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Prevalence, Economic Contribution, and Determinants of Trees on Farms across Sub-Saharan Africa

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Abstract

Trees on farms are often overlooked in agricultural and natural resource research and policy in Sub-Saharan Africa. This paper addresses this gap using data from the Living Standards Measurement Study–Integrated Surveys on Agriculture in five countries: Ethiopia, Malawi, Nigeria, Tanzania, and Uganda. Trees on farms are widespread. On average, one third of rural smallholders grow trees. They account for an average of 17 percent of total annual gross income for tree-growing households and 6 percent for all rural households. Gender, land and labor endowments, and especially forest proximity and national context are key determinants of on-farm tree adoption and management. These new, national-scale insights on the prevalence, economic contribution and determinants of trees on farms in Africa lay the basis for exploring the interaction of agriculture, on-farm tree cultivation, and forestry. This will improve our understanding of rural livelihood dynamics.

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1 Introduction

In Africa, as in many other parts of the world, trees on farms are often overlooked in research and policy making. In forestry, the focus is mostly on trees in forests rather than outside them (Barton, 2002; Fay and Michon, 2005). In agriculture and livelihood studies, the focus is typically on annual crops and their effects on household income. When perennials (such as coffee trees) are considered, it is mostly from a value chain perspective. The organization of extension and other services reflects this division, with agriculture and forestry typically separated in different institutions (de Foresta et al., 2013). As a result, trees on farms are often left out of forest-related, agricultural and livelihood statistics and little remains known about their prevalence and economic contribution, particularly at the national scale.

Yet, trees on farms are often a vital component of agriculture-forest landscapes. They perform important ecological functions, including the provision of soil nutrients, habitat for animals, and greater structural connectivity (Manning et al., 2006) and serve as a key basis for biodiversity conservation (Bhagwat et al., 2008; Schroth et al., 2013) and climate change adaptation and mitigation (Mbow et al., 2014a). At the same time, sub-national case studies further suggest that on-farm trees often also play an important role in rural livelihoods, whether directly as a source of income (from timber or non-timber products such as fruit) (Degrande et al., 2006; Kalaba et al., 2010; Mbow et al., 2014b), or indirectly for the ecological services they provide such as nitrogen fixing, prevention of soil erosion, or shade (Place and Garrity, 2015). Roughly a third of the agricultural land in Sub-Saharan Africa is estimated to have had at least 10% tree cover during 2008-2010 (Zomer et al., 2014). Trees and agricultural activities therefore often co-exist not only in larger landscape contexts but also in single landowner holdings.

The available research on trees on farms has so far largely focused on case studies within particular countries (e.g. Dewees, 1995b; Godoy, 1992; Pouliot and Treue, 2013). Region-wide aggregated approaches have also shed light on the prevalence of on-farm trees (Zomer et al., 2014), but because they are based on remotely sensed data such studies have not directly accounted for household perspectives and practices. Cross-national (Wunder et al., 2014) and global (Agrawal et al., 2013) syntheses of forest and broader environmental income also exist, but systematic comparative information on the prevalence and economic contribution of trees on farms remains missing. This is especially problematic given intensifying competition for land in Africa (Peters, 2013) and the challenge of simultaneously advancing human development and environmental protection goals.

This paper addresses this gap using nationally representative, geo-referenced household survey data from five African countries collected under the Living Standards Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA) initiative. Together, these countries (Ethiopia, Malawi, Nigeria, Tanzania, and Uganda) represent 41% of the population in Sub-Saharan Africa and cover many of its agro-ecological zones. In addition to comprehensive household level information about consumption and income sources, these surveys also collected geo-referenced plot level information on the different crops and trees grown on each farm as well as the products harvested. These features of the data are exploited here to measure the prevalence and economic contribution of trees on farms in Sub-Saharan Africa.

The long time lag between planting and harvesting, insecure property rights, small plots and landholdings, and remoteness, which often characterize smallholder farming in Africa, would all seem to play against the adoption of trees. Yet case study evidence from across Africa also shows that small farmers do plant and manage trees on their farms. So, what are the key drivers? We also explore this question by developing and testing theoretically informed models of the determinants of farmer decision-making as regards the management of on-farm trees.

In the next section we describe first our method for measuring trees on farms. Given the multitude of possible tree-like crops, the paper first presents a brief typology of the different trees considered, followed by a description of the data and methodologies used to measure and analyze their prevalence and contribution to overall household income and welfare, as well as their key correlates. Identification of the latter is motivated by insights from the literature on the socio-economic and agro-ecological drivers of trees on farms. Section 3 presents and discusses the findings, including the spatial relationship of tree crops to forests. Concluding remarks are offered in section 4.

2 Materials, Methods, and Theoretical Underpinnings

2.1 Identifying and counting trees on farms

The nationally representative household surveys conducted under the LSMS-ISA initiative during 2010-

12 from five African countries form the primary information base for this study.[2] They have been stratified to be representative for rural and urban areas. The surveys gather a wide range of socio-economic information on households and the communities of which they are a part, with detailed attention to their sources of income and geo-referenced, plot-level information on their agricultural activities and crops grown. Most importantly for this study, they also include for all uncultivated plots detailed information about the type of crop (including tree crops), the harvest, and expenses incurred. For fallow or uncultivated plots, farmers were explicitly asked whether they contained trees. In countries where two seasons of agricultural data were collected (Malawi, Tanzania and Uganda), the average presence of trees across both seasons was taken. Across these countries a total of 12,500 rural households (and 30,000 plots) were surveyed and through application of survey sampling weights a representative portrait of on-farm tree prevalence and their economic contribution to rural household incomes was obtained.

In the absence of a standard classification of crops as trees, potential trees were first identified from the LSMS-ISA agricultural crop production data, following the biological convention that to qualify as a tree a plant must be a woody perennial with a trunk or elongated stem that supports branches and leaves. With the help of several experts this list was subsequently divided into five subcategories: (1) fruit trees (e.g. mango, orange, etc.); (2) tree cash crops (e.g. coffee, tea, etc.); (3) timber and fuelwood trees (e.g. Mahogany, bamboo, etc.); (4) plant/herb/grass/roots (e.g. maize, banana, etc.); and (5) unidentified (e.g. voandzou, wechino, etc.) (Table A.1 includes a detailed list of all the crops considered as trees and their further classification across these five subcategories). As expected, most of the listed crops fell in the plant/herb/grass/roots category (across countries on average about 60%).

Only the first three subcategories are considered here. While they contain all three perennials (with substantial lags between planting and harvesting which distinguishes them from other crops), they are nonetheless still quite distinct in their biological and economic features and support systems. Unlike fruit and timber trees, cash crops have been extensively studied in the development literature, for example, but not in forestry, and they are usually politically important and part of well-organized and integrated cooperatives and value chains. Unlike timber trees, fruit trees yield an annual return. This dramatically changes the parameters of the investment decision. For these reasons, we explore the three tree

[2] For details, see Appendix A and www.worldbank.org/lsms . Niger was excluded because, unlike in the other LSMS-ISA countries, total income from trees or tree products was not recorded, only sales.

subcategories alongside each other.

The stock of trees on farms identified in our study likely represents a lower bound. First, home gardens are plausibly underreported as plots (and thus also trees in home gardens) and trees with no immediate productive function may have been left out of household questionnaires. Second, respondents may not recall all trees on their lands or may be hesitant to report them where, for example, colonial legacies of state control of tree resources persist (Ribot, 1999). Lastly, the study was unable to classify a few species for which only the local name was available (Table A.1). Yet, such omissions would especially affect the number of trees reported, and not so much their incidence or the share of land allocated to trees (for each plot it is recorded whether trees are present or not). Consequently, this paper focuses on analyzing the prevalence of trees on farms and the share of land allocated to trees as opposed to the number of trees per se.

2.2 Contribution to Household Income and Welfare

To examine the contribution of trees on farms to farmers' livelihoods, three indicators are examined: 1) how tree products are used (as a source of cash or mainly for own use or consumption); 2) their share in household crop and income portfolios (as an indication of their direct economic importance) and 3) the consumption levels among farmers with and without trees on farms. As a broader reflection of overall wealth, the last of these indicators also captures some of the more indirect contributions of trees on farms such as soil conservation, nitrogen fixing, water regulation, and carbon sequestration (Booth and Wickens, 1988; Nair, 2007; Place and Garrity, 2015) or their use as fodder for livestock or provider of organic fertilizer. None of these indirect aspects is typically addressed in the LSMS-ISA surveys (or household surveys more generally).

Information on the harvested amounts of the tree products and their different uses (sale, auto-consumption, or other uses[3]) was directly obtained in all surveys, except in Tanzania. Second, to assess their contribution to household income, we estimated the share of gross income derived from trees on farms as part of gross agricultural and gross overall income.[4] Gross household income was calculated

[3] This concerns their use as inputs into another production process (e.g. fodder for livestock, fruits for jam, timber for own house construction or fencing).

[4] A more refined measure would be to calculate the share of net income from trees on farms over the total net income per household. However, complete expense data were not collected in all study countries and when collected, they were not

using the standardized definitions and methods developed under the Rural Income Generating Activities (RIGA) Project (Davis et al., 2010).[5] This approach facilitated comparison across countries. Production that had been consumed or stored was valued at unit values either derived from reported sales or, when absent, from median unit values at community or district levels (see Davis et al. (2010) for details). Other in-kind income was valued at market prices. A similar approach was followed to value (in-kind) income from on-farm trees.[6]

Finally, as a broader, more encapsulating measure of the welfare effects associated with tree adoption and management, we compare average consumption levels among farmers growing trees on their farms with the consumption levels of those who do not grow trees on their farms, controlling for the characteristics of their environment. In particular, to do so real daily consumption per person (in 2011 purchasing power parity $) was regressed on whether the household had trees on farms or not and district fixed effects. The average difference in consumption is thus identified from the within-district difference in real daily consumption per person between tree and non-tree growing households

2.3 Correlates of on-farm tree adoption

At first glance, there appear few incentives for smallholder farmers to incorporate trees into their farming systems (Arnold and Dewees, 1997; Dewees, 1995a; Franzel, 1999; Godoy, 1992). There is a long time lag between planting and harvesting, while poor farmers are often liquidity constrained with a high discount rate. Access to (formal and informal) credit is limited, making it difficult to overcome the liquidity gap and poorer farmers often have smaller landholdings, necessitating attempts to generate revenues annually on all the land available to them. Insecure property rights further discourage

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collected at the crop level (see table A.2 for description of available data), making it difficult to attribute costs to a particular crop. Importantly, the gross income ratio used here remains unbiased, under the assumption that the share of net over gross income is the same for income from trees on farms as for overall agricultural or total income. Put differently, to the extent that the share of expenditures on tree crop production to income from trees on farms is smaller than the share of expenditures on all agricultural production to income from agricultural production, the gross income from trees to gross agricultural income ratios reported here will be underestimates. A similar reasoning holds for the ratio of gross income from trees to overall gross income.

[5] Under this method, seven basic categories of household income are considered: *(i)* crop production; *(ii)* livestock production; *(iii)* agricultural wage employment; *(iv)* non-agricultural wage employment; *(v)* non-agricultural self-employment; *(vi)* transfers; and (*vii*) when available, other income sources like rental income, fishing or saving accounts. See Davis et al. (2010) for details.

[6] In a recent study, Angelsen et al. (2014) show that environmental and forest incomes can also be important in certain communities, especially those with closer access to forests. As in most standard household budget surveys, such income is not appropriately recorded in the LSMS-ISA data and has not been accounted for here either. A forestry module for LSMS-ISA and other national surveys has recently been developed to address this information gap (Bakkegaard et al., 2016).

investment in land improvement and trees, which only pay off over time. Outdated policies relating to state forest and tree management claims sometimes provide more disincentives for farmers to invest in trees on their land (Scherr, 2004). The extent to which these factors play a role will differ depending on the characteristics of the tree types. Timber trees only yield a benefit at the end of their lives for example, while fruit and cash crop trees yield an annual return. The institutional support available also differs widely across tree type as does the purpose of production (home consumption or sales).

