Climate Trends and Farmers' Perceptions of Climate Change in Zambia

by

Brian P. Mulenga and Ayala Wineman

Working Paper No. 86
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The views expressed or remaining errors and omissions are solely the responsibility of the authors.

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EXECUTIVE SUMMARY

In Zambia like in many other developing countries, the agricultural sector is highly dependent on rain-fed production and therefore vulnerable to weather shocks. Maize is the primary staple crop in Zambia, and is widely grown by smallholder farmers throughout the country, with a dual cassava-maize regime found only in the northern region. Among the smallholder farmers almost all production is rain-fed with very few farmers using mechanized irrigation. Climate change therefore has the potential to significantly reduce agricultural production and exacerbate poverty and food insecurity.

Drought has been a major threat to food security, with large declines in maize yield consistently occurring in seasons with below normal rainfall. Studies have been conducted in Zambia to quantify the impact of climate change on agricultural yields, and how farmers are responding to such changes. While these provide quantitative evidence on the likely effects of climate change, they incorporate very limited qualitative analysis. However, qualitative analysis is important as it helps in recognizing how changes are perceived at the local level, and this is crucial to anticipating the impacts of climate variability and/or change, as only farmers who perceive a problem will implement strategies to adapt or respond to it.

The present study makes several contributions to the existing debate and literature on how best to interrogate climate trends, impacts and adaptation strategies amongst smallholder farmers in Zambia. First, we build on the method used in several papers from other countries, to compare local narratives of climate change with evidence found in meteorological records. If the two sources are aligned, it suggests that farmers correctly perceive environmental change. Where the two sources diverge, more research is needed to understand whether farmer perceptions are incorrect (with implications for their readiness to adapt to climate change), or whether meteorological records are inadequate for detecting some aspects of climate change. However, while other papers refer only to rainfall records, in the present study we analyze both temperature and rainfall. This sheds light on the reasons for any divergence between perceptions and evidence of change. Second, to our knowledge, this is the first study from Zambia that brings together a conventional meteorological analysis with local perceptions of climate change. While this approach exposes some difficult questions, it also produces a more comprehensive picture of climate change.

The objectives of the study are: (1) to assess farmers' perceptions of climate change; (2) to document the perceived impacts on agricultural households in Zambia, as well as the main adaptation strategies employed in response to climate variability and change; and (3) to compare evidence in meteorological records with farmers' observations regarding climate variability and change. Ultimately, this paper intends to offer guidance for an improved policy and research agenda related to climate change in Zambia.

We use both qualitative data from focus group discussions among smallholder farmers in six districts representing the three agro ecological regions, and historical meteorological records in order to discern climate trends and farmers' experiences of climate change and how farmers are responding to the perceived changes. While accounts do vary by location and gender, several themes are exceptionally consistent in the discussions. Results indicate that for temperature, there is clear overlap between farmers' observations and patterns found in the meteorological records. However, the meteorological data do not support the perception that the rainy season used to begin earlier, and at this temporal scale of analysis, we generally do not detect an increase in intra-season variability in rainfall. What underlies these

discrepancies between the farmers’ observations of climate change and empirical trends evident in meteorological data? We discuss several possible explanations: (1) Farmers are not able to accurately track probabilistic changes in climate; (2) Members of the focus groups feel compelled to offer a story in line with a dominant narrative of climate change; (3) Farmers’ accounts and meteorological data refer to different climate-related phenomena; and (4) Our scale of analysis and definitions of precipitation variables are inadequate, but can be refined with analysis of daily meteorological data.

In each discussion, farmers were asked to comment on whether they have observed changes in crop yields. The results are very mixed, and numerous reasons are given for observed changes. It is clear that farmers have trouble identifying the cause of any yield changes. They often attribute yield increases to better information on management practices, improved seeds, access to fertilizer, and conservation agriculture practices (e.g., planting basins and ripping). At the same time they attribute declining yields to changes in rainfall patterns, along with more frequent pest problems and soil degradation. Thus, farmers that use fertilizer may have seen an increase in maize yields while a neighbor without fertilizer experienced a decline. By extension, this implies that farmers perceive technological advances and improved crop management as ways to mitigate the negative effects of climate change. Although not solely due to climate change, soil degradation stands out as a consistent problem across all locations.

Farmers in each site have observed a decrease in water levels in streams, rivers, lakes, and wells. Again, it is not clear that this is due to climate change, and farmers noted the falling water levels even in groups that do not perceive a decline in rainfall. The farmers pointed out that women now spend considerably more time collecting water for household needs, as this is typically a woman’s task. This is the most prominent gender-differentiated experience of climate change that arose in the discussions. The decrease in water availability has another implication for household food security, as gardens are often maintained during the dry season and serve as an important source of food and dietary diversity. Groups in all locations note that gardening has become more difficult with declining water availability.

In terms of adaptation strategies, farmers have adopted a range of behaviors to actively mitigate the perceived impacts of climate change. For example, all groups listed the use of new seed varieties, and particularly early-maturing varieties, as a response to climate change. In Northern Province, farmers have begun to plant maize in stages in order to reduce the risk of losing an entire harvest due to unpredictable rainfall. Farmers in Southern/Lusaka and Eastern Provinces also cite conservation agriculture practices such as planting basins and ripping. These tillage methods involve minimal soil disturbance, and because land preparation can be completed during the dry season, planting can take place at the very beginning of the rainy season. Conservation agriculture practices are associated with moisture retention, and hence are considered effective at mitigating moisture stress during dry spells. However, the farmers note that minimum tillage methods result in a higher weed population later in the season, which requires the use of herbicides when household labor is inadequate for manual weeding. Ripping also requires access to animal draught power, while digging planting basins is said to be labor-intensive. For both minimum tillage practices and staggered planting, poor farmers are at a disadvantage because they lack access to animal draught power and cannot afford to hire in labor or purchase herbicides. Hence, wealthier farmers are better able to incorporate climate change adaption strategies into their farming systems.

In all three locations, farmers also cite the diversification of household livelihood portfolios in response to climate change. They diversify away from crops toward gardens, livestock, fishing or fish farming, and other activities that are not reliant on rainfall, such as petty trading. However, farmers in Southern Province note that women have fewer options to diversify out of agriculture, as they are less mobile than men. For the same reason, fishing is not an option for women in Northern Province. In addition, it is not obvious that all stated adaptations to climate change are, in fact, specific adaptations to climate. The focus groups make clear that climate change is but one factor affecting household welfare in rural Zambia. While it is perceived to reduce crop yield, it is sometimes overshadowed by the negative effect of soil degradation or counterbalanced by improved knowledge and input access. Farmers find it difficult to distinguish between environmental stressors (e.g., water pollution vs. falling water levels) with a common impact on their lives, and are quick to point out other problems (e.g., declining soil fertility) for which climate change is not the primary cause. The policy implication seems to be that development efforts must address climate change without losing sight of these other sources of tension in the smallholder system.

This study reveals various aspects of climate change in rural Zambia: Farmers offer remarkably consistent reports of a rainy season that is growing shorter and less predictable, with rising temperatures. Generally, farmers perceive that the rainy season has grown shorter within the past 20 years, along with an increase in rainfall variability and extreme climate events. Most farmers report that temperatures have increased, and that these trends have diminished crop yield and food security. The focus group discussions reveal that farmers in Zambia perceive climate change as a problem and actively manage the associated risks. To address climate variability, farmers adopt new seed varieties, management practices, and livelihood portfolios, and in at least two locations, conservation agriculture seems to be a widely recognized *toolbox* of potential responses to climate change. However, the higher labor requirement of minimum tillage techniques presents a burden for poor households that cannot afford to hire in labor or purchase labor-saving technology. In historical data from nearby meteorological stations, we find evidence of climate trends, including rising temperatures, which are consistent with some farmer reports. However, perceived rainfall trends are often not substantiated by the meteorological records.

We conclude that not all climate parameters of relevance can be detected through standard analyses of individual meteorological variables. A lack of statistical support does not imply the farmers' observations are invalid. In particular, the combination of stable rainfall and rising temperatures at the start of the rainy season may result in higher levels of evaporation, which leads farmers to conclude that rainfall levels are falling and the rainy season is growing shorter. Therefore, a complete picture of climate change requires contributions from multiple knowledge systems. The stories documented in this paper should be considered complementary rather than contradictory, and we hope it will motivate others to pursue a common understanding of the nature of climate change in Zambia.

