THE RELATIONSHIP BETWEEN MEDIUM-SCALE FARMS AND DEFORESTATION IN SUB-SAHARAN AFRICA

A Concept Note

JANUARY 2022

About the authors: Ayala Wineman is Research Associate, Michigan State University. T. S. Jayne is University Foundation Professor, Michigan State University. Caleb Stevens is Senior Advisor, Governance and Natural Environment, USAID Land and Resource Governance Division.

Acknowledgements: Much of the analysis contained in the report draws from a larger body of work funded by the Consultative Group on International Agricultural Research (CGIAR) Research Program on Policies, Institutions, and Markets (PIM); and the Agricultural Policy Research in Africa (APRA) Project, managed by the Institute for Development Studies/Sussex and funded by Foreign Commonwealth and Development Office (FCDO).

This document is made possible by the support of the American people through the United States Agency for International Development (USAID). It was prepared with support from the Integrated Natural Resource Management Task Order (Contract No. 7200AA18D00020/7200AA20F00010), under the Strengthening Tenure and Resource Rights II (STARR II) IDIQ. Its contents are the sole responsibility of the author or authors and do not necessarily reflect the views of USAID or the U.S. Government.

Date of publication: January 14, 2022

Front cover photo: Agricultural development and the associated clearing of the land pushes right up to the boundary of Bwindi Impenetrable National Park in Uganda. Photo by Jason Houston for USAID.

Back cover photo: Agricultural fields seen from the Mt. Muhabura Campsite near the border of Mgahinga Gorilla National Park. Near Kisoro, Uganda. Photo by Jason Houston for USAID.

Submitted by:
Robin Martino, Chief of Party
Integrated Natural Resource Management
DAI
7600 Wisconsin Ave, Suite 200
Bethesda, MD, 20814, USA
Telephone: 301.771.7600
Fax: 301.771.7777
www.dai.com

Suggested Citation

Wineman, A., Jayne, T.S., and Stevens, C. 2021. *The Relationship Between Medium-Scale Farms and Deforestation in Sub-Saharan Africa*.

Contents

1. Introduction

Forests serve numerous functions for this planet and its inhabitants. As the "lungs of the earth," they absorb carbon dioxide from the atmosphere and release oxygen. Intact forests thus serve as carbon sinks, regulating the earth's carbon dioxide levels. Forests also provide critical ecosystem services, such as the prevention of soil erosion and flooding, the regulation of precipitation, the cycling of nutrients, and a reduction in air temperatures (McPherson et al., 2005). Forests are also vital to rural livelihoods. Forest loss constricts options for forest-based livelihoods in rural areas; exacerbates land erosion and river degradation; species decline and extinction; and climate change that results from the release of carbon as forests are cut down (Dang et al., 2019; Ango, 2018; Ngoma et al., 2021; DeFries et al., 2010). Forests clearly provide essential and under-recognized ecosystem services required to sustain our planet and its inhabitants.

Forests in Africa are being lost at an alarming pace. While deforestation has been slower in sub-Saharan Africa (SSA) than in some other regions, it is accelerating rapidly with population growth. SSA has lost approximately 99 million hectares of forest since 1990 (authors' computation, see Section 2), roughly 13% of its 1990 forest area.

Given the importance of forests, it is imperative to identify the forces driving deforestation and the specific actors involved. Agricultural expansion is the most prominent driver of deforestation worldwide (Gibbs et al., 2010). While SSA has registered the highest rate of agricultural growth of any region of the world since 2000, 74% of this growth has come through area expansion rather than yield growth (Jayne and Sanchez, 2021). Since 2000, medium-scale farms of 5–100 hectares (ha) have accounted for a major share of this expansion of cultivated land in many African countries -- over 50% in Ghana and roughly 40% in Zambia and Tanzania (Jayne et al., 2019). Circumstantial evidence thus suggests that medium-scale farms may have directly contributed to deforestation in these countries to the extent that these farms are established in (or expand into) previously forested areas. The emergence of medium-scale farms may also indirectly contribute to deforestation by, for example, driving up land prices and encouraging smaller-scale farm-households to acquire new farmland through less expensive means, such as clearing forestland for their subsistence needs.

However, the precise link between medium-scale farms and deforestation patterns in SSA has yet to be explored rigorously and empirically and across a broad geography. Data is not available in any African country (to our knowledge) to assess when existing farm fields of any size category were converted from forest or grasslands into farmland; we are therefore unable to assess whether small, medium, or land-scale farms are the biggest contributors to agricultural-related deforestation. Given the urgent need to slow deforestation (or engage in forest restoration or agroforestry), it is critical to better understand this link in order to design and target effective conservation programs, and to align forestry and agricultural development policies to ensure that efforts to support agricultural transformation are not at the expense of environmental health.

This concept note summarizes the current state of knowledge regarding the pace and drivers of deforestation in SSA and the emergence of medium-scale farms across the region (Section 2). Section 3 presents a conceptual framework of the plausible linkages between medium-scale farms and deforestation. Section 4 reviews what is currently known regarding how medium-scale farms contribute to deforestation. Section 4 also identifies data needed to more precisely understand the link between medium-scale farms and deforestation and options for simultaneously supporting agricultural productivity growth and the protection of forests. We review the information collected in four widely used farm-household surveys. As there are numerous gaps in what is currently known, Section 5 identifies priority issues for future research, focusing on both study design/sampling considerations and a set of research questions that merit study.

2. Background

2.1. Deforestation in sub-Saharan Africa

2.1.1. Trends in deforestation

Forest cover has been steadily declining in SSA. An analysis of land cover data (FAOSTAT, 2021) indicates that, in aggregate across all SSA countries,[1] the area under forest declined from about 734 million ha in 1990 to about 635 million ha in 2018, a loss of 98.7 million ha (Figure 1). This translates into a loss of 13.45% of its 1990 forest area. It follows that SSA experienced a decline in the percent of land area covered by forest. Specifically, this value fell from 30.9% in 1990 to 26.6% by 2018 (a difference of 4.3 percentage points) (see Figure 2 on next page). Over this same period, the area under permanent meadows and pastures also declined by 1.5 percentage points, while cropland area increased by 3.1 percentage points, and "other" land (which is inclusive of built-up and related areas, among other land uses) increased by 2.7 percentage points.

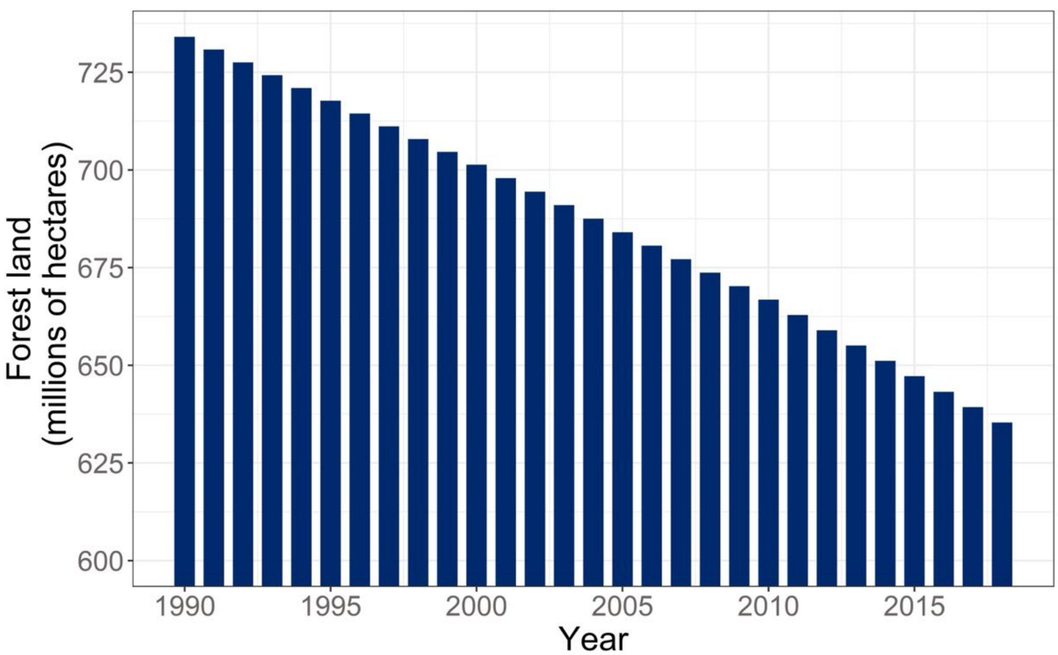

Figure 1: *Forest area in sub-Saharan Africa. Source: FAOSTAT (Authors' calculations).*

[1] In this analysis, SSA is inclusive of all countries in Africa with the exception of Algeria, Egypt, Libya, Morocco, Western Sahara, and Tunisia.