Against this background, a number of hypotheses and empirical insights have been advanced in the literature. With respect to the effects of the demographic composition of the household, fruit trees, which have been associated with better nutritional status of household members, have been found to be more prevalent in female-headed households (Ickowitz et al., 2014; Meijer et al., 2015). Larger households, with more labor available, are also more likely to adopt tree-based cultivation, which is especially labor intensive in the early stages of tree planting and management (Dewees, 1994; Godoy, 1992). Better endowed households, on the other hand, are likely better placed to overcome liquidity and credit constraints and thus more likely to adopt agroforestry practices (Pattanayak et al., 2003). The amount of land owned is in this regard a well-established determinant of the presence of on-farm trees (Cattaneo, 2001; Dewees, 1995a). The presence of trees also interacts with livestock assets. Studies in different African countries suggest two different relationships: small livestock (e.g. goats and sheep) may be associated with greater presence of trees on farms while cattle may be seen as a competitor for space (Place and Garrity, 2015; Scherr, 1995; Wunder et al., 2014).

Geographic, climatic and biophysical conditions further affect the degree of on-farm tree planting. Geographic location shapes the biophysical endowments and a household's comparative advantage in accessing markets, which in turn can influence incentives to adopt agroforestry practices (Pattanayak et al., 2003). Factors such as soil quality, slope of farmland, proximity to forest, among others create conditions more or less conducive to grow and maintain trees (Place and Garrity, 2015). Proximity to markets may also generate incentives to favor certain types of trees, especially those yielding perishable products like fruit (Godoy, 1992; Pattanayak et al., 2003).

To explore the importance of these different factors in determining the presence and extent of trees on farms, the following regression model is estimated:

$$\text{TreesOnFarms}_{ivc} = \propto_1 + \mathbf{HH'}_{ivc}\boldsymbol{\rho} + \mathbf{Assets'}_{ivc}\boldsymbol{\delta} + \mathbf{GeoClimate'}_{ivc}\boldsymbol{\gamma} + \sum_{k=1}^{5} \theta_k dT_k + \varepsilon_{ivc} \quad (1)$$

where sub-index i refers to a household in village v in country c. To explore whether the factors affecting adoption and the factors affecting the extent of tree planting differ, equation (1) was run separately using

(i) A binary measure of presence or absence of any trees on a given household's landholdings (i.e. *Trees on farm (yes=1)*) as the dependent variable; and

(ii) A continuous measure of the share of landholdings with presence of trees (i.e. $Area\ of\ plots\ with\ presence\ of\ trees\ (ha) \big/ Farm\ size\ (ha)$).

The former was estimated using a probit model, the latter using OLS. Furthermore, because key factors determining the differences in tree growing strategies may vary across tree types (Degrande et al., 2006), the analysis was also replicated by type of tree (i.e. fruit trees, tree cash crops and trees for timber or fuelwood). Exploiting similarity in the design of the questionnaires, the data were pooled across countries. This enabled us to identify those socio-economic and agro-ecological factors that were generic across countries in affecting the adoption and extent of on-farm tree growing. Through the inclusion of country dummies a sense of the importance of country-specific factors (e.g. policies and institutions) is also obtained.[7] Shapley values, which provide a decomposition of the explained variance of the dependent variable (measured by R^2) by each group of control variables (Shorrocks, 2013) are also reported. This approach helps to understand the mean contribution of each dimension or group of variables to the overall model (i.e. share of R^2 explained by dimension). Standard errors were corrected by household sampling weights.

To explore the effects of the household's human capital endowments ($\mathbf{HH'}_{ivc}\boldsymbol{\rho}$) the following variables were included: household size, number of children (<14 years old), age of household head, a dummy variable indicating a female headed household, and the level of formal education (in years) of the household head (Godoy, 1992; Pattanayak et al., 2003). To capture the effects of the household's physical capital ($\mathbf{Assets'}_{ivc}\boldsymbol{\delta}$), we included: (i) the size of the land owned (in hectares), and (ii) the number of tropical livestock units.

The set of geographic and climatic controls, $\mathbf{GeoClimate'}_{ivc}\boldsymbol{\gamma}$, included human population density, average percentage of tree cover within 20 km of each household, soil fertility, annual mean temperature (°C), and average annual precipitation. These control variables were constructed based on household

[7] Alternative specification using models for each country separately were used as robustness check. Results were qualitatively equivalent. These results are available upon request.

standardized geo-coordinates, which were collected in the LSMS-ISA survey data.[8] Farm location was used as a centroid to construct several variables covering the area within 20km. The average percent tree cover within a 20km radius of each household was derived using tree cover from MODIS Vegetation Continuous Fields (MOD44B) data (DiMiceli et al., 2011). An indicator of population density based on the number of people per km^2 within 20km of each household was created using data from the Global Rural-Urban Mapping Population Project (Balk et al., 2006; CIESIN et al., 2011). To construct a variable on the average percentage of fertile soil within 20 km of each household, we combined information from the FAO/UNESCO Digital Soil Map of the World (FAO/IIASA/ISRIC/ISSCAS/JRC, 2012) and Nunn and Puga (2010) estimates of percentage of land surface area with fertile soil.[9] Finally, we used two control variables— household specific measures of annual mean temperature (C) and average annual precipitation— that were created using a standard methodology by the World Bank LSMS-ISA team and made available for all LSMS-ISA surveys (see World Bank, 2015 for details).

Finally, all models included a set of country fixed effects to account for country-level unobservables ($\sum_{k=1}^{5} \theta_k dT_k$). They were also rerun with district fixed effects, purging the estimated coefficients from potential unobserved district level variables (such as relative price differences across crops or market access). Table 1 summarizes the main descriptive statistics for all covariates.

3 Prevalence, Economic Contribution, and Determinants of Trees on Farms

3.1 One-Third of Smallholder Farmers Cultivated Trees

With on average 33% of all rural households reporting having at least one tree on their land, trees are clearly not marginal on the smallholder farms across the African countries studied (Table 2). Prevalence was highest in Tanzania (54%) and Ethiopia (38%) and lowest in Nigeria (16%). Further disaggregation by type of tree shows that Tanzanian farmers emphasize fruit trees (with 45% growing fruit trees,

[8] LSMS-ISA surveys provide a modified coordinate to protect household confidentiality, by introducing a random distortion of 0-5km from the original location of the rural household. For more details on this type of method and its implications for statistical inference see Perez-Heydrich et al. (2013).
[9] Defined as soil that is not subject to severe constraints for growing rain-fed crops in terms of soil fertility, depth, chemical and drainage properties, or moisture storage capacity.

primarily mango, pawpaw (papaya), and oranges).[10] Tanzanian farmers also reported the highest prevalence of trees for timber (18%) and about a quarter reported (23%) growing tree cash crops.

By contrast, in Ethiopia less than 3.5% of landowners reported having trees for timber and fuelwood on their land, but the country had the highest proportion of farms with tree cash crops (32%), mainly coffee (65% of total tree cash crops) and chat (34% of total tree cash crops), and one in six farmers reported growing fruit trees. The small share of on-farm timber trees is likely an underestimate as the presence of Eucalyptus was not properly captured in the questionnaires. Recent case studies such as Bluffstone et al. (2015) report, for example, that in the six districts they surveyed 70% of households grew eucalyptus.

Uganda, which features much less land area in plantation forests, follows a similar pattern as Ethiopia, with few trees for timber or fuelwood reported and tree cash crops the most common type of tree (27%, nearly all of which (97%) are coffee trees). Abstracting from bananas (which are not classified as tree crops), few farmers report growing fruit trees. In Malawi, fruit trees (mainly mango (56%) and pawpaw (12%)) are the most common category (23%). Information was not available on tree cash crops for Malawi, which may lead to an underestimate of the prevalence of trees on farms in that country. Tree cash crops comprised the most frequent category found in Nigeria. Information on timber and fuelwood trees was not available for Nigeria.

On average, across the study countries, about 60% of trees on farms are reported in areas with other crops present (i.e. they are intercropped). But this figure masks again substantial variation (Table 2). Farmers in Malawi and Ethiopia appear to be much less likely to mix trees on their farms with other crops than farmers in Nigeria, Tanzania, and Uganda. Only 10% of trees on farms were reported as present in the same area as other crops in Malawi, for example. At the other extreme, more than 95% of on-farm trees are reported as part of intercropped systems in Uganda. The common practice of intercropping coffee with bananas is only part of the story (as in Tanzania and Uganda) and further country-by-country case study is needed. Nonetheless, the results highlight the prevalence of agroforestry practices in the study countries.

[10] Bananas are especially prevalent in Tanzania and Uganda, but they are classified under the category of plant/herb/grass/roots based on their biological characteristics (Parr et al. 2014).

Given the importance of agro-ecological conditions for tree growing, some spatial clustering of on-farm tree growing is expected. Statistically significant though moderate spatial correlation among our observations was found (within country Moran's I was on average, 0.1) (Table B.1).[11] Clustering was especially clear for Tanzania and Ethiopia, two countries with high prevalence of trees on farms (Figure 1; Table B.1). In Tanzania, households with tree cash crops (mainly cashew nut trees) were highly clustered in the southwest, suggesting spatial correlation with the presence of larger urban centers and seaports such as in *Lindi*. Ethiopia presents a similar pattern. There are few trees in the far east, which includes lower elevation land near Somalia, while landholders with fruit trees (46% of all households with trees on farms) were concentrated in the northwest and southwest of the country near some of Ethiopia's major population centers (e.g. Jimma and Bahir Dar respectively). Tree cash crops (e.g. coffee trees), on the other hand, were widespread and planted primarily in a mono-cropping system.

3.2 Trees on Farms Especially Prevalent Near Forests

In most LSMS-ISA countries the majority of households with trees on their farms are located within 10 km of forestland (see Table 3). In the study countries with a higher share of their land area covered by forest (using the 30 percent forest cover threshold) (i.e. Tanzania, Uganda, and Malawi), this rises to more than 80% of the households with trees on farms. Even when using the more stringent forest threshold of 50 percent, these countries still have more than half of the households with trees on farms within 10 km of the forest areas (rising to 67 % in Tanzania). Nigeria lies at the lower end of the spectrum with only 36% of its households with trees on farms located near forest areas at the less stringent 30% threshold. This is different in Ethiopia, which similarly only has about 11% of its land covered with forest (using the 30% tree cover threshold), but still more than half of its farms with trees located within 10km of a forest (Table 3).

These findings suggest that farms with trees are important components of broader agriculture-forest landscapes in at least four of the five LSMS-ISA countries. Even in Nigeria more than a third of households with trees on farms were near forests. The proximity of on-farm trees to forests and the

[11] We employed the Moran's I Spatial Correlation index. This index provides an intuitive measure of correlation among nearby households in space. Yet, as it is only based on geographical distances that ignore the sampling design of our data, its absolute value may under-estimate the actual spatial correlation among households. Nonetheless, its statistical significance indicates that households with trees on farms tend to be closer to each other in space (i.e. clustered) than the other households in the sample.

prevalence of intercropping across most of the study countries suggest substantial opportunities for more holistic, landscape-level approaches in policy and other practical efforts seeking to reconcile biodiversity conservation, climate change mitigation, and poverty reduction goals. Given the geographic and socio-economic diversity encompassed in our study countries, our results also suggest that such approaches may also be applicable in other countries across Africa as does a growing case study literature (e.g. Milder et al., 2014).

3.3 Contribution of Trees on Farms to Rural Livelihoods was Non-negligible

Products harvested from trees on farms in the study countries were used mainly for self-consumption or sale (Figure 2). The relative mix of these uses varied among the study countries. In Uganda, fruit tree products were used primarily for self-consumption, whereas in Malawi such trees served solely as a source of cash income. That fruit trees were used significantly for self-consumption in countries like Uganda (and also Ethiopia) suggests that such trees may play an important role in household food security, as shown in a variety of contexts across Africa (Garrity et al., 2010). In the case of tree cash crops, production was mainly used for sale, as expected, though in Ethiopia a non-negligible share was also used for own consumption (linked to coffee consumption) and in Nigeria to other uses.

Turning to the contribution to total income, income from trees on farms contributed on average 6% of overall annual gross household income (i.e. among tree and non-tree growers alike). The income share averaged 7% in Nigeria, Tanzania and Uganda, and only 3% in Malawi (Table 4). We note that estimates for Malawi may be low because information on tree cash crops was not provided in LSMS-ISA survey data. For those households with trees on their farms the average contribution across the study countries was almost three times as much, i.e. 17% and about 32% as a share of agricultural gross income.[12] Surprisingly, the contribution of trees on farms to gross income among tree growers was highest in Nigeria, even though tree growing occurred least frequently there, suggesting a high degree of specialization among tree growing households. At 18.7% income from trees among tree growing households is also more important in Uganda. Clearly, income from tree growing can be quite important, with the larger share typically coming from tree cash crops (14% of gross income among tree growers). Nonetheless, even though much less commented upon, income among fruit trees still contributes 5% of

[12] By comparison, a recent cross national study of households living in or near forests found that natural forests in Africa contributed 21% to household incomes and plantation forests less than 1% (Angelsen et al., 2014).

gross income and 16% of gross agricultural income. This share only stands to increase as households get richer and urbanize, a trend already underway in many African countries.

