Population Pressure, Land Tenure, and Natural Resource Management in Selected Areas of Africa and Asia

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INTRODUCTION

Massive degradation of natural resources, including forests, rangeland, and irrigation water, has been taking place in the Third World. The growing population has increased demand for land, trees, and water, which, coupled with tenure insecurity or the absence of clear property rights, has resulted in the over-exploitation of these natural resources (e.g., Deacon 1994). This in turn has threatened the sustainable development of agriculture, forestry, and livestock sectors. The critical question is whether the current trend will continue and result in further degradation of natural resources and ultimately significant deterioration of human welfare.

Boserup (1965) argues that population pressure does not necessarily result in disastrous consequences, as it will lead to the evolution of farming systems from land-using or natural resource-using systems, such as shifting cultivation, to land-saving and labor-intensive farming systems, such as annual cropping systems.[1] Her argument, however, is incomplete: While investment is required to establish intensive farming systems (e.g., investment in the construction of irrigation facilities, terracing, and tree planting), insufficient attention is paid to incentive systems which ensure that the appropriate investments are made. It is widely recognized that investment incentives are governed by the land tenure or property rights institution, as it affects the expected returns to investments accrued to those who actually undertake them (Besley 1995). In sparsely populated areas of Sub-Saharan Africa and islands in the South Pacific, land is often owned and controlled by the community where individual land rights are severely restricted and benefits are shared widely among members of extended families (Johnson 1972). If such communal ownership of land prevails and persists, investment incentives are likely to be weak and thus investments necessary for the intensification of farming systems may not be made (Besley 1995; Johnson 1972). Then, the extensive and natural resource-using farming systems may continue to be practiced, contrary to the Boserupian hypothesis.

Hayami and Ruttan (1995) argue that not only technologies but also institutions are induced to change in response to the changing resource endowments in order to save increasingly scarce resources. This would imply in our context that land tenure institutions will change towards individual ownership so as to provide appropriate investment incentives to save the use of natural resources. Consistent with the induced innovation thesis, a theory of property rights institution developed by Demsetz (1967) and Alchian and Demsetz (1973) asserts, based on the historical experience of hunting communities in Canada, that property rights institutions evolve from open access to private ownership when natural resources become scarce. In many parts of Sub-Saharan Africa, it is known that the system of communal property rights on cultivated agricultural fields has been considerably individualized (Bruce and Migot-Adholla 1993). Yet, no systematic research has been made as to the effect of population pressure on land tenure institutions and the effect of possible changes in land tenure institutions on the investment in land improvement towards the intensification of farming systems and the preservation of natural resources.

Based on the recently completed project on land tenure and the management of land and trees in Asia and Africa (Otsuka and Place 2001), this article attempts to identify the process by which population pressure leads to the individualization of land rights and its consequences on the management of land and trees. A particular focus will be placed on the development of agroforestry systems growing commercial trees, such as cocoa, coffee, cinnamon, and rubber, which are becoming important farming systems in agriculturally marginal areas, where people are particularly poor and natural forests have been degraded rapidly (Otsuka 2000).[2]

The conceptual framework is discussed in the next section, which is followed by the examination of the results of case studies on the management of trees and cropland. Policy implications of this study are discussed in the final section.

CONCEPTUAL FRAMEWORK

Communal Ownership

In this study, the focus is on communal ownership, [3] as it is prevalent in our study sites including southwestern Ghana, the north and east of Uganda, all regions of Malawi, and western Sumatra. Under the communal ownership regime, uncultivated forestland, woodland, and rangeland are owned communally and controlled by an authority such as a village chief, whereas exclusive use rights of cultivated land are assigned to individual households of the community and its ownership rights are held traditionally by the extended family.

The uncultivated portion of communally owned land can be regarded as common property, which is defined as the joint ownership and use of property by a group of people, e.g., for hunting and extraction of trees and minor forest products.[4] This area is, however, generally characterized by open-access for the community members almost without exception. Thus, uncultivated forests and woodlands have been rapidly cleared for cultivation with population growth in our study in our sites.