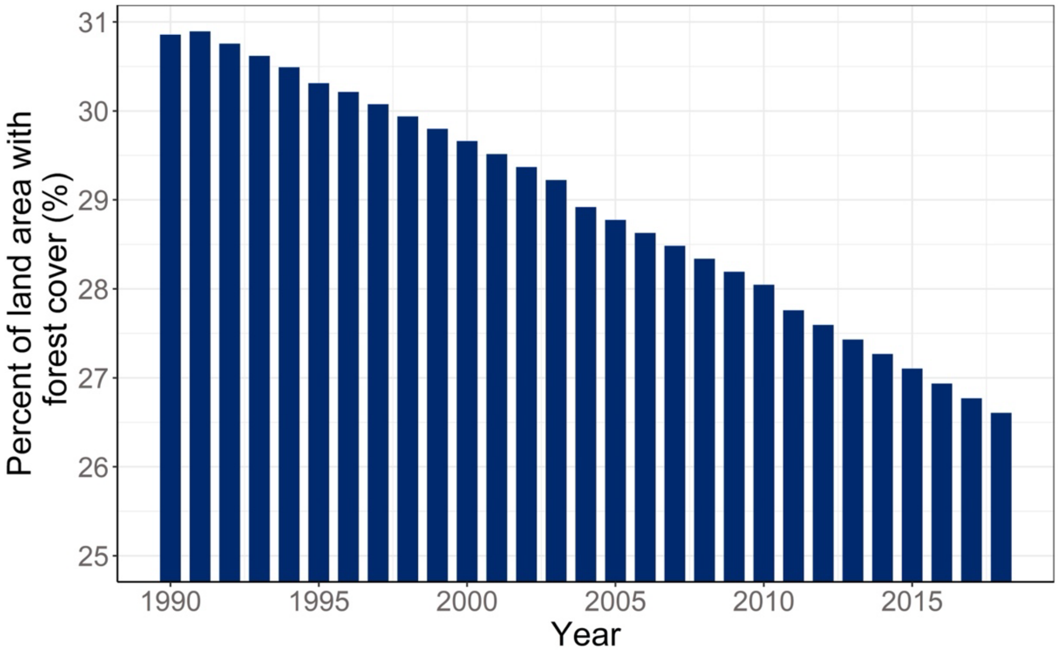

Figure 2: *Percent forest cover in sub-Saharan Africa. Source: FAOSTAT (Authors' calculations).*

The rate of forest loss in SSA is also accelerating over time. In the 1990s, the average annual decline in forest area was 0.45%. In the 2000s, this average annual decline was 0.50%, and from 2010 to 2018, it was 0.60%. There was a particularly sharp rise in the rate of forest loss in 2011 (from 0.52% in 2010 to 0.59% in 2011), and this higher rate was sustained in subsequent years. A visual inspection of the data indicates that this leap in 2011 occurred mostly in the Democratic Republic of the Congo, Chad, Sudan, and Zambia. Some countries do see a declining or even a negative rate of forest loss in recent years (i.e., a *gain* in forest area). For example, in Madagascar, the average annual share of forest area lost was 0.49% in the 1990s, 0.37% in the 2000s, and 0.11% from 2011–2018. In Rwanda, the average annual share of forest area lost from 2011 to 2018 was -0.42%, signifying a small expansion of forest area over this period.

Our analysis of the FAOSTAT data on land cover further reveals great variation in the rates of deforestation across countries. Over the 1990–2018 interval, the Democratic Republic of the Congo lost the greatest area of forest, followed by Angola, Tanzania, Mozambique, and Côte d'Ivoire (see Figure 3 on the next page and Figure 5 on page 7). At the other end of the spectrum, several smaller countries record a gain in forest area, e.g., due to reforestation activities. For example, Eswatini seems to have gained 34,000 ha of forest cover, although it should be noted that newly reforested land is generally less rich in terms of carbon and biodiversity than older growth forests.

When focusing on the rate of forest loss in percentage (rather than level) terms, a different set of countries emerge as most dire, with the fastest rate of forest loss occurring in Côte d'Ivoire, followed by Niger, Gambia, Malawi, and Benin (see Figure 4 on page 6). Specifically, Côte d'Ivoire lost 61% of its 1990 forest area by 2018. Note that these numbers do not capture the rate of forest degradation, though in some countries (such as Malawi), the area of land affected by forest degradation each year exceeds the area of forest cover that is lost (Skole et al., 2021). These national numbers also do not capture within-country variation in rates of forest loss. In southwest Ethiopia, for example, Ango et al. (2020) observe that forest cover loss has been most intense in the highlands, while it is almost absent in state forests.

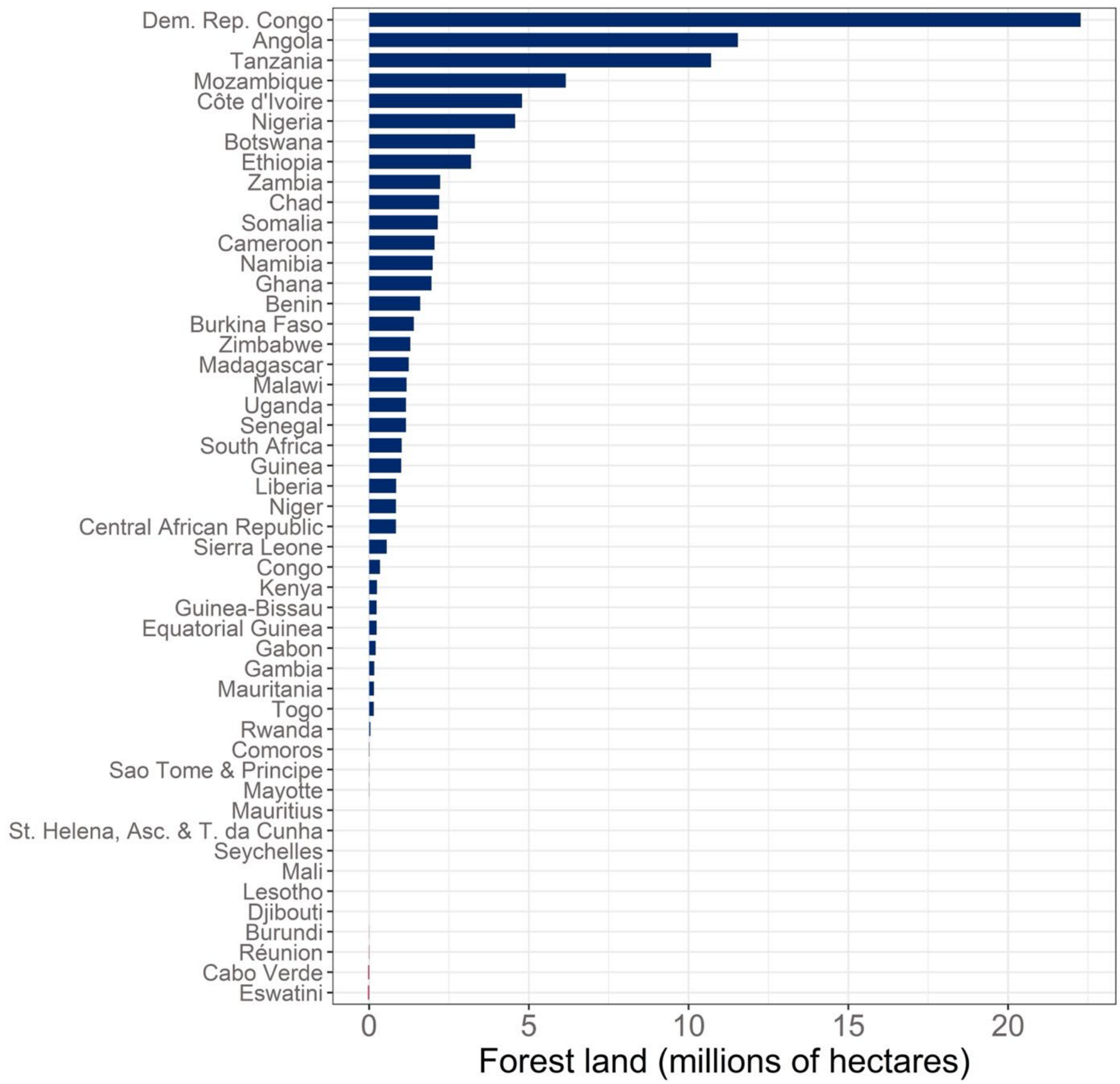

Figure 3: *Forest area lost between 1990 and 2018, by country. Source: FAOSTAT (Authors' calculations)*

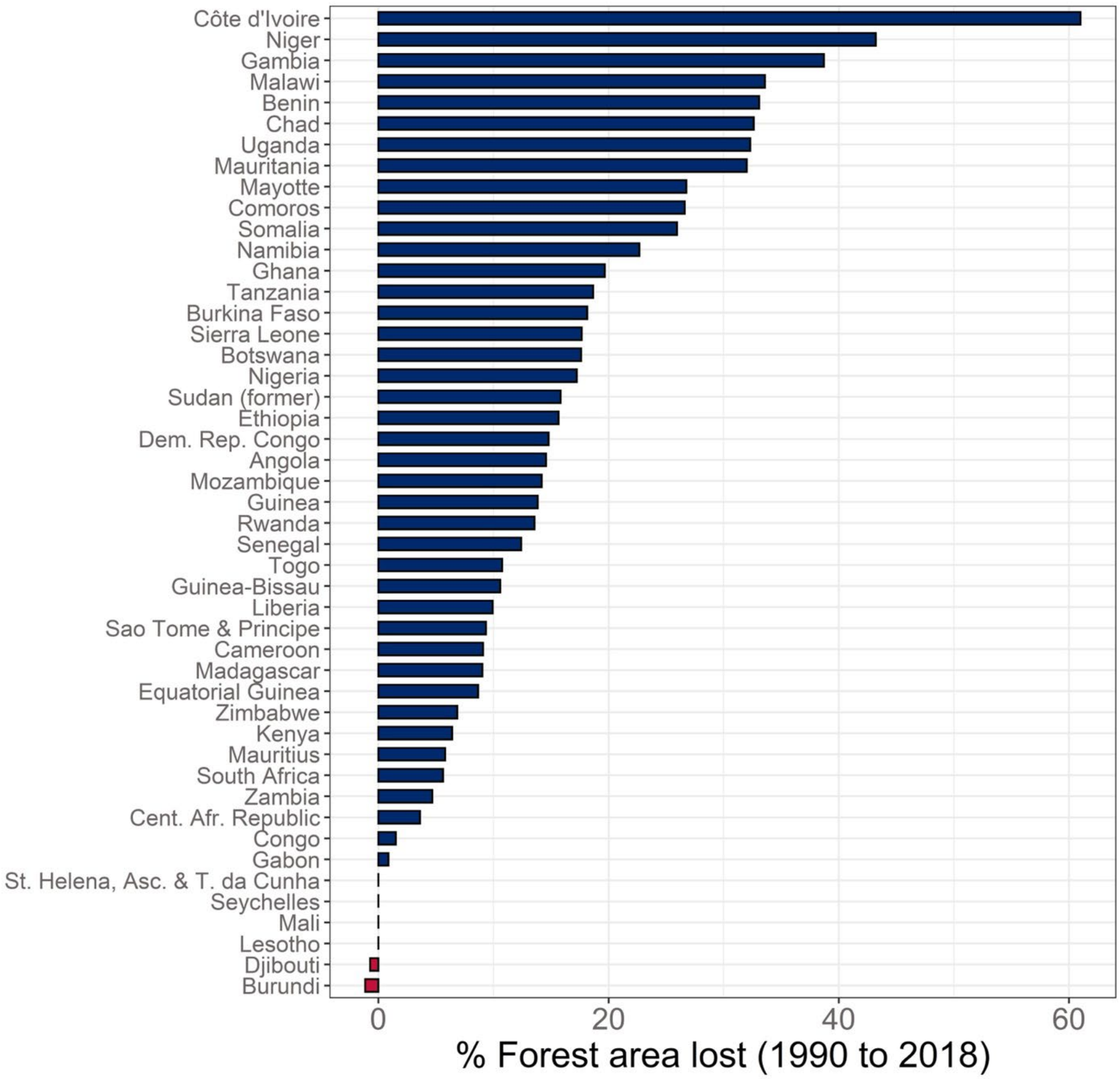

Figure 4: *Forest area lost between 1990 and 2018 as a percent of 1990 areas, by country. Note: For visual clarity, negative observations for Eswatini, Réunion, and Cabo Verde are not shown. Source: FAOSTAT (Authors' calculations).*

Overall, the forests of West Africa appear to be in a particularly precarious state (see Figure 5 on the next page). This observation is echoed by Ordway et al., 2017, who identify seven countries (Cameroon, Congo, Gabon, Liberia, Democratic Republic of Congo, Sierra Leone, and Côte d'Ivoire) that are most at risk of future forest loss due to agricultural expansion. This conclusion derives from their high percent forest cover (as of 2013) coupled with their low proportions of potentially available cropland outside forest areas.