Finally, taking a fully reduced form, we compared real per capita consumption levels (2011 PPP) among tree growing households and non-tree growing households controlling for district level effects (Table 5). As expected, tree cash crop growers were on average substantially better off (84% in Ethiopia, 19% in Nigeria, and 3% in Tanzania, though no difference was discerned in Uganda). Fruit tree growers were also better off in three of the five case countries (Ethiopia, Nigeria and Uganda), an important observation, given the potential for growth of Africa's rising middle class. However, no positive effect was found for timber tree growing. Households with timber and fuelwood on their land appeared to be even worse off in Malawi. This result may be due to characteristics particular to the tiny (0.18%) subset of households reporting having such timber or fuelwood trees. Also a large proportion of Malawi's territory includes areas where poverty and high forest cover overlap (Sunderlin et al., 2008).

3.4 Gender, Land, Proximity to Forest, and Country Factors Drive On-Farm Tree Growing

Tables 6a, b and c present the estimated effects of different correlates on the adoption of and land allocation to trees on farms by tree type. The model had little explanatory power in explaining the adoption or land allocation to timber trees (Table 6c), but a number of clear generic patterns emerge when looking at the correlates of tree cash crops and fruit trees. First, adoption and land allocation to fruit trees and tree cash crops increased with the education level of the household head, but the adoption and land allocation to tree cash crops was about 5 percentage points less among female-headed households. This result is consistent with studies showing lower land tenure security among women in Africa (Berry, 1988; Schroeder, 1999). It was substantially less pronounced for fruit crops however, consistent with the higher nutritional value of fruit trees (Degrande et al., 2006; Mbow et al., 2014b). Fruit trees also tend to be more likely among households with older heads, consistent with other studies (Pattanayak et al., 2003).

Land endowments mattered for the area allocation to both fruit and cash crop trees (as well as for the adoption of fruit trees). Household size mainly affected fruit tree growing, suggesting that labor constraints are likely more binding for fruit than tree cash crops where use of hired labor is more common. Adoption of fruit trees is also less common among households with livestock.

The previous finding of more on-farm tree planting in forest rich environments is confirmed in the multivariate setting. The generally positive association between nearby tree cover and presence of trees on farms merits further analysis, especially using panel data, to better understand how farmers respond to changes in the availability of forest resources—by increasing the density of trees on their farms as forest resources decrease (Arnold and Dewees, 1995) or by continuing agroforestry systems which may already have an integral relationship with nearby forest (e.g. Brottem, 2011; Degrande et al., 2006). On-farm trees also tend to be more prevalent in environments where the temperature is higher. Overall, geo-climatic variables were found to be very important. They accounted for around for 18.5% and 31% of the total variation in the adoption of fruit trees and tree cash crops respectively (Tables 6a and b). This result buttresses previous findings about biophysical conditions as key drivers of farmer decisions to adopt and maintain trees on-farm (Pattanayak et al., 2003; Place and Garrity, 2015). Surprisingly, no systematic correlation was found across countries with population density (or soil fertility).

Finally, country fixed effects also explained an important share of the variation (more than 40% for adoption). This underscores the importance of national level institutions and policies in shaping whether farmers decide to adopt trees on their farms or not. In many countries, forest regulations create disincentives for on-farm tree management (Place and Garrity, 2015; Ribot, 1999). But changes to such regulations can spur changes in practice as shown in the recent regreening in Niger, which has been catalyzed by political openings and reforms to colonial-era forest and rural policies that allowed local innovation in land management (Sendzimir et al., 2011).

4 Concluding Remarks

In this paper we used nationally representative household-level data to explore and compare the prevalence and economic contribution of trees on farms across five African countries. Three main findings emerge. First, trees on farms are widespread across the continent and comprise a key component of agricultural-forest landscapes. The East African countries of Tanzania, Uganda and Ethiopia had especially high incidence of trees on agricultural lands, with about a third to more than half of rural households reporting on-farm trees. Fruit trees and cash crop trees were the two most popular types of trees while trees for timber and fuelwood were much less prevalent (reported by 5% of respondents). The proximity of most households with trees on farms to forests and the high incidence of intercropping across the study countries suggest that on-farm trees are also a vital part of larger rural landscapes. As elsewhere in the developing world (Sayer et al., 2013), policies and practices designed to improve the management of such trees in Africa therefore hold significant promise for helping to reconcile the sometimes conflicting goals of reducing rural poverty, conserving biodiversity, and mitigating climate change.

Our second major finding is that trees on farms deliver sizeable economic benefits to rural households. Across the rural population as a whole, production from trees on farms accounts on average only for 6% of total annual gross income. Yet, this increases to 17% on average for those households growing trees on their farms. By way of comparison, these results are similar to available evidence on forest and environmental income. For example, a recent study using national-scale data from Mexico (López-Feldman, 2014) found that forest and other environmental resources contributed 6.2% to total incomes for Mexican rural households. For those households living in or near forests in a cross-national comparative study (Angelsen et al., 2014), income from natural forests and forest plantations accounted for 21% of total household income. Together, these studies suggest that trees—in forests and outside forests—provide significant income to rural households in Africa, especially but not only to those living with trees nearby or on their land.

Finally, results from models of the determinants of the adoption of and land allocation to trees on farms highlight the importance of national institutional and policy contexts in understanding differences in on-farm tree growing. Together they account for more than 40 percent of the explained variation of the models. Proximity to forests proves also an important predictor. Households with more land tend to allocate more of their land to trees (both cash crop and fruit trees). Female-headed households tend to be less engaged in tree growing, with the effect being largest for tree cash crops (possibly linked to higher land tenure insecurity for female farmers and consistent with the higher nutritional value of fruit trees).

Despite the already non-negligible prevalence and economic contribution of trees on farms that this paper demonstrates, the numbers are likely still underestimates. The household data are unlikely to fully account for non-crop trees (e.g. for shade or different kinds of non-provisioning ecosystem services) and trees with no immediate productive function because they were not queried explicitly in the LSMS-surveys. The indirect effects of trees on farms on crops, livestock, and other productive activities are also very difficult to account for (Wunder et al., 2014) and information on them was not directly collected in the LSMS-ISA surveys. Ethiopia also presented a rare case where information on a key productive tree species—eucalyptus—was not collected.

Overall, the results suggest that trees on farms should be given more attention in agriculture, food security and poverty-related policy debates in Sub-Saharan Africa, particularly as the need to tackle climate change becomes more urgent. The data and analysis presented here provide a baseline for future benchmarking as well as building blocks for improving the information base relating to privately owned trees in Africa, including through improved data collection in future surveys. The open access LSMS-ISA surveys and other national survey data provide an important opportunity to do so. They deserve full support and could be strengthened in at least two ways: 1) by capturing the full range of relevant trees on farms, including those that may not have an immediate productive function, and 2) by including cost information in a way that facilitates comparison of income across LSMS-ISA countries. We were unable to include Niger in our analysis, despite its status as an LSMS-ISA country and success in farmer managed natural regeneration and agroforestry (Garrity et al., 2010; Sendzimir et al., 2011) because income from trees on farms did not cover in-kind income from these trees, only income from sales.

The findings also point to several new avenues for exploring the interaction of agriculture, trees, and forests to better understand the dynamics of rural livelihoods in Africa and beyond. One area ripe for further exploration is the relationship between trees on farms and forest areas. Are trees on farms associated with more or less forest clearing? Why are households with trees on farms more likely to be located near forests? Panel data from LSMS-ISA surveys combined with newly available, high-resolution forest cover data make it possible to shed new light on these dynamics. LSMS-ISA panel data also enable study of the economic contribution of trees on farms over time so as to understand the extent to which such trees can provide a means for farmers to escape poverty or achieve more enduring prosperity. Finally, we see significant scope for future research to collect and analyze information on the economic contribution not only of trees on farms, but also from forests and other wildlands to gain a more complete picture of the dynamics of rural livelihoods in Africa over time at the national scale. This would require adding some specific questions to the LSMS-ISA questionnaires.

References

Agrawal, A., Cashore, B., Hardin, R., Shepherd, G., Benson, C., Miller, D.C., 2013. Economic Contributions of Forests, Commissioned Background Paper for a report to the UN Secretary General ed. United Nations Forum on Forests, New York, NY.

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N.J., Bauch, S., Börner, J., Smith-Hall, C., Wunder, S., 2014. Environmental Income and Rural Livelihoods: A Global-Comparative Analysis. World Development 64, Supplement 1, S12-S28.

Arnold, J.E.M., Dewees, P.A., 1995. Tree management in farmer strategies: responses to agricultural intensification. Oxford University Press, Oxford.

Arnold, J.E.M., Dewees, P.A., 1997. Farms, trees and farmers: responses to agricultural intensification. Earthscan, London.

Bakkegaard, R.K., Agrawal, A., Animon, I., Bosselmann, A., Hogarth, N., Miller, D.C., Persha, L., Rametsteiner, E., Wunder, S., Zezza, A., Zheng, Y., 2016. National socioeconomic surveys in forestry: Guidance and questionnaires for measuring the multiple roles of forests in household welfare and livelihoods. FAO, CIFOR, IFRI, and the World Bank, Rome.

Balk, D.L., Deichmann, U., Yetman, G., Pozzi, F., Hay, S.I., Nelson, A., 2006. Determining Global Population Distribution: Methods, Applications and Data. Advances in Parasitology 62, 119-156.

Barton, G.A., 2002. Empire Forestry and the Origins of Environmentalism. Cambridge University Press, Cambridge.

Berry, S., 1988. Property rights and rural resource management: the case of tree crops in West Africa. Cahiers des Sciences Humaines 24 (1), 3-16.

Bhagwat, S.A., Willis, K.J., Birks, H.J.B., Whittaker, R.J., 2008. Agroforestry: a refuge for tropical biodiversity? Trends in Ecology & Evolution 23, 261-267.

Bluffstone, R., Yesuf, M., Uehara, T., Bushie, B., Damite, D., 2015. Livestock and Private Tree Holdings in Rural Ethiopia: The Effects of Collective Action Institutions, Tenure Security and Market Access. The Journal of Development Studies 51, 1193-1209.

Booth, F.E.M., Wickens, G.E., 1988. Non-timber uses of selected arid zone trees and shurbs in Africa, FAO Conservation Guide. Food and Agriculture Organization of the United Nations, Rome.

Brottem, L., 2011. Rediscovering "Terroir" in West African Agroforestry Parklands. Society & Natural Resources 24, 553-568.

Cattaneo, A., 2001. Deforestation in the Brazilian Amazon: Comparing the Impacts of Macroeconomic Shocks, Land Tenure, and Technological Change. Land Economics 77, 219-240.

Center for International Earth Science Information Network (CIESIN) - Columbia University, International Food Policy Research Institute (IFPRI), World Bank, Centro Internacional de Agricultura Tropical (CIAT), 2011. Global Rural-Urban Mapping Project, Version 1 (GRUMPv1): Urban Extents Grid. NASA Socioeconomic Data and Applications Center (SEDAC), Palisades, NY.

Davis, B., Winters, P., Carletto, G., Covarrubias, K., Quiñones, E.J., Zezza, A., Stamoulis, K., Azzarri, C., DiGiuseppe, S., 2010. A Cross-Country Comparison of Rural Income Generating Activities. World Development 38, 48-63.

