

Within-Season Producer Response to Warmer Temperatures: Defensive Investments by Kenyan Farmers

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Motivation

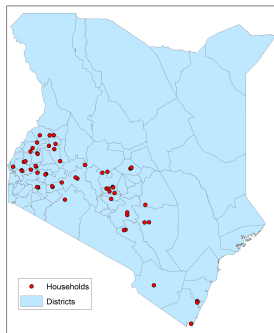
- Research Question: Can farmers in low-income countries adjust to short-run variation in the temperature? If yes, how?
 - ▶ Agricultural livelihoods in developing countries are especially fragile in the face of climate change (e.g., Rosenzweig and Parry, 1994)
 - ▶ Developing countries will see the greatest increases in temperatures (Harrington et al., 2016)
 - ▶ Farmers in low-income countries have limited resources to engage in adaptation and avoid permanent damage

Motivation

- Farmers can make their decisions sequentially, adapting to new information as it emerges (Antle, 1983; Fafchamps, 1993; Dillon, 2014)
- Evidence in the environmental economics literature is mixed; existing studies often *infer* agricultural adaptation:
 - ▶ Cross-sectional variation to compare outcomes in hot versus cold areas (e.g., Mendelsohn, Nordhaus and Shaw, 1994)
 - ▶ Comparing estimates from annual temperature fluctuations for a given area under hotter versus cooler conditions (e.g., Deschênes and Greenstone, 2011)
 - ▶ Differentiating estimates from annual temperature fluctuations with long-run impacts of higher than normal temperatures (e.g., Burke and Emerick, 2016)
- What are the mechanisms behind farmer adaptation?
 - ▶ Existing approaches may miss within-season producer responses

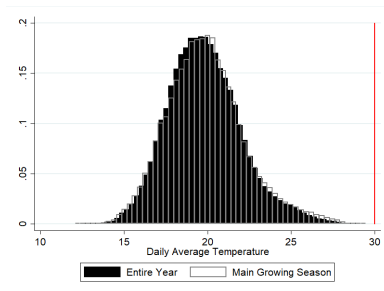
This Paper

- Use a household-level panel representative of maize farmers in Kenya's maize cultivating provinces and temperature disaggregated across different stages of the crop growth cycle
- Investigate how farmers adjust agricultural inputs within the growing season in response to temperature variation



Context

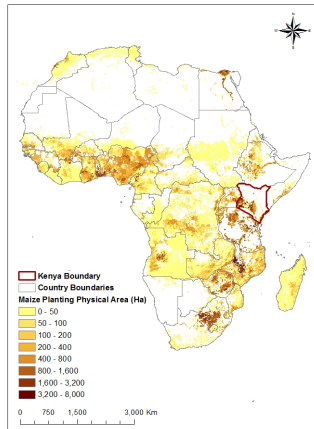
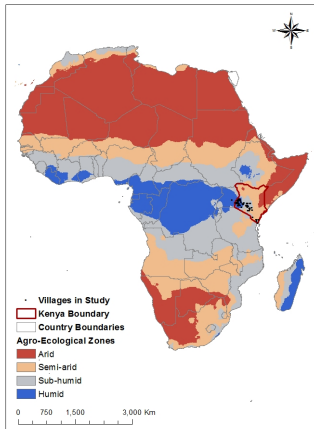
- **Daily average** temperatures in maize-growing regions of Kenya range from 12-29C
- Maize yields only decline above 29-30C (Lobell et al., 2011; Schlenker and Roberts, 2009)



- Any adverse yield effects in this context are almost surely result from indirect, biotic stresses arising from the temperature response of pests and pathogens

Context

Figure: Agro-Ecological Zones and Maize Production in Africa



Preview of Results

- We show that farmers respond promptly to temperature shocks
 - ▶ Result #1: Increase pesticide use in response to higher temperatures early in the growing season, responding to heat-induced increased biotic stress from diseases and pests that are most effectively addressed soon after emergence
 - ▶ Result #2: Increase household weeding effort throughout the season in response to higher temperatures that promote weed growth
 - ▶ Result #3: Reduce inorganic fertilizer use early in the growing season, contemporaneously with increased pesticide use; binding financial liquidity constraints plausibly induce trade-offs among input expenditures

Background: Temperature, Pests, Weeds and Pesticides

- Large body of evidence on the relationship between maize-specific pests and crop diseases, weeds, and temperature (e.g., Paul and Munkvold, 2005; Cairns et al., 2012; Dukes et al., 2009)
- Fungicide treatment for gray leaf spot, insecticide application for stem borers, and herbicides for weeds initiated early in the growing season (e.g., Ward, Laing and Rijkenberg, 1997; Orr, Mwale and Saiti, 2002; Gianessi, 2014)
- Effects on weeding labor might extend deeper into the growing season as labor inputs can be adjusted later in the growing season

