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Climate variability and educational attainment: Evidence from rural Ethiopia

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Abstract

This paper examines the effects of climate variability on schooling outcomes in rural Ethiopia. Investments in education serve as an important pathway out of poverty, yet reduced agricultural productivity due to droughts or temperature shocks may affect educational attainment if children receive poorer nutrition during early childhood, are required to participate in household income generation during schooling ages, or if households can no longer pay for school-related expenses. We link longitudinal socioeconomic, demographic, and schooling data from the Ethiopian Rural Household Survey to high-resolution gridded climate data to measure exposure to temperature and precipitation relative to historical norms. We then estimate a set of multivariate regression models to understand how climate variability impacts grade attainment and school enrollment. Results indicate that early life climatic conditions – namely milder temperatures during all seasons and greater rainfall during the summer agricultural season – are associated with an increased likelihood of a child having completed any education. In addition, greater summer rainfall during both early life and school ages is associated with having completed any schooling as well as with attending school at the time of the survey. These findings suggest that future climate change may reduce children's school participation in rural Sub-Saharan Africa, slowing progress toward human development goals and poverty alleviation.

1. Introduction

Climate change can act as a barrier to development among rural populations in low- and middle-income countries. Environmental change impacts agricultural productivity, which in turn affects the ability for households to invest in human capital and improve living standards. Populations in sub-Saharan Africa are particularly vulnerable to climate variability, as over 60% of the workforce is employed in agriculture and 96% of cropland is rain-fed (FAO 2012; World Bank 2015b). Indeed, variations in rainfall and temperature have impacted agricultural output more so there than in other regions of the developing world (Barrios et al. 2008). Warming temperatures over the past several decades have been found to lead to large reductions in the yields of maize, wheat, sorghum, and barley (Lobell & Field 2007), and extreme heat waves are becoming more common in Africa (Russo et al.

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2016). Future temperature increases and precipitation changes are predicted to reduce crop productivity, particularly in semi-arid regions (Niang et al. 2014; Schlenker and Lobell 2010). This is especially relevant among the extreme poor, who tend to live on smaller or more marginal plots of land. These households may be caught in what Barrett (2008) terms a “resource degradation poverty trap” – persisting at low levels of human development and unable to invest in additional income producing activities (e.g. irrigation technologies, machinery, or small businesses) or in human capital (e.g. paying school fees, accessing healthcare, or purchasing nutritional foods).

Investments in human capital – particularly education – serve as an important pathway out of poverty by expanding skills and labor market opportunities. Lack of access to schooling has impeded development in many low-income nations. In response, the United Nations aimed one of its eight Millennium Development Goals (MDGs) at achieving universal primary school education by 2015. Though great progress has been made since the adoption of the MDGs in 2000, 20% of primary school-aged children in sub-Saharan Africa remained out of school as of 2015 (United Nations 2015). These children may have never begun their schooling or may have dropped out before completing primary school. In addition, among those in school, many children are not in the appropriate grade for their age due to late entry as well as interruptions in school attendance (Lewin 2009). One important factor keeping rural children out of school is the demand for child labor, including assisting adult household members with agricultural activities, helping with other income generating activities, and performing domestic tasks (Abebe 2007; Admassie 2003; Cockburn & Dostie 2007; Haile & Haile 2012; Psacharopoulos 1997). Additional factors that affect school attendance in rural sub-Saharan Africa include poverty, gender norms, and food insecurity (Belachew et al. 2011; Hunt 2008; Lewin 2009; Mani et al. 2013). Despite falling short of their MDG schooling goals, the United Nations recently released a set of more ambitious Sustainable Development Goals (SDGs), one of which aims to achieve universal primary and secondary attainment by 2030 (United Nations 2016).

Both environmental change and the lack of access to schooling are linked to the ability for agricultural households to improve living standards, and lower educational attainment could represent an important and unexplored pathway by which future climate change undermines gains in human development. However, research on the relationship between environmental conditions and schooling remains limited. The goal of this paper is to examine the intersection between environmental change and education by studying how temperature and precipitation variability impact schooling outcomes in rural Ethiopia. Ethiopia is particularly vulnerable to the effects of changes in temperature and precipitation, as 84% of the population lives in rural areas, 42% of the country’s GDP is derived from agriculture, and only 3% of agricultural land is irrigated (Dorosh & Schmidt 2010; World Bank 2016; FAO 2011). In order to examine the relationship between climate and schooling in Ethiopia, we ask whether climate variability impacts schooling outcomes among children from rural agricultural households. Our paper offers new insights into the social impacts of global environmental change in sub-Saharan Africa, which can inform policies that address education, socioeconomic development, and poverty reduction in the face of increasing environmental variability.

2. Climate Shocks and Educational Outcomes in Developing Countries

Research on the links between climatic conditions and educational outcomes is limited, and the findings are mixed. One set of studies examines how shocks experienced during school ages impact education. Björkman-Nyqvist (2013) found that in Uganda, negative rainfall shocks in the year of the survey led to lower primary school enrollment among older girls. She finds no evidence that boys' or younger girls' enrollment is affected by rainfall shocks and attributes this to the fact that older females play a more important role in household labor during periods of stress than other children. In contrast, Mani et al. (2013) discovered that in rural Ethiopia, *higher* rainfall during the year of the survey was negatively correlated with enrollment and grade attainment for males relative to females, as male children are often pulled out of school to assist with farm labor. Similarly, Shah & Steinberg (2013) found that in India, children who experienced positive rainfall shocks in the year prior to the survey were more likely to drop out of school than those who experienced drought. The authors argued that positive shocks led to higher agricultural productivity, and therefore during these periods the returns to labor among children were higher than the returns to schooling.

Further, a study in Tanzania found that children from households who experienced severe crop loss increased their labor by 30% and were twenty percentage points less likely to be enrolled in school, but that wealthier households were buffered from these effects (Beegle et al. 2006). Lastly, a study in Honduras examined the impacts of Hurricane Mitch on secondary school attainment and found that children from credit-constrained households impacted by the hurricane experienced lower attainment (Gitter & Barham 2007). These studies indicate that the demand for child labor among agricultural households is an important determinant of educational outcomes, but that the effect of rainfall shocks may vary based on individual- and household-level characteristics as well as the cultural, environmental, and economic context in which the household operates.

Other studies have examined the relationship between shocks experienced in utero or infancy and educational outcomes in later childhood and adulthood. A study in Burkina Faso found that negative rainfall shocks in utero and before age two were negatively correlated with cognitive ability and school enrollment, and were positively correlated with child labor (Akresh et al. 2012). Likewise, in Indonesia, rainfall shocks during the year of birth were found to impact women's educational attainment in adulthood (Maccini & Yang 2009). In addition, children exposed to El Niño floods in Ecuador in utero, particularly during the first trimester, scored lower on cognitive tests five to seven years later (Rosales-Rueda 2014). Lastly, Shah & Steinberg (2013) found that in India, exposure to drought in utero and during the first few years of life led to lower cognitive abilities and lower likelihood of school enrollment. These findings suggest that lower agricultural output during periods of rainfall shocks is associated with decreased health and nutrition among pregnant mothers and infants, and therefore with lower levels of biological human capital among exposed children. This supports the argument by Alderman (2011) that the physical, cognitive, and socio-emotional effects of shocks in early childhood act as key determinants of future life outcomes.

We build on this emerging literature in three primary ways. First, while most prior studies focus solely on rainfall, we examine both rainfall and temperature. Because fluctuations in both temperature and precipitation due to climate change are expected to affect agricultural productivity in sub-Saharan Africa (Niang et al. 2014; Schlenker and Lobell 2010), examining the effects of precipitation alone does not provide a comprehensive picture of the impacts of climate change. Second, we look at climate over the first seven years of a child's life instead of studying only discrete shocks or climatic conditions experienced during the year of or year prior to the survey. Early childhood is a critical period for physical and cognitive development and is the time of life before formal schooling begins in Ethiopia. In addition, because climate change is a decadal process, we measure climate as deviations from long-term historical conditions, which may serve as a better proxy for understanding how climate change may impact educational outcomes in the future. Lastly, given the gendered nature of child labor in Ethiopia (Abebe 2007; Haile & Haile 2012; Rose & Al-Samarrai 2001) and the results of prior studies on the differential effects of climate on girls' and boys' schooling outcomes (Björkman-Nyqvist 2013; Mani et al. 2013), we examine the interactions between climatic conditions and the child's sex to determine whether climate variability impacts girls and boys differently.

