Estimating the Resiliency of Zambian Smallholder Farmers: Evidence from a Three-Wave Panel

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Selected Presentation prepared for presentation at the Agricultural & Applied Economics Association's 2014 AAEA Annual Meeting, Minneapolis, MN, July 27-29, 2014.

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Abstract:

Aggregate African agricultural production is expected to fall due to changes in temperature and rainfall under current economic models, but 65 percent of the African labor force is employed in agriculture activity. Therefore, climatic changes have the potential to significantly impact all African citizens, especially farmers. Agricultural producers must adapt to these climatic changes and the risk filled environment that rural households operate, especially small-holder farmers, which makes them particularly vulnerable to poverty and food insecurity without successful adaptation. The limited success of improving agricultural technology in Zambia makes it important to understand the determinants of changes in farm yield for major staple crops, including maize, groundnuts, sweet potatoes, and cassava. This paper generates an empirical model of the determinants of changes in farm yields using a three wave panel dataset for three agricultural seasons. Results indicate that over households have made minimal changes in crop choice and little impact has been observed due to changes in climate for Zambian farmers. Increases in yearly average rainfall and temperature positively affect maize yields. As temperatures continue to rise in the future, this relationship may not hold as the climate becomes unsuitable for large scale maize production. Changes in rainfall negatively affect household groundnut and sweet potato production which might result from switching between crops as weather changes. Finally, increased temperatures negatively affect cassava production.

Introduction

Since 2000, the near-surface mean air temperature on the African continent has risen by 0.16 degrees Celsius (Collins, 2011). Additionally, recent warming is occurring at a significantly faster pace than previously observed in Africa, and climate models predict continuation of rising temperatures for the remainder of this century (IPCC, 2007). Increasing temperatures can significantly stunt plant growth of many staple crops such as maize, wheat, and rice. Recent changes in rainfall patterns in Africa vary across the continent. Certain regions have experienced increased rainfall over the past decade, while others have become drier (Gianninni et al., 2008). However, most climate projections and models continue to show changes in rainfall in Africa, with increased likelihood of "extreme events", such as droughts or floods (IPCC, 2007). Aggregate African agricultural production is expected to fall due to changes in temperature and rainfall under current economic models (Lobell et al., 2008). Since 65 percent of the African labor force is employed in agriculture activity, climatic changes have the potential to significantly impact all African citizens, especially farmers.

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[1] Any views expressed are the authors' and do not necessarily reflect those of the U.S. Department of Agriculture.

In Zambia, several articles have explored the potential impact of climate change on household welfare (Thurlow et al., 2009; Nelson et al., 2013). Specifically, climate and crop computable general equilibrium (CGE) projections suggest that Zambia may face losses of up to 4 billion dollars and an additional 300,000 people below the poverty line by 2016 due to climatic change. Agricultural producers must adapt to these climatic changes and the risk filled environment that rural households operate, especially small-holder farmers, which makes them particularly vulnerable to poverty and food insecurity without successful adaptation. Anticipated impacts of reductions in crop yield and increase in yield variance can be mitigated through a combination of agricultural system strategies including adjustments in fertilizer use, adoption of drought-resistant seed, irrigation, or even adjusting the crop rotation and time of planting. However, smallholder farmers have particular difficulty adapting to changing conditions due to costs, resource availability, and knowledge (Lee 2005). In its 2007 report, the Intergovernmental Panel on Climate Change acknowledges that this is a potentially dangerous problem for smallholders, noting "agricultural production and food security (including access to food) in many African countries and regions are likely to be severely compromised by climate change and climate variability" (p. 435).