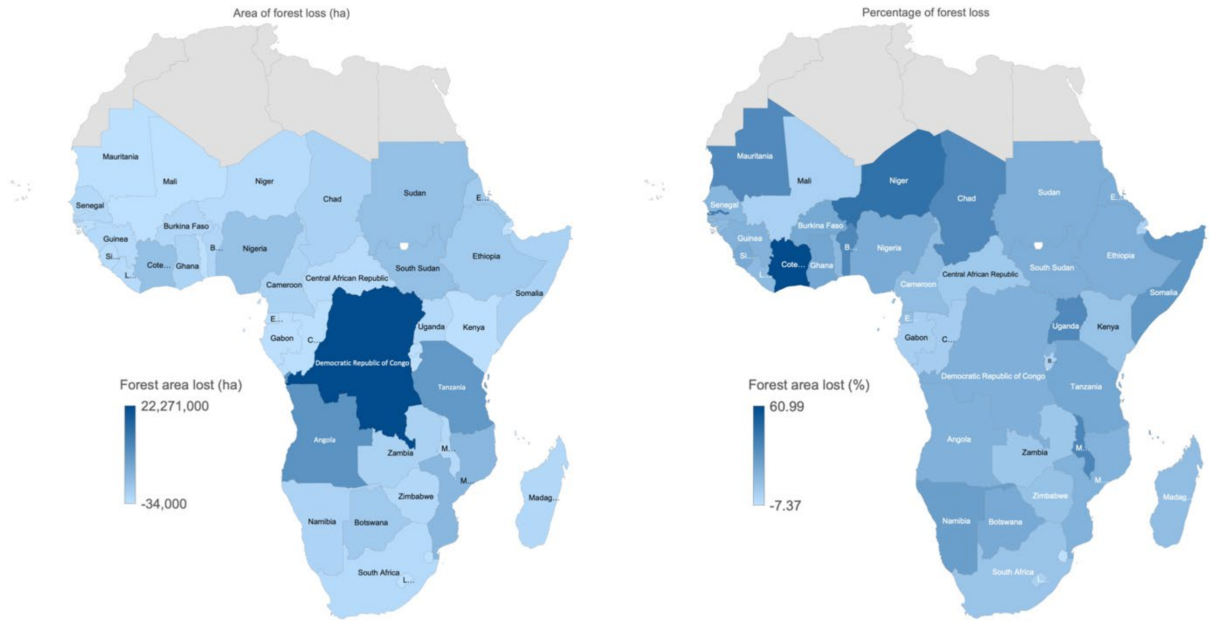

Figure 5: Area and percentage of forest area lost, 1990–2018. Source: FAOSTAT (Authors' calculations)

2.1.2. Drivers of deforestation

A wide set of interlinked factors that drive deforestation are highlighted in the existing literature, with "proximate causes", such as agricultural expansion, often distinguished from "drivers" or "underlying factors", such as population growth. As these forces originate from different sources and interact on different temporal and spatial scales (Kong et al., 2019), it can be difficult to find a clear cause-and-effect relationship with deforestation.

Agricultural expansion

Worldwide, agricultural land expansion is the main driver of deforestation. According to Gibbs et al. (2010), over 55% of new agricultural land between 1980 and 2000 was directly carved out of intact forests, with another 20% coming from disturbed forests. Within Africa, agricultural expansion among non-industrial-scale farms was responsible for 92% of deforestation between 2001 and 2015 (Curtis et al., 2018, cited in Ngoma et al., 2021). In total, from 1980 to 2000, 95% of cropland expansion in Africa replaced intact or disturbed forest areas (cited within Ordway et al., 2017). In interviews with rural residents in Uganda, Côte d'Ivoire, and elsewhere, it is no surprise that agricultural expansion is often among the first cause of deforestation to be cited (Acheampong et al., 2019; Kouassi et al., 2021). Such expansion may be comprised of cash crop plantations (for example, cocoa in Côte d'Ivoire and oil palm in Cameroon (Ordway, 2018; Kouassi et al., 2021) or subsistence-oriented farms. In Zambia, for example, cropland expansion by smallholders (i.e., farms of less than 20 ha)[2] into intact forests is responsible for 60% of the forest area lost per year (Ngoma et al., 2021). The crops with the greatest rates of expansion into forest include maize, cassava, rice, cocoa, oil palm, and soy (in that order) (Ordway et al., 2017). In some countries, several of these crops are Feed the Future priority crops, indicating a possible programmatic link with climate/biodiversity outcomes.

Population growth and migration

The population of Africa is expected to quadruple in the 21st century, presenting an urgent need for greater food production that underpins agricultural expansion. Population growth is widely regarded as a driver of deforestation (Laurance et al., 2013; Rudel, 2013). However, evidence is mixed regarding the nature of this relationship. At the country level, total population growth has been found to be only mildly significant, with a negative relationship with deforestation. Rural population growth rates, in particular, are not found to be significantly correlated with deforestation rates (DeFries et al., 2010). Another study focused on the Albertine Rift has also found that higher local population density was associated with lower rates of forest cover loss (Ryan et al., 2017), possibly because forests were already largely destroyed in densely populated rural areas.

The relationship between population growth and deforestation is undoubtedly mediated by both migration patterns and rates of urbanization (Kong et al., 2019). In Ethiopia, Ango et al. (2020) find that as people migrated from lower-altitude coffee areas (where they had engaged in forest maintenance for shade coffee production) to higher altitudes, they cleared these higher-altitude forests for annual crop production. In Uganda, it was noted that migration may lead to cultural changes in how trees and forests are valued (Twongyirwe et al., 2018).

Shifting cultivation practices

Shifting cultivation is a low-technology, extensive farming practice that continually requires additional forest to be cleared as other land is left to fallow. In settings where shifting cultivation is widely practiced, this necessarily contributes to forest loss.

Agricultural productivity (low or high)

There are competing theories regarding the relationship between land productivity and deforestation. The Borlaug hypothesis (or the "land-sparing" hypothesis) is that greater land productivity allows for more food production from already-cultivated land, thereby obviating the need for forest clearance. This underpins the assertion of Laurance et al. (2013) that "*to avoid environmental calamity, we must achieve ambitious goals for agriculture*." The Jevons Paradox counters that greater land productivity translates into greater profits in agriculture, which (paradoxically) incentivizes deforestation (summarized in Ngoma et al., 2021; Pelletier et al., 2020). In fact, there is evidence in support of both schools of thought. In Uganda, Abman et al. (2020) find that improved agricultural productivity is accompanied by reduced forest loss, and in Malawi, Abman and Carney (2020b) find that the provision

---

[2] Note that the class of farmers referred to as "smallholders" in Zambia (Ngoma et al., 2021) overlaps with what we consider in this concept note to be farms of medium scale—i.e., 5–100 ha.

of subsidized fertilizer reduced pressure to expand agriculture. In Zambia, Pelletier et al. (2020) arrive at a more nuanced conclusion that only some types of intensification are associated with reduced deforestation, and Ngoma et al. (2021) do not find any association between climate-smart agriculture and deforestation, in contradiction of Borlaug's hypothesis.

Overexploitation of natural forest resources

Another proximate cause of deforestation is illegal and/or unsustainable logging to meet domestic (or international) demand for timber. Along the same lines, firewood collection and charcoal production (whether for subsistence needs or as a source of income) are cited as key drivers of deforestation in Tanzania, Côte d'Ivoire, and elsewhere (Nzunda and Midtgaard, 2019; Kouassi et al., 2021). In Malawi, the construction industry is heavily reliant on wood energy for brick production (i.e., brick burning) (Ngwira and Watanabe, 2019).

Roads and other infrastructure

As noted by Laurance et al. (2013), new roads are a key proximate cause (or facilitator) of land use change. New roads that penetrate intact forests open up new areas for settlement and promote deforestation, and the likelihood of a land parcel being cleared rises steeply if it is adjacent to another area that has already been cleared—in other words, deforestation is spatially "contagious". Once forest fragments are created, they are less likely to stay standing than intact forest landscapes (Hanson et al., 2020). Along the same lines, Ordway (2018) observes that the location of mills for processing palm oil also influences the geography and extent of deforestation. This is because the fruit of oil palm decays rapidly once it is harvested, such that the placement of mills (especially informal mills operating in the informal economy) affects the decision of non-industrial producers to clear land for oil palm production.

Land tenure systems

Systems of land tenure are also related to deforestation. In some settings, clearing land may be an avenue to establish *de facto* property rights (Abman and Carney, 2020a). In other settings, governments may be unable to protect forests located on private land if the tenure system grants landowners full discretion on land use (Twongyirwe et al., 2018). The land tenure system may also drive deforestation indirectly by affecting the rate of land investment and therefore the level of agricultural productivity.

