interpretation of aerial photographs. One drawback of the inventory was that no ground truthing was undertaken (Kummer 1992a, Basa & Dalañgin 1991).

The two data sets, from 1969 and 1990, are obviously based on very different inventory techniques, and even the definition of “forest” may have changed in twenty years.

One manifestation of the problems related to the changes between the two inventories is that, based on the comparison of these two data sets, the natural forest cover of some provinces would even have increased in twenty years. This increment is more likely to be due to the differences in the inventory techniques used for the two data sets, or due to some other faults in the data, than to any real increases in forest area. It is, however, possible that a part of this increment in forest cover reflects a real increase in the area of plantation forests.

The number of provinces included in the models of this study was lower than the total amount of provinces in the Philippines. The provinces of Batanes and Tawi-Tawi were not included in the analyses since data on them were not available in the consolidated forest cover data basis for 1990. Moreover, provinces with zero forest cover (Cavite, Cebu, Marindique, Masbate, and Siquijor) were excluded from the analyses. It was thought that these cases do not represent the process of deforestation in the same way as the other provinces since it is not possible to know when, i.e. with which values of the independent variables, they lost their forest cover.

First, models based on these 64 provinces estimated. Then, provinces located close to Manila (Batangas, Bulacan, Laguna, Rizal, and Pampanga) were excluded from the analysis since they appeared as outliers and influential cases in the data. This apparently is due to the fact that they have lost most of their forest cover a long time ago due to, for example, rice cultivation in their lowlands. Due to the economic attractiveness of the capital area, the population density of these provinces is much higher than the average population density in the Philippines (about 200 persons/km^2), ranging from 460 to almost 800 people per km^2 in 1990. It is possible that the forest cover of these provinces has diminished to such a low level that the pressures to protect the remaining areas will be higher than the pressures to use them. Second, models based on the remaining 59 provinces were estimated. Finally, the provinces with increasing forest cover between the two data points (Davao Norte, La Union, Mountain Province, and South Cotabato) were left out of the models as potential data faults due to the differences between the two data sources, and models were re-estimated based on the remaining 55 provinces.

Due to the lack of time series data and reliable data on the actual rate of deforestation, deforestation has usually been modelled using cross-sectional data across several countries or other relevant units like communities or regions of a country. Palo *et al.* (1987) and Reis & Guzmán (1994), for example, think that countries or other cases used in cross-sectional analysis can be in very diverse stages of demographic and economic settlement, and thus mimic long run situations in the sense that the differences between the cross-sectional units can be thought to represent the changes between decades or centuries. In cases where data are available, pooled data, combining both cross sections and time series, can be a feasible way of modelling deforestation. Using pooled data instead of just cross-sectional data may help modelling, for example, by increasing the degrees of freedom and by giving some insight to the changes happening between both cross-sectional and time units. So far, combinations of cross-sectional and time series data have been used at least by Panayotou & Sungsuwan (1989, 1994) in North-East Thailand, and Barbier *et al.* (1993, 1994) and Osgood (1994) in Indonesia.

When analyzing the situation in the Philippines, it seems that cross-sectional as well as pooled data could be used in the way suggested by, for example, Palo *et al.* (1987) and Reis & Guzmán (1994). In the figure combining data from each province in two points of time, the trend of forest decline versus population density seems very similar to the trend in the national level from the sixteenth century to the present (Figure 3).

