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# Land tenure and farm management efficiency: The case of smallholder rubber production in customary land areas of Sumatra

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**Abstract**

This study assesses the impact of land tenure institutions on the efficiency of farm management based on a case study of rubber production in customary land areas of Sumatra, Indonesia. Using the modes of land acquisition as measures of land tenure institutions, we estimated tree planting, revenue, income, and short-run profit functions, and internal rates of return to tree planting on smallholder rubber fields. We find generally insignificant differences in the incidence of tree planting and management efficiency (defined as residual profits) of rubber production between newly emerging private ownership and customary ownership. This is consistent with our hypothesis that tree planting confers stronger individual rights, if land rights are initially weak (as in the case of family land under customary land tenure systems). On the other hand, short-term profits are higher on land that is rented through share tenancy. This result indicates that rubber trees are over-exploited under renting arrangements due partly to the short-run nature of the land tenancy contracts and partly to the difficulty landowners face in supervising tapping activities of tenants in spatially dispersed rubber fields.

## Introduction

While individual usufruct rights usually are well established under customary land tenure systems, including community, lineage, and extended family ownership, the rights to transfer and inheritance are often limited (Bassett, 1993; Sheppard, 1991). Such customary land tenure institutions have evolved towards individualized tenure, in which individual community members have clearer ownership rights, in response to population pressure and agricultural commercialization in many parts of Asia and Africa (e.g., Bruce and Migot-Adholla, 1993; Otsuka et al., 2000; Place and Otsuka, 2000a, b). It is not clear, however, whether and to what extent individualized tenure institutions are still governed by customary land tenure rules.

If individual land ownership rights are not secure under emerging individualized tenure, those who undertake long-term investments may not be able to reap the future benefits due to an inability to bequeath the property to desired heirs or to sell the land freely if the need arises. In this way, efficient farm management may be hampered by tenure insecurity (Besley, 1995). On the other hand, the spontaneous process of institutional choice may lead to the establishment of secure individual land tenure institutions in customary land areas, as envisaged by the evolutionary view

of farming systems proposed by Boserup (1965), the theory of property rights formulated by Demsetz (1967), and the theory of induced innovation postulated by Hayami (1997). In fact, tree planting may confer strong individual land rights (Shepherd, 1991), which may provide sufficiently strong incentives to invest in tree planting on customary land. Thus, it is an empirical question whether customary land tenure institutions deter tree planting or not.

The quantitative literature on customary land tenure institutions so far has focused on the impact of different tenure institutions on crop yields (Place and Hazell, 1993) and on the incidence of planting of commercial trees (e.g., Besley, 1995; Otsuka et al., 2000). In order to identify more clearly the implications of land tenure institutions for the efficiency of farm management, in this study we propose to assess their impacts not only on tree planting but also on the profitability of farm management by estimating the short-run profit function and the internal rate of return to investment in tree planting. Specifically, we explore the effect of newly emerging land tenure institutions on the efficiency of farm management based on this case study of smallholder rubber production in Sumatra, Indonesia. In our study site, the matrilineal system of inheritance in which land is bequeathed from a mother to her sisters, daughters, or nieces in accordance with the decision of lineage leaders has traditionally been practiced. While this system often is adhered to for the inheritance of lowland paddy and upland crop fields, it has been replaced for rubber fields by a modified matrilineal system in which land is inherited jointly by sisters and further by a single family patrilineal system in which land is bequeathed within a nuclear family from a father to his sons. Furthermore, sales of upland fields have become quite common, which leads to *de facto* private property. Strong land rights also are conferred upon new clearance of forest land, even though the land rights may decline if the cleared land is used for food production and then left fallow under traditional shifting cultivation (Otsuka et al., 2000). Also coexisting are family land that is temporarily borrowed and land that is rented through share tenancy arrangements. Under these arrangements borrowers and tenants possess weak short-term land use rights.

A major objective of this study is to examine how the different land tenure institutions represented by the modes of land acquisition affect tree planting decisions and the profitability of rubber production. As a null hypothesis, we postulate that single family ownership does not deter tree planting nor does it lead to lower profits compared with private ownership established through forest clearance and private purchase. These results may be explained by security enhancing effects of tree planting. On the other hand, the short-term nature of renting and borrowing arrangements may lead to over-exploitation of rubber trees, to the extent that landowners cannot effectively monitor activities of borrowers and tenants.

The organization of this article is as follows. We explain the selection of sites and sampling procedures in the next section, which is followed by a discussion of the prevailing land tenure institutions and land tenure rules by land use type. We then assess the revenue, income, residual profit, and labor use in rubber production. In order to assess profitability of rubber production, we must also assess the profitability of upland rice farming which is a major alternative use of upland fields. After estimating the revenue, income, and profit functions of rubber production, we estimate the internal rates of return to investment in rubber trees under different land tenure institutions based on the estimation results of the profit function for rubber. Finally, we conclude this article with a discussion of policy implications.

## Sampling procedures

Our previous study of land tenure institutions in various communities located over wide areas of West Sumatra and Jambi Provinces on the island of Sumatra in Indonesia revealed that the traditional matrilineal inheritance system had undergone substantial transformation (Otsuka et al., 2000).[1] Table 1 describes the land tenure institutions that prevailed in sites for this study as well as elsewhere in West Sumatra and Jambi Provinces. Traditionally, cultivated land, particularly paddy fields, has been owned collectively by a lineage, a group of relatives usually comprising three generations: a grandmother, her husband, and their children and grandchildren. When a woman

*Table 1.* Land tenure categories and their major characteristics in Sumatra, Indonesia.

| 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 |

dies, land is bequeathed to her sisters, nieces, and daughters in accordance with the decision of the lineage head, who is selected from among male members of the second generation. The basic principle of land allocation is to maintain equity among lineage members. Individual land rights, other than usufruct rights, are highly restricted in this system, in part to maintain paddy land within the lineage. This original lineage ownership system, however, had become rare in our study areas at the time of our survey in 1996. At that time, a woman's daughters usually jointly inherit paddy fields; we call this joint-family ownership. Furthermore, single-family ownership, in which daughters individually inherit shares of the land, has become widespread for paddy fields in some areas. For upland commercial tree fields, single-family ownership (in which both daughters and sons or only sons inherit the land individually) is more common than lineage and joint-family ownership. In addition, 'private' ownership has been widely created through land purchases and by clearing natural forest, particularly for upland fields.[2]

According to our previous community-level surveys, individual land rights are very weak under lineage ownership in which cultivators are usually not allowed to rent out, pawn, or sell land or to plant trees without permission from the lineage members. In the case of joint family ownership of upland fields, cultivators are allowed at most to rent out land under share tenancy and to plant trees without permission. Land rights are stronger under single family ownership, in which cultivators usually possess rights to rent out and sometimes to pawn without obtaining permission from the head of extended family. If the permission is obtained, land can be sold under the single family ownership system. In contrast, almost complete rights including rights to sell without permission are granted to privately purchased land and cleared forest land, even though land rights tend to decline in the latter case if land is left fallow for long periods. Tree planting has promoted the conversion from lineage ownership to joint family ownership and single family ownership, as efforts to plant trees are rewarded by strong individual rights according to the customary land tenure rules. In fact, after trees are planted, owners of single family land are often granted the right to sell the land. In other words, tree planting helps establish strong individual land rights, when such rights are originally weak. An important question is the implications of such evolutionary changes in land tenure institutions for the efficiency of land use.