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ACRONYMS AND ABBREVIATIONS

CFU	Conservation Farming Unit
CHP	Chipata
CSO	Central Statistical Office
CV	coefficient of variation
FGDs	Focus Group Discussions
FISP	Farmer Input Support Program
IAPRI	Indaba Agricultural Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
MACO	Ministry of Agricultural and Cooperatives
MAL	Ministry of Agricultural and Livestock
MPU	Mpulungu
MUN	Mungwi
OLS	Ordinary Least Squares
PET	Petauke
SIA	Siavonga
SIN	Sinazongwe
USAID	United States Agency for International Development

1. INTRODUCTION

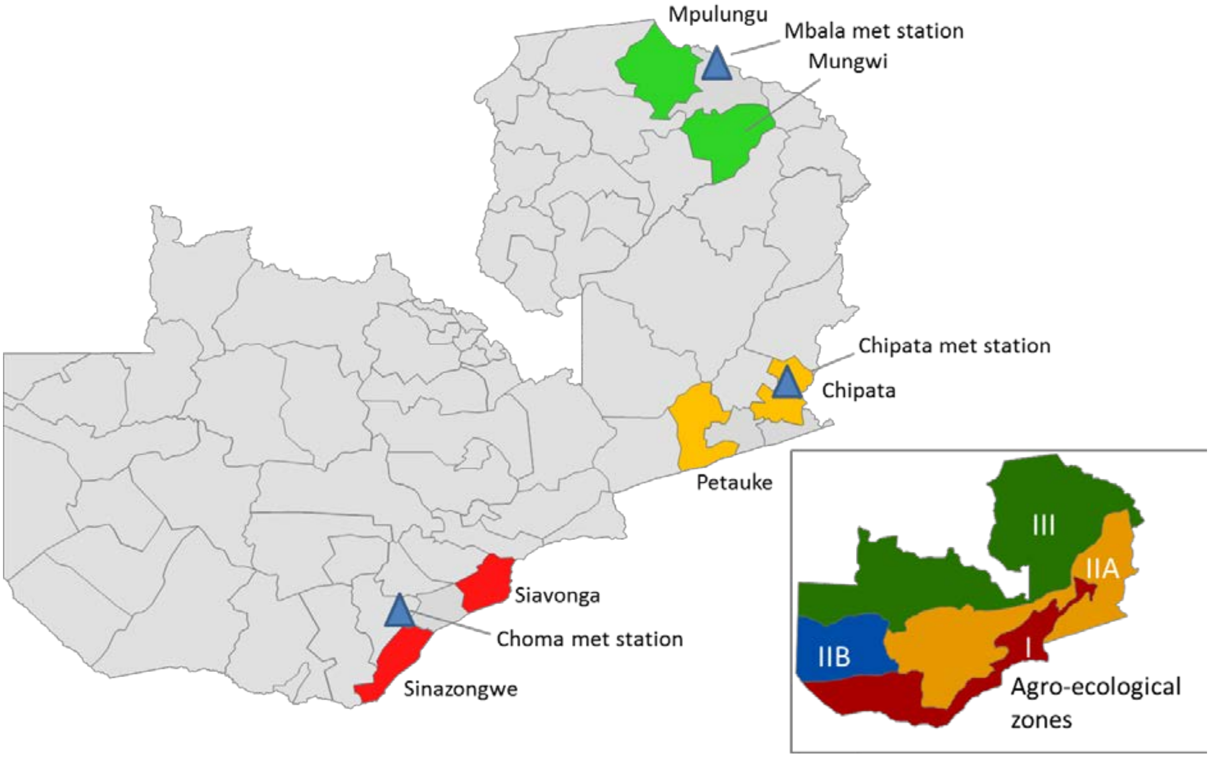
Over the past several decades, a number of changes in climate have been observed worldwide, including atmospheric warming and variability in precipitation. According to the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC 2013), rising temperatures and changing precipitation patterns will likely lead to an acute decline in rain-fed crop production in some African countries. Climate projections for southern Africa for the year 2050 indicate that the region will experience shifting precipitation patterns, rising temperatures (at least 1-2°C), and a higher frequency of extreme weather events. While different climate models agree that temperatures will rise, they offer markedly diverging predictions of rainfall levels (Hachigonta et al. 2013). Despite these variations in rainfall predictions, climate change is widely regarded as a challenge to agricultural development in the region.

Like most developing countries, Zambia's agricultural sector is highly dependent on rain-fed production and therefore vulnerable to weather shocks. Agriculture contributes 18-20% of gross domestic product and employs roughly two-thirds of the population (Jain 2006). Maize is the primary staple crop in Zambia, with a dual cassava-maize regime found only in the northern region. Smallholder farmers, including both small-scale and emergent farmers, total 1.4 million households and make up the majority of Zambia's rural population (CSO/MAL/IAPRI 2012). Among this group, almost all production is rain-fed with very few farmers using mechanized irrigation. Climate change therefore has the potential to significantly reduce agricultural production and exacerbate poverty and food insecurity.

Drought has been a major threat to food security, with large declines in maize yield consistently occurring in seasons with below normal rainfall (Muchinda 2001, cited in Jain 2006). However, Zambia sometimes experiences heavy localized floods that also threaten agricultural production. Zambia has a uni-modal rainfall pattern with three seasons, including the rainy season (November-April), cold season (May-July), and hot season (August-October). The single growing period extends from November through May/June, when crops are harvested. The country is divided into four agro-ecological zones distinguished by divergent rainfall patterns (Figure 1). In the south, zone I is relatively dry with unpredictable and poorly distributed rainfall. Zone IIa covers the central-eastern part of the country and has the highest agricultural potential, with evenly distributed rainfall and relatively fertile soil. In the west, zone IIb is characterized by low rainfall, sandy soils, and a high risk of drought. Zone III in the north experiences the highest rainfall, although this pattern has produced leached and acidic soils (Jain 2006).

A number of studies assess the impact of climate change on agricultural yields in Zambia (Thurlow et al. 2012 Jain 2006). While these provide quantitative evidence on the likely effects of climate change, they incorporate very limited qualitative analysis. Yet a qualitative approach is necessary to construct a more complete understanding of the nature of climate change, as well as the adaptive response of smallholders. Marin (2010) argues that a thorough, reliable, and relevant analysis of climate change can be gained from the integration of meteorological records and the observations of local people, as traditional knowledge may illuminate important but otherwise overlooked elements of change. Furthermore, awareness of climate change is a prerequisite to adaptation. As noted by Simelton et al. (2013), "Appreciating how changes are perceived at the local level is crucial to anticipating the impacts of climate variability and/or change, as only farmers who perceive a problem will implement strategies to adapt or respond to it."

Figure 1. Locations of Focus Group Discussions and Meteorological Stations



Source: Authors.

One study of farmers' perceptions of climate change in Zambia provides useful insight into some of the adaptation strategies that farmers employ (Nyanga et al. 2011). However, this paper relies solely on farmers' accounts of weather changes and does not interrogate these against meteorological data. Furthermore, it focuses narrowly on conservation agriculture as a response to climate change, and this emphasis may obscure important elements of the experience of climate change.

The present study makes several contributions to the existing literature. First, we build on the method used in several papers to compare local narratives of climate change with evidence found in meteorological records (Marin 2010; Simelton et al. 2013; West et al. 2008). If the two sources are aligned, it suggests that farmers correctly perceive environmental change. Where the two sources diverge, more research is needed to understand whether farmer perceptions are incorrect (with implications for their readiness to adapt to climate change), or whether meteorological records are inadequate for detecting some aspects of climate change. However, while other papers refer only to rainfall records, in the present study we analyze both temperature and rainfall. This sheds light on the reasons for any divergence between perceptions and evidence of change. Second, to our knowledge, this is the first study from Zambia that brings together a conventional meteorological analysis with local perceptions of climate change. While this approach exposes some difficult questions, it also produces a more comprehensive picture of climate change.

This study will: (1) assess farmers' perceptions of climate change; (2) document the perceived impacts on agricultural households in Zambia, as well as the main adaptation strategies employed in response to climate change; and (3) compare evidence in meteorological records with farmers' observations regarding climate variability and change. Ultimately, this paper intends to offer guidance for an improved research agenda related to climate change in Zambia. The rest of the paper is organized as follows: Data and methods are discussed in section 2, results are presented in section 3, a discussion follows in section 4, and conclusions are offered in section 5.