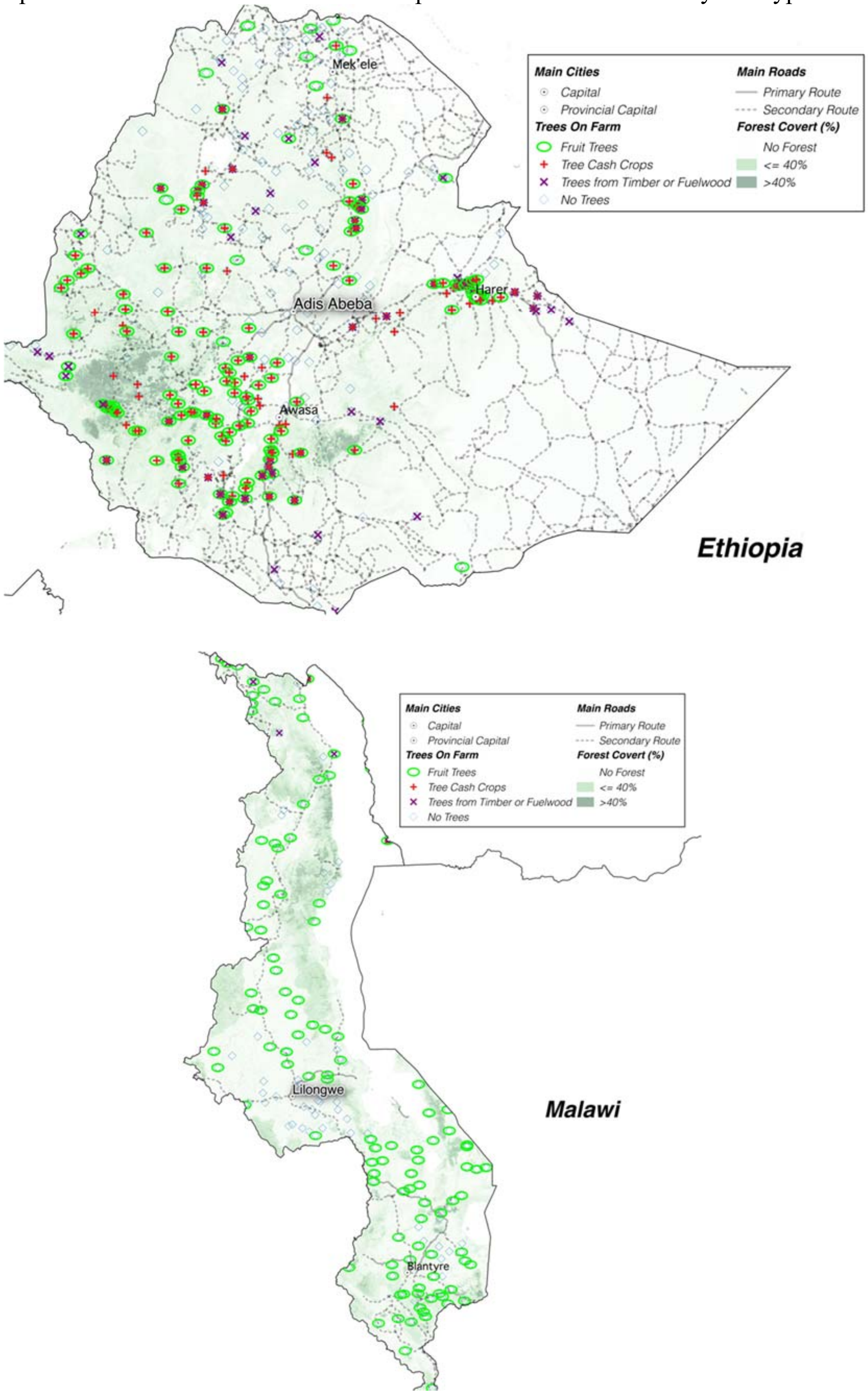
de Foresta, H., Somarriba, E., Temu, A., Boulanger, D., Feuilly, H., Gauthier, M., 2013. Towards the Assessment of Trees Outside Forests, Resources Assessment Working Paper. FAO, Rome.

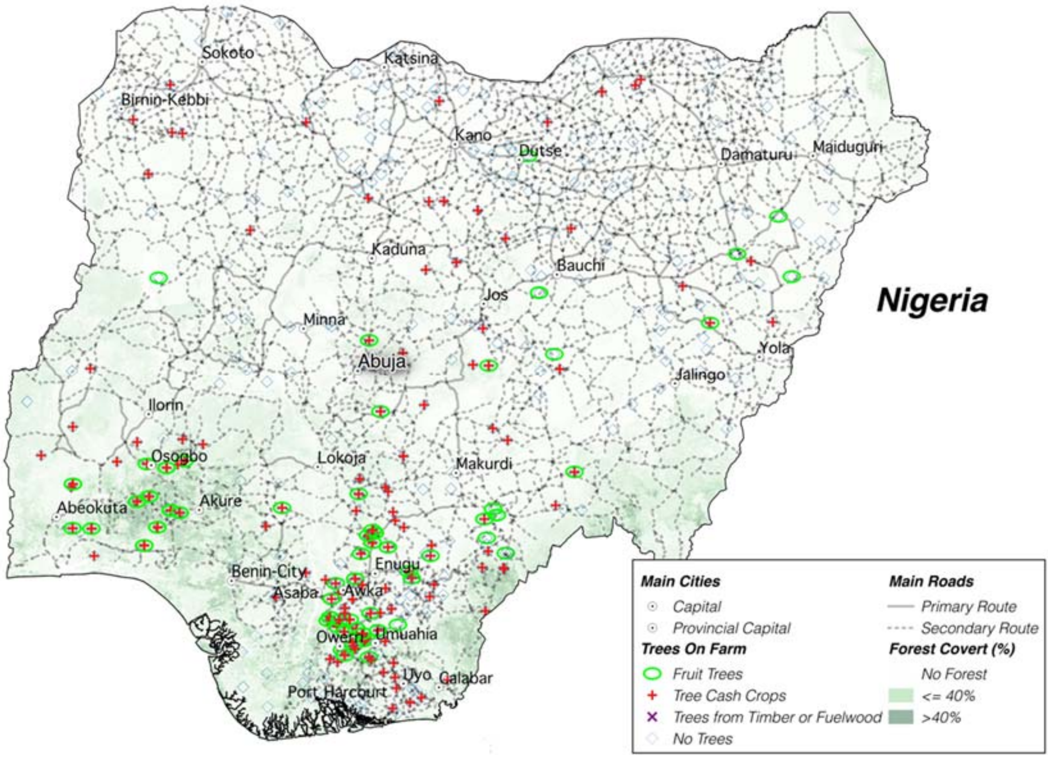
Degrande, A., Schreckenberg, K., Mbosso, C., Anegbeh, P., Okafor, V., Kanmegne, J., 2006. Farmers' Fruit Tree-growing Strategies in the Humid Forest Zone of Cameroon and Nigeria. Agroforest Syst 67, 159-175.

Dewees, P.A., 1994. Trees, Land, and Labor. The World Bank, Washington, DC.
Dewees, P.A., 1995a. Trees and Farm Boundaries: Farm Forestry, Land Tenure and Reform in Kenya. Africa 65, 217-235.
Dewees, P.A., 1995b. Trees on farms in Malawi: Private investment, public policy, and farmer choice. World Development 23, 1085-1102.
DiMiceli, C.M., Carroll, M.L., Sohlberg, C., Huang, C., Hansen, M.C., Townshend, J.R.G., 2011. Annual Global Automated MODIS Vegetation Continuous Fields (MOD44B) at 250 m Spatial Resolution for Data Years Beginning Day 65, 2000 - 2010, Collection 5 Percent Tree Cover, Collection 5 ed. University of Maryland, College Park, MD.
FAO/IIASA/ISRIC/ISSCAS/JRC, 2012. Harmonized World Soil Database (version 1.2), FAO, Rome, and IIASA, Laxenburg, Austria.
Fay, C., Michon, G., 2005. Redressing forestry hegemony when a forestry regulataory framework is best replaced by an agrarian one. Forests, Trees and Livelihoods 15, 193-209.
Franzel, S., 1999. Socioeconomic factors affecting the adoption potential of improved tree fallows in Africa. Agroforest Syst 47, 305-321.
Garrity, D.P., Akinnifesi, F.K., Ajayi, O.C., Weldesemayat, S.G., Mowo, J.G., Kalinganire, A., Larwanou, M., Bayala, J., 2010. Evergreen Agriculture: a robust approach to sustainable food security in Africa. Food Sec. 2, 197-214.
Godoy, R.A., 1992. Determinants of smallholder commercial tree cultivation. World Development 20, 713-725.
Ickowitz, A., Powell, B., Salim, M.A., Sunderland, T.C.H., 2014. Dietary quality and tree cover in Africa. Global Environmental Change 24, 287-294.
Kalaba, K.F., Chirwa, P., Syampungani, S., Ajayi, C.O., 2010. Contribution of agroforestry to biodiversity and livelihoods improvement in rural communities of Southern African regions, in: Tscharntke, T., Leuschner, C., Veldkamp, E., Faust, H., Guhardja, E., Bidin, A. (Eds.), Tropical Rainforests and Agroforests Under Global Change: Ecological and Socio-economic Valuations. Springer, Berlin, pp. 461-476.
López-Feldman, A., 2014. Shocks, Income and Wealth: Do They Affect the Extraction of Natural Resources by Rural Households? World Development 64, Supplement 1, S91-S100.
Manning, A.D., Fischer, J., Lindenmayer, D.B., 2006. Scattered trees are keystone structures – Implications for conservation. Biological Conservation 132, 311-321.
Mbow, C., Smith, P., Skole, D., Duguma, L., Bustamante, M., 2014a. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. Current Opinion in Environmental Sustainability 6, 8-14.
Mbow, C., Van Noordwijk, M., Luedeling, E., Neufeldt, H., Minang, P.A., Kowero, G., 2014b. Agroforestry solutions to address food security and climate change challenges in Africa. Current Opinion in Environmental Sustainability 6, 61-67.
Meijer, S.S., Sileshi, G.W., Kundhlande, G., Catacutan, D., Nieuwenhuis, M., 2015. The Role of Gender and Kinship Structure in Household Decision-Making for Agriculture and Tree Planting in Malawi Journal of Gender, Agriculture and Food Security 1, 54-76.
Milder, J.C., Hart, A.K., Dobie, P., Minai, J., Zaleski, C., 2014. Integrated Landscape Initiatives for African Agriculture, Development, and Conservation: A Region-Wide Assessment. World Development 54, 68-80.
Nair, P.R., 2007. The coming of age of agroforestry. Journal of the Science of Food and Agriculture 87, 1613-1619.
Nunn, N., Puga, D., 2010. Ruggedness: The Blessing of Bad Geography in Africa. Review of Economics and Statistics, 20-36.
Pattanayak, S., Evan Mercer, D., Sills, E., Yang, J.-C., 2003. Taking stock of agroforestry adoption studies. Agroforest Syst 57, 173-186.