3. The Ethiopian Context

Ethiopia is a low-income country in which 61% of rural primary school-aged children attend school (World Bank 2015a). Primary school runs for eight years from ages seven to 14, though many children do not begin their schooling on time. Secondary school consists of two two-year cycles, from ages 15 to 16 and 17 to 18 (Ministry of Education 2011). The Ethiopia Rural Socioeconomic Survey, a nationally-representative study of rural areas and small towns, found that among rural children aged seven to 18, primary school enrollment was 57% for boys and 59% for girls, and secondary school enrollment was approximately 2.5% for both boys and girls (CSA & The World Bank 2013). Among enrolled students, 55% of those who missed classes for more than a week reported work as a reason (CSA & The World Bank 2013). Other barriers to attending school in Ethiopia include insufficient money to pay for the school-related expenses, low parental educational attainment, and poor health of the child (Rose & Al-Samarrai 2001).

In rural Ethiopia, children begin participating in work activities as early as four years old (Haile & Haile 2012). According to Ethiopia's National Labour Force Survey, 71% of rural children aged 10–14 are employed, and the mean number of hours worked per week is 28 (32 for boys and 23 for girls) (CSA 2014). Studies have found gendered patterns of child labor in the country. Girls are more likely to perform domestic tasks such as preparing food, gathering water and firewood, and caring for siblings, while boys are more likely to engage in income-generating activities such as working on the farm (Abebe 2007; Haile & Haile 2012; Rose & Al-Samarrai 2001). In addition, Orkin (2012) found that in rural parts of the country, work and school often compete for children's time. For example, the schooling schedule frequently overlaps with the times that children participate in work, household chores and studying occur during the same time periods, and certain types of work cannot be divided into small chunks of time in order for the child to also attend school.

Agriculture in Ethiopia is dominated by smallholder farmers, as approximately 12 million smallholder households produce 95% of the country's agricultural products and account for 85% of the country's employment (FAO 2011). Ninety-three percent of rural households practice agriculture, and the average land area owned is 1.37 hectares (CSA & The World Bank 2013). Ethiopia's main crops are cereals including teff, maize, sorghum, barley, and wheat (Evangelista et al. 2013), though perennials such as coffee, chat, and enset are important in wetter regions of the country. Ninety-two percent of rural households own livestock, and livestock production accounts for 32% of the country's agricultural GDP (FAO 2011; CSA & The World Bank 2013). In addition to agriculture, approximately 20% of rural households own small businesses including shops, sell processed agricultural products (e.g. flour or local beer), trade products in the market, or sell firewood (CSA & The World Bank 2013).

Ethiopia's climate varies from tropical rainy to desert, with mean annual rainfall ranging from 300 mm in lowland arid regions to 2,000 mm in the highlands (Viste et al. 2013). There are two rainy seasons in the country – the primary summer *Kiremt* season, which typically lasts from June to September, and the secondary spring *Belg* season, which typically runs from February/March to May (Seleshi & Zanke 2004). The dry winter *Bega* season lasts from October to December/January. Crops grown during the summer season are harvested between September and December and account for 90–95% of total annual production, while crops grown during the spring season account for 5–10% of production (Bezabih & Di Falco 2012). The timing and amount of rainfall during the *Kiremt* growing season are therefore critical for crop production (Araya & Stroosnijder 2011). Climatic conditions during the *Bega* dry season can also affect production, as excessive rain may lead to crop diseases such as powdery mildew (Evangelista et al. 2013), and frost due to cold weather may damage crops in high altitude areas (Bevan & Pankhurst 1996).

The country suffers from periodic droughts and dry spells, with extreme geographical variation in the timing and severity of droughts. Widespread droughts occurred in most regions of the country in 1984, 1991, 2002, and 2009, and years in which some areas of the country experienced drought conditions include 1972–75, 1980–82, 1987, 1990, 1992, 1999–2000, 2003, 2008, and 2010 (Viste et al. 2013). Droughts such as these have important impacts on the health and well-being of affected communities. For example, the most severe negative rainfall shocks led to a reduction in household consumption by 7% to 25% (Porter 2012), and households who experienced lower levels of rainfall and higher rainfall variability were more likely to experience persistent food insecurity (Demeke et al. 2011). Southern Ethiopia has undergone a drying trend over the past 40 years, though no clear trend has emerged for central or northern Ethiopia (Viste et al. 2013). In addition, cool nighttime temperatures in highland Ethiopia are crucial for staple crop production, as they slow evaporation and enable a longer time period for crop development. Surface air temperature has been increasing by approximately 0.03˚C per year since 1948 in most of the country (Jury & Funk 2013).

Climate projections for Ethiopia predict warming temperatures in all four seasons with an annual warming of 2.2˚C by the 2050s (Conway & Schipper 2011). This will lead to a greater frequency of heat waves and to higher levels of evaporation. Climate model predictions for rainfall are less consistent, with some predicting drier conditions and others wetter conditions (Conway & Schipper 2011). Regarding the impacts of climate change on agriculture, even conservative emissions scenarios predict significant reductions in agricultural production (Evangelista et al. 2013). By 2050 the suitable land area for teff is expected to decrease by between 6% and 18% and the range for barley is expected to decrease by 21% to 49%. In addition, Seo, Mendelsohn, and Dinar (2009) find negative effects of increasing temperature and mixed effects of precipitation change on agricultural revenues in all of Ethiopia's agro-ecological zones.

4. Conceptual Model

Figure 1 presents a conceptual model of the relationship between environmental change, agricultural production, and educational attainment for children living in farming households. Changing environmental conditions (e.g. fluctuations in temperature and precipitation or soil degradation) affect agricultural households by impacting agricultural productivity, which in turn impacts household income. In response to negative income shocks, households may undertake a number of adaptation measures that influence schooling outcomes. On the one hand, households may reduce expenditures by changing food consumption habits, delaying health-seeking behaviors, or pulling children out of school due to the inability to pay for school fees and materials. On the other hand, households may generate additional income through involving children in agricultural labor or in non-farm livelihood diversification strategies (e.g. selling charcoal or panning for gold). An alternative outcome is that in times of reduced agricultural productivity, the returns to child labor are lower than the returns to schooling, and therefore children may be more likely to remain in school.

The impact of environmental change on agricultural income is also mediated by micro-level characteristics (e.g., wealth, use of drought-resistant crops, and social networks) as well as macro-level factors (e.g., producer food prices, government safety net programs, and crop insurance programs). Further, decisions on expenditures and income generation strategies are affected by non-climatic factors such as the sex of the child, current levels of income diversification, and local and distant labor market opportunities. Lastly, educational outcomes are also affected by non-climatic factors such as distance to schools, schooling costs, and the implementation of policies and programs to increase school attendance.

5. Data Collection and Study Area

This paper uses household survey data from the Ethiopian Rural Household Survey (ERHS), a large panel dataset collected from rural villages in Ethiopia. The ERHS was conducted with approximately 1,500 households in 15 Ethiopian villages in 1994, 1995, 1997, 1999, 2004, and 2009 (Dercon & Hoddinott 2009). Data were collected by Addis Ababa University, the International Food Policy Research Institute (IFPRI), and the University of Oxford and are publicly available. Figure 2 displays the locations of the 15 villages, which were selected in order to represent Ethiopia's varied agro-ecological zones. The sample includes the country's main farming systems as of 1994, but cannot be considered nationally representative as it does not include pastoralists or urban residents (Dercon et al. 2005).

