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**POPULATION PRESSURE, LAND TENURE, AND TREE
RESOURCE MANAGEMENT IN UGANDA**

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ABSTRACT

This study uses aerial photographs and survey data from sixty four parishes in east-central Uganda to identify the factors affecting conversion of woodlands and traditional grazing areas to agriculture. Regression analysis shows that customary land tenure institutions, greater population pressure and poor access to markets are significant causes of land conversion to agriculture, and hence to loss of trees. Private ownership of converted land promotes greater integration of trees and crops and leads to the highest density of trees on agricultural land. Given that continuing population growth will lead to further land conversion to agriculture, the best prospect for maintaining or increasing tree populations lies with agroforestry on cultivated land.

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Frank Place and Keijiro Otsuka*

1. INTRODUCTION

There is increased realization that long-term economic growth in most of sub-Saharan Africa hinges upon sustaining and improving the productivity of its natural resource base. Policy makers must face the challenge of identifying appropriate pathways for the development of natural resources in their jurisdictions and sets of policies which will steer their constituents towards these pathways. Unfortunately, policy makers in sub-Saharan Africa have little information about how the management of natural resources responds to socio-economic and policy forces. With respect to tree resources, empirical research has only recently begun to identify important driving forces behind household decisions to plant trees on their farms (Place, 1995; Scherr, 1995; Patel and Pinckney, 1995; Dewees, 1995). Another body of research centers on understanding changes in forested area at the national and international levels (Deacon, 1994; Capistrano and Kiker, 1995; Kahn and McDonald, 1995).

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A third scale or observational level which is particularly lacking in empirical research might be called the community or landscape level (exceptions are Cline-Cole, Main, and Nichol (1990) for two sites in Nigeria; and Southgate, Sierra and Brown (1991) for 11 sites within Ecuador). Given a sample of sufficient size, this level of observation offers unique insights into the study of factors whose effects on natural resource management are often unidentifiable in household studies because of lack of variation, but are too heterogeneous to be aggregated to the national level. Examples include land tenure institutions, which govern the use and allocation of land and natural resources; the degree of market access, which determines the structure of market-driven derived demands for these resources; and population pressure, which is considered to be the key variable affecting the choice of farming systems in the economic literature since Boserup (1965).

This paper attempts to improve our understanding of the impact of tenure, population density, and other variables on tree resource management through the analysis of parish level data in east-central Uganda.¹ In a departure from previous studies noted above, our study assesses woody vegetation both on- and off-farm. We believe that this coupling is crucial since some of the functions provided by trees in forest land can be compensated for by trees on farms (e.g., fuelwood). Equally unique to this study is the overlay of land use mappings with land tenure boundaries within parishes, which enables us to calculate and analyze land use and tree cover change conditional on tenure type.

¹A parish is the second lowest administrative level in Uganda and is the lowest level at which boundaries have been mapped. The mean parish area in the sample was 30 square kilometers, and the average population was close to 5,000 in 1991.

The remainder of the paper is divided into seven sections. Section 2 presents an overview of the tenure systems in the study sites and develops the research hypotheses regarding land tenure and tree management. This is followed by three descriptive sections, the first on general characteristics of the study sites and sampling methods, the second on land use and tree cover change, and the third on the key variables hypothesized to affect land use and tree cover change. Section 6 lays out the econometric model used to test the hypotheses. The final two sections contain the main results and conclusions.

2. HYPOTHESES ON LAND TENURE AND TREE RESOURCE MANAGEMENT

Our study sites are located largely in a savanna area in east central Uganda (see Figure 1), where grazing and crop farming are practiced. Across our sites, there were four categories of land tenure prior to 1975,² and even after the nationalization of all land in that year, the four types of tenure persist in the perceptions of the local population.³ The most widespread is customary land tenure which dominates our eastern and northern sites and is found in small pockets in the Buganda region (the southwestern-most sites). Customary lands in our sites were traditionally governed by clans who allocated plots of land to members. In many of the sites by the early 1900's, households had settled on lands and acquired strong permanent rights to specific parcels (Bazaara, 1992). In some areas, power shifted from clans

²A fifth category, freehold tenure, exists outside the study area in a few limited sites.

³The 1975 decree did have some impact on rights and tenure security, but did not affect the boundaries between the four main tenure types which are considered to be exogenous to communities.

to chiefs following colonial intervention but in 1966, kingdoms were formally abolished by the Ugandan government and this led to loss of control over land by traditional authorities in some cases. Some urban elites seized this opportunity to claim customary lands through the newly developed Land Commission.⁴ All customary systems follow patrilineal rules of descent and, in our study areas, inheritance is the most common method of land acquisition.

In the Buganda region, almost all land is under either “mailo” or public tenure. Vast tracts of land were given to individuals by the colonialists beginning in the early 1900’s and were known as private “mailo” land. In some cases, mailo owners occupy and farm their land; however, the majority of mailo land is occupied by “kibanja” tenants. Owners, lacking labor to till the land, had received fees and rents by settling tenants on their land. But tenants acquired legal protection against eviction in a 1928 law and rents were abolished under the 1975 land reform. Thus, many tenants have very strong rights over land they occupy, including the right to bequeath.

Other non-allocated land in the Buganda region was classified as Crown Land and included land considered as “waste”. Muhereza (1992) describes this land as resembling an open access resource. Later this became public land of which some has been settled by households. The fourth type of tenure is the leasehold for which use can be granted by the government for parcels on customary, mailo, or public lands. This form of tenure, which is close to private ownership like mailo, is rare countrywide as well as in our study areas. Therefore, we consider customary land, mailo cum lease land, and public land in this study.

⁴We do not know the actual impact of this in our study sites.

Since these land tenure systems were formed historically with the government intervention, they can be exogenous, by households and communities.

In analyzing the effect of land tenure on tree resource management, it is important to distinguish between factors affecting the conversion of uncultivated land to agricultural land and those that affect tree densities, because incentive structures underlying decisions to expand or acquire agricultural land and to protect or invest in tree resources could be different. As is the case elsewhere in Africa, the effort to convert uncultivated customary land to agricultural land by felling trees and burning fields had been traditionally rewarded by enhanced individual land rights in our study sites (Ault and Rutman, 1979). This institution implies that strong rights over new agricultural land could be acquired on a first-come-first-served basis, which obviously increased incentives to open up uncultivated land (Anderson and Hill, 1990). Further, customary tenure institutions have an equity objective in providing some land to all community members, which leads to the expansion of agricultural land with population growth.

