Published in final edited form as:
Glob Environ Change. 2019 July ; 57: . doi:10.1016/j.gloenvcha.2019.03.011.

Climatic Variability and Changing Reproductive Goals in Sub-Saharan Africa

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1. Introduction

Global climate change is expected to have significant demographic effects on human populations. Demographers and epidemiologists have already shown that climatic variability has robust effects on human migration (Gray & Mueller, 2012a; Thiede et al., 2016), mortality (de Waal et al., 2006), and health (Bakhtsiyarava et al., 2018; Grace et al., 2015), but less attention has been paid to whether and how such environmental changes may affect fertility dynamics (Grace, 2017). Attention to this outcome is merited given theoretical reasons to expect climate-related changes in reproductive decisions, and prior research showing fertility responses to resource constraints (Bilsborrow, 1987; Grace, 2017; Sobotka et al., 2011). Moreover, fertility dynamics are of widespread interest because they drive population growth, which is a fundamental determinant of economic development and has important implications for environmental sustainability, including greenhouse gas emissions (Bloom et al., 1998; Bongaarts & O'Neill, 2018). These population dynamics are particularly important across sub-Saharan Africa, where fertility declines have recently stalled (Gerland et al., 2014) and where persistently high rates of population growth are believed to be associated with poverty and vulnerability to climate change (IPCC, 2014; Schmidhuber & Tubiello, 2007).

We address this gap in evidence and contribute to knowledge regarding the demographic impacts of environmental change by analyzing the relationship between climatic variability and women's reproductive goals in sub-Saharan Africa. We specifically examine two indicators of women's reproductive goals: fertility preferences—the desire to have a first or an additional child; and ideals—women's ideal family size (IFS) irrespective of their fertility history—which are both important predictors of fertility behavior (Kodzi et al., 2010). We

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argue that climate-related changes in these outcomes provide insights into how women seek to modify their reproductive behavior in response to changing environmental conditions regardless of the constraints to doing so, which is an important but separate question.

This study represents one of the first empirical analyses to examine the links between climate and fertility (for exceptions see: Barreca et al., 2018; Sellers & Gray, 2019; Simon, 2017). We do so by linking high-resolution precipitation and temperature records from the University of East Anglia's Climate Research Unit (CRU) to 40 rounds of geo-referenced Demographic and Health Survey (DHS) data that were collected across sub-Saharan Africa between 1990 and 2015. We then estimate statistical models of the relationship between both precipitation and temperature anomalies and women's fertility goals, measured in terms of women's IFS and fertility preferences, and test for hypothesized variation across demographic groups. We find significant links between climate and reproductive goals across our main models, such that women generally want to adjust their fertility downwards during times of unfavorable environmental conditions—particularly hot spells—while responses to precipitation vary over the short- and longer-run. We also find that these associations differ across regions and populations of interest in potentially important ways that suggest demographic responses to environmental change will not be uniform.

To present these results, our paper proceeds as follows. In the next section, we draw on prior work to conceptualize the relationship between climatic variability and reproductive behavior. We then describe the data and methods used in the analysis and present our empirical results. The paper concludes by discussing the broader implications of our findings and identifying questions for future research in this emerging literature.

2. Climatic Variability and Reproductive Outcomes

Shifts in reproductive behavior have been used to adapt to a range of environmental changes and other shocks to household resources (Bilsborrow, 1987; Eloundou-Enyegue et al., 2000; Sasson & Weinreb, 2017; Sobotka et al., 2011). Despite a lack of empirical evidence on the links between women's reproductive decisions and global climate change (Grace, 2017), there is a strong conceptual basis to anticipate that such decisions will be influenced by climatic variability and its second-order socioeconomic effects. In stylized terms, we expect temperature and precipitation anomalies to disrupt multiple dimensions of households' livelihoods, leading to changes in resource constraints and perceptions of risk among affected individuals. We further expect that changes in reproductive behavior will be among the repertoire of tactics households consider when developing strategies to adapt to such changes. However, there is not a clear *a priori* expectation about the direction or strength of this relationship given the multiple and potentially offsetting mechanisms linking climate and reproductive decisions described below.

A first set of mechanisms stem from climate-induced changes in population health, and particularly risks to children's health. Specifically, women may adjust their fertility as a means of insuring against child mortality risk or adjusting to actual child deaths (de Sherbinin et al., 2008; Nobels, 2015; Preston, 1978; Winterhalder & Leslie, 2002), both of which have been shown to be affected by environmental conditions and corresponding changes in disease transmission and food security. A growing literature has documented links between climate change and maternal health and nutrition, which can lead to low birthweights and an increased risk for infant and child mortality (Bakhtsiyarava et al., 2018; Sheffield & Landrigan, 2011; de Waal et al., 2006). For example, a study in Ethiopia found drought-affected areas to have higher rates of child mortality than areas unaffected (de Waal et al., 2006). Another study found higher temperatures, and presumably poor agricultural conditions, were associated with reduced birthweights in rural Kenya and Mali, while precipitation anomalies were inversely associated with such outcomes (Bakhtsiyarava et al., 2018). These findings are generally consistent with results from a similar study of low birthweight across multiple countries in sub-Saharan Africa (Grace et al., 2015), and are also consistent with findings showing that hot and dry spells were associated with increased rates of malnutrition among young children across the continent (Davenport et al., 2017).

If high temperatures and low precipitation are associated with changes that worsen child health outcomes, such climatic conditions will be associated with upward pressure on fertility preferences through this insurance or replacement mechanism. This mechanism is unlikely to affect IFS, however, since insurance and replacement processes are largely a matter of adjusting to changing mortality risk to meet the same IFS goal. Two further qualifying points are important. First, the effects of precipitation on child health and mortality risk are not unambiguous. Beyond the well-documented effects of drought, above-average precipitation can also have adverse effects on child health outcomes (e.g., diarrheal illness rates) and mortality risk (Singh et al., 2001). Second, climate effects on child health may not cause changes in mortality of a magnitude likely to lead to widespread shifts in perceptions of risk—which we cannot observe in these data—at least over the short term. We therefore expect that other mechanisms may have a stronger impact on women’s reproductive goals.

Perhaps more importantly, women may shift their reproductive goals in response to climate-induced changes in socioeconomic circumstances. We expect at least three sets of inter-related changes to be particularly important. First, climate-induced changes in economic constraints may lead to shifts in demand for household labor. For example, increases in household labor supply have been shown to be a common response to declining agricultural productivity and other resource constraints associated with environmental change (de Sherbinin et al., 2008). Under such scenarios, women may seek to increase their fertility to the extent that children can be expected to provide household labor (Sasson & Weinreb, 2017). In other scenarios, however, changing demand for labor may lead to shifting work roles among family members. For instance, women may seek off-farm employment when drought or heat stress reduce agricultural production and income (Alston et al., 2018). To the extent that such changes increase work burdens among women and/or their spouses, evidence suggests this will place downward pressure on fertility preferences due to increasing opportunity costs of childbearing (Van dan Broeck & Maertens, 2015).