We selected a typical rubber growing village in Rantau Pandan Subdistrict in Jambi Province, called Muara Buat, for our intensive study of rubber growing farm households (see Figure 1). Almost all inhabitants belong to the Melayu Jambi ethnic group, which is related to the Minangkabau group of West Sumatra and, like the Minangkabau, traditionally practiced matrilineal inheritance. We conducted a census survey of the 122 households in the village in late 1996. After the survey it became clear that the number of upland plots was inadequate for the purpose of estimating the age-profile of profitability of rubber production. Thus, we added a randomly selected sample of forty households from a village contiguous to the first, which is called Karak. This increased the total sample size in our study to 162 households (see Table 2). A senior author of this article conducted the surveys for a period of nearly six months in cooperation with several students of the University of Jambi. As much as possible, we interviewed both husband and wife together, in which we asked family characteristics such as the number of family members, age and schooling of household head; modes and years of land acquisition, land use before acquisition and at present, and plot size

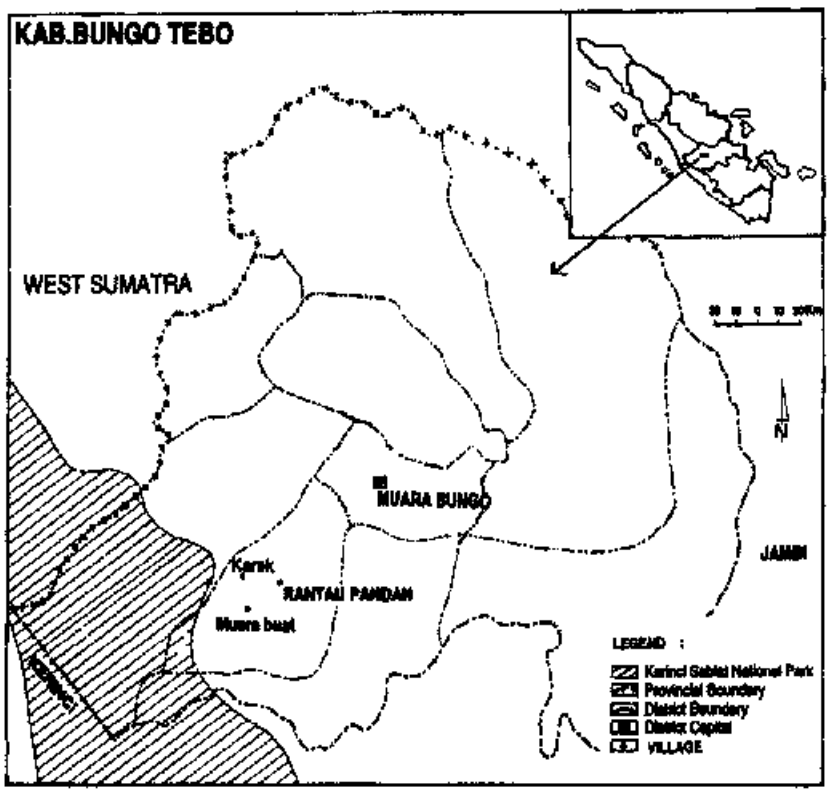


*Figure 1.* Location of study site.

*Table 2.* Distribution of sample plots by land use in upland areas of villages in Sumatra, Indonesia.

| | Number of plots | Number of households |
|---|---|---|
| Total | 550 | 162 |
| Upland rice fields | 27 | 27 |
| Young rubber fields[a] | 177 (33)[b] | 111 |
| Mature rubber fields[a] | 198 (128)[c] | 122 |
| Bush-fallow | 148 | 102 |

[a] Young and mature rubber fields refer to those with dominant tree age of zero to seven and eight and above, respectively.
[b] The number of young rubber fields selected for the assessment of cost of production.
[c] The number of mature rubber fields selected for the assessment of revenue and cost of production.

for all plots; age of rubber trees and walking time to rubber fields; and cost, family labor use, and revenue of selected rubber fields and upland rice fields. Note that we do not analyze the land use for lowland rice cultivation in this study because cultivators have never converted land productive in lowland rice to rubber fields; bush fallow and rubber are alternative uses of upland fields.

The sampled households operated 550 upland fields, of which 27 were planted to upland rice in the wet season of 1995/96. The rest of these plots comprised 177 young rubber fields (with dominant tree ages of one to seven years), 198 mature rubber fields (dominant tree ages of eight years and above), and 148 bush-fallow fields.[3] The rubber farming system under investigation sometimes is called 'jungle rubber' because wild woody species also are allowed to grow among the rubber trees, which may help protect the rubber from weeds (Gouyon et al., 1993). The plant biodiversity of the jungle rubber is half to two-thirds that of natural forest (Michon and de Foresta, 1995). The production technologies have changed little since rubber was introduced a century ago, despite the availability of seemingly profitable alternative technologies (Barlow and Jayasuriya, 1984). Bush-fallow areas are located generally in areas

far from village centers and were planted to food crops in the distant past. At present, some of them are secondary forests. We use all of these sample plots for the probit analysis of tree planting.

Because of the increase in prices of cinnamon relative to rubber in recent years, some farmers have experimented with intercropping cinnamon in young rubber fields. Thus, only 33 young rubber fields were pure rubber fields, whereas 128 mature rubber fields were pure stands (aside from the natural regeneration of wild species described above). By and large, cinnamon occupies only small areas, as the altitudes of our study site are too low for commercial cinnamon production. For the survey of production costs and revenue, we chose all the fields planted only to rubber and conducted interviews during the wet and dry seasons of 1996/97 (December 1996 and June/July 1997). We also measured the altitude and slope of the rubber plots as indicators of land quality. The quality of land may be affected not only by these physical characteristics but also by the extent of competition with weeds and the fertility of soil, which are significantly affected by the previous land use (Gouyon et al., 1993). Thus, we also determined the land cover (i.e., primary forest, rubber fields, or bush-fallow) on these plots before the current cohorts of trees were planted.[4] Among the three land cover types, land previously under forest cover is likely to have the highest soil fertility and the least weed problems.

## Land use and land tenure

The prevailing land tenure institutions were markedly different among upland rice, rubber, and bush-fallow fields. Table 3 shows the land tenure distribution of all sample plots by land use type. In the case of upland rice fields, communal/lineage ownership still dominates. Strictly speaking, use of this communal area is controlled by the village chief, who allocates land for shifting cultivation. After one season of cultivation of upland rice, fields are put into fallow. The average bush fallow period now is 5.8 years, which is much shorter than the previously common fallow periods of fifteen to twenty years that are considered sufficient to restore soil fertility (Gouyon et al., 1993). Under this system, individuals are prohibited from planting trees on the communal area and they have no rights to rent out land. Although there is no formal rule of access rights to this communal area, villagers obey the implicit customary rule on fallow periods and access rights assigned to various lineage groups. Usually lineage members work together in contiguous fields in order to protect rice crops from wild pigs, a serious pest in this region.