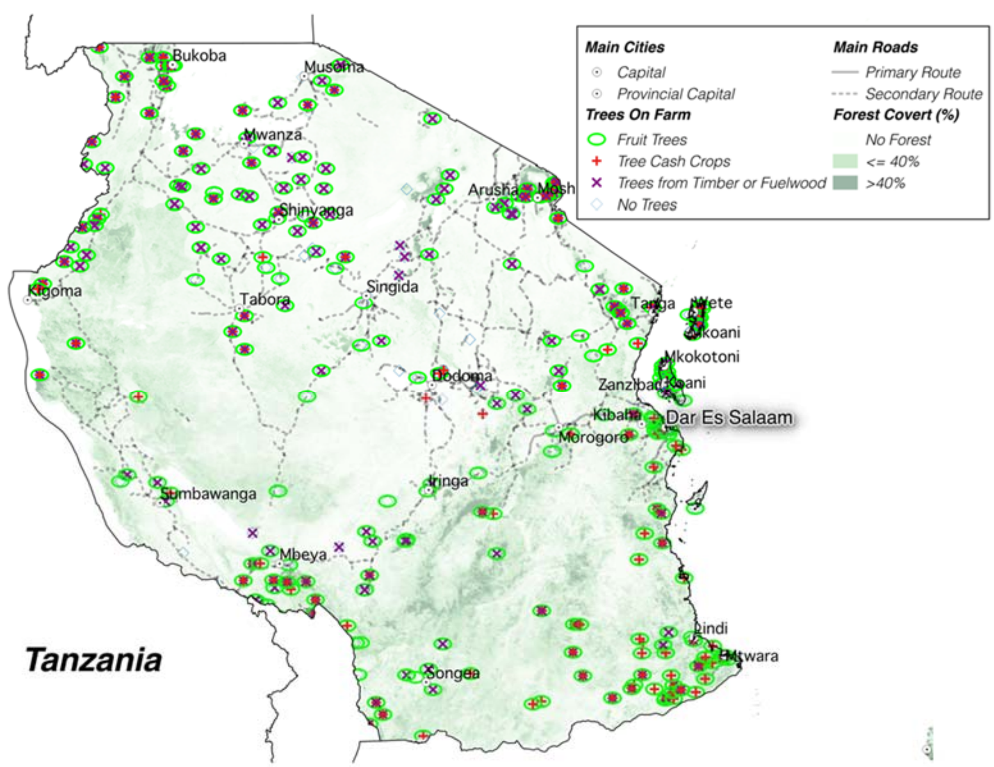
Perez-Heydrich, C., Warren, J.L., Burgert, C.R., Emch, M.E., 2013. Guidelines on the Use of DHS GPS Data, Spatial Analysis Reports No. 8. ICF International, Calverton, Maryland.
Peters, P.E., 2013. Land appropriation, surplus people and a battle over visions of agrarian futures in Africa. The Journal of Peasant Studies 40, 537-562.
Place, F., Garrity, D., 2015. Tree-based Systems in Africa's Drylands. World Bank Group, Washington, DC.
Pouliot, M., Treue, T., 2013. Rural People's Reliance on Forests and the Non-Fforest Environment in West Africa: Evidence from Ghana and Burkina Faso. World Development 43, 180-193.
Ribot, J.C., 1999. A history of fear: imagining deforestation in the West African dryland forests. Global Ecology and Biogeography 8, 291-300.
Sayer, J., Sunderland, T., Ghazoul, J., Pfund, J.-L., Sheil, D., Meijaard, E., Venter, M., Boedhihartono, A.K., Day, M., Garcia, C., van Oosten, C., Buck, L.E., 2013. Ten principles for a landscape approach to reconciling agriculture, conservation, and other competing land uses. Proceedings of the National Academy of Sciences 110, 8349-8356.
Scherr, S.J., 1995. Economic Factors in Farmer Adoption of Agroforestry: Patterns Observed in Western Kenya. World Development 23, 787-804.
Scherr, S.J., 2004. Building opportunities for small-farm agroforestry to supply domestic wood markets in developing countries. Agroforest Syst 61-62, 357-370.
Schroeder, R.A., 1999. Shady Practices: Agroforestry and Gender Politics in The Gambia. Univ of California Press.
Schroth, G., da Fonseca, G.A., Harvey, C.A., Gascon, C., Vasconcelos, H.L., Izac, A.M.N., 2013. Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington, DC.
Sendzimir, J., Reij, C.P., Magnuszewski, P., 2011. Rebuilding resilience in the Sahel: regreening in the Maradi and Zinder regions of Niger. Ecology and Society 16.
Shorrocks, A.F., 2013. Decomposition procedures for distributional analysis: a unified framework based on the Shapley value. The Journal of Economic Inequality, 99-126.
Sunderlin, W.D., Dewi, S., Puntodewo, A., Muller, D., Angelsen, A., Epprecht, M., 2008. Why Forests Are Important for Global Poverty Alleviation: a Spatial Explanation. Ecology and Society, 1-21.
World Bank, 2015. The Living Standards Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA), http://www.worldbank.org/lsms.
Wunder, S., Angelsen, A., Belcher, B., 2014. Forests, Livelihoods, and Conservation: Broadening the Empirical Base. World Development 64, S1-S11.
Zomer, R.J., Trabucco, A., Coe, R., Place, F., Van Noordwijk, M., Xu, J.C., 2014. Trees on farms: an update and reanalysis of agroforestry's global extent and socio-ecological characteristics. ICRAF, Bogor, Indonesia.

Figure 1. Spatial distribution of households with presence of on-farm trees by tree type





Nigeria
Sokoto
Katsina
Birnin-Kebbi
Kano
Dutse
Damaturu
Maiduguri
Kaduna
Bauchi
Jos
Minna
Abuja
Yola
Jalingo
Ilorin
Osogbo
Lokoja
Makurdi
Abeokuta
Akure
Benin-City
Enugu
Asaba
Awka
Owerri
Umuahia
Uyo
Calabar
Port Harcourt
Main Cities
Capital
Provincial Capital
Main Roads
Primary Route
Secondary Route
Trees On Farm
Fruit Trees
Tree Cash Crops
Trees from Timber or Fuelwood
No Trees
Forest Covert (%)
No Forest
<= 40%
>40%



Tanzania
Bukoba
Musoma
Mwanza
Shinyanga
Arusha
Kigoma
Tabora
Singida
Tanga
Wete
Mkoani
Mkokotoni
Dodoma
Zanzibar
Kibaha
Dar Es Salaam
Morogoro
Sumbawanga
Iringa
Mbeya
Songea
Lindi
Mtwara
Main Cities
Capital
Provincial Capital
Main Roads
Primary Route
Secondary Route
Trees On Farm
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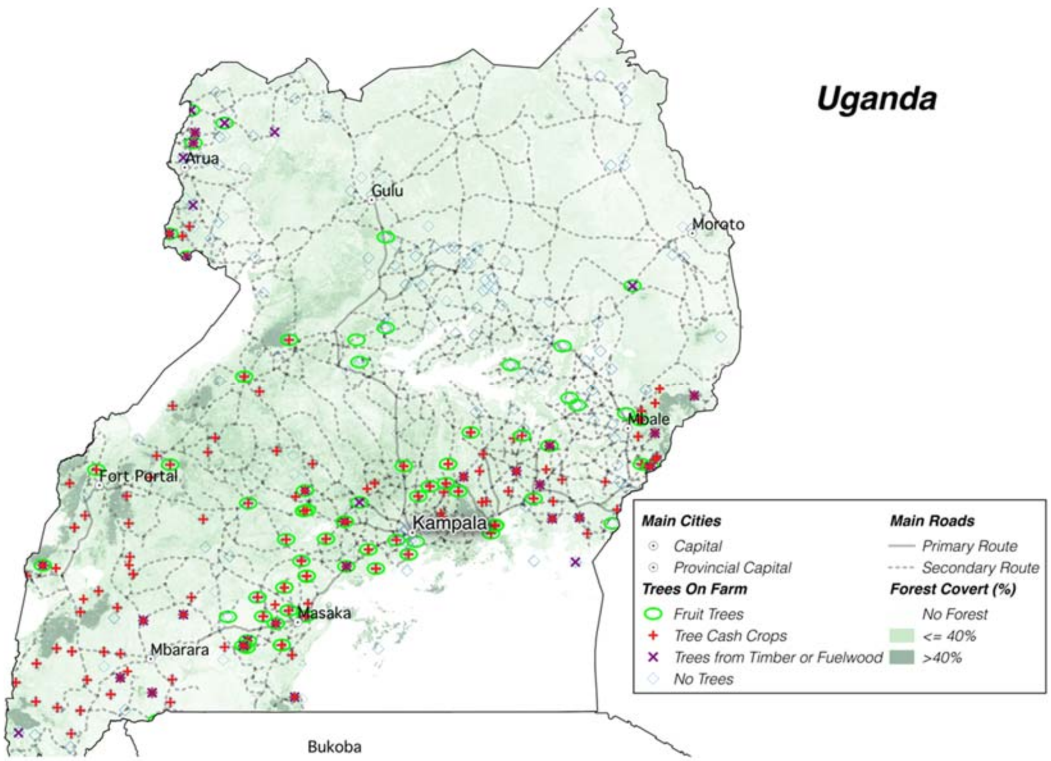
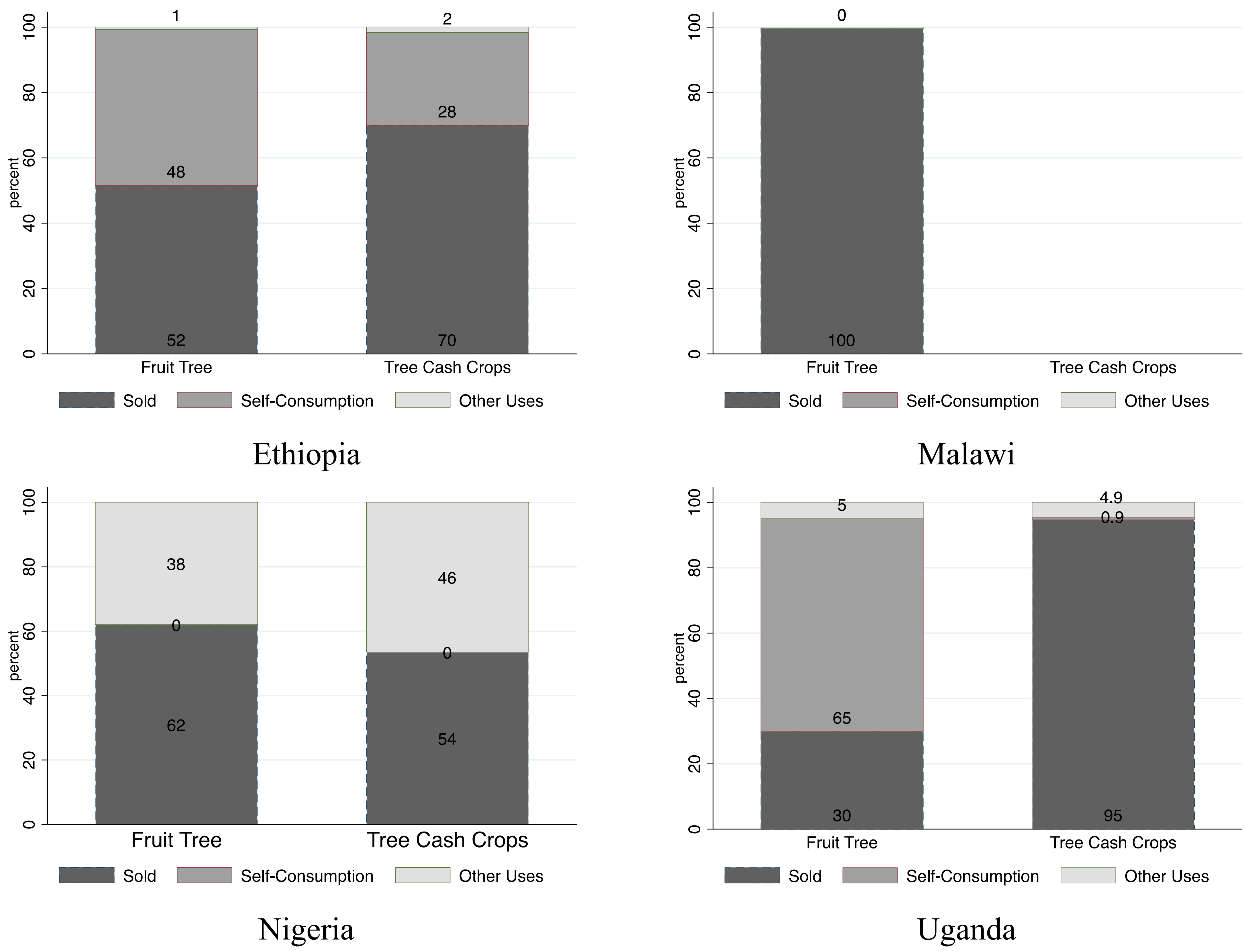
No Trees
Forest Covert (%)
No Forest
<= 40%
>40%



Note: Figure 2 shows the spatial distribution of trees on farms across the five study countries. Each map has a different scale depending on the country size. The geographical unit of analysis is the household. All statistics were corrected by sampling weight. *Data Source:* Authors' elaboration based on World Bank (2015).

Figure 2. Share of tree products by use, by country



Note: These figures show whether different categories of trees on farms were sold, used for self-consumption, or had other uses. Data were not available for Tanzania, as information on main uses for trees was not collected in that country. All statistics were corrected by sampling weight.