Within each study village, households were selected using a stratified random sampling method and linked across rounds based on the residence of the male household head or the residence of the majority of household members if the male head was absent (Dercon & Hoddinott 2009). The survey collected household-level data on demographic and socioeconomic characteristics, agriculture and livestock, health, and women and children's activities, as well as community-level data in 1997, 2004, and 2009 on topics including electricity and water, road quality, education, and health services (Dercon & Hoddinott 2009). The attrition rate at the household level is low, with 1.3% of households per year lost between 1994 and 2004 (Dercon & Hoddinott 2009).

The study villages range in elevation from 1200 to 2900 m, mean annual rainfall ranges from 470 to 1300 mm, and rainfall is highly seasonal (Gray & Mueller 2012). The majority of study households rely on smallholder agriculture as their primary source of income. Households in drier areas harvest primarily grains (e.g. teff, sorghum, wheat, and maize), while those in wetter climates rely primarily on perennials including coffee, chat, and enset (false banana) (Dercon & Hoddinott 2009). The study villages are characterized by high levels of poverty, though there have been major improvements in access to services in recent years. In 1997, among the fifteen study villages, one had access to electricity, two had access to piped water, and five contained no primary school. By 2009, ten of the communities had access to electricity, five had access to piped water, and only one community did not contain a primary school. Educational attainment has improved dramatically in the communities. In 1994, 62% of children aged 12 to 16 had no formal schooling, while by 2009 only 12% had never attended school. Despite these improvements, levels of poverty and food insecurity remain high. For example, in 2009, 52% of the households reported not being able to satisfy their food needs for at least three months during the year prior to the survey.

6. Analysis

6.1 Climate data

Data on temperature and precipitation were derived from the Climate Research Unit (CRU) Time Series (Harris et al. 2014). CRU provides monthly gridded mean temperature and precipitation data with a resolution of 0.5˚ latitude by 0.5˚ longitude. The CRU dataset was created by interpolating weather station data from over 4,000 stations throughout the world, and these data are considered reliable sources of climate information for sub-Saharan Africa (Zhang et al. 2013). We linked precipitation and temperature data to the survey data at the village level using Global Positioning System points collected in the field, and then used these data to generate measures of temperature and precipitation variability at the village-year scale. Figure 3 presents climate data for the study villages from 1970 to 2009. The top two panels display average monthly rainfall and temperature data. There is considerable rainfall variation between villages, with many villages experiencing one primary rainy season between June and September and others experiencing a short spring rainy season and a longer summer rainy season. Temperatures in the study villages are generally highest during the summer months and lowest during the winter months. The bottom two panels of Figure 3 present total annual rainfall and mean annual temperatures over the 40-year timespan. Rainfall is highly variable, with observable drought years occurring in 1984 and

2002, for example. Average annual temperatures exhibit a clear warming trend over the time period.

Our main measures of climate variability are temperature (˚C) and rainfall (mm/month) relative to a 1970–2009 reference period for the three main seasons: spring rainy season (*Belg)* from February to May, summer rainy season (*Kiremt)* from June to September, and winter dry season (*Bega)* from October to January. To generate these measures, we took the mean climate values for each season across years zero to six of life, where the year of birth was considered to be year zero. These mean values were then transformed into z-scores relative to all other consecutive periods from the same season of the same duration from 1970–2009. The early childhood z-score is therefore an indication of how different the seasonal climate was during the first seven years of a child's life versus the historical seasonal climate in the child's village. In addition, for supplementary specifications we created two additional variability measures: mean seasonal z-scores during school ages (age seven to current age) and z-scores in utero (the year before birth). Alternate climate measures include shock variables that counted the number of extreme springs, summers, and winters the child experienced during early childhood (hot, cold, wet, and dry). All are defined as a seasonal z-score greater than one (hot and wet) or less than negative one (cold and dry). Studies of drought define moderate droughts as a z-score between −1.00 and −1.49, severe droughts as a z-score between −1.50 and −1.99, and extreme droughts as a z-score less than −2.00 (Gebrehiwot et al. 2011; Dogan et al. 2012; Jain et al. 2015). We therefore use −1 and +1 as our cutoffs for temperature and precipitation shocks.

6.2 Household survey data

We use data from the 1994, 1999, 2004, and 2009 rounds of the ERHS for the analysis. The analytical sample includes children aged 12 to 16 at the time of the survey who were either children or grandchildren of the household head. This captures children during late primary school ages (12 to 14) and early secondary school ages (15 to 16). Prior research in the study villages has found that the majority of out-migration occurs among individuals aged 15 to 39 (Gray & Mueller 2012), so examining children aged 12 to 16 captures an age range prior to when most children begin leaving the household. Each child should appear in the dataset only once, as they should only be within the sample ages during one of the four survey rounds. In order to account for duplicate appearances due to the misreporting of ages for children who were surveyed in multiple rounds, we performed an age-correction procedure, as described below.

To correct for age misreporting, we first created a dataset to include individuals aged 0 to 31 in order to capture multiple appearances of the same individuals across multiple rounds. We then linked individuals across rounds using a within-household ID-sex match and created a mean birth year that averaged the birth year for the individual across rounds. Next we created a birth year error variable (birth year at round *n* minus mean birth year) and dropped individuals in which the birth year error was greater than ±2 years. For the remaining individuals, we used the mean birth year variable to create a corrected age, and extracted all 12 to 16 year olds using this corrected age variable. Approximately 48% of the final survey sample consisted of individuals with corrected ages.

The primary outcome variables are whether the child completed at least one grade of schooling (35% of children had zero grades of completed schooling) and whether the child attended school during the year of the survey (57% were attending). In addition, we created a categorical variable for schooling outcomes: no schooling completed, one to four grades completed, and five to 12 grades completed. To account for other factors that may influence educational outcomes, we included a number of control variables at the individual and household levels measured at the time of survey, shown in Table 1. These variables include relationship to the household head (child or grandchild), dummy variables for the child's year of age, the number of children aged zero to six in the household, the number of children aged seven to 18 in the household, age of the household head, whether the household head had any formal schooling, and land area owned by the household in hectares. Because land ownership was highly skewed, we transformed this variable in our models by taking the natural log of (land area + 1).

For the 1999, 2004, and 2009 survey rounds, children who entered the household since the prior round were considered new household members. Because they entered the household within five years of the survey, these children may have only been exposed to local climatic conditions for a short period of time. We therefore exclude the new members from our analysis. In addition, 41 households had missing values for land area. For these households, we averaged their land area from the other survey rounds and imputed that value. We include an indicator for interpolation in the regression, but do not display the results as they are non-informative. For individuals with missing data on sex, household head's educational attainment, or household head's age we extracted data from other survey rounds when possible. This left 32 individuals with missing data on educational attainment, sex, household head's educational attainment, and/or household head's age, who we excluded from the analysis. Excluding these individuals as well as those with missing data on outcome or control variables leaves us with an analytic sample of 3,336 individuals (1,720 boys and 1,616 girls) from 1,227 households.

6.3 Regression models

In order to understand the effects of precipitation and temperature variability on educational attainment, we estimated a set of binary logistic regression models predicting the likelihood of having completed at least one grade of schooling and separately the likelihood of attending school during the year of the survey. The primary predictors were seasonal climatic conditions during early childhood. In order to account for underlying differences in educational outcomes between communities and across time, we include both community and survey year fixed-effects in the models, which account for all time-invariant factors at the community level and all time-varying factors at the national level as long as these effects are linear. In addition, we include corrections for clustering at the community level to account for non-independence among households in the same community. Because we include community and survey year fixed-effects in the models, the results can be interpreted as comparing the effect of the predictors on two individuals living in the same community at the same time. In addition, we estimated a multinomial logistic regression model with three outcomes: no schooling completed, between one and four grades completed, and between five and 12 grades completed.

In addition, we subjected the results of our primary models to two robustness checks. The first excluded all children with a birth year error greater than ±1 year and results were consistent. The second excluded children who may have migrated to the study villages after birth. We excluded all children for which the original household head in the 1994 survey arrived in the study village after 1977 (the year before which the oldest children in the sample were born) and results were also consistent.