Second, the relative costs of children may change. Women may seek to reduce fertility in response to the negative economic impacts of unfavorable or unpredictable environmental conditions as the potential cost of having a child may increase relative to the economic resources available to the family (de Sherbinin et al., 2008; Lesthaeghe, 1989). Rather than seek to increase labor supply within the family, this mechanism suggests that households will seek to limit family size as a means of maximizing per capita resources within the household. Such expectations are based on evidence of reductions in fertility during macroeconomic downturns, as well as findings that parents reduced the size of their existing households via the out-fostering of children during periods of economic stress (Bachan, 2015; Lesthaeghe, 1989; Shapiro, 2014).

Third, climate-induced changes in resources may affect inter-personal dynamics within the household in ways that shape reproductive goals. For instance, climate-induced migration and spousal separation may shape intra-personal relationships among spouses, leaving less time or household support to invest in another child (Agadjanian et al., 2011; Gray & Mueller, 2012). On the other hand, climatic shocks could reduce adult employment, thus leaving individuals with more leisure time to spend with a spouse or partner, allowing for more time to invest in fertility (Burlando, 2014). It is unclear, however, whether such leisure time effects will result in conscious or desired increase in fertility goals or simply increase the risk of pregnancies. The impacts of climate change may also influence levels of conflict among spouses, which in turn can be expected to shape reproductive goals. For example, high temperatures have been associated with an increased risk of inter-personal and domestic violence (Hsiang et al., 2013; Sanz-Barbero et al., 2018), which evidence has shown impacts reproductive outcomes (Meiskin et al., 2015; Silverman et al., 2010). Equally as important, climate-related changes in income are likely to be inversely associated with such violence (Hidrobo et al., 2014; Roy et al., 2018). Therefore, to the extent that climatic variability leads to increased physiological stress or reductions in income, it may be expected to increase inter-spousal conflict and presumably reduce fertility preferences and IFS (Meiskin et al., 2015; Silverman et al., 2010).

Each of these alternative explanations are equally plausible, but clearly may operate in opposite directions and at varying magnitudes. For example, a given increase in temperature may both place upward pressure on fertility goals through increased demand for household labor and insurance effects, while also placing downward pressure on fertility due to increased spousal conflict. These mechanisms may also operate differently over varying time scales, such that increased demand for labor among adult members of the household leads to reduced fertility goals in the short-run, but eventually incentivize the desire for larger families over a longer time period. As such, we treat the direction and strength of the relationship between climatic variability and reproductive goals as an empirical question. We evaluate this question in the current study by examining whether and how women across 18 sub-Saharan African countries change their desired fertility goals in response to rainfall and temperature anomalies.

3. Research Objectives

Our analyses address two main objectives. First, we examine the overall association between temperature and precipitation anomalies and both fertility ideals and preferences among sub-Saharan African women. We focus on women's fertility *goals*, rather than outcomes, since measures of ideational change capture how women *would like* to adapt their fertility to changing environmental conditions irrespective of their ability to realize these desires. Many factors— including access to family planning, levels of female empowerment vis-à-vis their spouses, and women's fertility history—mediate a woman's ability to realize her fertility desires (Bongaarts, 1994; Bongaarts & Casterline, 2013). It is therefore difficult to produce non-attenuated estimates of the association between climatic variability and fertility *outcomes* themselves. For example, due to spatial and temporal variation in women's ability to realize changing fertility desires by accessing and using family planning, changing preferences will directly translate into changing outcomes among only some subsets of the population. For others, shifting preferences will not translate into changes in realized fertility due to these intervening factors, which are unobservable in our data. We aim to overcome this limitation by focusing on IFS and fertility preferences, which we argue are valid measures of women's reproductive goals in the face of climate-related changes in risks and resource constraints. Recent research has demonstrated that fertility goals are dynamic in response to varying forms of uncertainty, including rapidly changing economic conditions and shifts in disease transmission and mortality risk, such as those associated with HIV/AIDS (Agadjanian, 2005; Trinitapoli & Yeatman, 2017). We expect climate-induced changes to operate similarly.

The secondary objective of this study is to evaluate whether the association between climate variability and fertility goals varies across sub-populations defined by women's parity, educational attainment, residence in rural or urban areas, and regional context. We expect fertility goals to be more sensitive among high-parity women since they face disproportionately high baseline per capita demands for household resources, which are exacerbated by environmental change (Eloundou-Enyegue et al., 2000). Further, whereas higher-parity women are more likely to have raised children under economic and environmental constraints, women at lower parities lack such experience, and thus may not change their reproductive goals as much or as quickly. However, among the two outcomes we examine, climate effects on IFS may diverge from those on fertility preferences. For example, women at higher parities may be less likely to revise their IFS downward due to *ex post* rationalization, whereby women align their preferred family size to levels at or above their realized fertility. If such rationalization effects dominate, then our initial expectation may be reversed, and higher-parity women's fertility ideals may exhibit less responsiveness to climatic variability.

We also expect fertility desires to vary by maternal education, which we treat as a broad proxy for socioeconomic status. We assume women who have completed higher levels of education will have the capacity to leverage multiple resources as "buffers" in times of environmental uncertainty (Sasson & Weinreb, 2017). On the other hand, women with higher levels of educational attainment may be more likely to perceive their reproductive decisions as within their control, and to be exposed to more information about climate change and adaptation (Behrman, 2015). Given these potentially offsetting effects, we have neutral expectations as to whether climate anomalies will affect fertility goals among women with higher levels of education than their less educated peers.

Third, we anticipate climate-related changes in fertility goals to vary between rural and urban women. Rural women may be more sensitive to climate anomalies than their urban peers. This is particularly true in sub-Saharan Africa where the impacts of environmental change are expected to be most severe given widespread reliance on rainfed agriculture and an overall lack of access to resources and technologies needed for adaptation (IPCC, 2014; Serdeczny et al., 2016). However, urban livelihoods are increasingly vulnerable to climate shocks as well (Desbureaux & Rodella, 2019). For example, urban residents spend a higher portion of daily budgets on food purchases; thus, during times of agricultural stress, urban households may be adversely affected as food prices spike (Headey & Martin, 2016; Raleigh et al., 2015). Finally, and fundamentally, the lines between rural and urban areas are not always clear-cut. For example, it is common to engage in circular migration across sub-Saharan Africa, such that individuals may move between urban and rural areas throughout the year for wage labor and other income-generating opportunities (Mastrorillo et al., 2016). An implication is that rural households' livelihoods may in part be tied to the urban economy. We therefore leave the question of whether climatic variability affects the fertility goals of rural and urban women differently as an empirical one.