While the individual use rights on currently cultivated lands are established, the rights to transfer, including inheritance, sales, and leasing, are often vested in the village community or the extended family. The ownership of cultivated land, however, has evolved towards more individualized ownership over time, e.g., through a shift from the ownership of extended family to a single family (Ault and Rutman 1979; Bruce and Migot-Adholla 1993). This has led to the development of agroforestry systems in hilly and mountainous areas, where annual crop farming does not have a comparative advantage.[5]

An Evolutionary View of Land Tenure Institutions

Following Hayami and Ruttan (1985), a simplified version of our theoretical framework can be illustrated by assuming that there are only two factors of production, i.e., land and labor. Land represents natural resources and it could be cropland (with or without irrigation), rangeland, woodland, or forest land. The central issue is how the stock of natural resources (both quantity and quality) changes with evolution of farming systems from extensive to intensive systems -- or from natural resource-using to natural resource-saving systems. As a concrete example, I consider the evolution from shifting cultivation to sedentary farming.

Under shifting cultivation, food crops are grown usually for a couple of years after clearing forest and a fallow period of varying length follows until next cultivation. As Boserup (1965) emphasizes, fallow land is not "unused" land; fallowing is a labor saving method for restoring soil fertility. If initially population is scarce and land is abundant with vast areas of virgin forests, people have little incentive to claim individual property rights in land and, hence, the use of forest areas is unrestricted except for the exclusion of outsiders.

Since land is abundant, it is cost effective to practice shifting cultivation with sufficiently long fallow periods, which ensures complete restoration of soil fertility. Curve I_0I_0 in Figure 1 portrays the unit isoquant for an individual farmer to produce $1.00 worth of food crops by using land and labor under shifting cultivation in period 0. Here I measure land input in terms of area "used" for cultivation including fallow land, some of which may be secondary forest or woodlands, but excluding land which has never been cultivated. It is assumed for simplicity that the production function is subject to constant returns to scale, so that each technology or farming system is characterized by a single unit isoquant. The relative factor scarcity may be indicated by relative factor price line, P_0.[6] Then the optimum production point is given by E_0, where the production is sustainable.

As population increases, however, land becomes scarce relative to labor. The growing population will require increasing area for agricultural production and, hence, large areas of forest land are opened up. Eventually, however, the rate of area expansion falls short of the growth rate of population. As a result, the scarcity value of land increases relative to labor, which is reflected in changes in relative factor price ratio from P_0 to P_1 in period 1. Accordingly, the optimum production point changes to E_0', so long as shifting cultivation continues to be practiced. Fallow period at E_0' tends to be shorter than at E_0. Due to the shorter fallow cycle, soil fertility declines and farming becomes unsustainable at E_0', resulting in the shift of unit isoquant from I_0I_0 to I_1I_1. Thus, the equilibrium point moves to E_1.

An alternative to unsustainable farming under shifting cultivation and continued deforestation is to improve land quality by investing in land and trees. To maintain soil fertility under continuous cultivation of annual crops, new farming systems may be adopted involving the application of compost made from grasses and leaf litter collected from the forest and woodland, as well as manure.[7] Relative to pure cropping systems, the productivity of tree farming systems can be sustainable for longer periods of time with lower application of organic or inorganic fertilizer primarily due to their deeper and denser rooting systems and perennial ground cover which make them less vulnerable to soil loss and nutrient leaching. Because of the increasing use of labor and continuous cropping, new farming systems are labor-using and land-saving. Thus, the unit isoquant corresponding to this farming system is depicted by curve I_2I_2 in Figure 1.[8]

Given a relative factor price of P_1, the optimum is attained at E_2 in Figure 1 under the new farming system, at which production is assumed to be more profitable than at E_1, possibly E_0' as well. The shift from E_1 to E_2, however, is not costless. As was mentioned earlier, physical investment, such as terracing and tree planting, is required to adopt the new farming system. Thus, it does not pay to adopt the new farming system unless the difference in the short-run profitability between the old and new systems warrants the cost of long-term investment.