In order to shed light on mechanisms underlying the relationship between climate variability and educational outcomes, we estimated a supplementary set of models predicting per capita food consumption, food insecurity during the rainy season, crop yields, and child labor, as a function of climate from the year prior plus controls (see Appendix Table 1 for descriptive statistics of all supplementary predictor and outcome variables). The sample for these analyses includes one observation per household-survey round for all households with children in the sample. Households may appear more than once if children appear in multiple survey rounds. The crop data refer primarily to crops grown during the summer rainy season and harvested in October and November of the year prior to the survey. We use ordinary least squares (OLS) regression to estimate yields (kg/hectare) of teff, barley, maize, and wheat (the most commonly grown crops among the study households) based on temperature and precipitation during these two seasons. The majority of household surveys were conducted between March and September, and therefore in the food consumption and child labor models we use climate data from the current spring as well as the prior winter and summer. For these analyses, climate variables were defined as z-scores for climate during these specific seasons (from the survey year and year prior as indicated) relative to all other periods from the same season from 1970–2009. Per capita food consumption consists of all food consumed in the week prior to the survey, scaled to a month and then divided by the number of household members. Data on child labor include whether or not the child typically participated in farm and domestic labor, as well as the hours per week spent on those activities. Child labor data were only collected in the 2004 and 2009 surveys. In 2004, the majority of households were surveyed in April and May, and in 2009 the majority were surveyed in May and June. Fifty-seven percent of children participated in farm labor averaging 22 hours per week, and 81% of children participated in domestic labor averaging 20 hours per week.

7. Results

Model 1 in Table 2 presents results from a logistic regression of the likelihood of completing at least one grade of school. We find that early life climatic conditions are important determinants of schooling. A child who experienced average spring temperatures 0.5 standard deviations (SD) above the village's long-term mean has a 21% lower odds of completing at least one grade of school (p=0.049) (a SD of 0.5 is within the sample range for all of the climate variables). Similarly, experiencing summer temperatures 0.5 SD above the village long-term average is associated with a 28% lower odds of completing any schooling (p=0.001), and experiencing summer precipitation 0.5 SD above the mean is associated with a 22% higher odds (p=0.050). Lastly, experiencing average early childhood winter temperatures 0.5 SD above the village long-term mean is associated with an 43% higher odds of any schooling (p=0.016). These results suggest that mild temperatures (warmer winters and cooler springs and summers) as well as greater precipitation during the summer agricultural season play a key role in predicting future school attendance. Model 2 adds interactions between sex and climatic conditions, and we find that the effects of climate on completing any schooling does not differ by sex.

Model 3 presents results from a logit model of the likelihood of attending school during the year of the survey. Children who experienced average early life summer rainfall 0.5 SD above the village long-term average have a 45% higher odds of attending school (p=0.011). This is consistent with Model 1, providing further evidence that precipitation during the *Kiremt* growing season is an important predictor of future schooling outcomes. When sex interactions are added in Model 4, we find that females are marginally significantly more likely to be enrolled in school if they experienced warmer winters during early childhood, but there is no relationship between winter temperatures and school attendance for males. Regarding the control variables, the results are consistent with expectations. Females, individuals with older household heads, and individuals for whom the household head has no formal schooling are less likely to have completed any schooling. In addition, females, 16 year olds, individuals from households with older heads, and those from female-headed households are less likely to attend school. Lastly, having more children aged 7–18 in the household and having a household head who has completed any formal schooling are positively associated with school attendance.

Table 3 presents the results from models using alternative specifications. Model 5 presents estimates from a multinomial logit model predicting the likelihood of having completed either between one and four grades of schooling or between five and 12 grades versus no schooling. Similar to the results of Model 1, the likelihood of having completed between one and four grades is positively associated with summer rainfall and winter temperatures, and is negatively associated with spring and summer temperatures during early childhood. Completion of between five and 12 grades is positively associated with spring precipitation and winter temperatures and is negatively associated with summer temperatures. These results suggest that summer climate during the main growing season is particularly important for completion of early primary schooling.

Models 6 and 7 examine climate variation during three life periods: school ages, early childhood, and the year before birth. Consistent with Models 1 and 2, we find that climate during early childhood is the most important period for predicting whether the child has completed any schooling. In addition, greater summer precipitation during school ages is positively correlated with completing at least one grade. We do not find a significant relationship between prenatal climatic conditions and any schooling. With regard to school attendance, greater summer precipitation during both school ages and early childhood, and less winter precipitation during the prenatal period, are positively associated with school attendance during the year of the survey. These findings suggest that climatic effects on child health and development during early childhood play the strongest role in determining schooling outcomes, and that summer rainfall during school ages is also important.

Models 8 and 9 examine the relationship between the number of climatic shocks experienced in early childhood and schooling outcomes. Consistent with Model 1, we find that with each additional summer drought experienced by a child in early childhood, he or she has a 16% lower odds of having completed any schooling. In addition, with each hot winter experienced, the odds of completion increase by 32%. This indicates that droughts during the main agricultural season and warm temperatures during winter (when crops in some villages risk damage due to frost and mildew) play a key role in future schooling outcomes. In addition, the number of cold springs experienced in early childhood has a marginally positive effect on having any schooling. Regarding the likelihood of school attendance during the year of the survey, the number of cold springs and spring droughts experienced during early childhood both significantly increase attendance.

In order to begin to uncover the mechanisms underlying the relationships between climatic conditions and education, we present a number of supplementary models in Tables 4 and 5. The first model in Table 4 presents the results of an OLS regression on the relationship between recent climatic conditions and per capita food consumption. We find that experiencing a hotter spring in the year of the survey is associated with lower food consumption. While the other climate variables are not significant, they are all in the expected directions, and taken together these results suggest that warmer and drier springs and summers may lead to lower household food availability. The second model presents results from a logit model predicting the likelihood of experiencing food shortages during the prior rainy season, based on climatic conditions during that season. We find that households that experienced *Kiremt* temperatures 0.5 SD above the village long-term mean have a 25% greater odds of rainy season food insecurity (p=0.008). Greater rainfall during the prior summer is negatively associated with food insecurity, though the relationship is not statistically significant. These results indicate that both hot springs and summers play a key role in reducing food availability among the study households.

The additional models in Table 4 examine the relationships between climate during the prior growing season (summer) and harvesting season (winter) and crop yields for sample households that grew each crop. For teff – the most commonly grown crop among study households – hotter summers are associated with lower yields, and for wheat, greater winter precipitation is associated with higher yields. Wetter summers are associated with higher yields of all four cereal crops, though these relationships are not statistically significant. While data limitations do not allow us to draw strong conclusions on the relationship between climate and crop production among the study households, the results provide evidence that hot summers reduce agricultural production for teff. In addition, results suggest that more rainfall during the *Kiremt* growing season is beneficial for cereal crop yields.

Table 5 presents results on the relationship between recent climatic conditions and child labor. Consistent with the literature (Abebe 2007; Haile & Haile 2012; Rose & Al-Samarrai 2001), we see that females are less likely to engage in farm labor and more likely to engage in domestic labor than males. Further the number of hours spent on both farm and domestic labor is negatively correlated with the likelihood of attending school. With regard to climate, we find that experiencing higher precipitation during the prior summer is associated with a lower likelihood of engaging in farm labor among boys. This result provides important insight into the relationship between higher summer precipitation and a greater likelihood of having completed any schooling as well as attendance during the year of the survey. More rainfall during the summer growing season is likely associated with higher crop productivity, which reduces the need for male children to participate in income generation activities and thereby enables them to remain in school. When sex-climate interactions are added, we discover that females are less likely to engage in farm labor if they experienced a warmer spring, and are marginally more likely if they experienced a wetter spring. Cool, wet springs may encourage the planting of *Belg* crops, necessitating help from girls in the household. Regarding hours typically spent per week on farm labor, greater spring precipitation is correlated with fewer hours of labor among both males and females. The net effect is a nonlinear effect of spring precipitation on farm labor by girls, and a negative effect on boys.

