Econometric analysis of the causes of forest land use changes in Hainan, China

Yaoqi Zhang, Jussi Uusivuori, and Jari Kuuluvainen

Abstract: This paper addresses the effects of economic, demographic, and institutional factors on land allocation between forestry and other uses. A panel data set from Hainan Island in China and a generalized least squares estimation method, allowing individual effects for counties, are applied. The results indicate that higher timber prices have led to an acceleration in rain forest exploitation, but encouraged investment in plantation forests. Population growth is the driving force behind the loss of natural forests, but it is positively related to plantation forests. Decollectivization seems to have promoted plantation forests, but has not saved the rain forest. A higher share of forestry land owned by state-owned enterprises also fosters afforestation on wasteland, but seems to lead to faster exploitation of natural forest, at least initially. The uncertainty that existed in the early period of economic reform quickened the pace of resource extraction and deterred investment.

Résumé : Cet article traite des effets des facteurs économiques, démographiques et institutionnels sur l'allocation territoriale pour la foresterie et d'autres usages. On a utilisé un ensemble de données d'un panel sur l'Île de Hainan en Chine et une méthode d'estimation généralisée basée sur les moindres carrés, qui permet de tenir compte des effets individuels des comtés. Les résultats indiquent qu'une hausse des prix du bois a entraîné une accélération de l'exploitation dans la forêt humide, tout en encourageant les investissements pour la plantation d'arbres. La perte de forêts naturelles est principalement attribuable à l'accroissement de la population, qui est aussi relié positivement à la plantation d'arbres. Le fait de rescinder la collectivisation semble avoir favorisé la plantation d'arbres, sans toutefois avoir permis d'épargner la forêt humide. Le fait qu'une plus grande part du territoire forestier soit détenu par des entreprises d'État favorise aussi le reboisement sur les terres abandonnées mais cela semble engendrer une exploitation plus rapide de la forêt naturelle, du moins initialement. L'incertitude qui existait dans la période initiale de la réforme économique a provoqué l'accélération du rythme d'extraction de la ressource et découragé les investissements.

[Traduit par la Rédaction]

Introduction

Recently, the causal factors behind the processes that lead to conversion of forests into farmland, tropical cropland, and other nonforest lands have attracted considerable attention in the literature on forest land changes in less developed countries (LDCs). Forest loss has many serious negative environmental and socioeconomic impacts in LDCs, especially in the long run. Research has been able to shed some light on the factors behind the process. However, land conversion that leads to forest land expansion has received only little attention in the literature on land use economics. Yet, forest land expansion, mainly through an increase in plantation forests and active natural forest management, can reverse many, even if not all, of the adverse consequences of the loss of natural forests.

Many earlier studies that have addressed the problems related to forest land changes in tropical countries have analyzed the effects of demographic and economic conditions using data from either the cross-country (e.g., Capistrano 1994; Palo 1994; Rudel 1998) or subcountry levels (e.g., Kummer and Sham 1994; Panayoutou and Sungsuwan 1994). However, in the new institutional economics, it has been argued that in addition to economic factors, such as relative prices, institutional factors also affect economic development (e.g., North 1990). In the context of land use and forestry, the impacts of institutions have been examined by Bromley (1989, 1991), Wallace and Newman (1986), Mendelsohn (1994), Deacon (1994, 1999), Besley (1995), Zhang (1996), Zhang and Pearse (1996), Laarman (1996), Yin and Newman (1997), and Place and Otsuka (1997).

In this study, we examine the role of economic and institutional factors in the development of both plantations and natural forests in the Province of Hainan. One of the reasons why development of plantation forests has rarely been studied is that plantation forests are still relatively small in the tropics, and successful plantation programs are even more rare. With its established programs aimed at increasing forest plantations, the case of Hainan Island provides a good opportunity to shed some light on the underlying causes and long-term development of forestry in LDCs. In particular, we are able to address some of the factors that may reverse the decline in total forest land area.

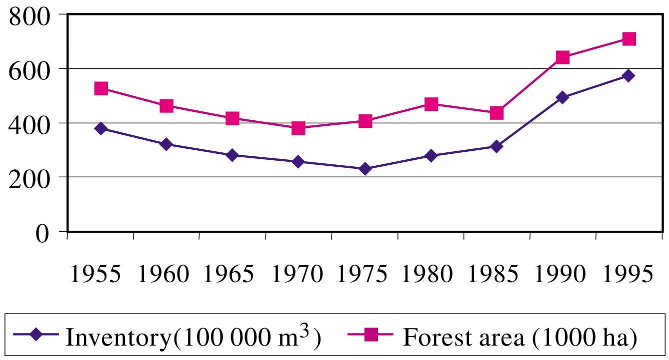
A major innovation of this paper is distinguishing between natural forest and forest plantation, while showing how various factors affect the two differently. Forest transition is the consequence of the shift from natural forest ex-

Received February 14, 2000. Accepted September 14, 2000. Published on the NRC Research Press website on November 25, 2000.

Y. Zhang,[1] J. Uusivuori, and J. Kuuluvainen. Department of Forest Economics, PL 24, 00014 University of Helsinki, Finland.

[1]Corresponding author. e-mail: yaoqizhang@yahoo.com

Fig. 1. Forest coverage and forest inventory (1950s–1990s). Data are from the Hainan Forestry Bureau (1957–1995).



ploitation to harvesting managed forests. Of particular interest in Hainan, as in other LDCs, is the effectiveness of structural adjustment policies aimed at adjusting government control, clarifying forest land property rights, and improving the possibilities for their enforcement. We also consider the roles of relative prices and transition policies in determining forest land changes in Hainan. The available panel data allow us to use regional dummy variables that are able to capture environmental and other differences that are not directly observed, across counties.