Finally, we expect climatic effects on fertility goals may differ across the geographic regions of Africa included in our sample. While the distinctions between West, East, and Southern Africa that we employ in this paper are admittedly coarse, they do vary systematically in terms of their agroecological systems, demographic patterns, and vulnerability to climate change. Such factors have been shown to modify the impact of climate shocks in other studies (Grace et al., 2015; Simon, 2017). In this case, a range of salient regional differences exist across our sample (Serdeczny et al., 2016). While agricultural systems are predominately rainfed across the entire continent, the arid and semi-arid regions common across East and Southern Africa may be more affected by temperature than precipitation shocks, as agriculture is already adapted to dry conditions. In contrast, agriculture in parts of West Africa may be more closely tied to the monsoon season, and thus more sensitive to precipitation. Additionally, there exist important regional differences in fertility trends and reproductive health policies. Sahelian countries generally place family planning and access to contraceptives as low national-level policy priorities, whereas several East African countries (e.g., Ethiopia and Rwanda) have prioritized these and experienced declines in fertility rates (Bongaarts, 2017). The implication of these and other differences is that both climate impacts and the malleability of fertility goals to such changes are likely to vary spatially.

4. Data and Measures

4.1 Data

Our analysis draws on microdata from the Demographic and Health Surveys (DHS), which we extract using the IPUMS-DHS system developed by the Minnesota Population Center (Boyle et al., 2017; DHS Implementing Partners, 2017). We use DHS samples of reproductive-age women, ages 15–49 years, and restrict our analytic sample to those individuals who had married or began to cohabitate with a partner for the first time within 10 years prior to the survey (n=70,879). While our main results are confirmed when using an age-based restriction criterion (i.e., 18–30 years) (Table S5), we follow Bongaarts and Casterline (2013) and restrict our sample to these recently first-married or first-cohabitating women since they are still relatively early in their reproductive careers and thus less prone to *ex post* rationalization of fertility ideals; and because never-married women are excluded from fertility questions in many rounds of the DHS.

Among the DHS samples harmonized by IPUMS, our analytic sample includes all files from sub-Saharan Africa that meet two criteria: (1) cluster-level geo-coordinates are publicly available (Figure 1); and (2) data on women's length of residence in their cluster of enumeration were collected. Geo-coordinates are needed to link individuals to the high-resolution climate data. Information on duration of residence is needed to properly identify individuals who were present in their cluster of enumeration during specific years of interest (i.e., the period over which we measure climatic variability). In this study, we exclude observations of women who had lived in their cluster of enumeration for less than five years, to correspond to the maximum look-back period over which we measure climatic variability. Note, however, that women who left the observed clusters during the period over which we measure climate but prior to the survey are excluded from the sample; and that duration of residence is self-reported and does not necessarily account for some forms of geographic mobility that may be regularly-occurring but considered only temporary (e.g., circular migration). These are inherent limitations of the DHS, which represent plausible sources of bias and should be addressed in future work using more detailed, longitudinal data. After these restrictions, our analytic sample includes data from 40 DHS surveys implemented in 18 sub-Saharan African countries between 1990 and 2015, for a total of 70,879 observations (Table 1).

We measure climatic variability using data from the University of East Anglia Climate Research Unit's Time Series (version 3.24) (Harris et al., 2014). These data are interpolated from over 4000 weather stations and are described in greater detail by Harris et al. (2014). We extract temperature and precipitation records from 1951–2015 at a monthly scale and 0.5° spatial resolution, which for reference is equivalent to an approximately 56km-by-56km grid cell at the equator. We link these climate records to the DHS according to the 0.5° grid cells that the coordinates of the DHS cluster fall into. Due to random displacement of DHS cluster coordinates—by 0 to 5km for most clusters, and up to 10km for 1 percent of rural clusters—for privacy purposes, a limited number of cases may be assigned climate data from the cell neighboring the cluster's true location. We expect that such instances will introduce a modest amount of noise, but not systematic bias, into our estimates. Finally, we draw on shapefiles from the GADM database of global administrative areas (version 2.8) to identify the temporally-consistent level-one subnational administrative unit (i.e. province) that each DHS cluster falls within (Global Administrative Areas, 2015).

4.2 Measures

Our first dependent variable is ideal family size (IFS), which measures the "total number of children the woman would have liked to have in her whole life, regardless of her actual childbearing" (Boyle et al., 2017). We use responses to the DHS question, "If you could go back to the time you did not have any children and could choose exactly the number of children to have in your whole life, how many would that be?" and for zero-parity women, "If you could choose exactly the number of children to have in your whole life, how many would that be?" to measure IFS. We recoded non-numeric responses of "as many as possible" and "as many as can care for" to 12—the 99th percentile of IFS in our sample—for the analyses below. However, our main results are robust to alternative recoding of these responses, including to as low as 1 (Table S4). We recoded the non-numeric response of "doesn't want any children" to 0 and excluded all other non-numeric responses. Such responses have systematically declined in frequency over time, in step with declining fertility rates (Frye & Bachan, 2017). As such, excluding these observations is likely to bias the mean fertility ideals of our sample downward, although we expect this bias to be modest given the number of excluded observations. Our second dependent variable is fertility preferences, specifically a binary variable denoting whether or not the woman would like to have another (or first) child. We draw on responses to the DHS question asking, **"**Would you like to have a (another) child or would you prefer not to have any (more) children?". We employ both IFS and fertility preferences as measures of reproductive goals throughout our models.

Our independent variables of interest are precipitation and temperature anomalies. These measures represent the deviations of precipitation and temperature in residential cluster c during interval t, of length n months prior to the DHS survey, from the respective long-term average of all n-length intervals from 1951–2015. Following conventions in the population-environment literature (e.g., Randell & Gray, 2016; Thiede et al., 2016), we standardize these differences over the standard deviation of all equivalent-length intervals, again using the entire 1951–2015 period as our benchmark. As such, these measures can be interpreted as the z-scores of precipitation and temperature in each woman's cluster of residence during the n months prior to the time of the survey. To account for possible differences in responses to short- and longer-term environmental changes, we estimate a parallel series of models that respectively measure climate over the 12- and 60-month periods prior to each survey. We also test for non-linearities (results nonsignificant, Table S1) and precipitation-by-temperature interactions, which suggest temperature effects may be amplified by low precipitation in some cases (Table S2).

We control for women's age (in years), primary school completion (yes/no), marital status (currently in union/previously in union), employment in activities paid in cash or in-kind (yes/no) and sector of employment (agriculture/non-agriculture), number of children ever born, and residence in a rural or urban cluster. We also include province and region-decade fixed effects. We define provinces as the first subnational administrative unit in each country, and these fixed effects capture all time-invariant characteristics associated with fertility goals that are common within each province. Our region-decade fixed effects respectively capture all temporal changes that occur commonly within West, East, and Southern Africa, and distinguish between samples collected before 2000, between 2000 and 2009, and from 2010 forward. The sample is described in Table 2.

5. Empirical Strategy

We test our main hypotheses by estimating a series of linear regression models. The initial, overall models take the form:

$$\mathrm{Y}_{i(s)} = \alpha_p + \alpha_d + \delta \mathrm{W}_{c(t)} + \beta \mathrm{X}_{i(s)}$$

where the fertility outcome (Y) of woman i, measured at the time of the survey (s), is a function of individual characteristics (X), climatic conditions (W) in cluster c during interval t, net of province (α_p) and region-decade (α_d) fixed effects. Using this framework, we estimate models of IFS and the probability that the woman would like to have another (or first) child. We separately model the effects of climate variability measured over 12- and 60-month periods, and in all models include the control variables listed above. Data are weighted using the person-level sample weights constructed by the DHS and standard errors are clustered at the 0.5°-by-0.5° cells for which we measure climate variability (Table 3).

