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THE ROLE OF TENURE IN THE MANAGEMENT OF TREES AT THE COMMUNITY LEVEL: THEORETICAL AND EMPIRICAL ANALYSES FROM UGANDA AND MALAWI

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ABSTRACT

This paper examines the effects of tenure on tree management at a community level. First, several important conceptual issues arising from this particular meso-level focus are discussed. Second, a description of the key tenure and tree management issues in Uganda and Malawi is presented. In each case, data representing changes in land use and tree cover between the 1960–70s and 1990s are analyzed. In both countries, there has been significant conversion of land from woodlands to agriculture. Tree cover has been more or less maintained over time in Uganda but has decreased in Malawi. Lastly, the paper explores the relationships between tenure and tree management using econometric techniques. Tenure is found to be linked to land-use and tree-cover change in both countries, though it is not necessarily the most important factor (e.g., population pressure is the key driving force for land-use change). In Uganda, conversion of land was more rapid under the customary tenure system and tree cover on nonagricultural land better maintained under the mailo system. In Malawi there was more rapid land-use conversion and tree cover depletion where there were more changes to traditional tenure systems taking place.

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1. INTRODUCTION

MOTIVATION FOR THE STUDY

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. Policymakers must face the challenge of identifying appropriate pathways for the use and management of natural resources in their jurisdictions and sets of policies that will steer their constituents towards these pathways. Unfortunately, policymakers in Sub-Saharan Africa have little information about the dynamic processes leading up to current land utilization patterns nor to related effects on the stock of natural resources and their productivity.

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, Pinckney, and Jaeger 1995; Dewees 1995). Another

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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). A third scale or observational level that is particularly lacking in empirical research might be called the community or landscape level (exceptions are Cline-Cole et al. 1990 for two sites in Nigeria and Southgate et al. 1991 for 11 sites within Ecuador). Given a sample of sufficient size, this level could offer a unique insight into the factors whose magnitudes are often constant across observations in household studies from a given village but whose aggregated averages are too crude across observations at a 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 will first endeavor to develop an analytical approach appropriate to improve our understanding of relationship between tenure and other factors on tree resource management at the community level. Second, the paper will provide new evidence as to how communities in the case study countries of Uganda and Malawi have managed their land and tree resources and what factors seemed to be most important in their decisions. This information is valuable to policymakers who continue to struggle with the twin objectives of alleviating poverty in the short run and in preserving the natural resource base in the long run so that future generations may have access to high quality income generating assets.

This paper is comprised of six sections. The first presents an introduction to the key issues concerning the determinants of tree cover change and elaborates on important analytical issues. The second section discusses tenure systems in Uganda and Malawi. Section 3 describes the study sites for the community level analysis of tree cover change. Section 4 presents theoretical and econometric models for land-use and tree-cover change in Uganda and Malawi. The results from the econometric analyses are discussed in Section 5. Lastly, Section 6 contains the key conclusions and implications of the study.

IMPORTANT ANALYTICAL ISSUES IN THE STUDY OF TREE MANAGEMENT

Conceptual Issues Regarding Changes in Tree Stocks

Trees serve many different purposes for households and communities. Therefore, ideally, one should analyze the different tree planting and management strategies of households and communities. This is because the different strategies may be determined by unique processes and factors. However, the many species, niches, and multi-purpose nature of many agroforestry systems complicate the classification of tree management strategies. These differences are all the more difficult to identify at the community level where different households may adopt similar tree species in similar configurations for different purposes. While acknowledging that the identification of these differences is important, we do not address such subtleties in this section. For the remainder of this section, we refer to the stock of tree resources per unit area as “tree cover” and to tree establishment, management, and harvesting systems as “tree management strategies.”

One distinguishing feature that separates trees from other types of long-term land improvements is that tree cover can grow and shrink without human interference through natural regeneration and fire and disease for instance.[1] That is, in addition to purposeful management of tree resources, there is a "biological supply side" implying that one cannot equate the *presence* of trees with *investment* in trees and increases in tree cover could simply result from neglect of the land by a land manager.

Another unique aspect of trees is their link with land tenure. First, it is well established that historically in Sub-Saharan Africa, the investment of labor in clearing of communal woodland was a necessary condition in establishing private rights to land (Ault and Rutman 1979; Noronha 1985; Bruce 1988). Second, in many societies, tree planting was seen as a way of establishing long-term rights to land (Fortmann and Bruce 1988). Third, certain tree species carry with them tenurial implications such as those that are customarily used for boundary demarcation or others that are viewed as "communal" trees (many types of indigenous fruit trees for example).

The observations above have implications on our analysis of investment in tree strategies. First, household level analyses are useful for understanding specific tree management objectives and strategies, whether the focus is on the household or community level. Second, careful attention must be paid to the treatment of tenure variables in the context of tree management. Some tenure variables cannot be viewed as

[1] This is not true of all species or of all purposeful tree systems such as a timber plantation.

exogenous given their strong links to trees. For instance, the duration of rights to land may be related to prior tree planting efforts.

Conceptual Issues Regarding Trees at the Community Level

Tree cover and tree strategies are found across virtually all tenure and land-use systems on a landscape.[2] Thus the study of tree cover, to be comprehensive, must cover an entire spectrum of landscapes and key decisionmakers managing the different lands. The reason for this is that the patterns of tree cover and the tree management strategies observed differ across tenure and land-use systems. For instance, tree cover density tends to be lower on agricultural land and higher on other land-use types such as forest and woodland. In the case of tenure systems, regardless of the degree of management of common pool resources, the vast proportion of tree planting is found on private agricultural land. Furthermore, trees on different landscapes are linked because there are complementary and substitution relationships between trees in different locations brought about because many of the tree products desired by households can be obtained by trees located anywhere on the surrounding landscape.[3]

Added to this complexity is the fact that tenure and land-use systems are often dynamic. Thus, changes in tree cover are the dresult of complex interactions of changes in

[2] The use of “tenure system” in this context is taken to be a broad classification such as “private” or “communal” within a customary tenure regime. A land-use system may be agriculture, woodland, bushland, forest, and wetland, among others.

[3] Restricted or limited rights of access to farm land, nonfarm land, and trees on these lands will affect the degree to which possibilities for complementarities or substitutions exist.

tenure, changes in land use, and changes in tree densities on each tenure/land-use niche. It is vitally important to take these different processes into account for they have their own "driving forces" and critical actors. For example, decisions on tree density on agricultural land may be purely an individual choice. However, the tenure conversion process by which the individual acquired his/her farm may have involved others such as state authorities, local authorities, clan leaders, and extended family members.