2. DATA AND METHODS

This study incorporates information from two sources: In late 2011 and early 2012 we convened a series of focus groups to elicit farmers' perceptions of climate change and experiences with adaptation. These took place at six locations, two each in Southern/Lusaka, Eastern, and Northern Provinces. Two districts from each Province representing an agro-ecological region were selected based on, among other criteria, presence of meteorological station (with relatively complete historical records of temperature and rainfall), and agricultural research station. Researchers from Zambia Agricultural Research Institute provided guidelines on selection of districts to ensure that the selected districts are a good representation of each region. The following districts were selected: Sinazongwe and Siavonga representing region 1; Chipata and Petauke representing region 2, and Mpulungu and Mungwi representing region 3. The sites were selected to represent the diversity of experiences across three of Zambia's agro-ecological regions (Figure 1). In each district, farmers were divided into groups of men and women to form 12 focus group discussions (FGDs) in total. The group sizes ranged from 7 to 20, and we spoke with 160 farmers (90 men and 70 women). Since climate change is a long term phenomenon, FGD participants were selected based on their length of stay in their current location. We deliberately oversampled those that had stayed in the same location for 20 years or more as this period is long enough for one to observe changes in climate. The discussions were structured around the participants' perspectives on how their local climate has changed in recent decades, how this has affected their livelihoods, and what actions they have taken to counteract the negative effects of climate change. While the conversations were not recorded, this paper refers to detailed reports of each discussion.

We then select one meteorological station from each location and analyze the historical records of rainfall and average maximum (daytime) and minimum (nighttime) temperature. These dekad-level data were collected by the Zambia Meteorological Department. For Southern Province we utilize the records of Choma meteorological station, for which we have precipitation records for 61 years (1950/51-2010/11) and temperature records for 31 years (1980/81-2010/11). For Eastern Province we select Chipata meteorological station, where the data cover the same period as Choma. For Northern Province we select Mbala meteorological station, for which we have precipitation records for 50 years (1961/62-2010/11) and temperature records for 31 years (1980/81-2010/11).

While the three meteorological stations have relatively consistent historical records, they are not entirely complete. We impute missing dekad-level observations with the dekad data of a nearby meteorological station of similar altitude. Chipata meteorological station has 10.13% missing temperature observations and 1.78% missing rainfall observations. For Choma these values are 11.20% (temperature) and 0.14% (rainfall), and for Mbala these values are 21.77% (temperature) and 0.33% (rainfall). The analysis is focused mainly on the growing season because this time interval is of the greatest consequence for agricultural households in Zambia. Three definitions of the growing season are offered, including October-April, November-March, and mid-December-February. Most rainfall occurs during the middle interval, while the latter interval is most critical to maize.

We use two methods to detect a temporal trend in climate. In a series of simple regressions, climate variables are used as dependent variables and year as the sole regressor. Although not reported in this paper, two robustness tests determine whether the results are influenced by our method of imputing missing observations. We first re-run all regressions with data that omits missing observations, and then re-run the seasonal temperature regressions with imputed data that omits any years with over 25% missing observations. However, because linear regressions require the data to be normally distributed, this may not be the most appropriate method to detect a climate trend. We therefore validate the results with a series of nonparametric Mann-Kendall (MK) tests that do not require the data to be of any particular distribution (Hirsch and Slack 1984). This test for monotonic change determines whether the climate variable and year are independent of one another. Where this null hypothesis is rejected, climate has significantly changed over the study period.

3. RESULTS

3.1. Farmers’ Observations of Climate

Both men and women generally share the same perceptions of climate parameters. With regard to changing rainfall patterns, almost all groups in the three locations observe that the season has grown shorter, with a later start (shifting from October to November) and an earlier end (shifting from April to March). One group that diverges from this narrative indicates only that the onset of the rainy season has become less predictable. Furthermore the farmers report an increase in intra-seasonal variation, with less dependable rainfall particularly during the January-February period that is critical to maize growth. Maize is most sensitive to drought during this period of silking and grain filling, when the flowers are pollinated and the grain begins to develop (Harrison et al. 2011). Farmers in Northern Province note that hailstorms and other precipitation extremes have increased, and farmers in both Siavonga and Chipata note that rainfall has become more localized, such that one farmer’s experience may vary from her neighbor’s. These changes are often considered to have begun in the early 1990s, although this estimate varies by location. For example, one group suggests the change began in the 1980s while another group lists the early 2000s. Although farmers do not often claim that rainfall levels have fallen, in every site they note a decrease in water levels in streams, rivers, lakes, and wells. Furthermore, farmers seem to regard the timing of rainfall (onset, cessation, and consistency) as more important than the total rainfall amount in a season, and this perception conforms with empirical evidence from agronomic studies (e.g., Barron et al. 2003; HarvestChoice 2010).

With regard to changes in temperature, farmers in Southern Province provide inconsistent accounts of whether there has been a trend, with two groups finding no change. However, although the remaining two groups agree that temperatures have risen, they differ on whether this has occurred mostly for daytime or nighttime temperatures. In Northern Province, three of four groups cite a temperature increase while women in Mungwi report a decrease, particularly during the winter. Here also, among the groups that report a warming trend, there is disagreement on whether this is driven by daytime or nighttime temperatures. In Chipata both men and women farmers agree that temperatures have increased, while in Petauke farmers note only that temperature extremes have increased. Generally, the focus groups spend more time detailing their perceptions of rainfall patterns than temperature change.

3.2. Empirical Climate Trends

An examination of historical climate records from nearby meteorological stations sometimes, though not always, reflects the narratives of farmers. The climate variables used in this analysis are summarized in the appendix (Table A1). Table 1 shows the results of a series of simple regressions in which year is the independent regressor and rainfall variables are used, in turn, as dependent variables. Only the coefficient and standard error of year are reported for each regression. To validate these Ordinary Least Squares (OLS) results, a nonparametric Mann-Kendall test for monotonic change is also performed for each variable, and both tests detect significant changes for a similar set of variables. Although not reported here, two robustness tests confirm that our method of imputing missing weather observations does not significantly affect the regression results. Rainfall levels over time are illustrated in Figures 2-4.

Rainfall levels are not found to significantly decline over the study period. In fact, total rainfall over the November-March growing season has increased in Chipata, and this has mostly occurred within the last eight years of the study period. Note, however, that the coefficients on rainfall seem quite small, and rainfall levels exhibit a high level of inter-annual variation even when this does not take the form of a trend. According to our definition of rainy season onset and offset, the length of the rainy season has decreased in Mbala, and Chipata also exhibits a negative trend that is almost significant. Interestingly, this seems to be driven more by an earlier offset than a delayed onset. The coefficient of variation (CV) for rainfall is significantly increasing for the October-April interval in Mbala, though not in the other sites.

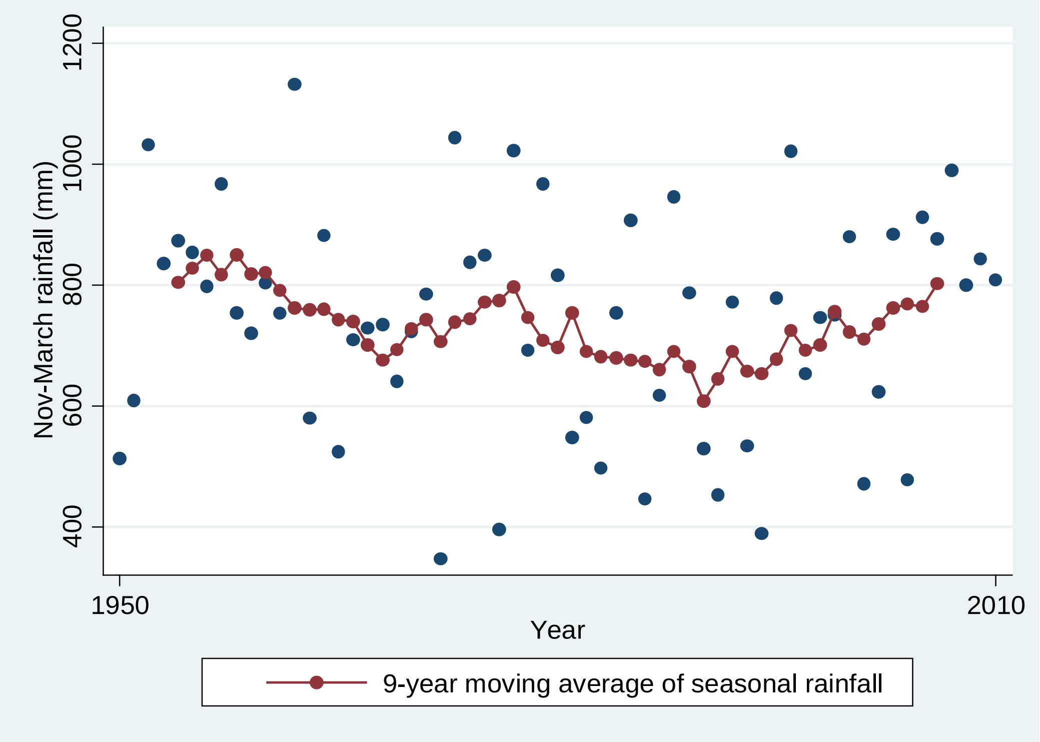
Table 2 is similarly structured for temperature variables, with temperature patterns illustrated in Figures 5-7. Even with a small sample size of 31 years of temperature records, each site shows a significant increase in average season temperature for the October-April period. Interestingly, in Choma this is driven by an increase in nighttime temperatures, while for Mbala this seems to be driven more by a rise in daytime temperatures. A month-by-month analysis of these trends indicates that temperatures are increasing across the three seasons, with the notable exception of most of the growing season in Choma. Two variables intended to capture intra-seasonal variation in temperature, the number of dekads with an average daytime temperature over 30°C and the coefficient of variation in dekadal average temperature, show few statistically significant trends. However, the signs of the coefficients are almost always positive. It is therefore possible that temperature variation is increasing, though the small sample size precludes detection of a trend.