Urbanization, growth in commodity crops, and changing diets

Rising incomes and urbanization can drive consumer demand for more diverse diets and particularly for meat, which increases pressure to clear forest for cattle production. While this pattern is more widely recognized in the Amazon (South America), it has also been observed in the Albertine Rift in Africa (Ryan et al., 2017). This is linked to other findings that it is not rural population pressure that drives deforestation (DeFries et al., 2010), and that African countries with more urbanized populations have higher rates of deforestation (Rudel, 2013). Ordway et al. (2017) find that it is domestic demand for commodity crops that is associated with most agricultural expansion into forests, though export-oriented agricultural expansion also occurs.

2.2. Medium-scale farms in sub-Saharan Africa

Historically, much of the discourse on agriculture in SSA has focused on whether agricultural policies should be oriented toward small-scale versus large, industrial-scale farms. This remains a hotly debated topic. Somewhat under the radar, medium-scale farms have emerged as an important category within the agricultural "landscape". Medium-scale farms (understood in this concept note to be between 5–100 ha)[3] are, in fact, more prevalent than large-scale farms and have been growing in number and in their role in agricultural production in several SSA countries (Jayne et al., 2016, 2019, and 2021; Anseeuw et al., 2016; Houssou et al., 2016; Wineman et al., 2020a). Though much attention regarding land (as well as deforestation) in SSA has been directed toward foreign large-scale investments, the aggregate area under medium-scale farms exceeds the land area acquired by foreign and domestic large-scale investors in Ghana, Kenya, and Zambia—and likely in other countries, too (Jayne et al., 2016).

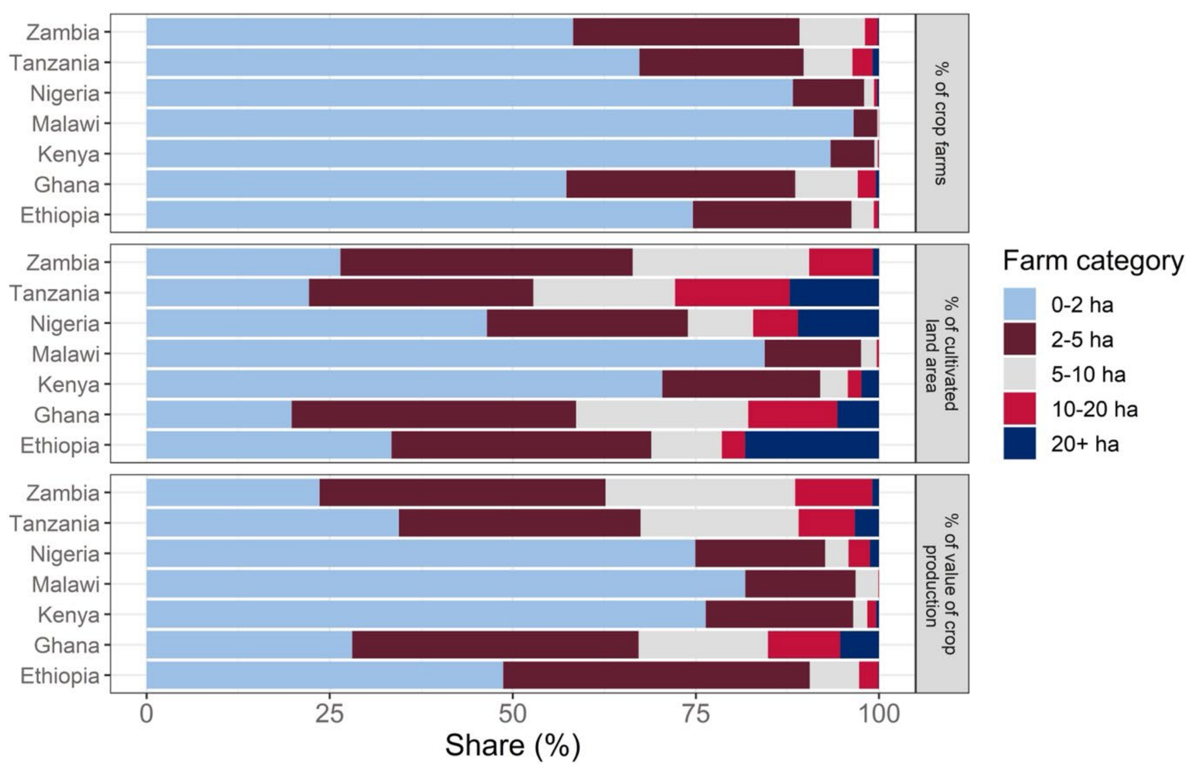

Figure 6: *Distribution of farm size categories across key agricultural indicators. Sources: Jayne et al. (2021) computed from LSMS-ISA data sets (Ethiopia, Malawi, Nigeria, and Tanzania); Ghana Living Standards Survey; Kenya Integrated Household Budget Survey; and Zambia Crop Forecast Survey*

[3] We consider farms to be of medium scale if they have between 5 and 100 hectares of operated farmland. Nevertheless, a review of the literature is somewhat complicated by the multiple definitions in use. For example, in Ethiopia, Ango (2018) classifies farms of 100–1,000 hectares as medium scale. Also in Ethiopia, Ali et al. (2017) consider farms up to 10 ha to be small-scale, while Bachewe and Minten (2020) consider medium-scale vegetable farms to be vegetable growers that rent in at least 0.5 hectares of land. There is clearly a need for greater coherence and consistency in the terminology used.

The distribution of farm size categories in the farm population for a set of SSA countries is shown in Figure 6 (on the previous page; taken from Jayne et al. (2021)). While medium-scale farms appear to be rare in some countries (Kenya and Malawi), they comprise over 10% of farms in Ghana, Tanzania, and Zambia. In all countries (almost by definition), the share of total cultivated land that is held by medium-scale farms is far higher than their prevalence in the farm population. Farms of more than 5 ha cover 31% of cultivated land area in Ethiopia, 41% in Ghana, 26% in Nigeria, 47% in Tanzania, and 34% in Zambia. In some countries, medium-scale farms also produce a sizable share of the value of crop production in the country: 33% in Ghana, 33% in Tanzania, and 37% in Zambia.

Table 1 presents changes over time in the shares of national agricultural indicators that are attributed to various farm size categories. The share of farms that are medium scale (pooling across all columns >5 ha)[4] has modestly increased over time in Ghana, Tanzania, and Zambia by 0.04, 2.11, and 3.74 percentage points, respectively. At the same time, in Tanzania and Zambia, the share of cultivated land area under medium-scale farms increased by 6.47 and 10.9 percentage points, respectively, over the time intervals captured in these countries. In Tanzania, this growth occurred specifically among farms of size 5–20 ha.

Table 1: *Change over time in shares of national agricultural indicators across farm categories (percentage points). Note: Changes over time reflect the following time intervals: Ethiopia (2014–2016), Ghana (1992–2017), Kenya (2005–2015), Malawi (2010–2019), Nigeria (2010–2015), Tanzania (2009–2015), and Zambia (2011–2017). Sources: Jayne et al. (2021) computed from LSMS-ISA data sets (Ethiopia, Malawi, Nigeria, and Tanzania); Ghana Living Standards Survey; Kenya Integrated Household Budget Survey; and Zambia Crop Forecast Survey.*

		Farm category				
		0-2 ha	2-5 ha	5-10 ha	10-20 ha	20+ ha
% of crop farms	Ethiopia	2.64	-2.05	-0.15	-0.16	-0.28
	Ghana	-4.49	4.46	1.49	-0.69	-0.76
	Kenya	5.38	-4.00	-0.88	-0.16	-0.33
	Malawi	0.40	-0.36	-0.02	-0.01	-0.01
	Nigeria	0.07	0.69	-0.81	0.13	-0.07
	Tanzania	-2.35	0.24	0.56	1.46	0.09
	Zambia	-3.95	0.20	3.07	0.68	-0.01
% of cultivated land area	Ethiopia	0.78	-1.04	-0.08	-2.42	2.76
	Ghana	-0.85	4.37	4.80	-3.31	-5.01
	Kenya	11.81	-5.24	-4.10	0.03	-2.50
	Malawi	1.19	0.03	0.06	-0.56	-0.73
	Nigeria	3.29	0.73	-5.79	1.94	-0.18
	Tanzania	-6.35	-0.12	1.37	7.66	-2.56
	Zambia	-6.75	-4.14	7.48	3.26	0.16

[4] Almost no farms larger than 100 ha are captured in these household data sets, such that all farms > 5 ha are categorized here as medium scale.

% of value of crop production	Ethiopia	3.24	-0.95	-1.38	-0.54	-0.37
	Ghana	-12.91	4.12	5.91	3.46	-0.58
	Kenya	-0.56	5.83	-2.71	-0.52	-2.04
	Malawi	-3.91	2.32	1.55	0.07	-0.03
	Nigeria	-2.29	1.66	-2.21	2.08	0.75
	Tanzania	-7.73	-4.55	7.00	4.60	0.67
	Zambia	-8.69	-4.80	8.61	4.74	0.14

Even more striking is the growth in the share of the value of crop production that is attributed to medium-scale farms. In Zambia, over 6 years, medium-scale farms grew from producing 24% to 37% of the national value of crop production, with most of this growth occurring among farms 5–20 ha in size. In Tanzania, over 6 years, medium-scale farms grew from producing 20% to 32.5% of the national value of crop production. In Ghana, over 25 years, medium-scale farms grew from producing 24% to 33% of the national value of crop production. Growth of crop production by medium-scale farms was more modest in Malawi and Nigeria and was negative in Ethiopia and Kenya, which are both land-scarce countries.

For the countries with growth in medium-scale farm production, Figure 7 (on the next page) illustrates how relatively larger farms are growing more rapidly than smaller farms in their contribution to the value of crop production. In Zambia, for example, farms of 0–2 ha are shrinking in their aggregate value of crop production by an average of 1.4% each year, while farms of 5–10 ha and 10–20 ha are growing in aggregate, at a rate of 11% and 14% per year, respectively. In Malawi, while farms of 0–2 ha are growing in their aggregate value of crop production by an average of 2.3% each year, this value is 11% for farms of 5–10 ha. In Ghana, while the smallest farms category is growing in production value at a rate of 0.6% per year, this value is 6.5 times greater for farms of 5–10 ha. This confirms the growing importance of medium-scale farms in countries across SSA.