Aside from communal land, which is located on a relatively flat and fertile plain, there are a small number of upland rice fields owned jointly by daughters, individually by daughters or sons, and privately by individuals who cleared their plots from forest land, as well as rice fields borrowed from relatives. Generally, these upland fields are scattered and susceptible to attack by wild pigs.

Land tenure on rubber fields is much more individualized. In fact, there is neither communal nor joint-family ownership of this type of land. Moreover, there are only a few cases of single-family ownership by daughters alone. Overall, single-family ownership by sons predominates. Most survey respondents indicated that rights to

*Table 3.* Land tenure distribution of sample plots by land use type in Sumatra, Indonesia (proportion (%)).

| | Upland rice | Young rubber | Mature rubber | Bush-fallow |
|---|---|---|---|---|
| Communal/lineage | 67 | 0 | 0 | 0 |
| Joint family | 4 | 0 | 0 | 4 |
| Single family | 11 (7)[a] | 35 (4) | 24 (1) | 37 (8) |
| Private-purchase | 0 | 44 | 53 | 21 |
| Private-forest clearance | 4 | 15 | 10 | 37 |
| Renting | 0 | 0 | 9 | 0 |
| Borrowing | 11 | 6 | 5 | 0 |
| Others | 4 | 0 | 0 | 0 |

[a] Numbers in parentheses refer to the proportion of single-family ownership of daughters alone.

rent out under leasehold and share contract, to pawn, and to sell exist not only under private ownership but also under single-family ownership and that in either system no permission is required from any other members of the extended family or lineage group. Strong property rights are necessary to provide incentives for the effort to plant and grow trees. Indeed, the act of planting trees traditionally has been rewarded by strong individual property rights in Sumatra and was recorded by European visitors in the late 18th century (Marsden, 1811). There also is some share tenancy in trees, in which output is shared 1/3 for the owner and 2/3 for tenant, as well as borrowing from relatives.[5]

The prevailing land tenure institutions on bush-fallow land are similar to those on rubber fields, although renting and borrowing are not practiced on bush-fallow land. Compared with neighboring areas of Sumatra, land tenure arrangements for bush-fallow fields are more clearly individualized in this study area (Otsuka et al., 2000).

Before sample plots were acquired by the current operator, about one-fifth of our selected rubber and bush-fallow plots were primary forests and two-fifths each were rubber fields and bush-fallow fields (Table 4). Although virtually all unexploited forested land in Indonesia officially is classified as state land, from a local perspective these primary forests are communally owned and under control of the village chief. Thus, community members who want to clear uncultivated forest land are supposed to obtain permission from the village chief. In practice, however, these forests are open access to community members, so that little easily-accessible primary forest remained in the study area at the time of our survey.[6] Roughly speaking, about half of both cleared forest plots and acquired bush-fallow plots were planted to rubber trees. The productive life span of a rubber tree can be sixty years or more.[7] Moreover, once established, rubber trees regenerate seedlings and with proper thinning and other management the rubber forest can be sustained over extended periods. Hence, with very few exceptions, acquired rubber fields remain rubber fields either through replanting or through regeneration to fill gaps with young rubber trees. As shown in Table 3, 88 percent of the present rubber fields in our sample also were rubber fields before the current cohort of trees was planted, which indicates that many rubber fields were cleared and replanted after trees became unproductive.[8]

## Revenue and cost

Labor, particularly family labor, is the main cost of rubber production. In order to estimate the total cost of production, we imputed the cost of family labor by activity and by season by using the relevant prevailing wage rates for hired labor. The wage rates are obtained from the survey of production costs of sample households (see Table 5 for sample size for the estimation of each wage category). Daily wage contracts are common for forest clearance, land preparation, and crop care (mostly weeding). Wage rates are quite uniform across activities in rubber and upland rice cultivation, but there are marked differences between wage rates for men and women. The average daily

*Table 4.* Land use before acquisition, at present, and before last planting of rubber trees of upland plots currently planted to rubber trees or under bush-fallow in Sumatra, Indonesia.

| Land Use before acquisition | No. of plots | Proportion of land use at present (%) | | Proportion of land use before planting (%)[a] | | |
|---|---|---|---|---|---|---|
| | | Rubber | Bush-Fallow | Forest | Rubber | Bush-fallow |
| Forest | 103 | 46 | 54 | 100 | 0 | 0 |
| Rubber fields | 202 | 99 | 1 | 4[b] | 88 | 9 |
| Bush-fallow | 218 | 59 | 41 | –[c] | – | – |

[a] Before planting of rubber trees of currently dominant age.
[b] Pertaining to 128 mature rubber plots selected for the assessment of revenue and cost of production.
[c] No data were collected.

*Table 5.* Average wage per day by crop and activity in Sumatra, Indonesia.[a]

| | Wet season (rupiah/day in 1996)[b] | | Dry season (rupiah/day in 1996) | |
|---|---|---|---|---|
| | Men | Women | Men | Women |
| Rubber: | | | | |
| Daily wage for clearance forest | 8,000 (10)[c] | – | 8,000 (10) | – |
| Daily wage for land preparation and crop care | 4,606 (21) | 2,966 (29) | 4,846 (12) | 3,105 (19) |
| Daily earnings for tapping | 7,693 (53) | 4,954 (3) | 8,800 (53) | 5,638 (5) |
| Upland rice (daily wage) | 4,576 (11) | 2,983 (46) | – | – |

[a] Daily wage includes imputed value of food provided to hired workers, whereas daily earnings refer to earnings per day under output sharing contract.
[b] The exchange rate was US$1.00: 2,400 rupiah in 1996.
[c] Numbers in parentheses are sample sizes.

wage was Rupiah 4,700 (or about $2.00) for men and Rupiah 3,000 for women. Wages for clearing natural forest, which requires heavy labor and entails significant risk of injury, typically are double other daily wages. Because of the nature of the work, forest clearing typically is done by men.

Labor requirements of rubber production change dramatically as trees mature. Table 6 presents the statistics on labor use per hectare by activity, gender, and age of rubber trees compared with labor use for upland rice cultivation based on 161 selected pure rubber fields. Several observations can be made. First, labor by men predominates in most rubber production activities. This may explain, at least partly, why the matrilineal inheritance system, which formerly covered all asset classes, gradually has been replaced for rubber plots by the patrilineal system, thereby providing incentives to the males who do much of the work on these plots. Second, there is a large difference in labor cost in the first year between clearance of primary forest and bush or old rubber fields, due partly to higher costs of felling big trees and partly to higher labor requirements for harvesting annuals crops intercropped with rubber seedlings. Because of the higher fertility of soils in plots recently cleared from natural forest, annual crops more often are planted on these plots and higher yields result. In contrast, annual crops are seldom intercropped with rubber seedlings on plots cleared from bush fallow. Third, labor requirements change over the years. Requirements are high in the first year; then they decline for several years when trees are immature. Labor requirements rise again when trees are old enough to be tapped and they increase until trees are about 30 years old with increases in harvesting labor. Finally, they decline with decreases in harvesting labor for the oldest trees.