Currently, over forty percent of the Zambian population lives in extreme poverty, surviving on less than $1.25 a day, with the majority of these impoverished households rural and agricultural (World Bank, 2013). As expected, anyone living on an extremely constrained budget must make tradeoffs, including basic necessities such as food. Any climatic impact that reduces long term yields or increases variability of yields stands to negatively impact both poverty and vulnerability to poverty in Sub-Saharan Africa (SSA). Additionally, recent research suggests that African farmers have lower yields than similar farmers in other low-income countries and show lower propensities to rapidly adopt technological innovations (Mugisha and Diiro, 2010; Barrios et al., 2008). Attempts to improve technological adoption through input subsidies in Zambia have had mixed results (Ricker-Gilbert et al. 2011, Xu et al. 2009, Mason and Jayne, 2013). The results have shown that input subsidies can help encourage fertilizer use in areas lacking private fertilizer providers yet reduces overall fertilizer privately distributed, especially in areas with active private markets.

The limited success of improving agricultural technology in Zambia makes it important to understand the determinants of changes in farm yield for major staple crops, including maize, groundnuts, sweet potatoes, and cassava. This paper generates an empirical model of the determinants of changes in farm yields using a three wave panel dataset for three agricultural seasons (1999/2000 harvest, 2002/2003 harvest, and the 2006/2007 harvest). Climatic impacts on changes in crop yield are estimated and the results are used in conjunction with climate model projections to assess the future resiliency of Zambian smallholder farmers to predicted temperature and rainfall changes. The analysis of this paper is limited to a relatively narrow time frame due to data limitations. Climate often focuses on long-term trends, yet, African farmers already face a changing climate and make adaptation decisions knowing that higher probabilities of extreme events exist. Therefore, this analysis contributes to the literature by assessing current adaptation strategies employed by Zambian farmers as climate changes.

The remainder of the paper is organized as follows: Section 2 outlines literature on resiliency and climate change within SSA and Zambia. Section 3 presents the conceptual framework and specifies the resulting empirical model. Section 4 presents survey summary statistics, while Section 5 presents the climatic impacts in crop yield on various crops. Section 6 contrasts the empirical results from other models and concludes.

Literature Review

A vast literature exists that explores the concepts of climate resiliency and agriculture. In general, this research covers a broad spectrum such as global agricultural production and climate change to very narrow studies that focus on the effects on a specific village or sample of vulnerable households. Since climate change is expected to have different impacts on different parts of the globe, both types of research are useful and are mutually supporting.

A recent round of inter-disciplinary articles explores the linkages between agriculture and climate change using global economic models (Nelson et al., 2013). Estimates of future global production under several different climate scenarios were estimated using a set of 10 global economic models maintained by a variety of different research groups. Results from the models are directly comparable because the same set of inputs and assumptions are used in every model (Valin et al., 2014). All models observe higher prices, lower yields, and lower consumption for five major agricultural composite commodities (maize, coarse grains, rice, sugar, and oil seeds), although the magnitude of the loss varied by model (Nelson et al., 2014). Sub-Saharan Africa is aggregated into a single region under these types of models and faces extreme difficulties in production due to limited agricultural technologies and worsening climates (Nelson et al., 2010). Alternatively, Lobell et al. (2008) disaggregate Africa into several different regions and find negative effects in Southern Africa (including Zambia) for maize and wheat. However, they do observe some positive effects on crop yields for other crops, such as sorghum and groundnuts. In a recent study by Fuglie and Rada (2013), the authors use a different metric, called Total Factor Productivity and note that it is still currently rising within Sub-Saharan Africa.

Alternatively, the Ricardian model (Mendelsohn et al., 1994) is a Hedonic choice model that looks at changes in land values due to climate change. The Ricardian analysis uses climatic and non-climatic exogenous variables to determine changes in land value and farm revenue. The model explicitly allows land to switch between farmland and other non-agrarian activities and is one of the few models that explicitly identifies the existence of other land use opportunities, meaning farmers do not have to grow crops on the land in the future. The farmer might switch to using the land for pasture or agri-tourism activities instead of crops due to changes in temperature and precipitation. Several studies have explored the impacts of climate change on various countries across the world (e.g. Seo and Mendelsohn 2008; Seo 2010a, 2010b; Kurkulasuriya et al, 2006). In one cross-sectional study of 11 African countries, Zambian farmers are observed to primarily plant maize or a combination of maize and groundnut, but are expected to transition away from these crops to other crops due to the changing climate (Kurkulasuriya and Mendelsohn, 2008). Throughout Africa, the Ricardian model finds significantly worse yields given climate change, though farmer adaptation helps mitigates this negative effect (Mendelsohn, 2008).