We then extend this overall model to test for heterogeneity in the association between climatic variability and both IFS and fertility preferences. Specifically, we estimate a series of models that respectively interact the measures of climatic variability with indicators of parity, educational attainment, rural or urban residence, and geographic region (Table 4). Given that the 12- and 60-month climate variables produce substantively similar results across most of these interaction models, we focus on the results of the 60-month climate variables for brevity. However, we highlight differences that are observed and provide results of the models using the 12-month measures in Table 5. Finally, note that we also conducted a number of supplemental analyses and robustness checks, which we present in the supplementary material available online.

6. Results

6.1 Overall Models

We begin by evaluating the overall, average associations between climatic variability and both fertility ideals and fertility preferences across the population of interest. We consider the respective effects of short-term climate fluctuations over the 12 months prior to the survey and anomalies over longer 60-month periods. Beginning with the former, the results of the overall model of IFS (Table 3, Model 1) show that both temperature and precipitation are inversely associated with IFS. According to point estimates, each one standard-deviation increase in temperature during the 12 months prior to the survey is associated with a reduction in IFS of approximately 0.042 children, while a comparable increase in precipitation is associated with a 0.052-child reduction. The negative association between temperature and IFS is consistent with the expectation that women may seek to reduce burdens on family resource demands during periods of environmental stress (e.g., due to the adverse agricultural impacts of high temperatures). However, the association between precipitation and IFS suggests the opposite. We observe reductions in IFS during spells of high precipitation and presumably good agricultural conditions, perhaps due to increasing demand for women's agricultural labor. Conversely, our results point to increasing IFS during low-precipitation periods.

We then estimate a similarly-specified linear probability model of fertility preferences, operationalized as an indicator of women's desire to have a first or an additional child (Table

3, Model 2). Consistent with the model of IFS, these results show that temperature anomalies are inversely associated with the probability that a woman would like to have a first or additional child. Point estimates indicate that each standard-deviation increase in temperatures is associated with an approximately one percentage-point reduction in the probability of reporting a desire for another child. Given that less than one-quarter of the sample (17.2%) reported not wanting an additional child, a marginal increase of this magnitude in such responses should be viewed as substantively important. In contrast to the model of IFS, the association between precipitation anomalies and fertility preferences is not statistically significant. Assuming women are more likely to revise their IFS downward slightly than cease wanting another child entirely, one plausible explanation of the difference in precipitation effects between Models 1 and 2 is that the net effect of precipitation on the mechanisms influencing fertility goals is simply less than that of temperature. This finding would be consistent with other population-environment literature, which has consistently found stronger temperature than precipitation effects on sociodemographic outcomes (Bohra-Mishra et al., 2014; Gray & Wise, 2016; Thiede et al., 2016).

Next, we assess whether exposure to longer 60-month periods of anomalous temperatures and precipitation leads to different changes in fertility goals than exposure to short-term climate variability as measured over 12-month periods. Results from the model of IFS (Table 3, Model 3) show a negative association between temperatures and such ideals. The sign on this estimate is consistent with Model 1, although we note that the magnitude of the coefficient estimate is more than twice as large (β= -0.101). In contrast to our 12-month model, when measured over this longer 60-month period, we find a positive association between precipitation and IFS. For each standard deviation that the total precipitation over a given five-year period is above the long-term average, women's IFS increases by approximately 0.059 children. The changes in the sign on the precipitation coefficient between the 12- and 60-month measures may reflect important substantive differences in how the underlying mechanisms are operating. For example, a short-term increase in precipitation may lead to increasing demand for the labor of existing household members (e.g., to manage increased agricultural production) and thus increased opportunity costs of childbearing. In contrast, a sustained period of favorable environmental conditions may lead women (and their spouses) to increase expectations of labor demand over the long-run, and therefore desire a larger family with additional workers. A complementary explanation would be that sustained spells of favorable environmental conditions may lead to wealth accumulation and thus increase availability of resources to support a larger family.

Results from a comparable 60-month model of fertility preferences (Table 3, Model 4) show a negative association between temperature and women's desire for an additional child. This estimate is consistent with other results. And, as expected, the magnitude of the coefficient estimate for temperature anomalies over a 60-month period (β= -0.017) is considerably larger than in the model of short-term (12-month) climatic variations (β= -0.010). The estimated association between precipitation anomalies and fertility preferences is not statistically significant, providing further support to our earlier speculation that temperature anomalies, as measured here, have a stronger effect on the determinants of reproductive goals than precipitation anomalies of comparable magnitudes.

6.2 Heterogeneous changes in fertility goals

Our next set of analyses examine how the associations between climate anomalies and reproductive goals vary across sub-populations of interest identified above. We focus on the models that employ the 60-month climate measures (Table 4) for brevity but describe the few instances in which the results of models using the 12-month measures (Table 5) differ. We begin by testing for climate-by-parity interactions. The model of IFS (Table 4, Model 5) indicates that the association between temperature anomalies and fertility ideals varies by women's parity: Women with no previous children report lower IFS under unusually warm conditions (β= -0.167), but this effect is partially offset as parity increases. According to our point estimates, the negative association between temperature and IFS is offset by approximately 0.033 per child previously born to the women in our sample. Panel A of Figure 2 illustrates the marginal effect of temperature anomalies according to the number of children ever born. This figure reveals that the negative effects of temperature are concentrated among low-parity women, with non-significant effects among women with four or more children already born. The association between precipitation anomalies and IFS does not vary significantly by women's parity. We note that the results of these climate-by-parity models differ somewhat when considering short-term climate anomalies: when measured over 12 months, we find a negative temperature effect regardless of parity. One speculative, but potentially notable, interpretation is that higher-parity women are more likely to have had children and subsequently revise their IFS upward during the 60-month period relative to the shorter 12-month period we consider.

We then examine whether and how the effects of climate anomalies on fertility preferences vary by parity (Table 4, Model 6). In contrast to the model of fertility ideals, childless women appear somewhat more likely to desire another child during high-temperature spells (β= 0.022), but this effect is quickly offset and becomes negative among higher-parity women (Figure 2, Panel B). For each one-child increase in the number of children ever born, the marginal effect of temperature anomalies is offset by approximately 1.9 percentage points. The implication is that for women with children, resource-constraints associated with unusually hot spells will reduce their desire for an additional child—at least temporarily. It is important to note that for most women—i.e., those at intermediate parities—the results of the IFS and fertility preference models are fairly consistent in direction. Only at the extremes do we find temperature-related changes in ideals moving in the opposite direction of preferences, and even here the evidence is not necessarily contradictory. For example, zero-parity women may revise their IFS downward while still increasing their desire for a first child.