It must be emphasized that land tenure institutions must change in order to encourage investments. Since land use rights are not totally secure and transfer rights are restricted under traditional land tenure institutions, the expected returns to investment may be depressed: those who plant trees may not be able to reap the benefits due to an inability to bequeath the property to desired heirs or to sell the land freely if the need arises (Fortmann and Bruce 1988, Besley 1995). This incentive issue is not considered in the

Boserupian model. I hypothesize that land rights institutions are induced to change towards greater individualization in order to provide appropriate incentives to invest in land and trees.,

Possible Pathways

Resource degradation may continue without accompanying intensification of farming systems, even if population pressure on increasingly limited land resources increases. Prohibitively high costs of investments in land improvements, poor returns from the investments, difficulties in reaching agreement on the communal rules of private ownership systems, and legal restrictions on the choice of property rights institutions may all inhibit innovative institutional responses, resulting in the delay of rehabilitation efforts and continued resource degradation. Otherwise, in flat, non-arid areas where crop farming has a comparative advantage over agroforestry, privatization of property rights may occur, which would accompany investment in the improvement of land quality for continuous crop farming. In sloping areas where agroforestry has a comparative advantage, privatization of property rights may take place, which will induce investment in commercial trees. It is worth emphasizing that the individualization of land rights is a prerequisite for these desirable changes in farming systems.

The implication of these arguments for changes in the stock of natural resources can be explained by using Figure 2. Forest resources will be depleted over time with population growth following path I, so long as community members have free access to the forest areas. But increases in population may induce successful changes in land tenure institutions at period T*, after which the stock of tree resources may increase following path II if agroforestry is developed. Timing of the turning point will depend not only on the cost of implementing the institutional innovation but also on the nature of the existing land tenure institutions. As Anderson and Hill (1990) demonstrate, if unexploited forest land is open access and strong individual rights are granted on cleared land, socially excessive forest clearance takes place. This pattern actually prevails across the study sites from Asia and Africa (Place and Otsuka 2000, 2001a; Otsuka, Suyanto et al. 2001; Quisumbing et al. 2001; Suyanto and Otsuka 2001).

If intensive annual crop farming systems are chosen, tree resources may continue to deplete along path III, as secondary forest and bushland, which are fallow lands under shifting cultivation, will disappear. Yet, investment in land improvement will be conducive not only to the conservation of soil fertility of the cultivated land but also to the preservation of remaining uncultivated forest areas located elsewhere because increased food production from the same unit of land will increase the supply of foods to the market and reduce food prices, thereby reducing incentives to clear uncultivated forest land for the production of food crops. In this way, the intensification of farming system will contribute to the improvement of natural resource base.

EMPIRICAL ANALYSES

Characterization of Study Sites

There are similarities and dissimilarities among our four study sites (see Table 1). Both the Ghana and Sumatra sites have a comparative advantage in agroforestry over pure food production under shifting cultivation, due to hilly or mountainous topography on which annual crops cannot be grown sustainably under increasing population pressure. Usually, food crops are intercropped with young trees on agroforestry plots for a few years after tree planting. In Western Sumatra, large areas of primary forest still exist in the national park, even though some portions have been converted to irrigated paddy fields, crop fields under shifting cultivation system, and fields of commercial trees such as rubber, coffee, and cinnamon (Otsuka, Suyanto et al. 2001). In Western Ghana, primary forests have largely disappeared and been replaced either by crop fields under shifting cultivation or by cocoa fields (Quisumbing et al. 2001; Otsuka, Quisumbing et al. 2001).