We start by describing the forest sector and economic reforms in Hainan province. The third section introduces the theoretical model for land allocation among different uses, leading to an estimable land allocation function. The following section introduces the panel data. Estimation results, for both natural forests and plantations forests, are presented after this, followed by conclusions.

Forestry and economic reform in Hainan

During the past 20 years the most important ways to reform land tenure in Hainan have been the following: (*i*) the control of public forestry land nominally owned by the state is given to the state-owned enterprises; (*ii*) the management authority for state-owned forestry land is transferred through decentralization from the national to the provincial level and then from the provincial to the county level, or from the state to the community level; (*iii*) forestry land is distributed, through decollectivization, to households, e.g., on the basis of the number of persons in the household; alternatively, parts (or all) of the management authority are transferred to contractors; and (*iv*) property rights are redefined by organizing various kinds of joint forest management ventures that combine different inputs. Below, we briefly describe the development of forests in Hainan before discussing the above land tenure reforms in more detail.

Hainan Island, which covers a total area of 3.4×10^6 ha, is located in the South China Sea and separated from the Chinese mainland by the Qiongzhou Straits. It is almost as large as Taiwan Island. Hainan has a typical tropical monsoon climate. In 1988, Hainan was upgraded to the provincial level and given the status of Special Economic Zone. Since then, the economic growth rate, averaging 20% annually from 1988 to 1995, has been the fastest at the provincial level in China. The population is also growing dramatically, from 5 million in the mid-1980s to 8 million at present (the actual population could be over 10 million).

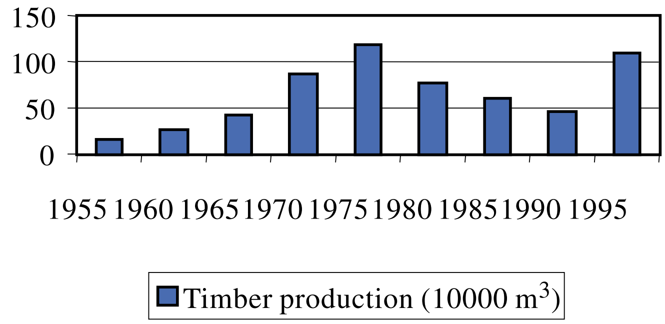
Originally, Hainan was covered mostly by rain forests (Situ 1992), but the effect of long-term human activities has caused serious deforestation and degradation of forest land. As in the rest of the tropical world, deforestation in Hainan was also directly caused by logging, shifting cultivation, agricultural land encroachment, and residential and industrial expansion. In addition, an even greater share of the land was abandoned without management, leaving open forest, shrubs, and long-term fallow.

It is widely agreed that the forest cover was about 30% at the beginning of the 1950s and the remaining forests were mostly located in the center of mountain ranges (Hainan Agricultural Zoning Commission 1980). Since the 1950s, the rain forest suffered further from logging because of the growing demand from within and outside the island. As harvesting was carried out like mining and there was insufficient silvicultural investment, Hainan went from being a net timber exporter in the 1950s–1970s to an importer in the 1980s. Tropical crops were introduced in Hainan at the beginning of this century, but it was not until the 1950s that they started to expand dramatically as a result of an increasing domestic demand for natural rubber materials (trade was blocked by the western world at that time). Over the past decades, agricultural land has not expanded significantly, while shifting cultivation, which has been widely practiced by local minorities, has destroyed large tracts of rain forest. It is estimated that 2700 ha of forest were destroyed annually in the 1970s–1980s (Bao 1991). After three decades of destruction, the forests shrank to their minimum level, 15% of total land area, in the late 1970s (Hainan Agricultural Zoning Commission 1980).

During the last two decades, the decreasing trend in forest land area has been reversed and in Hainan; forest land area is presently expanding (see Figs. 1–3). This provides empirical support for the “forest transition” hypothesis claiming that the declining forest land area will eventually begin to increase as the country develops, as suggested in Mather (1990), Hyde et al. (1996), Rudel (1998), and Zhang (2000) among others. Since 1990, income from woodchip exports has become an important source of foreign currency earnings and an important part of rural economy. Physically, forest expansion has been directly caused by massive plantation of forests for producing raw material for woodchip production and for environmental functions such as wind-breaking and water conservation. Also, the rehabilitation of degraded land by closing access to it and a significant reduction in logging of natural forest through stricter regulation have had a positive effect on maintaining rain forest.

Land tenure and administration in Hainan does not differ noticeably from that in the rest of China. The only special features are that state-owned forests and collective forests coexist and that forests play a special role in the island’s environment and in ecotourism. Under China’s land reform implemented in 1950–1956, all land owned by landlords was confiscated and most of it was distributed to local farmers. However, remote areas, particularly in the central island, i.e., the rain forests, were reallocated to the state-owned logging firms. During the 1950s and 1960s, about 350 000 ha of forestry land was allocated to state logging firms, of which

Fig. 2. Timber production (1950s–1990s). Data are from the Hainan Forestry Bureau (1957–1995).



80% went to the 11 largest ones (Hainan Agricultural Zoning Commission 1980).

In the “socialistic transformation” that started in 1957 the land was transferred from individuals back to the collectives in the first phase of “collectivization” and then to the “people’s communes” in the second phase. The people’s communes continued until the Mao’s death in 1976. There were also a couple of episodes of decollectivization, e.g., after the collapse of “the Great-Leap-Forward” in the late 1950s (Walker 1965). Compared with agriculture, the forestry sector was much more collectivised and centralized.

The “economic reform” started in the late 1970s. The most significant reform in agriculture has been the introduction of the “household responsibility system,” which actually represents a kind of privatization of land-use rights. In the forest sector, the reform in general began a little later and is far less intensive and extensive than in agriculture (Zhang et al. 1999). The institutional reforms in the Hainan forestry sector during the last 20 years are summarized in the following paragraphs.

