EPTD DISCUSSION PAPER NO. 31

DOES LAND TENURE INSECURITY DISCOURAGE TREE PLANTING? EVOLUTION OF CUSTOMARY LAND TENURE AND AGROFORESTRY MANAGEMENT IN SUMATRA

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December 1997

ABSTRACT

It is widely believed that land tenure insecurity under a customary tenure system leads to socially inefficient resource allocation. This article demonstrates that land tenure insecurity promotes tree planting, which is inefficient from the private point of view but could be relatively efficient from the viewpoint of the global environment. Regression analysis, based on primary data collected in Sumatra, indicates that tenure insecurity in fact leads to early tree planting. It is also found that customary land tenure institutions have been evolving towards greater tenure security responding to increasing scarcity of land.

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1. INTRODUCTION

While usufruct rights usually are established under customary land tenure, individual rights to transfer and inheritance are limited and controlled by community and lineage leaders.[1] Given unclear and uncertain individual rights, incentives to invest in land and tree resources may be thwarted (Besley 1995). However, relatively strong individual ownership rights are granted to those who clear communal forests for cultivation and to those who plant trees. Shepherd (1991, p. 155) argues that "It is the investment of labour which creates ownership." It is also important to realize that the individual land rights acquired through clearance of communal forests tend to diminish over time, if land use is limited to food crops grown under shifting cultivation (slash and burn). In particular, when land is fallowed, other members of the extended family or the community can claim the right

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[1] As will become clearer, there are more similarities than dissimilarities between land tenure institutions in Sub-Saharan Africa and Sumatra. See, e.g., Shepherd (1991) and Bassett (1993) for an overview of land tenure institutions in Sub-Saharan Africa.

to use this "unused" land. Under such institutional rules, an individual community member who has cleared forest land would have strong incentives to plant trees in order to establish secure land rights. This may result in excessively early tree planting, which would reduce the profitability of land use and, consequently, incentives to open up the communal forest.

Communal land tenure seems to be designed to achieve and preserve equitable distribution of land (and hence income) among community members, thereby assuring communal solidarity and food security. Such an institution works when land is abundant. As population increases, however, forest land is exploited and eventually the extensive margin closes. Under such conditions, investment in land improvement, such as terracing, irrigation, and tree planting, is often required in order to intensify land uses (Boserup 1965). Yet, distortions to individual incentives under customary land tenure may cause serious underinvestment in land. Customary land tenure institutions, however, may evolve towards greater individualization with more secure individual land rights (Ault and Rutman 1979).[2] Feder and Noronha (1989) and Feder and Feeny (1993) strongly argue for the efficiency of secure private ownership in providing appropriate incentives to invest in land improvement. Empirical evidence, however, is deplorably weak.

Interestingly enough, land tenure institutions have been evolving towards individualized ownership and commercial tree plots have been actively developed in Sumatra along the buffer zone of Kerinci Seblat National Park. Throughout this region, a matrilineal inheritance system, in which land is bequeathed from a mother to her daughters, has historically been practiced. Joint ownership

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[2] Articles included in an edited volume by Bruce and Migot-Adholla (1993) provide ample evidence that individualization of ownership rights to farm land growing annual crops has taken place in various parts of Sub-Saharan Africa. Yet, comparable evidence has not been supplied for tree crop areas converted from forest areas. See, however, Besley (1995) for the case of cocoa tree management in Ghana, and Place and Otsuka (1997) for the case of woodland management in Uganda.

of paddy fields by lineage members (consisting typically of three generations descended from the same grandmother) or by sisters also has been common. But for commercial tree crops, such as rubber, cinnamon, and coffee, more individualized tenure institutions have become dominant and their incidence has been increasing.

The purpose of this article is to identify the determinants and the consequences of the evolution of customary land tenure institutions based on a case study in Sumatra. We use two sets of survey data; one set is from an extensive survey of sixty communities located over a wide area and the other is from a survey of five households in each of these communities. The community survey data will be used to analyze the determinants of changes in land tenure institutions because these changes derive from decisions of the community or a group of family members in the community. On the other hand, the household survey data will be used to assess the consequences of the collective choice of land tenure institutions in terms of the probability of tree planting.

The organization of this paper is as follows. Section 2 presents a simple model of land use, which determines the optimum timing of tree planting. Section 3 reviews the characteristics of land tenure institutions and land use in selected villages in Sumatra. We examine the regression results concerning the choice of land area under different land tenure institutions in Section 4. Section 5 summarizes the household survey data on tree planting, which is followed by regression analysis on the determinants of tree planting in Section 6. Finally we discuss implications of this study in Section 7.

2. A MODEL OF TREE PLANTING

In this section, we develop a simple model of land use over time, which determines the optimum timing of tree planting under different land tenure rules. There are two types of acquired land under consideration: community-owned primary forest, which is characterized by open access and can be acquired through clearance by any community members (Angelsen 1995a), and family-owned bush-fallow area, which can be acquired through either inheritance or outright purchase. Shifting cultivation is widely practiced, in which bush-fallow or forest areas are cleared using slash-and-burn, then planted to annual crops usually for two to four seasons, and put into fallow for a certain number of years again. If left unused for decades, bush-fallow areas eventually become secondary forests. Although indigenous agroforestry systems begin with slash-and-burn to clear land and planting of food crops, they differ from shifting cultivation in that commercial trees are intercropped with annual crops for a couple of seasons immediately after trees are planted.

We assume that a farmer acquires a plot of land at time *0* and grows food crops alone until time *T* when he intercrops commercial trees with annual crops. We further assume that acquired land is immediately used for cultivation of food crops or tree-cum-food crops, because land is scarce and, hence, yields positive return from cultivation.[3] While timing of land acquisition is exogenously determined in the case of inheritance, it can be chosen in the case of opening forest or purchasing land. In this study, we focus on the choice of *T* with a view to deriving the testable hypotheses.[4]

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[3] Strictly speaking, there is also an option of fallow. Fallow may be chosen before planting food crops alone or tree crops intercropped with food crops, if a household that has acquired land does not have enough labor or capital to undertake cultivation right away.

[4] The optimum choice of timing of land acquisition can be obtained by maximizing net present value of future benefits associated with land acquisition, following model of optimal

Given the common practice that trees are planted in the whole plot in a short period of time, we do not consider partial planting of trees.

Figure 1 illustrates how the choice of T is made using a given parcel of land. A farmer may cultivate food crops alone and receive net revenue or profit along curve r until T . Curve r is downward-sloping partly because fertility of soil declines with continuous cultivation and partly because an increasing portion of this parcel is put into fallow. Net revenue becomes zero at τ, at which time the whole parcel needs to be fallowed again. The farmer, however, may plant trees along with annual crops at T, which requires costs of planting, weeding, and pruning in the beginning. Thus, net revenue curve under this agroforestry system is located below curve r due to the cost of tree planting and management, and possibly due to negative interaction between tree and food crop cultivation, until T' when annual crops are no longer intercropped. Subsequently, net revenue may remain negative due to the required cost of management but eventually mature trees yield positive returns along curve s.[5]