Table 1. Descriptive statistics

	Ethiopia 2011-12			*Malawi 2010-11*			*Nigeria 2010-11*			*Tanzania 2010-11*			*Uganda 2010-11*		
	N	*Mean*	*Std. Dev.*	*N*	*Mean*	*Std. Dev.*	*N*	*Mean*	*Std. Dev.*	*N*	*Mean*	*Std. Dev.*	*N*	*Mean*	*Std. Dev.*
Trees On Farm															
Trees On farm (yes=1)	3347	0.38	0.49	2272	0.24	0.43	2602	0.16	0.37	2621	0.55	0.49	1814	0.30	0.45
Fruit Trees (yes=1)	3347	0.17	0.36	2272	0.24	0.43	2602	0.06	0.23	2621	0.45	0.50	1814	0.05	0.21
Tree Cash Crops (yes=1)	3347	0.33	0.48	2272	-	-	2602	0.15	0.36	2621	0.22	0.41	1814	0.27	0.43
Timber of Fuel-wood (yes=1)	3347	0.03	0.14	2272	0.00	0.02	2602	-	-	2621	0.18	0.42	1814	0.02	0.15
Share of Farmland with presence of Trees	3347	0.18	0.34	2272	0.00	0.02	2602	0.08	0.25	2621	0.41	0.42	1814	0.35	0.65
Share of Farmland with presence of Fruit Trees	3347	0.05	0.19	2272	0.1	0.32	2602	0.04	0.17	2621	0.31	0.39	1814	0.05	0.26
Share of Farmland with presence of Tree Cash Crops	3347	0.17	0.33	2272	-	-	2602	0.07	0.23	2621	0.15	0.32	1814	0.32	0.63
Share of Farmland with Presence of Trees for Timber or Fuel-Wood	3347	-	-	2272	0.00	0.02	2602	-	-	2621	0.15	0.32	1814	0.02	0.16
Household Controls															
Household Size	3347	4.89	2.349	2272	4.85	2.30	2602	6.17	3.17	2621	5.34	3.18	1814	5.75	2.850
Number of Children (<14 years old)	3347	1.78	1.505	2272	2.37	1.68	2602	2.82	2.29	2621	2.38	2.09	1814	2.97	2.106
Head's Age (years)	3346	44.33	16.050	2252	43.48	16.72	2596	50.24	15.11	2620	47.52	16.05	1811	47.71	14.968
Head Female (yes=1)	3347	0.24	0.432	2272	0.24	0.42	2602	0.11	0.31	2621	0.23	0.42	1814	0.30	0.460
Head education (years)	3307	1.67	3.090	2249	5.04	4.02	2546	4.51	4.97	2569	4.98	3.92	1625	4.68	3.461
Assets and land															
Land Owned (area - ha)	2854	1.78	3.64	2272	0.85	0.75	2573	1.00	1.84	2212	2.61	4.02	1658	1.66	3.14
Tropical Livestock Units (TLU)	3347	2.51	2.78	2272	0.39	1.74	2602	3.12	17.17	2621	1.53	3.30	1814	1.24	2.95
Geo-climatic variables															
Population Density around 20km (people/km^2) (2010)	3347	200.08	180.87	2272	205.15	144.64	2602	284.89	281.76	2586	93.14	132.65	1812	309.23	313.61
Tree Cover % around 20km (mean) (2010)	3347	51.45	20.44	2272	65.62	11.74	2602	34.86	23.68	2586	59.91	24.29	1812	65.90	15.67
Fertile Soil % around 20 km (mean) (2010)	3347	0.73	0.27	2272	0.41	0.27	2602	0.53	0.31	2586	0.44	0.31	1812	0.20	0.23
Annual Mean Temperature (°C)	3347	18.42	3.18	2272	21.58	1.91	2602	26.36	0.99	2586	22.15	2.44	1812	21.79	1.86
Annual Precipitation (mm)	3347	1175	340	2272	1055	239	2602	1382	617	2586	1068	326	1812	1234	187

Note: Statistics are for rural areas only and reported with sampling weight correction. “-“ stands for missing information.

Table 2. Share of landholders with trees on their farms by category of tree (%)

Country	Percent of landholders with presence of any trees on farms	Percent of landholders with presence of fruit trees	Percent of landholders with presence of tree cash crops	Percent of landholders with presence of trees for timber or fuelwood
Ethiopia	38% (23.76% intercropped)	17% (23.73% intercropped)	33% (27.80% intercropped)	3%
Malawi	24% (10.13% intercropped)	24% (10.19% intercropped)	Not Available	0.1%
Nigeria	16% (85.91% intercropped)	6% (91.89% intercropped)	15% (86.67% Intercropped)	Not Available
Tanzania	55% (87.50% Intercropped)	45% (91.89% Intercropped)	22% (87.63% Intercropped)	18% (82.28% Intercropped)
Uganda	30% (95.59% Intercropped)	5% (99.66% Intercropped)	27% (96.59% Intercropped)	2% (77.89% Intercropped)
Overall Average	*33%* (59.31% Intercropped)	*19%* (60.85% Intercropped)	*20%* (63.74% Intercropped)	*5%*

Note: All descriptive statistics corrected by sampling weight.

Table 3. Household distance from nearest forest defined as A) 30% tree cover threshold and B) 50% tree cover threshold

A) 30% tree cover threshold

Country	Extent of tree cover (ha) by country (2000)	Percent tree cover relative to country land area (2000)	Households in our sample (#)	Share (%) of households with trees on farms within		
				10km of forest	20km of forest	50km of forest
Ethiopia	12,040,763	10.72	3,388	55.81	73.91	93.3
Malawi	1,521,741	16.17	2,272	85.87	100	100
Nigeria	10,033,216	11.13	2,692	36.33	46.51	59.7
Tanzania	26,42,2567	29.85	2,621	79.82	88.1	94.2
Uganda	7,768,069	37.83	1,815	91.85	98.02	100
Overall	6,272,758	17.95	14,839	58.47	68.91	77.05

B) 50% tree cover threshold

Country	Extent of tree cover (ha) by country (2000)	Percent tree cover relative to country land area (2000)	Households in our sample (#)	Share (%) of households with trees on farms within		
				10km of forest	20km of forest	50km of forest
Ethiopia	5,426,282	4.83	3,388	32.05	44.19	74.62
Malawi	313,115	3.23	2,272	53.57	87.81	100
Nigeria	4,716,199	5.23	2,692	20.17	29.27	42.53
Tanzania	9,702,599	10.96	2,621	66.84	77.68	86.65
Uganda	3,271,840	15.94	1,815	55.59	81.76	98.95
Overall	3,905,006	17.95	14,839	38.45	53.22	68.13

Note: To protect confidentiality household location coordinates in LSMS-ISA data are not exact, but rather based on a random distortion of 0-5km. Data on extent of tree cover by country and percent tree cover relative to country land area derive from Hansen et al. (2013). Note that "tree cover" is not the same as "forest cover" in these data. "Tree cover" refers to the biophysical presence of trees, which may be a part of natural forests or tree plantations. Information on household distance to forest are based on the authors' calculations from LSMS-ISA data sets (World Bank, 2015) and "MOD44B MODIS Vegetation Continuous Field Coll. 5–2000 through to 2010: Percent Tree Cover" (DiMiceli et al., 2011).

Table 4. Contribution of trees on farms to annual gross household and agricultural income

		Annual Gross Household Income			Annual Gross Agricultural Income		
		Contribution from trees on farm (%)	Contribution from Fruit Trees (%)	Contribution from Tree Cash Crops (%)	Contribution from trees on farm (%)	Contribution from Fruit Trees (%)	Contribution from Tree Cash Crops (%)
Ethiopia 2011-12	All Farmers	5.55	0.14	5.80	8.41	0.35	8.61
	Only Farmers with Trees On Farm	13.75	0.37	14.39	20.93	0.90	21.44
*Malawi 2010-11**	All Farmers	3.55	3.55	0.00	20.40	20.40	0.00
	Only Farmers with Trees On Farm	14.28	14.28	0.00	82.14	82.14	0.00
Nigeria 2010-11	All Farmers	6.90	1.40	6.40	6.76	0.94	5.82
	Only Farmers with Trees On Farm	36.20	7.92	33.31	36.14	5.28	30.86
Tanzania 2010-11	All Farmers	8.82	4.02	4.05	14.27	7.84	5.30
	Only Farmers with Trees On Farm	13.32	6.07	6.11	21.56	11.83	8.00
Uganda 2010-11	All Farmers	5.94	0.32	5.73	7.31	0.61	6.90
	Only Farmers with Trees On Farm	18.75	1.02	18.09	23.10	1.93	21.80
Overall	**All Farmers**	5.98	1.80	5.33	11.05	5.51	6.81
	Only Farmers with Trees On Farm	16.85	5.16	13.91	31.47	15.82	17.93

Table 5. Relationship of trees on farms and daily consumption per person

Dependent Variable = Log. Real Daily Consumption per person (in 2011 PPP)					
		(I)	(II)	(III)	(IV)
Ethiopia 2011-12	Trees On Farm (yes = 1)	0.597*** [0.037]			
	Fruit Trees On Farm (yes = 1)		0.382*** [0.053]		
	Tree Cash Crops on Farm (yes = 1)			0.612*** [0.039]	
	Trees for Timber or Fuelwood on Farm (yes = 1)				0.132 [0.134]
Malawi 2010-11	Trees On Farm (yes = 1)	0.000 [0.031]			
	Fruit Trees On Farm (yes = 1)		-0.006 [0.010]		
	Trees for Timber or Fuelwood on Farm (yes = 1)				-0.323*** [0.103]
Nigeria 2010-11	Trees On Farm (yes = 1)	0.212*** [0.035]			
	Fruit Trees On Farm (yes = 1)		0.252*** [0.046]		
	Tree Cash Crops on Farm (yes = 1)			0.177*** [0.030]	
Tanzania 2010-11	Trees On Farm (yes = 1)	-0.002 [0.030]			
	Fruit Trees On Farm (yes = 1)		0.011 [0.010]		
	Tree Cash Crops on Farm (yes = 1)			0.032*** [0.011]	
	Trees for Timber or Fuelwood on Farm (yes = 1)				0.010 [0.010]
Uganda 2010-11	Trees On Farm (yes = 1)	0.010 [0.025]			
	Fruit Trees On Farm (yes = 1)		0.102*** [0.032]		
	Tree Cash Crops on Farm (yes = 1)			0.002 [0.010]	
	Trees for Timber or Fuelwood on Farm (yes = 1)				0.002 [0.021]

Note: Sampling weights and fixed effect were used for all regressions. * p<0.10 ** p<0.05 *** p<0.01.

Table 6a. Multivariate Analysis of Fruit Trees

	Adoption Analysis (Probit)			*Determinants of share of farmland with trees*		
	Dep. Variable: Fruit trees on farm (yes=1)			*Dep. Variable: Share of farm area with presence of fruit trees*		
	(I)	(II)	Shapley Value	(III)	(IV)	Shapley Value
Household Controls			**0.008 (2.99%)**			**0.010 (3.32%)**
Household Size	0.002	0.003		0.014**	0.012**	
	[0.003]	[0.003]		[0.006]	[0.006]	
Number of Children (<14 years old)	-0.001	-0.002		0.002	0.002	
	[0.004]	[0.003]		[0.009]	[0.009]	
Head's Age (years)	0.002***	0.002***		0.003***	0.003***	
	[0.000]	[0.000]		[0.001]	[0.001]	
Head Female (yes=1)	-0.018**	-0.019***		-0.043	-0.044	
	[0.008]	[0.007]		[0.026]	[0.027]	
Head education (years)	0.005*	0.005*		0.006*	0.007**	
	[0.003]	[0.003]		[0.003]	[0.003]	
Assets and land			**0.005 (1.93%)**			**0.096 (59.30%)**
Land Owned (area - ha)	0.005***	0.005***		0.088**	0.086**	
	[0.001]	[0.001]		[0.032]	[0.032]	
Tropical Livestock Units (TLU)	-0.007***	-0.006***		-0.001	-0.001	
	[0.002]	[0.001]		[0.000]	[0.000]	
Geo- and climate variables			**0.053 (18.46%)**			**0.006 (4.35%)**
Tree Cover % around 20km (mean) (2010)	0.003***	0.003***		0.003**	0.003**	
	[0.001]	[0.001]		[0.001]	[0.001]	
Log Population Density around 20km (people/ km^2) (2010)	-0.000	0.000		0.000	0.001	
	[0.001]	[0.001]		[0.001]	[0.001]	
Fertile Soil % around 20 km (mean) (2010)	0.000	-0.000		-0.002	-0.003	
	[0.005]	[0.005]		[0.004]	[0.004]	
Log. Annual Mean Temperature (C)	0.014***	0.018***		0.020**	0.021***	
	[0.005]	[0.003]		[0.008]	[0.006]	
Log. Annual Precipitation (mm)	0.000	0.000		-0.000	-0.000	
	[0.000]	[0.000]		[0.000]	[0.000]	
Country Fixed Effects (Baseline Country: Ethiopia)			**0.13 (48.00%)**			**0.059 (36.81%)**
Malawi	-0.041	-0.038		-0.058	-0.050	
	[0.026]	[0.023]		[0.049]	[0.052]	
Nigeria	-0.211***	-0.245***		-0.117*	-0.111	
	[0.031]	[0.017]		[0.067]	[0.068]	
Tanzania	0.159***	0.143***		0.564***	0.510***	
	[0.051]	[0.050]		[0.076]	[0.080]	
Uganda	-0.133***	-0.128***		-0.056	-0.058	
	[0.021]	[0.008]		[0.082]	[0.107]	
(pseudo) R-Square	0.260	0.299		0.162	0.177	
Observations	11243	11243		11243	11243	
District/Zone Fixed Effect	No	Yes		No	Yes	

Note: This table presents the multivariate results for fruit trees on farms. Robust standard errors in brackets, clustered at strata level. Sampling weights used for all regressions. * p<0.10 ** p<0.05 *** p<0.01.