The case of mailo land is quite different, due principally to the restrictions on tenancies and resulting distortions on land use. Mailo owners have strong incentives not to “lease” land to tenants which tends to preserve uncultivated areas (e.g., woodlands or grazing lands) inasmuch as crop productivity under hired labor may be inefficient.⁵ This reinforces the tendency that the proportion of agricultural to total land is lower for mailo than customary land. The strength of land rights is essentially independent of land use patterns in the case of mailo land and the conversion to agricultural land is regulated, to some degree, in the case of

⁵Hayami and Otsuka (1993) report the significant inefficiency of crop production under seasonal labor contract compared with land tenancy contracts in Asia.

public land. Lastly, there is no counterpart on mailo or public land to the customary institution of providing land to all community members. Thus, we postulate the following hypothesis:

Hypothesis 1: Other things being equal, the rate of conversion to agricultural land is higher on customary land than mailo and public land.

On the other hand, incentives to invest in tree resources will be affected by tenure security, which influences the future returns to investment expected to be captured by those who actually invest (Besley, 1995). Individual land rights are strongest for private mailo land owned by resident owners who usually manage their lands directly, and have both incentives and capacity to manage land and tree resources intensively. On the other hand, absentee owners tend to use land less intensively and manage tree resources less effectively. If land is unoccupied by tenants, absentee owners usually employ herdsmen and overseers to look after their cattle but tree resources are often managed poorly due to difficulties of protecting trees from illegal cutting. If tenants occupy land and engage in crop farming, land owners, particularly absentee owners, have no rights over the use of land and can exercise only limited rights over tree resources. Therefore, we postulate the following two hypotheses:

Hypothesis 2: Tree densities are highest on mailo land and lowest on public land where considerable *de jure* control over land is retained by the State.

Hypothesis 3: Within mailo land, areas managed by resident owners have greater tree density than those managed by absentee owners, as the latter possess more limited tree rights or authority to control the disposition of trees.

3. STUDY SITES

Uganda is a landlocked country of about 19 million people, of which slightly less than 90 percent reside in rural areas. The average rural population/cultivable land ratio for all of Uganda is 88/km² and ranges between 51 and 319 in the districts containing our study sites (World Bank, 1993). It is estimated that the tropical forest area was 7,000 km² in 1990 representing about 3 percent of the land area (World Bank, 1993). Langdale-Brown (1960) estimated tropical forest area to be over 11,000 km² in 1958 and over 25,000 km² in the mid 1920's. More recently, the annual rate of deforestation (including all types of natural forests) had been estimated to be about 0.9 percent between 1980 and 1990 (World Bank, 1994). Given that the area remaining under forest remains small, concern about the sustainability of woody biomass production naturally directs one to the more abundant agricultural land, woodland, bushland, and wetland areas found in the landscape. As is documented in most countries in sub-Saharan Africa, the area under agriculture has expanded significantly at the expense of formerly wooded areas (Hosier, 1989). It is feared that the more recent expansion has occurred on marginal lands not well suited to intensive agriculture. The other major demand on woody vegetation has been for charcoal to satisfy urban commercial and household needs. Our study sites have been the major sources of charcoal for Kampala.

The data for this study come from 64 parishes in 10 districts of Uganda.⁶ The ten districts form a circle around Lake Kyoga in east-central Uganda. These sites were selected for several reasons: presence of differing population densities, different tenure regimes,

⁶The ten districts are: Mukono, Kamuli, Iganga, Tororo, Mbale, Kumi, Lira, Apac, Kiboga and Luwero.

relative homogeneity in topography and agroclimatic conditions, and availability of remote sensing material at two points in time. It is also important to note that our sites are largely free from organized tree planting interventions, so that changes in tree resources have not been exogenously influenced by government, NGOs and the like.

A stratified random sampling procedure was used. Five parishes were selected from each district with the exception of Luwero, Mukono, and Kiboga for which a greater number of parishes were selected to ensure an adequate number of mailo tenure cases. The sampling frame excluded parishes above the size of 150 square kilometers to ensure that parish level field data were meaningful (which eliminated only 2.1 percent of the parishes across the 10 districts). A further stratification rule based on availability of recent aerial photos was established but a random sample provided for sufficient numbers of parishes covered by aerial photographs and the rule was invoked in choosing only two additional parishes in the district of Mukono.

Although there are more subtle variances, the sites fall broadly within two agro-ecological zones. A drier zone cuts across the northern sections of Kiboga, Luwero, Mukono, Kamuli, and Iganga Districts, all located south of Lake Kyoga. Drier zones are also found as one moves to the north of Apac and Lira Districts. In some of the drier areas, soils tend to have a higher sand than clay component. The rest of the study sites are more humid due to the proximity to Lake Victoria. Despite the wide geographical area covered by the study, the degree of variation in topography is quite low.

Population densities range widely with the highest 1991 population density (the most recent census year) recorded being 629/km² in Bumasobo Parish in Mbale District, while the lowest is 26/km² in Mugongo Parish in northern Mukono District. The percentage of the

population that is urban in or adjacent to the parishes is low and agriculture is the main activity in all parishes. Within agriculture, coffee, maize and banana dominate in the more favorable areas while cassava, beans, and millet are more important in the drier areas. The importance of livestock varies considerably, with higher densities per land area (but lower numbers per household) found in the heavily populated parishes.

During the period 1960-95, a few notable events took place which impacted on agricultural activities and land use in our study sites. Arguably, the most important was the war of 1980-86. This led to prolonged displacement of the population in some areas leading to improved vegetative growth. Cattle rustling by soldiers also led to reductions in livestock herds in areas where people remained. A second important event was heavy cattle rustling by the Karamoja peoples affecting mainly the districts of Apac, Lira, and Kumi. Other than these events, there were isolated reported emergences of crop diseases (cassava mosaic, banana stem borer) and the elimination of livestock disease (trypanosomiasis) in others.

4. LAND USE AND TREE COVER

The baseline land use and tree cover information were generated from aerial photographs at a 1:30,000 scale taken mainly between 1955 and 1960. The source for the recent information for 42 parishes was also aerial photography. Aerial photographs at a scale of 1:60,000 taken in 1995 were used for 38 parishes and 1:25,000 photos taken in 1989 were used for 4 parishes.⁷ SPOT images from 1989 were used for the remaining 22 parishes which

⁷We greatly appreciate the assistance of the Japan International Cooperation Agency, PASCO International, and the Ugandan Department of Surveys and Mapping in obtaining

were not included in any recent aerial photography.⁸ All remote sensing data were taken during the dry season and thus there was no interference from clouds. The mainly flat terrain also made photo interpretation relatively trouble free. Any ambiguities were rectified through groundtruthing by the field survey team.