In addition to these temperature effects, we find that precipitation anomalies are positively associated with fertility preferences among low-parity women (β= 0.010 for zero-parity women). However, this association is offset at higher parities, with an approximately 0.4 percentage-point reduction in the net probability of desiring another child with each one-child increase in parity. Assuming precipitation anomalies are positively associated with agricultural outcomes and related demand for workers, these results are consistent with a scenario in which small families (e.g., of childless women) seek to increase fertility to overcome labor deficits. In contrast, women in larger families may not face such constraints and instead simply shift their time to agricultural tasks or care for existing children—and therefore may not need or have time for an additional child. Note that we find a similar pattern in the model of 12-month climate anomalies, except that precipitation effects are null rather than positive among childless women (Table 5, Model 14). This finding is consistent with the interpretation that adult labor utilization—and its suppression of fertility goals—outweighs demand for future children in the very short-run.

We then test for variation in the association between climate anomalies and IFS by women's education level, used as a broad proxy for socioeconomic status (Table 4, Model 7). When exposed to above-average temperatures, women without primary school completion report significantly lower IFS than during spells of average temperatures (β= -0.130; Figure 3, Panel A) but revise their fertility ideals upward when exposed to above-average levels of precipitation and presumably more favorable agricultural and economic conditions (β= 0.076; Figure 3, Panel B). Neither temperature nor precipitation effects are statistically significant among better-educated women, which is consistent with expectations that higher socioeconomic status women are less vulnerable to climate change than lower-status women, but not consistent with the expectation that the former are more likely to perceive fertility within their control than the latter. When climate is measured over a 12- rather than 60-month period, women without primary school completion adjust their fertility ideals downward when exposed to precipitation anomalies (β= -0.082). This is consistent with the expectation that immediate demands for agricultural labor—in which such women are concentrated—during periods favorable to agricultural production will lead to short-term declines in fertility.

A comparable model of fertility preferences (Table 4, Model 8) finds that higher temperatures are associated with a reduction in the probability that women with less than a primary school education will desire an additional child (β= -0.019). Precipitation has a null effect across this population. We find no associations between either temperature or precipitation anomalies and fertility preferences among women with a primary school education or more. Note that in the models of 12-month climate anomalies, higher temperatures are associated with a significant reduction of the desire for another child among both groups of women (Table 5, Model 16). A possible implication is that both groups of women respond to short-term changes, but the higher-status women are better able to adapt to environmental changes over the longer run.

Our third pair of interaction models tests for differences in climate effects on fertility goals across rural and urban areas (Table 4, Models 9 and 10). When exposed to spells of above-average temperatures, women in rural areas report significantly lower IFS than under average conditions. Each standard deviation increase in temperature anomalies reduces IFS by approximately 0.154 children. However, we find no association between precipitation and fertility ideals among rural women. In contrast, we find that urban women increase their IFS when exposed to high-precipitation spells (β= 0.110), and conversely reduce fertility during dry periods. In broad terms, this finding points to a scenario in which both rural and urban women reduce their fertility in response to adverse environmental conditions, respectively defined by high temperatures and low precipitation. It is less clear why temperature effects are most salient in rural areas and precipitation effects in urban areas. One speculative interpretation is that rainfall variations, such as the failure of the West African monsoon, are likely to covary across a wide spatial area and thus have stronger price effects than more idiosyncratic temperature variations. Such a dynamic would explain our findings and are in line with the expectations about the differential vulnerability of rural and urban women. Consistent with our other analyses, the model of fertility preferences (Table 4, Model 10) yields more conservative results, indicating a negative association between temperature anomalies and desire for another child (β= -0.019) among rural women, but no significant climate effects among urban women.

When climate is measured over 12-month intervals, we find negative temperature (β= 0.073) and precipitation (β= -0.069) effects on IFS among rural women (Table 5, Model 17), but positive temperature effects (β= 0.061) and null precipitation effects among urban women. The model of fertility preferences leads to similar conclusions among rural women (Table 5, Model 18), but shows null temperature effects and a significant positive association between precipitation and desire for another child among urban women. This pair of results does not support any robust conclusions about the association between short-term precipitation anomalies and fertility goals among urban women.

Fourth and finally, we assess whether the associations between climate anomalies and fertility goals vary across West, East, and Southern Africa. Here, we estimate a comparable pair of interaction models above, but include decade rather than region-decade fixed effects to avoid collinearity problems. We begin with the model of IFS (Table 4, Model 11), finding considerable variation across regional contexts. In West Africa, precipitation is associated with an increase in IFS (β= 0.063), but temperature anomalies are not associated with fertility ideals. In contrast, temperatures, but not precipitation, are significant predictors of IFS in East and Southern Africa. Point estimates suggest that the magnitude of these effects is considerably stronger in East Africa (β= -0.393) than among the Southern African countries included in the sample (β= -0.121). We illustrate these regional differences in temperature (Panel A) and precipitation (Panel B) effects in Figure 4, which plots the predicted IFS for each region across different climatic conditions. A similar model (Table 4, Model 12) of fertility preferences demonstrates that neither precipitation nor temperature variability are associated with the probability of desiring another child among West African women. Temperature anomalies are negatively associated with these fertility preferences in East and Central (β = -0.025) and Southern (β = -0.021) Africa, although we note that the net temperature coefficient estimate is marginally significant (p=0.054) in East Africa.

The models of fertility goals that use 12-month climate measures (Table 5, Models 19 and 20) provide additional support for the evidence that women in East and Southern Africa reduce their IFS and desire for another child during spells of high temperatures. The model of IFS also suggests that higher precipitation is associated with declining fertility goals in East Africa. Additionally, we find support for the conclusion that precipitation is positively associated with the fertility goals of West African women but note that these associations are only significant for fertility ideals over the short-run and fertility preferences over the long-run.

7. Discussion & Conclusion

We find evidence of a statistically and substantively significant relationship between changes in temperature and precipitation anomalies, and women's IFS and fertility preferences in sub-Saharan Africa. Exposure to higher temperatures during the 12- and 60-month periods prior to the DHS interview is associated with lower IFS, with a one standard-deviation increase in temperature corresponding to a reduction in IFS of greater than 0.042 and 0.101 children, respectively. We also found overall negative effects of temperature anomalies on fertility preferences, such that exposure to higher temperatures reduced women's desire to want a first or additional child. These results are consistent with the expectation that fertility declines in times of environmental and economic stress or uncertainty, when the cost of having many children may outweigh the benefits (de Sherbinin et al., 2008; Lesthaeghe, 1989). To note, other channels may also explain this negative association, such increases in intra-household conflict and entrance of women into the formal labor force (Hidrobo et al., 2016).

Results indicate that exposure to precipitation anomalies during the 12 months prior to each survey is associated with a significant reduction in IFS, but we find positive effects of precipitation anomalies on IFS when measured over a five-year period. Effects of unusual precipitation are null for women's fertility preferences at both shorter- and longer-term periods. We speculate that precipitation shocks in the short-term may increase immediate demand for labor among existing household members—thus reducing the desire for more children—whereas prolonged periods of high precipitation levels—and presumably favorable agricultural conditions (Bakhtsiyarava et al., 2018; Simon, 2017)—could increase the perceived need for permanent additions to the household labor supply (i.e., more children) or result in wealth accumulation enabling households to accommodate larger families.