In summary, studies of tree cover change for the purpose of addressing issues of biomass supply must include the different types of land uses and tenures found across the landscape.[4] Past studies that have focused solely on the implications of forestland for biomass supply have limited usefulness. Furthermore, the analysis of the different niches must be made in an integrated manner owing to the interactions of trees and other production systems. Lastly, it is crucial in models of tree cover changes to distinguish among the different processes affecting tree cover change.

Conceptual Issues Regarding Tenure at the Community Level

Numerous studies at the farm level have been able to conceptually define and empirically measure several important tenure variables affecting farmer incentives. These include those related to the nature of land holdings (e.g., farm size), the nature of land rights, duration of land rights, and possession of formal tenure documents, among others. In comparison, there is very little understanding of tenure factors at the community level. How can the diverse set of institutions within a community be effectively aggregated and

[4] For certain objectives (e.g., biodiversity, fauna), studying the changes to forests alone may be sufficient.

captured? At very broad levels, major legal tenure systems such as customary, freehold, and state systems can be viewed as exogenous. Many other tenure variables are likely to be endogenous at the community level. For instance, customary systems may differ in a number of ways including the degree of individualization (the extent to which rights are held by families as opposed to the state or communal authorities), exclusivity, and property inheritance patterns.

Conceptual Issues Regarding Land-use and Tenure Conversion at the Community Level

The dominant types of conversions have been tenure conversions from nonprivate to private and land-use conversions from nonagriculture to agriculture land uses. While the two types of conversions are clearly related, we first discuss each separately beginning with tenure conversion.

The major tenure conversion in sub-Saharan Africa has been towards privatization of land rights in arable areas (Noronha 1985; Migot-Adholla et al. 1991). In the literature, this has been linked to population growth and commercialization of agriculture (Migot-Adholla and Bruce 1994). However, there are three factors limiting the rate of conversion. First, a household cannot cultivate unlimited land area and local customs (for meeting equity objectives) may not allow the conversion of an area larger than what can be cultivated by the household. Second, there may be transaction costs associated with converting land which stem from the community's desire to maintain woodlands, wetlands, and the like for equity, reducing exposure to risk, or long-term productivity reasons. These costs are likely to increase with the proportion of land already converted.

Third, these benefits from woodlands may also generate collective action for management of woodland resources that could impose restrictions on conversion of land.

Whether or not land use is changed before, during, or following a tenure conversion is an empirical issue and depends on the relative profits and associated risks of different activities as well as access to capital and other resources. Tenure change may be preconditioned on land-use change where chiefs may require conversion to agriculture (often more specifically to food crop production) as a prerequisite for allocating land. This is embedded in strong adherence to equity motives over commercialization considerations. While land use can change from crop-based agriculture to other land uses this is not widely observed except for allocation of fields to woodlots, pastures, or long fallows. Equally rare from observation appears to be endogenous conversion from private tenure to other types of tenure.

2. BACKGROUND ON CASE STUDY COUNTRIES OF UGANDA AND MALAWI

Uganda and Malawi were selected as case studies for two primary reasons. First, they are part of a multicountry study examining the role of tenure on tree resource management that also included Ghana, Nepal, Vietnam, Indonesia, and Japan. The set of seven countries was selected to represent a range of different tenure regimes. Second, these particular countries were selected from among a handful of candidates because of the availability of aerial photographs from different dates (so that changes in tree resource stocks could be evaluated).

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 $88/km^2$ and ranges between 51 and 319 in the districts containing our study sites (World Bank 1993). Langdale-Brown (1960) estimated dense forest area to be over 25,000 km^2 in the mid 1920s and over 11,000 km^2 in 1958. In 1990, estimated tropical high forest area was 7,000 km^2, representing about 3 percent of land area (World Bank 1993). The annual rate of deforestation (including all types of natural forests) was estimated to be about 0.9 percent between 1980 and 1990 (World Bank 1994). As 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. Trees are not only important for environmental stabilization, but there is also major demand on woody vegetation for energy needs, as it is estimated that about 90 percent of cooking and heating energy comes from wood (World Bank 1996). Given that the area under closed forest remains small, concern about the sustainability of woody biomass naturally directs one to the more abundant agriculture land, woodland, bushland, and wetland areas found on the landscape.

Malawi, as elsewhere in Sub-Saharan Africa, has experienced a significant change in its landscape cover. Although reliable figures are hard to come by, the Forestry Department estimates the annual deforestation rate to be 1.3 percent per year in the 1980s (World Resources Institute 1994). This has raised concern about the future supply of fuelwood and other tree products and environmental services (French 1986; Hyde and

Seve 1993; and Dewees 1995). Much of the deforestation is believed to be linked to conversion of miombo woodlands into agricultural land. This involves expansion onto steep slopes and other fragile lands in many cases. Per capita food production has declined over the 1980s and early 1990s. Moreover, Bojo (1994) presents data showing high soil erosion rates and the subsequent high costs to the Malawian economy, which is heavily agriculturally based (World Bank 1995).

TENURE SYSTEMS IN UGANDA

Across our study sites in Uganda, several land tenure systems were prevalent prior to 1975, and despite the *de jure* nationalization of all land in that year, the same tenure systems are recognized both in the perceptions of the population and in formal land tenure reform debates. The most widespread of the tenure regimes is customary land tenure, which is virtually the only tenure system operating in our eastern and northern 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 1900s, households had settled on lands and acquired strong permanent rights to specific parcels (Bazaara 1992). In some areas, power shifted from clans to chiefs following colonial intervention, but in 1966, the Ugandan government formally abolished kingdoms 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. All customary systems follow patrilineal rules of descent and, in our study region, inheritance is the most common method of land acquisition.

In the Buganda region of central Uganda, the major tenure system is the "mailo" tenure system. Vast tracts of land were given to notables and elites by the colonialists beginning in the early 1900s and were known as private "mailo" land. A large area of land (958 square miles) went to the chief of the Buganda, known as the Kabaka. Owners, lacking labor to till such large land areas, and wishing to attain esteem in the community, received fees, rents, or other payments (e.g., sharing of output) by settling tenants ("kibanja") on their land. Subsequently, landlords powers to evict tenants were restricted by a 1928 law that required full compensation for any investments. Later, in the 1975 land reform, all rents were abolished. Although only mailo owners may acquire titles to the land, many tenants have very strong rights over land they occupy, including the right to bequeath. Today, some mailo owners occupy and farm their land; however, in many areas, occupation of land is overwhelmingly by "kibanja" tenants.

Other nonallocated land in the Buganda region was initially classified as Crown Land and included land considered as "waste." During the reign of traditional rulers, this land was loosely administered by chiefs and was akin to customary land, though Muhereza (1992) describes the management of many of these areas as resembling open access. Settlers on these lands in the Buganda region face more tenure security risks than do settlers on customary land in other regions because this region surrounds the capital, Kampala. The insecurity arises from the allocation of leaseholds to wealthy individuals and elites. In some highly publicized cases, these new settlers have evicted families (renamed "squatters"), who had occupied the land for several generations. It is difficult to know how many evictions there have been, but the local populations are well aware of them. Some occupants on public land claim that the state administers the land while others mention the Kabaka. Because of this ambiguity and the increased potential for conflict over rights to these lands, we distinguish them from the customary areas in the eastern and northern sites and refer to such land as “public” land.