By contrast with rubber, women provide most of the labor for upland rice. This is consistent with the persistence of joint- and single-family ownership of upland fields by daughters and also conforms to social norms regarding women's role in household food supply. Also, it is important to point out that rubber production is highly labor-intensive. Although labor use per cultivated hectare was higher for upland rice than for rubber, upland rice requires a fallow period of five years or more. Thus, if the fallow period also is included, the average labor intensity for the land use systems taken as a whole is much greater for rubber production than it is for upland rice. Thus, the shift from upland rice production under shifting cultivation to rubber production fits Boserup's (1965) generalization about agricultural intensification as the extensive margin closes.[9]

Output sharing is the dominant form of contract for tapping of latex from rubber trees and the sharetapper receives two-thirds of the revenue. Tapping in dense stands of jungle rubber,' as well as hauling of coagulated slab, is done primarily – but not exclusively – by men (Table 6; Barlow and Muharminto, 1982; Barlow and Jayasuriya, 1984; Gouyon et al., 1991).

Imputed daily earnings under the output-sharing contract for rubber sharetappers, corresponding to seven hours of work, are much higher than daily wages. Similar differences between daily wages

*Table 6.* Labor use for rubber production by activity, gender, and dominant age of trees in comparison with labor use for upland rice production in Sumatra, Indonesia.[a]

| Age range | Land preparation and planting (person-days/year/hectare) | | Crop care[b] (person-days/year/hectare) | | Harvesting and hauling (person-days/year/hectare) | | Total (person days/year/ hectare) |
|---|---|---|---|---|---|---|---|
| | Men | Women | Men | Women | Men | Women | |
| Rubber: | | | | | | | |
| 1 (Forest clearance) | 53.3 | 28.6 | 6.9 | 4.1 | 9.4[c] | 25.0[c] | 127.4 |
| 1 (Bush clearance)[d] | 19.6 | 12.2 | 17.8 | 7.7 | 1.0 | 1.0[c] | 59.3 |
| 2–3 | 2.9 | 0.0 | 24.2 | 6.3 | 0.0 | 0.0 | 33.4 |
| 4–7 | 0.0 | 0.0 | 9.8 | 4.2 | 0.0 | 0.0 | 14.0 |
| 8–10 | 0.0 | 0.0 | 4.8 | 4.6 | 62.2 | 6.2 | 77.8 |
| 11–15 | 0.0 | 0.0 | 4.8 | 1.4 | 90.5 | 4.5 | 101.2 |
| 16–20 | 0.0 | 0.0 | 3.2 | 2.6 | 78.9 | 3.1 | 87.8 |
| 21–25 | 0.0 | 0.0 | 4.0 | 11.5 | 94.3 | 0.0 | 109.8 |
| 26–30 | 0.0 | 0.0 | 4.2 | 0.0 | 109.3 | 0.0 | 113.5 |
| 30– | 0.0 | 0.0 | 4.8 | 4.2 | 81.7 | 0.0 | 90.7 |
| Upland rice | 29.2 | 53.6 | 10.1 | 38.5 | 11.5 | 29.8 | 172.7 |

[a] Based on 161 selected pure rubber and 27 upland rice fields
[b] Mostly weeding.
[c] Including small amount of labor for harvesting annual crops intercropped with rubber seedlings.
[d] Including only old rubber fields.

and remuneration under output sharing contracts are widely observed in rice cultivation in Asia and have been attributed to incentive and self-selection effects of output sharing contracts (David and Otsuka, 1994). As we will discuss below, however, incentive problems take on a different form for rubber because, unlike rice, harvesting intensity in one year is negatively related to production potential in later years.

Using average wages to impute costs of family labor, actual wage payments for hired labor, and actual costs of current inputs (seeds, seedlings, and chemical inputs for latex coagulation), we estimated actual paid-out costs and total production costs including the imputed costs of family labor for 161 rubber plots. We then calculated income, which is defined as gross revenue minus paid-out costs, and residual profit, which is defined as income minus costs of family labor (Table 7). While the residual profit is supposed to estimate returns to land and management effort and efficiency, the income will also include returns to family labor. Although theoretically the profit is preferable as an indicator of efficiency, the measured profit may suffer from bias to the extent that the shadow prices of family labor are different from the observed wage rates. Therefore, we use two alternative measures of efficiency; income and profit.

We assume that the cross-sectional age profile of revenue and cost closely mirrors the time profile on any one plot, to the extent that output and factor prices are stable. It is clear that the labor cost in the first year is much higher in the case of forest clearance compared with conversion of bush fallow and with replanting old rubber. Residual profit is negative for the first seven years, even though its magnitude declines as labor costs became smaller with aging of trees. Most trees, if not all, began to produce latex in the eighth year, and consequently both the residual profit, as well as income, turns positive. Subsequently, the growth rate of gross revenue exceeds that of cost, thereby producing annual increases in the residual profits until around age thirty, beyond which the productivity of rubber trees declines under this management system.

Since rubber trees are established and managed primarily by labor effort, the residual profit from mature trees will be higher, the larger the work and management effort over extended periods of time from the date of tree planting. As the simple model of Besley (1995) clearly indicates, it is reasonable to postulate that work effort is critically

*Table 7.* Gross revenue, production costs, and residual profit of rubber production per hectare by dominant age of trees in Sumatra, Indonesia.

| Age range | Sample size[a] | Gross revenue ('000 Rupiah in 1996)[b] | Labor cost ('000 Rupiah in 1996) | | Income ('000 Rupiah in 1996) | Residual profit ('000 Rupiah in 1996) |
|---|---|---|---|---|---|---|
| | | | Family[c] | Hired | | |
| 1 (Forest clearance)[d] | 10[e] | 197 | 655 | 51 | 107 | –548 |
| 1 (Bush clearance)[f] | 14 | 23[g] | 197 | 46 | –142 | –339 |
| 2–3 | 6 | 0 | 113 | 36 | –80 | –193 |
| 4–7 | 13 | 0 | 24 | 36 | 36 | –60 |
| 8–10 | 30 | 728 | 392 | 161 | 557 | 165 |
| 11–15 | 40 | 1,007 | 418 | 358 | 635 | 217 |
| 16–20 | 22 | 1,017 | 473 | 249 | 751 | 278 |
| 21–25 | 8 | 1,166 | 118 | 701 | 446 | 328 |
| 26–30 | 14 | 1,303 | 436 | 472 | 814 | 378 |
| 30– | 14 | 964 | 470 | 195 | 754 | 284 |

[a] Total sample size is 161 rubber plots.
[b] The exchange rate was US$1.00: 2,400 rupiah in 1996.
[c] Imputed costs of family labor by the prevailing wages.
[d] Pertaining to forest clearance, land preparation, and tree planting.
[e] Although we did not use in statistical analysis, we purposefully collected the data on cleared forest land from randomly selected 10 plots.
[f] Pertaining to bush clearance, land preparation, and tree planting.
[g] Small amount of food crops was harvested.

affected by land tenure security, as it affects the expected future benefits to those who planted and grew trees.[10] For instance, if land tenure is insecure, those who plant trees may not be able to receive the whole future benefits. It is important to note, however, that tree planting is likely to strengthen future land rights when initially land rights are weaker than those of privately acquired land. In other words, what matters in the tree planting decision will be the expected land rights, rather than the initial level of land rights at the time of land acquisition. This indicates that the incidence of tree planting and the subsequent management intensity may not be lower under single family ownership than under private ownership, if tree planting strengthens the expected land rights under single family ownership.