The Ricardian model, however, implicitly assumes a well-functioning market that accurately prices the net present value of farmland. In Africa, and especially SSA, this requirement is often not met. In many SSA countries, a land tenure system that provides accurate value to land is extremely uncommon (Gavian and Fafchamps, 1996). Land is often viewed as communal or government owned instead of the farmer's exclusive property. The absence of well-functioning land markets means that the model must be altered by using current year yield per hectare profits instead of land values as the dependent variable (Mendelsohn, 2008). Therefore, alternative strategies to measure climate impact on small-holder farmers are necessary.

Instead of a Ricardian analysis, detailed household surveys (both panel and cross-sectional) can help evaluate the impact of adaptation on farmer welfare and their coping strategies to climate change. In the Nile Basin of Ethiopia, farmer adaptation led to increased food production, and therefore greater food security (Di Falco et al., 2011). Demeke et al, (2011) also observe higher food security in Ethiopia for areas with less rainfall variability using an alternative dataset and a different food security metric. Ethiopian households also make adaptation decisions based on rainfall totals and variability; more rainfall leads to higher levels of fertilizer use, while more variability reduces it (Alem et al., 2010). In various East African countries, small-holder farmers adapt to climate change, but only make marginal alterations to farming practices without adopting many of the proven improved agricultural technologies (Kristjanson et al., 2012). Farmers in SSA also fail to accurately cope with climate variability by predicting more frequent negative outcomes and fewer positive outcomes (Cooper et al., 2008). While much of the analysis centers on areas outside of Zambia, rural farmers in southern Zambia actually attribute too much blame to climate variability instead of acknowledging the socio-political and agricultural technology deficiencies associated with small-holder farming (Mudbaya et al., 2012).

Under most climate change scenarios, the increase in variability and chances of extreme events potentially further worsens farmer welfare. Adoption of improved agricultural inputs, which can help mitigate these effects is crucial (e.g. Asfaw et al., 2012; Kassie et al., 2011; Minten and Barrett, 2008). In southern African countries such as Zambia and Malawi, input subsidy programs have been one method to increase adoption of agricultural technology in attempts to improve yields. Government expenditures on these programs are non-trivial. In Zambia, input subsidies account for an average of almost 40 percent of the agricultural sector budget, although improvements in agricultural productivity are limited (Mason and Jayne, 2013). Input subsidy programs are designed to increase total fertilizer use for small-holder farmers, but the overall effectiveness of the input subsidy program hinges on its ability to target households that would not have otherwise purchased fertilizer (Ricker-Gilbert et al., 2011). If households would have purchased fertilizer without the subsidy, then the expected increase in fertilizer is not as large. Evidence from research casts doubt that input subsidy policies are working efficiently (Xu et al. 2009; Ricker-Gilbert et al., 2011; Mason and Jayne, 2013). Input subsidies reduce private fertilizer expenditures that would have been purchased had there not been a subsidy. Additionally, not all subsidized fertilizer reaches farmers at subsidized prices. A significant portion of the fertilizer “leaks” onto the open market and is sold to farmers at or near market prices, which further reduces the effectiveness of the program (Jayne et al., 2013). In turn this means that for every one kilogram of government subsidized fertilizer, total fertilizer use only increases by an additional 0.54 kilograms, nearly halving the expected return (Mason and Jayne, 2013). Maize output does not increase drastically due to the subsidized fertilizer. An additional kilogram of subsidized fertilizer only increases maize output by an additional 1.88 kilograms (Mason et al., 2013).