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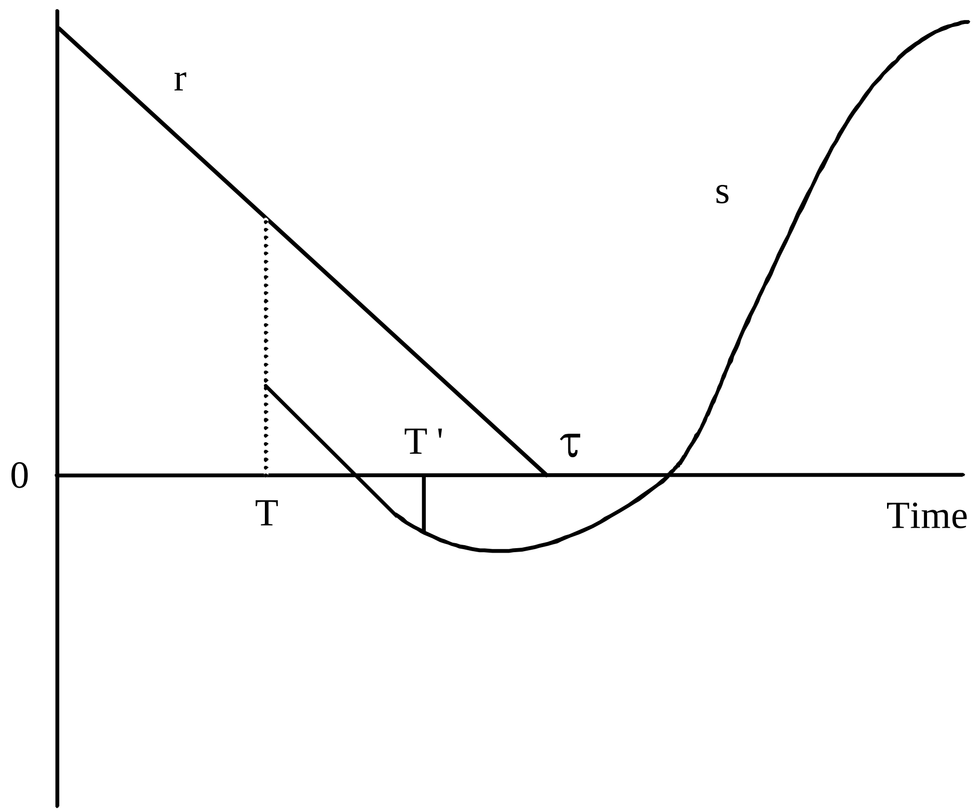
timing of innovations developed by Barzel (1968), which is applied to the case of timing of land acquisition by Anderson and Hill (1990). We do not pursue this question in this study, because the lack of data on supply-side variables, such as remaining forest area and endowment of bush-fallow land, precludes the specification of regression function including both supply and demand factors affecting the timing of clearing forest and purchasing bush-fallow land.

[5] In the case of cinnamon, trees are cut to remove bark about eight to fifteen years after planting. A few more productive cycles are possible from regrowth of felled trees before replanting is necessary. Incorporation of such characteristics, however, will not change the qualitative results of the model.

Figure 1 Flow of net revenue from shifting cultivation (r) and agroforestry (s)



If the farmer continues to cultivate food crops alone for another season, he receives an additional net gain from production of annual crops (indicated by the height of curve *r* at *T*) and gain or loss from agroforestry (indicated by the height of curve s at *T*), and incurs losses arising from the delayed planting of trees. If land tenure is insecure, there is a possibility that the farmer will not be able to receive the revenue from food cultivation and agroforestry production in the future. Security of tenure, however, can be established, if trees are planted because tree planting requires a large amount of work and that effort is rewarded by stronger land tenure security under customary tenure institutions.

Figure 2 illustrates how land tenure security changes over time, in which security of tenure is expressed in terms of the probability p(*t*) that the farmer still retains the right to receive the net revenue at *t*.[6] If land tenure is perfectly secure, p(*t*) is always unity, assuming away other risks. This situation arises when bush-fallow land is privately purchased, in which a written agreement is exchanged and witnessed by family members and village leaders. If a farmer opens communal forest and grows food crops alone, tenure security decreases over time implying that p(*t*) declines with time. Tenure security declines over time, because cleared land is subject to customary tenure rules, which stipulate that bush fallow land eventually returns to control of the community or the extended family in Sumatra (Angelsen 1995a; Mary and Michon 1987). In fact, any member of the group can request use of this land for cultivation, particularly when it is fallowed. Once trees are planted, however, the cultivator acquires perfectly secure ownership rights over the land under customary law. Thus, if the cultivator continues to retain the right to receive the revenue at *T*, further decline in p(*t*) can be prevented. As is shown in Figure 2, p(*t*) declines until *T* from which it remains constant. On the other hand, p is less than unity but stable or slightly declining if bush-fallow area is inherited under customary land tenure. Because of the restricted land rights, a farmer who has inherited land may not be able to obtain full benefits from land. For example, if the farmer becomes sick, land may be uncultivated temporarily due to the restrictions on land leasing. Therefore, p(*t*) is likely to be less than unity. As in the case of cleared forest land, p(*t*) may decline over time, particularly if the inherited land is fallowed, because other family members may claim to cultivate this land. If the land acquired by clearing forest is used for shifting cultivation with fallow, the land rights may approach those of inherited land.

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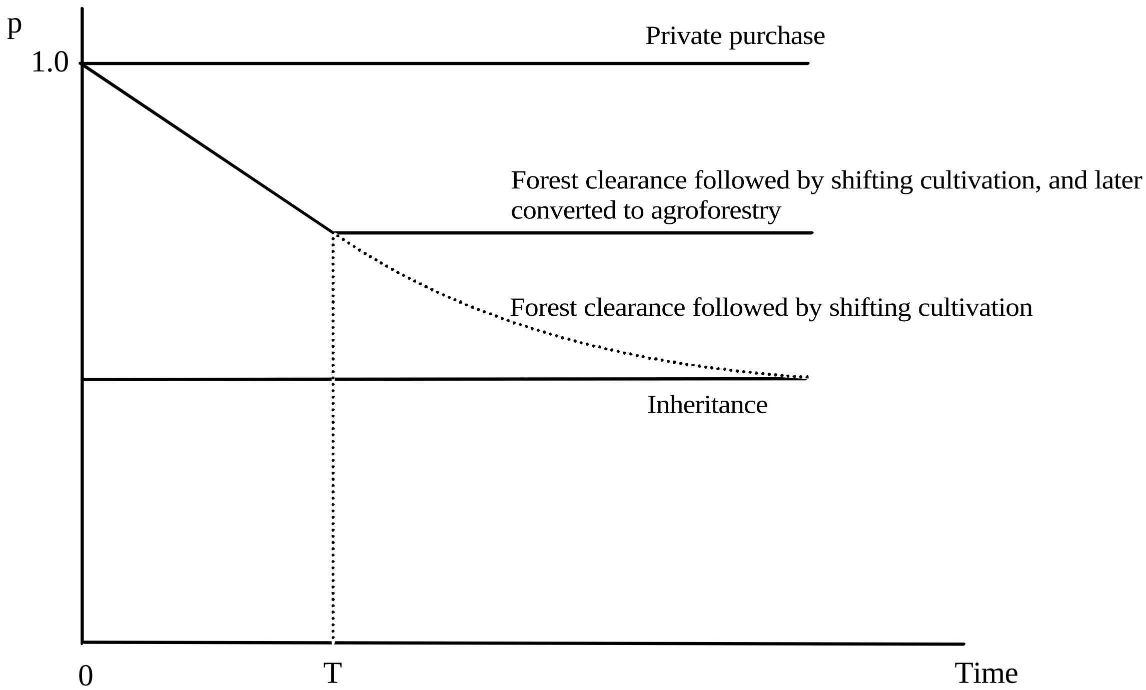
[6] If p(*t*) declines at a constant rate δ, p(*t*) can be expressed as $p(t) = p(0)\ ^{e\text{-}\delta t}$.

Figure 2 Changes in probability of retaining land rights under different land tenure arrangements



We assume that a farmer maximizes the net expected present value of land use, V(*L*), with respect to *T*, which can be formulated as:

$$V(L) = \max \{ \int_0^T p(t, L)\, r(t)\, e^{-\rho t}\, dt + p(T, L)\, e^{-\rho T}\, S(T) \}$$

$$= \max \{ \int_0^T p(t, L)\, r(t)\, e^{-\rho t}\, dt + p(T, L)\, e^{-\rho t} \int_T^\infty s(v - T, T)\, e^{-\rho(v - T)}\, dv \} \quad (1)$$

where p denotes the probability that the farmer can retain the right to receive the net revenue, which depends on the length of land use for food cultivation and land tenure institutions; ρ is a discount rate, which is assumed constant; S(*T*) stands for the net present value of tree cultivation beginning with planting at time *T*; and s is flow of net revenues, which is assumed to depend on the age of trees and the date of tree planting. The first term exhibits the present value of the net expected return from shifting cultivation,[7] whereas the second term corresponds to that of the expected return from agroforestry. The net revenue from food cultivation *r* depends on *t*, which designates the length of period during which food crops have been grown.