While Malawi is also characterized by communal ownership, agroforestry systems are less profitable as compared to food cropping systems than in Ghana or Sumatra, as many areas are characterized by flat topography and dry climate. There are also communally owned forests on hilly portions of Malawi, but they are largely open access (Place and Otsuka 2001a). Most community woodlands have been converted to crop fields in this country (with the exception of the sparsely populated north). The Uganda sites consist of communal and privately owned areas, in which coffee is grown in hilly and humid areas nearer to Lake Victoria and charcoal is a major product of woodland in the rest of areas, which are generally flat and dry. Like Malawi, woodlands have been degraded and converted to crop fields in most areas (Place and Otsuka 2000).

In Ghana, the so-called uterine matrilineal inheritance system is practiced, in which land is bequeathed from a deceased man to his brother or, ultimately, to his nephew. The cultivated land is traditionally owned by the extended family, in which an individual household possesses no more than use rights. In this system, it is obvious that a wife and children have little incentive to help manage cocoa trees, even though weeding labor provided by the wife or children is critically important to grow trees successfully. According to Otsuka and Quisumbing (2001) and Otsuka, Quisumbing et al. (2001), profitability of cocoa agroforestry is much higher than that of shifting cultivation. In order to provide incentives to establish cocoa agroforestry, the new system called "gift" has emerged, in which land is "given" to wife and children while man is still alive, provided that they have helped the establishment of cocoa fields. In this way, women "inherit" the land, which now accounts for about one-third of cultivated areas in our sites (Quisumbing, Payongayong, and Otsuka 2001). Although the transfer of land through gift must be approved by members of the extended family, once approved strong individual rights are given to such land. In fact, there are cases in which even the right to sell land, which is the strongest right, is granted to gifted land (Otsuka and Quisumbing 2001; Otsuka, Quisumbing et al. 2001). This institutional rule is consistent with the common rule of communal societies that efforts to invest in land, including forest clearance and tree planting, are rewarded by strong individual land rights (see, e.g., Shepherd 1991).

In Sumatra, lineage ownership system, consisting typically of three generations, has been traditionally practiced in which land use rights are transferred from a woman to her sisters, daughters, and nieces (Otsuka, Suyanto et al. 2001). Exactly who receives land rights through inheritance is determined by the extended family in consideration of equity among family members. Therefore, incentive problems akin to those in Ghana arise; there is no guarantee that those who invest in trees, or their desired heirs, will be able to reap returns to investment in future. Gradually over time, however, the lineage ownership system has been replaced by a joint family ownership system, in which two successive generations of family members jointly own the same piece of land, and further by single family ownership system. In the case of single-family ownership, rights to rent and pawn without the permission of any extended family members are given to land owners and even the right to sell may be granted depending on the results of negotiation. As a matter of fact, private land transactions are relatively active in Sumatra. Such changes have been accompanied by efforts in planting and growing trees. As in Ghana, tree planting strengthens individual land rights (Suyanto et al. 2001a, 2001b). Interesting enough, although women tend to inherit paddy land in areas where primarily females work for paddy production, men now tend to inherit rubber agroforests, in which primarily males work for rubber. If men and women work equally, such as on cinnamon fields, egalitarian inheritance by daughters and sons has become common (Quisumbing and Otsuka 2001a, 2001b). Thus, inheritance system seems to have evolved in such a manner as to provide appropriate work incentives to men and women.

Traditionally in southern and central Malawi, a matrilineal inheritance cum matrilocal residence system, in which land is transferred from a mother to her daughters and the husband resides in wife's village, has been practiced. Even under such system, it is primarily men who make major farm management decisions, including decisions to invest in land improvement. If the wife dies or the couple gets divorced, the husband has to leave his wife's village, which means that he may not be able to receive benefits from his past investments. Because of this tenure insecurity, it is thought that men do not have enough investment incentives (Place and Otsuka 2001a). In this country, the matrilineal/matrilocal system has given way to a patrilineal/patrilocal system, in which the wife moves to her husband's village. Since agroforestry system does not have a comparative advantage in flat areas of Malawi, the incidence of commercial tree planting did not play a major role in the transition from matrilineal to patrilineal inheritance systems.