The lack of data on the relevant independent variables restricted empirical modelling in this study. Unfortunately, provincial level data on factors related to the amount or distribution of income could not be found. Moreover, relevant data reflecting the employment situation, or the lack of non-farm job opportunities were not found. That is why these two important variables had to be left out of the empirical models. Data on population were available in national censuses. The percentage shares of small and tenant farmers were calculated on the basis of the data available in agricultural censuses. The problem with the 1971 census was that the data were tabulated on the basis of the residence of the farm operator, not the location of the farm itself as in the 1991 census. Thus, in the case of some prov-

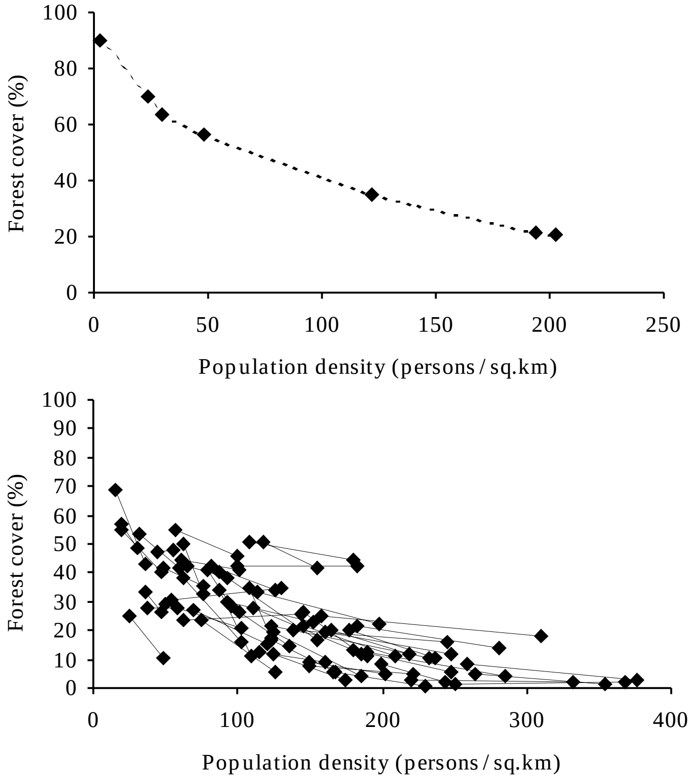

FIGURE 3. FOREST COVER (%) VS. POPULATION DENSITY (PERSONS / KM^2) IN THE PHILIPPINES. *Forest cover (%) vs. population density (persons/km^2) in the Philippines. Above, the data points reflect the national forest cover vs. population density in various points of time (from 1550 to 1990). Below, the lines connecting two data points reflect the forest cover vs. population density in each province from 1969 to 1990.*

inces, the 1971 data may not have been as accurate as desirable since the residence of the farm operator may have been different from the actual location of his parcels of land (Table 1).

Methods

The dependent variable, forest cover (FC) of each province (%), was calculated as the percentage share of the forests from the total area in each province, i.e. it was a variable the values of which were restricted to between zero and one (hundred). Thus, a so-called logit-transformation (e.g.

TABLE 1. THE DEFINITIONS AND DATA SOURCES OF THE INDEPENDENT VARIABLES OF THE EMPIRICAL MODELS.

NAME	DEFINITION OF THE VARIABLE
*PopD**	Population density in 1970, 1990 (persons / km^2)
*Tenant***	The share of the farms tenanted / leased of the total number of farms (%)
*Small***	The share of the farms below 1 ha of the total number of farms (%)

Sources of data:

* 1990 Census of Population and Housing (NSO 1991).

** Calculated on the basis of 1971 and 1991 Censuses of Agriculture (NCSO 1974, NSO 1995b).

Lappi 1993) was used for the dependent variable to achieve constant residual variance (Equation 2). First, a model with pooled data and a common intercept was analyzed using the ordinary least squares (OLS) method:

$$y_{it} = \alpha + \boldsymbol{\beta}'\mathbf{x}_{it} + \varepsilon_{i,t} \tag{1}$$

where

$$y_{it} = \ln\left(\frac{FC_{it}}{FC_{it}}\right) \tag{2}$$

and FC_{it} is the forest cover of each province at each point of time**,** $\mathbf{x}$ is the vector of the three included independent variables, i.e. population density, the share of the farms tenanted / leased of the total number of farms, and the share of the farms below 1 ha of the total number of farms, α is the intercept, $\boldsymbol{\beta}$ is the vector of the coefficients corresponding to the independent variables, ε_{it} is an error term, *i* refers to each province included, *t* to each point of time (T = 2).