For simplicity, we assume that r and s are the same regardless of whether primary forest is exploited or bush-fallow area is used for cultivation. Actually, however, soil is more fertile in the case of primary forest than the case of bush-fallow area, so that net revenue from food cultivation, r, tends to be smaller in the latter case. On the other hand, s is largely independent from the previous use of land. Thus, tree cultivation tends to be delayed in the case of exploitation of primary forest, if other things are the same. We argue, however, that trees are planted earlier when primary forest is exploited than when bush-fallow area is cultivated.

The first order condition for the interior optimum can be obtained by differentiating equation (1) with respect to *T*:

$$\partial V(L)/\partial T = e^{-\rho T}\{p(T, L)\, r(T) + p_1(T, L)\, S(T) - \rho\, p(T, L)\, S(T) + p(T, L)\,[\partial S(T)/\partial T]\} = 0\,, \quad (2)$$

where the first term stands for net expected revenue from cultivation of food crops in period *T*, the second term for the expected reduction in the probability of obtaining the present value of tree cultivation, which is non-positive (i.e., $p_1 = \partial p/\partial T \leq 0$), the third term for expected capital loss, and the last term for the reduction in the net present value of tree cultivation due to the delayed tree planting. By differentiation, we obtain

$$\partial S(T)/\partial T = -\, s(0, T) - \int_T^{\infty} [s_1(v - T, T) - s_2(v - T, T)]\, e^{-\rho(v - T)}\, dv + \rho\, S(T)\,, \quad (3)$$

[7] For simplicity, we do not consider subsequent cycles of food production under shifting cultivation.

where $s(0, T)$ corresponds to net revenue of agroforestry in the initial period, and $s_1 = \partial s/\partial(v - T)$ and $s_2 = \partial s/\partial T$. Since s_1 measures the effect of an increase in age of trees on net revenue, its sign is expected to be positive. Even if it becomes negative beyond a certain age, it will be reasonable to assume that the integral of s_1 in equation (3) is positive. The sign of s_2 is uncertain, even though it is likely to be positive reflecting increasing scarcity of land. Substitution of equation (3) into equation (2) results in

$$r(T) - s(0, T)+[p_1(T, L)/p(T,L)]\, S(T) - \int_T^4 [s_1 (v - T, T) - s_2 (v-T, T)]\, e^{-\rho(v - T)}\, dv = 0. \qquad (4)$$

The first two terms represent marginal changes in gain from postponing tree planting, whereas the last two terms represent marginal loss due to delayed tree planting. It is clear from the third term in equation (4) that early tree planting is promoted, if land tenure security declines when food crops are grown. In other words, tenure insecurity promotes tree planting if continued shifting cultivation reduces tenure security and tree planting confers strong security. Early tree planting is obviously inefficient from the private point of view, but it could be socially efficient from the viewpoint of environmental externalities.

If $p_1 = 0$ holds, equation (4) can be simplified to

$$r(T) - s(0, T) - \int_T^\infty [s_1 (v - T, T) - s_2 (v-T, T)]\, e^{-\rho(v - T)}\, dv = 0 , \qquad (5)$$

which implies that in our model the optimum timing of tree planting is unaffected by the level of land tenure security, regardless of whether it is perfectly secure private tenure or insecure but stable communal land tenure, which is subject to the traditional inheritance rules.[8] The choice of T in accordance with equation (5) is optimum from the private point of view.

The implications of our model can be summarized in the following testable hypothesis:

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[8] This property can easily be obtained from equation (1) by assuming constant value of p.

Hypothesis 1: Declining land tenure security under shifting cultivation, coupled with its enhancement by tree planting, promotes early tree planting.

We will test this hypothesis by estimating tree planting functions in the short run, i.e., one year after acquisition of land, and in the longer run, i.e., at the time of our field survey, in which various land tenure dummies, including dummies for acquiring land through clearance of communal forests and purchase of bush-fallow area, are included in explanatory variables. If our hypothesis is valid, we expect to observe that the dummy variables for acquiring land through clearance of primary forest is significant in the short-run tree planting function, whereas other land tenure dummies are expected to be less significant in both the short-run and longer-run functions.

So far we have considered the case where perfect rights to tree planting are assured under customary land tenure institutions. Actually, commercial trees are not allowed to be grown without approval if land is owned collectively by a group of families, e.g., lineage-owned land and joint-family land, as will be discussed shortly. Other members of a group of families can be expected to oppose tree planting, because those who plant trees on collectively owned land then can assert individual rights to those plots. Thus, approval of tree planting from other members is needed before planting and it may not be easily granted. In such cases, probability that those who plant trees receive net revenue from agroforestry will be lower than p(T, L) specified in equation (1). In contrast, if land is owned privately or by a single family, perfect tree planting rights exist.

If tree planting rights do not exist, incentives to tree planting are weakened. As population pressure increases, however, comparative advantage of agroforestry over shifting cultivation tends to increase, because net revenue from shifting cultivation tends to decrease due to the declining fallow period and fertility. Under such circumstances, more secure land tenure institutions may be induced to develop in order to capture larger potential benefits from investment in tree planting, in accordance with the evolutionary view of farming systems and the theory of induced institutional innovation (Boserup 1965; Hayami and Ruttan 1985; Hayami 1997).

The individualization of land tenure institutions, however, is less likely to occur if profitable investment opportunities are limited. This is the case for paddy fields, in which only small investments in the maintenance of simple traditional irrigation systems are required. Furthermore, the irrigation systems are locally public goods and their construction requires collective work. It may not pay to incur the transaction costs of changing institutional rules towards individualized ownership in such a case, compared with the case of uplands in which investment in the development of agroforestry potentially is quite profitable.[9] Thus, we postulate the following hypothesis:

Hypothesis 2: More secure individualized land tenure institutions will develop in response to increasing scarcity of land relative to labor in order to reap benefits from investing in land improvement.

In our empirical study, we will compare the evolution of land tenure institutions among paddy fields, bush-fallow areas, and tree plot fields. If our second hypothesis is valid, we expect to observe greater individualization of land tenure institutions in upland plots in general and tree planted plots in particular than in paddy fields.

[9] A detailed plot-level survey is under way in selected communities, which collects statistical data on net revenues of food and tree crops under different land tenure institutions.

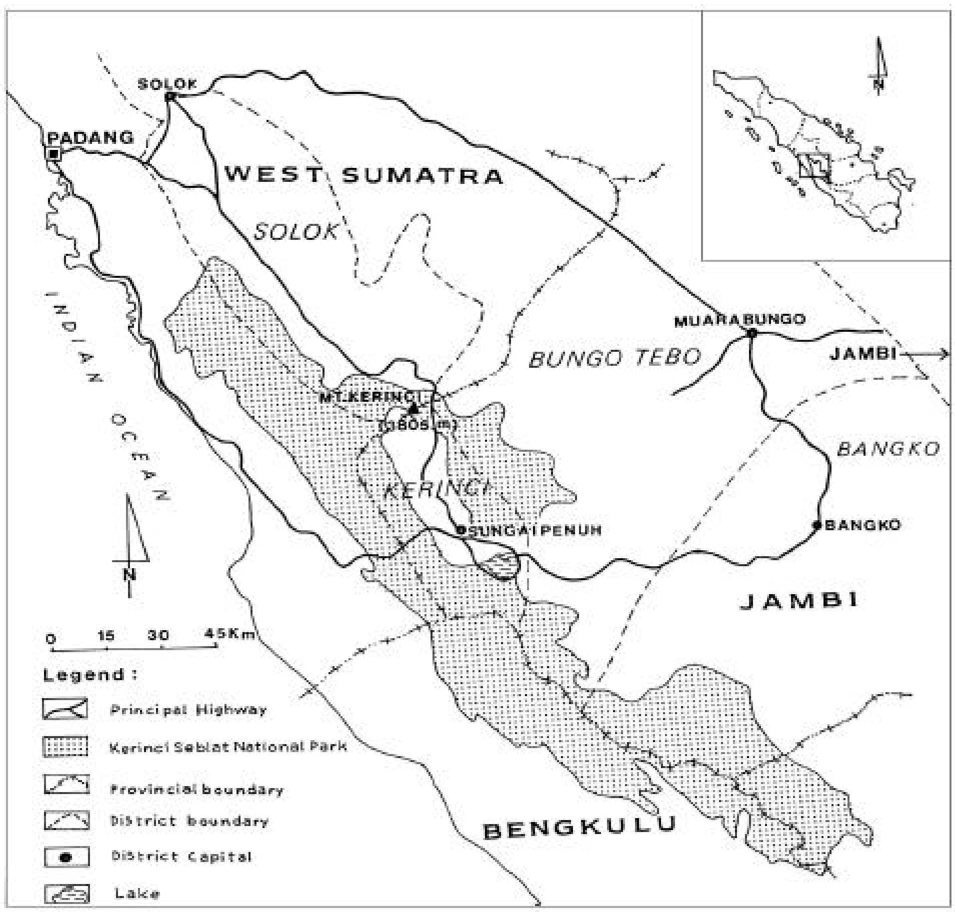
3. LAND TENURE AND LAND USE IN SAMPLE VILLAGES