TENURE SYSTEMS IN MALAWI

While there are three major tenure systems prevailing in Malawi, state, estate, and customary, our study sites are almost wholly from the customary tenure sector and this paper will focus only on this tenure system.[5] The customary sector consists mainly of smallholders and a key distinction here is between matrilineal and patrilineal ethnic groups. When land was abundant, both systems vested land in chiefs and village headmen. The village headmen in turn would cede rights over specific tracts of land to families and family leaders. New lands could be opened through requests to family leaders and village headmen.

In the matrilocal cum matrilineal system practiced by the Chewa and Yao in our study sites, husbands moved to live in the wife’s village and land was traditionally passed from mother to daughter or from family leader to female family members (Mkandawire 1983/84). Again traditionally, the couple often resided permanently in the wife’s village.[6] Matrilocal systems are distinct from those matrilineal systems where the couple moves to or

[5] The customary sector is estimated to occupy about 70 percent of land area. For more information on the state and estate tenure systems see Dickerman and Bloch (1991).

[6] This system is akin to matrilineal systems observed in some parts of Asia, such as Sumatra (Otsuka et al. 1997).

otherwise resides in the husband's village and the husband would acquire land from a village headman or family leader in his village. In this case, land would then pass from uncle to nephew or niece (perhaps through the family leader). This practice was virtually absent among our sampled households. We also found that traditional matrilocal and matrilineal practices were being circumvented by households who relocated to husband's villages or to new villages.

A patrilineal (and patrilocal) system, common in the north of Malawi, is similar to those elsewhere in Sub-Saharan Africa in that men claim land ownership and can pass on all land and property to their children. Married couples reside permanently in the husband's village. It has been customary among the Ngoni and Tumbuka at our sites to favor sons over daughters in inheritance practices.

The various modes of transfer and tenure arrangements might have different incentives on farm and tree management due to differences in tenure security. Land that passes through inheritance from parents to children, including from mother to daughter, seemingly offer the appropriate incentives to households to make long-term investments (labor and capital) on the land. While these appear to be the majority of cases in matrilocal systems, two types of situations are of concern with respect to the tenure security of males in our sample areas. The first is where husbands reside in the wife's village on what they believe will be a temporary basis; they may desire to leave their wives' villages to gain independence from the wives' families, to be able to pass on land to their sons, or to take up more favorable income generating opportunities. Each of these motives can reduce their incentives to work in their wives' villages. A second case concerns rights to land following death or divorce of a spouse. Upon divorce, the husband must leave the wife's village and similarly, following the death of the wife, the husband's rights to residence are not at all guaranteed (traditionally, they would be expected to return to their village). Where either a death or divorce becomes more likely, the nonresident spouse is likely to increase activities that enhance short-term returns at the expense of long-term returns. These have been hypothesized in the literature as hindering agricultural development (e.g., Dickerman and Bloch 1991; Nankumba 1994) under the assumption that males are the key decisionmakers over long-term residence and investments and therefore the tenure security of men acts as the critical constraint (Mkandawire 1983/84).

The customary sector includes both private and communal lands. The process of privatization in Malawi mainly concerns the permanent allocation of land to households primarily for cropping purposes. As a consequence of high population densities, farm holdings in much of Malawian customary land are small. There are also communally held lands, held by the clan or village headman, which are reported to be virtual open-access resources, with few rules on user group membership or use rates (Coote et al. 1993a; 1993b). One notable exception is the Village Forest Area system initiated in the 1920s, rekindled recently by the Forestry Department, in which communities demarcate woodland areas to be placed under special management rules (which are always conservation oriented). To date, these are very few in number and those in operation are very small in size.

3. METHODOLOGY AND DESCRIPTION OF STUDY SITES

SAMPLING

The sampling units chosen in both countries reflected units defined by the respective governments. In Uganda, the sampling unit was a parish, which is the smallest administrative unit for which georeferenced boundaries are known (they average 30 square kilometers in size). In Malawi, the unit selected was a census enumeration area and the average was 12 square kilometers in size. The boundaries of both parishes and enumeration areas were created by the governments to contain roughly similar sizes of population. Thus, in areas of high population density, the administrative areas are smaller whereas in low population density areas, they are larger. In Uganda, the parish also relates to a decision-making entity (the Local Council 2 level). In both Malawi and Uganda, these boundaries are drawn so that villages rest entirely within a single unit. We found that in Uganda, there were often five or six villages in a parish; in Malawi, we found two or three villages in a census enumeration area. The group surveys therefore sought representation from multiple villages.

To achieve the purposes of the study, the selection of sites required variation in land tenure systems, variation in population density, and availability of aerial photographs. The last criterion was not constraining in the case of Malawi, where countrywide aerial photographs are available for several dates, including the early 1970s and the mid-1990s. In Uganda, coverage of old aerial photography flown between the late 1940s to early 1960s is extensive, while recent (late 1980s to mid-1990s) aerial photography is highly selective. The widest recent air photo coverage was a wide strip north of Lake Victoria and south of Lake Kyoga starting from the Kenyan border in the east up to Kiboga District in the west. Where recent air photo coverage is missing in Uganda satellite images are available which were used in this study as well.

A second factor considered in sampling was tenure system. In Uganda, this is relatively easy to account for because the major tenure systems have well known boundaries that correspond closely to current district boundaries. Similarly, in Malawi we ensured a variation in customary tenure system (patrilocal vs. matrilocal) by sampling across different geographical regions.

The final variable of concern, population density, was not explicitly accounted for in the sampling procedure as it was felt that sufficient variation would emerge by following a random selection process based on geographical stratification. After stratifying by 11 districts in Uganda and by four broad regions in Malawi, samples were drawn randomly.[7] In Uganda, 64 parishes were selected for study from the districts of Kiboga, Luwero, Mukono, Kamuli, Iganga, Tororo, Mbale, Kumi, Lira, and Apac. In Malawi, 57 enumeration areas were analyzed more or less in equal numbers from north (Mzuzu Administrative Development Division, or ADD), north-central (Kasungu and Salima ADD), south-central (Lilongwe and Mchinji ADD), and south (Machinga and Blantyre ADD).

[7] Exceptions were urban centers and state-protected areas that were excluded. In Uganda, we also excluded extremely large parishes (of over 150 km^2) as we felt we could not obtain reliable field information for such sizes. This excluded less than 2 percent of parishes.

