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From Deforestation to Development of Agroforests in Customary Land Tenure Areas of Sumatra

S. Suyanto

International Centre for Research in Agroforestry

Keijiro Otsuka

International Food Policy Research Institute and
Foundation for Advanced Studies on International Development

This study attempts to explore the causes of deforestation and the development of agroforests using household data collected from 60 randomly selected communities in Sumatra. We found that decreases in inherited land per household and increases in the number of male workers and the dependency ratio led to the clearance of primary forests, whereas change in the inheritance system from a matrilineal to a bilateral system did not significantly influence the pace of deforestation. We also found that wealthier households tend to clear forest and develop agroforests more actively than their less wealthy counterparts.

Keywords: Population pressure, deforestation, customary land tenure institutions, individualization of land rights, development of agroforestry.

JEL classification codes: Q15, Q23, Q32.

I. Introduction

Massive deforestation has been taking place in many parts of the Third World. It is generally perceived that the growing population has increased demand for cropland, which, coupled with tenure insecurity or the absence of clear property rights on land, has resulted in the over-exploitation of forest land and tree resources (Deacon, 1994). Usually shifting cultivation is practised on cleared land. It is often argued that because of the population pressure on limited land areas, fallow periods have become shorter and, as a result, food production under shifting cultivation is becoming less sustainable (Otsuka and Place, 2001).

Empirical evidence on the causes and the consequences of deforestation, however, is weak in the literature on natural resource management.[1] This study

1. See, however, recent studies by Place and Otsuka (2000, 2001) and Tachibana, Nguyen and Otsuka (2001). Unlike these studies, which use village-level data on deforestation, this study uses household data.

attempts to explore the factors affecting deforestation and the development of agroforests growing commercial trees such as rubber, cinnamon and coffee, which have replaced shifting cultivation in sloping areas in tropical climates. Our study is based on household-level data collected from five households in each of 60 randomly selected villages in West Sumatra and Jambi provinces along the buffer zone of the Kerinci Seblat National Park.[2]

The first question we will explore is the extent to which population pressure, manifested in both reduction of inherited land area per household and an increase in household size, affects the pace of deforestation. Since inheritance is determined by the parent generation, it is assumed in our analysis that the inherited land area is exogenously given for individual households.

From our observation, primary forest areas are largely open access, at least for community members, even though the village chief is supposed to be a custodian of communally-held primary forest areas. As a result, forests have been cleared on a first-come-first-served basis, which has led to the rapid exhaustion of forest land and its conversion to cropland in many areas.[3] Since it is reasonable to assume that forests were abundant in earlier years, older household heads would have had better access to forest lands in their youth and, hence, would have acquired larger forest land areas. We will test this hypothesis statistically by regressing the acquired forest area on the age of the household head.[4]

It is considered that the development of profitable agroforesty systems will help prevent deforestation (Tomich and van Noordwijk, 1996). An implicit assumption of this argument is that the development of agroforest increases the demand for labour, which otherwise might have been allocated to forest clearance. Also the increased wealth due to the development of agroforest may reduce the supply of labour for such hard work as forest clearance. Angelsen (1995) does not concur, arguing that the pace of deforestation depends on the profitability of land use, so that the opportunity to grow profitable perennial crops will accelerate the speed of deforestation. In our view, the arguments of Angelsen are valid if labour markets are well developed. Even if labour demand for agoroforestry management increases, if labor markets are developed and agroforestry is profitable, labor can be hired to clear the forest. Thus, whether the development of agroforest deters or promotes deforestation is an empirical question. We will examine this issue by assessing the effect of inherited agroforestry land per household on the cleared forest area.

In our study sites, land tenure institutions have been evolving from collective ownership by extended family to individual family ownership and from a

2. The Kerinci forests were protected by the colonial government from 1929. The Indonesian government continued to maintain the protected status of the forests and introduced the enhanced conservation effort in 1982.

3. See the model of Anderson and Hill (1990), which describes how rapidly unused open-access land will be exploited when the property rights are conferred on those who have opened the land.