Joint plantation of fast-growing species of trees

When the eucalyptus woodchip market was expanding and a market-oriented economy was gradually emerging in China in the late 1970s, the Ministry of Forestry started planning to establish 130 000 ha of fast-growing trees in Hainan. A project, referred to as “2 million mu (15 mu = 1 ha) joint plantation of fast-growing and high-yield species of trees,” was formally launched in 1982. The joint partners were the Ministry of Forestry, which provided the capital, the local collectives, which provided the land, and the local people, who supplied labor. Encouraged by this initiative, several other joint plantation projects followed. A few banks, including the World Bank, provided substantial loans for these projects.

In general, these projects were successful. A total of 130 000 ha of eucalyptus and some other fast-growing species of trees were planted between 1982 and 1995, accounting for more than one-third of plantation forests during this period and contributing to a 4% increase in total forest cover. The General Fast-Growing Plantation Forest Company, established in 1984, has been in charge of administration, technology assistance, and the woodchip export monopoly.

Closed access management of degraded forestry land

From the 1950s to the 1980s, the degraded forestry land category, which included, e.g., open forest, shrubs, and long-term fallow, was larger in area than the other categories of forested land. Degraded forestry land accounted for one-quarter of the total land area in the mid-1970s (see Fig. 3), resulting, to a great extent, from repeated damage caused by fuel-wood gathering and shifting cultivation (Hainan Agricultural Zoning Commission 1980).

Along with population growth, economic development, and advances in silvicultural techniques, some good locations and productive bare land have been afforested. “Closed access management,” which has been mainly applied to degraded forestry land, has greatly accelerated its rehabilitation. Exclusiveness is a prerequisite for silvicultural investment (Zhang and Pearse 1996). In Hainan, contracts between the local collectives, who own the land and trees, and households, who receive an annual guardian fee or share of the return from the final harvests, have been used to reduce the costs of exclusion. Thus, this arrangement individualizes some of the benefits from the enforcement of the forest land property rights at low costs, serving as a kind of privatization. During the 1980s, it was estimated that more than 100 000 ha of degraded land had been rehabilitated in Hainan by this approach (Zeng 1994), as was almost the same area during the 1990s. Therefore, 6–8% of the total territory has been reforested by this method.

Restrictions on timber production from tropical rain forests

The topography of Hainan is characterized by mountainous ranges in the center that gradually fall away towards the coast. The tropical rain forests are mainly found in the center of the island and are presently managed by the state-owned forestry bureaus. After decades of exploitation, access is becoming more difficult and the quality of the forest is declining.

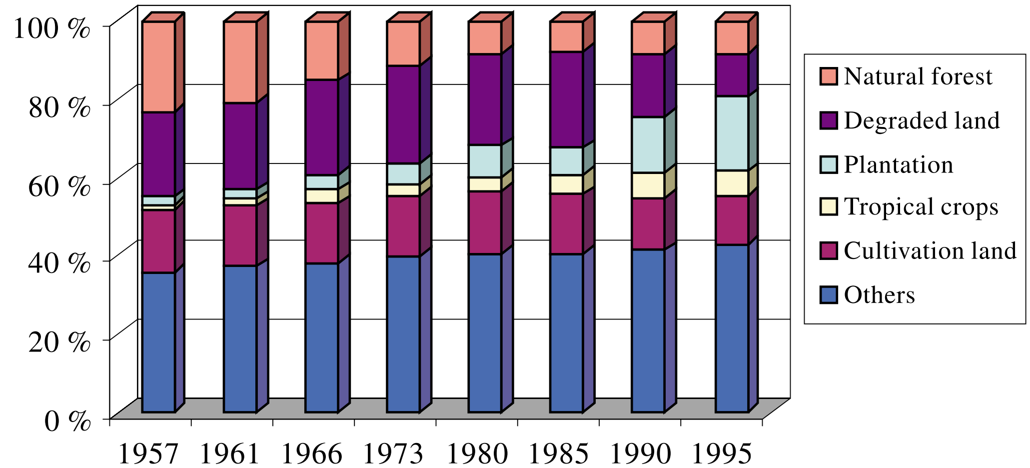
The rain forest has attracted greater attention from the public and government since it is widely believed that overall environmental deterioration, such as soil erosion, shortage of water sources, and loss of biodiversity, is due to the loss of the rain forest in Hainan. Therefore, more restrictions have gradually been imposed on rain forests. First, only selective cutting was allowed in the late 1970s. Then, a quota of allowable fellings was set in 1984 and has been gradually reduced since then. Finally, in principle, harvesting of all rain forests has been banned since 1993 and 1994.

Since the state-owned forestry bureaus depended heavily on rain forest logging, the economy suffered from the restriction. Financially, both the national and provincial levels compensated for some of the loss; banks, either encouraged or forced by governments, provided low interest loans to finance the shift to other fields of business, such as silviculture, furniture production, ecotourism, tropical crop plantations, construction of hydropower stations, mining, etc. After a decade’s efforts, it seems that the forests in most of the forestry bureaus are recovering, even though the local economies are still facing some difficulties.

Theoretical model of land allocation

The literature on spatial land allocation theory postulates that land is divided between alternative uses according to the highest land rent obtainable, with regards to location and

Fig. 3. Land use and cover classifications and their changes (1950s to 1990s). Data are from the Hainan Forestry Bureau (1957–1995), Hainan Statistical Bureau (1957–1995), and Hainan Agricultural Zoning Commission (1980).



physical conditions (see, e.g., von Thunen 1875; Hyde 1980; Chomitz and Gray 1996). In China, land is publicly owned. Therefore, land markets do not, in effect, exist and land prices reflecting land rent of a particular land-quality class in alternative use categories are not available. However, it can be assumed that individuals or (state) enterprises that have been given control over land will allocate the land to different uses according to profitability in the particular use category.

