Feed the Future Innovation Lab for Food Security Policy

Research Paper 162 December 2019

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CLIMATE-SMART AGRICULTURE, CROPLAND EXPANSION, AND DEFORESTATION IN ZAMBIA: LINKAGES, PROCESSES, AND DRIVERS

By

Hambulo Ngoma, Johanne Pelletier, Brian P Mulenga, and Mitelo Subakanya

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Food Security Policy *Research Papers*

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AUTHORS

Ngoma and Mulenga are Research Fellows, and Subakanya, Research Associate at the Indaba Agricultural Policy Research Institute (IAPRI); Pelletier is Postdoctoral Fellow at the Atkinson Center for a Sustainable Future and the Charles H. Dyson School of Applied Economics, Cornell University, Ithaca, NY.

Authors' Acknowledgment:

This study was made possible by the generous support of the American people provided to the Feed the Future Innovation Lab for Food Security Policy (FSP) through the United States Agency for International Development (USAID) under Cooperative Agreement No. AID-OAA-L-13-00001 (Zambia Buy-In). Additional funding support was provided by the Swedish International Development Agency (SIDA) and the USAID Mission to Zambia. The authors acknowledge Patricia Johannes for editorial and formatting assistance.

This Paper is also published as IAPRI Working Paper No. 151.

This study is made possible by the generous support of the American people through the United States Agency for International Development (USAID) under the Feed the Future initiative. The contents are the responsibility of the study authors and do not necessarily reflect the views of USAID or the United States Government

Published by the Department of Agricultural, Food, and Resource Economics, Michigan State University, Justin S. Morrill Hall of Agriculture, 446 West Circle Dr., Room 202, East Lansing, Michigan 48824, USA.

EXECUTIVE SUMMARY

Motivation: Although increasing agricultural production is necessary to feed a growing population and meet changing dietary preferences, basing this on expanding area cultivated at the expense of the forest is unsustainable. Expanding agriculture area into forests accounts for 80% of the deforestation globally. Zambia is estimated to lose between 167,000 and 300,000 ha of total forest per annum. Deforestation contributes to climate change, which in turn disproportionately affects smallholder farmers who depend on rainfed agriculture and yet have the least means to adapt to and cope with climate shocks. Climate-smart agriculture (CSA) is considered a necessary condition to increase agricultural productivity and resilience, as well as to adapt to and mitigate climate change. However, the pathways through which CSA can reduce deforestation are neither obvious, nor are they well understood. At conceptual level, the Borlaug hypothesis postulates that increasing agricultural productivity enables intensification, which in turn spares nature. However, increasing agricultural productivity makes agriculture profitable, which in turn might incentivize rather than reduce deforestation—a phenomenon called the Jevons Paradox. Understanding the different conditions and enabling environments for either of the opposing outcomes in different contexts remains an unresolved and important empirical regularity.

Purpose: This paper aims to contribute towards a better understanding of the linkages among CSA, cropland expansion, and deforestation. It unpacks how, why, and where cropland expansion is occurring among smallholder farmers in Zambia.

Approach and Methods: Based on detailed nation-wide household-level data, we use an instrumental variable approach to assess cropland expansion and drivers of that expansion, and assess whether CSA reduces cropland expansion in Zambia. We supplemented this analysis with the spatially-explicit Hansen et al. (2013) data to characterize district-level forest cover changes between 2001 and 2018 and correlate these data with district-level changes in cropland expansion to identify processes and patterns.

Findings: One-fifth of the 7,241 farm households surveyed in 2019 expanded cropland between the 2016/2017 and 2017/2018 farming seasons, clearing on average 0.18 ha, but only 13% expanded their cropland into forests, clearing an average of 0.10 ha of forestland per household. While not all cropland expansion necessarily leads to deforestation, smallholder cropland expansion into forests represents about 4.6% of cultivated land and about 60% (or 150,000 ha) of the 250,000 ha of forests lost per year in Zambia. Most households expanded cropland because of the need to meet subsistence food needs and a few others in response to market opportunities. Much of the cropland expansion among smallholder farmers is concentrated in Luapula, Muchinga, Northern, North-Western, and Western provinces, which are among the most agriculturally favorable areas given the good rainfall conditions (except for Western Province). However, these provinces have high soil acidity, further bringing to the fore a need to address soil health in these areas. Adopting CSA had no statistically significant effect on cropland expansion in our national sample, indicating that CSA alone might not avert expansion-led deforestation. However, age and education are associated with reduced expansion, while secure tenure, landholding size, being male-headed, and distance from the plot to the homestead are positively related to cropland expansion. Thus, CSA-led (technological) intensification alone might not reduce deforestation unless if complemented with improved natural resources management, which would control conversion of forestland to other uses, including agriculture.

Policy Implications: We draw three implications for policy. First, relying only on technological-driven intensification to spare forests may be risky. Productivity-enhancing agricultural technologies,

like CSA, would be more likely to lead to win-win outcomes for conservation and food production if accompanied by improved resource governance initiatives and better land use planning. Second, seeing that smallholder-led expansion accounts for about 60% of the reported deforestation in Zambia—and most of this expansion occurs in the current agricultural belt—signals the urgency with which policies are required to curb expansion. This is important in order to avert the likelihood that the current agricultural belt, which receives abundant rainfall in Zambia might start to experience reduced rainfall due to deforestation-induced climate variability. And, lastly, we contend that concerted efforts are needed to identify sustainable and efficient ways to scale-up and scale-out CSA adoption in Zambia and the region, given the strategic role CSAs play in building climate resilience.

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LIST OF ACRONYMS AND ABBREVIATIONS

CFS	Crop Forecast Survey
CSA	Climate Smart Agriculture
CSO	Central Statistical Office
FAO	Food and Agriculture Organization of the United Nations
FOC	First Order Conditions
GDP	Gross Domestic Product
GRZ	Government of the Republic of Zambia
Ha	Hectare
IAPRI	Indaba Agricultural Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
km	Kilometer
MoA	Ministry of Agriculture
NDC	Nationally Determined Contributions
RALS	Rural Agricultural Livelihoods Survey
SAI	Sustainable Agricultural Intensification
SSA	Sub-Saharan Africa
UNFCCC	United Nations Framework Convention on Climate Change

1. INTRODUCTION AND BACKGROUND

Expanding agriculture area into forests accounts for about 80% of the deforestation globally and it is the main cause of tropical deforestation (Kaimowitz and Angelsen 1998; Gibbs et al. 2010; FAO 2017). In Zambia, deforestation is estimated between 167,000 and 300,000 ha per annum (Kalinda et al. 2013; FAO 2015). While increasing production is necessary to feed a growing population and meet changing dietary preferences, basing this on expanding area at the expense of the forest is unsustainable, given the increasing land scarcity and population growth.

Deforestation contributes to climate change, which in turn disproportionately affects smallholder farmers who depend on rainfed agriculture and have the least means to adapt to and cope with climate shocks. Globally, agriculture, forestry and land use change accounted for 23% of anthropogenic emissions between 2007 and 2016 (IPCC 2019). Land use and land use change and forestry, and agriculture accounted for 7% and 87%, respectively of the total emissions estimated at 364 MtC02eq in Zambia in 2012 (CIAT and WorldBank 2017). Sustainable agriculture intensification (SAI) is largely seen as a viable option that could potentially raise crop productivity while conserving nature. SAI is defined as producing more output from the same area of land or from using inputs more efficiently, while sustainably reducing the negative environmental consequences (Pretty, Toulmin, and Williams 2011). As a central tenet of SAI, sustainable land management and in particular, climate-smart agriculture (CSA) is considered a necessary condition to increase agricultural productivity and resilience, adapt to, and mitigate climate change (IPCC 2019).

There are two possible pathways through which CSA might affect deforestation. First, CSA might affect deforestation through its effects on agricultural productivity. Second, the effects of CSA on labor allocations might affect deforestation by either making labor available or by using up idle labor that would otherwise be reallocated to other uses, including cropland expansion. Thus, it is difficult to tease out the exact pathways through which CSA or more generally SAI might reduce deforestation. This is complicated by the fact that CSA practices are associated with increased productivity in the medium- to long-term and yet, some CSAs, such as minimum tillage, are labor intensive (Thierfelder et al. 2015; Thierfelder et al. 2016). At conceptual level, the Borlaug hypothesis postulates that increasing agricultural productivity enables SAI, which in turn spares nature (Borlaug 2007; Angelsen 2010; Phalan et al. 2016). Another school of thought argues that increasing agricultural productivity makes agriculture profitable, which in turn might incentivize rather than reduce deforestation—a phenomena also called the Jevons Paradox (Phalan et al. 2016). Understanding the different conditions and enabling environments for either of the opposing outcomes in different contexts remains an unresolved important empirical question.

This paper aims to contribute towards a better understanding of the linkages among CSA, cropland expansion, and deforestation. Specifically, we use detailed household level data to unpack *how*, *why,* and *where* cropland expansion is occurring, and to assess drivers of cropland expansion and whether CSA reduces cropland expansion in Zambia. We supplement this analysis by using the spatially-explicit Hansen et al. (2013) data to characterize district-level forest cover changes between 2001 and 2018 and correlate these changes in forest cover with district-level changes in cropland expansion to identify processes and patterns.

We focus on CSA because it is part of national policy aimed at improving agricultural productivity, while building climate resilience in several Sub-Saharan Africa countries including Zambia, Kenya, Zimbabwe, Malawi, Tanzania, Mozambique, and Lesotho (Giller et al. 2015). CSA is defined in this paper as the use of minimum tillage (ripping, planting basins, and zero tillage) as the main tillage, agroforestry, or irrigation on at least one plot. CSA in Zambia is integral to addressing climate change, low agricultural productivity, and resilience as highlighted in the Seventh National Development Plan, the Second National Agricultural Policy and the National Policy on Climate Change (GRZ 2016b; GRZ 2016a; GRZ 2017). CSA is also among the main policy instruments for reducing greenhouse gas emissions from agriculture proposed in nationally determined contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) 2015 Paris Agreement (Richards et al. 2015). However, the mechanisms through which CSA can reduce agricultural land expansion are neither obvious nor very well understood (Ngoma et al. 2018). Notwithstanding, there is strong political support for CSA as part of the solutions to intensify agriculture, adapt to, and mitigate climate change, and reduce deforestation in the region (Thierfelder et al. 2017).