Details of the photo interpretation methodology can be found in Breyer (1996), but generally, two types of data were generated. The first was a mapping of land use classes in all 64 parishes, using minimum mapping unit size of 0.1 hectare.⁹ The land use classification scheme adopted was the same as the one used by the BIOMASS study in Uganda and included agricultural land, forests, plantations, woodland, bushland, grassland, wetland, urban land, barren land, and water. Forested land could be disaggregated into naturally stocked (virtually 100 percent cover) or depleted forest (mainly 90 percent cover with a minimum of 80 percent). For our land use analysis, we use the term forest to include both natural forests and plantations, though the latter are virtually nonexistent. Woodlands were defined as lands on which trees cover between 2 and 80 percent of the land area. A similar definition was used for bushland with the main difference being that bushland contained woody vegetation primarily below 4 meters in height. However, since average height is rather difficult to confirm in aerial interpretation, woodlands and bushlands were later aggregated together in

these photos.

⁸We thank the BIOMASS project for the use of the 1989 aerial photos and SPOT images. In return for the use of the photos and images, our project assisted the BIOMASS project in verification of its land use classification estimates.

⁹That is to say, any variation in land use which was less than 0.1 hectares could not be accurately identified and drawn on the photograph.

our analyses. Grasslands were defined as areas with less than 2 percent woody vegetation. Land with vegetation cover similar to woodland, bushland, or grassland, but which were within a visible field pattern was classified as agricultural land.

In the 42 parishes where recent aerial photographs were used, the woodland, bushland, and wetland classifications were further distinguished by four categories of tree cover density ranging from very dense (60 percent to 80 percent cover) to open (2 percent to 20 percent). Hence, the degree of tree cover could be estimated for all lands except for agricultural land. To fill this gap, the second type of data generated was an estimate of tree cover density on agricultural land.¹⁰ These estimates were formed by an average of grid samples overlaid on both earlier and recent aerial photographs.

For all 64 parishes, the area and proportion of land under the different land uses were calculated at two points in time. For the 42 parishes with recent aerial coverage, average parish tree cover was assessed by taking a weighted average of tree cover on non-agricultural land (using tree cover classes) and tree cover on agricultural land (grid sample estimates). For non-agricultural land, these two types of variables were also calculated for each tenure classification within a parish after overlaying tenure boundaries on the land use maps.¹¹

Table 1 shows some aggregate descriptive indicators pertaining to the land use variables. The mean share of agricultural land per parish increased from .57 to .70 between

¹⁰Tree cover included coffee but excluded banana. Coffee was included because it is often grown in small stands which were hard to distinguish and also because a common practice in Uganda is to grow coffee under shade trees.

¹¹Tree canopy on agricultural land was estimated only at the parish level. The agricultural land sampling was a lengthy task, comprising nearly 1,000 samples. As it was too costly to digitize the areas, it proved very difficult to match samples with tenure boundaries in parishes with multiple tenures.

1960 and 1995.¹² The lowest share of agriculture recorded was .05 in 1960, but this increased to .15 by 1995. This expansion came largely at the expense of woodland and bushland whose average share per parish fell from .28 to .18. Despite the fact that the large majority of parishes saw their share of woodlands decrease, nearly all parishes have some woodland or bushland remaining. The share of forested land fell by 50 percent from .04 to .02 of the total land area. In some cases, this reflected a complete depletion of forests -- of twenty parishes with some forest land in 1960, ten became completely deforested by 1995. There is significant variation in the current degree of woody vegetation and its change over time across the parishes. Taking the area under forest and woodland together, the absolute change in the share of total parish area varies from + .28 to -.51.

Table 1 Land use in the study sites (n=64)

Land Use	Average parish share in 1960	Average parish share in 1995	Share change interval which includes 80% of parishes	Most positive absolute change in share	Most negative absolute change in share
Agriculture	.57	.70	-.09 to +.46	.75	-.27
Forest	.04	.02	-.08 to .00	.01	-.71
Wood, Bush, & Grass Land	.28	.18	-.31 to +.07	.27	-.55
Wetland	.11	.10	-.05 to +.02	.11	-.19

Table 2 displays average tree cover per parish by broad land use category and for whole parishes after taking a weighted average. The average proportion of tree canopy cover

¹²We use the dates 1960 and 1995, although the beginning dates vary from 1955 to 1961, and 1995 includes 1989 for some parishes.

per parish was estimated to be .31 both in 1960 and in 1995 for the 42 parishes for which the variable could be calculated. Similarly, the average change in any of the individual land use categories was small. However, as noted above, this is not to say that woody vegetation has been stable within the parishes. In about 42 percent of parishes, the absolute change in average tree cover was greater than plus or minus .10 and the range was from +.30 to -.36. Two points of clarification are worth noting about the observed stability in the aggregate tree canopy. First, canopy may not be an accurate measure of biomass. Large trees which are cut (e.g., for charcoal) often grow back from several shoots which may form a wide canopy without a large woody biomass. Second, there is often a change in the composition of species as is the case when land is converted from woodlands (e.g., indigenous species like *Combretum spp.*) to agriculture (e.g., coffee and exotic fruits). Nonetheless, we believe that tree cover changes broadly capture trends of changes in biomass density. Particularly noteworthy is the increase in tree cover on agricultural land, which seems to have compensated, at least partly, for loss of woody biomass on non-agricultural land.

Table 2 Tree cover pattern in sites covered by recent aerial photos (n=42)

Land Use	Average parish tree cover in 1960	Average parish tree cover in 1995	Cover change interval which includes 80% of parishes	Most positive absolute change in cover	Most negative absolute change in cover
Agriculture	.23	.28	-.14 to +.31	.41	-.35
Forest	.94	.94	-.02 to .00	.10	-.05
Wood, Bush, & Grass Land	.44	.42	-.19 to +.12	.31	-.35
Wetland	.21	.19	-.14 to +.16	.27	-.40
Average	.31	.31	-.05 to +.02	.30	-.36

5. FACTORS DRIVING LAND USE AND TREE MANAGEMENT

The variables hypothesized to be the main factors behind land use and tree cover change came principally from a survey instrument administered in each of 64 parishes. The respondents consisted of local leaders, respected elders, and agricultural officers. One meeting was often enough to obtain the necessary data, but in some cases, the team traveled around to different parts of the parish to verify responses. A few variables, including soil type, rainfall, and population, were found from secondary sources. The survey elicited information about infrastructure and distance to markets, ethnic composition and extent of in-migration, cropping and livestock activities, tree species composition, major tree planting projects, prices of agricultural and wood products, natural and man-made shocks such as drought or war, and a set of tenure variables including rights over land and trees across broad tenure categories. Many variables captured both current and initial conditions in 1960.