Conceptual Framework

Our conceptual framework starts from a traditional agricultural household utility and production framework. Agricultural households, especially small-holder farmers, both consume and sell their crop output. Households attempt to maximize utility in a given time period, *t*. Utility is a function of owngood consumption (C_o), market-good consumption (C_m), leisure (ℓ_t), and a vector of household characteristics, a_i (Barnum and Squire, 1979; Benjamin, 1992).

$$U_{h,t} = U(C_{o,t}, C_{m,t}, \ell_t; a_{i,t}) \tag{1.1}$$

Agricultural household production for each crop is a function of capital (K), labor (L), land (Z), and climatic conditions (W).

$$q_{j,h,t} = q(K_t, L_t, Z_t, W_t) \tag{1.2}$$

Total agricultural production for each household is the sum of output for each crop, *j*, and is constrained by the total amount of endowments available to each household at each time period.

$$\begin{aligned} &Q_{h,t} = \sum_{j=1}^{J} q_{i,h,t}(\cdot), \\ &\text{subject to: } \bar{K}_h = \sum_{j=1}^{J} K_j;\ \ \bar{L}_h = \sum_{j=1}^{J} L_j;\ \ \bar{Z}_h = \sum_{j=1}^{J} Z_j; \end{aligned} \tag{1.3}$$

Climate outcomes are not observed until after land allocation and planting decisions have been made, but play an important role in crop production. Therefore, the households allocate land, labor, and capital to each crop based on a set of expectations regarding crop prices at harvest and climate conditions during the growing season. Equation (1.4) represents the household capital allocation decision for crop *j* (labor and land are modeled synonymously).

$$K_j = K(E[p_j], E[q_j \mid W_t]) \tag{1.4}$$

In a multi-period model, households can reallocate these resources as their expectations in weather change to continue to optimize output and utility. Therefore as climate conditions change, the set of crops and the allocation of resources likely changes.

Econometric Specification

The conceptual framework can be adapted and modeled econometrically using production data for various crops. Household yield in time *t* is a function of labor and capital inputs, land quality, technology used, and climatic variables along with an unobserved random error term. Crop yield of four crops important to Zambian small-holder farmers (maize, sweet potatoes, groundnuts, and cassava) are analyzed using this type of model.

$$y_{it} = X'_{it}\beta + u_{it} \tag{1.5}$$

The empirical model focuses on the changes in input factors and, most importantly, changes in climatic conditions between panel years. Using a fixed-effects panel model, it is possible to identify how changes in independent variables affect different crop yields. As a fixed effects model, however, many time-invariant household characteristics are constant between panel years which therefore eliminates their inclusion within the model. However, in instances where there is sufficient variation, some household characteristics are still included. Variables and their expected effect on crop yield are discussed in light of previous research. Most independent variables are expected to similarly influence yields of all four crops. However, when differences exist between crops, expected effects on individual crops are discussed.

Differences in yield are expected when the gender of the head of household switches between male and female (Quisumbing, 1996). When households switch from a female-headed household to male-headed, positive effects on yield are expected while households that become female-headed are likely to have lower yields often due to less access to improved technologies and agricultural extension (Doss, 2001). Household size is measured in terms of male adult equivalent members, which helps standardize labor force availability between households and years. Households with more adult equivalent members are expected to have higher yields for all crops as they have more labor to plant, weed, and take care of crops throughout the agricultural season. A measure of household wealth is included in yield equations. Wealthier households are often quicker to adopt improved technology and have easier access to credit (Langyintuo and Mungoma, 2008). The two measures of wealth are an asset index that changes between years and a measure of total income for each household that excludes income generated from the dependent crop. Household can use cash remittance to purchase additional inputs, including more land and labor, which would positively increase crop yield.

Land availability is a key component of crop yields and several different measures of the concept are included within the specification. Households with more land are expected to have higher yields based on the ability to cultivate more land. However, yield per hectare of land is likely to lower with larger farm sizes due to the surprising inverse farm size-productivity relationship observed in Africa (Barrett et al., 2010; Kimhi, 2006). Larger land holdings do not force farmers to actually use it for cultivation. Therefore, a measure of total number of hectares cultivated is also included within the specification for each crop. Other purposes for land include grazing for livestock and remaining fallow to restore nutrients. An indicator variable is included in the specifications for households owning livestock, which might affect the amount of land cultivated, but also provide an additional measure of wealth. Extensification is the process of generating higher crop yields through increased use of previously unused land. An indicator for households having available fallow land is included to determine whether changes in crop yields are partly due to extensification instead of improvements in yield per hectare.