A patrilineal inheritance system is practiced in Uganda, in which land is transferred from father to his sons. As in Malawi, men are the primary decision makers of farm management as well as inheritance. Thus, a relatively small number of family members, usually a father and his sons, are involved in the inheritance decisions. Under this condition, the individualization of land rights seems to have taken place more rapidly than in a matrilineal society, where both men and women have interests in the same property. Another interesting feature of the land tenure system in Uganda is the coexistence of communal land and private ownership (mailo) created during colonial periods. Thus, it is possible to make a comparison of management practice and efficiency of natural resource management under communal and private ownership systems. In relatively humid areas where coffee production is common, particularly strong land rights are conferred to those who establish coffee agroforest (Place and Otsuka 2001c).

Table 2 shows the average annual population growth rate and population density, using community-level population census data and other secondary data, as well as data on average farm size obtained from our own surveys. Neither population data nor data on village area were available in the Ghana site. Population growth rate is relatively low in Sumatra, because our sites are net out-migration area, where a lot of native people migrate to urban areas to seek permanent non-farm employment opportunities. This has been possible because of relatively rapid growth of non-farm sectors in Indonesia until the financial crisis broke out in 1997. Although population density is relatively low in the Sumatra site, this reflects largely the mountainous topography. In contrast to Sumatra, other two sites are net in-migration areas and, hence, population growth rates are much higher. This must be also true in the Ghana site, even though the relevant data are unavailable. Thus, aside from the Sumatra site, population pressure on land and other natural resources have rapidly been increasing in our study sites.

Table 3 confirms that substantial deforestation has taken place in the Malawi and Uganda sites, where aerial photographs taken 30 to 40 years ago and in recent years are available. It is clear that agricultural areas have expanded at the sacrifice of forestland and woodland.[9] Regression analyses reveal that the population growth rate and the population density in the initial periods are the most significant variables explaining the expansion of agricultural land (Place and Otsuka 2000, 2001a).

The Case of Trees

No strong evidence was found to support the validity of popular arguments that customary or communal land tenure systems hinder investment in Uganda, Ghana, and Sumatra: commercial trees have been planted under communal ownership systems as widely and actively as under more individualized ownership systems according to the results of the regression analyses of tree planting (Otsuka et al. 2001; Otsuka, Quisumbing et al. 2001: Place and Otsuka 2001c; Quisumbing et al. 2001; Suyanto et al. 2001a, 2001b). The relevant descriptive data are shown in Table 4. It will be clear that the despite the large differences in current land rights on different types of land, the incidence of tree planted areas are not appreciably different. I observed this in part because land rights have become highly individualized due to investment in trees and continuous tree cultivation by farmers driven by high population pressure. Furthermore, given the positive and significant effect of tree planting on individual land rights, sufficiently strong incentives to plant commercial trees seem to exist under the communal ownership system. Indeed, once trees are planted, the land ownership system is often converted to *de facto* private ownership within a community. Thus, as verified by the estimation results of profit functions, the management efficiency of commercial tree fields under the communal system is generally comparable to other ownership systems (Place and Otsuka 2001c; Quisumbing et al. 2001; Suyanto et al. 2001a, 2001b).[10] In other words, communal systems evolve towards individualized systems and do not impede the development of agroforestry. Supportive evidence is provided by Gray and Kevane from their field study in Burkina Faso.

It is important to point out that the institutional rule to grant strong individual land rights on fields planted with trees has been established in communities where agroforestry is more profitable than other cropping systems. Since most areas of Malawi are characterized by flat topography, agroforestry has no inherent profit advantage compared to maize and tobacco production. In such a production environment, it is observed that no institutional rule has emerged that grants strong individual land rights in return for tree planting (Place and Otsuka 2001b). It is likely that the costs to reach new communal agreements on property rights institutions and to enforce new community rules exceed the expected benefits. As a result, land tenure institutions affect the decision to plant trees in crop fields in Malawi, in which greater tenure security leads to more active planting of trees for poles, firewood, and fruits. [11]

In sum, communal land tenure institutions in no way deter the development of agroforestry, irrespective of the levels of tenure security in these systems, because of the expected increase in land rights after tree planting. In other words, communal land tenure institutions have built-in rules to ensure the intensification of land use as predicted by Boserup (1965) in areas where agroforestry has a comparative advantage.