4. We recognize that while the positive effect of the age of household head on acquired forest area is consistent with the hypothesis that forests have been cleared on a first-come-first-served basis, this does not necessarily prove that primary forest area is open access.

traditional matrilineal system, in which daughters inherit land, to a more egalitarian or bilateral system, in which both daughters and sons inherit the land. Furthermore, a patrilineal inheritance system has also emerged in some areas. This tendency is stronger for upland than lowland paddy land (Otsuka et al., 2001). As will be seen, these changes have been associated with strengthened individual land rights. We will explore empirically whether changes from matrilineal to egalitarian and patrilineal systems have any discernible influence on the pace of deforestation as well as on the development of agroforestry.

The last question to be addressed in this study is the implications of forest clearance and agroforest development for income distribution. When forest land was abundant, all community members would have had access to it, thereby assuring equitable distribution of income. As land becomes scarce with population growth, the race to acquire forest land and to develop agroforests also intensifies. The question is whether rich households acquire larger areas of forest land and develop larger agroforest fields relative to poor ones.

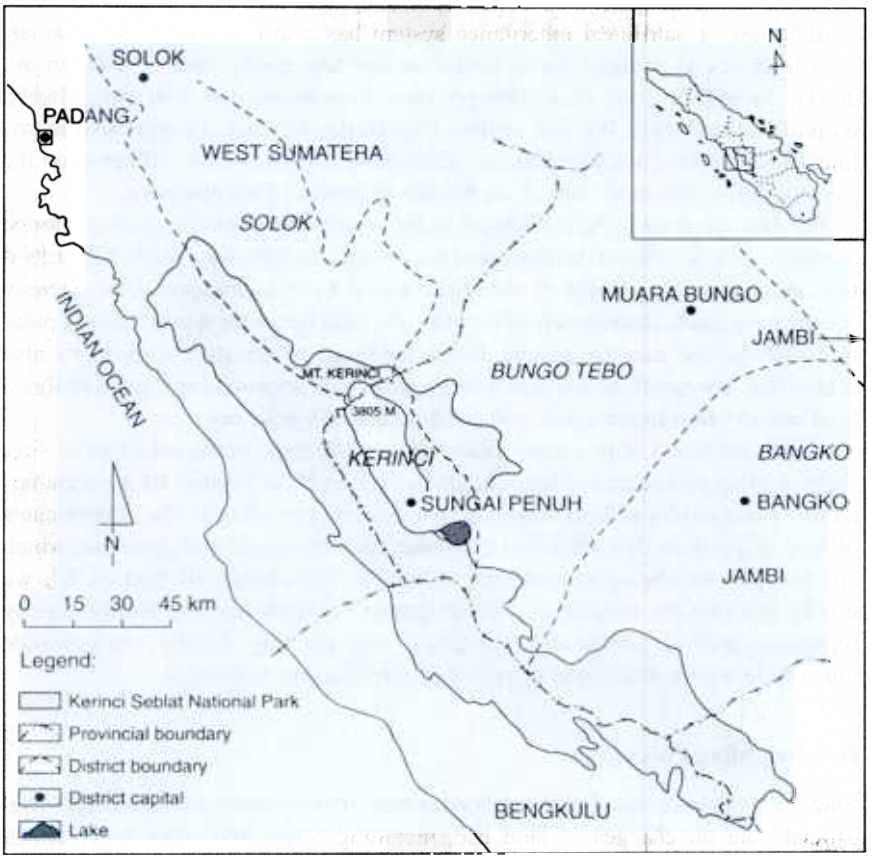
The organization of this paper is as follows. We explain the selection of sites and sampling procedures of households in Section II. In Section III we summarize the main modes of land acquisition and attempt to identify the determinants of land acquisition through forest clearance (deforestation) and purchase, which are endogenous choice variables of individual households. In Section IV, we briefly describe the incidence of development of agroforest and follow this by regression analysis on the determinants of tree planting. Finally, we conclude this article with a discussion of policy implications in Section V.

II. Sampling Pocedures

Since deforestation is a dynamic phenomenon, it is desirable to use village-level official data on changes in land use, including forest and other uncultivated areas, using the data collected in the past and at present, in order to analyse the determinants of deforestation (Place and Otsuka, 2000, 2001; Tachibana, Nguyen and Otsuka, 2001). Such data, however, are often unavailable. This study represents a unique attempt to use the recall data of sample households on land use in the past collected by survey methodology for the analysis of deforestation.