Importantly, our results are not only statistically significant, but appear substantively meaningful as well. The magnitude of these overall associations is modest but non-trivial. For example, the absolute value of each marginal effect in question is less than a quarter that of a one-child increase in parity ($\beta = 0.220$), but more than five times the marginal effect of a oneyear increase in women's age ($\beta = -0.008$). While acknowledging that such differences are not particularly large in the context of historical fertility transitions—when fertility preferences and realized fertility declined by multiple children—we underline that our analyses are focused on short-term variability in fertility desires, of which climate anomalies are an important determinant.

We also find notable results when examining variation in the association between climate anomalies and fertility goals across sub-populations, which are partially consistent with hypothesized mechanisms described above. Unusually high temperatures are associated with declines in IFS and preferences only in rural areas, which are distinctively vulnerable to climate change and where unfavorably warm conditions can hinder agricultural production (Rosenzweig et al., 2014). Yet we also see significant precipitation effects in urban areas, which suggests these populations are also affected by and responding to climatic changes.

Importantly, variation in the type of climate change impacts to which each population is responding suggests different mechanisms may be at play.

In terms of socioeconomic differences, we find that temperature anomalies are negatively associated with IFS and fertility preferences among women without primary school completion, and models of IFS suggest precipitation anomalies have a positive effect on fertility goals among this same population. Women with a primary school education or higher do not systematically change their reproductive goals in step with climatic anomalies, except for when exposed to short-duration spells of high temperatures, when they are less likely to want a first or additional child. These results are generally consistent with hypothesized mechanisms that educational attainment (and socioeconomic status) is associated with stocks of shock-buffering assets and thus, resilience to climatic variability. However, we also expected better-educated women to perceive their reproductive decisions (and climate change adaptation) as within their control more so than their less-educated peers (Behrman, 2015; Sasson & Weinreb, 2017). This expectation is not supported by our findings.

Third, we find that the effects of temperature on IFS and fertility preferences only varies in direction at usually high and low parities: for most women, temperature reduces both outcomes. At the tails of the parity range, we find temperature-induced changes in IFS moving in the opposite direction of preferences, which highlights the possibility that women may revise their IFS downward while still increasing their desire for a first child. Interestingly, we also found that parity only offset temperature effects on IFS when climate was measured over fiveyear periods. The effects of short-term temperature shocks were consistent across parities, highlighting differences between short- and long-term ideational responses among high-parity women.

Finally, we found evidence of spatial variation in climate impacts and responses. In West Africa, women’s fertility goals vary (positively) with precipitation patterns, while in East and Southern Africa, fertility goals are primarily driven by changing temperatures. While acknowledging the coarseness of this regional measure, the stark differences we observe raise important questions about the possible moderating roles of agroecological and sociocultural context for future research to explore. We expect many such questions, as this study is among the first to empirically assess the association between fertility goals and climatic variability. It provides new evidence that fertility goals change in response to climatic variability, and in ways that are generally consistent with hypothesized mechanisms. To the extent that our measures of fertility goals serve as valid predictors of future fertility behavior (Bongaarts & Casterline, 2013; Kodzi et al., 2010; Pritchett, 1994), these findings broadly suggest that the hotter and drier conditions expected across much of the continent will be associated with declining fertility rates and smaller family sizes. They further suggest that the downward pressures are most likely to be felt among rural and poorer women—who on average have the highest baseline fertility ideals— and women relatively early in their reproductive careers—who will have the greatest influence on future population dynamics in the region.

Our overall findings are robust to using alternative measurement and modeling decisions, but there is nonetheless room for future research to build on our results. For one, future studies should evaluate the effects of climatic variability on *achieved* fertility outcomes. Our focus on reproductive goals was motivated by the challenge of estimating the relationship between climatic variability and realized fertility over a spatially and temporally broad sample, where women's broadly-defined ability to control fertility varies considerably. Future research should take this challenge as a topic of inquiry and evaluate where and under what circumstances women are (not) able to adapt their fertility to environmental changes as desired. Second, while we exploit the breadth of the DHS data, additional studies should draw on data with greater depth and detail to empirically identify the pathways through which climate anomalies affect fertility preferences (Grace, 2017). Datasets that combine demographic records with information on agricultural production, economic resources, and inter-personal dynamics would be particularly useful for these efforts. Particularly for sub-Saharan Africa, these datasets can be exploited to better understand, and provide evidence about, the likely diverse mechanisms linking climate change impacts on agricultural productivity to changing fertility goals. In addition, future research should also evaluate whether and how the effects of climate change on reproductive outcomes vary across social and spatial contexts, such as in places like southern Asia where changes in flooding patterns may be more salient than temperature and have distinctive effects on fertility. Finally, future research should consider incorporating alternative climate measures, such as using daily climate records to measure the number of extreme temperature and precipitation days. Our findings highlighted differential responses to short- and longer-term climatic anomalies, and we expect other dimensions of climate may affect demographic outcomes in unique ways.

In closing, we underline the policy relevance of these findings. As climate change unfolds, it is important to understand the multiple ways in which individuals and households adapt or fail to adapt. While considerable attention has been paid to adaptation mechanisms occurring over relatively short periods of time—such as human migration (Gray & Mueller, 2012; Mastrorillo et al., 2016; Thiede et al., 2016), changes in agricultural practices (Rosenzweig et al., 2014), and changes in livelihood (Tanner et al., 2015)—our findings suggest that adaptation may also involve ideational changes that could affect behavior throughout women's reproductive years. Moreover, realization of the climate-related changes in fertility goals observed in this study presumes the absence of barriers to actualizing fertility desires. To the extent that such barriers exist (Casterline & el-Zeini, 2007), our findings suggest that increasing resources for family planning could be a useful component of climate change adaptation policies and programs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

This research was supported by the Population Research Institute at the Pennsylvania State University (partly funded through the Eunice Kennedy Shriver National Institute of Child Health and Human Development [P2CHD041025]) and by the Joan Luerssen Faculty Enhancement Fund. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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Highlights

- We link historical climate records to 40 rounds of Demographic and Health Survey data from 18 sub-Saharan African countries to analyze the relationship between climatic variability and fertility goals among reproductive-aged women.
- Exposure to temperature anomalies is inversely associated with ideal family size and the desire to have a first or additional child.
- Precipitation variability has less consistent effects on fertility goals, and the direction of these effects vary according to whether women are exposed to short or prolonged periods of anomalous temperatures.
- Climate effects on reproductive goals vary across sub-populations defined by parity, education, residence in rural or urban areas, and region.

Figure 1.