In addition, the data were analyzed using both the random effects model (REM) and the fixed effects model (FEM), called also the least squares dummy variable model (LSDV) (Greene, 1993; estimated using the Limdep econometric software package).The starting point for both models is the regression model:

$$y_{it} = \alpha + \boldsymbol{\beta}'\mathbf{x}_{it} + \varepsilon_{it}. \tag{3}$$

Besides the disturbance within the OLS models, the REM also includes a random disturbance u_i characterizing the ith case (Equation 4). The random effects model, estimated using the generalized least squares method, was of the form:

$$y_{it} = \alpha + \boldsymbol{\beta}'\mathbf{x}_{it} + u_i + \varepsilon_{it}. \tag{4}$$

where u_i is the random disturbance characterizing the ith observation, constant through time. Other notations as above.

In the fixed effects model, it is assumed that the differences across the units can be captured in differences in the constant term. Thus, in Equation 3, each α_i is an unknown parameter to be estimated.

According to Greene (1993), the fixed effects model is a reasonable approach when we can be confident that the differences between units can be viewed as parametric shifts of the regression function. In principle, the fixed effects model might be viewed as applying only to the cross-sectional units in the study and not to additional ones outside the sample, while the random effects model would be appropriate if we believed that sampled cross-sectional units were drawn from a large population. Greene (1993) also notes, however, that it has been suggested that the distinction between fixed and random effects models would be an erroneous interpretation, and discusses briefly some of the advantages and disadvantages of both. The Lagrange multiplier test was used here to test whether either the fixed or random effects model would be more appropriate than the standard model based on the effects of the used independent variables only. Hausman's chi-squared statistic was used to test the fixed against the random effects model to see which one would seem more appropriate here.

RESULTS

The models were estimated with three sets of provinces. The total number of provinces was 64. Five provinces located close to the capital city area, Metro Manila (Batangas, Bulacan, Laguna, Rizal, and Pampanga), were excluded since they appeared as outliers and influential cases in the data. Four other provinces with increasing forest cover between 1969 and 1990 were further excluded, and the models were re-estimated. The estimated models, analyzed excluding both the provinces located close to Metro Manila and the provinces with increasing forest cover, are presented in Table 2a. Two other sets of estimated models, first, the models including the provinces with increasing forest cover and second, the models including all 64 provinces, are presented in Appendix 1 (Tables 2b and 2c).

According to the models, forest cover was negatively related to all of the three independent variables in the models, i.e. forest cover would decrease when population density as well as the share of tenant and small farms increased. The independent variables were significant either at the 1 or 5 % level. The signs and magnitudes of the regression

TABLE 2A. RESULTS OF THE MODELS ESTIMATED WITH 55 PROVINCES.
Results of the models estimated with 55 provinces (n = 2 × 55 = 110). The model has been estimated by using the ordinary least squares (OLS), the fixed effects model (FEM), and the random effects model (REM) using generalized least squares (GLS).

VARIABLE	OLS		FEM		REM (GLS)	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
	p-value		p-value		p-value	
Constant	0.56423	(0.18847)			0.44131	(0.18938)
	0.0034***				0.0198**	
PopD	−0.00914	(0.00105)	−0.00482	(0.00243)	−0.008408	(0.00116)
	0.0000 ***		0.04991 **		0.0000 ***	
Tenant	−0.01864	(0.00700)	−0.01336	(0.00633)	−0.01737	(0.00535)
	0.0089 ***		0.0371**		0.0012 ***	
Small	−0.01536	(0.00469)	−0.02125	(0.00591)	−0.01531	(0.00399)
	0.0014***		0.0005 ***		0.0001 ***	
R^2 (adj. R^2)	0.63	(0.62)	0.95	(0.89)	0.63	
F (signif.)	60.04	(0.0000)	16.67	(0.0000)		
s.e.	0.71		0.38			
var[e]					0.152	
var[u]					0.379	
LM					26.91	(0.0000)
Hausman					3.15	(0.3686)

Note: The first figure after the name of the variable is the regression coefficient, the second one after it in parentheses is the standard error of the coefficient, and the last one below them is the significance level (in p-values). The level of significance is also been marked with stars (*): three stars: 0.01; two stars: 0.05. Hausman = Hausman's chi-squared test statistic; LM = Breusch and Pagan's Lagrange multiplier test statistic.