DATA COLLECTION MEASUREMENT OF VARIABLES

The data for this study came from three primary sources. The land-use cover and tree density data were generated entirely from aerial photos and satellite imagery, which were checked in the field. The variables hypothesized to affect land-use and tree cover were obtained either from secondary sources or from socioeconomic field surveys. Following discussions about the data sources and methods of data acquisition, mention will also be made about the analytical methods used.

Land-use cover data were acquired from a combination of aerial photography and satellite imagery in Uganda, and exclusively from aerial photography in Malawi. Tree cover estimates could only be obtained from aerial photography. Thus, in Malawi the number of sampling units for land-use and tree-cover change are identical, while in Uganda land-use figures are available for a greater number of parishes than are tree density figures.

In both countries, remote sensing data were acquired for two distinct periods of time. In Uganda, photos from eight different flight contracts were used and these were flown between 1948 and 1961. However, almost all were taken between 1957 and 1961. The recent aerial photography used was mainly flown in 1995 covering 42 parishes. In Malawi, aerial photographs were used for both periods of assessment, i.e., the 1971–73 period and then 1995. We used the year 1960 for Uganda and 1971 for Malawi as the year for which we collected information on initial conditions of explanatory variables such as population density.

Land-use Cover

A classification scheme was developed to describe land-use cover. Agricultural land includes all land for which a discernible field pattern could be detected with a whole complex of covers ranging from crops, fallows, grazing patches and clusters of trees and woodlots. Wooded land was divided into four types: plantations, tropical forests, woodlands, and bushlands. Although data were collected for each, in our analyses, plantations and forests were grouped together as were woodlands and bushlands. Remaining land was further disaggregated into grasslands, wetlands, urban land, barren land, and water. More details for land-use and tree-cover classifications can be found in Breyer (1996).

Tree Cover

Forests either were closed (100 percent tree cover) or slightly degraded (80–100 percent cover). Four subclasses of woodland/bushland and wetlands were distinguished based upon tree and shrub crown (or canopy) cover. Using woodlands as an example, open woodland has a crown cover density between 2 and 20 percent. Medium woodland has a crown cover density between 20 and 40 percent. Dense woodland has a crown cover between 40 and 60 percent. And finally very dense woodland has a crown cover density between 60 and 80 percent. For agricultural land, a different tree cover methodology was used. In Uganda, it was decided to sample agricultural land areas, calculate the proportion of area under tree cover in each sample area, then take the average of the samples as an indicator of aggregate tree canopy cover in agricultural land within a parish. In Malawi, agricultural tree cover was mapped according to ranges of cover, but bounds were much tighter than for nonagricultural land (e.g., 0–2 percent, 2–10 percent, 10–20 percent, and 20–40 percent).

Explanatory Variables

A field survey was administered at each of the sites (parishes or census enumeration areas) to collect information on hypothesized explanatory variables and to provide additional information about the characteristics of woody vegetation. The survey was administered to groups (comprising elders, local leaders, and extension, among others) in each site and generally took three to four hours to complete. The survey included sections on proximity of the site to markets and infrastructure; demographic variables; farming systems and livestock holdings; common tree species and characteristics; tree management interventions and markets for tree products; and tenure regimes and associated rights to land and trees. To the extent possible, questions distinguished the base year situation from the current (1995–96) situation.

Unique to Uganda was the participatory drawing of broad tenure boundaries (i.e., between customary, mailo, public, and leasehold tenure regimes) within parishes overlaid on remote sensing images. In Malawi, a similar approach was planned, but we found that customary tenure occupied all land in nearly all sites. Due to the complexity of cultural practices and tenure systems in Malawi, we also implemented a household and plot level survey to better assess key variables such as patterns of residence and mode of land acquisition. Other explanatory variables were taken from secondary sources. This includes population, average annual rainfall, soil type, soil texture, and elevation.

DESCRIPTIVE INFORMATION

General Description of Sites

Table 1 displays the means of important explanatory factors hypothesized to affect land-use and tree-cover change. There is considerable similarity among the set of sites in Uganda and Malawi in terms of population density, population growth and distance to tarmac. One notable difference is with respect to rainfall, where the Malawian sites were significantly drier than those in Uganda. Although there is a distinct drier zone encompassing the northernmost sites in Uganda, most of the Ugandan sites are in favorable agricultural zones with two rainy seasons. It is important to mention that each of the variables exhibited a high degree of variation across sites within a country. Many different cropping systems are found in the Ugandan sample, banana, coffee, maize, and sorghum to name a few. The Malawian sites, on the other hand, are unified by their emphasis on maize. There have been noted cases of pest, disease, and drought, in both countries, but perhaps the most noteworthy event affecting the use of land was the Ugandan war of the 1980s which, among other things, led to displacement of people in some of the sites. More details of site characteristics can be found in Place and Otsuka (forthcoming).

Table 1—Means of some key explanatory variables

Variable	Uganda	Malawi
Population density (Uganda: 1960, Malawi: 1971)	79	65
Annual population growth	4.5	4.1
Distance from site to major city (km)	181	120
Distance from site to tarmac (km)	25	25
Average annual rainfall (mm)	1230	915
Percentage of land in customary tenure	50.2	100.0
Percentage of land in mailo tenure	39.4	–
Percentage of plots acquired through the wife's family	0	46.0

Source: IFPRI-ICRAF (1996); Uganda Ministry of Finance and Economic Planning (MFEP) (1992); FAO (1984); Green and Mkandawire (1997).

Tenure Variables Uganda. As indicated above, there were three main types of tenure regimes whose boundaries remained fixed throughout the study period in the study areas. Customary land was found in 37 (58 percent) of the parishes. Customary land covered the entire parish area in 30 parishes and it occupied about 50 percent of all land in the study area. The mailo land tenure system was found in 29 (45 percent) of parishes and comprised 39 percent of all land area in the study. Within mailo land, we were also able to identify the approximate 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 (38 percent) of parishes, occupying about 10 percent of total land area.

In all tenure categories, individual rights to plant trees and to cut nontimber 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 of the legal protection for these species. As for land rights, in only a few cases was the unrestricted right of sale noted. Nearly all of these cases were in mailo land (where 55 percent of parishes reported prevalence of unrestricted rights). On the other hand, the unrestricted right of sale did was not common in any of the customary land areas surveyed or in 15 of 16 public land areas. 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. A recent study found that despite high rates of privatization of land rights, secondary rights to certain resources (e.g., grasses and firewood) remained strong under different tenure systems in Uganda (Baland et al. 1999). The higher percentage within the mailo tenure category may reflect the fact that large and often absentee owners are unable to enforce exclusion rights and that it is mainly on the larger mailo farms where supplies of such communally used resources are found.