Let us first review the types of land tenure institutions that prevailed in our study sites in Sumatra. We have selected 60 villages randomly with probability proportional to village population from four districts in Sumatra, i.e., Solok in West Sumatra Province, Kerinci, Bungo Tebo, and Bangko in Jambi Province (see Figure 3). Solok, which we call the High Region in this study, is located in the highest altitude of more than 1,000 meters above sea level and the major tree crop is coffee, even though the area planted to cinnamon has been increasing. Kerinci is called the Middle Region, where cinnamon is a major tree crop. Bungo Tebo and Bangko are adjacent districts located in a low-lying area, where rubber is the major tree crop. Since our sites in these two districts are similar in terms of ethnic composition, climate, and topography, we lump them together and call this the Low Region.[10]

Traditionally, the major ethnic groups -- Minangkabau in the High Region, Kerinci in the Middle Region, and Melayu Jambi in the Low Region -- have relied upon wet rice cultivation and, hence, areas along streams and rivers are predominantly used for paddy fields. Paddy fields are surrounded by agroforestry plots, including both mature trees and newly planted trees intercropped with annuals, and bush-fallow plots under shifting cultivation. Natural forests typically are located in the mountainous terrain farther from village centers. The bush-fallow area originally was converted from primary forests and is planted with food crops periodically for a few seasons followed by another fallow period.

[10] For more information on the dominant farming systems in Sumatra, see Angelsen (1994, 1995a) on shifting cultivation, Tomich et al. (forthcoming) on highland coffee, Aumeeruddy (1994) on cinnamon, and Barlow and Muharminto (1982), Barlow and Jayasuriya (1984), and Gouyon et al. (1993) on rubber.

Figure 3 Map of tenure survey areas



As is shown in Table 1, villages in High Region are endowed with large paddy areas, whereas paddy fields account for a small portion of land in Low Region. Bush-fallow area is smallest in Middle Region in terms of both absolute area and relative proportion in the total exploited area. In contrast, there remain large tracts of bush-fallow in Low Region. Unfortunately, official statistics do not distinguish between secondary forest, which is a part of the bush-fallow system, and primary forest, and farmers' estimates of primary forest area is subject to substantial errors. Thus, we estimated the primary forest area by subtracting the total exploited area estimated by a group of farmers from the total village area reported by official statistics. According to the results shown in

Table 1, primary forests still account for a lion's share of village land. This may be explained partly by the fact that a relatively well-protected national park accounts for about 58 percent of the area in High Region and 74 percent in Middle Region according to farmers' estimates, and partly by steep slopes of mountainous areas unsuitable for cultivation.

Table 1 Land use pattern and size of population in selected villages in Sumatra

	Sample size	Exploited area in 1995 (ha)[a] Paddy fields	Agro-forestry plots	Bush-fallow	Total village area[b]	Primary forest area [c]	Population in 1993[b]	Population density in 1993[d]
					(ha)	*(ha)*		*(persons/ km2)*
High Region	24	259 (31)	377 (45)	204 (24)	5,143	4,303	1,764	34
Middle Region	19	151 (19)	526 (66)	125 (16)	3,173	2,371	1,340	42
Low Region	17	102 (9)	594 (55)	385 (36)	6,735	5,654	772	11

[a] Based on community survey. Numbers in parentheses are proportions in exploited area in percentage terms.
[b] Based on Agricultural Census (Bureau of Statistics).
[c] Estimated by subtracting total exploited area form total village area.
[d] Population divided by village area.

Population density is highest in Middle Region and lowest in Low Region. None of the selected villages is newly settled and more than 90 percent of them were established before the Dutch period ended in 1942. Low population density in Low Region may be explained partly by the paucity of paddy fields in this area, whereas the rich endowment of flat fertile area suitable for rice cultivation and high profitability of cinnamon would explain the highest population density in Middle Region.

The three major ethnic groups all follow matrilineal inheritance and matrilocal residence systems, even though the inheritance system has undergone substantial transformation over time (Errington 1984; Kahn 1980). Table 2 shows key characteristics of the major land tenure categories.

Traditionally lineage land particularly for paddy fields has been owned collectively by a group of kin members, and this group usually consisted of a grandmother, her husband, children, and grandchildren. Land is bequeathed to sisters, nieces, and daughters of a woman who passed away, in accordance with the decision of a lineage head. The head is selected from uncles, i.e., a male member of the second generation, who exercises strong authority regarding land inheritance. The basic principle of land allocation is to maintain equity among lineage members.

Table 2 Land tenure categories and their major characteristics

Ownership categories	Owners	Inheritance to	Joint ownership
Lineage	Lineage members	Sisters, nieces, and daughters	Yes
Joint Family	Daughters	Daughters	Yes
Single Family I	Daughter	Daughters	No
Single Family II	Daughter or son	Daughters and sons	No
Private	Single person or family	Daughters, or daughters and sons	No

According to our interviews with farmers, it is primarily husbands who make farm management decisions under this version of the matrilineal system, even though they have no customary land rights. No single member of a lineage has ownership rights and land sales have been strictly prohibited. Although formal approval by a lineage or community head is required for clearing community-owned forests, such approval is easily granted. Women are the custodians of lineage and family land and are expected to oppose the transfer of land to non-family members. Now lineage land occupies only small areas in our sample villages.

Land under joint family ownership, which is inherited and owned jointly by daughters, is much more common than lineage ownership. The major difference from lineage tenure lies in the fact that land is owned by a smaller number of family members. A system of rotating land use among sisters' families is often practiced for cultivation of wet rice fields to prevent excessive fragmentation. All types of decisions regarding land use, inheritance, renting, and mortgaging are made jointly by sisters and their husbands without intervention of other lineage members.

Joint family land tenure has developed along two paths. First, lineage members agree to divide lineage land into joint family land, usually at the time of inheritance. Second, daughters jointly inherit private land, which was acquired either by opening forest land or by purchasing already-exploited bush-fallow. Although the sale of lineage and family land traditionally has been prohibited, such land actually can be sold with the consent of the group members.

Single family ownership, which has evolved from joint family ownership, is also emerging. Like joint family ownership, daughters inherit land under single family ownership, but ownership rights are more individualized. Another form of the single family ownership system has appeared in which sons are permitted to inherit some land, even though daughters inherit shares greater than or at least equal to sons. Single family ownership could have evolved from joint family ownership or from inheritance of private lands.

Through group interviews, we obtained estimates of the proportions of land under different land tenure institutions by type of land use. Since measurement of areas under different land tenure at the village level has never been done, such data are necessarily crude and subject to errors. Thus, we combine similar land tenure categories, such as single family ownership by daughters, and daughters and sons, in order to reduce measurement errors associated with the finer classification of land tenure categories. Nonetheless, as is demonstrated in Table 3, some clear tendencies can be observed. First, lineage land is observed mostly in bush-fallow areas and in limited areas of paddy land. Second, joint ownership is dominant for paddy fields in Middle and Low Regions, but accounts for only three to 19 percent of bush-fallow and smaller portions of tree crop plots in all regions. Third, single family ownership is more important than joint ownership except for paddy fields. Fourth, private ownership tends to dominate in tree crop plots and accounts for a sizable portion of bush-fallow.