In 1995, we conducted a random sample survey of five households in each of 60 villages selected by random sampling 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 1). Solok, which we call the High Region in this study, is located at the highest altitude of more 1,000 metres above sea level. The major tree crop in Solok is coffee, even though the area planted to cinnamon has been increasing. Cinnamon is a major tree crop in Kerinci, which we call the Middle Region. 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 aggregate these districts into the Low

Figure 1 Location of Study Site



Region. The sample villages are located in the buffer zone surrounding Kerinci Seblat National Park, the largest zone of continuous primary forest in Sumatra with an area of 14,847 km^2.

The agricultural landscape in our site follows multi-strata agroforestry, where paddy fields are located in valleys and flat areas, and agroforestry fields with both mature trees and newly planted trees intercropped with annuals and bush-fallow fields under shifting cultivation are developed in the surrounding hills and mountains. Table 1 shows the characteristics of villages in the three regions. Villages in the High Region have a high proportion of paddy fields, while in the Low Region, paddy fields account for only a small portion of the exploited area. The Middle Region has the least bush-fallow both in terms of absolute area and of relative share in the total exploited areas. In contrast, there remain large tracts of bush-fallow land in the Low Region.

Table 1 Land Use Patterns and Population Size in Selected Villages in Sumatra

	Sample size	Exploited area in 1995 (ha)[a]			Total village area[b] (ha)	Primary forest area[c] (ha)	Population in 1993[b]	Population density in 1993[d] (persons/km^2)
		Paddy fields	Agroforestry plots	Bush-fallow				
High Region	24	259 (31)	377 (45)	204 (24)	5143	4303	1764	34
Middle Region	19	151 (19)	526 (66)	125 (16)	3173	2371	1340	42
Low Region	17	102 (9)	594 (55)	385 (36)	6735	5654	772	11

Notes: [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.

We asked farmers to estimate the areas of primary forest in their villages. Their estimation, however, is subject to substantial errors. Because official statistics do not distinguish between secondary forest, which is a part of the bush-fallow system, and primary forest, the use of this data source is not helpful. Therefore, we estimated the primary forest area by subtracting the total exploited area as estimated by a group of farmers from the total village area reported by official statistics. This estimation showed that primary forest still accounts for a large proportion of village land. This could be explained by the existence of a relatively well-protected national park as well as by steep slopes, which render mountainous areas unsuitable for cultivation. Although we cannot provide concrete evidence, we have an impression that our procedure overestimates primary forest areas.

Population density is lowest in the Low Region and highest in the Middle Region. The limited availability of paddy fields in the Low Region seems to explain the low population density. In contrast, the extensive flat fertile areas suitable for rice cultivation and the high profitability of cinnamon seems to sustain the high population density of the Middle Region.[5]

Our total sample consists of 300 households. Since the major purpose of this article is to assess the behaviour of households with regard to deforestation and the use of cleared upland, we focus on the 273 households which actually owned upland fields in our analysis of the determinants of land acquisition, including forest clearance. Similarly, for the analysis of determinants of the development of agroforest, we focus on those households which have ever acquired bush-fallow and forest land. There are 231 such households, whose data are useful for the statistical analysis.

III. The Determinants of Deforestation and Land Purchase

The village societies in our study sites have traditionally followed a matrilineal inheritance and matrilocal residence systems, even though these systems have undergone substantial transformation over time (Errington, 1984; Kahn, 1980). Land used to be owned 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 deceased woman, in accordance with the decision of a lineage head. Such lineage land ownership, however, had become uncommon by the time of our survey. The traditional customary land tenure institutions have evolved from lineage ownership to more individualized single-family ownership. Moreover, within the single family system, we also found a change from the matrilineal inheritance system, in which daughters inherit land, to a more bilateral or egalitarian system in which both daughters and sons inherit land, or even to a patrilineal system in which only sons inherit land.

5. Suyanto et al. (2001b) estimated the internal rates of return to investment in cinnamon trees in Middle Region to be between 29 and 42%.