Zambia makes an appropriate study country because agricultural land expansion has been identified as one of the major causes of the nearly 250,000 ha of forest lost annually (even though the quantified contribution of expansion to deforestation is unknown) and CSA practices have been promoted in the country for over two decades (Haggblade and Tembo 2003; Vinya et al. 2011; Kalinda et al. 2013; FAO 2015; Ngoma et al. 2016). The higher deforestation rates and the projected increase in demand for food show the pressing need to identify policy options that can help reconcile food production and forest conservation. The projected increases in climate shocks necessitate action to reconcile food production and conservation but also adds to the complexity of matters to be addressed.

We complement extant literature in at least four main ways. First, we extend the analyses in Ngoma and Angelsen (2018) and Pelletier et al. (forthcoming) who focus only on minimum tillage and improved inputs, respectively, by using a broader definition of CSA including minimum tillage, agroforestry, and irrigation. Second, to the best of our knowledge, this is the first study to quantify the extent and intensity of cropland expansion at national and province level in Zambia, also disaggregating which of this expansion is done at the expense of forests. Third, unlike studies done at the global, or regional scale, or studies that are mostly theoretical (e.g., Balmford, Green, and Scharlemann 2005; Rudel et al. 2009; Rudel 2013; Babigumira et al. 2014; Byerlee, Stevenson, and Villoria 2014), we use detailed household and forest cover change data to study cropland expansion decisions at household and district levels among smallholder farmers. Lastly, we take advantage of detailed household-level data and use an instrumental variable approach to control for the endogeneity of CSA use in cropland expansion decisions at household level, while controlling for other potential confounding factors.

The rest of the paper is organized as follows. Section 2 zeroes in on the linkages between agriculture and deforestation and presents a theoretical framework. Data and methods are presented in Section 3 and results are in Section 4. Section 5 discusses the main results and the paper concludes in Section 6.

2. AGRICULTURE AND DEFORESTATION: A THEORETICAL FRAMEWORK

A lot of work has been done on the linkages between agriculture and deforestation, with special attention to the question: *when* and *how* can agriculture technologies reduce deforestation. Although the land sparing hypothesis postulates that intensifying agriculture spares nature, empirical results are mixed. In some cases, cropland is expanded into forests in response to market opportunities, to secure tenure, or to meet subsistence needs (Angelsen 1995; Angelsen 1999; Angelsen 2010). This is more complex if multiple factors are at play. The outcomes then depend on the commodity in question, its market position, price elasticity of demand, context, and factor intensities (Hertel 2011; Hertel 2012; Ngoma et al. 2018). For example, in Malawi where land is scarce, Chibwana, Jumbe, and Shively (2013) found some evidence suggesting that participating in the subsidy program helped intensify agricultural production and might have reduced forest clearing. By contrast, in Zambia, a previous study showed that access to subsidies did not have a statistically significant effect on cropland expansion (Ngoma and Angelsen 2018). Similarly, for Zambia, Pelletier et al. (forthcoming), using a combination of small area estimation and econometrics modeling, find that while the use of hybrid maize seed is significantly associated with reduced forest cover loss, the effects of fertilizer use on forest cover change are inconclusive.

The direct effects of other CSA practices on deforestation or cropland expansion remain understudied. In a another recent study, Ngoma and Angelsen (2018) found that the use of minimum tillage did not overall reduce cropland expansion among smallholder farmers in Zambia. However, authors found some negative association between minimum tillage use and cropland expansion among minimum tillage adopters, suggesting perhaps that the labor intensity of minimum tillage utilizes labor that would otherwise be available for expansion. The mechanisms through which agricultural technologies can lead to reduced cropland expansion are complex and depend on the context.

2.1 Farm Level Cropland Expansion Decisions

Following Ngoma and Angelsen (2018) and Angelsen (1999), farm household decisions to expand cropland can be motivated from an agricultural household model. To fix ideas, assume a representative household who aims to maximize utility $U = U(c, l; \boldsymbol{h})$ by choosing either consumption (*c*) or leisure (*l*). Let *U* with diminishing marginal utilities in *c* and *l be* maximized subject to a well behaved, twice differentiable production $Y = f\left(l^a, CSA, A; X\right)$. Production is a function of labor$\left(l^a\right)$, climate-smart agriculture (*CSA*), land area (*A*), and inputs ($\boldsymbol{X}$). We assume complementarities among the arguments in the production so that $f_{l^a}, f_A, f_{CSA} > 0;\ f_{l^a l^a}, f_{AA}, f_{CSACSA} < 0$; $f_{l^a A}, f_{l^a CSA}, f_{CSA} > 0$ and $f_{ACSA} = f_{CSAA} = 0$; and zero cross partials in utility $U_c, U_l > 0; U_{cc}, U_{ll} < 0; U_{cl}, U_{cl} = 0$. The resulting utility maximization problem can be solved subject to a budget and time/labor constraint to give four key first order conditions (FOCs):[1]

- FOC 1 suggests that the marginal productivity of agricultural labor (or leisure) is equal to the shadow wage, i.e., the marginal rate of substitution between consumption and leisure;
- FOC 2 suggests that a household will expand cropland until the marginal productivity of land equals the sum of the cash and labor cost of land and expansion;

[1] Readers are referred to Ngoma and Angelsen (2018) for details on the theoretical model.

- FOC 3 suggests that CSA is profitable as long as its marginal benefit is equal to the cost of implementing it; and
- FOC 4 defines the shadow wage as the marginal rate of substitution between consumption and leisure.

Comparative statics based on the FOCs show that the impact of changes in CSA adoption on cropland expansion is the net effect of the substitution and income effects. The substitution effect is analyzed by holding the shadow wage constant, while the income effect is analyzed through changes in the shadow wage (Angelsen (1999). Following Ngoma and Angelsen (2018), a lower (higher) cost of CSA adoption increases (reduces) adoption. Higher CSA adoption increases the marginal productivity of land, given the complementarity assumption. Expansion becomes more profitable, and the substitution effect predicts a negative relationship between the cost of CSA adoption and cropland expansion and a positive relationship between CSA adoption and expansion. The net income effect is a lot more complex. All else equal, a lower cost of CSA adoption reduces the costs of production and raises consumption. Higher consumption raises the shadow wage, but the substitution effect predicts a higher CSA, A and l^a when CSA costs are lower. Thus, the household will both produce and work more, and have less leisure. The income effect, therefore, predicts a positive relationship between the cost of CSA adoption and expansion and a negative relationship between CSA adoption and cropland expansion into forests.

Following Ngoma and Angelsen (2018), we surmise that it is difficult to sign the overall effects of CSA adoption on cropland expansion, *a priori*. The substitution effect predicts a positive effect of CSA adoption on expansion, reflecting the higher profitability of land expansion. The income effect is, however, negative because higher consumption and less leisure increases the household shadow wage rate, which in turn reduces the profitability of land expansion.

Determining the net effect is an empirical question that is yet to be resolved. We conjecture following Ngoma and Angelsen (2018) and Angelsen (1999) that household preferences, social economic status, and production technology matter.

3. DATA AND METHODS

3.1 Data Sources

Data used in this paper are drawn from three main sources: the 2015 and 2019 Rural Agricultural Livelihoods Survey (RALS), the Crop Forecast Surveys (CFS) and the Hansen data on forest cover change. The RALS data collected by the Indaba Agricultural Policy Research Institute (IAPRI) in collaboration with the Ministry of Agriculture (MoA) and the Central Statistical Office (CSO) in Zambia are statistically representative at national and provincial level, and at district level in Eastern Province. We mainly use the 2019 RALS data collected from 7,241 rural households between June and July 2019 in Zambia. The 2019 RALS included questions on whether a household expanded cropland, the size of the new plot, and prior land use and why they expanded. We took advantage of the fact that the 2019 RALS sample was a subset of 2015 RALS and used some variables from the later as base characteristics. Since RALS is only administered to smallholder farmers cultivating 0 – 20 ha, cropland expansion among larger farms in not captured here. Sampling details for RALS can be found here (CSO/MAL/IAPRI 2015; CSO/MAL/IAPRI 2019).

The CFS are detailed annual data collected from cross sectional samples of nearly 13,600 households. CFS data is statistically representative at the national, province, and district levels and collects detailed agricultural production data. More details on the CFS sampling are in GRZ (2011). For this study, we used data for about 122,000 smallholder households over the nine-year period of 2010-2018. We computed district level changes in area cultivated by subtracting area cultivated in year $t-1$ from year t. Both CFS and RALS are collected using face-to-face interviews where enumerators physically visit all sampled households to administer questionnaires.

We complement these household survey data with the spatially-explicit Hansen et al. (2013) forest cover change data, which were processed by Pelletier et al. (forthcoming). The Hansen data provides a 30 m resolution annual global Landsat-based forest cover loss, gain, and percentage tree cover. Raster calculation was used to quantify area of forest cover loss per district between 2001 and 2018 in Zambia. This was done by determining the number of forest loss pixels per administrative unit and per year, calculating the number of pixels deforested in each year within each district and converting pixel counts to hectares. Forest cover change is defined as a stand-replacement disturbance, or a change from a forest to non-forest state, during the period 2000-2018. Table 1(following) defines and presents summary statistics for the main variables used in the analysis and signs their expected effects on cropland expansion into forests.

3.2. Empirical Strategy

The main aim of this paper is to assess the effects of CSA use on cropland expansion-led deforestation. There are three main empirical challenges here. First CSA adoption is non-random and might, therefore, be endogenous to cropland expansion decisions at the household level. Second, not all households expanded cropland, so the outcome is censored, and lastly, cropland expansion decisions at time t are influenced by realizations at t-1, i.e., current expansion is influenced by expected outcomes that can be represented by past events.