Table 3 displays a general description of some of the important non-tenure variables hypothesized to affect land use and tree cover.¹³ The average population density among the parishes was 79 per square kilometer in 1960 and the range was from 9 to 461. Population growth was high in all our sample parishes, with a mean annual growth rate of 4.5 percent per year. As a result, the average population density increased to 164 in 1991. In terms of market integration, the two most important variables collected were distance to a tarmac road

¹³In addition to the field survey, the following secondary sources were used: Uganda Ministry of Finance and Planning (1992) for population figures, FAO (1984) for growing season data, Ollier et al (1969) for soil types, and ICRAF's GIS lab for rainfall data.

and distance to Kampala, the main urban area. Several parishes were located on paved roads so the lowest value was 0 while the mean and maximum were 25 and 102 kilometers, respectively. The nearest parish to Kampala was 29 kms, the mean was 181 kms and the furthest was 435 kms. Among many reported exogenous shocks, the 1980-86 war was mentioned by respondents to be the most influential on land use patterns. Although the war probably affected all parishes in some way, based upon responses we classified 29 (or 45.3 percent of) parishes to have been severely impacted in terms of population displacement and land use change. Because of population growth, the war, and heavy cattle rustling, the density of livestock is reported to have dropped considerably over the 1960-95 period and is estimated to average 28 per km² in 1995.

Table 3 Some key characteristics of the study sites (n=64)

Variable	Mean	Minimum	Maximum
1960 population per km ²	79	9	461
Annual population growth	4.5	-1.3	10.1
Distance to Kampala (km)	181	29	435
Distance to paved road	25	0	102
Annual rainfall (mm)	1230	1070	1575
Number of dry days/year	82	43	123
Sandy soils (1 if yes)	.44	0	1
Coffee is a major crop (1 if yes)	.47	0	1
Severe war impact (1 if yes)	.45	0	1

The topography of the study sites was mainly flat with the exception of only a handful of parishes in Mbale and Kiboga. Soils were of two types, reddish brown clay-loams and

those which were more sandy and shallow (43.8 percent). To assess climate, secondary data on average annual rainfall and the number of “dry days” (the number of days per year which are evaluated to be strictly unsuitable for crop growth) were obtained. The average number of dry days ranged from a low of 43 to a high of 119 days and average annual rainfall varied from 1070 to 1575 mm across the parishes with a mean of 1230 mm. As far as tree characteristics are concerned, it is perhaps not surprising that in parishes occupied by humans for several centuries, almost all of the common trees coppice well (i.e., regrow after cutting) as non-coppicing species would fail to reproduce.¹⁴ In virtually all parishes, respondents reported that the density of high-valued timber trees had fallen and the median number per square kilometer fell from 47 to 18. Coffee was a significant crop in 30 parishes or slightly under 50 percent. Our survey found that significant tree planting projects (of non-coffee trees) occurred in only 7 parishes.

As indicated in the Section 2, there were four main types of tenure regimes operating in the study areas. Customary land was found in 37 (or 57.8 percent of) parishes (see Table 4). In 30 parishes, customary land covered the entire parish area and occupied about 50 percent of all land in the study area. Within customary land, respondents indicated that by 1960, most land was already claimed by households, implying that land controlled directly by community or clan chiefs had largely disappeared. Thus, despite relatively low population densities in some parishes, by 1960 the customary land area was completely claimed in nearly 80 percent of parishes. The median farm size reported in customary areas in 1995 was five acres. Table 4 shows the percentage of land by tenure, the boundaries of which were drawn

¹⁴Exceptions are the valuable hardwood timbers which are managed differently than other species.

by participatory mapping method. According to this table, the percentage of land under agriculture was highest in customary tenure systems in both 1960 and 1995, which is consistent with our hypothesis that incentives to expand agriculture area are stronger under customary tenure systems.

Table 4 Area and land use by type of tenure (n=64)

Tenure Type	% of Parishes in which found	% of Total Land Area	% of Land in Agriculture in 1960	% of Land in Agriculture in 1995
Customary	57.8	50.2	64.5	81.3
Mailo/lease	45.3	39.4	36.6	53.8
Public	37.5	10.4	19.1	28.0

The mailo land tenure system was found in 29 (or 45.3 percent of) parishes and comprised 39 percent of the total land area in the study. Leasehold tenure was found in a handful of sites but comprised a large enough area for mapping in only two parishes. The characteristics of leasehold tenure are quite like those of mailo tenure; they are often large farms, sometimes with absentee owners, and many are divided and occupied by tenants. For this reason, mailo and leasehold tenures have been merged together for our data analysis. There was considerable variation in the estimated proportion of land occupied by owners and tenants in 1960 (ranging from 5 to 90 percent), but by 1995 tenants had occupied the majority of mailo land in most parishes. The average farm size in 1995 was five acres for tenants and 15 acres for owner-cultivators. The median number of mailo owners in a parish was 12. Within mailo land, we were also able to identify the percentage of owners who were absentee.

In 34 percent of mailo areas, virtually all mailo owners were resident while the remaining two-thirds had moderate to high levels of absentee ownership.

Public land was found in 24 (or 37.5 percent of) parishes, occupying about 10 percent of the total land area. Some public land remains gazetted and non-settled, but other public lands are occupied by households, some in government rice schemes (small plots) and others in more traditional farm settings (farms of a few acres). Of the three predominant tenure systems in the study area, public land has the lowest share of agricultural land, though the rate of change over the 1960-95 period was the highest.

In order to identify the relative strength of land and tree rights under different tenure, a series of questions about land rights were asked for up to eight tenure categories.¹⁵ In all tenure categories, individual rights to plant trees and to cut non-timber trees were ubiquitous. The only tree right to exhibit much variation concerned the right to cut timber trees (e.g., *Chlorophora excelsa*) which reflected differences in awareness that these tree species are legally protected. As for land rights, in only a few cases was the unrestricted right of sale found. In the case of customary tenure, the unrestricted right of sale was completely absent. Free grazing, hence less-exclusive rights to land, was reported for 32 percent of customary areas, 66 percent of mailo areas, and 42 percent of public lands. The higher percentage within the mailo tenure category may reflect the fact that large and often absentee owners are unable to enforce exclusion rights.

¹⁵These were customary (claimed and unclaimed), public (claimed and unclaimed), mailo (owner and tenant), and leasehold (owner and tenant).