The profitability of land use depends on the relative prices of products in different land-use categories. Because we do not have data on the prices of land with different characteristics, we will ignore land-quality classes. Assume that the landowner (an individual, a household, or an other administrative unit with land tenure) seeks to maximize the total land rent from different land uses on homogenous land under his control by allocating the total land area optimally between n different uses. Distance to markets and other factors affecting the return on land enter the model in our specification indirectly through the production function properties. In particular, production y_i of the ith product is a strictly concave function of land area A_i allocated to ith land-use category and of the composite input E_i used. The landowner's problem is to maximize the profit, while being constrained by the total land area under his control:

$$[1] \qquad \max_{A_i,\, E_i} R(p_i, A) = \sum_{i=1}^{n} [p_i y_i(A_i, E_i) - cE_i]$$

$$\text{st} \qquad \sum_{i=1}^{n} A_i \le A, \qquad A_i E_i \ge 0$$

where p_i (i = 1,..., n) is the scalar for the product prices, E_i is the aggregate input used to produce the output y_i, A_i is the size of the land area allocated to produce the respective product, and c is the unit cost of composite input. The production functions are such that $\partial y_i/\partial A_i > 0, \partial^2 y_i/\partial A_i^2 < 0$ and $\partial y_i/\partial E_i > 0, \partial^2 y_i/\partial E_i^2 < 0$, i.e., the marginal products of land and composite input are positive, but decreasing in each land-use category. Setting up the Lagrangean, we obtain

$$[2] \qquad \max_{A_i,\, E_i} R(p_i, A) = \sum_{i=1}^{n} [p_i y_i(A_i, E_i) - cE_i] + \lambda(A - \sum_{i=1}^{n} A_i)$$

The Kuhn–Tucker conditions are

$$[3a] \qquad \frac{\partial L}{\partial A_i} = p_i \frac{\partial y_i}{\partial A_i} - \lambda \le 0, \qquad (p_i \frac{\partial y_i}{\partial A_i} - \lambda) A_i = 0 \qquad i = 1, \ldots n$$

$$[3b] \qquad \frac{\partial L}{\partial E_i} = p_i \frac{\partial y_i}{\partial E_i} - c \le 0, \qquad (p_i \frac{\partial y_i}{\partial E_i} - \lambda) E_i = 0 \qquad i = 1, \ldots n$$

$$[3c] \qquad \frac{\partial L}{\partial \lambda} = A - \sum_{i=1}^{n} A_i \ge 0, \qquad (A - \sum_{i=1}^{n} A_i)\, \lambda = 0$$

The terms $p_i(\partial y_i/\partial A_i)$ are the marginal income from additional land to be used. Thus they represent shadow land rents. According to [3], land is optimally allocated so that these rents for a homogenous land are equal for each land-use category. For an interior solution we obtain the following equilibrium condition from [3]:

$$[4] \qquad \frac{p_i}{p_j} = \frac{\partial y_j/\partial A_j}{\partial y_i/\partial A_i}, \qquad i \ne j$$

According to [4], the ratio of the marginal products of land under land use j and i equals the ratio of the net prices of products i and j. The condition gives the marginal rate of substitution between two different land uses. For example, if productivity of a certain land-use category increases, more land will be allocated to this particular use.

The optimal land areas in different use categories implied by the first-order conditions are functions of the product prices, the composite input price, and the available total land area and they can be written as

$$[5] \qquad A_i^* = A_i^*(\boldsymbol{p}, c; A)$$

Table 1. Land classification.

Categories	Description and notes
(A1) Built-up, roads, and unproductive land	Comprises mainly residential and industrial areas, roads, mining areas. This category also includes technologically unforestable land such as water bodies and excessively degraded land which makes up 8% of the total land.
(A2) Cultivation land	Subsistence agricultural land (rice, vegetable, nontree fruits, etc.).
(A3) Tropical cropland	Tropical crops (rubber trees and other crops, tropical tree-fruits, etc.).
(A4.1) Actively managed forest	Comprises mainly plantation forest but includes some actively managed secondary natural forest.
(A4.2) Degraded but afforestable land	Low biomass woody land such as open forest, shrubs, and long term fallow. But all are technologically afforestable.
(A4.3) Nonactively managed forests	Frontier forests or natural forest with very limited human disturbance.

where $\boldsymbol{p}$ is the vector of product prices (Chambers 1988, p. 281 about restricted production optimization).

The optimal land allocation functions, the $A_i^*(\boldsymbol{p}, c; A)$'s, are nondecreasing in p_j ($i = j$). It can be also shown that the cross-price effects are nonpositive. For the purposes of the empirical modeling, these results give us the expected positive sign for the effect of a change in timber price on the amount of land allocated for forest and an expected negative sign for the cross-price effects of the various land-use classes. The effect of c, the composite input price, on $A_i^*(\boldsymbol{p}, c; A)$ depends on the substitution effect between land and the aggregate input, plus the output effect. A priori, the total effect of c is indeterminate in sign.

As we argue, besides markets and prices, institutional factors play a key role in rural land allocation in Hainan. Therefore, we include in the forest land allocation model one variable describing the economic development and one for population, as well as two variables describing the land property rights policies in China. The first two variables are gross output value (GOP) and population density (PD) in each of the Hainan counties.[2]

The land reform variables are the percent share of land under the household-responsibility system (H) and the percentage of forestry land under state ownership (SF). These variables thus measure the effects of land-tenure shift and decentralization of forest land management in Hainan. Accounting for the market-driven and the institutional factors, the implicit model for forest land allocation within the counties in Hainan can be written as

$$[6] \qquad \text{Forest land allocation} = F(\boldsymbol{p}, c, A; \text{GOP}, \text{PD}; \text{SF}, H)$$

where $\boldsymbol{p}$ is a vector of output prices of rural crops including timber prices, c is the cost index for rural inputs, A is the total land area in the county. In Hainan, the institutional changes from socialist transformation to current economic reforms have been less endogenous with the socioeconomic development, but greatly determined by political ideology. Therefore, they can be treated as exogenous variables (Besley 1995).