Table 1. Summary Statistics of Key Variables and their Sources

Variable Definition	Hypothesized effects on expansion	Mean	SD	Source	n
Expanded cropland between 2016/2017 and 2017/2018 seasons (yes =1)		20.79	40.59	RALS19	7121
Expanded cropland in forest between 2016/2017 and 2017/2018 seasons (yes =1)[d]		13.03	33.67	RALS19	7121
Area of expanded cropland between 2016/2017 and 2017/2018 seasons (ha)		0.18	0.56	RALS19	7121
Area expanded into forest between 2016/2017 and 2017/2018 seasons (ha)[d]		0.09	0.36	RALS19	7121
Used CSA (min till, irrigation and agroforestry)	+/-	0.34	0.47	RALS15	7241
Ha under CSA (min till, irrigation and agroforestry)	+/-	0.54	1.40	RALS15	7241
Gross value of crops harvested	+	5297.72	7229.66	RALS15	7241
Distance from homestead to new plot (Km)	+/-	2.80	4.04	RALS19	7121
Distance to the nearest feeder road (Km)	+	2.12	39.13	RALS19	7241
Adult equivalents	+	4.26	7.14	RALS19	7241
Landholding size, net expanded area	+	5.00	17.20	RALS19	7121
Male headed household (yes =1)	+	0.72	2.19	RALS19	7241
Level of education, head (years)	-	5.68	0.45	RALS19	7241
Age, household head (years)	-	51.28	3.63	RALS19	7241
New plot has formal title (yes =1)	+	0.01	14.77	RALS19	7121
Maize seed rate per hectare in 2015 (Kg/ha)	+/-	21.44	0.09	RALS15	7241
Fertilizer rate per ha	+/-	172.22	11.13	RALS15	7241
Fertilizer cost per kg	+/-	8.53	181.82	RALS15	7241
Median maize price (kw/kg)	+/-	1.20	0.84	RALS15	7241
Related to chief or headman (yes =1)		0.56	0.42	RALS15	7241
Current member of parliament from area (yes =1)		0.12	0.50	RALS15	7241
District level percent change in cultivated land (t+1 – t) (%)[e]		7.76	36.07	CFS	648
District level forest cover loss per year (ha)[e]		3,084.34	3832.33	Hansen data	648

Source: CSO/MAL/IAPRI (RALS) 2015 and 2019.

Notes: [d] denotes dependent variables used in the final models; [e] not used in the household models.

We used instrumental variables (IVs) to address the first empirical challenge. We instrumented CSA adoption using a dummy variable = *1 if either the spouse of head of household is related to the chief or village head* and another dummy = 1 *if there is a current serving member of parliament who hails from the current locality of the household*. We argue that, and test that these social capital variables are more likely to increase availability of CSA information and therefore, the probability of CSA adoption (Table 6) but might not directly affect cropland expansion into forests except through CSA. We used Tobit, a censored regression model to address the fact that not all households expanded cropland in our sample.

Because survey data usually asks about specific reference periods, it is difficult to get a sense of household factors in the past, say at *t-1*. We took advantage of the fact that the same households interviewed in RALS 2015 were reinterviewed in 2019 and used some of the RALS 2015 covariates as base characteristics. These are indicated with a subscript *t-1* in Eq. 1 and the source column in Table 1. All other variables are captured at the current time *t*. All variables used in this analysis were selected based on the theoretical framework in section 2 and literature (Angelsen 1995; Angelsen 1999; Holden 2001; Maertens, Zeller, and Birner 2006; Angelsen 2010; Byerlee, Stevenson, and Villoria 2014; Ngoma and Angelsen 2018; Pelletier et al. forthcoming).

We can write a parsimonious representation of the estimable regression as:

$$\begin{aligned} agdef_t = \beta_0 + \beta_1 hacsa_{t-1} + \beta_2 gvharv_{t-1} + \beta_3 ae_t + \beta_4\, farmsize_t + \beta_4 tenure_t + \beta_5 seedrate_{t-1} \\ + \beta_6\, fertrate_{t-1} + \beta_7\, fert\cos t_{t-1} + \beta_8 maizeprice_{t-1} + \boldsymbol{dist}_t \partial + \boldsymbol{X}_t \gamma + \boldsymbol{agzone\alpha} + \varepsilon_t, \end{aligned} \quad (1)$$

where *agdef* is ha of area expanded into forests; *hacsa* is area under CSA (min till, agroforestry and irrigation) in 2015; *gvharv* is the gross value of harvest capturing agricultural productivity in 2015, *ae* is adult equivalent measuring labor availability, *farmsize* is total landholding net of expanded area; *tenure* captures whether the new plot has secure land tenure in the form of a title deed; *seedrate* and *fertrate* are application rates (kg/ha) for maize seed and fertilizer, respectively; and *fertcost* and *maizeprice* are per kg prices for fertilizer and maize, used as proxies for input and output prices, respectively, and based on CSO/MAL/IAPRI 2015. ***Dist*** is a vector including distances from the homestead to the new plot and the nearest feeder road, ***x*** is a vector of household demographics including age and education of the household head and whether the head of household is male. ***agzone*** is vector for agro-ecological zones, which control for spatial effects.

A positive effect of CSA on expansion is given by the partial effect $\partial agdef / \partial hacsa > 0$ and the opposite gives the negative effect. For identification CSA use is instrumented using *relations to chief/headman* and *whether there is a current serving MP who hails from the households' current location*. The hypothesized effects of the different variables on expansion are indicated in Table 1. In sum, we expected CSA, market access variables as well as costs and price variables to have mixed effects on expansion. We hypothesized that secure tenure, a larger land holding and male-household heads to be expansionary.

4. RESULTS

4.1. Extent and Intensity of Cropland Expansion and their Spatial Location in Zambia

About 21% of all farm households surveyed in the RALS 2019 expanded cropland between the 2016/2017 and 2017/2018 farming seasons, clearing on average 0.18 ha (Tables 2 and 3). If we define deforestation as expansion into virgin forests and fallow lands older than 15 years, the proportion of households who expanded cropland into forests reduces to about 13% of households, clearing an average of 0.09 ha of forest per household (Tables 2 and 3).[2] From henceforth, we will focus on expansion into forests.

Table 2. Proportion of Cropland Expansion by Province

Province	Proportion of households that expanded cropland	Proportion of households who expanded cropland into forest	n
Central	8.13	4.28	554
Copperbelt	3.96	3.17	486
Eastern	3.12	1.56	1,875
Luapula	56.14	22.48	606
Lusaka	4.57	1.06	397
Muchinga	29.84	21.67	670
Northern	46.79	35.79	702
North-Western	43.32	34.38	478
Southern	3.39	2.05	804
Western	16.37	9.57	549
Total	20.79	13.03	7,121

Source: CSO/MAL/IAPRI (RALS) (2019).

Notes: Column percentages do not add up to 100% because these are proportions of households who expanded cropland from the full sample.

Table 3. Extent of Cropland Expansion by Province

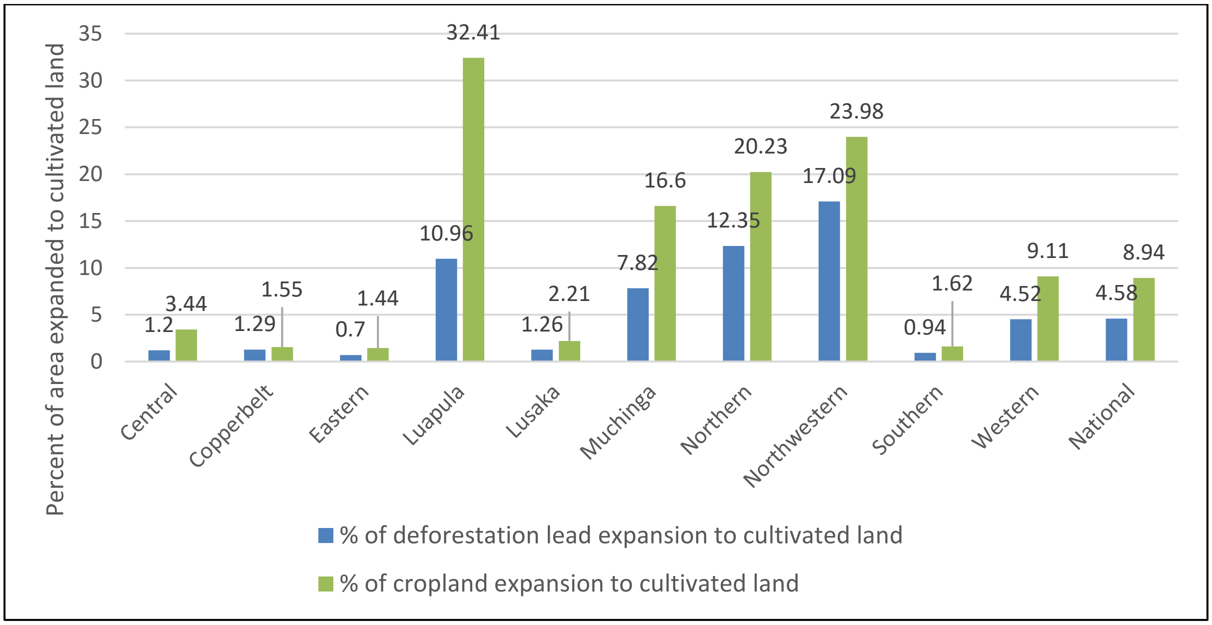
Province	Average size of area expanded for cropland	Average size of area expanded for cropland into forests	n
Central	0.09	0.03	554
Copperbelt	0.02	0.02	486
Eastern	0.03	0.02	1,875
Luapula	0.45	0.15	606
Lusaka	0.03	0.02	397
Muchinga	0.26	0.12	670
Northern	0.39	0.24	702
North-Western	0.37	0.27	478
Southern	0.05	0.03	804
Western	0.18	0.09	549
Total	0.18	0.09	7,121

Source: CSO/MAL/IAPRI (RALS) (2019).

[2] We define forests as land parcels larger than 0.5 hectares and not in agricultural use, with tree canopy cover of more than 10% and that these trees should reach a minimum height of 5 meters in situ FAO (2015). This includes primary and secondary forest, native or exotic, as well as closed and open forest (e.g., woodlands).