Table 6b. Multivariate Analysis of Tree Cash Crops

	Adoption Analysis (Probit)			Determinants of share of farmland with trees		
	Dep. Variable: Tree cash crops on farm (yes=1)			Dep. Variable: Share of farm area with presence of tree cash crops		
	(I)	(II)	Shapley Value	(III)	(IV)	Shapley Value
Household Controls			**0.007 (2.70%)**			**0.006 (4.29%)**
Household Size	0.005	0.010**		-0.003	0.002	
	[0.006]	[0.005]		[0.013]	[0.012]	
Number of Children (<14 years old)	-0.001	-0.003		-0.012	-0.015	
	[0.007]	[0.006]		[0.009]	[0.010]	
Head's Age (years)	0.001*	0.001		0.002*	0.001	
	[0.001]	[0.001]		[0.001]	[0.001]	
Head Female (yes=1)	-0.052***	-0.048***		-0.055**	-0.052**	
	[0.014]	[0.015]		[0.025]	[0.023]	
Head education (years)	0.002	0.003*		0.008**	0.009**	
	[0.002]	[0.002]		[0.004]	[0.004]	
Assets and land			**0.001 (0.37%)**			**0.061 (44.08%)**
Tropical Livestock Units (TLU)	-0.002	-0.002		-0.001	-0.001	
	[0.002]	[0.002]		[0.001]	[0.001]	
Land Owned (area - ha)	-0.002	0.000		0.111**	0.112**	
	[0.003]	[0.003]		[0.043]	[0.044]	
Geo- and climate variables			**0.084 (30.35%)**			**0.021 (15.24%)**
Log Population Density around 20km (people/ km^2) (2010)	-0.002	-0.002		-0.000	0.001	
	[0.001]	[0.001]		[0.001]	[0.001]	
Tree Cover % around 20km (mean) (2010)	0.007***	0.008***		0.007***	0.006***	
	[0.002]	[0.001]		[0.002]	[0.002]	
Fertile Soil % around 20 km (mean) (2010)	0.012*	0.008		0.001	-0.003	
	[0.007]	[0.006]		[0.005]	[0.004]	
Log. Annual Mean Temperature (C)	0.019**	0.020**		0.021	0.014	
	[0.009]	[0.009]		[0.015]	[0.014]	
Log. Annual Precipitation (mm)	-0.000	0.000		-0.000**	-0.000	
	[0.000]	[0.000]		[0.000]	[0.000]	
Country Fixed Effects (Baseline Country: Ethiopia)			**0.11 (42.02%)**			**0.015 (10.85%)**
Malawi						
Nigeria	-0.287***	-0.295***		-0.133	-0.037	
	[0.067]	[0.060]		[0.112]	[0.109]	
Tanzania	-0.198***	-0.205***		-0.074	-0.005	
	[0.043]	[0.028]		[0.101]	[0.083]	
Uganda	-0.189***	-0.191***		0.185	0.246	
	[0.041]	[0.025]		[0.183]	[0.168]	
(pseudo) R-Square	0.192	0.263		0.122	0.141	
Observations	8994	8975		8994	8994	
District/Zone Fixed Effect	No	Yes		No	Yes	

Note: This table presents the multivariate results for tree cash crops on farms. Robust standard errors in brackets, clustered at strata level. Sampling weights used for all regressions. * p<0.10 ** p<0.05 *** p<0.01.

Table 6c. Multivariate Analysis of Trees for Timber or Fuelwood

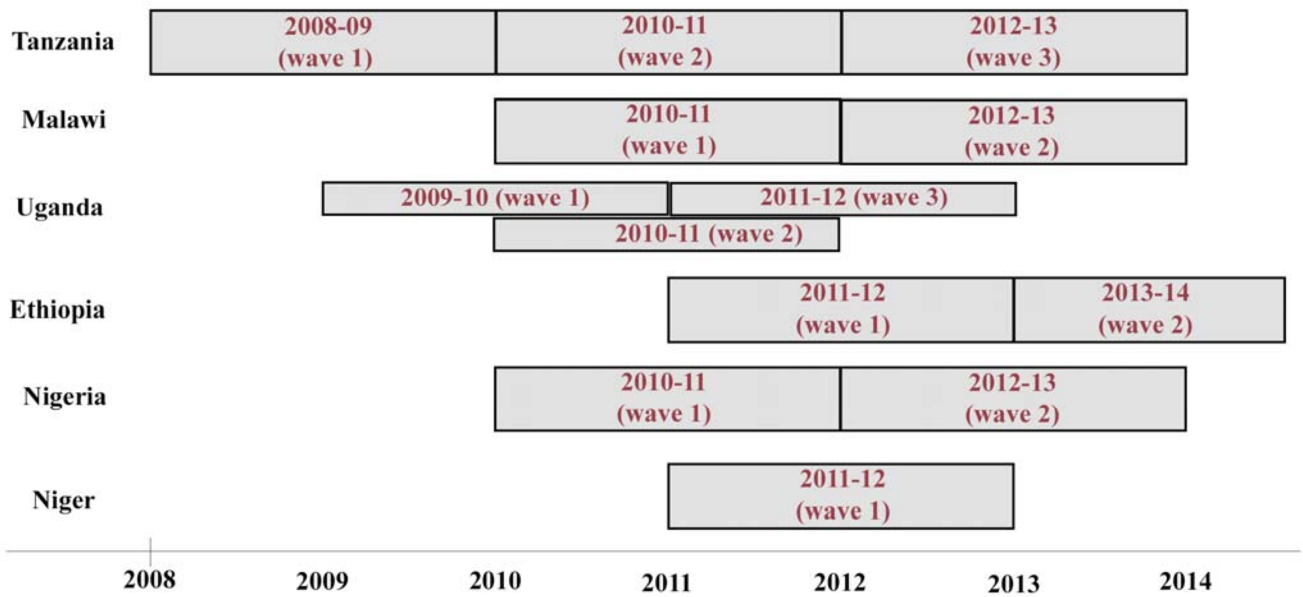
	Adoption Analysis (Probit)			Determinants of share of farmland with trees		
	Dep. Variable: Trees for timber or fuelwood on farm (yes=1)			*Dep. Variable: Share of farm area with presence of trees for timber or fuelwood*		
	(I)	(II)	Shapley Value	(III)	(IV)	Shapley Value
Household Controls			**0.007 (2.70%)**			**0.010 (3.32%)**
Household Size	-0.000	-0.001		-0.005	-0.015	
	[0.002]	[0.002]		[0.015]	[0.018]	
Number of Children (<14 years old)	0.003	0.003		0.014	0.019	
	[0.003]	[0.003]		[0.013]	[0.014]	
Head's Age (years)	0.001**	0.000***		0.001	0.002	
	[0.000]	[0.000]		[0.001]	[0.001]	
Head Female (yes=1)	-0.002	-0.004		0.082	0.051	
	[0.006]	[0.005]		[0.075]	[0.057]	
Head education (years)	0.001	0.001		-0.002	-0.005	
	[0.001]	[0.001]		[0.005]	[0.006]	
Assets and land			**0.001 (0.37%)**			**0.122 (55.22%)**
Tropical Livestock Units (TLU)	0.001	0.000		0.019	0.013	
	[0.001]	[0.001]		[0.019]	[0.017]	
Land Owned (area - ha)	0.001	0.001		0.144	0.145	
	[0.001]	[0.001]		[0.101]	[0.100]	
Geo- and climate variables			**0.084 (30.35%)**			**0.007 (3.34%)**
Log Population Density around 20km (people/km^2) (2010)	-0.000	-0.000		-0.002	0.001	
	[0.001]	[0.001]		[0.002]	[0.002]	
Tree Cover % around 20km (mean) (2010)	-0.000	0.000		-0.005	-0.005	
	[0.000]	[0.000]		[0.003]	[0.003]	
Fertile Soil % around 20 km (mean) (2010)	0.002	0.001		0.012	-0.001	
	[0.003]	[0.003]		[0.013]	[0.010]	
Log. Annual Mean Temperature (C)	-0.005***	-0.003**		0.002	0.012	
	[0.001]	[0.001]		[0.012]	[0.013]	
Log. Annual Precipitation (mm)	0.000	0.000		0.000	0.000	
	[0.000]	[0.000]		[0.000]	[0.000]	
Country Fixed Effects (Baseline Country: Ethiopia)			**0.11 (42.02%)**			**0.023 (10.43%)**
Malawi	-0.040***	-0.038***		0.227*	0.273	
	[0.005]	[0.005]		[0.127]	[0.160]	
Nigeria						
Tanzania	0.245***	0.165***		0.571***	0.415***	
	[0.065]	[0.050]		[0.154]	[0.128]	
Uganda	0.018	-0.001		0.097*	0.035	
	[0.017]	[0.011]		[0.057]	[0.056]	
(pseudo) R-Square	0.250	0.300		0.182	0.221	
Observations	8728	8697		8728	8728	
District/Zone Fixed Effect	No	Yes		No	Yes	

Note: This table presents the multivariate results for tree for timber or fuelwood on farms. Robust standard errors in brackets, clustered at strata level. Sampling weights used for all regressions. * p<0.10 ** p<0.05 *** p<0.01.

APPENDIX A. LSMS-ISA Data Relating to Trees on Farms

A1. LSMS-ISA data availability by country

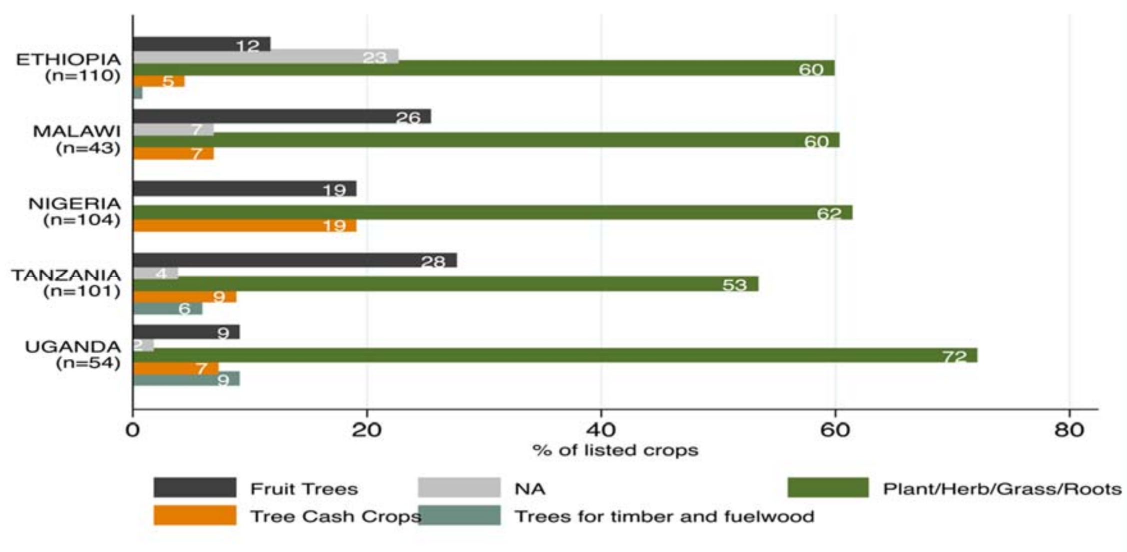
Figure A.1. Data availability per LSMS-ISA country, 2008-2014



Note: This figure shows the different waves of LSMS-ISA survey implementation. For our analysis we use: Tanzania (2010-11), Ethiopia (2011-12), Uganda (2010-11), Malawi (2010-11) and Nigeria (2010-11).