Intensification increases crop yield through improved inputs and agricultural technologies. Changes in fertilizer use and its intensity would indicate improvements in crop yield through intensification and are therefore included (Morris et al., 2007). As households apply more fertilizer per hectare, diminishing returns on crop yield are expected, which is captured through the inclusion of fertilizer per hectare squared. In Zambia, fertilizer is primarily used for maize, meaning fertilizer application intensity would not affect yield for sweet potatoes, cassava, and groundnuts. Therefore, fertilizer per hectare is not included within those crop yield specifications. Fertilizer use, however, is still included as it can attempt to proxy for other types of improved inputs or practices. Households that adopt fertilizer use have been shown to adopt other improved technologies as well (Teklewold et al., 2013).

Climate variables are included within the specification as well. Mean daily rainfall for the past agricultural growing season and mean daily temperature are included in each crop specification. Given that temperatures have not increased drastically during the panel time frame, increases in temperature are likely to have positive benefits toward most crop yields (Lobell et al., 2011). Lower rainfall would significantly hurt crop yields. The one exception to this type of analysis is for cassava. Cassava does not have a distinct growing season and is often grown as insurance against poor harvests (Schenkler and Lobell, 2010; Barratt et al., 2006). To determine whether there is any potential shift of small-holder farmers to cultivating more cassava, an additional regression for changes in hectares of cassava planted is estimated as well. The diversity of crops households choose to grow likely affects changes in yield. An indicator for households planting cash crops (coffee and tobacco) is included in all crop yield specifications. Other indicators for planting of high value crops (groundnuts and other legumes) and “other” staple crops (sweet potatoes, rice, millet, etc.) are included in specifications where crop yield for that type of crop is not the dependent variable. No indicator for households planting maize is necessary because all households that grew other crops always planted maize. Finally, two indicator variables are included to determine how yields change depending on unobserved effects between agricultural seasons, with the base year being the 1999/2000 agricultural season.

Data

The Zambian Central Statistical Office, in conjunction with the Ministry of Agriculture and Cooperatives and the Food Security Research Project, established a three wave, nationally representative panel of agricultural households within Zambia. The survey focuses on agricultural production and household characteristics, with limited information about expenditures and consumption. The initial round of surveys covers the 1999/2000 agricultural season that combines information from an initial survey of respondents in August and September of 2000 with a supplemental survey conducted in May 2001. Another supplemental survey interviewed the same panel households in May 2004 to gain information about the 2002/2003 agricultural season. Finally, a third supplemental survey interviewed households in June and July 2008 to collect the necessary information about the 2006/2007 agricultural season.

A three-stage sample method chose an initial sample of 7,699 households from 70 districts within Zambia (Megill, 2005). Sample attrition occurred throughout the three waves, beginning with the first supplemental survey; only 6,922 households of the initial 7,699 households were re-interviewed. The supplemental survey in 2004 lost an additional 1,564 households (22.6 percent), resulting in 5,358 successful interviews. Only 4,286 households of those that were successfully interviewed in 2004 were re-interviewed in 2008. While there is relatively large attrition loss in the survey, previous research has not found attrition bias within the sample (Mason and Jayne, 2013). Therefore, we use households that grew maize, sweet potatoes, cassava, and groundnuts during at least one agricultural season. The number of households within the sample varied by crop and year and the summary statistics are presented in table 1.

As expected, most households in Zambia grow maize and fewer households grow other crops of interest. Household size (in terms of adult equivalent members) is relatively constant across the different crops, with all households having over 5 adult equivalent members, except for the sample of households growing cassava. Households growing sweet potatoes have the largest average at 5.56 household members. Average income for groundnuts and sweet potatoes are much higher relative to households that grow maize and cassava. Cassava growers are the poorest households in both terms of income, value of assets, and ownership of livestock. Households that grow sweet potatoes receive the lowest levels of remittance.