If the matrilineal rule of inheritance to daughters is strictly adhered to, the privately acquired land ought to become joint family land in the next generation and lineage land after two generations. Yet area under joint family and lineage ownership is generally small in all the regions, which indicates erosion of the traditional matrilineal inheritance system. A major exception is bush-fallow area, in which lineage land remains observed in relatively large areas. This reflects the fact that land tenure institution of bush-fallow land is often individualized after it is converted to tree plots. As was discussed earlier, private ownership rights acquired by clearing forest are insecure and subject to traditional inheritance rules, unless trees are planted.[11] This explains why joint family ownership is more prevalent for bush-fallow than for tree crops.

[11] The role of trees in establishing land claims was noted by one of the earliest Europeans to publish on Sumatra. Marsden (1811. p 69), drawing on his experience living in Sumatra in the late 16th century long before rubber and coffee were introduced, wrote that "... property in land depends on occupancy, unless where fruit-bearing trees have been planted." For a more recent analysis, see Angelsen (1995b).

Table 3 Distribution of area under different land tenure by land use type[a]

	Lineage ownership	Joint family ownership	Single family ownership	Private ownership I (Purchase)	Private ownership II (Clearance)
			(percent)		
1. *Paddy field:*					
High Region	2.2	9.0	75.7	7.9	4.1
Middle Region	10.4	63.9	6.3	5.5	7.8
Low Region	0.0	64.6	29.2	6.1	0.1
2. *Tree plots:*					
High Region	3.1	5.2	41.8	10.4	37.1
Middle Region	4.7	1.5	61.7	13.5	18.5
Low Region	0.0	3.0	45.6	12.4	38.7
3. *Bush-fallow area:*					
High Region	15.5	8.5	36.3	5.2	32.6
Middle Region	10.3	19.4	43.1	14.3	12.5
Low Region	22.5	3.1	41.7	5.7	27.0

[a] Based on community survey. Numbers in some lines do not add up to 100% because of small area of land under state ownership.

In order to assess the strength of property rights under different land tenure institutions, we asked a group of farmers in each village whether the cultivating household possesses rights to rent out under share tenancy, rent out under fixed-rent leasehold tenancy, pawn, and sell with and without approval of family and/or lineage leaders for the various tenure categories. The right to rent out under share tenancy is the weakest right followed closely by the right to rent out under leasehold tenancy,[12] whereas the strongest right rests in the right to sell without approval. Pawning is problem-ridden, because if a pawner cannot repay the loan, the land may eventually be confiscated by a

[12] This could be because there is stronger incentive to mine the soil under leasehold tenancy than share tenancy, because the whole marginal product accrues to leasehold tenants, unlike share tenants who receive only a portion of incremental output. See Otsuka et al. (1992) for a survey of the literature on the land tenancy contracts in agrarian economies.

pawnee. Except for the case of lineage-owned paddy fields, in which there is no individual right to sell at all, farmers' answers were either "yes without approval" or "yes with approval," for all categories. Therefore, we characterized the strength of individual land rights in terms of the number of rights without requiring approval (see Table 4).[13] Since there is no difference in land rights between bush-fallow and agroforestry plots for the same category, these two types of land are combined under the category of upland fields.

Individual land rights under lineage ownership are very weak, possessing at best the right to rent out under share tenancy. It is interesting to observe that individual land rights for paddy fields under joint family ownership in the Middle and Low Regions are comparatively high, even greater than the land rights under single family ownership by daughters in these two regions. It appears that individual land rights under joint family ownership have been strengthened by the deliberate agreement of the family members.[14]

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[13] Besley (1995) constructs a similar variable and treats it as a continuous variable for the regression analyses. This procedure is problematic: Unless the differences in land rights between all contiguous land tenure categories are equal, the land right index should be treated as an ordinal rather than a cardinal variable.

[14] There is another important reason for the persistence of joint family ownership of paddy land. Where population density is high, it is common to rotate use of paddy land among households with a claim on it. This rotational system is a workable response to fragmentation of paddy units because the production cycle is confined to several months. Thus, members of a generation can look forward to their turn to use this land for rice production every few seasons. This approach is unworkable for perennials, where the productive life of the trees may exceed the length of a human generation. Alternating years of use of land planted with perennials would raise at least two types of problems. The first is how to create efficient incentives for optimal maintenance of trees during the establishment phase. The second is how to create disincentives to harvesting practices that reduce production in later periods.

Table 4 Average number of land property rights under different land tenure[a]

	Lineage land	Joint family ownership	Single family ownership I (daughters)	Single family ownership II (daughters & sons)	Private ownership (purchased & cleared)
1. *Paddy field:*					
High Region	0.5	0.8	1.6	3.2	3.6
Middle Region	0.8	2.2	2.0	2.8	3.9
Low Region	n.a.	2.7	2.0	n.a.	3.8
2. *Upland field:*[b]					
High Region	0.0	0.6	1.6	2.0	3.1
Middle Region	0.8	0.9	1.9	2.9	3.8
Low Region	0.0	1.0	1.9	2.8	3.8

[a] Four rights are considered; rights to rent out under share tenancy, rent out under leasehold tenancy, pawn, and to sell. Numbers refer to the average number of rights without obtaining approval of the family and/or lineage members.

[b] Upland field refers to both agroforestry plots and bush-fallow.

Except for this somewhat anomalous phenomenon, land rights are stronger under single family ownership than joint family ownership, and within single family ownership, the rights are stronger in the case of ownership by both daughters and sons. But even under single family ownership by daughters and sons, there is no right to sell without the approval of family members. The right to sell without approval is granted only to land acquired by clearing forests or by purchasing land. There is practically no difference in land rights between cleared and purchased land at the time of acquisition. Particularly in the Middle and Low Regions, land rights in privately acquired land are close to perfect private ownership. Even in the High Region, where individuals' rights over cleared and purchased land are weaker, it does not seem too difficult to obtain approval from one's family members in order to sell land. The major difference between private ownership in Sumatra and the western world is the lack of official registration, so that land cannot be used as collateral for loans from banks. It is important to note that land rights acquired by clearing forests tend to decline over time if it is planted to food crops and fallowed. How fast this decline occurs, however, is difficult to quantify.

Table 5 compares tree rights under different land tenure institutions. Two rights are considered; rights to plant and replant trees. As in the case of land rights, we characterized the strength of individual tree rights in terms of the number of rights without requiring approval in this table. It is clear that tree rights are markedly weaker under the collective ownership (i.e., lineage and joint family ownership) than under the individualized ownership (i.e., single family ownership and private ownership), which confers almost perfect tree planting and replanting rights. In the case of collective ownership, members of the group usually oppose to tree planting because those who plant trees tend to demand ownership or long-term use rights on land. Therefore, the collective ownership is likely to be replaced by more individualized ownership systems, as comparative advantage of agroforestry system increases overs shifting cultivation with increases in population pressure.

Table 5 Average number of tree rights under different land tenure[a]

	Lineage owner-ship	Joint family ownership	Single family ownership (daughter)	Single family ownership I (daughter and son)	Private ownership (purchase and cleared)
High Region	0.6	0.6	1.9	2.0	2.0
Middle Region	0.5	0.8	2.0	2.0	2.0
Low Region	0.5	0.5	1.7	1.7	2.0

[a] Two rights are considered; rights to plant and replant trees. Numbers refer to the average number of rights without obtaining approval of the family members.

Based on the data in Tables 3 to 5, it seems reasonable to hypothesize that land tenure institutions have evolved towards individualized tenure in order to enhance incentives to invest in commercial trees in the face of increasing population pressure on land. On the other hand, investment in traditional irrigation works for paddy production requires a minimum of effort to maintain and repair these simple, small-scale facilities. Thus, less individualized land tenure for paddy fields is not as much of a problem from the standpoint of required investment incentives. If population pressure is the driving force toward individualization of land tenure institutions, we would expect to observe a predominance of more individualized tenure on tree crop plots in areas where population density and population growth rates are high.