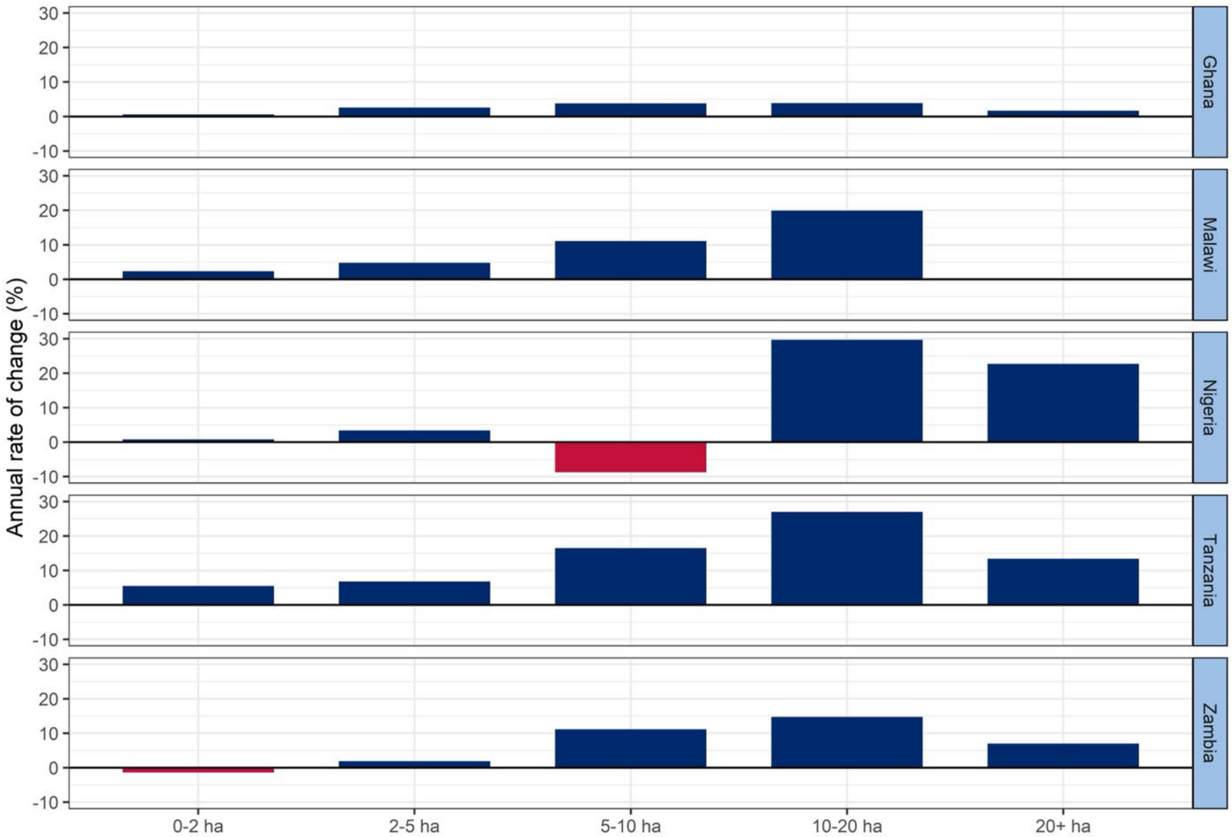

Figure 7: *Annual rate of change (%) in the aggregate value of crop production across farm categories. Sources: Jayne et al. (2021) computed from LSMS-ISA data sets (Ethiopia, Malawi, Nigeria, and Tanzania); Ghana Living Standards Survey; Kenya Integrated Household Budget Survey; and Zambia Crop Forecast Survey.*

It should be emphasized that our understanding of the emergence of medium-scale farms is obscured by the way typical farm-household surveys tend to under-sample relatively large farms. In a comparison of the Tanzania LSMS-ISA and Agricultural Census Sample Survey from 2008/09, both data sources indicate a similar land area under farms up to 5 ha. However, the census indicated that there were 51% more hectares under medium-scale farms (5–100 ha) and 60% more hectares under larger-scale farms, as compared to the LSMS-ISA (Jayne et al., 2016). The upshot is that medium-scale farms are likely to be even *more* prevalent among the farm population than what is rendered visible with the LSMS-style surveys on which we often rely.

3. Conceptual framework

Medium-scale farms in SSA may plausibly cause or influence deforestation through direct or indirect avenues. First, the *direct* relationship between medium-scale farms and deforestation is illustrated in Figure 8, which conveys the two broad avenues through which medium-scale farms can procure new land. On one hand, they can access land that had previously been used for agricultural purposes by other farmers. The nature of these transactions likely ranges from willing buyer-willing seller exchanges (in a well-functioning land market) to coercive arrangements characterized by the involuntary displacement of smaller farm-households. In the latter case, wealthier medium-scale farmers may negotiate with customary leaders who allocate or sell land, despite not having the approval of the current land users/residents. In either case, accessing land used by other farmers likely results in farm consolidation but not deforestation.

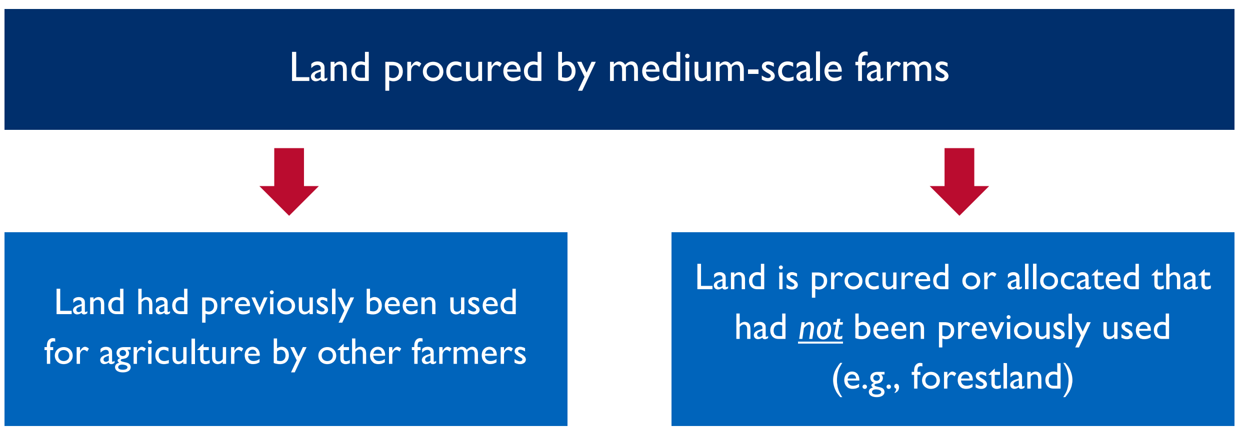

Figure 8: *Direct link between medium-scale farms and deforestation.*

On the other hand, medium-scale farms can access land that had not been previously used—most notably, forestland. This forested land can be obtained through several processes: allocations by customary authorities, purchases from other landowners, long-term leases, or transfer of rights by government. In Ethiopia, Ango (2018) recounts how the Ethiopian government transferred land from state forests (which had been widely used by local farm populations) to medium-scale coffee growers. Deforestation results when medium-scale farms clear land through these avenues. Given the rapid growth of medium-scale farms in SSA, knowing the history of the land they now hold is directly relevant for identifying the actors that execute deforestation and for the design of policies intended to deter deforestation.

The multitude of drivers of deforestation enumerated in section 2.1.2 also point toward several *indirect* ways in which medium-scale farms may influence deforestation. For example, the rise of medium-scale farms may contribute to land scarcity, precluding the natural expansion of smaller farms as local populations grow. This could be relevant if heightened land scarcity caused (at least partly) by medium-scale farm growth is what spurs smaller farms to revert to carving out forestland. In this scenario, while smaller-scale farm-households directly execute deforestation, medium-scale farms are an “underlying factor” that requires attention in the design of policies to slow or reverse deforestation. The growth of medium- and large-scale farms may also drive up local land prices, with ripple effects that result in deforestation. In Cambodia, for example, rising land prices have been found to “tempt” the poorest households to sell their land and then search for other forest tracts to clear in more marginal or remote areas (Kong et al., 2019).

Another indirect avenue through which medium-scale farms may influence deforestation is through technology diffusion. Specifically, larger farms often provide tractor services to small farms in their communities (Houssou et al., 2014). Consistent with this hypothesis of technology sharing, small-scale farms in Tanzania are more likely to cultivate a greater proportion of their landholdings when they are in the presence of more medium-scale farms (Wineman et al., 2020b). This “spillover effect” of medium-scale farms could be plausibly linked to deforestation if it facilitates agricultural expansion by smallholders into forests.

4. Evidence regarding the link between medium-scale farms and deforestation

4.1. Survey of the existing literature

Given the dearth of attention given to medium-scale farms in SSA, it is no surprise that few analysts have considered the link between the growth of medium-scale farms and patterns of deforestation. Far more attention has been given to the deforestation impacts of genuinely large-scale agriculture, particularly in the context of foreign land acquisitions (industrial-scale land concessions) in the 2007/08 land rush (Balehegn, 2015; Davis et al., 2020). With few exceptions, studies that do consider non-industrial-scale farms tend not to distinguish between those of small and medium scale to more precisely identify the actors behind deforestation. It follows that measures of medium-scale farms' role in deforestation are completely lacking.

At a global scale, Dang et al. (2019) analyze the spatial relationship between crop field size and rates of forest loss and find that small field sizes appear more commonly in deforested areas in Africa and Asia than in other regions. However, it is likely that the authors' reference to "small" fields in Africa encompasses all non-industrial-scale fields. Within countries, larger fields tend to be associated with deforestation in areas of lower agricultural value, while smaller fields are more likely to be found in the deforested areas of protected forests.