6. ECONOMETRIC MODEL

We consider two production activities; “crop farming” on agricultural land and livestock farming cum charcoal burning on grazing land. Crop farming includes production of food crops, perennial crops (e.g., coffee and fruits), and other products extracted from trees grown on the farm (e.g., firewood and poles). Composite products produced from agricultural land are denoted by Q_A , whereas composite products of livestock and charcoal production from non-agricultural land are expressed by Q_N . While we assume that each cultivating household maximizes its utility under resource and land constraints, we focus on aggregate behavior at the parish level. In order to derive the function explaining conversion of grazing land to agricultural land, we define static production functions which are conditioned by prior investments in land and trees at the parish level:

$$(1) \quad Q_A = F(L_A, X_A, T_A, M, E) = F(L_A, X_A, d_A X_A, M, E)$$

$$(2) \quad Q_N = G(L_N, X_N, T_N, M, E) = G(L_N, X_N, d_N X_N, M, E)$$

where F and G represent production functions for crop and livestock farming; L_i , X_i , T_i and d_i denote labor, land, stock of trees, and tree density, where subscripts ($i = A, N$) refer to crop and livestock cum charcoal farming; and M and E stand for livestock population and an environmental variable. M enters equation (1) because manure is deposited on crop fields through free grazing on agricultural land during the dry months. E is a shift variable affecting the nature of the production functions, which may be captured by rainfall patterns and soil types. Since wetland areas have changed little and the forest area remains small, we either

assume them away or include them in X_N . We assume that charcoal burning reduces tree density on grazing land (d_N) but not on agricultural land (X_N), because trees are selectively felled for charcoal burning. We further assume that the production functions are subject to constant returns to scale with respect to labor, land, tree stock, and livestock population.

In our framework, land, tree density, and livestock population are state variables, which change only with investments, i.e., conversion of grazing land to agricultural land, tree planting and management, and raising calves. While farming households individually choose the extent of changes in the tree density on agricultural land and the number of livestock in customary land tenure areas, they can change the tree density on non-agricultural land and the area of land conversion only after receiving approval from other community members. Thus, the pace of deforestation in customary areas depends on how easily other community members grant their approval. Also, in tenant cultivation areas, the approval from landlords is required for land conversion and some types of tree felling and tree planting. On the other hand, labor is a variable input so that each household decides its allocation between crop and livestock farming each period. In order to incorporate dynamics into the model, we follow Besley (1995) and consider a two-period model consisting of two production years, 0 and 1.

Let us analyze how investment decisions are made by taking the case of investment in the conversion of land from grazing to agricultural use. In the beginning of the first year, the allocation of land between agricultural and grazing areas is predetermined:

$$(3) \quad \underline{X} = X_{A0} + X_{N0},$$

where \underline{X} is total parish area which is fixed over time. During the first year a portion of grazing land (ΔX) is converted to agricultural land for cultivation in the second year. For simplicity, it is assumed that investment activity does not affect crop and livestock production in the first year. This assumption may be justified because farmers use labor time during the off-peak, dry season for the conversion of land and because livestock can be grazed on uncultivated agricultural land during this season. In the second year, land allocation changes in the following way:

$$(4) \quad \underline{X} = X_{A1} + X_{N1} \\ = (X_{A0} + \Delta X) + (X_{N0} - \Delta X).$$

Pay-off to investors to be realized in the second year, denoted by V_1 , depends not only on the amount of investment, ΔX , but also on the bundle of land rights (e.g., rights to use, rent out, mortgage, and sell) in that year, R_1 , and the relative profitability of crop and livestock farming. Land rights on newly converted land are conditioned by the prevailing land tenure rules, whereas the relative profitability depends on relative output prices (P_1), factor endowments or the ratio of working population to land (N_1/\underline{X}), and factor intensities of the production functions, which may be affected by E .¹⁶ Thus, the pay-off function can be expressed as:

$$(5) \quad V_1 = V_1 (\Delta X, R_1, P_1, N_1/\underline{X}, E)^{17} .$$

¹⁶We do not consider endowments of livestock and tree density in the second year, because they are endogenous. Note that we are not necessarily treating population density as exogenous. Since population pressure is hypothesized to be a key variable affecting land use, we explicitly show it in the model.

¹⁷For simplicity, we do not explicitly show the discount rate in the V_1 function.

The major cost of investment in land conversion is labor cost, hence investment cost (C_0) depends on off-farm wage rate, w_0 , or the marginal disutility of labor, which should depend positively on income per capita or on the endowment of assets per capita and the output price structure in the initial year, which may be captured by N_0/\underline{X} and P_0 .¹⁸ Investment cost also depends on the ease of land conversion, which is assumed to be reflected in the proportion of area already converted to agricultural land (X_{A0}/\underline{X}), and on land rights in the initial year (R_0), because, if individual land rights are not well established, an investor must incur negotiation costs with other people, who possess partial land rights, such as other community members in customary land tenure areas and mailo owners. Like R_1 , R_0 is conditioned by land tenure institutions. Thus, the cost function for investment can be expressed as:

$$(6) \quad C_0 = C_0(\Delta X, R_0, P_0, w_0, N_0/\underline{X}, X_{A0}/\underline{X}) .$$

The rational behavior of households ensures that the equilibrium amount of land conversion is determined at the point where the net benefit of investment, $V_1 - C_0$, is maximized. Assuming the existence of unique interior maximum, the investment function can be derived as:

$$(7) \quad \Delta X = \Delta X(R_0, R_1, P_0, P_1, w_0, N_0/\underline{X}, N_1/\underline{X}, X_{A0}/\underline{X}, E) .$$

¹⁸Strictly speaking, the endowment of livestock and tree stocks on agricultural and non-agricultural land per capita in the initial year should be included in the cost function. We do not include them here, partly because they are highly correlated with other explanatory variables and partly because the small sample size of this study precludes the use of all potentially important variables in the regression analysis.

Since land rights are conditional on the prevailing land tenure institutions (I), output prices and the wage rate are governed by access to markets (A), and population effects can be separated into the effects of population density in the initial year and population growth rate (g), equation (7) can be transformed into the following estimable form:

$$(8) \quad \Delta \underline{X} / \underline{X} = f(I, A, N_0 / \underline{X}, g, X_{A0} / \underline{X}, E),$$

where the dependent variable is normalized by total parish area to adjust for differences in the total size of parishes. In actual estimation, we use proportions of customary and mailo land tenure areas to denote I, both independently and jointly with interaction terms with exclusive land use dummies, and two distance variables to represent A, one to paved road and another one to Kampala. The population growth rate may be legitimately considered endogenous to the extent that people migrate to less populated areas to acquire land. We therefore apply the two-stage least squares regression functions in addition to the ordinary least squares regression in the estimation of equation (8). Finally E is captured by variables such as soil type, annual average rainfall, and by days unsuitable for cultivation (see section 4).