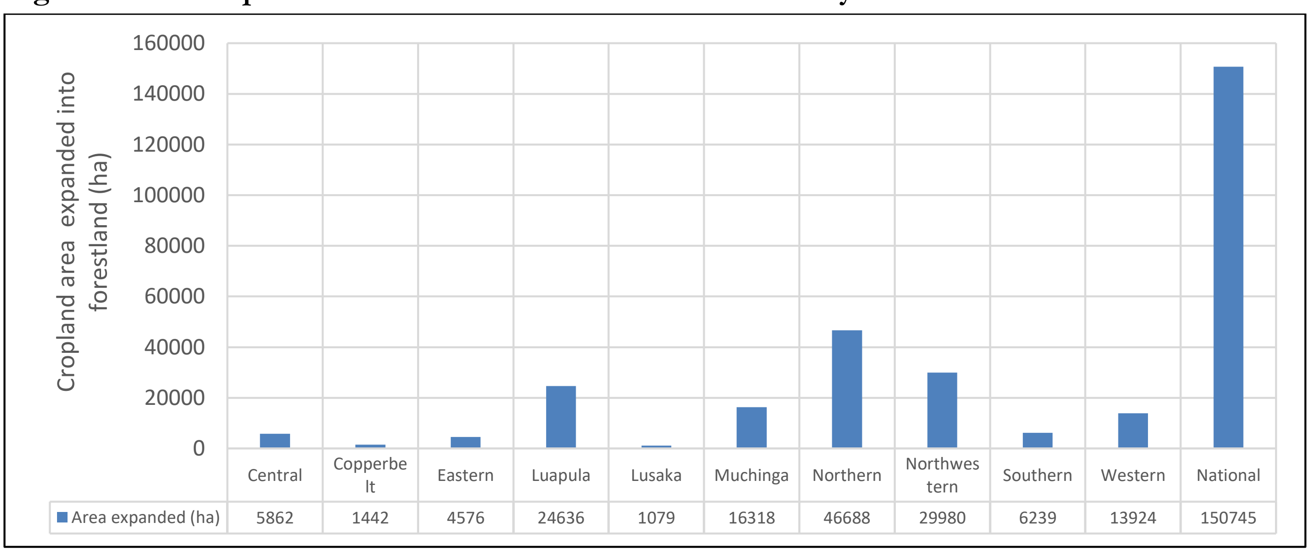
At national level, cropland expansion into forests accounts for about 4.6% of cultivated land by smallholders and about 60% (or 150,000 ha) of the estimated 250,000 ha of forests lost per year (Figures 1 and 2).[3] Cropland expansion overall and into forests is higher in Luapula, Muchinga, Northern, North-Western, and Western provinces (Tables 2 and 3 and Figures 1 and 3).

Figure 1. Percentage of Area Expanded in General and Area Expanded into Forests to Total Cultivated Land



Source: CSO/MAL/IAPRI (RALS) (2019).

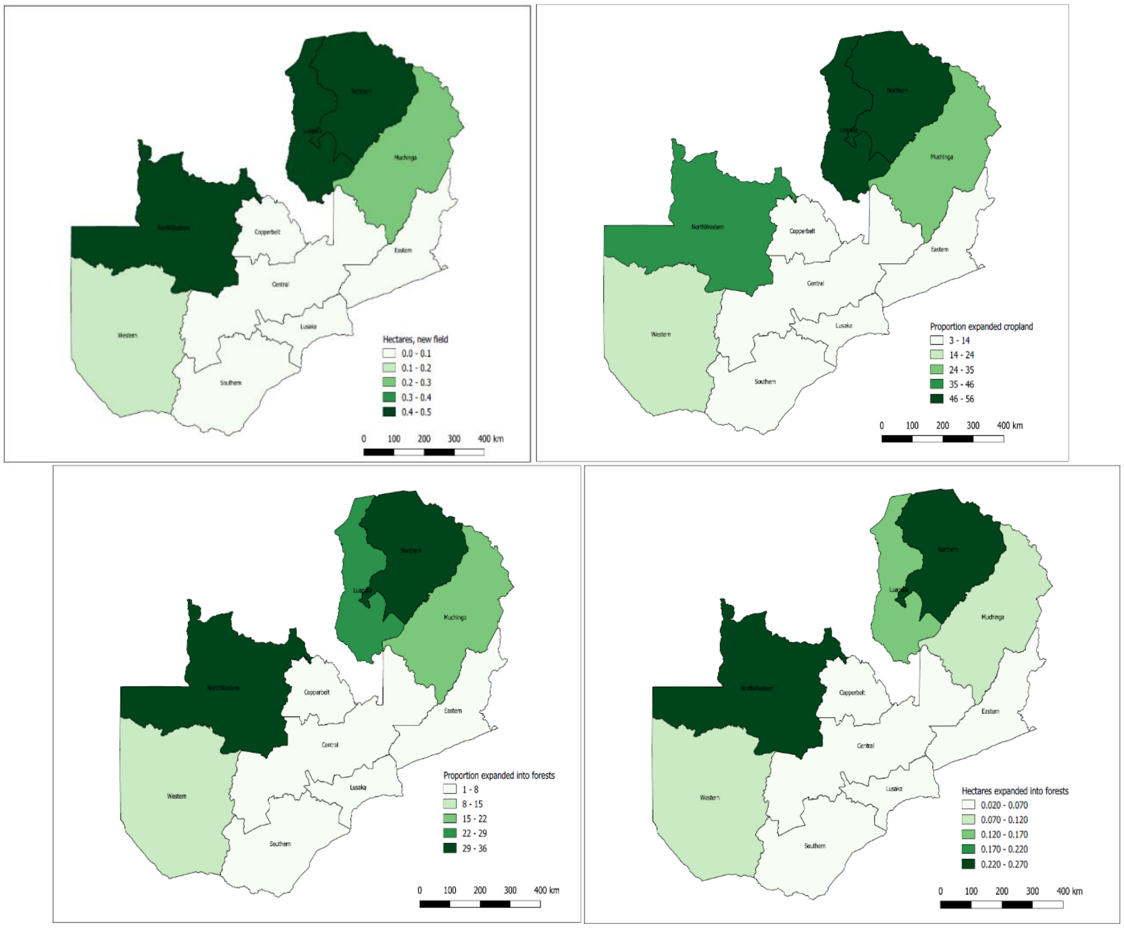
Figure 2. Area Expanded into Forests at National Level and by Province



Source: CSO/MAL/IAPRI (RALS) (2019).

[3] Total cropland expansion is the weighted sum of the area of new plots by all households that expanded at national and provincial level.

Figure 3. Province Level Spatial Distribution of Cropland Expansion (Top Left Panel), Cropland Expansion into Forests (Top Right Panel), Area Expanded (Bottom Left Panel) and Area Expanded into Forests (Bottom Right Panel)



Source: CSO/MAL/IAPRI (RALS) (2019).

When disaggregated by farm size structure, we find that while a larger proportion of 0-2 ha farms expanded cropland, the intensity of expansion is higher among the 5-10 ha farms who presumably have access to larger land holdings and finances to support expansion (Table 4).

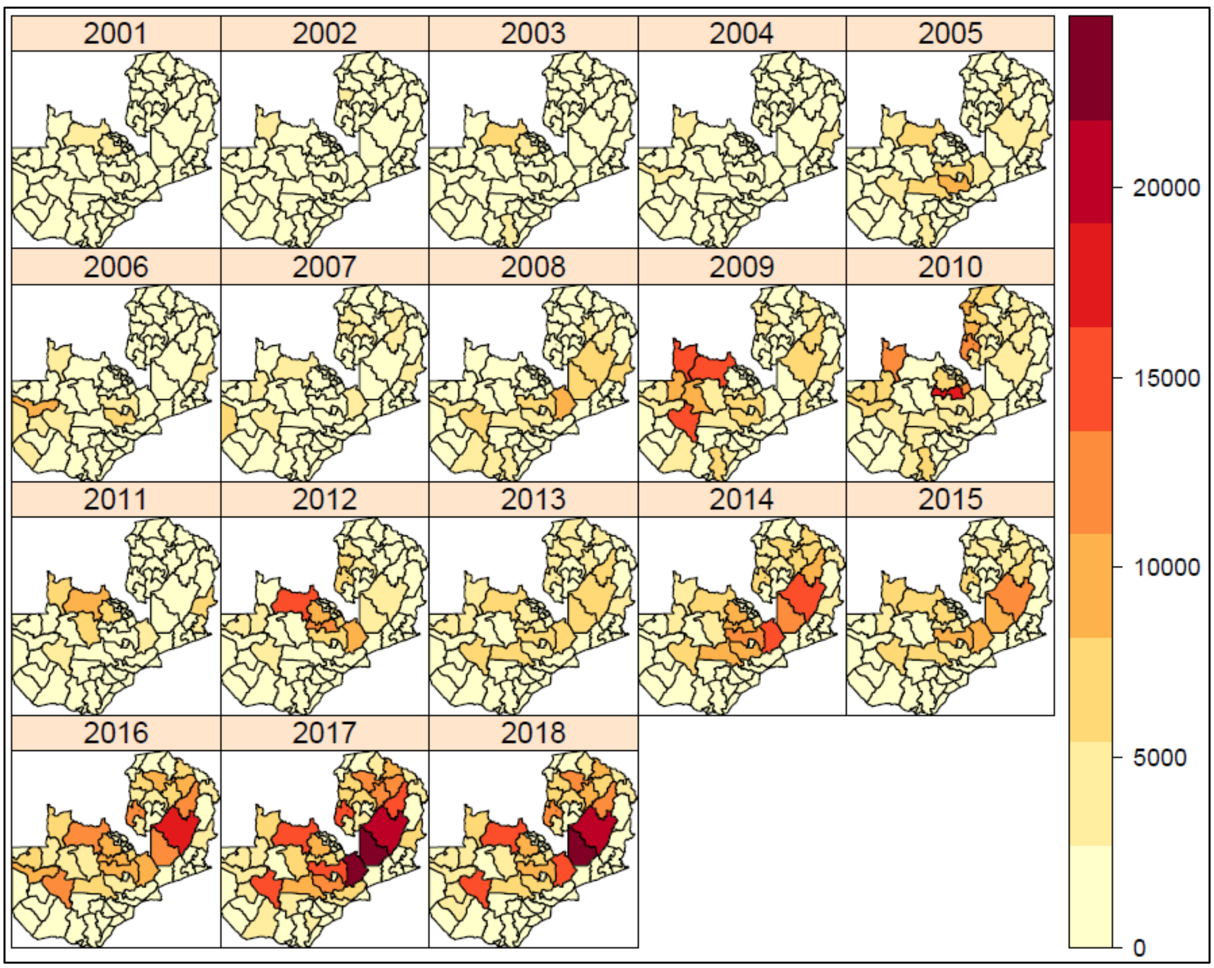
Table 4. Extent and Intensity of Cropland Expansion by Farm Size Structure

	Proportion of households that expanded cropland	Proportion of households who expanded cropland into forests	Average size of cropland expanded	Average size of cropland expanded into forests	n
0-2ha	21.99	13.58	0.17	0.09	4,334
2-5ha	18.70	12.01	0.20	0.10	2,147
5-10ha	18.66	13.09	0.30	0.12	524
>10 ha	5.16	3.44	0.10	0.07	116
Total	20.79	13.03	0.18	0.09	7,121

Source: CSO/MAL/IAPRI (RALS) (2019). Notes: Columns percentages do not add up to 100% because these are proportions of households who expanded cropland from the full sample.