Malawi. The major difference between customary tenure systems in Malawi was in the pattern of land inheritance. Over 90 percent of all sampled parcels were acquired from parents, with about 46 percent determined to have been through the wife's side of the family. The prevalence of matrilineal inheritance systems is strongest in the south, weakest in the north where patrilineal systems dominate, and is moderate in the transitional north-central zone. The Chewa, a traditional matrilineal and matrilocal group, was the most prevalent group, found in 48 percent of enumeration areas. In our sample, 30 percent of enumeration areas had other matrilocal or matrilineal groups as a majority, while 23 percent of enumeration areas reported that patrilineal groups were the most prevalent.

Further questions regarding land rights and markets did not produce much variation in response. For instance, there was not one purchase of land among the 570 households surveyed and the right of sale was not recognized by any of the communities surveyed. Likewise, there was little variation in responses by groups to questions on other land and tree rights.

Land-use Cover and its Change

For discussion purposes, the land-use cover classifications have been grouped into agriculture, forest or plantation, woodland, bushland, and wetland. The figures in the tables are simple averages across observational units (parishes or enumeration areas).[8]

Uganda. Table 2 shows the broad land-use patterns as of 1960 and 1995 (across 64 parishes) in Uganda. Agriculture was the most widespread land use in 1960 and in 1995. The share of land under agriculture increased over the period from .57 to .70. The increase in agriculture came largely at the expense of bushland and woodland whose share fell from .28 to .18 during the same time period. Forested land also saw its share cut in half over the period from .04 to .02. On the other hand, wetland area remained fairly constant at .11 in 1950s and .10 in 1990s. Some wetlands were found to be difficult to convert due to perennial waterlogging.

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[8] Using a weighted aggregation, the proportion of land under agriculture would be lower since the sampling units for which the share of agriculture is low are generally larger (because of the relationship to relatively low population density).

Table 2—Land use in Ugandan and Malawian sites at two points in time (share of land under each land-use category)

Country	Land Use	Time Period	
Uganda		1960	1995
	Agriculture	.57	.70
	Woodland/bushland	.28	.18
	Forest	.04	.02
	Wetland/grassland	.11	.10
Malawi		1971-73	1995
	Agriculture	.52	.68
	Woodland/bushland	.33	.19
	Forest	.01	.01
	Wetland/grassland	.14	.13

Source: IFPRI-ICRAF (1996); Green and Mkandawire (1997); Breyer (1996).

In Malawi, the data on land-use change paints a similar picture as in Uganda, though the change seems to have occurred in a more rapid manner (Table 2). The share of land in agriculture increased over the 1971-95 period from .52 to .68 across all study sites. There was substantial variation among the study sites, with the range being from +.73 to –.32. This expansion came almost exclusively from woodlands and bushlands, whose share of land area fell from .33 to .19. The remaining land-use categories remained nearly constant: wetlands at around .14 and forests at around .01.

Tree Cover and its Change

Uganda. Table 3 shows the simple average tree cover canopy across sample sites in 1960 and in 1995. The proportion of area under trees has remained nearly constant at

.31.[9] Movements in aggregate tree cover change are influenced by two key processes, change in land use (see above) and change in tree density on particular land uses. The change in land use has had a negative impact on aggregate tree cover since forests, woodlands, and bushlands, which have been reduced, have traditionally had higher proportions of tree cover than agriculture. However, tree cover densities on the specific land-use categories did not remain constant. The most impressive increase was found on agricultural land. Our samples found that while in 1960 average proportion area under trees was .23, in 1995 the proportion had been increased to .28. This increase partially offset the negative effect of land-use change on tree cover (i.e., reduced area under forest and woodland) and led to the realization of a constant aggregate tree cover. Average tree cover on woodlands and bushlands decreased slightly from .44 to .42. Tree cover density on forested land (see the definition above) was unchanged at .97 and that on wetlands was unchanged at .17. Given these changes, the contribution of agricultural land to total tree canopy (taking into consideration proportion of area and tree density) increased from 35 percent in 1960 to 58 percent in 1995.

[9] Recall that data on tree cover is from 42 parishes rather than the full 64 used for land use change. This excludes the northern districts of Apac, Lira, and Kumi that would be expected to have a lower tree density due to their dryness.

Table 3—Tree cover in Ugandan and Malawian sites for two points in time (proportion of land under tree canopy cover)

Country	Land Use	Time Period	
Uganda		1960	1995
	Agriculture	.23	.28
	Forest	.97	.97
	Woodland/bushland	.44	.42
	Wetland	.17	.17
	Aggregate	.31	.31
Malawi		1971–73	1995
	Agriculture	.02	.02
	Nonagriculture	.24	.17
	Aggregate	.17	.10

Sources: IFPRI-ICRAF (1996); Green and Mkandawire (1997); Breyer (1996).

Malawi. Table 3 displays some summary statistics pertaining to tree canopy cover across the enumeration areas. In 1972, the average canopy cover was estimated to be about 17 percent, but the median was much lower, at 9 percent. By 1995, tree cover had fallen to an estimated cover of 10 percent (the median being only 3 percent). There are significant differences in tree cover according to whether the primary land use was agriculture or not. Table 3 shows that tree canopy cover in agriculture land was very low in the sites, estimated to be only around 2 percent in both years. This level of cover has remained constant across most enumeration areas as noted by the fact that the change in absolute tree cover was between –02 and +.01 for 80 percent of the sites. Tree cover in nonagricultural areas was much higher, but has shown a more marked decline. From a level of about 24 percent in 1971, tree cover in nonagricultural areas has dropped to 17 percent.[10] As many as 44 sites experienced a decrease in nonagricultural land tree cover, while nine showed an increase.

4. THEORETICAL AND ECONOMETRIC MODELS OF TREE COVER CHANGE AT THE COMMUNITY LEVEL

THEORETICAL FRAMEWORK AND HYPOTHESES

As mentioned in the introduction, there are two types of decisions of concern: decisions concerning the choice of land-use system and decisions concerning the management of trees within the resulting land uses. We hypothesize that land-use choice is linked primarily to two key factors: the expected profits from alternative land uses and the costs (ease) of conversion from one land use to another.[11] We now analyze these decisions in Uganda and Malawi under the assumption that there are two land uses available to households and communities, agriculture and woodland. More detailed theoretical models are developed for Uganda and Malawi in Place and Otsuka (forthcoming), and Place and Otsuka (1997), respectively.

In Uganda, there are three types of exogenous tenure systems in which to analyze land-use and tree-cover decisions. In customary land, evidence indicates that the use of

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[10] Again, note that because the northern enumeration areas are larger and have a greater tree density, the weighted average tree cover for Malawi would be much higher than indicated by our simple averages across sites.