For both males and females, hotter springs and drier winters are associated with a lower likelihood of engaging in domestic labor. In addition, hotter summers and warmer winters are marginally associated with a lower likelihood of domestic labor among both sexes and among females, respectively. Further, experiencing greater winter and spring precipitation is associated with performing fewer hours of domestic labor. When sex-climate interactions are added, we see that there is no relationship between climate and hours of domestic labor among males. For females, more summer precipitation is associated with fewer hours of domestic labor, and hotter summers and springs are marginally associated with greater hours of domestic labor. This finding suggests that during hotter, drier summers and springs, girls may be needed more for domestic tasks as other family members spend more time on income generation activities due to less ideal growing conditions. Warm, dry winters may increase domestic labor in agricultural processing as this is the main harvest season.

8. Discussion and Conclusions

Taken together, these findings indicate that climate variability is an important determinant of schooling outcomes among children from agricultural households in Ethiopia. Early life climatic conditions – namely milder temperatures during all seasons and greater rainfall during the summer *Kiremt* agricultural season – are associated with an increased likelihood of a child having completed any education. In addition, greater summer rainfall during both early life and school ages is associated with having completing any schooling as well as with attending school during the year of the survey. Further, with each additional summer drought a child experiences in early childhood, he or she has a 16% lower odds of having completed any schooling.

Our findings suggest that multiple pathways may underlie the relationship between climate and schooling. Adverse climatic conditions (hot springs and summers, dry summers, and cold winters) may reduce agricultural productivity, which lowers household income as well as food availability. Indeed, we find links between hot springs and/or summers and lower food consumption, greater food insecurity, and lower teff yields among our study households. Early childhood is a critical period for physical and cognitive development (Alderman 2011), and therefore children experiencing poorer climatic conditions during this period of life may form lower levels of biological human capital due to decreased nutrition and healthcare access. Indeed, studies have discovered important links between climatic conditions and health at birth and in early childhood (e.g., Grace et al. 2012; Grace et al.

2015; Hoddinott & Kinsey 2001; Kumar et al. 2016). Further, research on rainfall and education has found that children exposed to precipitation shocks in utero and early childhood had lower educational attainment and cognitive abilities later in life (Akresh et al. 2012; Maccini & Yang 2009; Rosales-Rueda 2014; Shah & Steinberg 2013). Our findings suggest that adverse climatic conditions during early childhood deplete individual and/or household capital, potentially including biological human capital, and thereby undermine future educational outcomes.

In addition, we discover that greater summer precipitation during school ages is linked to positive educational outcomes. Two pathways may underlie this relationship. The first is between rainfall during the primary *Kiremt* growing season, agricultural production and income, and the demand for child labor to assist with household income generation and domestic activities. We find that higher precipitation during the summer prior to the survey is associated with a lower likelihood of participating in farm labor among males and with fewer hours of domestic labor among girls. This pathway supports findings that school and labor compete for a child's time (Orkin 2012) and that a lack of rainfall may lead children to spend more time on farm and domestic labor and less on schooling, as households face stresses on income generation and food security. Another potential pathway underlying the relationship between summer precipitation during school ages and educational outcomes is one between rainfall during the primary *Kiremt* growing season, agricultural production and income, and the ability for households to pay for school fees. Lower agricultural income as a result of summer droughts may force households to pull children out of school in order to reduce expenditures.

These findings indicate that among the rural poor in sub-Saharan Africa, future climate change may act as a key barrier to children's school participation. Experiencing a greater frequency of droughts and heat waves during the most important seasons for agricultural production could slow progress toward human development goals and poverty alleviation in the region. Yet we also find that warmer winters during early childhood are associated with positive schooling outcomes in rural Ethiopia. In contrast to the dominant narrative that tends to view warming temperatures as universally negative in this region of the world, our results suggest that warming during winter – particularly in highland regions that are vulnerable to frost – may actually benefit agricultural households. A nuanced understanding of how both temperature and precipitation changes affect households in different agro-ecological zones is therefore a key step towards holistically understanding the relationship between climatic change, agriculture, and education. In addition, this study shows that an opportunity exists for future research to examine socio-environmental outcomes of climate change outside of its effects on agriculture, migration, and conflict, which have been the focus of much of the climate vulnerability literature. A greater understanding of the relationship between climate change and topics such as education, health, gender, food security, and livelihood diversification will greatly enhance our knowledge of the feedbacks between climate, environment, and society.

It is also important to consider the role of education in the short-term adaptive capacity to climate change. Adaptive capacity – the resources and assets available from which adaptation decisions can be made – is key in reducing vulnerability to climate change

(Adger & Vincent 2005). On the one hand, pulling children out of school to assist with on-farm labor or other forms of income generation may improve short-term household adaptive capacity by increasing income and food security. On the other hand, achieving higher education may improve the ability for households to adapt agricultural practices and non-agricultural income generation activities to changing climatic conditions. Asfaw & Admassie (2004) found that greater education among adult household members in Ethiopia was associated with the adoption of chemical fertilizer use, which increases agricultural productivity. This suggests that higher educational attainment may improve adaptive capacity among agricultural households. Education may therefore serve as a key element of adaptive capacity in rural Ethiopia and other environmentally vulnerable regions.

Lastly, our findings suggest that policies to buffer against the economic and health impacts of climate change will better enable households to keep their children in school, and will protect them from the negative socioeconomic impacts of a changing climate. Examples of programs and policies that could safeguard rural households against unfavorable climatic conditions include crop insurance programs, the provision of drought and heat tolerant crop varieties, and the reduction or elimination of school fees. Future research is needed to better understand which pathways between climate variability and educational outcomes are most important in different geographic, agro-ecological, and social contexts. This will help to inform the development of effective policies to achieve the goal of universal primary and secondary education in the face of climate change.

Appendix Table 1.

Descriptive statistics for variables used in supplementary regression analyses

	Unit	Level	Mean	Min	Max
Schooling outcomes					
Completed between 1 and 4 grades	0/1	Individual	0.43	-	-
Completed between 5 and 12 grades	0/1	Individual	0.22	-	-
Climate variables					
Spring temperatures - school ages	z-score	Community	0.20	−0.71	0.97
Spring precipitation - school ages	z-score	Community	−0.16	−1.22	0.80
Summer temperatures - school ages	z-score	Community	0.53	−0.55	1.31
Summer precipitation - school ages	z-score	Community	0.06	−0.69	0.98
Winter temperatures - school ages	z-score	Community	0.17	−0.76	0.97
Winter precipitation - school ages	z-score	Community	0.18	−0.57	0.95
Spring temperatures - prenatal	z-score	Community	−0.12	−2.49	2.56
Spring precipitation - prenatal	z-score	Community	0.35	−1.79	3.73
Summer temperatures - prenatal	z-score	Community	−0.17	−2.16	1.69
Summer precipitation - prenatal	z-score	Community	−0.27	−2.35	2.83
Winter temperatures - prenatal	z-score	Community	0.01	−2.85	2.73
Winter precipitation - prenatal	z-score	Community	−0.06	−1.65	2.57
Number of hot springs	#	Community	1.35	0	3
Number of cold springs	#	Community	1.28	0	4