Table 1. Rainfall Trends at Meteorological Stations

		Choma					Chipata					Mbala				
		OLS			MK Test		OLS			MK Test		OLS			MK Test	
Interval	Dependent variable	Coef on year	SE	Sig.	Z-score	Sig.	Coef on year	SE	Sig.	Z-score	Sig.	Coef on year	SE	Sig.	Z-score	Sig.
Oct-April	Season rain (mm)	-0.663	(1.242)		-0.212		5.284	(2.289)	**	1.873	*	-1.843	(2.042)		-1.012	
	CV rain	0.000	(0.004)		-0.187		0.005	(0.004)		1.319		0.013	(0.005)	***	2.367	**
	Deviation from avg rain start	0.002	(0.006)		1.007		0.007	(0.006)		1.068		0.011	(0.009)		0.923	
	Rain start	-0.001	(0.010)		0.357		0.005	(0.010)		0.748		0.003	(0.014)		0.249	
	Rain end	0.005	(0.013)		0.221		-0.016	(0.010)		-1.893	*	-0.035	(0.008)	***	-3.072	***
	Length of rainy season	0.061	(0.162)		0.452		-0.212	(0.132)		-1.712	*	-0.382	(0.151)	**	-1.951	*
Nov-Mar	Season rain (mm)	-0.671	(1.261)		-0.274		5.621	(2.300)	**	1.910	*	-1.268	(2.084)		-0.694	
	Stress	-0.003	(0.009)		-0.270		-0.004	(0.006)		-0.629		0.008	(0.007)		1.071	
mid-Dec-Feb	Season rain (mm)	-1.032	(0.882)		-1.120		2.954	(1.795)		0.797		1.028	(1.166)		0.460	
	CV rain	0.000	(0.001)		-0.734		0.001	(0.001)		0.423		0.003	(0.002)		0.477	
Oct	Rain	-0.051	(0.235)		0.194		0.033	(0.083)		-0.640		0.473	(0.557)		-0.731	
Nov	Rain	-0.130	(0.391)		-0.224		0.053	(0.465)		-0.230		-1.143	(0.768)		-1.313	
Dec	Rain	-0.428	(0.704)		-0.411		2.493	(1.020)	**	2.215	**	-0.428	(0.785)		-0.811	
Jan	Rain	0.153	(0.499)		0.124		1.477	(0.955)		1.394		0.908	(0.817)		0.837	
Feb	Rain	-1.012	(0.542)	*	-1.929	*	0.370	(0.950)		-1.693	*	-0.497	(0.766)		-0.184	
Mar	Rain	0.747	(0.517)		1.780	*	1.228	(0.721)	*	1.767	*	-0.109	(0.635)		-0.535	
Apr	Rain	0.059	(0.199)		-0.462		-0.370	(0.374)		-1.848	*	-1.048	(0.614)	*	-1.456	

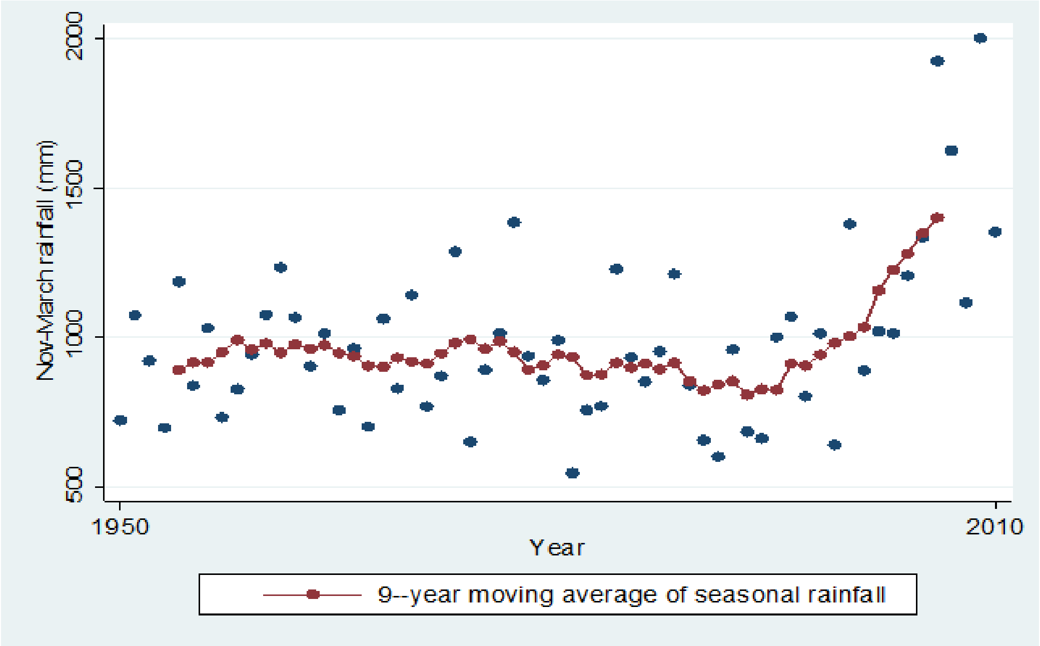
Source: Zambia Meteorological Department.
Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
No. obs.: Choma (61), Chipata (61), Mbala (50)

Figure 2. Choma Rainfall - 1950-2010



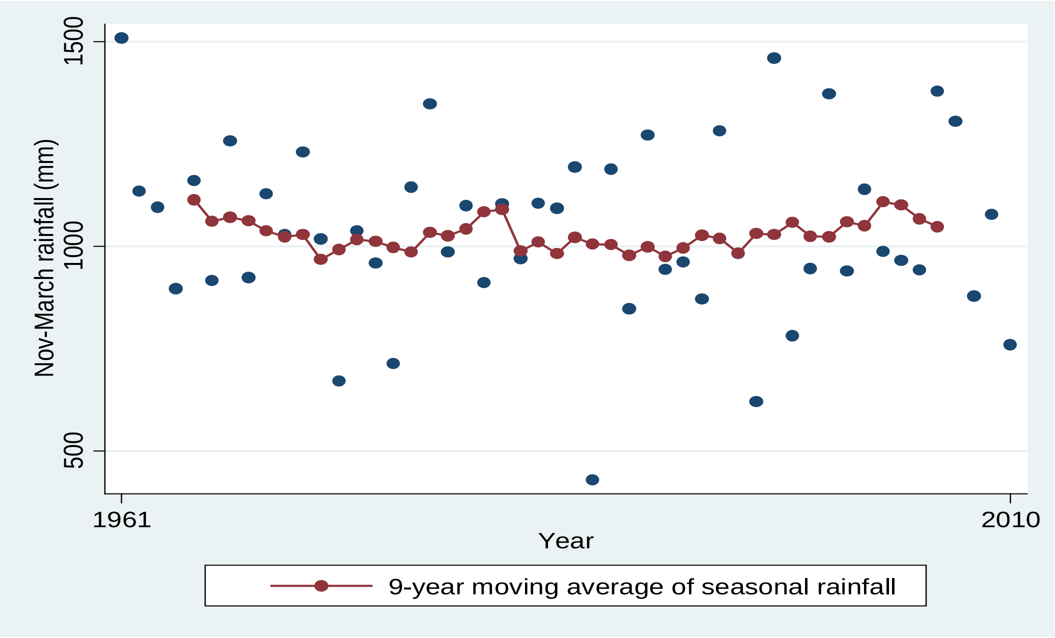
Source: Zambia Meteorological Department.