The spatial distribution of cropland expansion based on RALS is qualitatively similar to district level changes in forest cover captured using satellite data and the district level changes in area cultivated based on CFS data. Figure 4 shows forest cover loss at district level from 2001 to 2018. The locus of forest cover loss as of 2018 is centered on North-Western, Muchinga, Copperbelt, Northern, and Luapula provinces. Unlike Figure 3, which only shows the changes at provincial level and only for agricultural expansion among smallholder farmers, Figure 4 captures the total forest cover loss at district level. The spatial distribution of changes in forest cover appears to be concentrated in districts where there is a combination of mining and agricultural production, and where there are still forests. (Deforestation occurs where there are standing forests). Readers are referred to Kalinda et al. (2013) for details on forest biomass distribution in Zambia.

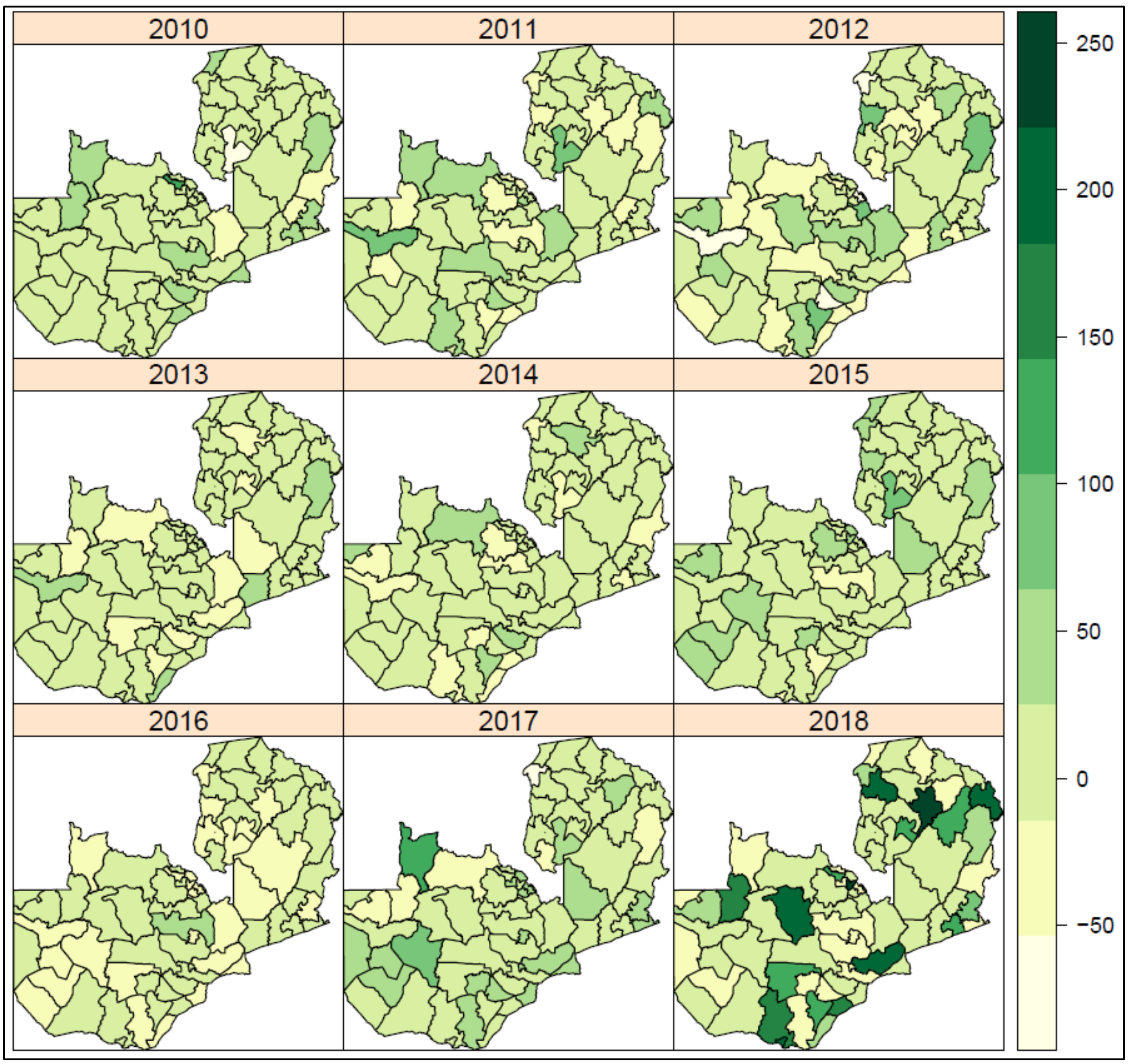
Figure 4. District Level Spatial Distribution of Forest Cover Loss by Year from 2001 to 2018 (in ha)



Source: Author compilation using Hansen et al (2013) forest cover change data.

To complement Figure 3, which only shows cropland expansion at province level, we used the CFS data to compute changes in cultivated land at district level in year *t+1* relative to year *t*. Figure 5 reports these results and shows how area cultivated has evolved between 2010 and 2018 in Zambia. It should be noted here that Figure 5 reports changes in area cultivated, but does not take into account whether this expansion was into forests or not. A positive change signals cropland expansion. The main results are somewhat preserved. The spatial pattern shows that cultivated area has expanded the most between 2010 and 2018 in parts of North-Western, Northern, Muchinga, Luapula, Copperbelt, Eastern, and Southern provinces.

Figure 5. District Level Spatial Distribution of Changes in Cultivated Land between Year t and Year t+1 (Percent)



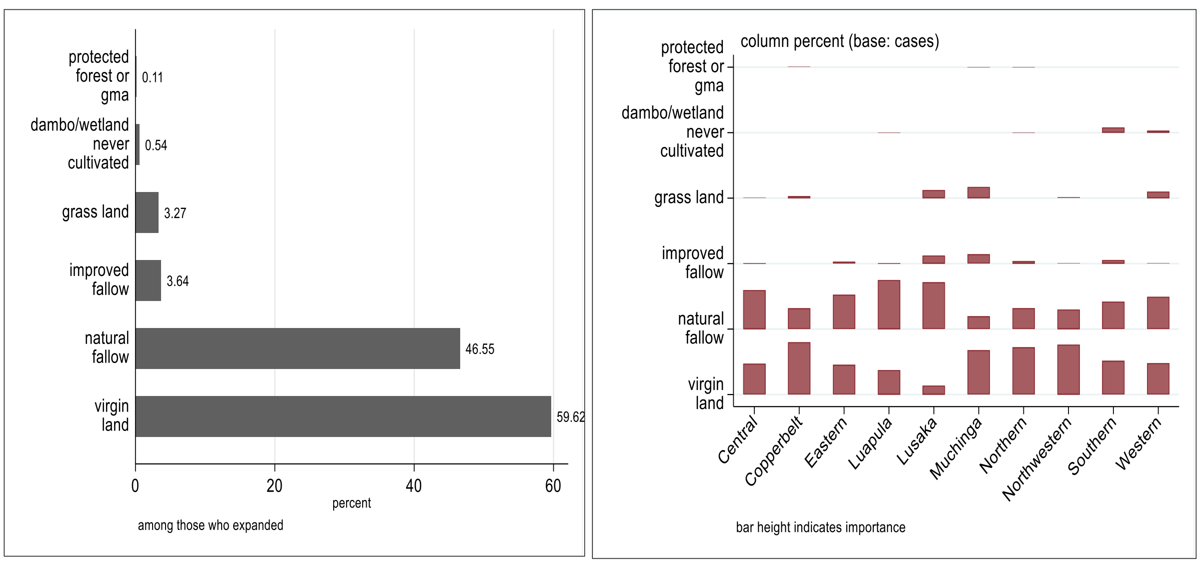
Source: CSO/MAL/IAPRI (RALS) (2019).

4.2. Why Do Households Expand Cropland and what Land Parcels Do they Expand into in Zambia?

Among households who expanded cropland, most (or about 60%) expanded into virgin forests, while about 47% expanded into natural fallows (Figure 6).[4] About 4% expanded into improved fallows and 3% expanded into grasslands, and less than 1% expanded into wetlands or protected forests. The right panel in Figure 6 shows a similar pattern at provincial level.

Nearly all households who expanded cropland (90%) did so in order to meet subsistence food requirements, while about 6 and 10 % expanded in response to availability of virgin land and improved market opportunities, respectively (Figure 7). About 2 and 3 %, respectively expanded due to declining soil productivity and in response to improved market conditions from the Food Reserve Agency (FRA). Less than 1% of households expanded cropland to secure tenure, or in response to access to input subsidies or other farm inputs.