Thus, if we can successfully control for the quality of land, the difference in residual profit among different land tenure institutions, if there is any, can be attributed to the incentive effects on work effort of land tenure institutions. One may argue, however, that discount rates could also be different among our sample households and that land tenure institutions may affect the choice of inputs, such as the quality of seedlings. While it is reasonable to assume that the quality of seedlings varies little across sample plots, because planting materials usually is simply propagated from abundant local seed, discount rates could be different. Ideally we would use a household-level fixed-effects or random-effects model. The application of such estimation methods is precluded, however, because most of our sample households operate only one mature rubber plot. Thus, we included variables representing land quality as much as possible and variables pertaining to household wealth, such as the size of owned paddy and rubber plots, in the regression analyses, assuming that land ownership captures the effects of wealth and indirectly the effects of different discount rates.

To assess the scarcity value of land, it is useful to estimate the profitability of upland rice production, which presently is the main alternative to rubber production (Table 8). Current inputs are mostly seeds, and only one farmer applied a small amount of chemical fertilizer and another farmer applied a little pesticide. Manure was not used, in part because most fields are far from farmers' dwellings. (On average, it took about an hour to reach upland rice fields.) Hired labor is

*Table 8.* Gross revenue, cost of production, and residual profit per hectare of upland rice cultivation in Sumatra, Indonesia.[a]

| | Communal/lineage ('000 Rupiah in 1996)[b] | Others ('000 Rupiah in 1996) | Average ('000 Rupiah in 1996) |
|---|---|---|---|
| Gross revenue (1) | 617 (100) | 632 (100) | 622 (100) |
| Cost of current inputs (2) | 19 (3) | 24 (4) | 21 (3) |
| Cost of labor (3): | 550 (89) | 690 (109) | 597 (96) |
| Men | 210 | 279 | 233 |
| Women | 340 | 411 | 364 |
| Residual profit (1) – (2) – (3) | 47 (8) | –81 (–13) | 4 (1) |

[a] Numbers in parentheses are percentage to gross revenue.
[b] The exchange rate was US$1.00: 2,400 rupiah in 1996.

uncommon, so that income from upland rice cultivation is similar to gross revenue. In any case, it is clear that the profitability of upland rice production is very small. The residual profit per hectare of upland rice grown on communal land is positive but far smaller than the profit from mature rubber trees. It is negative in the case of non-communal fields, which may be explained partly by less favorable location of these fields, including more exposure to attacks by wild pigs. Another factor affecting the low profitability of upland rice is the shortening of fallow periods because of increasing population pressure and limited access to new forest land.[11]

The average residual profit of all 27 upland rice plots was almost identical to zero.[12] Considering that upland rice fields are located in flat upland areas compared with sloping rubber fields, the low profitability indicates that annual crop farming is not profitable on uplands where rubber trees are currently grown. In other words, the financial opportunity cost of land in the case of rubber production is nil. The higher profitability of planting rubber compared to the upland rice-bush fallow system explains the trend toward conversion from the latter to the former land use. The question is whether tenure security, particularly under single family ownership, significantly affects the profitability of rubber production for those who actually invest in tree planting.

## Regression analysis

In this section, we estimate the gross revenue, income, and residual profit functions using data for mature tree plots, in order to identify the effect of land tenure institutions on the profitability of rubber production. We chose plots, not households, as the unit of analysis, because land tenure institutions could be different for different plots owned by the same household.[13] Since the residual profits sometimes were zero or negative, we used a linear specification. Considering that the choice of rubber production is endogenous, we applied Heckman's two-step estimation procedure, in which the probability of planting rubber trees is estimated with a probit regression model using the whole sample of 523 rubber and bush-fallow plots. In the tree choice function, the dependent variable is unity if trees already were planted at the time of our survey in 1996. Other functions were estimated by ordinary least squares (OLS) regression using the inverse Mill's ratio and the subsample of 128 mature rubber plots.

We used plot-, household-, and household head-specific variables as explanatory variables, while assuming that they are either exogenous or predetermined. Output and input prices are not included, because they are uniform within a village community. Other village-specific variables are also excluded. Table 9 summarizes the means of explanatory variables by type of field. The first four variables represent plot-specific characteristics, the next four variables pertain to household characteristics, and the last three variables refer to characteristics of household head. Bush-fallow fields generally were located in the most remote areas measured in terms of walking time. In contrast, young and mature rubber fields were located nearer home. In terms of altitude and slope, there was no difference

*Table 9.* Means of explanatory variables for plot-level analysis of tree planting and rubber production by type of field in Sumatra, Indonesia.

| | Young rubber field | Mature rubber field | Bush-fallow field | Average |
|---|---|---|---|---|
| Year of land acquisition | 1987 | 1983 | 1981 | 1984 |
| Walking time (minutes) | 37.6 | 39.4 | 63.1 | 45.5 |
| Altitude (m) | 177 | 178 | – | |
| Slope (degrees) | 15 | 17 | – | – |
| Paddy area owned (ha) | 0.74 | 0.87 | 0.92 | 0.84 |
| Rubber area owned (ha) | 2.79 | 3.83 | 2.75 | 3.17 |
| No. of family workers (16–60)[a] | 2.5 | 2.5 | 2.6 | 2.5 |
| No. of family workers (26–70)[b] | 1.8 | 1.8 | 1.8 | 1.8 |
| Age of head at acquisition (years) | 31.6 | 31.5 | 32.0 | 31.7 |
| Age of head in 1996 (years) | 41.1 | 44.2 | 47.2 | 44.0 |
| Schooling of head (years) | 7.2 | 5.8 | 5.2 | 6.1 |
| Sample size | 33 | 128 | 148 | 309 |

[a] No. of male or female family members between 16 and 60 years of age.
[b] No. of male or female family members between 26 and 70 years of age.

between young and mature rubber fields. Plots located in distant areas with steep slopes and high altitudes are unfavorable for rubber cultivation, so that the incidence and profitability of rubber production will be lower for plots with these characteristics.

Total lowland paddy area and the rubber area owned by the household are used as proxies for the wealth of these farm households. Of course, the area of land owned also affects the demand for labor. One interesting question is whether land-rich, wealthy people acquire and establish disproportionally larger rubber areas and obtain higher profits from rubber production. According to Table 9, the differences in the ownership areas and the number of family workers among different types of fields were not large.