Figure 3. Chipata Rainfall - 1950-2010



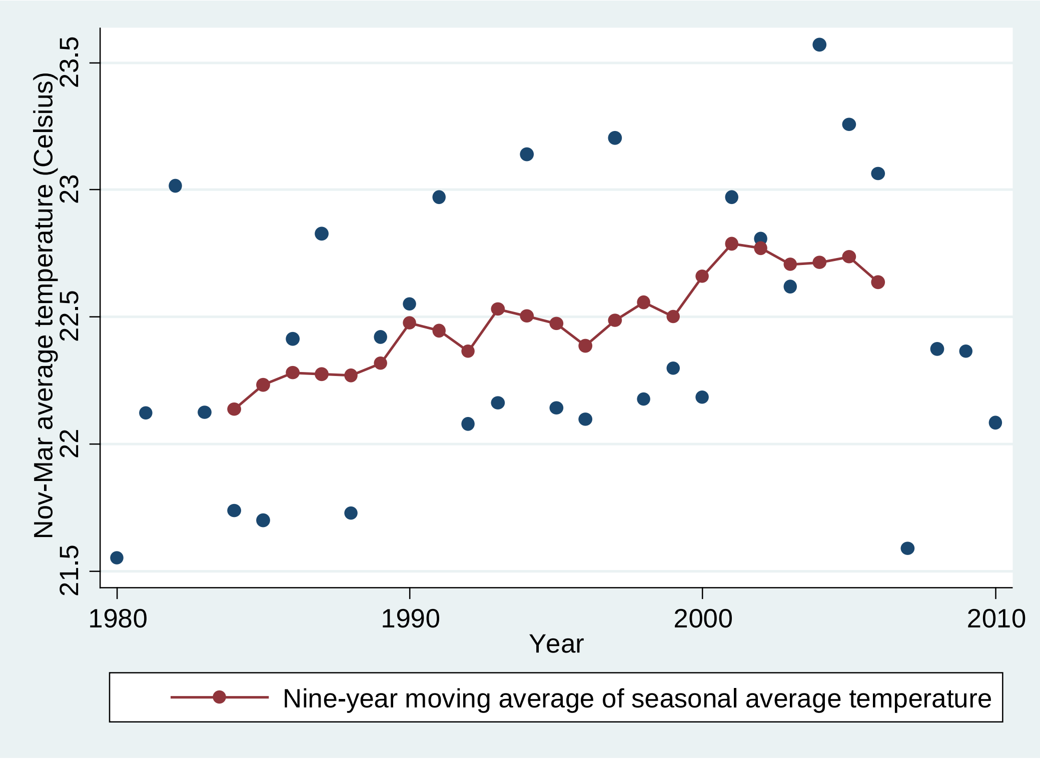
Source: Zambia Meteorological Department.

Figure 4. Mbala Rainfall - 1950-2010



Source: Zambia Meteorological Department.

Figure 5. Choma Average Temperature - 1980-2010



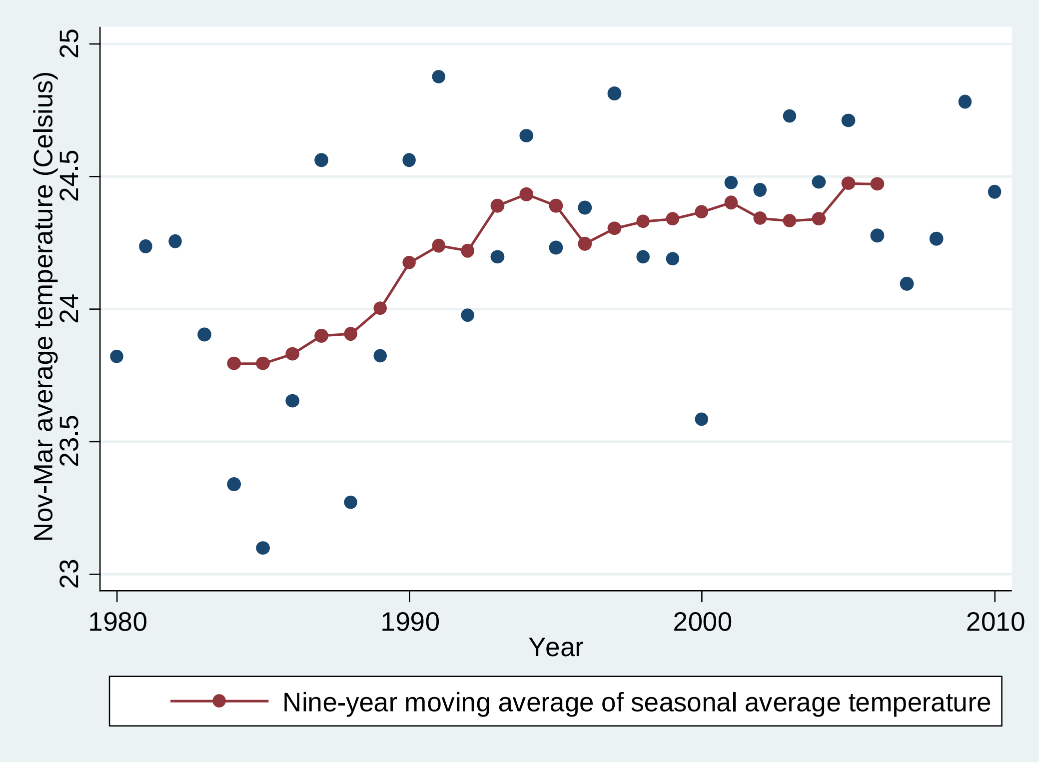
Source: Zambia Meteorological Department.

Table 2. Temperature Trends at Meteorological Stations

		Choma					Chipata					Mbala				
		OLS			MK Test		OLS			MK Test		OLS			MK Test	
Interval	Dependent variable	Coef on year	SE	Sig.	Z-score	Sig.	Coef on year	SE	Sig.	Z-Score	Sig.	Coef on year	SE	Sig.	Z-Score	Sig.
Oct-Apr	Avg max temp	0.020	(0.015)		1.207		0.038	(0.009)	***	3.416	***	0.060	(0.021)	***	2.770	***
	Avg min temp	0.023	(0.008)	***	2.788	***	0.020	(0.005)	***	3.096	***	0.007	(0.006)		0.935	
	Avg season temp	0.022	(0.010)	**	2.023	**	0.029	(0.007)	***	3.468	***	0.034	(0.012)	***	2.668	***
	No. hot dekads	0.072	(0.048)		1.768	*	0.063	(0.034)	*	1.997	**	0.069	(0.030)	**	2.082	**
	CV temp	0.000	(0.000)		0.459		0.000	(0.000)		0.187		0.000	(0.000)		-0.221	
Nov-Mar	Avg season temp	0.017	(0.011)		1.802	*	0.025	(0.008)	***	2.397	**	0.030	(0.013)	**	2.516	**
Mid-Dec-Feb	Avg max temp	0.009	(0.020)		0.731		0.025	(0.012)	**	1.938	*	0.057	(0.024)	**	2.108	**
	Avg min temp	0.018	(0.010)	*	2.043	**	0.016	(0.008)	**	2.533	**	0.010	(0.007)		1.394	
	Avg season temp	0.013	(0.012)		1.258		0.021	(0.009)	**	2.278	**	0.034	(0.014)	**	2.176	**
	No. hot dekads	-0.004	(0.020)		-0.134		0.004	(0.012)		0.285		0.003	(0.003)		0.783	
	CV temp	0.000	(0.000)		-0.799		0.000	(0.000)		-0.935		0.000	(0.000)		-1.717	*
Oct	Avg temp	0.053	(0.017)	***	2.618	***	0.049	(0.010)	***	3.451	***	0.05	(0.017)	***	2.652	***
Nov		0.031	(0.017)	*	1.751	*	0.038	(0.020)	*	1.853	*	0.036	(0.022)		1.479	
Dec		0.016	(0.016)		1.684	*	0.022	(0.016)		1.105		0.014	(0.017)		1.020	
Jan		0.013	(0.013)		1.020		0.023	(0.009)	**	1.905	*	0.034	(0.014)	**	2.195	**
Feb		0.015	(0.013)		1.139		0.027	(0.011)	**	2.329	**	0.044	(0.016)	**	2.550	**
Mar		0.011	(0.016)		1.037		0.012	(0.011)		1.429		0.022	(0.014)		1.479	
Apr		0.017	(0.027)		0.969		0.029	(0.019)		1.462		0.037	(0.012)	***	2.737	***
May		0.033	(0.021)		2.074	**	0.025	(0.018)		1.632		0.032	(0.010)	***	2.839	***
June		0.046	(0.019)	**	2.108	**	0.049	(0.014)	***	2.906	***	0.03	(0.012)	**	2.074	**
July		0.060	(0.016)	***	2.941	***	0.036	(0.014)	**	2.279	**	0.021	(0.013)		1.854	*
Aug		0.053	(0.024)	**	2.193	**	0.04	(0.014)	***	2.483	**	0.029	(0.009)	***	2.312	**
Sept		0.033	(0.019)	*	2.006	**	0.02	(0.012)		1.870	*	0.021	(0.010)	*	2.058	**