Land holdings are greater for both groundnuts ant sweet potatoes (3.2 hectares) than land holdings for farmers that grow maize (2.7 hectares) and cassava (2.3 hectares). Households seem to have significant fallow land across all crops with farmers growing maize showing the lowest levels (36.4 percent) and households growing cassava the highest levels (49.2 percent). Households that grow groundnuts and sweet potatoes show slightly higher levels of fertilizer use compared to the maize sample, but significantly higher levels relative to the cassava sample. Average fertilizer per hectare for maize is 103 kg per hectare, which is lower than the recommended use suggested by international agricultural organizations.

The panels are not balanced between crops, but roughly a third of each set of observations come from each sample year, with some crops having slightly higher samples from the 2002/2003 harvest year. Summary statistics for rain and temperature are not very informative as they are essentially a three year annual average within Zambia for the panel years. The share of households growing cash crops is highest (26 percent) for households that grow groundnuts and lowest (4 percent) for households that grow cassava. High value crops are planted by 48 percent of households that grew maize, 59 percent of households that grew sweet potatoes and 46 percent of households that grew cassava. Finally, over half of the households that planted maize or groundnuts also planted other staple crops.

Results

Estimation results are presented in table 2 for all four different crops. Results are discussed by crop. As a fixed effects model, the parameter estimates represents how changes between periods affect changes in crop yields. Hausman tests for maize, groundnuts, and cassava all reject the use of a random effects model. For sweet potatoes, the hausman test fails to reject the concept of random effects, but since the primary interest concerns changes in climate between years, the fixed effects specification is preferred.

For maize, household size is significant, with increases to household size contributing to significantly higher maize yields.[2] No difference in yield is observed when household change between having a male or female as head of household. This result is consistent with previous research in Zambia, where no significant relationship exists between head of household gender and input choices (Mason and Jayne, 2013). Changes to household wealth also affect maize yield, although the estimated impact is quite small

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[2] Significance, unless otherwise noted, refers to parameter estimates different from zero at the *p*-value = 0.05 in a two-tailed *z*-test.

based on the parameter estimate. Positive changes in income lead to increased yields, but it takes roughly 14 dollars of additional income between years to increase maize yield by a single kilogram. The similar parameter estimates for household assets also means that it will take an increase of roughly 14 dollars in assets to increase yield by one kilogram.

Changes in livestock and landholdings do not significantly affect changes in maize yield, although increasing the number of hectares cultivated increases maize yield by 1000 kg. No change in maize yield is observed as households switch between fallow land and land used for other productive purposes. Households that switch to using fertilizer have significantly higher maize yields. Similarly, increases in fertilizer per hectare also significantly increase maize yield, though the significance of the squared term indicates that there are very slight diminishing returns to additional application. No significant effect is observed from indicator variables of harvest years relative to the initial harvest in 1999/2000.

Most importantly, changes in climate data significantly affect maize production. A change in yearly average rainfall significantly($p = 0.10$) increases maize production by almost 300 kg. While this amount might seem quite larger for a relatively small change in rainfall, it is important to point out that this variable is the yearly average. Increasing the average rainfall by a single millimeter requires more sustained rainfall throughout the year, which is why the effect is larger. Similarly, the large positive effects on higher temperatures observed must also be caveated by the fact that this is a yearly average. Finally, households that switch between growing cash crops, high value crops, and other staple crops all show significantly lower maize yields, likely due to the limited resources available within each household.

For groundnuts, the results are quite similar. Positive changes in household size lead to higher groundnut yield, though the increase is yield is much smaller than for maize. Positive changes in wealth measures also significantly increase groundnut yield, but are still quite small. Households that increase the number of hectares cultivated continue to see positive increases in groundnut yield. Households that indicate changes in fallow land show negative changes in groundnut yield. This is not surprising as groundnuts often are used to help return nutrients to the soil. Positive impacts in groundnut yield were observed between the 1999/2000 harvest and the 2002/2003 harvest, while no significant difference exists for the 1999/2000 and 2006/2007 harvest.