Equation (8) can be estimated using the full sample of 64 parishes. We assume a linear specification except for population density (N_0 / \underline{X}), for which we add a square term in order to test for positive but decelerating impacts of population pressure on the expansion of agricultural land due to the limitation of cultivable area. We hypothesize that population growth and environmental factors conducive to agricultural production have positive effects on the expansion of agricultural land. We also hypothesize that customary tenure has a

positive effect because the conversion of uncultivated land to agricultural land strengthens individual land rights under the customary law. This effect, however, may be weak in customary areas where the uncultivated area is used as a grazing area by community members at large, so that individual rights to convert grazing to agricultural land is restricted. On the other hand, prohibition of rent payments from cultivation of crops would retard the conversion of mailo land to agricultural fields. Distance is supposed to reflect access to market. We expect that reduced access to markets increases relative prices of major livestock products (i.e., meats) over food crops, because cattle can be brought to local markets on foot by farmers. One could also argue that reduced market access decreases wage rate, as well as output prices relative to prices of purchased inputs, such as chemical fertilizer, thereby increasing the relative advantage of the external expansion through land conversion over agricultural intensification.

Analogous to equation (8), we specify the functions explaining changes in tree density on agricultural and non-agricultural land as:

$$(9) \quad \Delta d_A = \Delta d_A (I, A, N_0/\underline{X}, g, X_{A0}/\underline{X}, d_{N0}, d_{A0}, E)$$

$$(10) \quad \Delta d_N = \Delta d_N (I, A, N_0/\underline{X}, g, X_{A0}/\underline{X}, d_{N0}, d_{A0}, E),$$

where the tree densities in the initial period are included to test the hypothesis that lower tree density on non-agricultural land, as well as on agricultural land, induces tree planting on agricultural land and more strict control of tree felling on non-agricultural land. It is also of interest to assess the impacts of the population pressure on the tree densities on agricultural and non-agricultural land. Particularly of interest is whether and to what extent private land

rights under the mailo ownership system are conducive to preservation of trees on non-agricultural land and to planting of trees on agricultural land. In estimating equations (9) and (10), we used tree cover as a proxy for tree density. Since data on tree cover are available only for 42 parishes where aerial photos are available, we used the sub-sample for the estimation. In the case of equation (10), we have separate tree cover data for more than one land tenure system for 19 parishes, so that we use 67 observations for the actual estimation.

7. RESULTS

The results from the regressions of change in share of agricultural land are given in Table 5. The models were based on observations from all 64 parishes and the resulting adjusted R-squared values were very encouraging, in the range of .60.¹⁹ Models 1 and 2 contain the output from a regression on the broad tenure categories under the assumption that population growth is exogenous, while models 3, 4, and 5 are 2SLS models with population growth treated as endogenous.²⁰ The results in Table 5 indicate that the change in agricultural land share is linked to customary land tenure category. Customary tenure, notably customary

¹⁹We ran models after annualizing land use and tree cover change to account for differences in beginning and ending dates for remote sensing interpretation. The statistical significance of the models and of individual variables were unchanged from those presented here. Other explanatory variables, such as livestock density and other environmental variables were found to have little statistical significance in other regression specifications.

²⁰The first-stage regression on population growth explained 56 percent of variation. Percentage of top three major ethnic groups, percentage of migrants in 1960, and rainfall were explanatory variables omitted from the land use change regression. We did not use the share of tenure variables in the first-stage regression because there is no clear theoretical justification to include them. In any case, they are insignificant.

tenure which is relatively more individual or exclusive, is positively related (in comparison to public land) to agricultural land conversion, in all models. This could imply the existence of weak indigenous institutional management of lands in which land clearing is not regulated. It could, however, also indicate a purposeful strategy on the part of indigenous institutions to respond to demands for agricultural land by its ever-increasing constituents. There is no significant difference in land use change between mailo and public tenure systems in any of the models. There was further no significant difference in the change in agricultural land share within mailo areas differing on the basis of exclusivity of land rights or residency of owners.

Population variables were extremely important in explaining land use change. Increased agricultural land share was linked to higher population growth and higher population density, the latter at a non-linear decreasing rate. Population growth was positively linked to agricultural land expansion whether treated as exogenous or endogenous. If we take the coefficient of 0.035 based on 2SLS estimation, an increase in population growth rate of one percentage point is expected to lead to an increase in agricultural land of 3.5 percentage points. This is consistent with a well noted observation made by others (e.g., Boserup, 1965). The effect of population density is also expected. At low levels of population density, the change in share of agricultural land is high as families clear large areas for their farms. As population increases, the land frontier diminishes and little new land can be found. Eventually, new families must find land from within existing agricultural areas. Model 3 predicts that the level of population at which agricultural land would actually decline is 350, a level which was exceeded in only one parish.

Table 5 Results from OLS and 2SLS regressions of change in share of agricultural land (n=64) ¹

Variable	OLS Model 1	OLS Model 2	2SLS Model 3	2SLS Model 4	2SLS Model 5
Constant	.124 (1.10)	.127 (1.13)	.012 (0.71)	.024 (0.15)	-.0007 (-0.00)
Share of customary tenure	.158 (1.82)		.181 (2.08)		.179 (2.09)
<i>Exclusive customary tenure^b</i>		.170 (2.01)		.191 (2.25)	
<i>Open customary tenure^b</i>		.055 (0.58)		.077 (0.80)	
Share of mailo tenure	-.010 (-0.11)		.026 (0.28)		
<i>Exclusive mailo tenure²</i>		-.033 (-0.32)		-.006 (-0.06)	
<i>Open mailo tenure²</i>		-.009 (-0.11)		.027 (0.29)	
<i>Resident mailo tenure²</i>					.089 (0.86)
<i>Absentee mailo tenure²</i>					-.002 (-0.02)
1960 population density	.0016 (2.31)	.0011 (1.62)	.0020 (2.52)	.0015 (1.89)	.0019 (2.45)
1960 pop. density squared	-.000003 (-1.76)	-.000002 (-1.37)	-.000003 (-1.96)	-.000003 (-1.58)	-.000003 (-1.80)
Population growth	.020 (2.38)	.019 (2.38)			
<i>Predicted pop. growth</i>			.033 (2.00)	.032 (1.98)	.0364 (2.22)
Number of dry days	.001 (1.17)	.001 (1.37)	.0008 (0.90)	.001 (1.08)	.0008 (0.85)
Distance to Kampala	-.0001 (-0.36)	-.00004 (-0.14)	-.00002 (-0.07)	.00005 (0.14)	.00002 (0.07)
Distance to paved road	.0018 (2.27)	.0015 (1.84)	.0022 (2.60)	.0019 (2.13)	.0022 (2.68)
1960 share of agriculture land	-.649 (-7.74)	-.606 (-7.10)	-.651 (-7.67)	-.611 (-7.06)	-.663 (-7.86)
Adj. R-squared	.60	.62	.59	.61	.60