Background: Fertilizer Use Under Financial Constraints

- Farmers facing binding financial constraint may reduce fertilizer use in favor of pesticides (e.g. Rosenzweig and Binswanger, 1993; Dercon and Christiaensen, 2011)
 - ▶ Warmer temperatures may increase risk of future harvest or induce input trade-offs due to liquidity constraints
- Moreover, like pesticides, fertilizer use decisions are likely influenced by temperatures during the early vegetative growth phase
 - ▶ Basal fertilizer is applied at planting; topdressing fertilizer is seldom applied if basal fertilizer is not applied
 - ▶ Kenyan agricultural markets are relatively well-developed compared to other countries in sub-Saharan Africa (Sheahan and Barrett, 2017); Kenyan farmers usually buy fertilizer just before applying it (Duflo, Kremer and Robinson, 2011)

Data

- Tegemeo Agricultural Monitoring and Policy Analysis Project (TAMPA)
 - ▶ Balanced panel of 1242 maize-growing households collected over five rounds: 1996-97, 1999-00, 2003-04, 2006-07, and 2009-10
 - ▶ Outcomes of interest: pesticide use, fertilizer use, and weeding labor
- Kenya Weather Data
 - ▶ Gridded and satellite data sets
 - ▶ Daily weather data at the village level: temperature, precipitation, relative humidity and soil moisture

Kenya Maize Calendar

- We use calendar for each agro-ecological zone (AEZ) in Kenya from the Food and Agriculture Organization (FAO)

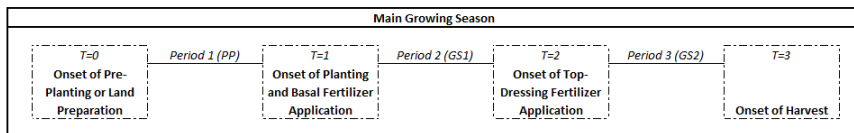


Table: Climate Change in Kenya?

	(1) Farmer Noticed Change in Temperature?	(2) Famer Affected by Changes in Temperature?
2009		
No	53.14	17.70
Yes	46.86	82.30

Notes: Sample includes 1242 households, balanced over 5 survey rounds, in the 2009-10 TAMPA survey.

Qualitative Evidence

Table: How was farming affected by this change in temperature?

	(1) Affected by Changes in Temperature, How?
2009	
Decline in Yields	44.68
Decrease in Land Quality	4.38
Difficult to Time Seasons	6.89
Increase in Yields	5.43
Other	1.88
Weeds/Pests/Diseases	36.74

Notes: Sample includes 1242 households, balanced over 5 survey rounds, in the 2009-10 TAMPA survey.

Table: Why Didn't You Use Fertilizer?

	(1) Why No Fertilizer?
2009	
Fertilizer Not Available	0.92
Lack of Advice	3.06
No Money/Too Expensive	57.80
No Need To Use Fertilizer	38.23

Notes: Sample includes 1242 households, balanced over 5 survey rounds, in the 2009-10 TAMPA survey.

Research Design

We estimate the following model:

$$Y_{ijqt} = \beta_1(GDD_{PP} > 21C)_{jqt} + \beta_2(GDD_{GS1} > 21C)_{jqt} + \beta_3(GDD_{GS2} > 21C)_{jqt} + f(Rain_{jqt}) + \alpha_i + \mu_{qt} + \varepsilon_{ijqt} \quad (1)$$

- Y_{ijqt} is outcome of interest, for household i in village j in province q in round t
- Fixed effects: village (α_j) and province-by-year (μ_{qt})
- Standard errors: clustered by village
- $(GDD > 21C)_{jqt}$ is the sum of degree days over 21C during each stage of the main growing season

Main Results

Table: Temperature, Fertilizer and Pesticide Use (Per Acre)