[11] Considerations of risks (e.g., climatic risk) may play a more important role if individuals are risk averse.

woodlands is virtually open-access. As such, expected profits from woodlands are low and there are strong benefits from conversion to private tenure and agriculture. Moreover, conversion is not restricted by tenure institutions that follow the common rules of accommodating land demands from new households and rewarding the conversion of land with stronger individual rights to land.

The case of mailo land is quite different, due principally to the restrictions on tenancies that have arisen from land tenure policy and resulting distortions on land use. Mailo owners now have strong incentives not to “lease” land to tenants. Because land is unevenly distributed in mailo areas (there are still some relatively large landowners remaining) the restrictions on leasing/renting, along with possible inefficiencies of crop production due to labor supervision costs (as found in Asia, see Hayami and Otsuka 1993), tend to preserve uncultivated areas (e.g., woodlands or grazing lands). Leasing/renting could equally have emerged in customary land, but the relatively equitable distribution of land did not provide the necessary incentives for this to occur. This reinforces the tendency that the proportion of agricultural land is lower in mailo land than in customary land (and thus more areas with high tree cover). The tenure security of mailo owners is essentially independent of land-use patterns while in the case of public land, conversion to agricultural land has been regulated to some degree by the State. Lastly, there is no counterpart on mailo or public land to the customary institution to provide land to all its members. Thus, we hypothesize that, other things being the same, the rate of conversion to agricultural land is higher in 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 in private mailo owned by resident owners who usually manage their lands directly, and have both incentives and capacity to manage land and tree resources intensively. Mailo tenants also have strong planting rights with the exception of a few high-value timber trees. Therefore, we hypothesize that tree densities are highest in mailo land and lowest in public land where uncertainty and insecurity has been evidenced in some areas and at some times. We also hypothesize that within mailo land, areas managed by resident owners have greater tree density than those managed by absentee owners, as the latter have less control over the disposition of trees. Farmers in customary land may have strong rights to plant trees and the action of tree planting can help strengthen one's rights in land. We therefore expect tree densities on agricultural land to be higher in customary land than on public land, but expect no difference in tree cover in nonagricultural land since tenure is essentially open-access in both cases.

In Malawi, as in Uganda, it has been noted that there are few management rules regulating the use of woodlands. Thus, woodlands tend to be open-access which means that individuals have incentive to degrade or convert woodlands whenever they can gain short-term profit by doing so. In comparing the incentives for degrading or converting land between matrilocal and patrilocal households, there appears to one overriding factor. Because husbands in patrilocal households have greater security of tenure (in many, but not all cases), they will have higher expected profits from agriculture than their matrilocal counterparts. Thus, given that men are the primary decisionmakers regarding land use, we hypothesize that incentives for conversion are greater among patrilocal households.

We expect that where tenure security for males is greater, more sustainable land-use systems are chosen by men. In our case, this implies greater investment in tree planting or preserving tree resources in patrilocal rather than in matrilocal systems. However, because open-access seems to prevail in woodlands throughout Malawi, we anticipate that such differences will only be observed on agricultural land. Thus, for woodlands, our hypothesis is that there are no significant differences in tree cover under the different customary systems. In the case of agricultural land, we were unable to test the hypothesis because there was hardly any variation in tree cover change on agricultural land (this itself suggests that residence patterns have had little impact on tree cover on agricultural land).

Econometric Testing

Although expected profits feature as a key factor in our framework, we have no way of directly measuring the profits of alternative activities. Instead, we use proxies to reflect prices and productivity, and include tenure variables to proxy for the probability of realizing expected returns. Prices are determined by relative factor endowments and market access and these are captured by population density, proportion of land under agriculture in base year, distance to paved road, and distance to major urban center. Productivity is captured by environmental variables such as soil type and annual rainfall.

In Uganda, tenure refers to the three broad tenure regimes found in the study sites: mailo, public, and customary tenure. Specifically, the proportion of land under each of two tenure categories was used as explanatory variables (the third tenure category is the base case for comparison). These tenure measures can be reasonably considered as exogenous to the communities. Some further distinctions within these categories, such as the degree of individualization of rights or the degree of absentee ownership in mailo tenure, are also tested.

In Malawi, the tenure variable is the proportion of plots acquired through the wife's family and as such is an index of the importance of the matrilocal system. This variable should rightly be treated as endogenous since there appears to be quite a bit of latitude within communities and families insofar as land acquisition methods are concerned. We do include this as dependent variable in a single equation model and present the results. Using this variable, actual or predicted, in second stage regressions on land-use change, tree cover change, or yield change resulted in insignificant coefficients in all cases. However, we found that by interacting the tenure variable with geographical (and therefore ethnic) zone, some interesting results are obtained. Unfortunately, it is difficult to endogenize the interaction terms through estimation and the tenure variables are therefore assumed to be exogenous. In all cases, we estimate the equations independently. In Malawi, we also estimated the three natural resource management equations simultaneously using three-stage least squares. Those results are essentially the same as those reported here.

The econometric models tested are as follows:

Econometric Models Tested and Methods Applied	
Uganda	
Land-use change	*f* (tenure, profit indicators, productivity indicators)
Method	OLS, 64 observations
Tree-cover change in agricultural land	*f* (tenure, profit indicators, productivity indicators)
Method	OLS, 42 observations
Tree-cover change in nonagricultural land	*f* (tenure, profit indicators, productivity indicators)
Method	OLS, 67 observations (from 42 sites)
Malawi	
Proportion of plots acquired through matrilineal ties	*f* (profit indicators, productivity indicators, ethnic variables)
Method	Two-stage least squares, 57 observations
Tree-cover change in nonagricultural land	*f* (tenure, profit indicators, tree characteristics, yield change, land-use change)
Method	Two-stage least squares, 57 observations
Land-use change	*f* (tenure, profit indicators, productivity indicators, tree-cover change, yield change)
Method	Two-stage least squares, 57 observations

5. EMPIRICAL FINDINGS

Before turning to the specific findings, it should be emphasized that the explanatory power of the models is very high. In Malawi, adjusted R-squared measures ranged from .52 to .80 in most equations and in Uganda the same values ranged from .52

to .72. There were also several significant variables in each equation and these are now discussed in more detail.

UGANDA

The results in Table 4 indicate that the type of land tenure regime affects the change in agricultural land share. Customary tenure 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. This may be related to the fact that there are some controls over conversion of these lands on part of individual owners (mailo land) and the government (public land).