Figure 6. Prior Land Use of Parcels Converted To Cropland in the 2017/2018 Farming Season at National Level (Left Panel) and Province Level (Right Panel)

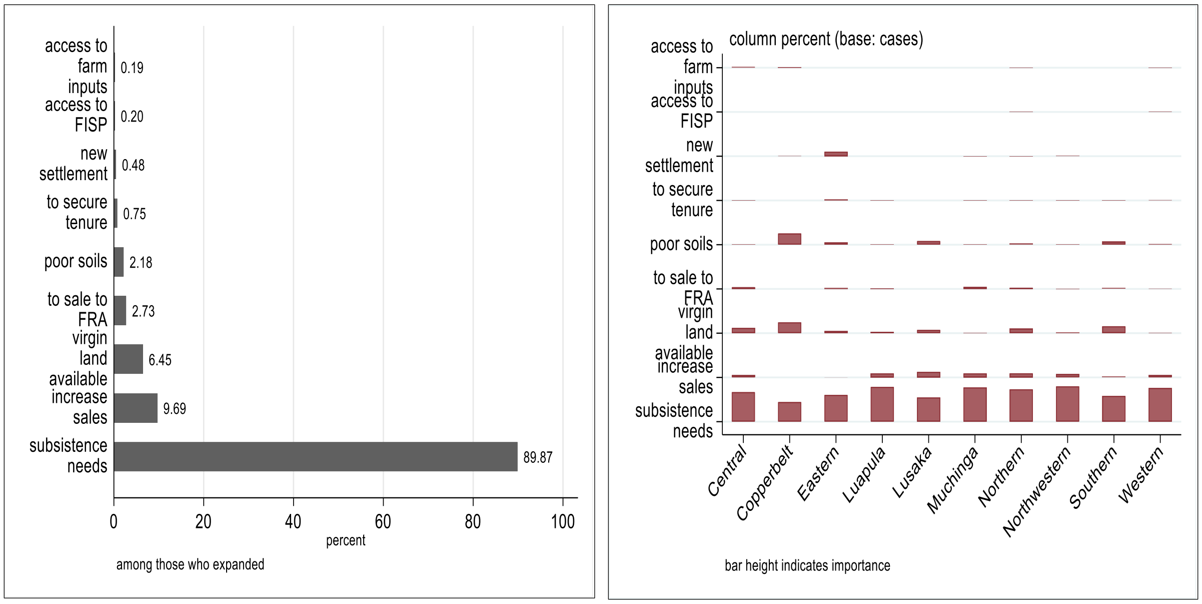


Source: CSO/MAL/IAPRI (RALS) (2019).

Notes: Percentages need not add up to 100% because a household might have had more than one plot, with each plot drawn from different prior land uses.

[4] Virgin forests refer to forestland that has never been cultivated before. It is pristine forestland. Natural fallow are fallows with naturally growing tree species whereas improved fallows are those planted with selected, fast growing, soil-heath improving tree species.

Figure 7. Main Reasons Households Expanded Cropland in the 2017/2018 Farming Season at National Level (Left Panel) and by Province (Right Panel)



Source: CSO/MAL/IAPRI (RALS) (2019).

Notes: Percentages need not add up to 100% because a household might have expanded cropland on multiple plots for different main reasons.

4.3. Are Households that Expanded Cropland Different from those that Did not Expand?

As a prelude to the more robust econometric estimations, we first compared key characteristics of households that expanded cropland to those that did not. Compared to households that did not expand cropland, expansionary households had higher gross value of output, larger landholdings, and were headed by more educated males (Table 5). In addition to using more fertilizer per ha and having higher maize prices and adult equivalents, expanding households were located farther from the newly opened plots and a larger proportion of their new plots had secure tenure. Households that expanded cropland had statistically smaller areas under CSA than those that did not expand (0.3 vs 0.6 ha, on average per household)

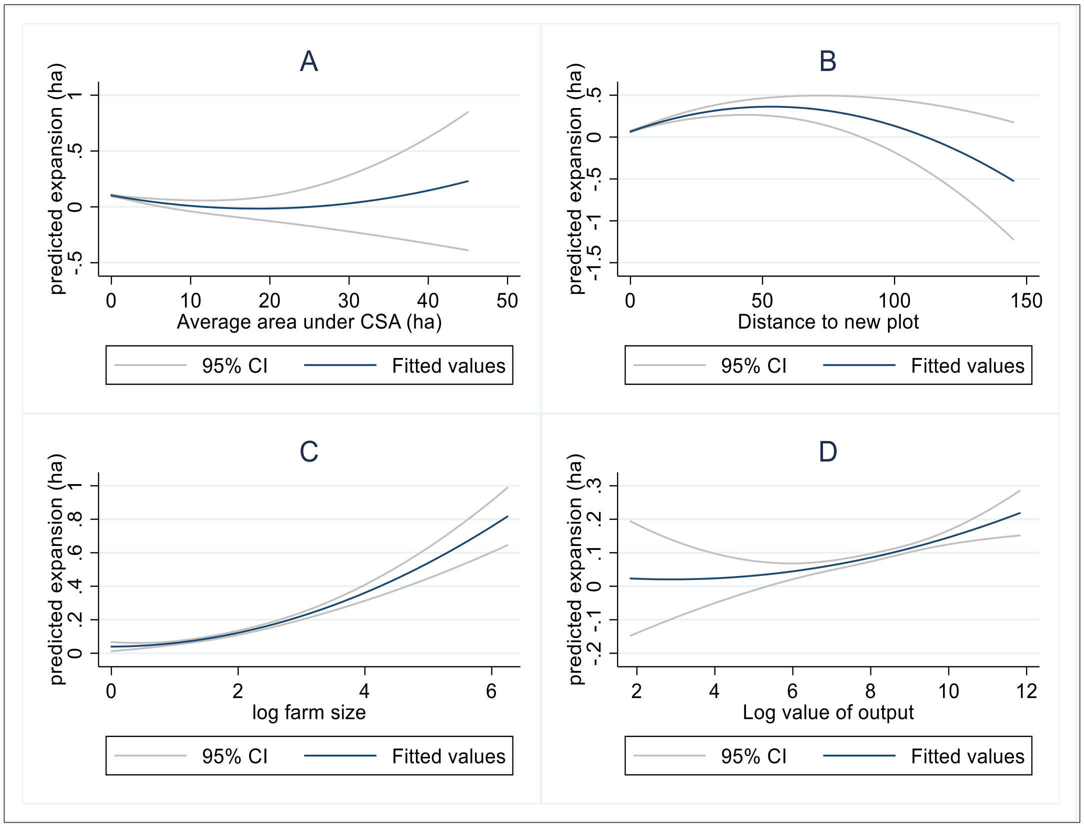
Without controlling for potential confounders, bivariate relationships in Figure 8 suggest that there are quadratic relationships between cropland expansion and area under CSA, and between cropland expansion and distance from homestead to the new plot. Cropland expansion is negatively correlated with 0-20 ha area under CSA but appears positively correlated to larger area under CSA (Figure 8). Cropland expansion is positively correlated to distance from the homestead to the new plot up to 30km, beyond which the correlation appears negative. Figure 8 also suggests that cropland expansion is positively associated with the log of farm size and value of output.

Table 5. Mean Differences in Key Variables by Whether a Household Expanded Cropland into the Forest or Not

Variable	Expanded cropland into forest		T-test
	(1) No	(2) yes	(1) - (2)
	Mean/SE	Mean/SE	Difference
Ha under CSA (min till, irrigation and agroforestry)	0.583	0.281	0.302***
	[0.028]	[0.033]	
Used CSA (min till, irrigation and agroforestry)	0.346	0.277	0.069***
	[0.009]	[0.021]	
Gross value of crops harvested	5210.520	6262.225	-1051.705***
	[143.627]	[310.209]	
Distance from homestead to new plot (Km)	2.617	4.031	-1.414***
	[0.071]	[0.234]	
Distance to the nearest feeder road (Km)	2.245	1.407	0.838***
	[0.118]	[0.193]	
Adult equivalents	4.245	4.479	-0.235**
	[0.041]	[0.086]	
Landholding size, net expanded area	4.49	8.39	-0. 235***
	[0.225]	[2.119]	
Male headed household (yes =1)	0.708	0.839	-0.131***
	[0.009]	[0.017]	
Level of education, head (years)	5.629	5.856	-0.226
	[0.074]	[0.162]	
Age, household head (years)	51.464	49.661	1.803**
	[0.302]	[0.634]	
New plot has formal title (yes =1)	0.003	0.045	-0.042***
	[0.001]	[0.009]	
Maize seed rate per hectare in 2015 (Kg/ha)	21.749	19.800	1.949***
	[0.216]	[0.547]	
Fertilizer rate per ha	169.055	199.269	-30.214***
	[3.381]	[8.956]	
Fertilizer cost per kg	8.553	8.360	0.193***
	[0.015]	[0.066]	
Median maize price (kw/kg)	1.195	1.204	-0.009***
	[0.001]	[0.002]	
Accessed CSA extension in 2015 (yes =1)	0.786	0.711	0.075***
	[0.008]	[0.021]	
Related to chief or headman (yes =1)	0.560	0.598	-0.038
	[0.010]	[0.023]	
Current member of parliament from area (yes =1)	0.112	0.134	-0.021
	[0.007]	[0.016]	

Source: CSO/MAL/IAPRI (RALS) (2019).
Notes: The value displayed for t-tests are the differences in the means across the groups; ***, **, and * indicate significance at the 1, 5, and 10 percent critical level, and N= 7121, (6,278 = no)

Figure 8. Bivariate Relationships between Cropland Expansion and Area under CSA (A), Distance to New Plot (B), Log of Farm Size (C), and Log of Value of Output (D)



Source: CSO/MAL/IAPRI (RALS) (2019).

4.4. Effects of CSA Use on Cropland Expansion among Smallholders in Zambia

Table 7 reports the main results. Columns 1-3 are presented for robustness checks because they either do not control for the endogeneity of CSA use (columns 1 and 3) or do not take into account the censored nature of the outcomes (column 2). Column 4 in Table 7 presents results from the instrumental variable Tobit model, which will be discussed unless otherwise stated. Table 6 shows the first stage regression results and confirms that our IVs are strongly correlated with whether a household uses CSA or not. A joint F-statistic of 8 and the strong positive correlation between our IVs (in bold) and CSA use intensity confirms the validity of our instruments.