¹ t-statistics in parentheses

² interaction term between tenure and land right or owner residence dummies

Other important variables in the change in agricultural land share regressions were the 1960 share of agricultural land and the distance to a paved road. The coefficient on the 1960 share of agricultural land was negative and very strong; this is expected because at higher share levels, the potential for additional expansion is less.²¹ Distance to a paved road was positively and significantly related to increased agricultural land share in all cases indicating that greater agricultural expansion during the 1960-95 period was taking place away from major roads where large uncultivated area still existed.

Tables 6 and 7 show the results from the tree cover change regression on agricultural (equation 9) and non-agricultural (equation 10) land respectively. Both contain two OLS models assuming population growth to be exogenous and three 2SLS models under an assumption of endogeneity. The models for agricultural land explained a large share of observed variation, between 70 - 73 percent. The models for non-agricultural land did not show such a strong fit, but nevertheless explained a respectable 50 percent of variation in tree cover change. Below, we discuss together the results from the two tables.

Among tenure variables, the main effect found was that tree cover change on agricultural land was positively related to mailo tenure (compared to public land). This was confirmed in all models, although the significance levels are weaker in the 2SLS models. There were no observed differences between “more exclusive” and “more open” mailo land, but positive tree cover change was stronger in mailo land dominated by resident owners. According to the estimated coefficients, tree cover in agricultural area of mailo land was about 20 percent higher than in public land and 10 to 15 percent higher than in customary

²¹When this variable was removed, the results on the tenure variables were unchanged with one exception. The impact of exclusive customary tenure in model 4 becomes positive and statistically significant.

Table 6 Results from OLS and 2SLS Regressions of change in tree cover on agricultural land (n=42) ¹

Variable	OLS Model 1	OLS Model 2	2SLS Model 3	2SLS Model 4	2SLS Model 5
Constant	.422 (2.49)	.413 (2.32)	.523 (2.21)	.534 (2.18)	.489 (2.07)
Share of customary tenure	.054 (0.80)		.047 (0.69)		.042 (0.62)
<i>Exclusive customary tenure²</i>		.055 (0.74)		.049 (0.66)	
<i>Open customary tenure²</i>		.095 (1.06)		.090 (1.01)	
Share of mailo tenure	.204 (2.13)		.187 (1.91)		
<i>Exclusive mailo tenure²</i>		.196 (1.95)		.173 (1.68)	
<i>Open mailo tenure²</i>		.230 (2.15)		.213 (1.98)	
<i>Resident mailo tenure²</i>					.201 (2.06)
<i>Absentee mailo tenure²</i>					.149 (1.46)
1960 population density	.0008 (0.91)	.001 (1.05)	.00035 (0.32)	.0005 (0.43)	.0002 (0.15)
1960 pop. density squared	-.0000004 (-0.88)	-.0000004 (-0.98)	.0000003 (0.29)	.0000003 (0.28)	.0000003 (0.27)
Population growth	-.0022 (-0.24)	-.0016 (-0.17)			
<i>Predicted pop. growth</i>			-.0127 (-0.65)	-.0141 (-0.70)	-.0095 (-0.49)
Number of dry days	.00009 (0.07)	-.00001 (-0.01)	.00001 (0.01)	-.0001 (-0.08)	.0002 (0.17)
Sandy Soil	-.118 (-2.82)	-.117 (-2.64)	-.129 (-2.85)	-.129 (-2.72)	-.120 (-2.64)
Distance to paved road	-.002 (-2.62)	-.003 (-2.38)	-.0028 (-2.64)	-.0032 (-2.46)	-.0027 (-2.58)
Distance to Kampala	.0002 (0.54)	.0003 (0.69)	.0002 (0.43)	.0003 (0.60)	.0001 (0.33)
1960 share of agriculture land	-.357 (-3.21)	-.392 (-3.06)	-.362 (-3.26)	-.402 (-3.15)	-.357 (-3.24)
1960 agric. tree cover	-.970 (-6.36)	-.956 (-6.04)	-.971 (-6.41)	-.956 (-6.11)	-.978 (-6.51)
1960 non-agric. tree cover	-.106 (-1.15)	-.104 (-1.03)	-.076 (-0.76)	-.073 (-0.69)	-.073 (-0.74)
Coffee important crop	.066 (1.51)	.078 (1.62)	.063 (1.45)	.076 (1.60)	.068 (1.57)
Adj. R-squared	.72	.70	.72	.71	.73

¹ t-statistics in parentheses

² interaction term between tenure and land right or owner residence dummies

Table 7 Results from OLS and 2SLS Regressions of change in tree cover on non-agricultural land (n=67) ¹