Table 2 Average Upland Area per Household by Manner of Land Acquisition and Site

Land Acquisition	High Region		Middle Region		ow Region	
			Ha	%	Ha	
Inherited by:						
Daughters	0.48	42	0.13	10	0.81	20
Daughters and sons	0.03	3	0.18	14	0.00	0
Sons	0.00	0	0.07	5	0.41	10
Forest clearance	0.49	42	0.40	31	1.84	42
Purchase	0.15	13	0.51	39	1.06	26
Total	1.17	100	1.29	100	4.12	100

Let us now review the data on the manner of acquisition of upland fields in our study sites (see Table 2). First, we found that the proportion of inherited land is well below 50%, suggesting that the importance of inheritance has declined over time. We gathered from informal interviews that historically inheritance had been a predominant mode of land transfer. In all likelihood, the declining importance of land inheritance is a consequence of increasing population pressure on land, as the need to allocate land efficiently, through means other than inheritance, would have increased with an increase in the scarcity value of land. In fact, it appears that the proportion of purchased land has increased, even though land transactions have traditionally been prohibited. The proportion of inherited land is highest in the High Region, which may be related to the preservation of the traditional matrilineal inheritance system in this region.

We also found that the average upland area per household in the Low Region is higher than in the High and Middle Regions. This indicates low population pressure on land in the Low Region compared to the other two regions. It must also be pointed out that land acquisition by forest clearance is quite high in the Low Region, because of greater availability of forests in this region.

In order to assess the strength of newly emerging land ownership systems, we asked a group of farmers in each village whether the cultivating households possess rights to rent out land 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 types. Among those various rights, the right to sell without approval is the strongest right. In fact, the land with an established individual right to sell can be regarded as perfectly private land, even though it cannot be used as collateral for bank loans because of the lack of official certificates. In contrast, the right to rent out under share tenancy is the weakest right followed closely by the right to rent out under leasehold tenancy.[6]

6. There is a stronger incentive to mine the soil under leasehold tenancy than under share tenancy, because the marginal product accrues entirely to leasehold tenants, whereas share tenants receive only a portion of incremental output. See Otsuka et al. (1992) for a survey of the literature on land tenancy contracts in agrarian economies.

Table 3 Average Number of Land Rights on Upland 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)
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

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

Table 3 shows the average number of rights with no need to obtain approval from other family members by region and land tenure. According to this table, land rights under single family ownership are stronger than under joint family ownership, and within single family ownership, the rights are stronger in the case of bilateral inheritance by daughters and sons. Even under this system, however, there are no rights to sell without the approval of family members. The right to sell without approval is granted only to land acquired by forest clearance or by purchase. It can be argued that land rights affect the expected benefits accrued from forest clearance and tree planting to those who have actually cleared forests and planted trees (Besley, 1995). Therefore, it is of interest to explore how the differences in land rights among different land inheritance systems affect the manner of land acquisition through forest clearance and purchase, and the development of agroforestry.

It can be assumed that the acquisition of land through forest clearance or purchase is a choice made by an individual household, while the acquisition of inherited land is determined by the parental generation. In the Low Region, land was first acquired by inheritance, followed by forest clearance and purchase (Table 4). In the High and Middle Regions, forest lands were acquired slightly earlier than lands acquired by purchase and inheritance. Even though forest lands tend to be acquired earlier, it seems reasonable to assume that young farmers are able to predict relatively accurately how much land they will acquire

Table 4 Average Year of Land Acquisition by Manner and Site[a]

Land acquisition	High Region	Middle Region	Low Region
Inherited by:			
Daughters	1984	1981	1982
Daughters and sons	1982	1982	
Sons		1981	1981
Forest clearance	1981	1980	1988
Purchase	1982	1982	1988

Note: [a] Excluding households which have never inherited land.

through inheritance in the future. This is because inheritance decisions by parents are public knowledge for their heirs. If they perceive that land to be received as a bequest will not be sufficient, they will acquire more land by clearing forest or purchasing. Therefore, it is reasonable to hypothesize that the amount of inherited land areas, either actual or expected, influence individual decisions to acquire land privately. Assuming that the reduction in inherited land area per household reflects the increased population pressure, we hypothesize that as the area of inherited land decreases, farmers tend to clear more forest or purchase more land.