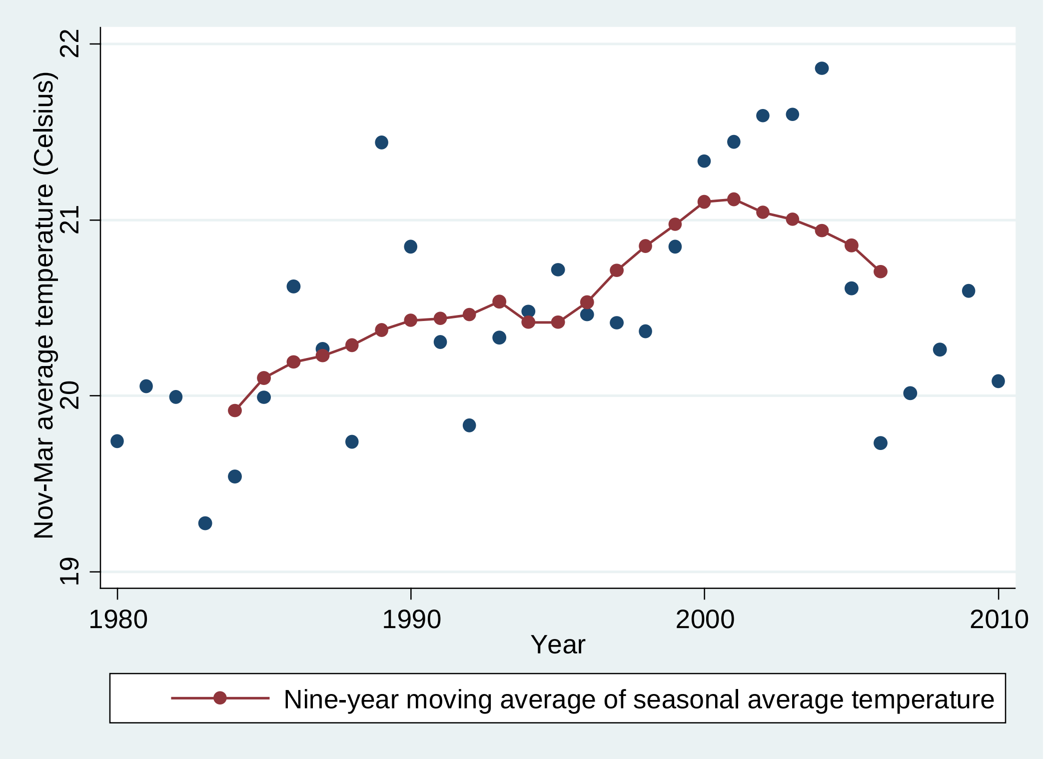
Source: Zambia Meteorological Department.
Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
No. obs.: Choma (31), Chipata (31), Mbala (31)

Figure 6. Chipata Average Temperature - 1980-2010



Source: Zambia Meteorological Department.

Figure 7. Mbala Average Temperature - 1980-2010



Source: Zambia Meteorological Department.

3.3. Comparison of Perceptions and Empirical Trends

Table 3 provides a comparison of the farmer reports of climate change (Section 3.1) and the statistical evidence of such trends (Section 3.2). An observation is considered to be consistent with the meteorological records when both the OLS regression and MK test indicate a significant change in the expected direction. Some observations (e.g., rainfall has become more localized) cannot be interrogated with data from a single meteorological station. Generally, we find more consistency among observations related to temperature, with statistical evidence corroborating accounts of rising temperatures in all sites and more frequent extremes in Eastern Province. However, at each site farmers offered diverse stories of *how* temperatures are rising (e.g., daytime versus nighttime temperatures), and only some of these narratives are reflected in the data. Note that the diverging perceptions of temperature change in a single region may be due to the use of different baselines from which respondents estimate change.

Although farmers offer detailed accounts of how rainfall patterns have changed in their areas, we detect surprisingly few rainfall trends in the meteorological data. Consistent with all focus groups in Northern Province, we find that the rainy season is ending earlier in Mbala. In addition, intra-seasonal variability in rainfall is increasing, albeit not within the narrow interval from mid-December through February. While farmers in all three sites perceive that the rainy season is beginning later, this is not evidenced in the data. In fact, in Choma the coefficient on *rain start* is negative. Although farmers often report an increase in the frequency or duration of dry spells during the growing season, we do not find a significant trend in *rain stress* at any site, and only in Mbala is the coefficient positive. Similarly, while farmers in Southern/ Lusaka and Eastern Provinces cite an increase in intra-seasonal variability, the coefficient on *CV rain* is not significant in either location.

It should be noted that, while most rainfall variables do not change significantly over the study period, the coefficients often do have the *correct* sign. For example, farmers in Southern/ Lusaka and Northern Provinces note a decrease in total rainfall levels, and the coefficient on *season rainfall* is correspondingly negative. Farmers in Eastern Province report that rainfall starts later and ends earlier, and the coefficients on *rain start* and *rain end* do reflect this story. However, these trends seem to be insignificant. Furthermore, we do not find a significant decrease in October and November rainfall at any site, in contrast to farmer recollections that it used to rain more during this interval.

Table 3. Comparison of Farmer Reports and Meteorological Evidence of Climate Change

Province	Observation	FGD	Climate variable	Consistent w/ meteorological records?	Sign of coefficient
Southern/ Lusaka	Rainfall level has decreased	SIA-men	Season rain (Oct-Apr)	No[1]	-
	Rainy season onset increasingly delayed (Oct → Nov)	All	Rain start	No	-
	Rainy season offset occurs earlier (April → March)	All	Rain end	No	+
	Increased frequency of droughts	SIN-men	Stress	No	0
	Rainfall has become erratic (less dependable) at the critical time for maize	SIA-women and men	CV rain (Dec-Feb)	No	0
	Rainfall has become more variable	SIA-men	CV rain (Oct-Apr)	No	0
	Rainfall has become more localized	SIA-men	N/A		
	Temperature has increased (night more than day)	SIA-women	Average temp (season, max, and min)	Yes[2]	+ (all)
	Temperature has increased (day more than night)	SIN-men	Average temp (season, max, and min)	No	
	No change in temperature	SIN-women and SIA-men	Average temp (season, max, and min)	No	
Eastern	Rainy season onset increasingly delayed (Oct → Nov/Dec)	CHP-men and women, PET-women	Rain start	No	+
	Rainy season offset occurs earlier (April → March)	CHP-women, PET-women	Rain end	No	-
	Rainfall has become more variable in its onset	PET-men	Deviation rain start	No	+
	Increased frequency of dry spells	CHP-men and women	Stress	No	-
	Rainfall has become erratic (less dependable) at the critical time for maize	PET-men	CV rain (Dec-Feb)	No	+
	Fewer storms	PET-men	N/A		
	Rainfall has become more localized	CHP-men	N/A		
	Temperature has increased (both day & night)	CHP-men and women	Average temp (season, max, and min)	Yes	+ (all)
	Temperature has become more variable	PET-men and women	CV temp (Oct-Apr)	No	0
	Temperature extremes have increased	PET-men and women	No. hot dekads (Oct-Apr)	Yes	+
Northern	Rainfall level has decreased	MPU-women	Rainfall (Oct-Apr)	No	-
	Rainy season onset is increasingly delayed (Sept/Oct --> Nov)	All	Rain start	No	+

Table 3 con't.