Approximate location of residential clusters in analytic sample, by country

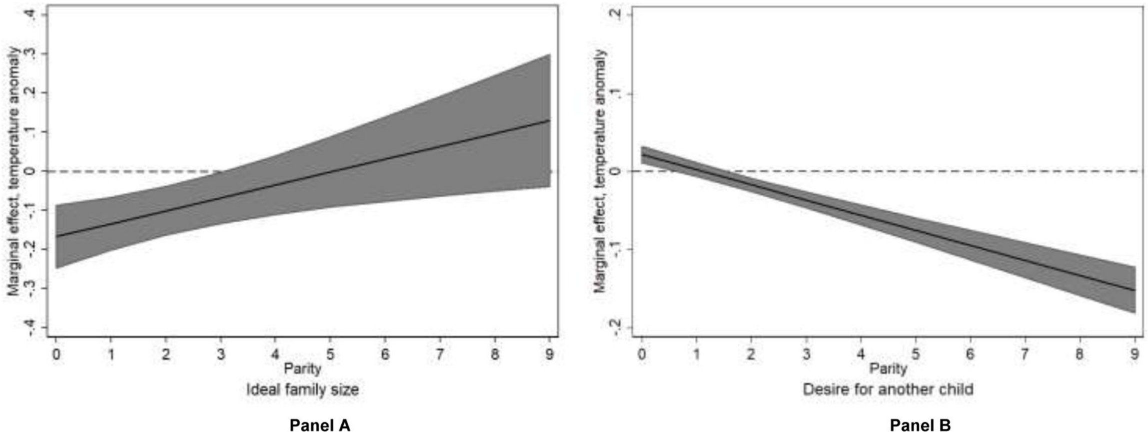
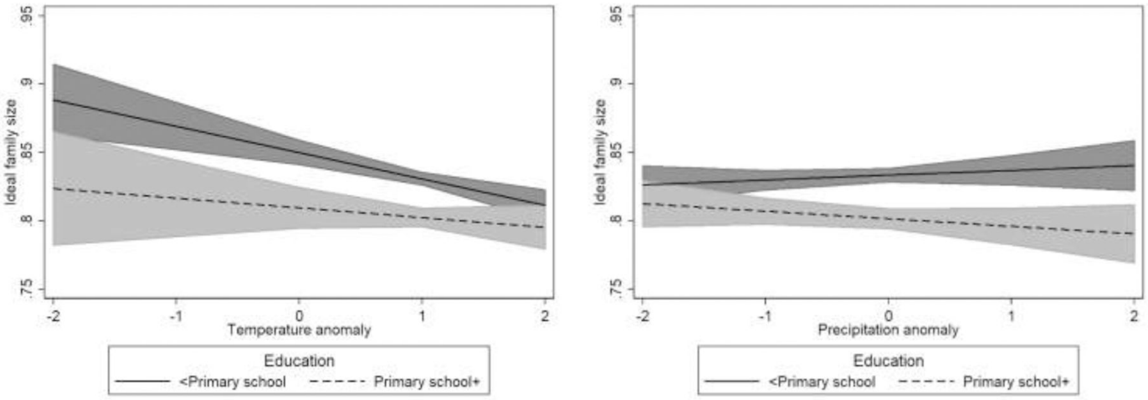


Figure 2.

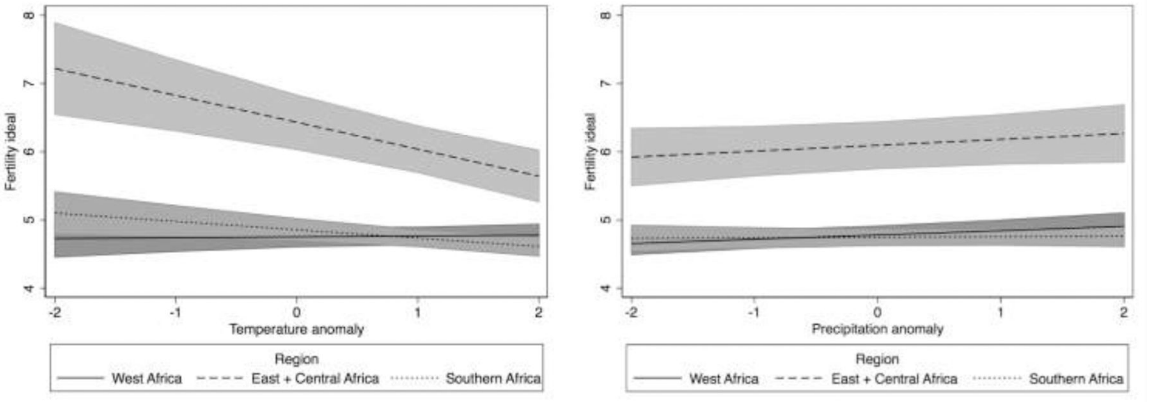
Marginal effect of temperature anomalies on fertility ideals (Panel A) and intentions (Panel B), by parity



Panel A **Panel B**

Figure 3.

Predicted ideal family size by temperature (Panel A) and precipitation (Panel B) anomalies, by educational attainment



Panel A **Panel B**

Figure 4.

Predicted ideal family size by temperature (Panel A) and precipitation (Panel B) anomalies, by region

Table 1.

Sample by country

Country	Region	DHS Year(s) Used	No. of Provinces	N	%
Benin	West	1996, 2001	12	2,335	3.3
Burkina Faso	West	1993, 1998, 2003	13	4,881	6.9
Cameroon	West	1991, 2004, 2011	10	2,425	2.4
Cote d'Ivoire	West	1994	14	1,262	1.8
Ethiopia	East	2000, 2005	11	5,459	7.7
Ghana	West	1993, 1998, 2003, 2008	12	3,316	4.7
Guinea	West	2005	8	1,412	2.0
Kenya	East	2003, 2008	50	2,432	3.4
Madagascar	South	1997, 2008	6	5,815	8.2
Malawi	South	2000, 2004	29	10,045	14.2
Mali	West	1995, 2001, 2006	10	7,772	11.0
Niger	West	1992, 1998	9	2,370	3.3
Nigeria	West	1990, 2003, 2008	38	7,034	9.9
Rwanda	East	2005	5	1,430	2.0
Tanzania	East	1999, 2004, 2015	30	3,350	4.7
Uganda	West	2001, 2006	55	1,573	2.2
Zambia	South	2007, 2013	11	3,111	4.4
Zimbabwe	South	2005, 2015	10	4,857	6.9
Total			*333*	*70,879*	*100*

Table 2.

Description of sample

Variable	Mean (SD) / Percentage	Minimum	Maximum
Climate variables			
Temperature z-score (12-month mean)	0.7 (1.0)	−2.8	3.4
Precipitation z-score (12-month total)	−0.2 (0.8)	−3.0	3.2
Temperature z-score (60-month mean)	0.9 (0.6)	−1.2	2.3
Precipitation z-score (60-month total)	−0.3 (0.7)	−3.0	2.2
Fertility variables			
Ideal family size	5.0 (2.6)	0.0	40.0
Desire for another child (%)	82.8	-	-
Control variables			
Age	23.8 (4.7)	15.0	49.0
Number of children ever born	2.0 (1.3)	0.0	12.0
Primary school or higher (%)	35.3	-	-
Rural residence (%)	71.3	-	-
Occupation status (%)			
Employed, not in agriculture	30.3	-	-
Employed in agriculture	35.4	-	-
Not employed	33.2	-	-
Missing or unknown	1.2	-	-
Married or living together (%)	90.2	-	-
Region-decade fixed effects (%)			
West Africa, 1990s	17.3	-	-
West Africa, 2000s	29.0	-	-
East & Central Africa, 1990s	1.2	-	-
East & Central Africa, 2000s	15.4	-	-
East & Central Africa, 2010s	3.6	-	-
Southern Africa 1990s	3.2	-	-
Southern Africa 2000s	18.4	-	-
Southern Africa 2010s	12.0	-	-
N	70,879	-	-

Estimates subject to minor rounding error.