A2. Crops identified in LSMS-ISA surveys

Figure A.2. Crops identified in LSMS-ISA surveys by country and crop classification (percent of total)



Note: n = number of listed crops by country. Total number of unique listed crops = 230

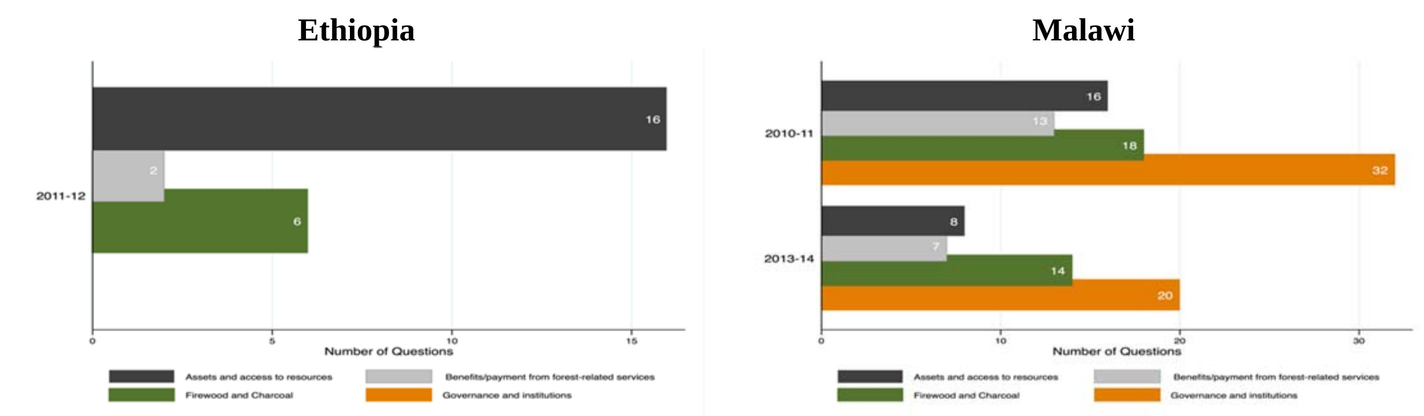
A3. Forest-related questions in LSMS-ISA surveys

The LSMS-ISA surveys do not have a separate agroforestry or forestry module, but they contain a series of questions related to trees or forest products that are scattered across the different survey modules. Four different types of questions related to trees and forest products are distinguished:[13]

- *Assets and Access to Resources:* questions related to access and use of timber and other forest products within the household and the community.
- *Benefits/Payment from Forest Related Services:* questions on forest-related activities with possible economic benefits.
- *Firewood and Charcoal*: questions related to access, marketing and use of the firewood and charcoal within households.
- *Governance and Institutions:* questions related to local governance and management of forest resources.

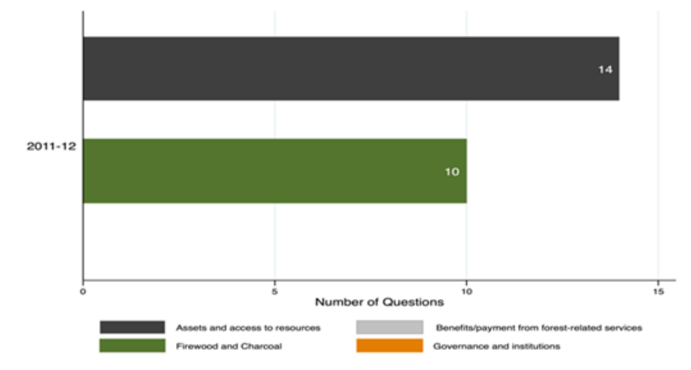
Figure A.3 shows the number of forest-related questions by country. On average, LSMS-ISA surveys included 47 forest-related questions; Malawi (2010-11; 2013-14) averaged 100 forest-related questions, but Niger only had 25. Questions about "*Firewood and Charcoal*" were the most common (31% of the total forest-related questions), most of them relating to their use as energy source (e.g. lighting or cooking). The second most frequent question area related to *"Assets and Access to Resources,"* with 19% of total forest-related questions falling in this category. Here, questions about floor and roofing materials were the most common. Very few questions were asked regarding *"Governance and Institutions,"* with the exception of Malawi. In Malawi question were also asked about entrepreneurship based on forest-products (i.e. *"Benefits/Payment from Forest Related Services"*).

Figure A.3. Forest-related questions in LSMS-ISA surveys by country

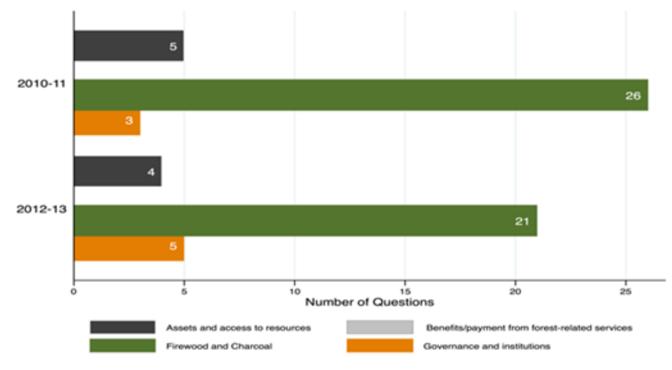


[13] These categories were taken from a report by Russo, L. (2014) "Review of the coverage of forest-related socioeconomic issues in selected surveys." Washington, DC: World Bank. The LSMS team is developing a separate (agro-) forestry module, which incorporates the lessons learned from analyzing the data presented in this paper.

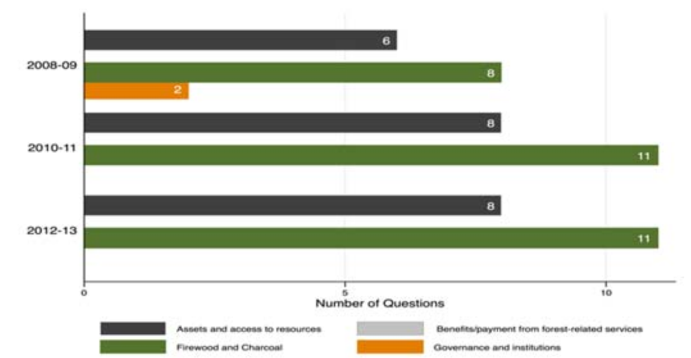
Niger



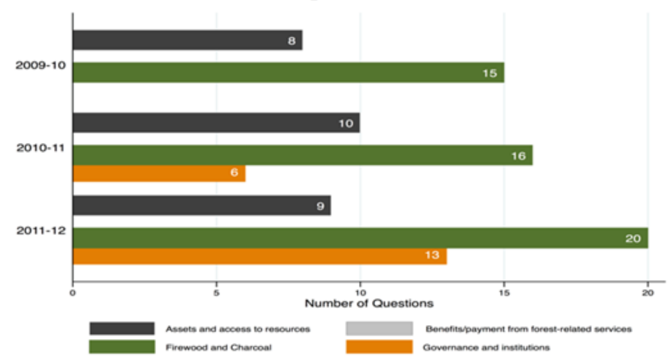
Nigeria



Tanzania



Uganda



Note: This Figure shows the different LSMS-ISA waves. Data source: Authors' elaboration based on World Bank (2015).

A4. Crop/tree classifications

Table A.1. Crop/tree classification by type of tree in LSMS-ISA data

CROP	Type of Tree	CROP	Type of Tree
Agbono (Oro Seed)	Fruit Tree	Black Pepper	Tree Cash Crops
Apple	Fruit Tree	Cashew	Tree Cash Crops
Avocado	Fruit Tree	Cashew Fruit	Tree Cash Crops
Bilimbi	Fruit Tree	Cashew Nut	Tree Cash Crops
Bitter Kola	Fruit Tree	Castor Beans	Tree Cash Crops
Bread Fruit	Fruit Tree	Chat	Tree Cash Crops
Buya	Fruit Tree	Clove	Tree Cash Crops
Cherry (Agbalumo)	Fruit Tree	Cocoa	Tree Cash Crops
Cinnamon	Fruit Tree	Cocoa Beans	Tree Cash Crops
Coconut	Fruit Tree	Cocoa Pod	Tree Cash Crops
Custard Apple	Fruit Tree	Coffee All	Tree Cash Crops
Date Palm	Fruit Tree	Dry Leaves (Kuka)	Tree Cash Crops
Durian	Fruit Tree	Gomme Arabique	Tree Cash Crops
Fig	Fruit Tree	Gum Arabic	Tree Cash Crops
Gishita	Fruit Tree	Iyere	Tree Cash Crops
God Fruit	Fruit Tree	Locust Bean	Tree Cash Crops
Grape Fruit	Fruit Tree	Macadamia	Tree Cash Crops
Guava	Fruit Tree	Monkeybread	Tree Cash Crops
Jackfruit	Fruit Tree	Moringa	Tree Cash Crops
Kolanut	Fruit Tree	Oil Palm	Tree Cash Crops
Kolanut Shelled	Fruit Tree	Palm Kernel	Tree Cash Crops
Kolanut Unshelled	Fruit Tree	Ronier	Tree Cash Crops
Lemon	Fruit Tree	Rubber	Tree Cash Crops
Lime	Fruit Tree	Rubber Lump	Tree Cash Crops
Malay Apple	Fruit Tree	Rubber Sheet	Tree Cash Crops
Mandarin/Tangerine	Fruit Tree	Shea Nuts	Tree Cash Crops
Mango	Fruit Tree	Tea	Tree Cash Crops
Masau	Fruit Tree	Three Leave Yam	Tree Cash Crops
Oranges	Fruit Tree	Bamboo	Trees for timber and fuelwood
Paw	Fruit Tree	Black Wattle	Trees for timber and fuelwood
Peaches	Fruit Tree	Fence Tree	Trees for timber and fuelwood
Pear	Fruit Tree	Firewood/Fodder	Trees for timber and fuelwood
Plum	Fruit Tree	Kapok	Trees for timber and fuelwood
Pomegranate	Fruit Tree	Mahogany	Trees for timber and fuelwood
Pomelo	Fruit Tree	Natural Forest Trees	Trees for timber and fuelwood
Pomme Du Sahel	Fruit Tree	Other Forest Trees	Trees for timber and fuelwood
Rambutan	Fruit Tree	Plantation Trees	Trees for timber and fuelwood
Star Fruit	Fruit Tree	Timber	Trees for timber and fuelwood
Tamarind	Fruit Tree		
Walnut	Fruit Tree		

Data source: World Bank 2015.

A5. Information Available on Cost and Revenue

Table A.2. Information availability for crop costs and revenues in LSMS-ISA surveys

Country	Item	Level
Ethiopia	(+) Total Production	Crop level
	(-) Seeds	Crop level
	(-) Fertilizer	Household level
	(-) Labor (post-planting)	Plot level
	(-) Labor (post-harvest)	Crop level
	(-) Other uses (e.g. Gift, self-consumption, etc.)	Crop level
Malawi	(+) Total Production	Crop level
	(-) Seeds	Plot level
	(-) Fertilizer	Plot level
	(-) Labor	Plot level
	(-) Other uses (e.g. Gift, self-consumption, etc.)	Crop level
Tanzania	(+) Total Production	Crop level
	(-) Labor	Plot level
	(-) Seeds	Crop level
	(-) Fertilizer	Crop level
	(-) Land rent	Plot level
	(-) Machinery rent	Plot level
Uganda	(+) Total Production	Crop level
	(-) Transport cost, seeds and fertilizer	Plot level
	(-) Labor	Plot level
	(-) Other cost, Machinery, extension services	Household level
	(-) Other uses (e.g. Gift, self-consumption, etc.)	Crop level
Nigeria	(+) Total Production	Crop level
	(-) Fertilizer	Plot level
	(-) Seeds	Crop level
	(-) Labor	Plot level
	(-) Extension charges	Household level
	(-) Other related cost	Household level
	(-) Other uses (e.g. Gift, self-consumption, etc.)	Crop level

Note: Figures in LSMS-ISA surveys are provided in local monetary units. (+) = Revenues; (-) = Cost. “Other uses” refers to instances where one crop is used in the production of another crop such as, for example, use of a tree for fertilizer for an annual food crop.

APPENDIX B. Additional Descriptive Statistics

Table B.1. Spatial Correlation Index (Moran's I)

Country	*Number of plots with trees*	*Number of plots with fruit tree*	*Number of plots with tree cash crops*	*Number of plots with trees for timber or fuelwood*
Ethiopia	0.13***	0.06***	0.13***	0.08***
Malawi	0.05***	0.05***		0.01***
Nigeria	0.08***	0.05***	0.07***	
Tanzania	0.15***	0.11***	0.15***	0.09***
Uganda	0.07***	0.02***	0.08***	0.001

Note: This table presents the correlation index for key variables of interest. We estimate the haversine distance to estimate the distance matrix. While the Euclidean distance traces straight lines, haversine takes into account the curvature of earth by estimating geodesics. Since information on type of tree is not available for all countries, there are some missing values for the spatial correlation index. Standard deviation in brackets. Two-sided null hypothesis reported. * p<0.10 ** p<0.05 *** p<0.01. Data source: Authors' calculations from LSMS-ISA datasets, World Bank (2015)