Province	Observation	FGD	Climate variable	Consistent w/ meteorological records?	Sign of coefficient
	Rainy season offset occurs earlier (May --> March/April)	All	Rain end	Yes	-
	Increased frequency and duration of drought/ dry spells	MUN-men and women, MPU-women	Stress	No	+
	Rainfall has become erratic (less dependable)	MPU-men	CV rain (Oct-Apr)	Yes[3]	+
	More hailstorms and extreme rainfall events	MPU-men and women, MUN-women	N/A		
	Rainfall has become more localized	MUN-women	N/A		
	Temperature has increased (day more than night)	MPU-men	Average temp (season, max, and min)	Yes	+ (all)
	Temperature has increased (night more than day)	MUN-women	Average temp (season, max, and min)	No	
	Temperature has decreased (both day and night)	MPU-women	Average temp (season, max, and min)	No	

Source: Authors' summary.

Abbreviations: Siavonga (SIA), Sinazongwe (SIN), Chipata (CHP), Petauke (PET), Mpulungu (MPU), Mungwi (MUN)

1 Significant decrease in rainfall only in Feb; 2 No significant change in average temperature from Dec-May; 3 No significant increase in CV rain for the Dec-Feb interval

3.4. Perceived Impacts of Climate Change and Adaptation Strategies

In each discussion, farmers were asked to comment on whether they have observed changes in crop yields. The results are very mixed, and numerous reasons are given for observed changes. In Southern Province, most accounts are of a decline in yields, particularly for maize, although women in Sinazongwe also report an increase in yields due to improved management. In Eastern Province, women in Chipata claim that maize yields have decreased while women in Petauke say the opposite. Similarly in Northern Province, men in Mpulungu note that maize yields have decreased while men in Mungwi report the opposite. It is clear that farmers have trouble identifying the cause of any yield changes. They often attribute yield increases to better information on management practices, improved seeds, access to fertilizer, and conservation agriculture practices (e.g., planting basins and ripping). At the same time they attribute declining yields to changes in rainfall patterns, along with more frequent pest problems and soil degradation. Thus, farmers that use fertilizer may have seen an increase in maize yields while a neighbor without fertilizer experienced a decline. By extension, this implies that farmers perceive technological advances and improved crop management as ways to mitigate the negative effects of climate change. Although not solely due to climate change, soil degradation stands out as a consistent problem across all locations.

Farmers in each site have observed a decrease in water levels in streams, rivers, lakes, and wells. However, farmers in Mpulungu do note that it is not yet a problem in their area. Again, it is not clear that this is due to climate change, and farmers noted the falling water levels even in groups that do not perceive a decline in rainfall. In Southern Province, livestock must now travel farther afield to reach water, while in Mpulungu, farmers are careful to point out that the decline in water levels is not yet a problem. In Sinazongwe, Petauke, and Mungwi women now spend considerably more time collecting water for household needs, as this is typically a woman’s task. This is the most prominent gender-differentiated experience of climate change that arose in the discussions. The decrease in water availability has another implication for household food security, as gardens are often maintained during the dry season and serve as an important source of food and dietary diversity. Groups in all locations note that gardening has become more difficult with declining water availability.

Another problem the farmers associate with climate change is an uptick in both animal and human diseases. Thus, Southern Province has seen a heightened disease burden for cattle, while such diseases are becoming more common for goats and chickens in Northern Province. Focus groups in Northern Province also report that malaria is now a year-round problem, along with a higher prevalence of diarrheal diseases. Women in Siavonga note that there has been some out-migration from the area, although other focus groups in Southern Province do not offer a similar story.

In addition to the coping strategies identified above, farmers have adopted a range of behaviors to actively mitigate the perceived impacts of climate change (Table 4). For example, all groups listed the use of new seed varieties, and particularly early-maturing varieties, as a response to climate change. In Northern Province, farmers have begun to plant maize in stages in order to reduce the risk of losing an entire harvest due to unpredictable rainfall. Farmers in Southern/Lusaka and Eastern Provinces also cite conservation agriculture practices such as planting basins and ripping. These tillage methods involve minimal soil disturbance, and because land preparation can be completed during the dry season, planting can take place at the very beginning of the rainy season.

Table 4. Climate Change Adaptation Strategies

Adaptation measure	Province	Rationale given
Plant new seed varieties	All sites	
Plant early-maturing crop varieties	Eastern, Southern	These require a shorter rainy season
Plant open-pollinating crop varieties	Southern	
Change timing of planting	Eastern, Northern	
Plant early	Eastern	
Plant in stages	Northern	Reduce the risk of loss due to unpredictable rainy season onset
Conservation agriculture	All sites	
Planting basins and ripping	Eastern, Southern	Crops more readily survive dry spells and droughts
Mixed cropping	Northern	Spread the risk of crop failure
Rotate crops	Northern	
Cease *chitemene* (slash-and-burn)	Northern	
Diversify into gardening	Northern	Gardens can be irrigated more easily than field crops
Diversify into livestock	Eastern, Northern	Less dependent on rainfall
Diversify into fish farming or fishing	Northern	Less dependent on rainfall
Diversify income sources (sell clothes or charcoal)	Southern	Less dependent on rainfall

Source: Authors' Summary.

Conservation agriculture practices are associated with moisture retention, and hence are considered effective at mitigating moisture stress during dry spells (CFU 2010).

However, the farmers note that minimum tillage methods result in a higher weed population later in the season, which requires the use of herbicides when household labor is inadequate for manual weeding. Ripping also requires access to animal draught power, while digging planting basins is said to be quite labor-intensive. For this reason, men in Petauke indicate that adoption of conversation agriculture has been limited. For both minimum tillage practices and staggered planting, poor farmers are at a disadvantage because they lack access to animal draught power and cannot afford to hire in labor or purchase herbicides. Hence, wealthier farmers are better able to incorporate climate change adaption strategies into their farming systems.

In all three locations, farmers also cite the diversification of household livelihood portfolios in response to climate change. They diversify away from crops toward gardens, livestock, fishing or fish farming, and other activities that are not reliant on rainfall, such as petty trading. However, farmers in Southern Province note that women have fewer options to diversify out of agriculture, as they are less mobile than men. For the same reason, fishing is not an option for women in Northern Province.

4. DISCUSSION

For some climate parameters, there is clear overlap between farmers' observations and patterns found in the meteorological records. However, the meteorological data do not support the perception that the rainy season used to begin earlier, and at this temporal scale of analysis, we generally do not detect an increase in intra-season variability in rainfall. What underlies these discrepancies between the farmers' observations of climate change and empirical trends evident in meteorological data? We discuss several possible explanations: (1) Farmers are not able to accurately track probabilistic changes in climate; (2) Members of the focus groups feel compelled to offer a story in line with a dominant narrative of climate change; (3) Farmers' accounts and meteorological data refer to different climate-related phenomena; and (4) Our scale of analysis and definitions of precipitation variables are inadequate, but can be refined with analysis of daily meteorological data.

It is possible that farmers perceive a trend when there is none, or vice versa. According to Weber (2010), "Climate change, as a slow and gradual modification of average climate conditions, is a difficult phenomenon to detect and track accurately based on personal experience." This is because memory can be faulty, with unique events attributed to climate change while incremental change goes unnoticed. Farmers are more likely to recall recent years of unusual rainfall, as well as classic droughts, rather than the rainfall events in intermediate years (Slegers 2008). Interestingly, Cooper (2008) documents a similar pattern in Kenya where farmers overestimate the frequency of poor-rainfall seasons. Note that some farmers in Southern Province incorrectly report no temperature change, while one group in Northern Province even reports a cooling trend. It seems likely that farmers recall several recent seasons of unusually low temperatures in these areas (such Figures 5 and 7), such that their perception of a long-term temperature increase is obscured.

Perceptions of climate change may also be influenced by dominant narratives, as expectations of change or stability can color one's capacity to detect probabilistic changes (Weber 2010). Particularly in group interviews, a narrative of declining rainfall or an increasingly shorter rainy season may be a well-established narrative from both local and international sources (Mertz et al. 2009). For this reason, members of the group may feel obliged to relate a story of change, even if they have not perceived any change in climate.