	Unit	Level	Mean	Min	Max
Number of wet springs	#	Community	1.53	0	5
Number of dry springs	#	Community	0.83	0	4
Number of hot summers	#	Community	1.35	0	5
Number of cold summers	#	Community	0.75	0	3
Number of wet summers	#	Community	0.68	0	3
Number of dry summers	#	Community	1.12	0	4
Number of hot winters	#	Community	1.38	0	3
Number of cold winters	#	Community	0.83	0	3
Number of wet winters	#	Community	1.07	0	4
Number of dry winters	#	Community	0.91	0	4
N individuals	3336				
Consumption, food security, and crop yields[1]					
Per capita food consumption (N=2394)	Birr/month	Household	88.93	2.93	766.39
Household experienced food insecurity during prior rainy season (N=1163)	0/1	Household	0.63	-	-
Teff yields (N=862)	kg/ha	Household	650.04	4.00	2720.00
Barley yields (N=729)	Kg/ha	Household	872.81	1.00	4000.00
Maize yields (N=727)	kg/ha	Household	1238.1	1.55	8000.00
Wheat yields (N=704)	kg/ha	Household	1033.2	2.30	4000.00
Child labor outcomes[1]					
Works on family farm, cattle herding, other family business (N=1656)	0/1	Individual	0.57	-	-
Hours per week among those who do farm work (N=1109)	hours	Individual	21.65	1	84
Does domestic work such as fetching water, firewood, cleaning, cooking, child care, etc. (N=1657)	0/1	Individual	0.81	-	-
Hours per week among those who do domestic work (N=1338)	hours	Individual	20.02	1	96

[1] Food security and child labor data were only collected in the 2004 and 2009 surveys

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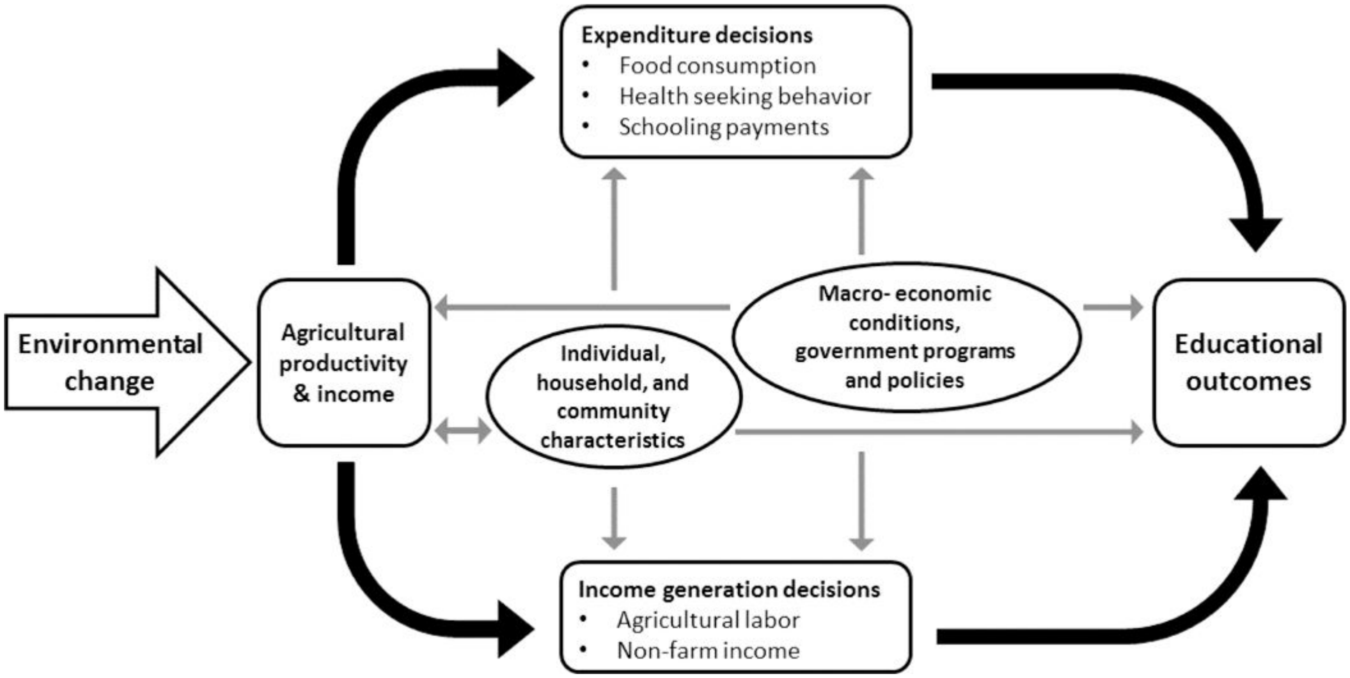

Figure 1.

A conceptual model of the relationship between environmental change and educational outcomes among children from agricultural households.

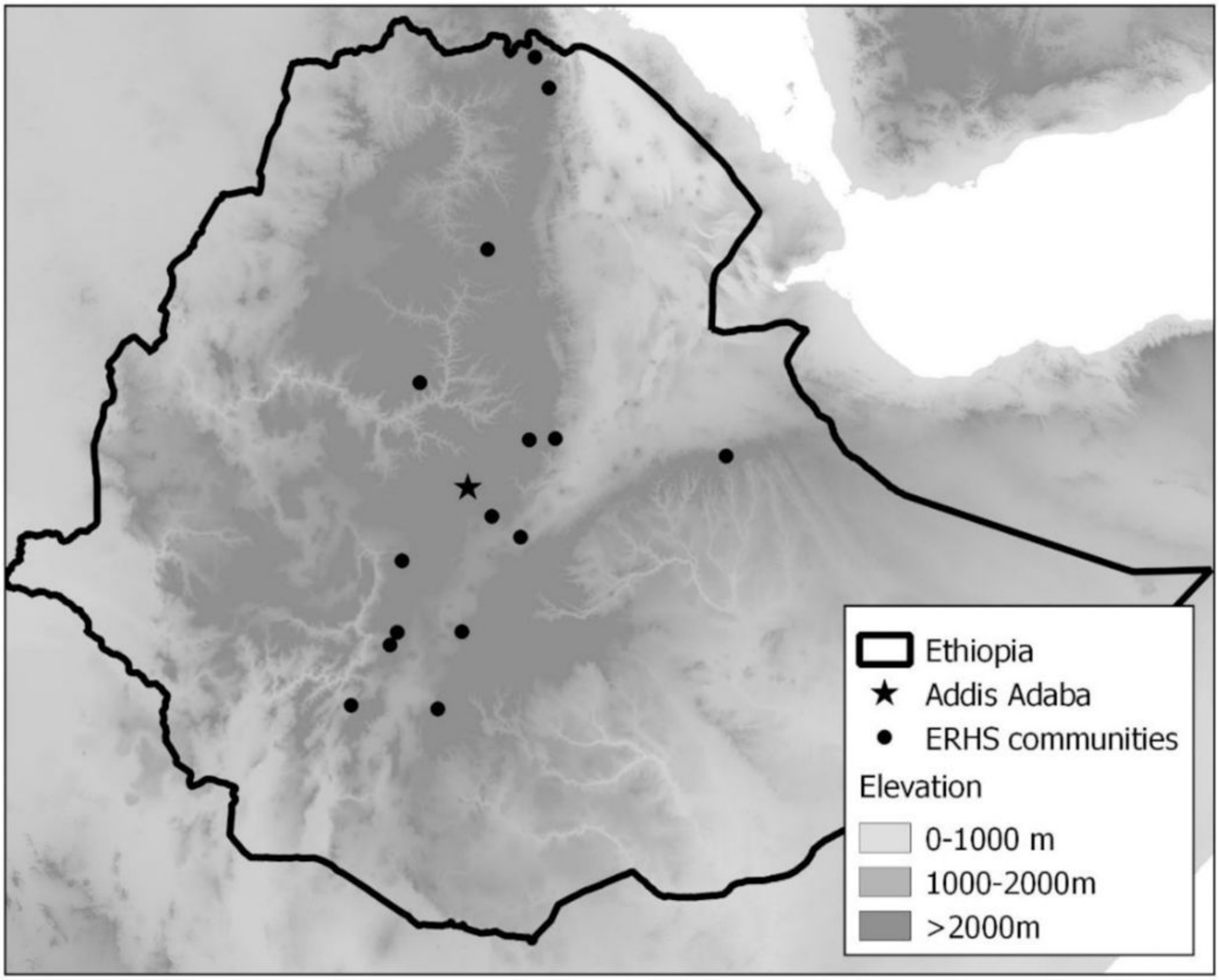

Figure 2.
Map of study communities.