Note: The Tables 2b and 2c with a different number of provinces are presented in Appendix 1.

coefficients were about the same when using either the ordinary least squares or random effects model. On the other hand, the magnitudes of the coefficients in the fixed effects model were somewhat different from the other two, in particular the one of population density (Table 2a).

Using the ordinary least squares method seemed to give satisfactory results. The large value of Breusch and Pagan's Lagrange multiplier (LM) statistic, however, argues in favour of either the fixed or the random effects model against the classical regression model without group specific factors. Based on the value of Hausman's chi-squared test statistic, the random effects model would be a more feasible way of estimation than the fixed effects model (Table 2a).

When the four provinces with increasing forest cover were included (n = 2×59 = 118), the changes in the magnitudes of the regression coefficients were not statistically significant compared to the models with these provinces excluded (i.e. the models of the Table 2b compared to the ones of 2a). The results of the least squares and random effects models were about the same, but in the fixed effects model, the coefficient of population density was not statistically significant, and the coefficient of the share of tenant farmers was less significant than in the model in which these four provinces were excluded. Based on the value of the Hausman's chi-squared test statistic, it was not clear whether the random effects model or the fixed effects model would be a more feasible way of estimation in this case (Table 2b in Appendix 1).

When all the 64 provinces were included, the magnitudes of the regression coefficients in both the least squares and the random effects models were significantly different from the coefficients of the models with less provinces included. In the fixed effects model, the coefficient of population density was not statistically significant. According to the test statistics, the fixed effects model seemed a more appropriate way of estimation than the random effects model.

The condition index of the OLS model was 6.5 which does not indicate serious multi-collinearity in the model. The bivariate correlations between the independent variables were, however, about 0.2–0.4 and significant at either the 1

Table 3. Bivariate Correlations between the Independent Variables as well as the Shares of Farm and Forest Areas of Each Province (n = 110).

	FC	*FaC*	*PopD*	*Small*	*Tenant*
FC	1	–0.636**	–0.727**	–0.403**	–0.307**
FaC		1	0.646**	–0.133	0.342**
PopD			1	0.421**	0.227*
Small				1	–0.309**
Tenant					1

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). *FC* = Forest cover (% of the total area of each province). *FaC* = Farm cover (% of the total area of each province). Other variables as in Table 1.

or 5 % level. Both the share of tenant farms and the population density were significantly correlated with farm density of each province. The farm cover and the forest cover were, of course, highly correlated (Table 3). These bivariate correlations may complicate the interpretation of the results of the causal relationships in the models of this paper.

Evaluation

Based on the models of this paper, population density as well as the shares of tenant and small farms affect the forest cover in the Philippines. The more there were small and tenant farms and the bigger the population density, the less there was forest in each province. This might indicate that agricultural expansion by subsistence farmers into the uplands, led by the conditions in the lowlands, indeed has been a major cause of deforestation during the two decades from 1969 to 1990.

Unfortunately, due to the lack of relevant and reliable data, some of the independent variables regarded important in the theoretical basis, the variables reflecting the amount and distribution of income, and the lack of nonfarm employment opportunities, could not be included in the empirical models. Omitting such variables may cause serious bias in the results of the models. In future, including a variable reflecting income changes, as hypothesized, for example, by Shafik (1994) and Palo & Lehto (1996), would presumably improve the models. One possibility would of course be to use regional level data, since some of the empirical data not available at the provincial level maybe could be found at the regional level in the Philippines. The problem might, however, be the small number of the degrees of freedom for modelling purposes, since the number of regions is only twelve.