Data

Before proceeding, we divided land use in Hainan into four broad classes (see Fig. 3 and Table 1). In Table 1, total forest area has been divided into three categories: actively managed forests, degraded but afforestable land, and natural forests. The first and the third categories are classified as being part from forest land in official Chinese statistics, while all three combined form the “forestry land category”. Therefore, in Table 1, category 4 represents the forestry land class. In our study we will examine categories 4.1 and 4.3.

Counties in Hainan are economic and administrative units, but they also reflect the natural, geological, economic, and even social integration of each unit. Therefore, the cross-section observations in the study are based on counties.

Hainan has a total of 19 counties and one state reclamation bureau. Because frequent changes occurred in the administrative system, we combined the neighboring counties of Haikou City and Qiangshan County; Tongza, Qingzhong, and Baotin; Chenmai and Linguo; and Baisa and Changjiang. This ensures that the 13 cross-section units thus obtained remain the same throughout the examined period. Since data on the state reclamation bureau are very spare, the bureau is excluded from this study. Our sample covers 17 points in time in the period from 1957 to 1994 and 13 cross-section units, i.e., 221 observations.

We use GOP instead of gross domestic product (GDP) because GDP was not used in the earlier statistical reports and also because GOP is a good proxy for GDP. Nominal GOP has been deflated by the retail price index (base year = 1957). Prices are obtained from local statistics, mainly *Hainan Statistical Yearbooks* (Hainan Statistical Bureau 1957–1995). Timber price used for plantation forests is the price for eucalyptus while the timber price for rain forests is an average hardwood price. All prices are at the provincial level and deflated using the general retail price index. The data on forest resources were combined with the forestry statistics of forestry bureaus that are based on the Institute of Forest Resources Investigation (Hainan Forestry Bureau 1957–1995). Data on the natural variables were obtained from Hainan Agricultural Zoning Commission (1980).

[2] Generally population pressure affects land allocation, but the effect on managed and natural forests may differ. Population density may also, among other things, be related to the distance of forestry land to markets. In addition, both economic prosperity (GOP) and population density (PD) may affect forest land allocation through directly unobservable nontimber values of forests.

The percent share of forestry land managed by state logging firms and farms (SF) was obtained from the Hainan Forestry Bureau, while *H*, the percent share of land under the household responsibility system, was collected by this study and from information provided by forestry bureaus at the county level.

Econometric specification and methods

The econometric specification for both managed forests and rain forests is based on [6]. To avoid omitted variables bias, resulting from unobserved county-specific institutional and environmental factors, a panel data analysis with individual constant terms for counties was used. Fixed-effect panel data estimation is appropriate when cross-section units are not sampled from a large population and the differences between units can be viewed as parametric shifts of the regression function (Greene 1997, p. 623). This clearly is the case in the present study, because our sample includes all the counties in Hainan. Therefore, the estimated parameters cannot be used to predict behavior outside the present sample, although our method should be applicable in other studies of land allocation.

As macroeconomic, geographic, and socioeconomic factors are likely to affect land allocation in different counties in Hainan, we allow contemporaneous correlation of cross-section units (Greene 1997, p. 658; Hsiao 1986). Lagged values of exogenous variables did not improve the statistical performance of the two estimated equations. Therefore, to take into account the relatively strong autocorrelation in the data, the Cochrane–Orcutt transformation is used and the model is estimated using the iterative generalized least squares method (Kmenta 1986 pp. 622–625; Greene 1997, pp. 651–669). The econometric specification is

$$[7] \qquad \mathrm{FC}_{it} = \alpha_1 + \sum_{i=2}^{13} \alpha_i D_i + \beta_1 \mathrm{PD}_{it} + \beta_2 \mathrm{GOP}_{it} + \sum_{n=1}^{3} \beta_{2+n} P_{it}^{n} + \beta_6 \mathrm{SF}_{it} + \beta_7 \mathrm{H}_{it} + \beta_8 \mathrm{SU}_{it} + \beta_9 \mathrm{H}_{it} \mathrm{DU}_t + \varepsilon_{it}$$

where subscripts *i* and *t* indicate the counties and years, respectively; D_i is the regional dummy variable; FC denotes the forest cover (%); PD is population density (in persons per ha); GOP is the deflated per capita output value (Yuan per capita); P^n (n = 1, 2, 3) is the real price index of agricultural products, tropical crops, and timber, respectively, i.e., they are divided by the index for rural industrial materials, following Yin and Newman (1997);[3] SF denotes the ratio of land owned by state forestry firms to total forestry land; and *H* is the ratio of the household responsibility forestry land to total forestry land. All variables except SF and *H* are in natural logarithms.

The period we examined covers the years from 1957 to 1994. The years 1980 to 1987 were characterized by uncertainty concerning the direction of economic reforms, which were in an experimental phase. Farmers and local, even provincial, government officials did not know whether and how the reforms would be carried through. Forests suffered greatly from this uncertainty across the country. Therefore, a dummy variable, DU, is used to allow both the intercept and the slope of the decollectivization (*H*) to differ from the rest of the period studied.

To examine the difference between managed (mainly plantations) and natural forests (mainly rain forests), a behavioral model is estimated for both categories.[4] As stated above, hardwood price is used as the timber price for the rain forest; the timber price for the plantation forest equation is the price of timber produced from plantations, mainly eucalyptus. Although the same economic principles apply to managed and rain forests, the development of managed and rain forest areas may respond differently to relative prices and the institutional variables because investment in plantation forestry resembles investment in other sectors, such as agriculture, while harvesting of natural forests is a mining-like activity.