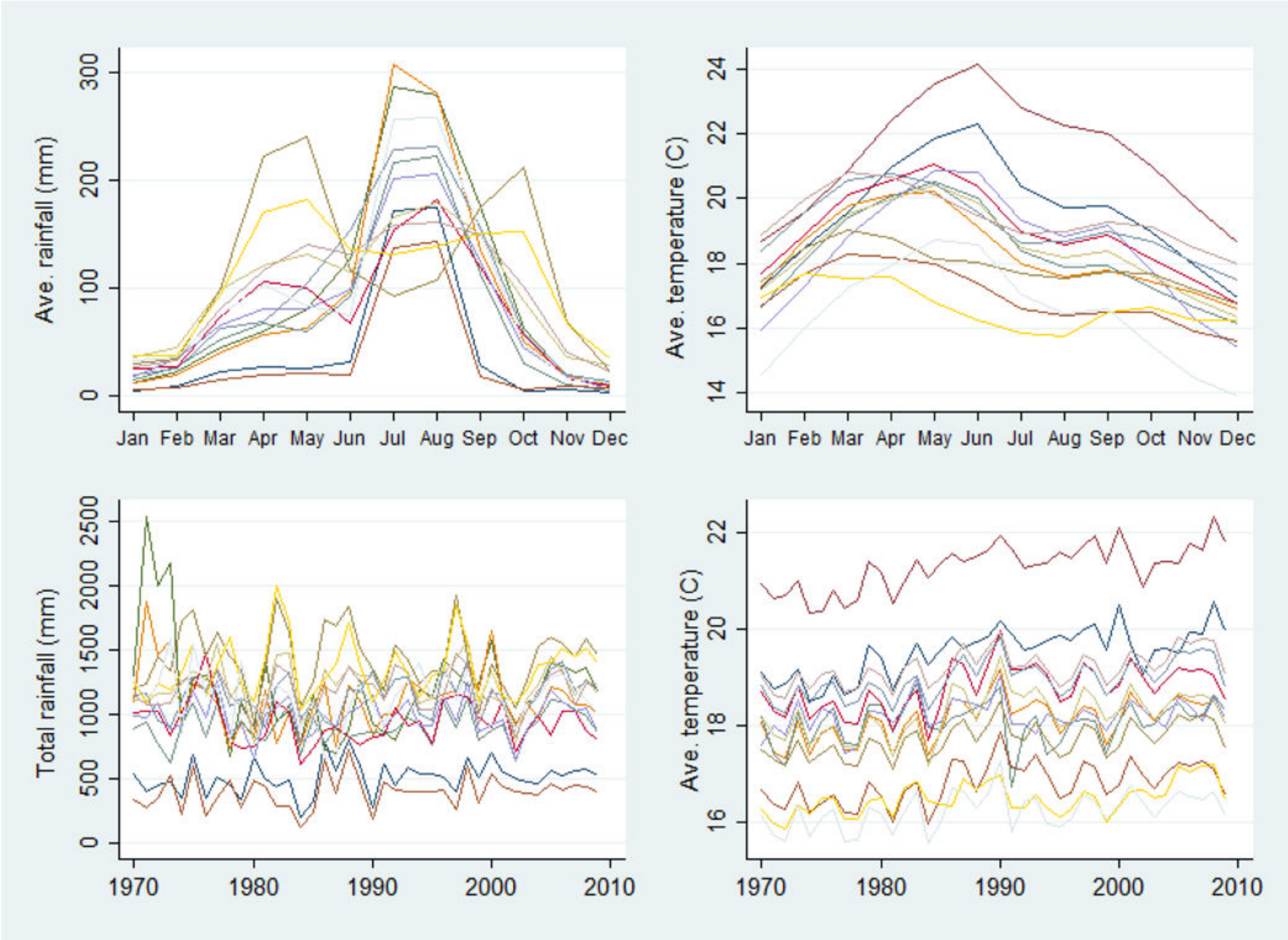

Figure 3.
Average monthly rainfall and temperature (top panels) and total annual rainfall and average annual temperature (bottom panels) in the 15 study villages, 1970–2009

Table 1.

Descriptive statistics for variables used in main regression analyses

	Unit	Level	Mean	Min	Max
Schooling outcomes					
Completed at least one grade of schooling	0/1	Individual	0.65	-	-
Attended school during year of survey	0/1	Individual	0.57	-	-
Completed between 1 and 4 grades	0/1	Individual	0.43	-	-
Completed between 5 and 12 grades	0/1	Individual	0.22	-	-
Climate during early childhood					
Spring temperatures	Z-score	Community	0.04	−0.76	0.80
Spring precipitation	Z-score	Community	0.21	−0.93	1.08
Summer temperatures	Z-score	Community	0.15	−1.00	1.06
Summer precipitation	Z-score	Community	−0.18	−1.03	0.67
Winter temperatures	Z-score	Community	0.16	−0.85	1.05
Winter precipitation	Z-score	Community	−0.01	−0.87	0.95
Controls					
Child of household head [grandchild is reference]	0/1	Individual	0.93	-	-
12 years old	0/1	Individual	0.23	-	-
13 years old	0/1	Individual	0.20	-	-
14 years old	0/1	Individual	0.19	-	-
15 years old	0/1	Individual	0.20	-	-
16 years old	0/1	Individual	0.17	-	-
Female	0/1	Individual	0.48	-	-
Number of children aged 0–6	#	Household	1.17	0	10
Number of children aged 7–18	#	Household	3.29	1	10
Age of household head	Years	Household	51.10	19	110
Household head has any formal schooling	0/1	Household	0.24	-	-
Female-headed household	0/1	Household	0.22	-	-
Land area	Hectares	Household	1.60	0	42.50
N individuals	3336				

Table 2.

Odds ratios from logistic regression models predicting the effects of early childhood climate on completion of at least one grade and on school attendance

	Completed at least one grade		Attends school	
	Model 1	**Model 2**	**Model 3**	**Model 4**
Climate variables				
Spring temperatures	0.58 *	0.56	0.79	1.11
Spring precipitation	1.23	1.34	0.87	0.92
Summer temperatures	0.45 **	0.45 **	0.73	0.81
Summer precipitation	1.44 *	1.66 +	1.90 *	2.12 **
Winter temperatures	1.86 *	1.74 +	1.23	0.83
Winter precipitation	0.90	0.77	1.14	0.91
Individual controls				
Child of household head	0.83	0.83	0.78	0.77
13 years old [12 years old is baseline]	0.99	1.00	1.00	1.01
14 years old	0.94	0.93	0.99	0.99
15 years old	1.08	1.08	0.89	0.88
16 years old	0.97	0.97	0.72 *	0.73 *
Female	0.51 *	0.49 *	0.61 *	0.58 +
Household controls				
Number of children aged 0–6	0.99	0.99	0.93	0.93
Number of children aged 7–18	1.03	1.03	1.09 *	1.09 *
Age of household head	0.99 +	0.99 +	0.99 *	0.99 *
Household head has any formal schooling	2.01 ***	2.00 ***	1.76 ***	1.76 ***
Female-headed household	0.80	0.80	0.68 *	0.68 *
Ln (land area + 1)	1.42	1.43	1.35	1.37 +
Interactions				
Female X spring temperatures		1.10		0.51
Female X spring precipitation		0.84		0.88
Female X summer temperatures		0.98		0.79
Female X summer precipitation		0.74		0.79
Female X winter temperatures		1.17		2.28 +
Female X winter precipitation		1.38		1.63
Joint tests				
Climate variables	31.09 ***	39.24 ***	24.83 ***	28.40 ***
Interactions		2.78		12.94 *
Community fixed-effects	300000.00 ***	39206.92 ***	16759.97 ***	18543.28 ***
Survey year fixed-effects	95.37 ***	88.79 ***	53.50 ***	48.88 ***

	Completed at least one grade		Attends school	
	Model 1	Model 2	Model 3	Model 4
Constant	22.18***	22.39***	11.21***	11.40***
N individuals	3336		3336	

+p < 0.1;

*p < 0.05;

**p < 0.01;

***p < 0.001

Table 3.