The estimation for results reported in here clustered standard errors at enumeration area level to control for intra-cluster correlations and controlled for agro-ecological zone fixed effects. Focusing on results in column 4 in Table 7, we find that using CSA has no statistically significant effects on cropland expansion among smalholder farmers in our sample. But distance from the homested to the new plot, farm size, secure plot tenure and being a male-headed household lead to increased cropland expansion, while age and education level of the household head negtaively influence expansion in our sample.

Table 6. Effects of Social Capital (Relation to Chief/Headman and Having a Current MP) on Using CSA

	(1) OLS	(2) T-Stat
Related to chief or headman (yes =1)	0.200***	3.886
Current member of parliament from area (yes =1)	0.268*	1.876
Gross value of crops harvested	0.056***	6.016
Distance from homestead to new plot (Km)	-0.011***	-2.685
Distance to the nearest feeder road (Km)	0.001	0.292
Adult equivalents	0.456**	2.097
Landholding size, net expanded area	-0.006	-1.008
Total land cultivated (2015)	0.020	0.441
Male headed household (yes =1)	0.005	0.936
Level of education, head (years)	-0.002	-1.027
Age, household head (years)	-0.067	-0.618
New plot has formal title (yes =1)	-0.276	-1.353
Maize seed rate per hectare in 2015 (Kg/ha)	-0.037**	-2.495
Fertilizer rate per ha	0.006	0.311
Fertilizer cost per kg	-1.236***	-2.790
Agro-ecological zone FE	Yes	
Constant	1.842***	2.930
Observations	7,021	
R-squared	0.165	

Source: CSO/MAL/IAPRI (RALS) (2019).

Notes: *** p<0.01, ** p<0.05, * p<0.1; joint F-Stat for IVs = 7.59; the dependent variable is hectares of land under CSA.

Table 7. Average Partial Effects of Using Climate-Smart Agriculture on Cropland Expansion

	(1) OLS	(2) 2sls	(3) Tobit	(4) IV-Tobit
Ha under CSA (min till, irrigation and agroforestry)	0.000	0.092	-0.002	-0.003
	(0.014)	(1.627)	(-0.493)	(-0.044)
Gross value of crops harvested	0.003***	-0.002	0.002***	0.002
	(2.855)	(-0.602)	(3.365)	(0.605)
Distance from homestead to new plot (Km)	0.005**	0.006***	0.002**	0.002**
	(2.423)	(2.631)	(2.525)	(2.069)
Distance to the nearest feeder road (Km)	0.000	0.000	-0.000	-0.000
	(0.329)	(0.262)	(-0.259)	(-0.332)
Adult equivalents	-0.001	-0.043	-0.005	-0.005
	(-0.020)	(-1.115)	(-0.200)	(-0.131)
Landholding size, net expanded area	0.005	0.005	0.003**	0.002*
	(1.486)	(1.544)	(2.078)	(1.649)
Male headed household (yes =1)	0.049***	0.047***	0.056***	0.056***
	(4.011)	(3.511)	(5.723)	(4.934)
Level of education, head (years)	-0.003	-0.003*	-0.004**	-0.004**
	(-1.583)	(-1.732)	(-2.357)	(-2.371)
Age, household head (years)	-0.001*	-0.001	-0.001**	-0.001**
	(-1.963)	(-1.512)	(-2.319)	(-2.253)
New plot has formal title (yes =1)	0.372***	0.376***	0.437***	0.424***
	(4.436)	(4.408)	(4.791)	(5.006)

	(1) OLS	(2) 2sls	(3) Tobit	(4) IV-Tobit
Maize seed rate per hectare in 2015 (Kg/ha)	0.126**	0.156**	0.033	0.041
	(2.127)	(2.376)	(0.776)	(0.843)
Fertilizer rate per ha	0.004	0.008*	0.005*	0.004
	(1.082)	(1.863)	(1.682)	(1.245)
Fertilizer cost per kg	-0.016	-0.016	-0.009	-0.009
	(-1.034)	(-1.027)	(-1.219)	(-1.180)
Median maize price (kw/kg)	0.045	0.144	0.104	0.081
	(0.451)	(1.217)	(0.977)	(0.661)
Agro-ecological zone FE	yes	yes	yes	yes
Uncensored observations			820	820
Left censored			6,201	6,201
Right censored			0	0
Observations	7,021	7,021	7,021	7,021

Source: CSO/MAL/IAPRI (RALS) (2019).

Notes: wald test exogenity = 6.20 ($\boldsymbol{\rho}$ =0), p = 0.01 for column 4, implies CSA is endogenous; the dependent variable is hectares of land under CSA; T-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1; 2sls – two-stage least squares; IV – instrumental variable.

As further robustness checks, we also estimated a model where we used farmers' perceptions on soil quality, land availability, access to inputs, output prices, and subsistence needs as reasons for expanding cropland. We also assessed the correlation between changes in forest cover and cultivated land at district level. We report these results in Table 8 and Figure 9. The main result on CSA is preserved and farmer perceptions are strongly correlated with expansion. Perceived improvements in access to inputs and markets, the need to meet subsistence food needs, availability of uncultivated land, and declining soil productivity are strong drivers of cropland expansion among smallholders in our sample (Table 8).

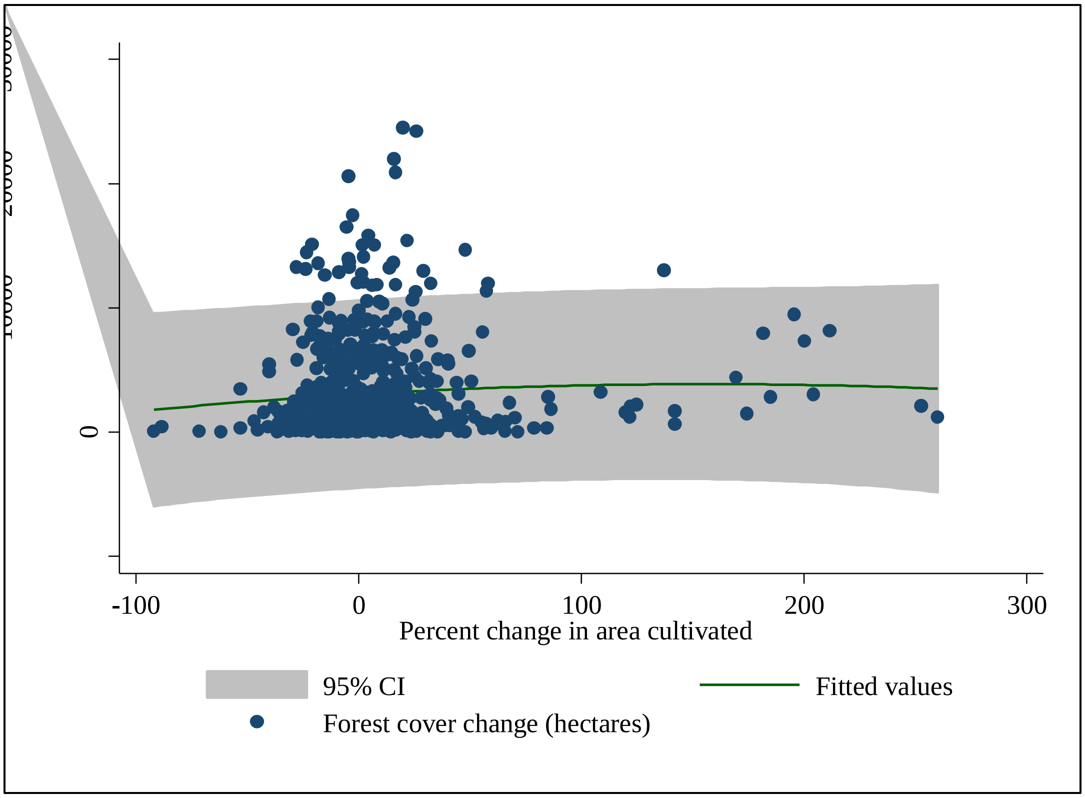
Although we can not read too much into bivariate relationships, we find a weak positive relationship between changes in cultivated area and forest cover at district level (Figure 9). While admitedly, a lot more forest were lost in districts with negative to very small positive changes in cultivated area, forest cover loss appears to increase with an increase in cultivated area at district level.

Table 8. Average Partial Effects of Using Climate-Smart Agriculture on Cropland Expansion, Controlling for Perceptions

	(1) 2sls	(2) IV-Tobit
Ha under CSA (min till, irrigation and agroforestry)	0.038	0.004
	(0.924)	(0.112)
Gross value of crops harvested	-0.000	0.001
	(-0.147)	(0.427)
Distance from homestead to new plot (Km)	0.002	0.001
	(1.608)	(1.196)
Distance to the nearest feeder road (Km)	0.000	-0.000
	(0.194)	(-0.251)
Adult equivalents	-0.011	-0.005
	(-0.349)	(-0.159)
Landholding size, net expanded area	0.001	0.001
	(0.517)	(1.011)
Male headed household (yes =1)	0.011	0.023***
	(0.988)	(2.788)
Level of education, head (years)	-0.000	-0.000
	(-0.063)	(-0.226)
Age, household head (years)	-0.000	-0.000
	(-0.802)	(-1.068)
New plot has formal title (yes =1)	0.055	0.033*
	(0.605)	(1.843)
Improved access to input access (private and FISP) (yes =1)	0.412	0.152**
	(1.497)	(2.167)
Increase output sales to FRA and private traders (yes =1)	0.478***	0.189***
	(4.064)	(3.635)
Meeting substance needs (yes =1)	0.388***	0.378***
	(13.208)	(9.608)
Uncultivated land available (yes =1)	0.539***	0.630***
	(5.444)	(6.292)
Declining soil productivity (yes =1)	0.596***	0.349***
	(3.189)	(3.568)
Agro-ecological zone FE	yes	yes
Observations	7,021	7,021

Notes: T-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1; the dependent variable is hectares of land under CSA.

Figure 9. Bivariate Relationships between District-Level Changes in Forest Cover and Cultivated Area between 2010 and 2018 in Zambia



Source: Authors.