Three different ways of modelling were used in this paper. When the provinces with increasing forest cover were removed as potential data faults and the provinces located close to Metro Manila left out as outliers and influential cases, it seemed that the so-called random effects model would be a feasible way of estimation but the results of the ordinary least squares were satisfactory as well, and did not differ much from those achieved by the random effects model. According to Greene (1993), the fixed effects model is a reasonable approach when we can be confident that the differences between the units can be viewed as parametric shifts of the regression function. Here, it was assumed that this is not the case but rather that the provinces have a common intercept, which could be interpreted as the original forest cover without any significant human influences. This is however a rather strong assumption since there probably have always been some differences in forest cover between the provinces.

An interesting result was that when the provinces with increasing forest cover as well as the provinces located close to Metro Manila were included in the modelling, the results changed in a statistically significant way, and the fixed effect approach seemed to become a more feasible way of estimation than the random effects model. It also seemed as if the differences in the constant terms for each province would have captured the effect of population density in the model, since population density was no longer statistically significant. This is, however, not surprising taking into account the fact that the provinces located close to Manila were left out of the models because of their extremely high population density caused by the closeness of the capital city area. Nevertheless, this result may call for a more careful investigation into the role of population density in deforestation.

As in several other studies on deforestation elsewhere (Lugo *et al.*, 1981; Palo *et al.*, 1987; Panayotou & Sungsuwan, 1989; 1994; Reis & Margulis, 1991; Katila, 1992; Kummer, 1992a; Barbier *et al.*, 1993), population density seemed to be an important variable explaining the diminishing forest cover in the Philippines. Kummer & Sham (1994) disagree, however, with the conclusions of the authors, according to whom population is the major cause of deforestation. They argue that the results, according to which forest cover is related to population density, are entirely expected because by definition, very few human settlements are found in forests. In the analyses of this paper, the correlation between the population density, and farm cover was statistically significant, positive and as high as the negative correlation between population density and forest cover. Moreover, the bivariate correlations between the independent variables of the models were statistically significant as well. The correlations between these variables make the interpretation of the results of this paper difficult and suggest more careful analysis about how the demographic and the socio-economic conditions affect the land-use changes in the Philippines.

The provinces with zero forest cover (Cavite, Cebu, Marindique, Masbate, and Siquijor) were totally excluded from the analyses of this paper since it was thought that these cases do not represent the process of deforestation in the same way as the other provinces since it is not possible to know when, i.e. with which values of the independent variables, they have lost the forest cover. It is important to note, however, that all the four provinces besides Cavite have a common feature: they are small islands. It is possible that because if this, their forests have been more accessible than the forests of some other provinces. Moreover, intuitively it would seem clear that the mountainous, and thus less accessible areas, would be the last to loose their forests. This might call for more thorough research on the role of accessibility together with the socio-economic and demographic factors.

The empirical models presented in this paper should not be regarded as comprehensive causal models for several reasons. First, as explained before, some of the theoretically relevant variables had to be left out of the empirical models. Second, even if the expansion by subsistence farmers may have been the major direct cause of deforestation in the Philippines during the study period 1969–1990, it is quite probable that the expansion of also “commercial” or “large-scale” agriculture has still been significant, at least, during the 1970s. Thus, in a comprehensive causal model the indirect causes affecting this type of agricultural expansion should be included. Yet another reason why the models presented can be regarded as simplified ones is that the direction of the effect may not only be one-way, since deforestation or forest cover changes may affect the socio-economic conditions as well (see also Reis & Guzmán 1994). For example, the declining forest cover may lessen the area available for expanding the farm area. This may force the existing farm land to be divided between an increasing number of people, thus increasing the proportion of small farms.