4. DETERMINANTS OF LAND TENURE CHOICE

In order to identify the determinants of the choice of land tenure institutions, we estimated functions explaining the proportion of land under lineage, joint and single family ownership, and the two types of private ownership (i.e., for purchased and cleared land) separately for paddy fields, tree crop plots, and bush-fallow areas. More specifically, we estimated the following functions while using a common set of explanatory variables:

$Y_{ij} = Y_{ij}$ (Population density, Population growth rate, Proportion of paddy area, Proportion of ethnic minorities, Traveling time to subdistrict town, Walking time to forest, Regional dummies), where Y_{ij} shows the proportion of i-th type of land ownership (i = 1, 2, 3, 4) on j-th type of land (j = 1, 2, 3), and explanatory variables are all village-specific except regional dummies represented by Middle and Low Region dummies. By definition, in principle, $\Sigma i \ Y_{ij} = 100\%$.[15]

Means of explanatory variables by region are exhibited in Table 6. Population density in 1983, the earliest census year for which consistent village population statistics are available, was highest in the Middle Region and lowest in the Low Region. Annual average population growth rate for 1983-93, however, was lowest in the Middle Region, indicating the high population pressure on limited land resources in this region. Annual population growth rates were around 1 percent, which strongly suggests that our study sites were net out-migration areas. Percentage of paddy area is included to capture the importance of paddy fields for supplying food. The percentage is computed from data in Table 1, which were collected independently from the data on distribution of area under different land tenure systems. In this measure, the High Region is located in the most favorable area with paddy fields covering 5.7 percent of the village land. The percentage of outsiders was highest in Middle Region, most of whom were migrants from Java. The Javanese are not matrilineal and their inflow might have affected the traditional land ownership systems in these matrilineal societies. Travel time to the subdistrict capital by motorcycle was included to take into account the impact of access to local markets, whereas walking time to the nearest forest was included to capture the effects of proximity of forests to residential areas. Partly as a result of its well-maintained infrastructure, travel time to the subdistrict capital was shortest in the Middle Region. In this region, little forest land is left near villages, so that walking time to forests

[15] The sum, however, does not add up to 100 percent in some cases because of small area of land under state ownership.

was longest. We estimated thirteen regression functions and the estimation results are shown in Table 7 while excluding the case of lineage ownership of paddy field and tree plots which occupied small areas. Since Y_{ij} are truncated below zero, we applied the Tobit estimation method.[16]

Table 6 Means of explanatory variables for village-level regression analysis on land tenure choice

	Population density in 1983	Annual population growth rate	Percentage of paddy field	Percentage of outsiders	Traveling time to subdistrict capital	Walking time to forest
	(persons/km2)		*(percent)*		*(minutes)*	
High Region	37.9	1.1	5.7	1.6	35.3	50.6
Middle Region	53.1	1.0	3.7	4.6	20.4	194.8
Low Region	11.5	1.0	1.2	1.4	29.7	171.6

The validity of our basic hypothesis that population pressure promotes the individualization of land tenure can be tested by examining whether higher population density and greater population growth rates are associated with greater incidence of private ownership and smaller incidence of family ownership.[17] Consistent with our hypothesis, population density has a negative and significant effect on the incidence of joint family ownership and positive and significant effects on the incidence of single family ownership and private ownership through purchase in the case of paddy field. Since all forest areas suitable for conversion to paddy cultivation have been exhausted, individualization took the form of replacing collective ownership by single family ownership and inducing market

[16] Since tree crop plots under single family ownership existed in all sites, Tobit and ordinary least squares (OLS) regressions are identical in this case. According to the OLS estimation, R^2 is 0.39.

[17] Note, however, that the results of our statistical test must be qualified to the extent that population variables are endogenous.

transactions in land. Note that the Middle and Low Region dummies have positive effects on the proportion of joint family ownership and negative effects on the proportion of single family ownership in the paddy field equations. These results are consistent with the observation from Table 4 that land rights for joint family tenure in the Middle and Low Regions were similar to or even stronger than land rights of single family ownership. According to the estimation results of the determinants of land tenure in agroforestry plots, higher population density promoted private ownership by stimulating the clearance of forests at the expense of single family ownership. The effect of population density on joint family ownership, however, is insignificant presumably because of the small area remaining under ownership (see Table 3).

Population growth has a significant impact only on land tenure distribution in agroforestry plots, but not on tenure from paddy and bush-fallow land. Similar to population density, higher population growth resulted in lower incidence of single family ownership and higher incidence of private ownership through clearance of forests.

It is interesting to observe that proportion of paddy area tends to have negative effects on the clearance of forest, which is different from the effect of population variables. This is expected, because the larger endowment of paddy fields, which produce more grain per unit of area than upland fields, lessens the population pressure on land. Larger proportion of paddy fields also led to the preservation of lineage ownership in bush-fallow land.

Table 7 Tobit regression of proportion of area under different land tenure by land use type[a]

	Paddy fields				Agroforestry plots				Bush-fallow				
	Joint family	Single family	Purchased	Cleared	Joint family	Single family	Purchased	Cleared	Lineage Ownership	Joint family	Single family	Purchased	Cleared
Intercept	21.29	75.29	3.54	5.73	-0.74	56.58	7.44	27.74	-101.86	0.78	54.86	-13.50	30.36
	(8.01)	(8.90)	(2.71)	(15.28)	(12.52)	(7.98)	(5.09)	(8.14)	(42.80)	(12.33)	(14.13)	(10.07)	(15.34)
Pop. density	-0.20*	0.21*	0.11*	0.13	0.22	-0.47**	0.07	0.27*	0.09	0.13	0.09	-0.13	-0.04
	(0.12)	(0.11)	(0.04)	(0.31)	(0.22)	(0.15)	(0.10)	(0.15)	(0.50)	(0.20)	(0.25)	(0.17)	(0.32)
Pop. growth	0.39	-3.16	-0.32	4.07	-3.74	-4.88**	-2.45	6.36**	-2.48	-2.35	-4.36	1.62	4.89
	(2.09)	(2.35)	(0.79)	(3.61)	(3.54)	(2.19)	(1.41)	(2.25)	(9.83)	(3.33)	(3.64)	(2.62)	(3.96)
% paddy area	0.28	-0.27	0.00	-7.73**	-1.45	2.11**	-0.85	-1.35	6.18*	-0.24	-1.86	0.39	-1.16
	(0.60)	(0.88)	(0.29)	(3.38)	(1.31)	(0.85)	(0.56)	(0.67)	(3.00)	(1.13)	(1.44)	(0.94)	(1.67)
% outsiders	-7.04**	-0.16	0.04	3.45**	0.47	-0.49	0.26	0.23	-9.07	0.65	-1.06*	0.43	1.18*
	(1.67)	(0.77)	(0.24)	(1.14)	(0.52)	(0.37)	(0.24)	(0.41)	(6.44)	(0.51)	(0.62)	(0.47)	(0.67)
T. time to town	-0.10	-0.07	0.02	-0.24	-0.14	-0.05	0.15*	-0.02	0.69	-0.23	-0.27	0.14	-0.05
	(0.11)	(0.12)	(0.04)	(0.17)	(0.18)	(0.09)	(0.06)	(0.10)	(0.43)	(0.16)	(0.18)	(0.11)	(0.17)
T. time to forest	0.11	0.37	-0.29	-1.10	-0.14	-0.47	1.15*	-1.73	-4.66	0.39	3.58	0.19	-3.38
	(0.65)	(0.99)	(0.32)	(3.11)	(1.76)	(0.88)	(0.55)	(1.55)	(6.68)	(2.69)	(2.83)	(1.81)	(3.72)
Middle Region	75.09**	-87.38**	-4.20	-7.76	-30.44	29.90**	-0.77	-25.99**	52.86	6.68	-3.63	20.35*	-40.27
	(8.54)	(10.10)	(2.93)	(14.00)	(16.12)	(8.29)	(5.29)	(8.59)	(41.28)	(13.31)	(15.15)	(10.63)	(16.96)
Low Region	51.28**	-45.34**	0.85	-35.40	-18.31*	0.47	-2.03	8.19	86.81	-15.32	-10.33	1.40	0.04
	(8.03)	(9.03)	(2.92)	(19.09)	(13.93)	(8.14)	(5.21)	(8.57)	(38.42)	(13.69)	(14.21)	(10.40)	(15.97)
Log likelihood	-221.57	-204.45	-171.51	-67.40	-80.53	-257.83	-207.60	-232.10	-107.61	-116.79	-231.91	-133.94	-193.26
Sample size	55	55	55	55	58	58	58	58		53	53	53	53

[a] Numbers in parentheses are standard errors. ** indicates significance at the 1%, and * at the 5% level.