The Case of Cropland

Land tenure rules affect expected future benefits accruing to those who invest in land improvement, including tree planting. Therefore, these rules affect long-term but not short-term management incentives. In support of this, I found that land tenure institutions did not have any impacts on production efficiency of food crop fields in Ghana and paddy fields in Sumatra, neither of which require much long-term investment (Otsuka and Quisumbing 2001a). The same point applies to farming of maize in Malawi, for which I did not observe any difference in management efficiency between patrilineal and matrilineal inheritance systems, despite greater security of tenure under the former (Place and Otsuka 2001b).

Table 5 illustrates this tendency by using the data from the Sumatra site. It is clear that there is no noticeable difference in gross value of output and the residual profit (i.e., gross value of output minus both actual and imputed costs of non-land inputs) per hectare across paddy fields under joint family ownership, single family ownership, private ownership acquired by purchase, and fixed-rent tenancy.

I observed, however, some differences in management efficiency of annual crop production under different land tenure institutions. In Malawi, farmers subject to patrilineal inheritance have introduced more profitable burley tobacco farming more quickly and more widely than those subject to matrilineal inheritance, after abolishment of the policy to prohibit burley tobacco production by small landholders in Malawi (Place and Otsuka 2001b). Being the new crop, investment in the acquisition of relevant new farming knowledge (e.g. on crop rotations), purchased inputs, such as chemical fertilizer, and in marketing relationships was required for tobacco production. Unlike tree planting, however, the adoption of new technology does not confer strong individual land rights and, hence, those who are subject to tenure insecurity under the matrilineal inheritance tend to adopt the new crop less actively.

Because of the increasing population pressure, farmers in Malawi invested in terracing and water management to improve the quality of cropland, which require substantive work efforts. According to the analysis of the determinants of such investments by Place and Otsuka (2001b), there is no significant tenure effect. Although these authors did not confirm from their field research, it is possible that like commercial tree planting in Ghana, Uganda, and Sumatra, such result might well have been obtained because of the changing tenure rules which confer strong individual rights on terraced land and land with better water management facilities.

According to the accumulated empirical evidence from Sub-Sahara Africa, land tenure institutions do not seem to affect the productivity of sedentary farming significantly (Place and Hazell 1993). A plausible hypothesis seems to be that like tree planting, investment in land investment, such as terracing and destumping, strengthens one’s land rights where such investments are highly profitable. This hypothesis must be tested as carefully as possible, because unless and until this hypothesis is supported empirically, I cannot fully accept the Boserupian hypothesis that population pressure by itself directly leads to the intensification of farming systems.

CONCLUDING REMARKS

Farmers engaged in shifting cultivation and management of agroforests generally belong to the poor segment of society, if not the poorest as in arid areas. Land is mostly sloping and, hence, often marginal for agriculture. Unless decent work opportunities are made available, it is practically impossible to relocate them to restore forest conditions. Like forest, agroforestry provides positive environmental externalities such as carbon sequestration, increased flora biodiversity, and the prevention of soil erosion (Gockowski et al. 2001; Tomich et al. 2001). Moreover, it is more sustainable and profitable than shifting cultivation in marginal areas because of the low yields of pure food crop enterprises on these lands. Therefore, it will be socially desirable to promote agroforestry systems.