In the case of rain forest, only 8 of the 13 cross-section units were of significant size during the period studied. The harvesting of rain forest has been regulated and either only a selective cut has been allowed since the late 1970s, or harvesting has been prohibited altogether since the mid-1980s (in other words they have become “managed forest”). Therefore, the five cross-section units where rain forests make up less than 2% of the total area of the county (in the late 1970s) and the period after 1985 were excluded from the regression model explaining the area of rain forests.[5] The total number of observations is 72 (eight units for nine points in time). The estimated function includes the same explanatory variables as [7].

Estimated results

The estimated results for managed forest and rain forest obtained with [7] are given in Table 2. Standard errors clearly decreased when cross-sectional heteroscedasticity and contemporaneous correlation were allowed, indicating an increase in efficiency when using generalized least squares (GLS). However, some of the variation between cross-sectional units is not explained by the variables included, as indicated by the statistically significant coefficient estimates of the regional dummies. To account for the directly unobservable regional differences, such as climate, topography, and history, a common intercept and 12 regional dummy variables were retained.

[3] This specification provided the best statistical performance. Together with the logarithmic transformation the specification implies that the impacts of output prices and composite input price are assumed to be equal in absolute terms but to differ in sign.

[4] The aggregation of natural and managed forest land may be appropriate for regions dominated by either natural forest or plantation forest. In the case of Hainan Island, natural forest and plantation forests each account for half of total forests. Aggregation necessarily loses information, therefore, separate regressions are necessary.

[5] Because the estimation periods differed, seemingly unrelated regression method could not be used to estimate the managed and rain forest equations together and to improve the efficiency of the estimates. No significant contemporaneous correlation between the error terms from the equations for rain forest and managed forests was found when the same sample length was used.

Table 2. Generalized least squares estimation results for managed and rain forest cover in Hainan from 1957 to 1994.

	Variable description*	Managed forest cover (%)	Rain forest cover (%)
α_1	Constant	–3.74 (7.03)	2.98 (3.40)
Pa	Agricultural products price	0.11 (1.16)	0.33 (6.55)
Pc	Tropical crop product price	–0.40 (4.22)	1.29 (7.68)
Pt	Timber price	0.61 (5.81)	–1.52 (4.80)
PD	Population density	2.21 (42.57)	–0.61 (21.51)
GOP	Per capita gross output value	0.59 (22.48)	–0.31 (18.33)
SF	Percentage of state-owned land to total (%)	0.42 (7.17)	–0.77 (7.80)
H	Ratio of the household responsibility system to total	0.79 (8.56)	–0.54 (16.06)
DU	Dummy for uncertainty	–0.09 (2.73)	–0.76 (0.88)
H×DU	Joint effect of the household responsibility system and uncertainty	–1.55 (15.49)	0.66 (17.07)
$\rho^\dagger$	Autocorrelation coefficient	0.64	0.53
Log-L	Log-likelihood	134.7	144.6

Notes: Data for managed forests is from 1957 to 1994 across 13 units; data for rain forest is from 1957 to 1985 across eight units. The values in parentheses are *t* values.

*The regional dummy variables are excluded in the table.

†A single autocorrelation coefficient is adopted because we found that different autocorrelation coefficients did not change the estimated results or standard errors markedly.

As expected, higher timber prices promote forestry investment in managed forests, as measured by plantation forest cover. However, the rain forest land area decreases as timber price increases, implying that the increasing hardwood price has, at least in the past, increased mining-type harvesting of rain forests. The agricultural product price has a positive impact on both managed and natural forest cover. This runs counter to the theoretical hypothesis and suggests that rising agricultural product prices do not lead to encroachment on forest land in Hainan. In a developing subsistence economy, this result may be due to the fact that farmers can meet their income needs with less harvest income when agricultural prices increase. Also there does not seem to be any serious conflict between agriculture and forestry. A similar result was obtained for mainland China by Yin and Newman (1997). Plantation forests respond negatively to the tropical crop product price, implying that tropical crops compete for land with plantation. However, the rain forest and tropical crops may even be complementary, as indicated by the positive coefficient of tropical crop price in the rain forest equation.

Like many other studies, our estimated results indicate that population has a negative effect on rain forest coverage. This suggests that a growing population generally causes some rain forest to be converted into agricultural, industrial, and residential land and probably into wasteland after logging if access to logged land is not regulated and land ownership is not defined. However, the managed forest area in Hainan has increased with population. Thus, rising population has speeded up the exploitation of natural forest, but may have promoted plantation in Hainan.

The effect of economic development (or welfare), measured by per capita output value, also has a positive effect on managed forest cover. One explanation for this may be that economic development reduces, e.g., transportation costs and costs of protecting property rights as infrastructure and law implementation are improved. The economic development may also have demand side effects. Strengthening demand for timber is reflected in timber prices. However, a wealthier society may also appreciate the in situ benefits of forests, causing a positive correlation between plantation forest and GOP. For example, in Hainan, about 20% of plantation forest is intended for environmental purposes. The positive effect of GOP on managed forests does not contradict the negative sign of GOP in the rain forest equation. Natural forests have been examined over the period of 1957–1985. Since then, harvesting in rain forest has been fully regulated, indicating increased environmental concerns and a change in preferences towards protection of natural forests. The expansion of managed forest accelerated in the 1990s, in line with the economic growth.

The share of forestry land controlled by state-owned enterprises seems to have a positive effect on plantation forest cover, but the effect is significantly negative for rain forest before 1985. This can be explained by the fact that state-owned forestry bureaus (or farms) were set up for two purposes: to afforest public wasteland and to exploit public natural forest. Our results also show that decollectivization (*H*) promoted the loss of natural forest in the early part of the explored period (the negative sign of *H* in the second column of Table 2.), but may have worked in the other direction in the 1980s (the positive sign of $H \times$ DU in the second column of Table 2).

In summary, the disaggregation of total forest land area into managed forests and natural forests is justified when explaining the development of forest land area. The results indicate different responses of plantation and rain forest to evolving timber prices, population growth, economic development, and institutional changes.