Table 4—Two-stage least squares independent regression models for Uganda

Variable	Change in Share of Agricultural Land	Tree Cover on Agricultural Land	Tree Cover on Non-Agricultural Land
Constant [a]	.012 (0.71)	.523** (2.21)	-.837** (-3.12)
Share of customary tenure	.181** (2.08)	.047 (0.69)	-.052 (-1.00)
Share of mailo tenure	.026 (0.28)	.187* (1.91)	-.011 (-0.27)
1960 population density	.0020** (2.52)	.00035 (0.32)	.0010 (0.88)
1960 population density squared	-.000003** (-1.96)	.0000003 (0.29)	-.000003** (-2.49)
Population growth (predicted)	0.33** (2.00)	-.0127 (-0.65)	.065** (2.79)
Number of dry days	.0008 (0.90)	.00001 (0.01)	.0055** (3.76)
Sandy soil	– –	-.129** (-2.85)	.181** (3.40)
Distance to paved road	.0022** (2.60)	-.0028** (-2.64)	.0028** (2.29)
Distance to Kampala	-.00002 (-0.07)	.0002 (0.43)	-.0004 (-1.20)
1960 share of agriculture land	-.651** (-7.67)	-.362** (-3.26)	.356** (2.90)
1960 agricultural tree cover	– –	-.971** (-6.41)	-.291* (-1.93)
1960 nonagricultural tree cover	– –	-.076 (-0.76)	-.520** (-5.29)
Coffee important crop	– –	.063 (1.45)	– –
Adjusted R-squared	.59	.72	.52

Note: ** –significant at 5 percent level; * –significant at 10 percent level.
a. t-statistics in parentheses

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 nonlinear decreasing rate. 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 and the value of the resources in nonagricultural land may rise sufficiently to warrant some regulation or protection. 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. This is likely due to the simple fact that land near main roads was heavily populated and already converted in response to market opportunities prior to 1960.

Table 4 also shows the results from the tree cover change regression on agricultural and nonagricultural land respectively. 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). 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 as opposed to absentee owners (both of which may include numerous tenants). These results (not shown here) support our hypothesis that the highly individual rights to land and trees in mailo land (compared to public land) lead to greater incentives for long-term investment in trees, especially where mailo owners are resident. No other tenure variables were statistically significant, including none in the nonagricultural land regression. This indicates, *inter alia*, that trees on nonagricultural land are managed similarly under different tenure systems.

Population density and population growth had much less impact on tree cover change than on land-use change. The exception was the positive and statistically significant relationship between predicted population growth and tree cover in nonagricultural land. The reason for this is not apparent but the variable may be picking up the effect of the 1980–86 war, which may have simultaneously ravaged vegetation cover and lowered population growth in these sites.[12] This indicates that although increased population unambiguously leads to conversion of land to agriculture, the effect of population on tree cover or its change on agricultural or nonagricultural land is ambiguous.

Though there are several other statistically significant results, we highlight only three. Distance from a paved road was negatively related to the change in agricultural tree cover change. This is the expected effect if market access leads to more favorable prices for outputs and induces adoption of tree planting for coffee/shade, fruit, and fuelwood. Table 4 also indicates that proximity to paved roads has adversely affected tree cover in nonagricultural lands. Both results together suggest that in areas near paved roads incentives for exploiting trees are greater; only in agricultural land, where tenure is individualized, has this led to improved long-term tree management. The coffee variable was not significant, showing that tree cover change did not depend exclusively upon increased coffee plantings, though these certainly did contribute to improved tree cover.[13] Lastly, it is worth noting the significance of the 1960 tree cover variable. The strong negative signs on the 1960 tree cover variables indicate that individuals and communities are induced to react to the increasing scarcity value of trees by planting and protecting

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[12] Indeed the effect disappears when a dummy variable for parishes strongly affected by the war is included. The war dummy itself was not significantly related to land-use or tree-cover change when included.

[13] Our data indicate that tree cover change was greater in parishes where coffee was important than where it was not. However, these coffee-growing parishes have favorable climate and infrastructure, which promote the adoption of noncoffee tree species. Lastly, as earlier mentioned, a great deal of coffee is intercropped with other trees in agroforestry systems.

tree resources. This is especially true in the case of agricultural land as evidenced by the high coefficient estimate.

MALAWI

The first column of Table 5 shows the results of a regression model explaining the prevalence of the matrilocal system. While our study design (rapid community survey) is not well suited to the explanation of tenure arrangements, the results are reported for two reasons. First, an understanding of the relationships between tenure and other variables sharpens the interpretation of the results in the main regressions. Second, it was deemed important to demonstrate that relationships between tenure and other variables can be quantified at suprahousehold levels. About two-thirds of the variation was explained by the included explanatory variables. Prevalence of the matrilocal system was found to be related to the southern zone, to the non-Chewa matrilineal groups, closer proximity to paved roads, and further distance from major cities. These results indicate that the non-Chewa groups are more likely than the Chewa to retain their traditional matrilineal practices and differentiate themselves from patrilocal groups. Chewa, especially in the nonsouthern zone, are more likely to be changing. In areas more remote from major cities, traditions appear to be better maintained. Proximity to roads has the opposite effect of proximity to cities and is difficult to explain. Interestingly, neither population pressure nor population growth had a significant impact on the pace of change in traditional inheritance practices.

Table 5—Two-stage least squares regressions for extent of matrilineal system, land-use change, and tree cover change in Malawi

Variable	Extent of Matrilineal System	Change in Share of Agricultural Land	Tree-Cover Change on Nonagricultural Land
Constant	-13.762 (-1.22)	-.919* (-1.84)	.406* (1.74)
North-central zone	-.039 (-0.24)	-.099 (-0.70)	-.441** (-3.46)
Southern zone	.309** (2.16)	-.081 (-0.56)	-.423** (-4.78)
Pct of population of main ethnic group	.0002 (0.10)	– –	.0004 (0.93)
1970 population density	.007 (1.19)	.011* (1.95)	.002 (0.46)
1970 population density squared	-.00003 (-1.04)	-.00005* (-1.65)	-.00001 (-0.50)
Log of distance to tarmac	-.061** (-2.32)	-.011 (-0.61)	.003 (0.25)
Log of distance from tarmac to major city	.065* (1.94)	.028 (1.14)	-.026** (-2.52)
1970 log of yield	– –	.108** (2.01)	– –
1970 share of land in agriculture	-.006 (-0.03)	-.588** (-3.00)	-.109 (-0.93)
1970 woodland tree cover	– –	– –	-.748** (-6.06)
1970 census area tree cover	– –	-.272 (-0.59)	– –
Proportion of trees that coppice well	– –	– –	.045 (1.37)
1970 percentage of Village Forest Area to total area	– –	– –	.002** (2.83)
Log of trees planted by external projects	– –	– –	-.001 (-0.23)
1970 pct of households with cattle	– –	.002* (1.66)	.0004 (0.84)
Mean Altitude	– –	.00009 (0.98)	– –
Average years since plots acquired	.007 (1.23)	– –	– –
Chewa ethnic group	-.126 (-1.37)	– –	– –
Patrilineal ethnic groups	-.201** (-2.66)	– –	– –
Percentage of plots acquired by women in north zone	– –	-.419 (-1.15)	-.569** (-4.35)
Percentage of plots acquired by women in north central zone	– –	-.011 (-0.07)	.179* (1.89)
Percentage of plots acquired by women in south zone	– –	-.158* (-1.66)	.044 (0.63)
Population growth[a]	.022 (0.59)	.020 (0.67)	.003 (0.15)
Change in woodland tree cover[a]	– –	-.780** (-1.99)	– –
Change in yield[a]	– –	.107 (1.18)	-.112** (-2.82)
Change in share of agricultural land[a]	– –	– –	-.143 (-1.25)
Adjusted R-squared	.59	.46	.69

Note: Figures in parentheses are t-values. Regressions are corrected for heteroscedasticity.