	(1) Pesticides 0/1 β / SE	(2) Ln Pesticide β / SE	(3) Fertilizer 0/1 β / SE	(4) Ln Fertilizer β / SE	(5) HH Weeding Days β / SE
CY PP DD >21C	0.0019 (0.0014)	0.0084 (0.0090)	-0.0003 (0.0005)	-0.0054 (0.0055)	0.0323** (0.0149)
CY GS1 DD >21C	0.0063** (0.0026)	0.0450*** (0.0159)	-0.0018** (0.0008)	-0.0180** (0.0087)	0.0375 (0.0271)
CY GS2 DD >21C	-0.0004 (0.0015)	-0.0108 (0.0079)	0.0003 (0.0004)	0.0005 (0.0044)	0.0392* (0.0219)
Village FE	Yes	Yes	Yes	Yes	Yes
Prov-by-Year FE	Yes	Yes	Yes	Yes	Yes
Rainfall Controls	Yes	Yes	Yes	Yes	Yes
Observations	3726	3726	6210	6210	3726
R ²	0.336	0.354	0.594	0.656	0.165

Notes: The table presents the effects of temperature (captured via degree days (DD) over 21C) on agricultural input use. CY: current year; PP: pre-planting or land preparation - onset of planting; GS1: planting or basal fertilizer application - onset of top dressing fertilizer; GS2: top dressing fertilizer application - onset harvest. Standard errors are in parentheses, clustered by village. *Significant at 10%. **Significant at 5%. ***Significant at 1%.

Robustness Checks

- District-by-year fixed effects
- Honoré semi parametric fixed effect tobit estimator (Honoré, 1992)
- Conley standard errors to reflect spatial dependence (Conley, 1999; Hsiang, 2010)
- Sensitivity to the choice of lower bound used to calculate cumulative degree days
- Accounting for within-day temperature variations (Snyder, 1985; Roberts, Schlenker and Eyer, 2013)
- Robust to inclusion of daily humidity and soil moisture

Heterogenous Effects - by Wealth

- Exploit exogenous changes in temperature over time across 'poor' and 'wealthy' households; average land ownership as a proxy for wealth
- Are households with different abilities to accommodate ex-ante risk or absorb income shocks (i.e., through higher wealth) differentially influenced by an increase in pest and disease pressure?
- Add an interaction term between degree days in each phase, and a 0-1 binary variable, where an household i take value 1 if average land holding for i is $< 33p$ (2.5 acres), 0 otherwise

Heterogenous Effects - by Wealth

Table: Pesticides, Weeding Labor and Fertilizer Use (Per Acre), by Wealth (Round 1-5)

	(1) Pesticides 0/1 β / SE	(2) Ln Pesticide β / SE	(3) Fertilizer 0/1 β / SE	(4) Ln Fertilizer β / SE
CY PP DD >21C	0.0026 (0.0017)	0.0126 (0.0111)	-0.0001 (0.0006)	-0.0035 (0.0062)
CY GS1 DD >21C	0.0071** (0.0031)	0.0496** (0.0190)	-0.0014 (0.0009)	-0.0155* (0.0092)
CY GS2 DD >21C	-0.0011 (0.0020)	-0.0142 (0.0114)	0.0003 (0.0004)	0.0013 (0.0044)
CY PP DD >21C*Bottom Wealth Tercile	-0.0015** (0.0006)	-0.0088** (0.0038)	-0.0006 (0.0004)	-0.0049 (0.0039)
CY GS1 DD >21C*Bottom Wealth Tercile	-0.0014 (0.0011)	-0.0073 (0.0077)	-0.0009 (0.0006)	-0.0058 (0.0057)
CY GS2 DD >21C*Bottom Wealth Tercile	0.0025 (0.0018)	0.0138 (0.0163)	-0.0001 (0.0008)	-0.0032 (0.0076)
Household FE	Yes	Yes	Yes	Yes
Prov-by-Year FE	Yes	Yes	Yes	Yes
Rainfall Controls	Yes	Yes	Yes	Yes
Observations	3726	3726	6210	6210
R ²	0.588	0.589	0.740	0.788

Notes: The table presents the heterogeneous effects of temperature (captured via degree days (DD) over 21C) on agricultural input use, by wealth. CY: current year; PP: pre-planting or land preparation - onset of planting; GS1: planting or basal fertilizer application - onset of top dressing fertilizer; GS2: top dressing fertilizer application - onset harvest. Average landholding of the 33rd percentile is 2.5 acres. Standard errors are in parentheses, clustered by village. *Significant at 10%. **Significant at 5%. ***Significant at 1%.

Conclusion

- We show that farmers in a low-income country can quickly adjust agricultural input use to within-season temperature variation
- Greater heat compels farmers to divert investment from productivity-enhancing technologies like fertilizer to adaptive, loss-reducing, defensive inputs like pesticides and weeding labor
- Warmer temperatures can affect agriculture due to temperature-induced biotic stresses even in regions where temperatures are not high enough to directly, adversely affect crop growth

Thank you!
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