Cross-sectional differences

The regional constant terms represent differences between counties that are omitted from the model because the data necessary for their inclusion are not available (Hsiao 1986). Even if it is not possible to explain all regional variation with the available data, the estimated regional constant terms can be used to study possible reasons for this variation. In the present case, it can be assumed that regional differences

Table 3. The ordinary least squares estimates for intercepts equations.

	Variable description	Intercepts (in managed forest cover)	Intercepts (in rain forests land cover)
α	Constant	–7.60 (3.45)	3.74 (0.70)
ML (%)	Mountain area	0.05 (0.62)	0.46 (1.53)
SL (%)	Hilly and slope land	1.92 (4.93)	–0.51 (0.31)
RF (100 mm)	Rainfall	–0.02 (0.04)	–0.33 (0.30)
R^2	Adjusted R^2	0.80	0.27

Note: The values in parentheses are *t* values.

are at least partly due to natural and geological factors (e.g., Hoshino 1996). As we have only 13 cross-section units for managed forest (eight units for rain forests), the results must be considered with caution. However, to tentatively test whether geological factors explain the regional differences, we regress region-specific constants, α_i^* ($\alpha_1^* = \alpha_1$; $\alpha_i^* = \alpha_1 + \alpha_i$, for $i \neq 1$), on the share of mountain land with minimum 500 m a.s.l. (ML, %), the share of hilly land (with an altitude between 250–500 m a.s.l.) plus the land with a minimum slope of 12°, but an altitude of less than 250 m a.s.l. (SL), and the annual rainfall (RF). The estimated ordinary least squares model becomes

$$[8] \qquad \alpha_i^* = \alpha + \beta_1 ML_i + \beta_2 SL_i + \beta_3 RF_i + \varepsilon_i$$

According to the results reported in Table 3, the regional constant terms are statistically related to the natural variables. The dummy variables for managed forest are very strongly related to the SL, while the dummy variables for rain forest seem to be related mostly to ML[6]. This is intuitively interpretable. Flat and low land is best suited to agriculture and tropical crop plantations, the middle and high mountains are likely to be rain forest because of their difficult accessibility, while the hilly and low mountains are best suited to tree plantations.

Rainfall does not explain regional variation in managed forest and rain forest. This is also understandable. Rainfall might be important for timber volumes per land unit, but not necessarily for allocation of forest land. The region that was first settled is on the western coast of the island where rainfall is much lower and cultivation is easier. Rainfall helps forest grow but it also helps agriculture, and the accessibility of rain forest mostly depends on distance and topography rather than the types of rain forest, which are determined by rainfall.

Conclusions

This study has demonstrated that natural forest land and plantation forests react differently to economic and institutional factors explaining their development over time. Therefore, studies explaining the development of aggregated forest land areas may give misleading results and also their policy implications could be questioned. According to our results, higher timber prices have promoted the clearing of rain forests in Hainan. In contrast, higher timber prices seem to have been an incentive to investment into forestry and have had a positive effect on the expansion of plantations in Hainan. The conflict between agricultural and forestry land seems to be less serious than the conflict between tropical crops and forest plantations.

In Hainan, there is much land that has a defined owner, but the owner is unable or unwilling to enforce property rights making these areas in effect open access. Because of, e.g., poor land quality and low output prices, revenues may not have been sufficient to cover the costs of protecting the property (cf. Allen 1991; Barzel 1997). Consequently, the property rights are not enforced and inactive management is a rational choice. In spite of this, land tenure reforms play an important role in forest investments in China. Empirical results of this study suggest that decollectivization in the form of the household-responsibility system is an incentive to forest investment into plantations, but may have initially increased rain forest exploitation.

Privatization is not the only way to reform land tenure. Changes in land tenure characteristics, such as renting, transferring part of property rights to individuals and cooperatives among different input owners, may also promote forestry. For example, the increased control of state-owned forest land by state-owned enterprises has increased plantations, but it has also promoted clearing of rain forest. Therefore, these results suggest that privatization and increasing timber prices do not necessarily help rain forest conservation and that public intervention to protect rain forests, as practiced in Hainan, has been justified.

Population growth is not necessarily a serious problem for forestry development when managed forestry is concerned. The existing potentially forestable land area is as large as the currently forested land in Hainan (see Fig. 3). Therefore, deforestation resulting from agriculture and industrial expansion may not actually be as big a problem as the nonactive management of this forestable land.

Finally, some limitations of this study should be noted. Our data were collected mainly from official sources. Changes in conceptual definitions and statistical data collection methods occurred during the observation period. Also, land reforms affecting other land categories (such as real estate business and agricultural sectors) that clearly have direct or indirect influences on the relative value for forest management could not be studied. However, the results indicate that when studying land allocation between forestry and other land uses, it is important to disaggregate forest land into managed and natural forests to derive relevant policy implications.

[6] The lower statistical significance of the coefficient for mountain area in the rain forest equation is clearly a result of the fact that we have omitted counties without mountain regions where there are no rain forests left. Therefore, mountain area may be more critical for rain forests than our regression shows.

Acknowledgments

This work was supported by the International Development Research Centre's (IDRC) Economy and Environment Programme for Southeast Asia (EEPSEA). For helpful comments, the authors thank Heminia Francisco, William Hyde, Nancy Olewiler, Thomas P. Tomich, and three anonymous reviewers. All errors are responsibilities of the authors.

References

Allen, D. 1991. What are transaction costs? Res. Law Econ. **14**: 1–18.

Bao, K. 1991. The provincial government is making an initiation: experiment of sustainable development in hainan. *In* Proceedings of International Advisory Meeting on the Economic Development of Hainan in Harmony with the Natural Environment, 13–14 Sept. 1990, Haikou, China. International Advisory Council on the Economic Development of Hainan, Haikou, China. pp. 93–96.