Variable	OLS Model 1	OLS Model 2	2SLS Model 3	2SLS Model 4	2SLS Model 5
Constant	-.294 (-1.40)	-.338 (-1.56)	-.837 (-3.12)	-.885 (-3.24)	-.882 (-3.26)
Share of customary tenure	-.020 (-0.37)		-.052 (-1.00)		-.054 (-1.03)
<i>Exclusive customary tenure^b</i>		-.054 (-0.86)		-.084 (-1.44)	
<i>Open customary tenure²</i>		.048 (0.61)		.019 (0.26)	
Share of mailo tenure	-.0008 (-0.02)		-.0105 (-0.27)		
<i>Exclusive mailo tenure²</i>		.008 (0.14)		.006 (0.12)	
<i>Open mailo tenure²</i>		-.004 (-0.09)		-.019 (-0.42)	
<i>Resident mailo tenure²</i>					.026 (0.51)
<i>Absentee mailo tenure²</i>					-.033 (-0.75)
1960 population density	-.0009 (-0.83)	-.0007 (-0.71)	.0010 (0.88)	.0012 (1.02)	.0009 (0.80)
1960 pop. density squared	.0000002 (0.39)	.0000002 (0.37)	-.000003 (-2.49)	-.000003 (-2.58)	-.000003 (-2.57)
Population growth	.0059 (0.54)	.0077 (0.70)			
<i>Predicted pop. growth</i>			.065 (2.79)	.067 (2.86)	.069 (2.93)
Number of dry days	.0041 (2.72)	.0043 (2.80)	.0055 (3.76)	.0057 (3.83)	.0057 (3.85)
Sandy Soil	.103 (2.10)	.112 (2.21)	.181 (3.40)	.192 (3.51)	.189 (3.53)
Distance to paved road	.0008 (0.80)	.0008 (0.74)	.0028 (2.29)	.0029 (2.21)	.0028 (2.32)
Distance to Kampala	-.0003 (-0.90)	-.0003 (-0.69)	-.0004 (-1.20)	-.0004 (-0.97)	-.0004 (-1.19)
1960 share of agriculture land	.285 (2.19)	.287 (2.10)	.356 (2.90)	.364 (2.81)	.361 (2.94)
1960 agric. tree cover	-.246 (-1.54)	-.252 (-1.57)	-.291 (-1.93)	-.298 (-1.97)	-.296 (-1.97)
1960 non-agric. tree cover	-.390 (-3.97)	-.370 (-3.67)	-.520 (-5.29)	-.504 (-5.08)	-.521 (-5.31)
Adj. R-squared	.46	.45	.52	.52	.53

¹ t-statistics in parentheses

²interaction term between tenure and land right or owner residence dummies

land. These results support our hypothesis that individual rights to land and trees are strongest for mailo land, especially where owners are resident. No other tenure variables were statistically significant, including none in the non-agricultural land regression. This indicates, *inter alia*, that management of trees on non-agricultural land under different tenure systems has more or less the same consequences for aggregate tree cover change.

Compared with the land use change model, the effects of population density and growth on tree cover change are weaker, particularly on agricultural land.²² Population growth, however, affects positively tree cover change on non-agricultural land, which may be taken to imply that trees are better managed under the increasing population pressure. These indicate that although increased population leads to conversion of land to agriculture, the effect of population on tree cover or its change is relatively small or even positive. This is consistent with increasing tree cover on agricultural land during 1960-95.

Other noteworthy findings include the importance of market access, soil type, and climate. As expected, distance from a paved road was negatively related to the change in agricultural tree cover. Tenure institutions appear to have been too weak to prevent severe tree cover loss on non-agricultural land near major roads (evidenced by the significant coefficient on paved roads in Table 7). Thus, proximity to paved roads is associated with less conversion to agricultural land, greater tree density on agricultural land, and lesser tree density on non-agricultural land. Poor soil quality had a negative effect on tree cover change on agricultural land and a positive effect on tree cover change on non-agricultural land. The result for agricultural land is expected; farmers plant and protect trees where they are likely

²²Population can, however, change overall tree density at the parish level by changing the mix of agricultural and non-agricultural land use.

to grow best. On non-agricultural land, a similar result, together with a positive coefficient on the number of dry days, seems contrary to biological growth theory. Therefore, they may instead indicate that the types of trees found on poorer soils are not highly valued. The coffee variable in Table 6 was not significant in showing that the results do not depend on the presence of coffee production, though it is included in the tree cover estimates.

Lastly, it is worth noting the significance of the 1960 tree cover and agricultural land share variables. Given the fact that average tree cover increased from 1960 to 1995, the strong negative signs on the 1960 tree cover variables indicate that individuals and communities do react to relatively low tree cover by planting and protecting tree resources. This is especially true in the case of agricultural land as evidenced by the high coefficient estimate. Controlling for initial tree cover, the initial share of agricultural land had a positive effect on tree cover change on non-agricultural areas but a negative effect on tree cover change on agricultural land. The positive effect on non-agricultural land would be expected as a means of meeting tree product needs of communities. For agricultural land, the variable could be capturing a comparative advantage for cereal cultivation through tree clearing or perhaps a lack of access to tree germplasm, due to few natural wooded areas nearby.

8. CONCLUSION

In this study we obtained strong statistical evidence, based on parish level data in Uganda, that population pressure, market access, and land tenure are important factors affecting land use and tree resource management. While the data used in this study, which are based on estimates from aerial photography and spot images and on group interviews, are

admittedly crude and subject to errors, we do believe that enormously wide variations in land use and tree covers across selected parishes help identify significant statistical relationships.

Specifically, it is found that the population pressure is the most important variable affecting the conversion of woodland and grazing land to agricultural fields. While agricultural land expansion was positively related to population growth, our evidence shows that the rate of area expansion declines with increases in population density. Population pressure, however, did not affect tree cover on agricultural land and somewhat increased tree cover on non-agricultural land. Thus, population pressure leads to reductions in tree cover primarily through the conversion of land from non-agricultural to agricultural uses. Customary land tenure institutions promote, or at least do not retard, the pace of land conversion. By comparison, private mailo tenure, as well as public land ownership, are less destructive to forests, woodlands, and bushlands. Whether private ownership systems per se are conducive to the preservation of woodland and grazing land or whether the tenancy regulations retard the conversion to agricultural land, however, is not clear from our data.

We obtained strong evidence from the analysis of tree cover changes that private mailo tenure, particularly resident mailo tenure, contributes to increasing tree density on agricultural land (in relation to public tenure). This observation suggests that to encourage a higher tree density, land reform which transfers ownership of public land to actual cultivators and introduces measures to resolve absentee land ownership by means of progressive land tax or other non-distortionary measures are needed. Yet, the extent to which absentee mailo and public ownership systems are inefficient in managing land and tree resources needs to be investigated further based on micro data before making clear-cut policy recommendations.

Another important finding of this study is the faster increase in tree density on agricultural land, which had a lower density in 1960. Thus, tree planting has been taking place at the same time as the conversion of woody areas to agricultural land and “deforestation” is neither ubiquitous nor inevitable, if one considers all tree resources. Our data show a more or less stable tree cover over time, with the contribution of agricultural land to overall tree resources (measured by cover) rising from .35 to .58 over the study period. Given rapid population growth, as well as lack of increasing employment opportunities in non-agricultural sectors, the conversion of non-agricultural land to agricultural fields will be inevitable. In order to increase the tree resource base, therefore, the feasible strategy is to support tree planting on agricultural land. This strategy is compatible with farmers’ incentives, as land rights are well established on agricultural land unless land is owned by the state. Tree planting programs would certainly be appropriate and our analysis suggests that land tenure and infrastructure policy can also play a catalyzing role in changing the stock of tree resources.

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