It is widely believed, however, that because of weak individual land rights or tenure insecurity, trees are not planted and well managed under communal ownership in which the extended family has strong influence over use rights in cultivated land (e.g., Johnson 1972; Besley 1995). If this is indeed the case, it will be difficult to disseminate agroforestry in marginal areas, even though agroforestry has comparative advantage over food production under shifting cultivation. This paper clearly demonstrates that the communal tenure institutions do provide sufficient incentives to plant and manage trees, which enhance efficiency of land use and reduce the incidence of poverty in marginal areas.

Thus, there are good economic and social reasons to support the development of agroforestry systems by means of public-sector research and development, and publicly supported extension programs, as well as the promotion of efficient marketing systems. Nonetheless, to date, only a few isolated efforts have been made to develop agroforestry systems growing commercial trees.

While it is highly likely that increasing population pressure on land in marginal, sloping areas will induce the development of agroforestry systems in a manner consistent with the Boserupian hypothesis, it is not clear whether and how land tenure institutions change in response to population pressure in high-potential agricultural areas where continuous crop farming has a comparative advantage. If land rights are strengthened by major investments in land improvement in such areas, serious efforts should be made to disseminate new technologies, which will enhance the profitability of such investments. This development strategy will bring about the intensification of land use, which in turn will increase food production and contribute to the conservation of natural resources. On the other hand, if land rights in areas where they are not sufficiently individualized are not strengthened by investment in land, entirely different development strategies must be sought for the sake of efficient management of land, trees, and other natural resources in the Third World.

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ENDNOTES

1. See Pingali et al. (1987) for the evidence on the intensification of farming systems associated with population pressure in Sub-Saharan Africa.
2. Note that such commercial tree crop systems in Africa are not found in what people would describe as the most marginal areas – they are in humid climate areas and higher elevations.
3. Other important land rights institutions include private ownership, state ownership, and common property. For the issues of common-property forest management, see Kijima Salkurai, and Otsuka (2000), Otsuka and Tachibana (2000), and Sakurai et al. (2000), as well as Tachibana et al. (2001).
4. There are a lot of confusions on the terminology of land rights institutions in the land tenure literature. The distinction between the communal ownership and common property is not made in many studies (e.g., Johnson 1972). Demsetz (1967) and Alchian and Demsetz (1973) identify the communal ownership with open-access. Open-access is considered to be a category of land tenure institutions by some researchers (e.g., Feder and Feeny 1993). I consider it more appropriate to regard open-access as an extreme outcome of land management rules, which can theoretically occur

under any land tenure regime.

5. I believe that the basis of comparative advantage of trees and tree crops on sloping land is the perennial cover that reduces soil erosion.
6. While straight factor price line indicates the existence of perfect factor markets, such an assumption is unnecessary for our arguments. A critical assumption is that the slope of factor price curve becomes flatter as population pressure increases.
7. I can also consider application of commercial fertilizer. To do so, however, requires an extension of our model to the case with more than two inputs, which is straightforward but cumbersome.
8. Crops grown under the new farming system are likely to be different from crops grown under shifting cultivation. I directly compare the efficiency of producing different crops in figure 1, because I define the unit isoquant in terms of the combination of inputs necessary to produce $1.00 worth of output regardless of which crops are grown.
9. Other areas are mostly marshy and rocky areas.
10. We were unbale to show descriptive statistics of profit per hectare or other efficiency indicators acoross different land tenure instituions in table of the manageable size, simply because the profitability of tree crop farming per production period depends critically on ages of trees. Thus, given already complicated land tenure categories, such table becomes excessively large.
11. Note that tobacco production relies on trees for drying and constructing drying sheds. Thus, as woodlands disappear, prices and profits of pole production should increase.