In order to identify the determinants of the choice of private land acquisition, we estimated functions explaining the area of land acquired by forest clearance (deforestation) and by purchase. Since there are many sample households, which have never cleared forest land or purchased land, we applied the familiar Heckman's (1976) two-step estimation procedures, in which the probability of forest clearance or purchase is determined by the first-stage probit regression and cleared or purchased area is determined by the second-stage ordinary least squares (OLS) regression with the use of inverse Mill's ratio. The explanatory variables in our regressions include the area of inherited land, interaction terms of inherited land with two inheritance-system dummies with the base for comparison being inheritance by daughters, area planted with trees at the time of acquisition of inherited land, age of household head, schooling of head, owned paddy area, and the number of male and female workers between 16 and 60 years of age. In addition, we used the dependency ratio (i.e., the ratio of dependent members to the total number of household members) in the first-stage regression. The idea behind this specification is that while a larger dependency ratio leads to greater demand for new land, it is the number of working members that determines the areas of acquired land. We used interaction terms of inherited land area with two inheritance system dummies in our specification, in order to identify the possible differences in impacts of changing land tenure institutions on land acquisition behaviour. Means of explanatory variables by region are shown in Table 5.

Table 5 Means of Other Variables

Variables	High Region	Middle Region	Low Region
Owned paddy area (ha)	0.6	0.3	0.8
Age of household head (years)	44.8	42.2	40.6
Schooling of head (years)	6.3	6.4	6.2
Inherited area planted to trees (ha)	0.22	0.10	0.50
Proportion of inherited land planted with trees (%)	42.8	42.2	40.6
No. of male workers[a]	1.5	1.4	1.3
No. of female workers[a]	1.6	1.4	1.4
Dependency ratio[b]	0.40	0.36	0.40

Notes: [a] Number of male or female family members between 16 and 60 years of age.
[b] Ratio of the number of non-working members to the total number of household members.

The average paddy area was larger in the Low and High Regions, reflecting the comparatively favourable endowment of paddy land relative to population. The average inherited area planted to trees per household was by far the largest in the Low Region, even though there were no appreciable differences in the proportion of trees planted area in inherited land among the three regions. There were also no noticeable regional differences in the age and schooling of household head, the number of male and female workers per household, and the dependency ratio. The estimation results are shown in Table 6.

The first two columns show the estimation results of the determinants of acquired forest areas through forest clearance or deforestation. As we expected, inherited land has negative and significant effects on the probability and area

Table 6 The Determinants of Land Acquisition: Probit and OLS Regressions[a]

	Forest Clearance		Purchase	
	Probability of forest clearance (probit)	Cleared area (OLS)	Probability of purchase (probit)	Purchased area (OLS)
Intercept	−1.39	0.40	−1.22	18.74
	(0.53)	(1.82)	(0.53)	(12.54)
Inherited land	−0.61*	−2.67***	−0.77**	4.01
	(0.31)	(0.86)	(0.38)	(3.90)
Interaction of inherited land and dummy for bilateral inheritance	−0.06	−0.28	0.13	−0.35
	(0.30)	(1.05)	(0.27)	(1.35)
Interaction of inherited land area and dummy for patrilineal inheritance	0.29	−0.015	−0.10	−0.14
	(0.163)	(0.53)	(0.21)	(1.69)
Inherited area planted to trees	0.39	2.93***	0.59	−2.66
	(0.32)	(0.76)	(0.38)	(2.84)
Age of head	0.002	−0.0005	0.01	−0.12*
	(0.007)	(0.02)	(0.007)	(0.06)
Schooling of head	−0.016	0.099	0.02	−0.04
	(0.023)	(0.07)	(0.023)	(0.17)
Own paddy area	0.35**	1.26***	0.06	1.82***
	(0.14)	(0.463)	(0.14)	(0.62)
No. of male workers	0.22*	0.58	−0.08	1.27
	(0.12)	(0.35)	(0.12)	(0.78)
No. of female workers	0.08	−0.21	0.13	−1.28*
	(0.12)	(0.35)	(0.12)	(0.70)
Dependency ratio	1.53***		0.28	
	(0.46)		(0.46)	
Inverse Mills' ratio	–	−0.28	–	−11.56
		(1.32)		(8.17)
Log likelihood	−168.25		−157.5	
R^2		0.31		0.32