Changes in climate are far less important for groundnuts relative to maize. Only rainfall is marginally (*p*= 0.10) significant and indicate increases in rainfall lead to negative effects on groundnuts. Changes in other variables do not significantly affect groundnut yield.

Sweet potatoes have fewer significant results compared to maize or groundnuts. For sweet potatoes, only changes in household assets significantly affects yield. Increasing the number of hectares cultivated continues to show positive benefits for sweet potato yield as well. Large decreases in sweet potato yield are observed in the 2002/2003 and 2006/2007 harvest relative to the 1999/2000 harvest. These values are likely due to a bumper harvest in the base year. There are several observations with sweet potato yields that are an order of magnitude (or more) higher in the base year when compared to the other harvests. Therefore, these changes are likely inflated. Changes in rainfall show significant differences in sweet potato output, which again is likely correlated with the data issues observed between the original 1999/2000 harvest data.

Finally, for cassava, increases in household size lead to positive benefits in yield (*p* = 0.10), although changes in other household characteristics, including income and wealth do not significantly affect cassava yield. Changes in land holdings and hectares cultivated both positively increase cassava yields. Additionally, an increase in cassava yield is observed between the 1999/2000 harvest year. Finally, while changes in weather were not expected to affect cassava yield, increases in the average temperature lead to a significantly lower cassava yield. This potentially could be due to households switching between cassava and other plants as other the temperature increases and become more conducive to more profitable crops.

Conclusions

Climate models continue to project changes in the African weather. Increases in air temperature, changes in rainfall, and increases occurrences of extreme events are all predicted. The results presented within this paper provides some of the first household level analysis that looks at how small-holder farmers react to changes in climate using a three wave panel from Zambian farmers. This is especially important since 65 percent of the African labor force is employed in agricultural activity.

Results indicate that overall households have made minimal changes in crop choice and little impact has been observed due to changes in climate for Zambian farmers. Increases in yearly average rainfall and temperature positively affect maize yields, which is expected given the limited increases observed within the data. As temperatures continue to rise in the future, this relationship may not hold as the climate becomes unsuitable for large scale maize production. Changes in rainfall negatively affect household groundnut and sweet potato production which might result from switching between crops as weather changes. Finally, increased temperatures negatively affect cassava production. More analysis is needed to better understand how households cope with a changing climate, but the results continue to suggest that households internalize the changes and continue to adapt.

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Table 1: Summary Statistics for all Crops

	Maize		**Groundnuts**		**Sweet Potatoes**		**Cassava**	
	N = 10,418		N = 5,116		N = 2,523		N = 4,989	
Variable Name	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Harvested Yield of Crop (kilograms)	2109.212	4649.892	172.921	242.007	1367.894	3072.810	776.034	1032.084
Household Size (Adult Equivalent)	5.323	2.771	5.453	2.894	5.558	2.964	4.811	2.288
Female Headed Household = 1	0.206	0.404	0.217	0.412	0.187	0.390	0.222	0.416
Household Income (less income from crop) (U.S. Dollars)	585.083	1934.644	829.373	1893.241	771.281	1535.171	451.956	2177.269
Value of Household Assets	291.423	1762.334	272.895	1166.332	308.110	1511.838	83.781	497.834
Household Remittance (U.S. Dollars)	20.361	94.670	22.743	99.401	18.539	81.633	18.545	80.746
Household owns Livestock = 1	0.825	0.380	0.888	0.315	0.861	0.346	0.773	0.419
Household Land Holdings	2.724	4.071	3.252	5.025	3.216	5.703	2.311	2.159
Total Hectares Cultivated	2.086	2.297	2.517	2.540	2.385	2.398	1.738	1.614
Household had Fallow Land = 1	0.364	0.481	0.395	0.489	0.456	0.498	0.492	0.500
Household Uses Fertilizer = 1	0.370	0.483	0.392	0.488	0.392	0.488	0.183	0.387
Fertilizer per Hectare	103.317	204.721	---	---	---	---	---	---
Production data from the 2002/2003 harvest = 1	0.340	0.474	0.386	0.487	0.326	0.469	0.372	0.483
Production data from the 2006/2007 harvest = 1	0.340	0.474	0.375	0.484	0.266	0.442	0.283	0.450
Yearly Average Rainfall (mm)	2.839	0.316	2.815	0.283	2.911	0.346	2.933	0.310
Yearly Average Temperature (C^o)	21.955	0.719	21.937	0.718	21.687	0.625	21.541	0.464
Household Planted Cash Crops = 1	0.202	0.401	0.260	0.438	0.130	0.337	0.041	0.198
Household Planted High Value Crops = 1	0.481	0.500	---	---	0.592	0.492	0.462	0.499
Household Planted Other Staple Crops = 1	0.509	0.500	0.563	0.496	---	---	---	---