5. DISCUSSION

5.1. Extent and Intensity of Cropland Expansion

Cropland expansion is an increasing phenomenon in Zambia's smallholder agricultural sub-sector. Overall, our results show that 21% of all farm households surveyed in RALS 2019 expanded cropland between the 2016/2017 and 2017/2018 farming seasons, clearing on average 0.18 ha. However, only about 13% of households expanded their cropland into forests, clearing an average of 0.10 ha of forest per household. Thus, while not all cropland expansion necessarily leads to deforestation, smallholder cropland expansion into forests accounts for a large share of the current deforestation rate in Zambia. In fact, our estimated intensity of cropland expansion into forests at national level is about 4.6% of cultivated land and about 60% (or 150,000 ha) of the estimated 250,000 ha of forests lost per year. Thus, smallholder cropland expansion is an important driver of deforestation in Zambia.

The locus of cropland expansion is concentrated in Luapula, Muchinga, Northern, North-Western, and Western provinces. Except for Western Province, cropland expansion among smallholders is highest in areas where smallholder agriculture is shifting to, owing to favorable rainfall conditions, but these are also areas with high soil acidity and high forest biomass (Kalinda et al. 2013; Burke, Jayne, and Black 2017; Pelletier et al. forthcoming). Our estimates on cropland-led deforestation are very similar to those in Ngoma and Angelsen (2018) who estimated that 19% of households surveyed in Nyimba, Mumbwa, and Mpika districts expanded cropland, clearing on average 0.14 ha in 2014.

Generally, our results indicate a higher proportion of small farm (0-2 ha) owners expanding cropland into forest relative to large farms (>2 and < 10 ha). However, in regards to intensity of expansion, large farms expanded more into forests in terms of hectarage compared to small farms. As stated earlier, the large expansion into forests by large farm owners is perhaps due to better access to land relative to small farm owners. Large farm operators tend to have good financial and social capital, which enables them to access more land and perhaps, likewise, to support expansion.

Research across the developing world, including Sub-Saharan Africa (see for examples Gibbs et al. 2010; Byerlee, Stevenson, and Villoria 2014; Villoria, Byerlee, and Stevenson 2014; Ngoma and Angelsen 2018), has identified a number of push factors for cropland expansion into forest, with the most recurring ones being favorable output price, availability of uncultivated land, need to meet food needs, and declining soil fertility. Our analysis shows that about 90% of the sampled households cited the need to meet basic food needs as a reason for expanding cropland. This is most likely tied to declining crop productivity, compelling smallholders to expand into forest land to increase output and compensate for declining yields. Another push factor for cropland expansion is improved market access and favorable crop output prices, cited by about 8% of the sampled households. Zambia's agricultural sector has seen an increase in private sector participation in markets over the past decade, with a rising number of commodity buyers penetrating areas that were once considered too remote for private sector. This has improved farmers' access to markets, which has in turn spurred production, mostly through expanding cropland. These findings are line with the assertion that improved market access spurs rather than averts deforestation (Balmford, Green, and Scharlemann 2005; Rudel et al. 2009).

With increased private sector participation, competition among private sector is high, thereby pushing up prices. Furthermore, the above-market prices for maize usually offered by FRA appear to be a push factor mostly in Muchinga and Central provinces, which are among the major suppliers of maize to FRA. Another push factor appears to be a need to secure land tenure (cited by about 1% of sampled households) through clearing into virgin and fallow lands as a way to claim ownership and prevent encroachment.

5.2. Climate-smart Agriculture and Cropland Expansion

Empirical model results on the factors affecting cropland expansion into forests show no influence of CSA practice on reducing cropland expansion. This result is consistent with similar studies (e.g., Ngoma and Angelsen 2018), who find limited to no effect of CSA on cropland expansion. As stated before, the hypothesis around CSA and deforestation is that since CSA improves yield, smallholder farmers deploying such practices are less likely to expand cropland because they are able to produce more per given unit of land. However, our results do not support this hypothesis, as we find no influence of CSA on reducing cropland expansion into forests. This is despite households who expanded cropland having less land under CSA at 0.3 ha compared to 0.6 ha on average for those that did not expanded cropland (Table 5).

One plausible explanation for this finding is that while improved productivity (that may be realized from practicing CSA) may lead to increased profitability, providing further incentives to smallholders to produce more and possibly expand cropland, the effects of CSA on cropland expansion via the labor story (not fully investigated here) might lead to different outcomes. This might be the case here because even if households that used CSA had a larger gross value of crops than those who did not use CSA in our sample, our overall result suggest that CSA does not significantly affect cropland expansion.

5.3. Other Drivers of Deforestation

In addition to the factors discussed above, other factors, most of them based on respondent perceptions influence cropland expansion into forests. Smallholders' perceptions of declining soil fertility, coupled with availability of uncultivated land, tend to act as push factors in cropland expansion. As farmers perceive soil fertility to have declined, there is high propensity to expand cropland, including into forests to compensate for reduced yields. Further, availability of uncultivated land coupled with low yield tend to encourage cropland expansion into forests, a result consistent with Villoria, Byerlee, and Stevenson (2014). Similarly, smallholders' perception that output and input market access have improved are push factors for cropland expansion. In line with other studies, e.g., Babigumira et al. (2014) and Ngoma and Angelsen (2018), we find a few demographic factors, specifically age and education level of the head of household, to have a high propensity to reduce cropland expansion.

The positive correlation between landholding size and cropland expansion is in line with *a priori* expectations. A large landholding relaxes land constraints that would otherwise be binding on cropland expansion into own forestlands. Although tenure security can have ambiguous effects on cropland expansion decisions, its positive correlation with expansion in our paper suggests that secure tenure gives smallholder farmers the leverage to do as they please on their land. These findings on the effects of tenure security on expansion from a national survey in Zambia are different from results based on three districts reported in Ngoma and Angelsen (2018).

While the finding that households are more likely to expand cropland into forest on plots located far away from the homestead would appear counter intuitive, it may have implications on alternative land uses. Households will unlikely access forest products on plots located farther away from their homestead and therefore would be more likely to convert such parcels to agricultural land or other alternative uses. Although not statistically significant, the cost of fertilizer (input) and maize (output) price have the expected negative and positive signs on cropland expansion, respectively. The non-significant effect of maize seed rate on cropland expansion is not surprising because we did not limit this variable to only improved seed varieties, which would arguably better lead to intensification as shown in Pelletier et al. (forthcoming).

Three caveats are in order when reading the results in this paper. First, while we used an IV approach to control for the potential endogeneity of CSA adoption in cropland expansion decisions, we might not have been fully successful given the somewhat weak IVs. As such, results in this paper should be interpreted as correlations. Second, while it is plausible to use data from 2015 to capture household characteristics in the past, the extent to which these factors aptly capture future expectations that can better explain current cropland expansion decisions might be questionable, given the large gap between survey years. And, lastly, since RALS only captures data from smallholder farmers cultivating 0 – 20 ha, the estimates of cropland expansion in this paper do not account for expansion among large-scale farmers and cropland expansion from large-scale agricultural land acquisitions.

6. CONCLUSIONS

This paper assessed linkages among climate-smart agriculture (CSA), cropland expansion, and deforestation. We used detailed household level data to unpack *how*, *why,* and *where* cropland expansion is occurring, and an instrumental variable approach to assess drivers of cropland expansion, and whether CSA reduces cropland expansion in Zambia. We supplemented this analysis with the spatially-explicit Hansen et al. (2013) data to characterize district-level forest cover changes between 2001 and 2018**,** and correlated these data with district-level changes in cropland expansion to identify processes and patterns. We focused on CSA (minimum tillage [ripping, planting basins, and zero tillage] as the main tillage, agroforestry, or irrigation) because it is part of national policy to improve agricultural productivity and to build climate resilience in several Sub-Saharan Africa countries.

Overall, one-fifth of all farm households surveyed in 2019 expanded cropland between the 2016/2017 and 2017/2018 farming seasons, clearing on average 0.18 ha. However, only about 13% of households expanded their cropland into forests, clearing an average of 0.10 ha of forest per household. Thus, while not all cropland expansion necessarily leads to deforestation, smallholder cropland expansion into forests accounts for a large share of the current deforestation rate in Zambia. Smallholder cropland expansion into forests represents about 60% (or 150,000 ha) of the 250,000 ha of forests lost per year in Zambia.

The locus of cropland expansion is concentrated in Luapula, Muchinga, Northern, North-Western, and Western provinces, which are among the most agriculturally favorable areas given the good rainfall conditions (except for Western Province). These provinces, however, also have high soil acidity (Burke, Jayne, and Black 2017; Pelletier et al. forthcoming), further bringing to the fore a need to address soil fertility in order to ensure the sustainability of smallholder farming in Zambia. We did not find that adopting CSA had any significant effects on cropland expansion in our national sample, perhaps, indicating that CSA alone might not avert expansion-led deforestation. However, age and education are associated with reduced expansion, while secure tenure, landholding size, being male-headed, and distance from the plot to the homestead are positively related to cropland expansion. We, therefore, conclude in line with Rudel, et al. (2009), Byerlee, Stevenson, and Villoria (2014), and Ngoma and Angelsen (2018) and posit that CSA-led (technological) intensification alone might not reduce deforestation unless it is complemented with improved natural resources management to control conversion of forestland to other uses.

We draw three implications for policy. First, relying only on technological-driven intensification to spare forests may be risky. We posit that productivity-enhancing agricultural technologies like CSA would be more likely to lead to win-win outcomes for conservation and food production if accompanied by improved resource governance initiatives, such as payments for environmental services and better land use planning. For example, expansion into degraded forests would be better than expanding into forests and biodiversity–rich habitats. Second, seeing that smallholder-led expansion accounts for about 60% of the reported deforestation rate in Zambia, and most of this expansion occurs in the current agricultural belt, signals the urgency with which policies are required to curb expansion. If left unchecked, there is a possibility that the current agricultural belt, which receives abundant rainfall in Zambia, might soon start to experience reduced rainfall due to deforestation-induced climate variability. And, lastly, given the strategic role CSA plays in building climate resilience in smallholder agriculture, concerted efforts are needed to identify sustainable and efficient ways to scale-up and scale-out CSA adoption in Zambia and the region.

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