The supply of family labor is represented by the number of family workers aged between 16 and 60. Most children go to junior high school and the lower age bound coincides with the age of graduation from that school level. The upper age bound is somewhat arbitrary. We also show family workers between 26 and 70 years of age, because this age bracket would be more appropriate for the potential supply of family workers when uplands were acquired, which was a little more than ten years ago on the average. Average age of household head at the time of land acquisition and at the time of the survey (1996) and the average schooling years are also shown in Table 9. Because of the effect of household life cycles, owners of young rubber fields were among the youngest at the time of the survey. These younger households had received the longest period of schooling largely because of the cohort effect arising from the spread of education opportunities in rural Indonesia.

The estimation results of the first-stage probit function are shown in column (1) of Table 10, whereas the second-stage estimation of gross revenue, income, and residual profit functions for mature rubber fields are shown in columns (2) to (4). With respect to the land tenure institutions, we used three dummy variables for the tree planting function (viz., joint-family tenure, purchased land, and land obtained by clearing forest), whereas we specified four dummies in the other functions (viz., purchased land, forest clearance, land borrowing, and land renting). In both cases, basis for comparison is single-family ownership. Joint-family ownership appears only in the former regression because it did not exist in mature rubber fields. Borrowing and renting dummies were not included in the tree planting function because only fields already planted to trees were rented and borrowed. Thus, the decisions to plant trees on these two types of land are predetermined and this is captured by the dummy variable for rubber fields at the time of acquisition. In the revenue, income, and profit regressions, we included the dominant age of trees and its squared term.

As expected, estimation of the tree choice function produces a highly significant dummy

*Table 10.* Two-stage regression of rubber tree choice function, and gross revenue, total cost and residual profit of rubber productions in Sumatra, Indonesia.[a]

| | Tree planting (Probit) (1) | | Gross revenue (OLS) (2) | | Income (OLS) (3) | | Residual profit (OLS) (4) | |
|---|---|---|---|---|---|---|---|---|
| Intercept | 43.42 | (13.59) | −81.77 | (378.88) | 621.44 | (337.96) | −359.84 | (193.37) |
| Dominant age of trees | – | | 35.62* | (15.57) | 9.82 | (14.00) | 20.38* | (8.01) |
| (Dominant age of trees)$^2$ | – | | −0.55* | (0.27) | −0.16 | (0.24) | −0.29* | (0.14) |
| Slope | – | | −1.68 | (3.84) | 0.06 | (3.43) | −1.35 | (1.96) |
| Altitude | – | | 1.17 | (0.73) | 1.41* | (0.65) | −0.28 | (0.37) |
| Bush (before planting) | – | | −256.11 | (150.45) | −194.89 | (134.20) | −47.31 | (76.78) |
| Dummy for rubber field[b] | 1.64** | (0.19) | – | | – | | – | |
| Walking time | 0.01** | (0.00) | −0.11 | (1.02) | −0.74 | (0.92) | 0.53 | (0.52) |
| Age of head[c] | 0.01 | (0.01) | 1.58 | (3.93) | −3.11 | (3.50) | 1.58 | (2.00) |
| Schooling of head | −0.01 | (0.02) | 17.94 | (12.70) | −10.87 | (11.32) | −0.67 | (6.48) |
| Year of acquisition | −0.02** | (0.01) | – | | – | | – | |
| Paddy area owned | 0.04 | (0.08) | 42.35 | (48.02) | 75.71 | (42.84) | 15.51 | (24.51) |
| Rubber area owned | −0.06 | (0.04) | −39.21* | (15.41) | −70.10** | (13.75) | 2.23 | (7.86) |
| No. of family workers | 0.01 | (0.09) | 124.08** | (42.51) | 80.71* | (37.92) | 39.54 | (21.69) |
| Joint-family | −2.91 | (5.31) | – | | – | | – | |
| Purchase | −0.03 | (0.16) | 98.77 | (100.98) | −16.98 | (90.08) | 67.36 | (51.54) |
| Forest clearance | −0.12 | (0.18) | 42.87 | (208.17) | 30.82 | (185.69) | 200.69* | (106.25) |
| Borrowing | – | | 351.1 | (206.46) | 233.67 | (184.16) | 182.62 | (105.37) |
| Renting | – | | 34.51 | (146.74) | 144.93 | (130.89) | 209.30** | (74.89) |
| Inverse Mill's ratio | – | | 373.08 | (287.92) | −201.23 | (256.82) | 219.89 | (146.95) |
| Log-likelihood | −218.76 | | | | | | | |
| $R^2$ | | | 0.28 | | 0.36 | | 0.22 | |
| Pseudo $R^2$ | 0.33 | | | | | | | |
| Sample size | 523 | | 128 | | 128 | | 128 | |

[a] Numbers in parentheses are standard errors. ** indicates significance at 1% level and * at 5% level.
[b] Dummy for rubber field at the time of land acquisition.
[c] At the time of acquisition for the tree planting function and at present or in 1996 for other functions.

variable for plots that already were planted with rubber at the time of land acquisition. Walking time has a positive effect on tree planting, which is unexpected, because it is more costly and, hence, less profitable to cultivate distant plots, as argued by Angelsen (1995). It may be that newly planted rubber plots were located far from residential areas because closer areas already had been planted. Another possible explanation is that monitoring to prevent losses from pests and from theft is more difficult for isolated plots and that rubber may be relatively less susceptible to these risks than upland rice.

Another significant variable is the year of land acquisition, which has a negative coefficient, suggesting that availability of fields suitable for rubber production has decreased over time. Neither the coefficient of the area of rubber plots owned nor that for area of paddy owned is significant, which indicates that wealthier households (those owning larger areas) do not necessarily plant more rubber trees. Lack of significance of these proxies for wealth may also result from relative lack of social stratification within this community.

None of the land tenure variables is significant. The coefficient of joint-family ownership is negative but far from significant, partly because there are only four such cases (see Table 3). The fact that the two private ownership variables are not significant suggests that the lower tenure security of single family ownership status does not decrease incentives to invest in trees due to tenure security enhancing effect of tree planting.

The coefficients of the inverse Mill's ratio are insignificant in all three second-stage regressions, which indicates that selectivity bias is not a serious problem.[14] As expected, age of rubber trees and age squared have positive and negative coefficients, respectively, and both coefficients are

significant in the gross revenue and residual profit functions. Judging from the estimated coefficients, the peak ages of trees are 32 and 34 years for the gross revenue and residual profit, respectively. The income, however, is not significantly affected by age of trees, which may indicate that when the revenue is low, more family labor is used.

While ownership of paddy land does not affect revenue, income, and profit, ownership of rubber fields has a significant, negative effect on gross revenue and income. It seems that effect of wealth, in the form of paddy land ownership, on management efficiency of rubber fields is not particularly strong, whereas the size of rubber fields reduces both revenue and income. This may well be related with different shadow prices for family labor across farm households. Yet, judging from its insignificant effect on the residual profit, field size does not seem to affect production efficiency. In other words, the management of larger rubber areas leads not only to lower revenue and income per hectare but also to lower total costs, so that it has no significant effect on the residual profit. Number of family workers has significantly positive effects on gross revenue and income. It seems that larger households have higher costs and revenues but household size does not affect production efficiency as defined by residual profit.