Proportion of outsiders is associated negatively with the incidence of joint family ownership of paddy fields, suggesting that the inflow of outsiders helped undermine the traditional family ownership system of the matrilineal society.[18] Outsiders seem to have acquired paddy land in the past by clearing forest areas suitable for paddy cultivation, which is reflected in its positive coefficient in the cleared area regression for paddy fields.

By and large, both travel time to the subdistrict town and walking time to forests have no significant effects on the distribution of land ownership, with exceptions being the positive effects of both variables on the incidence of purchased agroforestry plots. The former result that poorer access to local markets stimulates the transaction of agroforestry plots is difficult to interpret. The latter result, which points to the high incidence of purchase of the existing agroforestry plots in areas where there is little forest near the village, is tenable.

To sum up, there is fairly strong evidence that population pressure induces the individualization of land ownership. A major question is the relative speed by which primary forest and bush-fallow areas have been converted to commercial tree plots planted to rubber, cinnamon, and coffee under different land tenure institutions. If the major source of tree plots is primary forest, agroforestry development comes at the expense of the natural environment. On the other hand, if tree plots were primarily converted from bush-fallow, this development brings environmental benefits. These are the issues to which we now turn.

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[18] The proportion of outsiders, however, may be regarded as endogenous if they were attracted by the ease of obtaining paddy fields due to a more individualized ownership system.

5. HOUSEHOLD SURVEY DATA

Given the complex and endogenous nature of land tenure institutions in Sumatra, it is difficult to identify statistically the consequences of the choice of land tenure institutions on the use of land if we use village level data. It may not be unreasonable to assume, however, that land tenure institutions are exogenous or predetermined for an individual household, because they were determined by group decisions or in the past. Under this assumption, we estimated a tree planting function using the plot level data of individual households. Aside from basic household characteristics, we collected data on the land use before and one year after acquisition of the plot, year and manner of acquisition, and on the land use in 1995.

We are interested in tree planting in the very short run and the longer run. Although clear individual land rights are granted to those who clear primary and secondary forest in the very short run, the original rights tend to be eroded if land is used for food crop production and fallowed under the bush-fallow farming system. Our hypothesis postulates that it is the erosion of land rights and its restoration after tree planting that prompt the early tree planting.

Table 8 presents data on land use changes in 557 upland plots, classified by land use before acquisition and by region, collected in the random sample survey of 300 farmers in 60 villages. Thus, a single household owns, on the average, two upland plots. It is clear that when an agroforestry plot is acquired, with very few exceptions, it continues in that land use. Thus, agroforestry plots that were planted before acquisition were excluded from the analysis of tree planting. Instead, we focused on how land use has changed where land was bush-fallow or forest before acquisition. It is important to observe that one year after acquisition, a much larger proportion of forest had been converted to agroforestry compared to land that was bush-fallow. Furthermore, the incidence of tree planting was lower and slower to increase in the case of purchased bush-fallow areas compared with acquired forest. Those who purchased bush-fallow land are assured of secure land rights so that they did not have to plant trees hastily. The land rights under single family ownership acquired through inheritance remain relatively stable even if bush-fallow is practiced, so that "premature" tree planting is not predicted by our theoretical model.

Aside from the land tenure variables, we examined the effects on tree planting of the following variables: plot characteristics (such as plot size, walking time to plot from owner's house, and year of acquisition) and household characteristics (such as age of household head at the time of acquisition, years of schooling of the head, present family size, size of paddy and upland fields, and outsider household dummy). Means of these explanatory variables are shown by region in Table 9.

The average plot size and paddy and upland fields were larger in the Low Region, reflecting the comparatively abundant endowment of both forest and bush-fallow areas. Walking time to the nearest forest was longest in the Middle Region, because of the near complete conversion of uncultivated areas in locations near settlements. While there were not many regional differences in the age and schooling of household heads, a difference existed with respect to present family size. Family size was smallest in the Middle Region, suggesting that family size may be endogenous and depend partly on the amount of land acquired in the

Table 8 Land use before acquisition, used for agroforestry one year after acquisition and at present[a]

Land use before acquisition	Total no. of plots	No. of plots planted to trees, one year after acquisition	No. of plots planted to trees in 1995
High Region:			
Agroforestry	44	43 (98)	41 (93)
Bush-fallow:			
Inherited	36	13 (36)	24 (67)
Purchased	9	4 (44)	7 (78)
Forest	64	45 (70)	53 (83)
Middle Region:			
Agroforestry	38	37 (97)	35 (92)
Bush-fallow:			
Inherited	35	18 (51)	28 (80)
Purchased	35	16 (46)	24 (69)
Forest	17	16 (94)	16 (94)
Low Region:			
Agroforestry	107	107 (100)	106 (99)
Bush-fallow:			
Inherited	63	40 (63)	47 (75)
Purchased	20	8 (40)	11 (55)
Forest	87	65 (75)	65 (75)

[a] Numbers in parentheses are percentage of the total number of plots.

past. On average, the year of acquisition was more recent in the Low Region, reflecting the abundant endowment of uncultivated land. Yet, our random sample indicates that few outsiders migrated to the Low Region. Even though the land endowment is relatively rich in the Low Region, the infrastructure is least developed and income levels are the lowest among the three regions.

6. DETERMINANTS OF TREE PLANTING

In order to identify the effects of land tenure institutions on the probability of tree planting, we estimated tree planting functions one year after acquisition and at present using 368 observations for plots that were forest or bush-fallow at the time of acquisition. We apply a logit model in which the dependent variable is unity if the plot was converted to agroforestry. Land tenure institutions are expressed by three dummy variables; single family ownership by daughters and sons, private ownership through purchase, and private ownership of land acquired through clearing primary forest.[19] The base for comparison is single family ownership by daughters.[20] We applied two estimation methods. Since more than one plot

[19] We did not observe lineage and joint family land in household survey data, even though such ownership systems exist according to Table 3. This is primarily because our sample households did not use or cultivate collectively-owned land at the time of our survey.

[20] Suspecting that tenure effects are different in different regions growing different commercial trees, we also estimated the tree planting functions with interaction terms between land tenure variables and regional dummies. The interpretation of estimation result was unclear as one interaction term was significant out of six interaction terms. The major qualitative conclusions on the effects of land tenure institutions, however, remained unchanged by this specification.

Table 9 Means of explanatory variables for household-level regression analysis on tree planting

	Size of plot	Average paddy area	Average upland area	Walking time to plot	Age of household head at time of acquisition	Schooling of household head	Family size at present	Year of acquisition[a]	Percentage of outsiders
	(ha)	*(ha)*	*(ha)*	*(minutes)*					
High Region	0.75	0.63	1.08	57	31.6	5.9	5.5	1981.7	9.0
Middle Region	0.86	0.36	1.35	115	30.3	6.4	4.6	1981.4	6.2
Low Region	1.20	0.84	4.46	65	31.8	6.3	5.3	1986.1	1.7

[a] Either forest land or bush-fallow area.

were sampled from the same household in many cases, we used dummies for multiple plot ownership in order to control for the variance in error terms between households possessing different number of plots. Second, we applied conditional logit estimation to obtain consistent estimates in the presence of village dummies.