Table 2: Regression Results (by crop)

	Maize		**Groundnuts**		**Sweet Potatoes**		**Cassava**	
Variable Name	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Household Size (Adult Equivalent)	69.312 **	19.380	7.528 **	2.595	14.901	56.933	23.310 †	12.190
Female Headed Household = 1	-122.030	178.204	-28.619	24.465	240.460	601.056	-43.957	97.925
Household Income (less income from crop) (U.S. Dollars)	0.068 **	0.021	0.020 **	0.003	-0.078	0.114	0.001	0.009
Value of Household Assets	0.078 **	0.020	0.012 **	0.004	0.261 **	0.098	-0.038	0.053
Household Remittance (U.S. Dollars)	0.199	0.395	0.001	0.048	0.274	1.193	0.284	0.261
Household owns Livestock = 1	39.649	104.074	4.205	16.223	296.659	388.279	12.986	49.102
Household Land Holdings	5.060	11.765	-0.547	1.023	4.167	59.263	45.185 *	19.114
Total Hectares Cultivated	1001.307 **	24.161	20.493 **	2.616	212.737 *	90.326	84.846 **	24.327
Household had Fallow Land = 1	16.744	80.031	-22.180 *	10.482	211.810	270.043	-74.529	45.740
Household Uses Fertilizer = 1	598.257 **	129.018	17.140	12.738	463.124	307.898	28.011	63.055
Fertilizer per Hectare	2.280 **	0.415	---	---	---	---	---	---
Fertilizer per Hectare Squared	-0.001 **	0.0002	---	---	---	---	---	---
Production data from the 2002/2003 harvest = 1	-156.776	102.374	41.194 **	14.730	-2710.167 **	345.895	14.188	46.284
Production data from the 2006/2007 harvest = 1	79.624	92.780	-1.997	13.183	-2321.182 **	331.149	163.275 **	45.850
Yearly Average Rainfall (mm)	295.244 †	173.102	-44.868 †	25.476	-1319.345 *	541.213	70.577	79.527
Yearly Average Temperature (C^{o})	365.311 *	171.874	-28.556	20.561	661.459	617.608	-551.414 **	82.579
Household Planted Cash Crops = 1	-921.017 **	119.224	-1.600	14.514	-397.625	448.766	-201.744	132.414
Household Planted High Value Crops = 1	-327.078 **	87.497	---	---	327.222	276.026	-8.986	48.563
Household Planted Other Staple Crops = 1	-514.813 **	94.322	-11.076	13.938	---	---	---	---
Constant	-9064.817	3754.233	811.073	450.927	-8985.919	13208.950	12072.56	1745.512
Number of Observations	10,418		5,116		2,523		4,989	
R^2: within	0.2956		0.0905		0.2020		0.0511	
R^2: between	0.6047		0.1109		0.0481		0.0670	
R^2: overall	0.5034		0.1160		0.0792		0.0581	

**: Significant at p = 0.01 level   *: Significant at the p = 0.05 level   †: Significant at the p = 0.10 level