Another explanation is that both farmers' recollections and the meteorological records are correct, though they reference different phenomena. As in our study, Marin (2010) also finds disparities between the climate accounts of Mongolian herders and the statistical trends detected in meteorological records. The author suggests that the herders consider only *significant* rains when quantifying rainfall, and that they estimate the quantity of rainfall by observing its effect on agriculture. Other studies have similarly found that farmers in Africa hold a definition of drought that is broader than a simple lack of rain (Slegers 2008). Rather, they focus on the aggregated impact of multiple climate variables. In Zambia, it seems reasonable that farmers are focused on the concept of *agricultural drought* and not *meteorological drought*. Thus, rising temperatures in the month of October may result in reduced soil moisture during planting, even without a decrease in October rainfall. It may be this change that farmers interpret as a decrease in October rainfall.

Along these lines, farmers track the climate parameters that are salient in their lives and not necessarily the variables included in standard climatological analysis. As seen in the focus groups in Zambia, these include changes in the spatial distribution of rain and the intensity of rainfall over hours, rather than over days or dekads. Farmers observe climatic changes over a larger area, at a finer spatial scale and, in certain respects, in greater detail than the information collected at meteorological stations (Marin 2010).

Interestingly, Simelton et al. (2013) also find that farmers in both Botswana and Malawi consistently perceive that rains used to start earlier and end later, although this is not reflected in historical rainfall data. In fact, the authors find no evidence that rainfall in south Malawi was ever substantial during the month of September, in contrast with respondents' recollections. The authors suggest that changes in farming system sensitivity may be conflated with changes in rainfall. This is because it is difficult to differentiate yield impacts of weather from yield impacts of other confounding factors. For example, hybrid maize used without fertilizer may be more sensitive to weather extremes, as compared with traditional maize varieties. Perhaps farmers have become more reliant on government programs for seed or fertilizer access or on a narrower range of resources, and are therefore less able to respond to weather stress. Such an increase in vulnerability can make it seem that weather extremes are increasing.

Finally, it is possible that our definition of the start of the rainy season is not the signal used by farmers. While we focus on the first dekad with substantial rain (Table A1), this may not serve as the cue to begin planting. Rather, farmers may be skeptical and wait until the next major rainfall, or may plant only once the soil horizon is moist to a certain depth, and not when it has rained a certain amount. In addition, our use of dekadal averages most likely masks daily extremes that affect agriculture and stand out in farmer memories. In Mpulungu, farmers observe that when it rains, it occurs within a single day rather than spread evenly over the course of a week, as it once did. However, without daily rainfall data we are unable to capture such a fine temporal scale of variability. By studying a single meteorological station in each site, we also cannot determine whether rainfall has become more localized.

Several additional findings can be drawn from this study. The climate trends detected in each region have implications for the likely effect of a changing climate on agriculture in Zambia. For example, while both Choma and Mbala have experienced an increase in average temperature, this is driven by rising daytime temperatures in Mbala and rising nighttime temperatures in Choma. It seems possible that crops exhibit different levels of sensitivity to a rise in minimum versus maximum temperatures. Maize exhibits a negative relationship between nighttime temperatures and the duration of grain-filling (Harrison et al. 2011), though it is also sensitive to daytime highs above a critical threshold of 30°C (Lobell et al. 2011). In designing climate-smart agricultural policies, perhaps different crops or crop varieties should be promoted to suit the distinct climate trends in each region.

In addition, it is not obvious that all stated adaptations to climate change are, in fact, specific adaptations to climate. The focus groups make clear that climate change is but one factor affecting household welfare in rural Zambia. While it is perceived to reduce crop yield, it is sometimes overshadowed by the negative effect of soil degradation or counterbalanced by improved knowledge and input access. Nyanga et al. (2011) similarly observe that climate change is not the most pressing problem among smallholder farmers in Zambia. Along these lines, in a study of farmers in the Sahel, Mertz et al. (2009) find that isolating climate as a direct driver of any change in land use or livelihoods is difficult.

In our study, farmers find it difficult to distinguish between environmental stressors (e.g., water pollution vs. falling water levels) with a common impact on their lives, and are quick to point out other problems (e.g., declining soil fertility) for which climate change is not the primary cause. The policy implication seems to be that development efforts must address climate change without losing sight of these other sources of tension in the smallholder system.

5. CONCLUSIONS

This study reveals various aspects of climate change in rural Zambia: Farmers offer remarkably consistent reports of a rainy season that is growing shorter and less predictable. In all sites, some farmers have observed rising temperatures. To address climate variability, farmers adopt new seed varieties, management practices, and livelihood portfolios, and in at least two locations, conservation agriculture seems to be a widely recognized toolbox of potential responses to climate change. However, the higher labor requirement of minimum tillage techniques presents a burden for poor households that cannot afford to hire in labor or purchase labor-saving technology. Given the wide range of adaptation strategies employed by farmers, it seems imperative to determine which are the most effective and feasible in each region. For example, although staggered planting is also problematic for cash-constrained households, it would be useful to explore whether it is a reasonable alternative to conservation agriculture.

This analysis underscores the need for region-specific policy responses to facilitate climate change adaptation in Zambia. Farmers in Northern Province note that they would like to use 500-series maize but can only access 700-series seeds through the national Farmer Input Support Program (FISP). Because experiences vary at each location of our focus group discussions, as do the options available to local residents, policy decisions should reflect the priorities of local farmers. Such decisions range from what currently available seed varieties should be promoted or made available through FISP, to how agricultural research institutes in Zambia should prioritize the development of seed varieties with specific characteristics (e.g., drought- versus heat-tolerance).

Some climate trends can be found in the meteorological data, with temperature exhibiting a sharper pattern. Not surprisingly, Zambia has grown warmer over the past three decades. An analysis of rainfall records suggests a more ambiguous story, with a recent uptick in rainfall levels in Eastern Province and a shorter rainy season in Northern Province, but few other noteworthy trends. We offer several explanations for the seeming divergence between farmers’ observations of rainfall and the empirical records. Our analysis may be too coarse; farmer recollections may be incorrect; or farmers may track different climate-related parameters that are salient in their lives but difficult to document with only meteorological data and/or analyses of individual climate variables. A lack of statistical support does not imply the farmers’ observations are invalid. In particular, the combination of stable rainfall and rising temperatures at the start of the rainy season may result in higher levels of evaporation, which leads farmers to conclude that rainfall levels are falling and the rainy season is growing shorter.

Our comparison of qualitative and quantitative narratives of climate change suggests that the study of climate change should not be left to expert judgment or scientific observation. Rather, local systems of knowledge contribute different parameters that cannot be tracked by measuring only rainfall or temperature, and offer a more contextual interpretation of these climate parameters. The stories documented in this paper should be considered complementary rather than contradictory, and we hope it will motivate others to pursue a common understanding of the nature of climate change in Zambia.

APPENDIX

Table 5. Climate Variable Definitions

Climate variable	Variable construction
Season average maximum temperature (°C)	Average of dekadal daytime high temperatures (Oct-April; November-March; mid-December-February)
Season average minimum temperature (°C)	Average of dekadal nighttime low temperatures (Oct-April; November-March; mid-December-February)
Season average temperature (°C)	Average of dekadal maximum and minimum temperatures (Oct-April; November-March; mid-December-February)
Monthly maximum, minimum, and average temperature (°C)	
No. hot dekads	No. dekads in growing season with average daytime high temperature ≥ 30°C
CV Temperature	Coefficient of variation over the season (Oct-April; November-March; mid-December-February) CV Temp = $\sqrt{\sum(Avg\ temp_i} - Avg\ season\ temp)^2$, where *i* indexes each dekad
Season rainfall (mm)	Total precipitation (Oct-April; November-March; mid-December-February)
Monthly rainfall (mm)	Total precipitation for each month
Rain stress	No. 20-days periods with <= 40 mm rainfall (Oct-April; November-March; mid-December-February)
CV Rainfall	Coefficient of variation over the season (Oct-April; November-March; mid-December-February) CV Rain = $\sqrt{\sum(Rain_i} - Avg\ dekadal\ rain)^2$, where *i* indexes each dekad
Deviation from long-term average (mm) (absolute value)	Absolute value of the deviation in Nov-Mar rainfall from the average Nov-Mar rainfall over the study period
Rain start	No. dekads from the beginning of November until ≥ 20 mm rainfall
Rain end	No. dekads from the end of April until ≥ 20 mm rainfall
Length of rainy season (days)	No. days between rain start and rain end
Deviation rain start	Absolute value of the deviation in rain start from the average dekad of rain start over the study period

Source: Authors' Summary.

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