Several important results were obtained regarding the effects of land tenure institutions. First, private ownership of land acquired through private purchase has no significant effects on gross revenue, income, or residual profit. This indicates that there is no difference in the incentive structure between single family ownership and this type of private ownership. The implication is that the advent of single family ownership system, coupled with the effect of tree planting on future land rights, is an institutional innovation in these indigenous communities to establish *de facto* private property. Secondly, private ownership acquired through forest clearance has no significant effects on revenue and income but a significantly positive effect on the residual profit. These findings imply that the lower costs under this tenure category result in higher residual profit. This may not be inconsistent with the first finding in view of the fact that cleared forest land is more fertile than bush land.

Third, renting through share tenancy has a positive and significant coefficient in the residual profit regression. The significance of renting in this case runs counter to the familiar Marshallian argument of inefficiency of share tenancy arising from shirking by tenants, because shirking ought to reduce gross revenue, cost, and residual profit before rent payments (see Otsuka et al., 1992; Hayami and Otsuka, 1993). Recall that renting tends to be a short-term arrangement in the study area. As a result, temporary tenant operators may seek to squeeze as much output from rubber trees as possible in the short run. This finding is not inconsistent with the weakly significant and positive effect of borrowing in the residual profit function.

Unlike the case of annual crops, such behavior (known as 'overtapping') can have detrimental effects on profitability over time, since tapping intensity is negatively related to future latex production. Moreover, while 'overtapping' involves deeper tapping it does not necessarily require more tapping effort. Indeed, Binswanger and Rosenzweig (1986) presented a theoretical argument that rubber sharetapping should be rare because of this incentive incompatibility. In reality, however, this institutional arrangement is common in Sumatra. The first part of the explanation of this puzzle rests with social relations within the study villages. While the incentives producing a tendency toward overtapping remains, monitoring and enforcement apparently are easy enough within the context of these close-knit village societies to prevent serious effects on long-term profitability. The second part of the explanation rests with our data set, which uses a cross section of rubber plots to estimate a yield curve over time. Since it is likely to pick up the current productivity enhancing effects of overtapping under share tenancy without the offsetting effects on future yields, this data set is not well suited to capturing the long-term effects of overtapping, which probably could only be observed in a longitudinal study.

### Internal rate of return

It is widely believed in Indonesia that so-called 'jungle rubber' is a primitive and unprofitable method of growing rubber, even though careful

quantitative studies of this system seldom have been attempted (Barlow and Jayasuriya, 1984 and Gouyon et al., 1993 are noteworthy exceptions). In order to assess whether investment in rubber trees is profitable, we computed the real internal rate of return (IRR) for three land tenure types (i.e., inheritance by single family, purchase, and forest clearance). We do not consider the cases of borrowing and renting, because these arrangements are of a short-term nature. The estimation procedure is as follows: (1) since land preparation, including felling of trees, is much more costly in the case of forest clearance than in the case of bush clearance (see Table 7), we accounted for these different costs for the first year; (2) assuming that cost of growing young rubber trees is the same for all tenure categories in their second and third years, we used actual annual average costs for trees in those age groups; (3) given the similarity of costs from the fourth to the seventh years of age, we used the average annual costs for this period for trees aged from four to seven; and (4) we used the predicted profits from the estimated regression coefficients of age and age squared and land tenure dummies in the residual profit regression for the eighth to the sixtieth years, while inserting the average values of other explanatory variables. Since sample size is small, the validity of the second assumption cannot be confirmed from our data. However, the generally weak effects of the land tenure variables in the residual profit regression supports this assumption. In this computation we assumed that the land has no opportunity cost, which is reasonable because we showed that the profitability of upland rice cultivation is nil and that some areas of bush-fallow land still are available. (Note that the estimated internal rates of return are not significantly affected by changing the time horizon for analysis to sixty years). The IRR is an indicator of relative profitability of investments in tree planting.[15]

The results of these calculations are shown in Table 11. In line with the insignificance or the generally weak effects of the land tenure dummies, the estimated internal rates of return are similar among the three tenure institutions compared. The estimated real internal rates of return under these ownership systems range from 10 to 15 percent per year. These estimates imply that investment in rubber trees is not highly lucrative but may reasonably be decently profitable, contrary to the popular belief.[16] This is reasonable in view of the fact that while no special skill or knowledge is required for clearing fields, planting and managing rubber trees, there are price risks and seven to nine years of gestation. It appears that 10 to 15 percent returns are just sufficient to cover the costs of risk and patience.

*Table 11.* Estimates of internal rate of return (IRR) to investment in rubber trees by land tenure in Sumatra, Indonesia.

| | IRR (%) |
|---|---|
| Single family | 10 |
| Purchase | 12 |
| Forest clearance | 15 |

The estimated real internal rates of return may understate the return to future production, since real domestic rubber prices have increased at the annual rate 1.4% and 2.0% from 1970 and 1980 to 1996, respectively. Moreover, this study was completed before Indonesia's monetary crisis and the resulting collapse in the value of the Indonesian currency. This massive real exchange rate devaluation has significantly increased the profitability of all export-oriented activities that require few imported inputs, including smallholder rubber production. In parallel, this has enhanced incentives for smallholders and large-scale operators to convert natural forest into various export-producing land uses, accelerating pressure on remaining forest areas.

## Concluding remarks

Land tenure institutions in customary land areas of Sumatra have been changing from lineage ownership to joint family ownership, and further to single family ownership in which not only daughters but now in some cases only sons inherit certain classes of land in what traditionally were matrilineal and matrilocal societies. We also found that cultivation of upland rice in the traditional bush fallow rotation is much less profitable than planting rubber, which together with further population pressure is driving the transformation from more communal forms of tenure to quasi-private arrangements necessary to establish

incentives for efficient investment in and production of perennials. These shifts would appear to have important effects on intra-household distribution of assets, as limited wet rice land becomes fragmented among growing numbers of daughters with each successive generation, while the growing (albeit slowly) stock of rubber area passes to male heirs.

On the other hand, however, this study indicates that the innovation of single family ownership is no different from private ownership regarding the levels of efficiency in management of a perennial crop, rubber. This finding strongly indicates that customary land tenure institutions have evolved towards more individualized systems to capture profitable investment opportunities in the face of increasing population pressure on land.

We do not imply that land tenure institutions have evolved solely for economic reasons. Yet, it seems clear that economic incentives are an important reason for institutional change, as argued by the induced innovation hypothesis. If so, increased profitability of rubber cultivation facilitates private appropriation of bush fallow and forest, which is accomplished by conversion to rubber.

This study suggests that community-level institutions may be able not only to manage tree resources efficiently but also to adapt to emerging challenges arising from population pressure on degraded natural resources. However, the way ahead will require much better understanding of how such institutions can be adapted to the pursuit of broader environmental objectives, such as the protection of buffer zones of national parks. In turn, this requires a shift in attention of economists from their established focus on the efficiency of institutional arrangements within the context of private property and the objectives of individuals and households to the broader questions of efficiency of institutional arrangements for protection of public lands and the supply of such public goods and services as the conservation of biodiversity and carbon sequestration.