Note: [a]Numbers in parentheses are standard errors. *** indicates significance at 1%, ** at the 5%, and * at the 10% level.

of deforestation. This is consistent with the popular belief that increasing population pressure on limited land is a major cause for deforestation, to the extent that declining area of inherited land is due to an increase in the household size. Interaction terms of inherited land with two inheritance dummies, however, were not significant, suggesting that there is no substantive difference in the decision to clear forest among matrilineal, bilateral, and patrilineal inheritance systems. From this result we may be able to conclude that the land under single-family ownership acquired by matrilineal inheritance provides incentives to invest in forest clearance as strongly as the recently emerged bilateral and patrilineal inheritance systems. Owned paddy area has a positive and significant effect on deforestation, which suggests that wealthier farmers tend to clear more forest land by employing hired labourers. This interpretation is reinforced by the fact that the purpose of forest clearance is to establish agroforest, which also requires labour and capital. According to Quisumbing and Otsuka (2001), owned paddy area is in fact an important determinant of household expenditures.

The area planted to trees has a positive and significant effect on cleared forest area, which indicates that a farmer who inherits larger areas of agroforest land tends to clear larger areas of forestland. This could be due partly to the wealth effect and partly to the effect of exposure to profitable farming systems, which stimulated further expansion of agroforests by increasing cleared fields. It is therefore doubtful if the development of profitable agroforestry deters deforestation.

The age of the household head has no significant effect on deforestation. This result is inconsistent with our hypotheses that the older the household head, the greater the access to forest land in youth and, hence, the larger the acquired forest land area.[7] We found, however, that the larger is the dependency ratio, the greater is the probability that new land is acquired by forest clearance. This suggests that population growth tends to result in deforestation, as the higher dependency ratio is probably the result of higher fertility. We also found a significant influence of the increasing number of male workers on the probability that forest is cleared. Since forest clearance requires hard work by male workers, this result is not surprising.

The third and fourth columns show the estimation results of the determinants of purchased land. Inherited land has a negative and significant effect on the probability of land purchase, but not purchased land area. Interaction terms of inherited land with the two inheritance dummies are insignificant. Thus, the hypothesis that the development of the land transaction market is induced by the population pressure on a limited land area is supported only weakly. Owned paddy area has a positive and significant effect on purchased land area, which indicates that wealthier farmers tend to purchase larger areas of upland.

7. This hypothesis, however, was supported empirically by a similar study conducted in cocoa growing areas of Ghana by Quisumbing et al. (2001).

IV. The Determinants of the Development of Agroforestry

Having demonstrated how population pressure and land tenure institutions affected deforestation and land transactions, we turn to the question of how they may affect the development of agroforestry. As population increases, forest land is exploited and eventually becomes less readily available. Under such conditions, investment in land improvement, such as terracing, irrigation and tree planting, is often required to intensify land use (Boserup, 1965). Moreover, Hayami (1997) and Hayami and Ruttan (1985) argue, in line with the theory of induced innovation, that both technological and institutional innovations that save scarce resources occur in response to changing resource endowments. The farming system in Sumatra has changed from a land-using shifting cultivation system to a more labour-using tree-based farming system. This is because traditional shifting cultivation with long fallow periods can be sustained only when land is abundant. When population pressure increases and land becomes scarce, the fallow period tends to become too short for sustainable food crop production. If shifting cultivation continues with a shorter fallow period, soil fertility will decline, leading to further reduction in production efficiency.

Commercially important trees such as rubber (*Hevea braziliansis*), cinnamon (*Cinnanomum burmannii*) and coffee (*Coffea canephora*) have been introduced in our study areas where shifting cultivation had been practised (De Foresta and Michon, 1990).[8] Such changes in farming systems are consistent with the view of Boserup, Hayami and Ruttan that new profitable opportunities induce investment in land improvement. In fact, Suyanto et al. (2001a, 2001b) demonstrate that investments in the development of rubber and cinnamon agroforests in Sumatra have high payoffs.