One of the limitations of our statistical analysis is the failure to control adequately for the quality of sample plots, even though we expect that walking time to plot and year of plot acquisition may partly capture the plot specific effects. If unobserved plot characteristics are correlated with explanatory variables, the estimates of the regression coefficients will be biased. It is important to recall, however, that we are interested in changes in the magnitudes and the significance of estimated coefficients of land tenure variables between the short run (one year after acquisition) and the longer run (at present). The assessment of these changes may not be seriously distorted, to the extent that the estimation bias remains unchanged between the two estimates. Another problem is that we failed to obtain data on family size at the time of acquisition. Thus, we estimated the functions one year after acquisition with and without family size at present.

The regression results for tree planting one year after acquisition and at present are shown in Table 10; the first two functions in each year use 59 village dummies to control for locational differences. For simplicity, estimates of these coefficients are not reported here. The last function uses conditional logit estimation. As is clear from this table, the results are quite robust with respect to changes in estimation procedures. Among household characteristics, age of head has significant coefficients in the current period regression. Walking time to plot has negative effect on tree planting in the current period regression, which suggests the importance of distance as a variable affective rate of return to investment in trees (Angelsen 1995a). Positive effects of year of acquisition imply that trees were more often planted in more recent years when land became more scarce.

Table 10 Logit regression of tree planting on formerly forest and bush-fallow plots[a]

	Logit with village dummies			Conditional logit		
	One year after acquisition	One year after acquisition	At Present	One year after acquisition	One year after acquisition	At Present
Plot size	0.29 (0.28)	0.27 (0.28	-0.09 (0.22)	0.25 (0.26)	0.24 (0.26)	-0.07 (0.21)
Walking time to plot	-0.0003 (0.004)	-0.0003 (0.003)	-0.01* (0.003)	-0.002 (0.003)	-0.002 (0.003)	-0.007* (0.003)
Paddy area	-0.15 (0.29)	-0.12 (0.29)	-0.21 (0.28)	-0.13 (0.27)	-0.11 (0.27)	-0.17 (0.26)
Upland area	-0.05 (0.07)	-0.06 (0.06)	-0.05 (0.05)	-0.06 (0.06)	-0.06 (0.06)	0.04 (0.04)
Ages of head	-0.00 (0.02)	-0.00 (-0.01)	0.05* (0.02)	-0.00 (0.02)	-0.00 (0.02)	0.04* (0.02)
Schooling of head	0.01 (0.05)	-0.01 (0.05)	0.02 (0.05)	0.01 (0.05)	0.00 (0.05)	0.02 (0.05)
Family size[b]	-0.22 (0.12)		-0.17 (0.11)	-0.18 (0.11)		-0.14 (0.11)
Year of acquisition	0.08** (0.02)	0.07** (0.02)	0.05* (0.02)	0.06** (0.02)	0.06** (0.02)	0.04* (0.02)
Outsider dummy	0.17 (1.31)	-0.42 (1.29)	-0.60 (1.76)	0.15 (1.19)	-0.31 (1.15)	0.53 (1.62)
Single family - daughters & sons	-0.03 (0.66)	-0.17 (0.64)	-0.60 (0.67)	-0.01 (0.61)	-0.16 (0.58)	-0.50 (0.62)
Private ownership - purchase	-0.32 (0.59)	-0.14 (0.57)	-1.02* (0.57)	-0.24 (0.53)	-0.09 (0.52)	-0.86 (0.53)
Private ownership - clearance	1.15* (0.50)	1.17* (0.50)	0.32 (0.49)	1.00* (0.46)	1.03* (0.45)	0.26 (0.45)
Dummy for two plots	-0.46 (0.47)	-0.61 (0.46)	-0.08 (0.46)	-0.38 (0.42)	-0.49 (0.41)	-0.07 (0.42)
Dummy for more than two plots	-0.29 (0.66)	-0.31 (0.66)	-0.77 (0.60)	-0.23 (0.61)	-0.24 (0.61)	-0.66 (0.56)
Log likelihood	-146.65	-148.26	-150.12	-105.87	-107.18	-109.86

[a] Numbers in parentheses are standard errors. ** indicates significance at 1%, and * at the 5% level.

[b] Data refer to present period.

Several important results have been obtained on the impact of land tenure on tree planting. First, the dummy variable representing single family ownership by daughters and sons is insignificant.[21] Thus, the bequest of land rights to sons did not significantly change tree planting decisions. Second, the dummy for private ownership by purchase of bush-fallow areas consistently has negative coefficients but is significant at the 5 percent level only in the third equation. These two findings are generally consistent with our hypothesis that the optimum timing of tree planting is largely independent of the level of tenure security. Although we do not have concrete evidence, there is a possibility that, like the acquisition of forest land, individual land rights of inherited land slightly and gradually decline over time before trees are planted. This may explain the negative effect of private ownership on tree planting compared with the effect of the single family ownership.

Lastly, and most importantly, it is found that the dummy variable representing private ownership acquired by clearing forest has positive and highly significant coefficients for tree planting one year after the land acquisition, but not at present. The former finding strongly supports our hypothesis that those who opened forests would plant trees soon after acquisition. It is also instructive to observe that in the longer run there is no significant difference in tree planting behavior between family ownership and this type of private

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[21] Although not reported here, we estimated a paddy yield function, which shows no significant effect of single family ownership compared with joint family ownership. These findings are consistent with those reported in Table 9 and with the findings of Place and Hazell (1993) that customary land tenure institutions do not matter much in tree and food crop yields in indigenous communities.

ownership.[22] Also note that there are highly significant differences between the coefficients of the two private ownership dummies in all four regression functions. These findings reinforce the validity of our hypothesis that private ownership rights acquired through clearing forest are subject to erosion unless trees are planted, so that trees are planted on this type of land "prematurely" from the private efficiency point of view.[23]

7. CONCLUDING REMARKS

This study provides statistical evidence that population pressure promotes individualization of land tenure institutions in indigenous societies. The extent of individualization, however, was different for different types of land. Ownership of paddy land is least individualized, which is consistent with the small investment requirement for paddy field. Thus, joint family ownership still prevails in many areas. The ownership of bush-fallow land is more individualized than paddy fields but less so than agroforestry plots. In fact, joint family cum lineage ownership accounts for about one-fourth of bush-fallow but for well less than 10 percent of agroforestry. These observations suggest that both clearing forests and planting trees enhance individual ownership rights under these indigenous land tenure

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[22] Our findings are consistent with those of Tyndall (1996), who finds more active tree planting on unregistered land with insecure land rights than on registered land in Kenya.

[23] It is also possible that land is purchased for speculation, in which case the decision to purchase is made earlier than the decision to use the purchased land. See Anderson and Hill (1990) on this point. In our observation, however, this behavior is not common.

institutions. These institutional rules seem to reflect the general principle that labor effort for long-term investments is rewarded by stronger individual land rights.

We also obtained statistical evidence that supports the hypothesis that tenure security of land acquired by clearing communal forest tends to diminish over time if food crops are grown under shifting cultivation (slash and burn). Under these institutional rules, excessively early tree planting occurs from the private point of view, because tree planting enhances land tenure security, which otherwise will continue to decline. This is supported by our finding that the pace of tree planting tends to be slower in the case of purchased bush-fallow land than the case of primary forest clearance, even though individual land rights acquired through purchase of bush-fallow land are most secure. This secure tenure will be efficient from a private point of view, but the use of land for bush-fallow farming may not be efficient from the viewpoint of the global environment.

If tenure insecurity under private ownership acquired through clearing primary forests leads to earlier tree planting, the profitability of using cleared land will be smaller than the case where strong and secure individual land rights are granted after forest clearance. Then tenure insecurity will discourage deforestation and it may well be more socially efficient from the global point of view. In consequence, land policies which attempt to enhance private land rights over cleared forest, e.g., by granting land titles, are likely to be counter-productive for sustaining natural forest environments and creating agroforestry, because they increase the value of cleared land and decrease the profitability of early tree planting. Similarly, policies to promote the profitability of agroforestry will face a tradeoff: they will promote not only tree planting but also deforestation. Thus appropriate policy interventions involving customary land tenure institutions and agroforestry technology must consider not only their direct impacts on the use of exploited land but also their effect on the conversion and the use of forest land.

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