The estimated models are not well suited for prediction, since the future changes of only one of the independent variables, population density, can be predicted to any extent. Other independent variables reflecting the socio-economic conditions are more difficult from the point of view of forecasting future changes since the changes in themselves cannot be forecasted reliably enough. The past trends in these variables in each province would of course give some idea of the possible future changes if the model were used for scenario making purposes. Despite of the potential modelling problems, it would be quite important to construct and estimate a model for prediction purposes as well.

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APPENDIX 1

TABLE 1. MODELS ESTIMATED WITH VARYING NUMBER OF PROVINCES (SEE TABLE 2A IN THE TEXT).

TABLE 2B. RESULTS OF THE POOLED AND PANEL MODELS ESTIMATED WITH 59 PROVINCES.

Results of the models estimated with 59 provinces (n = 2 x 59 = 118). The model has been estimated by ordinary least squares (OLS), the fixed effects model (FEM), and the random effects model (REM) using generalized least squares (GLS).

VARIABLE	OLS		FEM		REM (GLS)	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
	p-value		p-value		p-value	
Constant	0.58772	(0.18470)			0.43866	(0.18541)
	0.0019***				0.0180**	
PopD	-0.00951	(0.00099)	-0.00339	(0.00238)	-0.008573	(0.00108)
	0.0000 ***		0.1572		0.0000 ***	
Tenant	-0.01949	(0.00690)	-0.01222	(0.00669)	-0.01861	(0.00549)
	0.0055***		0.0705*		0.0007 ***	
Small	-0.01354	(0.00446)	-0.02159	(0.00585)	-0.01330	(0.00391)
	0.0029***		0.0003 ***		0.0007 ***	
R^2 (adj. R^2)	0.65	(0.64)	0.94	(0.88)	0.64	
F (signif.)	69.50	(0.0000)	15.45	(0.0000)		
s.e.	0.71		0.40			
var[e]					0.179	
var[u]					0.352	
LM					23.98	(0.0000)
Hausman					6.83	(0.0776)

Note: The first figure after the name of the variable is the regression coefficient, the second one after it in parentheses is the standard error of the coefficient, and the last one below them is the significance level (in p-values). The level of significance is also been marked with stars (*): three stars: 0.01; two stars: 0.05. Hausman = Hausman's chi-squared test statistic; LM = Breusch and Pagan's Lagrange multiplier test statistic.

TABLE 2C. RESULTS OF THE POOLED AND PANEL MODELS ESTIMATED WITH 64 PROVINCES.

Results of the models estimated with 59 provinces (n = 2 x 64 = 128). The model has been estimated by ordinary least squares (OLS), the fixed effects model (FEM), and the random effects model (REM) using generalized least squares (GLS).

VARIABLE	OLS		FEM		REM (GLS)	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
	p-value		p-value		p-value	
Constant	0.51699	(0.23321)			0.05084	(0.20343)
	0.0285**				0.8026	
PopD	-0.00444	(0.00072)	-0.00055	(0.00088)	-0.00291	(0.00063)
	0.0000 ***		0.5330		0.0000 ***	
Tenant	-0.03526	(0.00785)	-0.01305	(0.00585)	-0.02474	(0.00494)
	0.0000***		0.0274 **		0.0000 ***	
Small	-0.02544	(0.00547)	-0.02697	(0.00380)	-0.02490	(0.00348)
	0.0000***		0.0000***		0.0000***	
R^2 (adj. R^2)	0.51	(0.50)	0.96	(0.91)	0.47	
F (signif.)	43.08	(0.0000)	20.284	(0.0000)		
s.e.	0,95		0.40			
var[e]					0.182	
var[u]					0.829	
LM					36.50	(0.0000)
Hausman					15.64	(0.0013)

Note: The first figure after the name of the variable is the regression coefficient, the second one after it in parentheses is the standard error of the coefficient, and the last one below them is the significance level (in p-values). The level of significance is also been marked with stars (*): three stars: 0.01; two stars: 0.05. Hausman = Hausman's chi-squared test statistic; LM = Breusch and Pagan's Lagrange multiplier test statistic.