Establishment of agroforestry requires significant effort in land preparation, tree planting, weeding and pruning, for which property rights institutions need to provide appropriate incentives. Under customary law, relatively strong individual rights are given to those who plant trees not only in Sub-Saharan Africa (Shepherd, 1991; Quisumbing et al., 2001), but also in Sumatra (Otsuka et al., 2001). Under such an institutional rule, an individual community member who has acquired land through forest clearance and inheritance may have a strong incentive to plant trees in order to obtain secure individual land rights.

Table 7 shows the acquired forest and bush areas and the incidence of tree planting (development of agroforest) by manner of land acquisition and region. The percentages of bush-fallow and forest area converted to agroforests are similar in all regions. Furthermore, the incidence of tree planting tends to be higher in cleared forest and inherited land than in purchased land, with the exception of the High Region. The incidence of purchased land in the High

8. See Aumeeruddy (1994) who describes the development of cinnamon-based agroforestry in the Kerinci Valley, and Guoyon et al. (1993) and Penot (1997) who provide historical perspectives on the development of rubber agroforestry in Sumatra.

Table 7 Acquired Forest and Bush Areas and the Incidence of Tree Planting by Manner of Acquisition and Site[a]

Land Acquisition	Acquired Bush and Forest Area (Ha)	Area Planted to Trees (%)
High Region:		
Matrilineal inheritance	0.33	69
Bilateral inheritance	0.00	n.a
Patrilineal inheritance	0.00	n.a
Forest clearance	0.62	79
Purchase	0.08	95
Tenancy	0.03	78
Total/average	1.06	77
Middle Region:		
Matrilineal inheritance	0.13	95
Bilateral inheritance	0.12	90
Patrilineal inheritance	0.04	77
Forest clearance	0.48	94
Purchase	0.42	71
Tenancy	0.16	77
Total/average	1.33	84
Low Region:		
Matrilineal inheritance	0.55	74
Bilateral inheritance	0.00	n.a
Patrilineal inheritance	0.12	45
Forest clearance	1.93	71
Purchase	0.35	29
Tenancy	0.01	100
Total/average	2.96	66

Note: [a] Excluding tree-planted areas at the time of land acquisition.

Region, however, is very low. Since land rights on purchased land are very high (see Table 3), the above observation indicates that incentives to invest in tree planting are not simply determined by the initial strength of land rights or the level of land tenure security, but also by expected changes in land rights after tree planting.

In order to identify the determinants of the development of agroforests, we estimated determinants of tree planting function by applying the Heckman's (1976) procedure. The explanatory variables include acquired forest land and purchased land areas, in addition to other explanatory variables used in the analyses of land acquisition reported in Table 6. The estimation results are shown in Table 8.

Both forest land and inherited land have positive and highly significant effects on tree planting. The estimated coefficients of around 0.7 in the second-stage estimation indicate that an increase in acquired land of one hectare either through inheritance or forest clearance is associated with 0.7 hectare of tree-planted area.

Table 8 Determinants of Area Planted to Trees: Probit and OLS Regressions[a]

	Probability of tree planting (probit)	Tree planted area (OLS)
Intercept	−0.008	−0.77
	(0.64)	(0.4)
Forest land	0.53**	0.75***
	(0.21)	(0.03)
Inherited land	0.72*	0.68***
	(0.35)	(0.08)
Interaction of inherited land and dummy for bilateral inheritance	−0.21	−0.06
	(0.79)	(0.24)
Interaction of inherited land area and dummy for patrilineal inheritance	−0.71	−0.48*
	(0.60)	(0.25)
Purchased land	−0.28	0.51***
	(0.24)	(0.06)
Age of head	0.005	0.01*
	(0.01)	(0.005)
Schooling of head	0.02	0.05**
	(0.03)	(0.017)
Own paddy area	0.037	−0.12
	(0.28)	(0.10)
No. of male workers	−0.15	0.12
	(0.20)	(0.08)
No. of female workers	0.07	−0.08
	(0.70)	(0.09)
Dependency ratio	0.75	
	(0.70)	
Inverse Mill's ratio		1.17*
		(0.59)
Log likelihood	−71.1	
R^2		
		0.85

Note: [a] Numbers in parentheses are standard errors. *** indicates significance at 1%, ** at the 5%, and * at the 10% level.