Odds ratios from models predicting attainment and attendance during year of survey using alternative climate specifications or outcomes

	1st–4th grade vs. no schooling	5th–12th grade vs. no schooling
	Model 5	
Spring temperatures	0.54 *	0.97
Spring precipitation	1.00	1.73 *
Summer temperatures	0.43 ***	0.37 **
Summer precipitation	1.57 **	1.24
Winter temperatures	1.58 +	2.31 *
Winter precipitation	0.96	0.75
Joint test	63.96 ***	
	Completed at least one grade	**Attends school**
	Model 6	Model 7
Spring temperatures - school ages	1.11	0.66
Spring precipitation - school ages	1.11	1.16
Summer temperatures - school ages	0.93	1.36
Summer precipitation - school ages	1.92 ***	2.07 **
Winter temperatures - school ages	1.29	1.03
Winter precipitation - school ages	0.65	0.95
Spring temperatures - early childhood	0.59	0.66
Spring precipitation - early childhood	1.05	0.69
Summer temperatures - early childhood	0.36 **	0.67
Summer precipitation - early childhood	1.90 ***	2.77 ***
Winter temperatures - early childhood	2.23 *	1.29
Winter precipitation - early childhood	0.82	1.13
Spring temperatures - prenatal	1.00	0.97
Spring precipitation - prenatal	1.01	0.97
Summer temperatures - prenatal	0.95	1.07
Summer precipitation - prenatal	1.12	1.11
Winter temperatures - prenatal	1.06	1.08
Winter precipitation - prenatal	0.93	0.85 *
Joint test	256.76 ***	433.48 ***
	Model 8	Model 9
Number of hot springs	0.85	1.01
Number of cold springs	1.09 +	1.18 *
Number of wet springs	1.09	1.07

	1st–4th grade vs. no schooling	5th–12th grade vs. no schooling
Number of dry springs	1.23	1.35 **
Number of hot summers	0.93	1.00
Number of cold summers	1.11	0.92
Number of wet summers	1.05	1.21
Number of dry summers	0.84 *	0.90
Number of hot winters	1.32 *	1.08
Number of cold winters	0.97	1.05
Number of wet winters	1.07	1.04
Number of dry winters	1.11	1.05
Joint test	271.76 ***	186.32 ***

Models also include control variables, not shown

The joint test is a Wald test of the schooling coefficients, for the climate variables

+ $p < 0.1$;

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$

Table 4.

Results from models predicting per capita food consumption, rainy season food security, and crop yields based on recent climate

	Per capita food consumption (logged)	Household experienced food insecurity during prior rainy season[1]	Crop yields (logged)			
			Teff	Barley	Maize	Wheat
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Climate variables						
Summer temperature, t-1	−0.18	1.50**	−0.61**	0.09	−0.35	0.28
Summer precipitation, t-1	0.05	−0.64	0.05	0.12	0.23	0.20
Winter temperature, t	0.00		0.09	−0.01	−0.08	−0.13
Winter precipitation, t	0.03		−0.16	−0.31	0.01	0.35*
Spring temperature, t	−0.16*					
Spring precipitation, t	0.04					
Household controls						
Number of children aged 0–6	−0.11***	0.03	0.03	0.02	0.02	0.00
Number of children aged 7–18	−0.06***	−0.07	0.00	0.03	0.02	0.02
Age of household head	0.00	0.00	0.01*	0.00	0.00	0.00
Household head has any formal schooling	0.02**	−0.08*	0.01	0.01	0.02	0.01
Female-headed household	−0.03	0.29+	−0.17*	−0.24***	−0.11	−0.09*
Ln (land area + 1)	0.19**	−0.43+	−0.42**	−0.50*	−0.03	−0.24*
Joint tests						
Climate variables	2.88*	10.83**	8.57**	0.92	0.72	3.80*
Community fixed-effects	35514.68***	21000.00***	6729.68***	641.20***	6520.23***	36473.63***
Survey year fixed-effects	12.11***	6.42*	6.69**	2.95+	10.52**	2.61
Constant	4.11***	0.19*	5.15***	6.36***	5.96***	5.84***
N households	2394	1163	862	729	727	704
N villages	15	15	12	9	13	12

[1]Food security data were only collected in the 2004 and 2009 survey rounds

Table 5.

Results from logit and OLS models on participation in and hours of child labor based on recent climate, 2004 and 2009

	Any farm labor		Hours of farm labor (logged)		Any domestic labor		Hours of domestic labor (logged)	
Climate variables	Odds ratio		Coefficient		Odds ratio		Coefficient	
Summer temperature, t-1	1.37	2.02	−0.06	−0.09	0.48+	0.44+	0.02	−0.07
Summer precipitation, t-1	0.39*	0.36*	−0.09	−0.13	1.60	1.60	−0.06	0.05
Winter temperature, t	0.64	0.56	0.15	0.13	0.66	0.83	−0.09	0.03
Winter precipitation, t	1.13	0.79	0.13	0.16	0.34*	0.32*	−0.14*	−0.03
Spring temperature, t	1.05	1.38	0.09	0.12	0.19***	0.16***	0.07	0.03
Spring precipitation, t	1.02	0.58	−0.30*	−0.29*	1.49	1.42	−0.13+	−0.08
Individual controls								
Child of household head	0.96	0.95	0.03	0.04	0.81	0.82	−0.06	−0.05
13 years old [12 years old is baseline]	1.17	1.17	0.10*	0.10*	1.06	1.06	0.05	0.05
14 years old	1.08	1.07	0.00	0.00	1.28	1.28	0.13**	0.13**
15 years old	0.87	0.85	0.04	0.04	1.37	1.35	0.15***	0.15***
16 years old	1.14	1.14	−0.01	−0.01	0.87	0.87	0.06	0.05
Female	0.14***	0.54	−0.37***	−0.37**	16.13***	5.50+	0.41***	0.14+
Attends school	0.83	0.89	−0.37***	−0.36***	1.26	1.25	−0.18***	−0.19***
Household controls								
Number of children aged 0–6	0.86+	0.87	−0.02	−0.02	1.01	1.01	0.02	0.02
Number of children aged 7–18	0.97	0.97	0.01	0.01	0.86*	0.86*	0.00	0.00
Age of household head	0.99	0.99	0.00	0.00	0.99+	0.99	0.00	0.00
Household head has any formal schooling	0.96	0.95	−0.03	−0.03	1.01	1.02	−0.04	−0.04
Female-headed household	0.75	0.74	0.04	0.04	1.19	1.17	0.02	0.02
Ln (land area + 1)	1.12	1.09	0.03	0.03	1.13	1.12	0.07+	0.08*
Interactions								
Female X summer temperature, t-1		0.71		0.06		1.93		0.19+
Female X summer precipitation, t-1		1.48		0.10		1.30		−0.22*

	Any farm labor		Hours of farm labor (logged)		Any domestic labor		Hours of domestic labor (logged)	
Female X winter temperature, t		1.13		0.07		0.25^{+}		−0.19
Female X winter precipitation, t		1.07		−0.06		0.81		−0.16
Female X spring temperature, t		0.50***		−0.06		2.25		0.11^{+}
Female X spring precipitation, t		2.32^{+}		−0.01		1.59		−0.10
Joint tests								
Climate variables	17.81**	6.81	6.92**	3.55*	150.48***	80.25***	7.73***	1.18
Interactions		44.81***		1.98		6.90		11.78***
Community fixed-effects	739.94***	3567.94***	16372.49***	2316.32***	4996.66***	3282.24***	2717.43***	1649.41***
Survey year fixed-effects	2.32	1.51	0.47	0.61	12.03***	10.29**	0.05	0.04
Constant	8.43	4.18	3.13***	3.10***	150.66**	225.03**	2.70***	2.79***
N individuals	1656		1109		1657		1338	

$^{+}$ $p < 0.1$;

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$