In Zambia, Kazungu et al. (2021) do consider the relationship between land size (though only among small-scale farms) and the deforestation of Miombo woodlands and find that relatively larger land sizes are weakly associated with reduced deforestation in the Northwestern Province but are unrelated to deforestation rates in other regions. In the Northwestern Province, the authors speculate that it is the responsible regulation of land access by customary authorities that keeps deforestation in check, and they further note that deforestation due to charcoal and firewood collection would be unrelated to land size.

In Cameroon, oil palm expansion into forestland is found to be associated with small- and medium-scale farmers rather than industrial plantations (Ordway, 2018; Ordway et al., 2017). These non-industrial farms tend to clear the forest in proximity to the establishment of informal mills for oil palm processing. The authors acknowledge that distinguishing between the role of small- versus medium-scale farms would improve our understanding of causal mechanisms driving the relationship between commodity crop expansion and deforestation.

In Ethiopia, Ango (2018) presents one of the only case studies (to our knowledge) that even peripherally captures the relationship between medium-scale farms and deforestation. With a focus on state transfers of forestland in southwestern Ethiopia to primarily domestic investors in coffee production, the author documents how these transfers led to the conversion of forest into coffee plantations. While smallholders had produced “forest coffee”, which preserved the forest biodiversity using local knowledge and production techniques, medium-scale growers engaged in far more destructive forms of production while restricting other farmers’ access to, and use of, what had earlier been communal forests.

4.2. Tabulation of relevant information captured in typical farm-household surveys

Table 2: *Information needed to better understand the link between medium-scale farms and deforestation.*

Land currently held
Prior use of land before acquisition
Mode and year of land acquisition
Identity of prior landowners, residents, or users
Relationship between current landowner(s) and local community
Statutory and non-statutory documents of ownership, lease, or transfer
Process of land acquisition
Prior forest status
Prior nature of governance
Current use of the land
Land formerly held
Prior use of land (before disposal)
Mode of land disposal
Identity of the new owners
Motivation for land disposal (if voluntary)
Nature of the transaction

Typical farm-household surveys tend not to capture many of the pieces of information that would be useful to unpack the relationship between medium-scale farms and deforestation. Table 2 enumerates some of these pieces of information. To better discern whether medium-scale farms have a direct link to deforestation (see Figure 8 on page 14), it is necessary to gauge the history of the land currently held—particularly the prior use of the land before acquisition by the current farmer. The key distinction is whether the land had previously been used for agriculture or whether it had been forestland or another land type (such as permanent meadow or grassland).

To inform the design of forest and agricultural policies, farmers should be asked about the mode of land acquisition, including purchases through the informal (not titled or state-backed) land market. Even where land sales are not sanctioned in customary norms, "clandestine" markets may exist; such underground markets have been noted in Zambia (Chitonge et al., 2017; Sitko, 2010), Malawi (Takane, 2008), Ethiopia (Ango, 2018), and Ghana (Byamugisha, 2016). In the countries around Lake Victoria, informal land sales markets tend to be widespread and operate aboveground (Wineman and Liverpool-Tasie, 2017). Information should also be gathered on both statutory documents of ownership or lease and non-statutory documents of ownership/land transfer that have local legitimacy, even if they are not backed by the state. In northwestern Tanzania, for example, land sales are sealed with a contract signed by buyer and seller and witnessed by neighbors proximate to the parcel of land being exchanged (Ibid.).

To better understand how farmers acquired forestland, it is also useful to gather detailed information on the process of land acquisition, such as direct negotiation with local leaders, direct negotiation with prior residents, or use of a middleman who originates from the community and facilitates the land transfer (Lusasi et al., 2020). Along these lines, it is useful to understand the current landowners' status as autochthonous or migrant, and to know whether any previously forested land had been a public forest estate, a customary forest, private forested land holdings, or another tree-based system. This can tell us about the prior nature of governance (e.g., land in the commons), with policy implications for sound forest guardianship. Finally, it is important to identify how the land is currently used, whether it is cultivated for subsistence versus commodity crop production; whether it is used for subsistence versus commodity livestock production (as grazing land); or (plausibly) whether it is maintained as forestland.

We also need to capture similar pieces of information on the other side of a land exchange, i.e., on land disposals or land losses. Residents that had disposed of any land may provide information on the state of the land at the time of transfer, the mode of disposal (sale, bequest, transfer, abandonment, etc.), the identity of the new owners, the motivations that led to the land disposal (such as distress), and the nature of any transaction (for example, voluntary versus coercive). This sort of information is likely to be sensitive.

In addition to the pieces of information enumerated in Table 2 (on the previous page), it is also critical for surveys to adequately capture relatively large farms, as population-based household surveys tend to under-sample large farms (Jayne et al., 2016). This may be accomplished through deliberate efforts to include larger farms (as in stratified sampling by farm size). Relatedly, surveys need to capture the agricultural ventures of urban-based or otherwise nonresident domestic investors. As most surveys take the form of face-to-face interviews, this key subpopulation is likely to be missing from many samples.

Table 3 (on the next page) contains a tabulation of the information captured in a set of four English-language LSMS-ISA surveys in SSA. Across four countries (Ethiopia, Malawi, Nigeria, and Tanzania), <u>no</u> questionnaire captures the history of land before it was acquired by the current owner. Thus, in no country do we know the prior land use, the identity of the prior landowners, the process of land acquisition (for example, whether a middleman was used), the prior forest status, and the prior nature of land governance. In addition, <u>none</u> of these surveys ask about land that had been formerly held but has been disposed of (or lost), so analysts almost never have sight of the supply side of the local land market or the sellers' motivations or consequences of land exchanges.

Table 3: *Information captured in LSMS-ISA questionnaires/ Sampling strategy of LSMS-ISA surveys. Source: LSMS-ISA questionnaires (Authors' tabulations)*

	Ethiopia (2015)	Malawi (2019)	Nigeria (2018)	Tanzania (2014)
Information: Land currently held				
Prior land use				
Mode of land acquisition	✓	**	✓	✓
Year of land acquisition				
Identity of prior landowners and/or users				
Relationship with local community	Region-level	✓		✓
Statutory documents of ownership	✓	✓	✓	✓
Non-statutory documents of ownership		✓	✓	Some
Process of land acquisition				
Prior forest status / year field was converted from forest/grassland to agriculture				
Prior nature of governance				
Current land use	✓	***	✓	✓
Information: Land formerly held				
Prior use of land*				
Mode of land disposal				
Identity of the new owners				
Motivation for land disposal				
Nature of the transaction				
Sampling/Study design				
Over-sample large farms + use of household weights to improve precision of estimates for farms > 10 hectares				
Include nonresident domestic investors	Undercount	Undercount	Undercount	Undercount

**Some panel surveys may capture this information if the plot ID is maintained over survey waves, as was done in the Tanzania LSMS-ISA from 2008-2012.*

***This information is captured in the Malawi LSMS-ISA questionnaire but missing in the actual data set.*

**** In Malawi, nearly all plots are reported as being cultivated, which leads us to question whether uncultivated plots (for example, land retained as forest) are accurately represented in this data set.*

None of the surveys in Table 3 are designed to ensure that relatively large farms are accurately represented in the sample; given what we know of the under-sampling of large farms in population-based farm-household surveys (Jayne et al., 2016), it seems these data sources may not provide a complete view of medium-scale farms. Finally, the design of all surveys should be suitable to capture the agricultural activities of nonresident domestic investors. However, a review of Demographic and Health Surveys (DHS) from across SSA indicates that urban households often own a considerable share (5–35%) of agricultural land (Ibid.), a pattern that is not evident when analyzing these LSMS-ISA data sets. This suggests that nonresident domestic investors are under-represented in these LSMS-ISA surveys.

4.3. Descriptive statistics

Though much of the information needed to truly characterize the link between medium-scale farms and deforestation is not found in existing data sets, Table 4 presents some relevant information on medium-scale farms that *is* available in the Tanzania LSMS-ISA. In 2012, there were 6.2 million small-scale farms of less than 5 ha, over 680,000 farms of 5-20 ha, and over 68,000 farms greater than 20 ha in Tanzania. Though very few farms report having some land that is forested, small farms are more likely than larger farms to possess forested land (at 2.7% versus 1.6–1.7%). Given the average forested areas among farms in each farm size category, this data set indicates that small-scale farms hold approximately 502,886 ha of forestland, in aggregate. Farms of 5–20 ha hold approximately 82,300 ha of forestland, and farms larger than 20 ha hold 5,233 ha of forestland, in aggregate. (Recall, however, that this data set likely undercounts relatively large farms.)

Table 4: *Characteristics of medium-scale and small-scale farms in Tanzania (mean values). Source: Tanzania National Panel Survey (also known as the LSMS-ISA) (Taken from Wineman et al., 2020b)*

	Small (0–5 ha)	Medium 1 (5–20 ha)	Medium 2 (> 20 ha)
Farm characteristics			
Land size (ha)	1.56	7.46	35.25
Proportion area cultivated in main season	0.70	0.64	0.58
1= Possesses some forested land	0.027	0.016	0.017
1= Possesses purchased land	0.36	0.60	0.62
Forest area (ha)	0.08	0.12	0.08
1= Possesses inherited land	0.55	0.49	0.32
1= Possesses formal land title	0.12	0.15	0.13
Geographic and household characteristics			
1= Urban	0.15	0.09	0.11
Population density (persons/km^2) at homestead	357.22	254.54	270.01
Distance to town of 20,000 population (km)	49.74	62.75	65.28
Distance to main road (km)	18.66	21.47	20.66
1= Enumeration area contains a medium 1 farm	0.37	N/A	0.69
1= Enumeration area contains a medium 2 farm	0.04	0.09	N/A

1= Non-resident farmer (resides ≥ 10 km from largest plot)	0.09	0.11	0.15
1= Head is a migrant	0.32	0.36	0.48
1= Head moved for land-related reasons (if head = migrant)	0.12	0.23	0.37
Proportion of household income from farm	0.60	0.73	0.72
Number of farms in 2012	**6,190,282**	**684,749**	**68,579**

Farms of 5–20 ha are slightly more likely than small-scale farms to have a household head that arrived in their present community from elsewhere (36% versus 32%), though this value is higher for farms of more than 20 ha (at 48%). In addition, farms of 5–20 ha are only slightly less likely than small-scale farms to possess at least some land that was acquired through inheritance or gift (at 49%), potentially reinforcing their ties to the local community—with possible implications for the likelihood that they will engage in deforestation. Interestingly, among migrants, medium-scale farm-household heads are much more likely than small-scale farm-household heads to cite land-related reasons (at 23% or 37%, as compared with 12%) as their motive for moving to their present community. Opportunities for agricultural expansion may therefore play a role in the decision of medium-scale farm-households to relocate/establish themselves.