Barzel, Y. 1997. Economic analysis of property rights. 2nd ed. Cambridge University Press, Cambridge, U.K.

Besley, T. 1995. Property rights and investment incentives: theory and evidence from Ghana. J. Polit. Econ. **103**(5): 903–937.

Bromley, D.W. 1989. Property relations and economic development: the other land reform. World Dev. **17**(6): 867–877.

Bromley, D.W. 1991. Environment and economy: property rights and public policy. Blackwell Publishers, Malden, Mass.

Capistrano, A.D. 1994. Tropical forest depletion and the changing macroeconomy 1967–85. *In* The causes of tropical deforestation. *Edited by* K. Brown and D.W. Pearce. UCL Press, London. pp. 68–85.

Chambers, R.T. 1988. Applied production analysis: a dual approach. Cambridge University Press, Cambridge, U.K.

Chomitz, K.M., and Gray, D.P. 1996. Roads, land, markets and deforestation: a spatial model of land use in belize. World Bank Econ. Rev. **10**(3) 487–512.

Deacon, R.T. 1994. Deforestation and the rule of law. Land Econ. **70**: 414–430.

Deacon, R.T. 1999. Deforestation and ownership: evidence from historical accounts and contemporary data. Land Econ. **75**(3): 341–359.

Greene, W.H. 1997. Econometric analysis. 3rd ed. Prentice-Hall International Inc., New York.

Hainan Agricultural Zoning Commission. 1980. Collection of Hainan agricultural zoning reports. Hainan Agricultural Commission, Haikou, China.

Hainan Forestry Bureau. 1957–1995. Hainan forestry statistical materials. Hainan Forestry Bureau, Haikou, Hainan.

Hainan Statistical Bureau. 1957–1995. Hainan statistical materials. Hainan Statistical Bureau, Haikou, China.

Hoshino, S. 1996. Statistical analysis of land-use change and driving forces in the Kansai District, Japan. Working Pap. 96-120. International Institute for Applied Systems Analysis, Vienna.

Hsiao, C. 1986. Analysis of panel data. Cambridge University Press, Cambridge, U.K.

Hyde, W.F. 1980. Timber supply, land allocation, and economic efficiency. The Johns Hopkins University Press, Baltimore and London.

Hyde, W., Amacher, G.S., and Magrath, W. 1996. Deforestation, scarce forest resource, and forest land use: theory, empirical evidence, and policy implication. World Bank Res. Observ. **11**: 223–248.

Kmenta, J. 1986. Elements of econometrics. 2nd ed. Macmillan Publishers Ltd., London.

Kummer, D., and Sham, C.H. 1994. The causes of tropical deforestation: a quantitative analysis and case study from the Philippines. *In* The causes of tropical deforestation. *Edited by* K. Brown and D.W. Pearce.UCL Press, London. pp. 146–58.

Laarman, J.G. 1996. Government policies affecting forests in Latin America. Environment Division of Social Programs and Sustainable Development Program, Inter-American Development Bank, Washington.

Mather, A. 1990. Global forest resources. Timber Press, Portland, Oreg.

Mendelsohn, R. 1994. Property rights and tropical deforestation. Oxf. Econ. Pap. **46**: 750–56.

North, D. 1990. Institutions, institutional change and economic performance. Cambridge University Press, Cambridge, U.K.

Palo, M. 1994. Population and deforestation. *In* The causes of tropical deforestation. *Edited by* K. Brown and D.W. Pearce. UCL Press, London. pp. 42–56.

Panayoutou, T., and Sungsuwan, S. 1994. An econometric analysis of the causes of tropical deforestation: the case of northeast Thailand. *In* The causes of tropical deforestation. *Edited by* K. Brown and D.W. Pearce. UCL Press, London. pp. 192–210.

Place, F., and Otsuka, K. 1997. Population density, land tenure, and tree resource management in Uganda (Draft). International Food Policy Centre. Environment and Production Technology Division Discussion Pap. 24.

Rudel, T.K. 1998. Is there a forest transition? Deforestation, reforestation, and development. Rural Sociol. **63**(4): 533–552.

Situ, S. 1992. Historical land use development in Hainan. [In Chinese.] Hainan Press, Haikou.

von Thunen, J.H. 1875. The Isolated state in relation to land use and national economy. Schmaucher Zarchlin, Berlin.

Walker, K.R. 1965. Planning in Chinese agriculture: socialization and the private sector 1956–1962. Franl Cass & Company Ltd., London.

Wallace, T.D., and Newman, D.H. 1986. Measurement of ownership effects on forest productivity in North Carolina from 1874–1984. Can. J. For. Res. **16**: 733–738.

Yin, R., and Newman, D. 1997. Impacts of rural reforms: the case of the Chinese forest sector. Environ. Dev. Econ. **2**: 289–303.

Zeng, Q. 1994. A brief introduction to closing the land for reforestation in Hainan Province. International Tropical Timber Organization, Tropical Forestry Newsletter 2.

Zhang, D. 1996. Forest tenure and land value in British Columbia. J. For. Econ. **2**(1): 7–29.

Zhang, D., and Pearse, P. 1996. Differences in sivicultural investment under various types of forest tenure in British Columbia. For. Sci. **42**(4): 442–449

Zhang, Y. 2000. Deforestation and forest transition: theory and evidence in China. *In* World forests from deforestation to transition? *Edited by* M. Palo and H. Vanhanen. Kluwer Academic Publishers, Dordrecht, the Netherlands. pp. 41–65. In press.

Zhang, Y., Dai, G., Hung, H., Kong F., Tian, Z., Wang, X., and Zhang, L. 1999. The forest sector in China—towards a market economy. *In* World forests, society and environment. *Edited by* M. Palo and J. Uusivuori. Kluwer Academic Publishers, Dordrecht, the Netherlands. pp. 371–393.