Table 1. Characterization of Study Sites

Sites	Topography	Major products of agroforest/forest	Changes in land tenure
Ghana	Hilly	Cocoa	Emergence of gift under uterine matrilineal system
Sumatra	Mountainous	Rubber, cinnamon, & coffee	Transition to single family ownership under matrilineal system
Malawi	Flat/ Hilly	None/ Minor forest products	Transition from matrilineal to patrilineal inheritance system
Uganda	Hilly/ Flat	Coffee/ Charcoal	Individualization of communal land (coexisted with private land)

Table 2. Average Annual Population Growth Rate, Population Density, and Farm Size in Study Sites

	Population growth rate (%)	Population density (persons/km^2)	Farm size (ha)
Ghana	n.a.	n.a.	11.0 (1996)
Sumatra	1.0 (1983-93)	30.0 (1993)	5.1 (1997)
Malawi	4.1 (1991-95)	171.0 (1995)	5.0 (1997)
Uganda	4.5 (1960-95)	368.7 (1995)	3.7 (1997)

Notes: "n.a." refers to "not available." Population data are taken from population census at the community level. Farm size data are based on our survey data. Numbers in parentheses show the relevant periods or years.

Table 3. Changes in Land Use in Malawi and Uganda Sites (%)

	Malawi		Uganda	
	1971	1995	1960	1995
Agriculture	52	68	57	70
Forest /Woodland	34	19	32	20
Others	14	14	11	10

Note: Based on data generated from aerial photographs.

Table 4. Proportions of Commercial Tree Planted Area by Land Tenure Type in Ghana, Sumatra, and Uganda Sites

Ghana (Cocoa):	
Temporarily allocated family land	45
Inherited land	53
Cleared forest land	60
Gift	63

Sumatra (Coffee, Cinnamon, and Rubber):	
Single-family land	79
Private land acquired through purchase	65
Private land acquired through clearance	81
Uganda (Coffee):	
Customary land	15
Private land	15

Table 5. Gross Value of Output and Residual Profit of Lowland Rice Production per Hectare by Land Tenure Type in Sumatra Site (1,000 Rupiah)

	Joint family	Single family	Private	Fixed-rent tenancy
Gross value of output	2,151	2,130	2,074	1,940
Residual profit	779	835	839	786

Figure 1 A model of induced institutional innovation

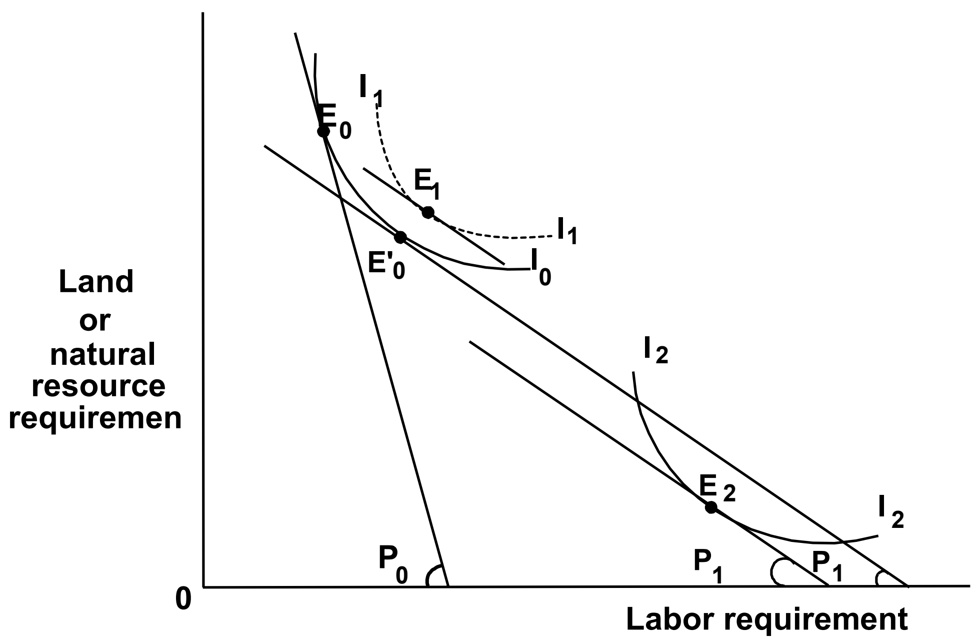

Figure 2 Evolutionary changes in stock of natural resources