Medium-scale farms are more likely than small-scale farms to access some land through purchase (at 60% and 62%, as compared with 36%). However, the rate at which farms possess a formal land title is low across all categories (ranging from 12% to 15%), suggesting that purchased land was not acquired through the conversion of state land, but rather through Tanzania's burgeoning informal land market. Furthermore, 54% of farms of 5–20 ha that are non-migrants possess purchased land, which suggests that land purchase may have been a path through which local farmers transitioned into medium-scale status.

5. Suggestions for future research

The preceding discussion points to a need for new types of data collection and gives rise to new research questions that urgently merit attention.

5.1. Considerations in study design

5.1.1. Agricultural census data and/or stratified sampling in farm-household surveys

As noted earlier, population-based household surveys tend to under-sample relatively large family farms and are therefore not an especially reliable source of information on medium-scale farms (Jayne et al., 2016). A different approach to data collection is needed. Rather than a typical sample survey, a census approach can be employed for larger farms, as was done in the Tanzania Agriculture Sample Census Survey of 2007–2008. An alternative to the census approach is a stratified sample that makes an explicit effort to over-sample relatively large farms; this was attempted in the Malawi National Agricultural Census of Agriculture and Livestock of 2006–2007.

5.1.2. Information on land acquisitions and prior land uses in farm-household surveys

Our tabulation of the widely used LSMS-ISA survey instruments demonstrates that agricultural household surveys rarely capture information on land transactions or the state in which land was acquired. Such information is essential to understand the links between medium-scale farm growth and deforestation. In the design of questionnaires, analysts should therefore take note of the relevant pieces of information enumerated in section 4.2.

Among other considerations, farmers may not be forthright in responding to survey questions regarding modes of land acquisition, particularly if land was procured through "clandestine" land sales markets. Careful survey design, combined with sensitivity toward local norms, may mitigate this challenge. Many surveys only ask about land titles or customary rights of occupancy—both provided by the state. However, in settings where informal land markets prevail, it is necessary to acknowledge the mechanisms local people devise to convey the legitimacy of transactions, including the use of documents provided by local authorities or sales contracts forged between buyers and sellers.

With respect to urban-based investors, it is important to capture whether and how different members of local communities actively take part in forestland transactions (Lusasi et al., 2020). This may require interviews with land sellers or other actors who give investors access to local land. A final consideration in the design of questionnaires is that they often assume a single mode of acquisition per plot of land. Anecdotal evidence indicates that farmers often exploit multiple channels to "cobble together" land over time. A precise understanding of land acquisition may therefore warrant greater nuance in questionnaire design.

5.2. Research questions

5.2.1. What are the direct and/or indirect links between medium-scale farms and deforestation in SSA?

The overarching research question centers around the direct and indirect avenues through which medium-scale farms either execute or influence deforestation. In section 3, we proposed three such avenues/hypotheses: Medium-scale farms may procure forested land and convert it to agricultural land; medium-scale farms may exacerbate land scarcity, driving smaller-scale farms to clear nearby forests for their own use; and medium-scale farms may make tractor technology available to their neighbors, facilitating the cultivation of larger tracts of land and, thus, the expansion of other farms. Other avenues may also be possible. Once these linkages are better understood empirically, we may then be in a position to help policymakers identify strategies that encourage forest preservation and restoration while also promoting agricultural production growth on existing farmland.

5.2.2. How does this link vary across different agro-ecologies, commodities, population densities, or land tenure systems?

The relationship between medium-scale farms and forests is likely mediated by a host of factors. For example, medium-scale farms may indirectly influence other farmers to engage in deforestation in settings of high population density, where their presence exacerbates local land scarcity or drives up land prices beyond the reach of poorer residents. As another example, there are reasons to believe medium-scale farms may proliferate in settings of more individualized land tenure (or where land is increasingly commoditized); to the extent that this is accompanied by the conversion of communal forests into privately held land, it may influence the link between medium-scale farms and deforestation.

5.2.3. What conditions mitigate the impact of medium-scale farms on deforestation?

Certain conditions or policy environments may moderate the link between medium-scale farms and deforestation. For example, where village land governance is more democratic and less hierarchical (as with the village assembly in Tanzania), it may be less common for medium-scale farms (particularly those established by non-community members) to access initially communal forestland through negotiations with customary leaders, a pattern that is often observed in Zambia (Sitko and Jayne, 2014).

5.2.4. Does this link vary depending on the characteristics of medium-scale farms—for example, whether they are indigenous members of the local community or whether they are outside investors?

As medium-scale farms are not homogenous, it will be useful to explore their diversity and how this may intersect with their tendency towards natural resource exploitation. Lusasi et al. (2020) group domestic investor farmers into five categories: (1) urban-based investors without local ties, (2) urban-based investors originating in the area in which the investments are taking place, (3) resident villagers, (4) government and/or religious institutions, and (5) local leaders. To this typology we might add (6) diaspora investors. Each type of investor may interact with forests differently. For example, Twongyirwe et al. (2018) note that migrants in Uganda assign different value to trees and forests, as compared to native residents.

5.2.5. What policy options would be most effective at limiting deforestation among medium-scale farms or attenuating the indirect link between medium-scale farm growth and deforestation by others?

Over a quarter of forests in low- and middle-income countries are formally owned/managed by local (particularly indigenous) communities (Hajjar et al., 2021). While the outcomes of community forestry management are mixed, this governance structure would seem to have the potential to protect forests, particularly in settings where medium-scale farms are being established in forested areas by non-community members, or where wealthier community members are exploiting their privileged status to carve into a shared natural resource and claim portions for their own use. It should be noted, however, that communities with considerable in-migration have seen fewer positive outcomes associated with community forestry management, as migration is associated with increased pressure on natural resources and heightened contestation of use rights.

5.2.6. Do the potential policy options differ when this issue is framed, not in terms of deforestation, but in terms of forest recovery?

Griscom et al. (2021) identify three categories of natural climate solutions, namely protection, improved management, and restoration of ecosystems (such as forests). ‘Protect’ refers to preventing forest loss (i.e., avoiding forest conversion); ‘restore’ refers to extending forest cover to areas that had previously been lost (i.e., reforestation); and ‘manage’ refers to management practices to enhance carbon sinks on working lands without cutting into agriculture production. Reforestation involves displacing lower intensity agricultural production systems (especially grazing lands) with new forests. In Uganda, Twongyirwe et al. (2018) observe some areas with forest regeneration over time. It would be interesting to understand the conditions that bring about forest recovery, and whether medium-scale farms may play a role.

5.2.7. Can medium-scale farms be incentivized to cultivate tree crops, engage in agroforestry (including silvopastoral systems), or maintain trees for sustainable harvesting?

Among the three types of natural climate solutions identified by Griscom et al. (2021), ‘management’ involves the incorporation of trees within agricultural lands, including silvopastoral systems (combining tree production with the production of livestock). This approach can preserve biodiversity by providing habitat for tree-dwelling species and can ensure the provision of ecosystem services, such as air filtration, flood control, and nutrient cycling. Medium-scale farms may be open to agroforestry, particularly when they learn of the benefits for their own farms. Similarly, where forests are being cleared for timber, fuelwood, or charcoal, medium-scale farms may be able to interrupt this pattern by cultivating trees for sustainable harvesting (particularly if a profit can be made).

References

Abman, R., and C. Carney. 2020a. Land rights, agricultural productivity, and deforestation. *Food Policy*, 94: 101841. https://doi.org/10.1016/j.foodpol.2020.101841.

Abman, R., and C. Carney. 2020b. Agricultural productivity and deforestation: Evidence from input subsidies and ethnic favoritism in Malawi. *Unpublished*. Accessed at: https://ssrn.com/abstract=3393260.

Abman, R., T. Garg, Y. Pan, and S. Singhal. 2020. Agriculture and deforestation. Unpublished. Accessed at: https://cega.berkeley.edu/wp-content/uploads/2020/03/Garg_PacDev2020.pdf.

Acheampong, E. O., C. J. Macgregor, S. Sloan, and J. Sayer. 2019. Deforestation is driven by agricultural expansion in Ghana's forest reserves. *Scientific African*, 5: e00146. https://doi.org/10.1016/j.sciaf.2019.e00146.

Ali, D. A., K. Deininger, and A. Harris. 2017. Using national statistics to increase transparency of large land acquisition: Evidence from Ethiopia. *World Development*, 93: 62–74. https://doi.org/10.1016/j.worlddev.2016.12.027.

Ango, T. G. 2018. "Medium-scale" forestland grabbing in the southwestern highlands of Ethiopia: Impacts on local livelihoods and forest conservation. *Land*, 7 (24). https://doi.org/10.3390/land7010024.

Ango, T. G., K. Hylander, and L. Borjeson. 2020. Processes of forest cover change since 1958 in the coffee-producing areas of southwest Ethiopia. *Land*, 9 (278). https://doi.org/10.3390/land9080278.

Anseeuw, W., T. S. Jayne, R. Kachule, and J. Kotsopoulos. 2016. The quiet rise of medium-scale farms in Malawi. *Land,* 5 (3): 19. https://doi.org/10.3390/land5030019.

Bachewe, F. N., and B. Minten. 2020. Efficiency and profits of emerging medium-scale farms in Africa: Evidence from Ethiopia's commercial horticultural sector. Strategy Support Program Working Paper 156. International Food Policy Research Institute: Washington, D. C.

Balehegn, M. 2015. Unintended consequences: The ecological repercussions of land grabbing in sub-Saharan Africa. *Environment: Science and Policy for Sustainable Development*, 57 (2): 4-21. https://doi.org/10.1080/00139157.2015.1001687.