** significant at 5 percent level; * significant at 10 percent level.

a. Fitted values from first stage instrumental variable regression used.

Both tenure and population density had statistically significant impacts on land-use change. Conversion of woodlands into agricultural land was accelerated in patrilocal areas relative to matrilocal areas, but in the southern region only. Within the southern region, more patrilocal practices indicate areas experiencing more profound changes to the traditional system. Thus, greater change in the traditional tenure system is associated with greater land-use conversion. Population density has the expected positive, but diminishing effect on the rate of conversion of woodlands to agricultural land. Population growth, however, was not significantly related to conversion.

The initial share of agricultural land was negatively related to conversion as expected. The log of yield was significant and had a positive effect on conversion also, as expected. Greater conversion to agriculture is associated with faster loss of nonagricultural tree cover. This would be anticipated if the resulting loss in tree cover lowered profits of woodlands relative to profits from conversion to agriculture. Finally, conversion to agricultural land is associated with a greater percentage of households with cattle in the initial period. This is contrary to the notion that households with cattle would prefer to retain more woodland cum grazing land.

The change in woodland tree density is found to be related to tenure, but not in the manner hypothesized earlier. In the northern region, more matrilocal systems led to faster decline in tree cover. However, in the north central region, the presence of matrilocal systems appears to increase tree cover. Tenure did not play a role in the more densely settled southern region. A consistent explanation for this is that faster loss of trees is associated with the influx of migrant groups, the matrilineal groups into the patrilineal north and the patrilineal groups into the Chewa dominated north central. These types of households may well have different long-term strategies than indigenes and make the creation and enforcement of conservation rules more difficult.

We found that the proportion of land under Village Forest Areas had a positive effect on tree-cover change (as seen in smaller decreases in tree cover). These were identified by respondents as specially managed areas, implemented with the assistance of the Forest Department. Since our surveys suggested that these areas are very small, the presence of a Village Forest Area may also proxy for a broader interest in managing tree resources. The change in tree density was strongly and negatively related to the initial period tree cover, suggesting that change is more rapid when the scarcity value was lower. Tree cover loss was found to be more severe in areas further from major cities. This is contrary to expectations, but may simply mean that woodlands nearer to cities were cleared prior to 1970 (this would be expected under virtual open-access conditions). Tree cover loss was also greater where yield change was higher (less negative). This is not self evident, but it may be that yield losses are not as great in areas where tobacco is more prevalent (residual impact of fertilizer use) in which case we would expect greater removal of trees for tobacco drying. Finally, tree cover change is related to region. There has been greater tree density loss in the north-central region, characterized by estate development and high wood demands for tobacco drying and curing. There has also been greater tree density loss in the southern region, where demand for wood for fuel and shelter is acute.

6. SUMMARY AND IMPLICATIONS

Our data find, that given current conditions and institutions, conversion of land into agriculture will continue with its negative consequences on tree cover. In Uganda, the effect is mitigated significantly by relatively high tree densities on farms. Aggregate tree cover was the same (.31) in 1960 and 1995. In Malawi, tree cover on farms is very low with little change. Off-farm, there is evidence of significant depletion as tree cover has declined by about 33 percent between 1972 and 1996. Thus, off-farm sources continue to provide a substantial amount of tree products to households and have not been replaced by agroforestry systems on farms.

What may contribute to the differences between Uganda and Malawi? A number of factors may play a role. First, there is likely more competition for land from crop enterprises in Malawi where farmers must produce all their food crops in a single rainy season. Second, the coffee and banana systems found in many of the Ugandan sites are highly suited to integration with trees. Third, most types of vegetation grow better in Uganda due to favorable ecological conditions. Fourth, until very recently, Malawian farmers had a single parastatal source for all agricultural inputs. While this proved adequate in the provision of inputs necessary for maize production, it offered virtually no other options for farmers, including tree seed. Lastly, the 1980–86 war in Uganda had a positive impact on vegetation in some of our sites. Such factors appear to play a stronger role than tenure factors.

In order to increase the tree resource base, the most promising strategy is to support tree planting in agricultural land. This strategy is compatible with farmers' incentives, as land rights are generally well established on agricultural land. Our analysis suggests that infrastructure policy can also play a catalyzing role in changing the stock of tree resources. Connection to markets could raise long-term benefits from resources and improve household incentives to manage them. We found that in Malawi, proximity to major urban areas was positively associated with yield change and at the same time did not lead to degradation of tree resources over the study period. In Uganda, proximity to a paved road positively affected tree cover on agricultural land. The fear that infrastructure development will have deleterious effects on the environment is therefore questioned in these countries.

On nonagricultural land, prescriptions are less clear. In the presence of loss of land area and even depletion of trees on remaining areas in Malawi, one encouraging finding was that when tree cover became very low, further depletion was somehow better controlled by communities. This may indicate that under extreme scarcity, the value of the woodlands rises to a sufficient level to induce improved management.

What are some research implications? First, assessing tree cover in nonforested land is markedly more difficult than on forested land. Detailed analyses are certainly not possible on the types of satellite imagery available, especially in past years. Second, one must be cautious in interpreting the results on tree cover. Tree cover may not be a good proxy of biomass and certainly cannot be used to make inferences on biodiversity. Hence, this single measure should not be over-used as a proxy to assess natural resource management performance. Third, we have not established any link between tree cover and social welfare. It may well be that some communities are better off after some tree cover loss while others are better off after some tree cover increase. Fourth, our unit of analysis was a defined administrative boundary and we were not able to neither measure nor include tree resources from adjacent areas in our analysis.

As for our understanding of the role of tenure factors, there are clear tradeoffs among the different approaches taken. We have selected numerous sites in order to be able to have sufficient variation in tree cover assessments and to ensure adequate degrees of freedom to disentangle the effects of many mitigating factors. A consequence of the large sample size was the cost of obtaining in-depth information about social and economic variables at the community level. Nevertheless, we feel that the marriage of remote sensing data with primary and secondary socio-economic and ecological data proved to be very powerful in explaining changes in land use and tree cover. These types of marriages between disciplines should be pursued.

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