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## Notes

1. Although it was reported earlier in the literature that the matrilineal inheritance system is being transformed, the pace of transformation seems much more rapid for some types of land use than was thought in the literature. See, for example, Errington (1984) and Kahn (1980).
2. Private ownership is established by forest clearance because the labor effort creates private ownership according to the rule of customary land tenure systems (Shepherd, 1991). Individualized rights on cleared forest land, however, are subject to erosion over time, unless it is planted to trees in Sumatra (Angelsen, 1995; Otsuka et al., 2000).
3. Although there are also lowland paddy fields, we do not analyze their management in this study. Note that we measure the age of trees by the 'dominant' age, because gap refilling and natural regeneration result in rubber trees of various ages being included in older rubber plots.
4. Investigation of the previous land use was difficult and time-consuming because present cultivators often did not possess the relevant information, either because they acquired land relatively recently or because the acquired fields have been rubber fields for long periods.
5. On average, tenants and borrowers operated plots for 2.1 and 6.0 years, respectively.
6. See the model of Anderson and Hill (1990), which describes how unused open-access land would be exploited when the property rights are conferred to those who have opened the land.
7. The average life of rubber trees in our sites seems significantly longer than the case reported by Barlow and Muharminto (1982) of fifteen to twenty-five years for regular tapping after reaching tappable age of about ten. They also point out, however, that the productive life of rubber trees is negatively related to the intensity of tapping.
8. More recently, however, farmers may have been less inclined to replant rubber since wild pigs also eat the roots of young rubber trees and the problem of depredation by pigs appears to be worsening.
9. An added advantage of rubber is the largely uniform labor requirement throughout the year. Tapping is carried out throughout the year and there are only slight seasonal differences in labor requirements
10. Besley (1995) finds in his analysis of cocoa tree planting

in Ghana that the initial level of tenure security positively affects the probability of tree planting. There are several analytical problems in his estimation, including the mis-specification of land tenure variables and the use of the number of land rights as continuous cardinal variables. See Otsuka et al. (2000) for further discussion.

11. Low profitability of upland rice cultivation with five-year bush fallow rotation was independently confirmed in an unpublished study in the same area by Arifin and Hudoyo with additional analysis by Budidarsono (Tomich et al., 1998).
12. We estimated the residual profit function of upland rice production, using previous fallow periods and a communal land tenure dummy as explanatory variables, among others. Although the coefficients of both variables have the expected signs, none of them were significant, partly because of the small sample size.
13. Considering that the tree planting and management decisions on plots owned by a single household are unlikely to be independent, we also applied the household-level fixed-effects model for the choice of tree planting. The estimation results, however, are not different in terms of the significance of the estimated coefficients of plot specific variables.
14. Although it may be interesting to consider whether the behavior of households with only immature rubber plots are significantly different from that of households with mature rubber plots, it is not feasible to do so because there are only 11 households with immature rubber plots alone.
15. As often is the case, because of the great uncertainty regarding the opportunity cost of capital in imperfect factor markets in developing countries, we did not use the alternative net present value (NPV) indicator.
16. Gouyon et al. (1993) point out that about 10% of net income accrues from the extraction of fruits, fuelwood, and timber from jungle rubber. If this is the case, as seems likely, our estimates of the internal rates of return are biased downward by the omission of such income sources.

## References


Anderson TL and Hill PJ (1990) The race for property rights. Journal of Law and Economics 33: 177–197

Angelsen A (1995) Shifting cultivation and deforestation. World Development 23: 1713–1729

Barlow C and Jayasuriya SK (1984) Problems of investment for technological advance: the case of Indonesian smallholders. Journal of Agricultural Economics 35: 85–95

Barlow C and Muharminto (1982) The rubber smallholder economy. Bulletin of Indonesian Economic Studies 18: 86–119

Bassett TJ (1993) Introduction: the land question and agricultural transformation in Sub-Saharan Africa. In: Bassett TJ and Crummey DE (eds) Land in African Agrarian System. University of Wisconsin Press, Madison

Besley T (1995) Property rights and investment incentives Journal of Political Economy 103: 913–937

Binswanger HP and Rosenzweig MR (1984) Behavioral and material determinants of production relations in agriculture. Journal of Development Studies 22: 503–539

Boserup E (1965) The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure. George Allen and Unwin, London

Bruce JW and Migot-Adholla SE (1993) Searching for Land Tenure Security in Africa. Kendall/Hunt, Dubuque

David CC and Otsuka K (eds) (1994) Modern Rice Technology and Income Distribution in Asia. Lynne Rienner, Boulder, CO

Demsetz H (1967) Towards a theory of property rights. American Economic Review 57: 347–359

Errington FK (1984) Manners and Meaning in West Sumatra: The Social Context of Consciousness. Yale University Press, New Have, CT

Gouyon A, de Foresta H and Levang P (1993) Does jungle rubber deserve its name? An analysis of rubber agroforestry systems in Southeast Sumatra. Agroforestry Systems 22: 181–206

Hayami Y (1997) Development Economics: From the Poverty to the Wealth of Nations. Oxford University Press, Oxford

Hayami Y and Otsuka K (1993) The Economics of Contract Choice: An Agrarian Perspective. Clarendon Press, Oxford

Kahn JS (1980) Minangkabau Social Formations: Indonesian Peasants and the World Economy. Cambridge University Press, Cambridge

Marsden W (1811) The History of Sumatra, Reprint of Third Edition. Oxford University Press, Singapore

Michon G and de Foresta H (1995) The Indonesian agroforest model. Forest resource management and biodiversity conservation. In: Halladay P and Gilmour DA (eds) Conserving Biodiversity outside Protected Areas. The Role of Traditional Agro-Ecosystems. The World Conservation Union (IUCN), Gland, Switzerland

Otsuka K, Chuma H and Hayami Y (1992) Land and labor contracts in Agrarian economies: theories and facts. Journal of Economic Literature 30: 1965–2018

Otsuka K, Suyanto S, Sonobe T and Tomich TP (2000) Evolution of customary land tenure and development of agroforestry: evidence from Sumatra. Agricultural Economics, in press

Place F and Hazell P (1993) Productivity effects of indigenous land tenure in Sub-Saharan Africa. American Journal of Agricultural Economics 75: 10–19

Place F and Otsuka K (2000b) Population pressure, land tenure, and tree resource management in Uganda. Land Economics 76: 233–251

Place F and Otsuka K (2000a) Population, land tenure, and natural resource management in Malawi. Journal of Environmental Economics and Management, in press

Shepherd G (1991) The communal management of forests in the semi-arid and sub-humid regions of Africa. Development Policy Review 19: 151–176

Tomich TP, van Noordwjik M, Budidarsono S, Gillison A, Kusumanto T, Murdiyarso D, Stolle F and Fagi AM (eds) (1998) Alternative to Slash-and-burn in Indonesia: Summary Report of Phase II. ASB-Indonesia Report Number 8. ASB-Indonesia Consortium and ICRAF, Bogor, Indonesia