Table 3.

Coefficient estimates, linear regression models predicting fertility ideals and fertility preference

	12 months		60 month	
	Model 1 Fertility Ideals	**Model 2 Fertility Preferences**	**Model 3 Fertility Ideals**	**Model 4 Fertility Preferences**
Temperature	−0.0422 **	−0.0095 ***	−0.1012 ***	−0.0169 ***
Precipitation	−0.0520 **	−0.0017	0.0591 ***	0.0002
Age	−0.0082 ***	−0.0047 ***	−0.0082 ***	−0.0047 ***
Number of children ever born	0.2204 ***	−0.0659 ***	0.2202 ***	−0.0659 ***
Educational attainment				
No primary school attainment	(ref)	(ref)	(ref)	(ref)
Primary school or higher	−0.6477 ***	−0.0283 ***	−0.6468 ***	0.0281 ***
Rural/urban status				
Rural	(ref)	(ref)	(ref)	(ref)
Urban	−0.5384 ***	−0.0288 ***	−0.5389 ***	−0.0292 ***
Occupation status				
Employed, not in agriculture	(ref)	(ref)	(ref)	(ref)
Employed in agriculture	0.1844 ***	0.0203 ***	0.1892 ***	0.0203 ***
Not employed	0.1505 ***	−0.0114 ***	0.1495 ***	−0.0115 ***
Marital status				
Married or living together	(ref)	(ref)	(ref)	(ref)
Formerly in union	−0.3754 ***	−0.1630 ***	−0.3768 ***	−0.1633 ***
Region-decade fixed effects				
West Africa, 1990s	(ref)	(ref)	(ref)	(ref)
West Africa, 2000s	−0.1428 ***	0.0099 *	−0.0906 *	0.0184 ***
East & Central Africa, 1990s	1.2556 ***	0.1943 ***	1.3251 ***	0.2137 ***
East & Central Africa, 2000s	−0.0904	0.1139 *	0.0822	0.1393 **
East & Central Africa, 2010s	1.1736 ***	0.2236 ***	1.3049 ***	0.2488 ***
Southern Africa 1990s	0.1411	−0.0505 **	0.1117	−0.0290
Southern Africa 2000s	−0.2174 **	−0.0347 **	−0.1853 **	−0.0182
Southern Africa 2010s	−0.0753	0.0318 **	−0.0324	0.0461 ***
Joint test, climate variables	***	***	***	***
N	70,879	70,879	70,879	70,879
R^2	0.3416	0.1682	0.3418	0.1682

Fixed effects for level-1 sub-national units and decade included in all model specifications; results not shown. Coefficient estimate for “missing or unknown” occupation status not shown.

[*] p< 0.10

[**] p < 0.05

[***] p < 0.01.

Table 4.

Interaction models estimating the effect of climate variability on fertility ideals and fertility preferences (60-month climate measures)

	By Parity		By Education		By Rural/Urban Status		By Region	
	Model 5 Fertility Ideals	Model 6 Fertility Preferences	Model 7 Fertility Ideals	Model 8 Fertility Preferences	Model 9 Fertility Ideals	Model 10 Fertility Preferences	Model 11 Fertility Ideals	Model 12 Fertility Preferences
Temperature	−0.1670 ***	0.0216 ***	−0.1303 ***	−0.0192 ***	−0.1535 ***	−0.0185 ***	0.0120	−0.0077
Precipitation	0.0523 *	0.0095 **	0.0758 **	0.0036	0.0423	−0.0002	0.0625 **	0.0024
Temperature*parity	0.0330 ***	−0.0193 ***						
Precipitation*parity	0.0031	−0.0044 **						
Temperature*primary school+			0.1367 ***	0.0121 *				
Precipitation*primary school+			−0.0486	−0.0091				
Temperature*urban status					0.2328 ***	0.0072		
Precipitation*urban status					0.0674 **	0.0019		
Temperature*East and Central Africa							−0.4052 ***	−0.0178
Precipitation*East and Central Africa							0.0226	0.0048
Temperature*Southern Africa							−0.1332 **	−0.0131
Precipitation*Southern Africa							−0.0536	−0.0095
Joint test, climate variables	***	***	***	***	***	***	***	**
Joint test, interaction terms	**	***	***	**	***		***	
N	70,879	70,879	70,879	70,879	70,879	70,879	70,879	70,879
R^2	0.3420	0.1702	0.3421	0.1683	0.3424	0.1682	0.3425	0.1683

Fixed effects for level-1 sub-national units and decade included in all model specifications; results not shown. Model controlled for age, number of children ever born, education, rural/urban status, and marital status.

[*] $p < 0.10$

[**] $p < 0.05$

[***] $p < 0.01$.

Table 5.

Interaction models estimating the effect of climate variability on fertility ideals and fertility preferences (12-month climate measures)

	By Parity		By Education		By Rural/Urban Status		By Region	
	Model 13 Fertility Ideals	**Model 14 Fertility Preferences**	**Model 15 Fertility Preferences**	**Model 16 Fertility Ideals**	**Model 17 Fertility Preferences**	**Model 18 Fertility Preferences**	**Model 19 Fertility Ideals**	**Model 20 Fertility Preferences**
Temperature	−0.0591 ***	0.0137 ***	−0.0637 ***	−0.0098 ***	−0.0728 ***	−0.0100 ***	0.0570 **	0.0049 *
Precipitation	−0.0532 *	0.0057	−0.0824 ***	−0.0032	−0.0689 ***	−0.0055 **	0.0286	0.0058 **
Temperature*parity	0.0088	−0.0120 ***						
Precipitation*parity	0.0004	−0.0035 **						
Temperature*primary school+			0.0750 ***	0.0009				
Precipitation*primary school+			0.0957 ***	0.0044				
Temperature*urban status					0.1335 ***	0.0028		
Precipitation*urban status					0.0835 **	0.0143 ***		
Temperature*East and Central Africa							−0.3147 ***	−0.0205 **
Precipitation*East and Central Africa							−0.1591 ***	−0.0149 *
Temperature*Southern Africa							−0.1073 ***	−0.0185 ***
Precipitation*Southern Africa							−0.0528	−0.0093
Joint test, climate variables	***	***	***	***	***	***	***	***
Joint test, interaction terms		***	***		***	**	***	***
N	70,879	70,879	70,879	70,879	70,879	70,879	70,879	70,879
R^2	0.3416	0.1699	0.3419	0.1682	0.3421	0.1684	0.3428	0.1685

Fixed effects for level-1 sub-national units and decade included in all model specifications; results not shown. Model controlled for age, number of children ever born, education, rural/urban status, and marital status.

[*] p< 0.10

[**] p< 0.05

[***] p < 0.01.