Byamugisha, F. 2016. Securing Land Tenure and Easing Access to Land. Background paper for: African Transformation Report 2016: Transforming Africa's Agriculture. African Center for Economic Transformation.

Chitonge, H., O. Mfune, D. Kafwamba, and G. Kajoba. 2017. Hybrid land markets: monetarised customary land transactions in Zambia. *Canadian Journal of African Studies,* 51 (1): 123-143. https://doi.org/10.1080/00083968.2017.1303389.

Dang, D. K. D., A. Patterson, and L. R. Carrasco. 2019. An analysis of the spatial association between deforestation and agricultural field sizes in the tropics and subtropics. *PLoS One,* 14 (1): e0209918. https://doi.org/10.1371/journal.pone.0209918.

Davis, K. F., H. I. Koo, J. Dell'Angelo, P. D'Odorico, L. Estes, L. J. Kehoe, M. Kharratzadeh, T. Kuemmerle, D. Machava, A. D. J. R. Pais, N. Ribeiro, M. C. Rulli, and M. Tatlhego. 2020. Tropical forest loss enhanced by large-scale land acquisitions. *Nature Geoscience*, 13: 482-488. https://doi.org/10.1038/s41561-020-0592-3.

DeFries, R., T. Rudel, M. Uriarte, and M. Hansen. 2010. Deforestation driven by urban population growth and agricultural trade in the twenty-first century. *Nature Geoscience Letters*, 3: 178-181. https://doi.org/10.1038/ngeo756.

FAOSTAT Database. 2021. Indicator Database of the Food and Agriculture Organization of the United Nations. Accessed June 24, 2021. http://www.fao.org/faostat/en/#home.

Gibbs, H. K. et al., 2010. Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. *Proceedings of the National Academy of Sciences*, 107 (38): 16732–37. https://doi.org/10.1073/pnas.0910275107.

Griscom, B. W., et al., 2021. National mitigation potential from natural climate solutions in the tropics. *Philosophical Transactions of the Royal Society B*, 375: 20190126. https://doi.org/10.6084/m9.figshare.c.4784610.

Hajjar, R., J. A. Oldekop, P. Cronkleton, P. Newton, A. J. M. Russell, and W. Zhou. 2021. A global analysis of the social and environmental outcomes of community forests. *Nature Sustainability,* 4: 216–224. https://doi.org/10.1038/s41893-020-00633-y.

Hanson, M., Wang, L., Song, X-P., Tyukavina, A., Turubanova, S., Potapov, P. & Stehman, S., 2020. *Science Advances,* 6(11), 11 March 2020, DOI: 10.1126/sciadv.aax8574

Houssou, N., X. Diao, and S. Kolavalli. 2014. Can the private sector lead agricultural mechanization in Ghana? Ghana Policy Note No. 4. International Food Policy Research Institute: Washington, D.C.

Houssou, N., A. Chapoto, and C. Asante-Addo. 2016. Farm transition and indigenous growth: The rise to medium- and large-scale farming in Ghana. Discussion Paper No. 01499. International Food Policy Research Institute: Washington, D. C.

Jayne, T. S., J. Chamberlin, L. Traub, N. Sitko, M. Muyanga, F. K. Yeboah, W. Anseeuw, A. Chapoto, A. Wineman, and C. Nkonde. 2016. Africa's changing farmland ownership: The rise of medium-scale farms. *Agricultural Economics*, 47S: 197–214. https://doi.org/10.1111/agec.12308.

Jayne, T. S., M. Muyanga, A. Wineman, H. Ghebru, C. Stevens, M. Stickler, A. Chapoto, W. Anseeuw, D. Vanderwesthuisen, and D. Nyange. 2019. Are medium-scale farms driving agricultural transformation in sub-Saharan Africa? *Agricultural Economics*, 50 (S1): 75–95. https://doi.org/10.1111/agec.12535.

Jayne, T. S., and P. A. Sanchez. 2021. Agricultural productivity must improve in sub-Saharan Africa. *Science*, 372 (6546): 1045–47. http://doi.org/10.1126/science.abf5413.

Jayne, T. S., A. Wineman, J. Chamberlin, M. Muyanga, and F. K. Yeboah. 2021. Changing farm size distributions and rural transformation in sub-Saharan Africa. Forthcoming in the *Annual Review of Resource Economics*.

Kazungu, M., R. F. Velasco, E. Zhunusova, M. Lippe, G. Kabwe, D. J. Gumbo, and Sven Gu̇nter. 2021. Effects of household-level attributes and agricultural land-use on deforestation patterns along a forest transition gradient in the Miombo landscapes, Zambia. *Ecological Economics*, 186: 107070. https://doi.org/10.1016/j.ecolecon.2021.107070

Kong, R., J.-C. Diepart, J.-C. Castella, G. Lestrelin, F. Tivet, E. Belmain, and A. Bégué. 2019. Understanding the drivers of deforestation and agricultural transformations in the Northwestern uplands of Cambodia. Applied Geography, 102: 84-98. https://doi.org/10.1016/j.apgeog.2018.12.006.

Kouassi, J.-L., A. Gyau, L. Diby, Y. Bene, and C. Kouamé,. 2021. Assessing Land Use and Land Cover Change and Farmers' Perceptions of Deforestation and Land Degradation in South-West Côte d'Ivoire, West Africa. Land, 10 (429). https://doi.org/10.3390/land10040429.

Laurance, W. F., J. Sayer, and K. G. Cassman. 2013. Agricultural expansion and its impacts on tropical nature. Trends in Ecology & Evolution, 29 (2); 107-116. http://dx.doi.org/10.1016/j.tree.2013.12.001.

Lusasi, J., E. Friis-Hansen, and R. H. Pedersen. 2020. A typology of domestic private land-based investors in Africa: Evidence from Tanzania's timber rush. *GeoForum*, 116: 163-171. https://doi.org/10.1016/j.geoforum.2020.07.009.

McPherson, E.G., J. R. Simpson, P. J. Peper, S. E. Maco, and Q. Xiao. 2005. Municipal forest benefits and costs in five US cities (PDF) (6 pp, 267K). *Journal of Forestry* 103(8):411–416.

Ngoma, H., J. Pelletier, B. P. Mulenga, and M. Subakanya. 2021. Climate-smart agriculture, cropland expansion and deforestation in Zambia: Linkages, processes and drivers. *Land Use Policy*, 107: 105482. https://doi.org/10.1016/j.landusepol.2021.105482.

Ngwira, S. and T. Watanabe. 2019. An analysis of the causes of deforestation in Malawi: A case of Mwazisi. *Land*, 8 (48). https://doi.org/10.3390/land8030048.

Nzunda, E. F., and F. Midtgaard. 2019. Deforestation and loss of bushland and grassland primarily due to expansion of cultivation in mainland Tanzania (1995–2010). *Journal of Sustainable Forestry*, 38 (6): 509-525. https://doi.org/10.1080/10549811.2019.1598437.

Ordway, E. M. 2018. Commodity Crop Expansion Pathways and Impacts in Tropical Forest Regions of Africa and Asia. Dissertation. Department of Earth System Science, Stanford University.

Ordway, E. M., G. P. Asner, and E. F. Lambin. 2017. Deforestation risk due to commodity crop expansion in sub-Saharan Africa. *Environmental Research Letters*, 12: 044015. https://doi.org/10.1088/1748-9326/aa6509.

Pelletier, J., H., Ngoma, N. M. Mason, and C. B. Barrett. 2020. Does smallholder maize intensification reduce deforestation? Evidence from Zambia. *Global Environmental Change*, 63: 102127. https://doi.org/10.1016/j.gloenvcha.2020.102127.

Rudel, T. K. 2013. The national determinants of deforestation in sub-Saharan Africa. *Philosophical Transactions of the Royal Society B*, 368: 20120405. http://dx.doi.org/10.1098/rstb.2012.0405.

Ryan, S. J., M. W. Palace, J. Hartter, J. E. Diem, C. A. Chapman, and J. Southworth. 2017. Population pressure and global markets drive a decade of forest cover change in Africa's Albertine Rift. *Applied Geography*, 81: 52-59. http://dx.doi.org/10.1016/j.apgeog.2017.02.009.

Sitko, N., 2010. Fractured governance and local frictions: the exclusionary nature of a clandestine land market in southern Zambia. *Africa,* 80 (1): 36–55. https://doi.org/10.3366/E0001972009001259.

Sitko, N., and T. S. Jayne. 2014. Structural transformation or elite land capture? The growth of "emergent" farmers in Zambia. *Food Policy*, 48: 194-202. https://doi.org/10.1016/j.foodpol.2014.05.006.

Skole, D. L., et al., 2021. Direct measurement of forest degradation rates in Malawi: Toward a national forest monitoring system to support REDD+. *Forests*, 12: 426. https://doi.org/10.3390/f12040426.

Takane, T. 2008. Customary land tenure, inheritance rules, and smallholder farmers in Malawi. *Journal of Southern African Studies* 34 (2): 269–291. https://www.jstor.org/stable/40283138.

Twongyirwe, R., M. Bithell, and K. S. Richards. 2018. Revisiting the drivers of deforestation in the tropics: Insights from local and key informant perceptions in western Uganda. *Journal of Rural Studies*, 63: 105-119. https://doi.org/10.1016/j.jrurstud.2018.08.013.

Wineman, A., and L. S. O. Liverpool-Tasie. 2017. Land markets and the distribution of land in northwestern Tanzania. *Land Use Policy*, 69: 550–563. http://dx.doi.org/10.1016/j.landusepol.2017.09.043.

Wineman, A., T. S. Jayne, E. I. Modamba, and H. Kray. 2020a. The changing face of agriculture in Tanzania: Indicators of transformation. *Development Policy Review*, 38 (6): 685–709. https://doi.org/10.1111/dpr.12491.

Wineman, A., T. S. Jayne, E. Isinika Modamba, and H. Kray. 2020b. Characteristics and spillover effects of medium-scale farms in Tanzania. *European Journal of Development Research*. https://doi.org/10.1057/s41287-020-00323-7.

U.S. Agency for International Development
1300 Pennsylvania Avenue, NW
Washington, DC 20523
Tel. 202–712–0000
Fax. 202–216–3524
www.usaid.gov