Purchased land also has positive but weaker effect, judging from its significantly smaller coefficient than the coefficients of forest and inherited land in the second-stage regression. Thus, the incentive to plant trees in purchased land is lower, even though the strength of property rights on purchased land is very high. Because of the secure land right, farmers probably do not have to hurry to plant trees. In contrast, if land use is limited to food crops grown under shifting cultivation, the strength of individual rights acquired through forest clearance tend to diminish over time. When land is fallow, other community members can claim the right to use this 'unused' land (Mary and Michon, 1987). Relatively strong individual ownership rights, however, are granted if trees are planted (Marsden, 1811). Under such institutional rules, an individual community member who has cleared forest land would have a particularly strong incentive to plant

trees in order to establish secure land rights. Similarly, if individual household members have not planted trees on bush-fallow land received by inheritance, other members of the extended family may be able to claim the 'unused' land.

The interaction terms of the inheritance dummies (bilateral inheritance by daughters and sons and patrilineal inheritance by sons only) do not have significant coefficients. It appears that the incentives to invest in tree planting are more likely and are more strongly affected by expected changes in land rights after tree planting than by the level of land rights before tree planting. Similar phenomena are reported in a case study of cocoa planting in Western Ghana (Quisumbing et al., 2001). Our result, however, is quite different from the findings of Besley (1995), who uses a data set from Western Ghana to show statistically that stronger land rights lead to a higher incidence of tree planting. We would argue that Besley's methodology of simply counting the number of rights (e.g., rights to rent out and sell) to measure the tenure security without considering the relative importance of each right leads to biased estimation.[9]

The numbers of both male and female workers have no significant effects on tree planting. These results are somewhat unexpected, since the establishment of agroforest requires primarily male labour (Suyanto et al., 2001a; Barlow and Muharminto, 1982). If the labour market functions effectively, however, the resource allocation among farms tends to be equalized regardless of the endowment of household-owned resources. Thus, the insignificant effects of the male and female family labour endowments indicate the existence of efficient labour markets in our study sites. Finally, we found that more educated farmers tend to establish agroforests more actively, indicating that it is primarily the wealthy educated farmers who can afford to develop profitable agroforestry systems.

V. Concluding Remarks

This study provides statistical evidence that population pressure results in deforestation in Sumatra. We also found that land-rich farmers clear forests extensively and educated farmers develop agroforestry intensively. Moreover, we found that the development of agroforestry exerted a positive effect on the pace of deforestation. Therefore, we cannot support the popular belief that the development of agroforestry deters deforestation. If it is desirable to preserve primary forest, from the social or global viewpoint, measures other than the promotion of profitable agroforestry need to be implemented.

We also obtained statistical evidence that the probability of tree planting is higher in formerly forest and inherited land than in purchased land, and that the difference in the strength of land rights between matrilineal and egalitarian

9. As Quisumbing and Otsuka (2001) point out, Besley's study does not recognize the difference in land rights of inherited land between matrilineal and patrilineal societies. Moreover, the tree planting is expressed as a binary variable, which is irrelevant where tree planting areas and densities are vastly different.

inheritance does not have any effect on the pace of tree planting. These results support our hypothesis that the incentive to invest in tree planting is affected not only by the strength of individual land rights but also by expected changes in land rights after tree planting. In other words, customary land tenure institutions have built-in incentive mechanisms that ensure active tree planting. In all likelihood, therefore, farmers in customary land areas invest in tree planting, if agroforestry is profitable. Thus, we do not recommend the government to interfere with the customary land tenure systems, as they are naturally evolving in the right directions.

The establishment of profitable agroforestry systems will contribute to the well-being of poor farmers residing in mountainous areas by improving the efficiency of land use and by the improvement of the natural environment by replacing bush-fallow areas. Furthermore, their establishment facilitates individualization of land rights, which, in turn, will promote the diffusion of agroforestry systems. Thus, there are good economic and social reasons for allocating public resources to the development of profitable agroforestry systems.

This study indicates that inequality between rich and poor farmers may increase with the process of deforestation and the development of agroforestry, as wealthy farmers clear forests and develop agroforestry more actively than poor farmers. It seems to us that our major challenge is how to achieve equitable development of agroforestry without sacrificing efficiency of resource use. In order to identify the desired policy instruments, further in-depth studies are required.

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