Whether it’s Weather or Climate:

The Link between Temperatures and Deprivation in Sub-Saharan Africa[[1]](#footnote-1)\*

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**Abstract**

In this paper, we leverage a large-scale, geo-referenced household-level survey covering 28 African countries over 16 years to provide new evidence on the link between rising temperatures and living standards in a particularly vulnerable region. We thereby evaluate both the short-term response to temperature (shocks) and the long-term equilibrium effects of climate change by matching daily- and long-term average temperature data to 168,585 individuals across 14,186 unique survey locales. Our results consistently confirm the expected negative relationship between temperature and individual living standards in Sub-Saharan Africa. Elevated temperatures are linked to greater insufficiencies in meeting basic needs such as access to food, water, healthcare, and income, whether experienced as shocks or long-term averages. However, the quantitative relevance of temperature increases on deprivation is comparatively modest. Furthermore, our findings underscore the role of local infrastructural investments in moderating the negative impacts of both short-term weather variability as well as long-term climate change.

**Keywords:** Sub-Saharan Africa, Temperature, Climate Change, Development

**JEL Classification:** Q54, N57, O12.

## Introduction

The inquiry into the economic impact of increasing temperatures has largely provided evidence for a negative overall effect (for a recent overview see Tol 2024).[[2]](#footnote-2) Notably, this average result masks considerable variability both in the magnitude as well as the direction of expected effects (e.g. Newell et al. 2021).[[3]](#footnote-3) However, a rather consistent result across the literature is that (more severe) negative effects are anticipated for countries and regions which are hotter to begin with (e.g. Burke et al. 2015b)[[4]](#footnote-4) as well as for those that are poor (e.g. Dell et al. 2012).[[5]](#footnote-5)

In this paper, we systematically investigate the link between temperatures and *individual livelihoods* in Sub-Saharan Africa, one of the hottest and poorest regions in the world. We evaluate both the short-term response to weather (shocks) as well as the long-term equilibrium effects of high temperatures (climate change) by matching daily as well as long-term average temperature data to a geo-referenced household-level survey consisting of a total of 168,585 individuals sampled across 28 African countries over 16 years. The data structure allows us to account for country-year-month fixed effects and, crucially, local geographic and individual-level controls which address a significant gap in prior cross-sectional studies on the economic impacts of climate change (see Hsiang 2016; Kolstad and Moore 2020).

Our inquiry complements a growing literature studying the impact of climate (change) at the individual level and in particularly vulnerable regions. Studies have investigated outcomes such as household wealth (Park et al. 2018), physical health (Hyland and Russ 2019), education (Wilde et al. 2017), fertility (Thiede and Strube 2020), child health (Thiede and Strube 2020; Baker and Anttila-Hughes 2020; Blom et al. 2022; Rajkhowa and Chakrabarti 2024), child marriage (Tsaneva 2020), labour market outcomes (Henderson et al. 2014; Brookes Gray et al. 2023), migration (Helbling et al. 2021), mental health (Adhvaryu et al. 2024), political trust and conflict (Vestby 2019; Aboyadana and Alfano 2021; Cerkez 2024; Ahlerup et al. 2024), intimate partner violence (Sekhri and Storeygard 2014; Cools et al. 2020; Díaz and Saldarriaga 2023) and household deprivation (Bukari and Aluko 2023).

Our paper adds to the literature in three distinct ways: First, we compare the effect of short-term weather (shocks) to the long-run equilibrium effects of climate on (subjective) individual living conditions, providing insight into these two competing dimensions discussed in the literature. Second, using our data we can assess the importance of potential coping strategies, that is we analyse the moderating role of local institutional quality and local infrastructural investments on the link between temperature and individual livelihoods. And, third, we comprehensively investigate an underutilised geo-referenced dataset, the Afrobarometer, which allows us to tap into both objective- and, importantly, subjective evaluations of how climate may affect individual living standards. So far, the Afrobarometer has only been used sparsely to investigate these links.[[6]](#footnote-6)

Our results show that higher temperatures are consistently associated with increased individual deprivation, whether we evaluate short-term weather (shocks) or long-term climatic conditions. In quantitative terms, an increase of one degree Celsius in the two-week average temperature prior to the interview increases the occurrence of deprivation in food, water, medical care, and cash income by about 2.6 percent relative to the mean in the sample; and by 2.7 percent for the same increase in the long-run (monthly) average temperature. We find relatively larger negative effects in rural settings as well as for individuals engaged in agricultural occupations. Importantly, our findings also highlight the influence of infrastructural endowments as a relevant moderator, able to render temperature effects almost negligible in specific configurations. Moreover, the coefficients for infrastructure quantitatively exceed the impact of temperature alone, suggesting that the availability of essential infrastructure not only serves as an effective coping strategy to mitigate the adverse effects of rising temperatures but may also be a more crucial focal point to economic development in hot and impoverished regions. Importantly, our results are robust to a large array of robustness tests, including restrictive choices on fixed effects (at the country-year-month-day level), different clustering strategies for standard errors (at the country-year as well as Conley standard errors allowing for spatial correlation), and different sample adaptations.

The remaining sections of the paper are organized as follows: Section 2 discusses the theoretical channels via which short-term temperature and long-term climatic conditions are expected to influence economic development with a particular focus on Sub-Saharan Africa. Section 3 introduces the data used and the empirical strategy. Section 4 presents and discusses our findings. Section 5 provides concluding remarks.

## Economic Impacts of Climatic Conditions in Sub-Saharan Africa

A close examination of the hypothesized channels through which temperature may affect individual livelihoods underscores Sub-Saharan Africa’s particular vulnerability to current climatic conditions as well as future climate change (for recent surveys on the empirical support of channels see Carleton and Hsiang 2016; Acevedo et al. 2020).

Given the direct connection between climatic conditions and land use, rising temperatures have been suggested to negatively impact agricultural yield (see Carter et al. 2018 for an overview of this channel), and there is evidence for sizeable negative effects in Sub-Saharan Africa (see e.g. Schlenker and Lobell 2010). Relatedly, an additional stressor of the continent is the continuous prevalence of pests and diseases, which further burdens agricultural output (e.g. Alsan 2015). Given that over 50 percent of Africans depend on agriculture for their livelihood (World Bank 2022), higher temperature is likely to be connected to individual deprivation through this channel, particularly as evidence for successful adaptation in agriculture is mixed, even in highly developed countries (e.g. Schlenker and Roberts 2009; Hornbeck 2012; Burke and Emerick 2016).[[7]](#footnote-7)

Increased heat stress associated with rising temperatures may directly affect labour productivity and supply. Evidence points to shortened work hours, effort, as well as intensity due to high temperatures, both in high- and low-income settings as well as labour- and capital-intensive firms (Zhang et al. 2018; Letta and Tol 2019; Somanathan et al. 2021); these effects are particularly pronounced among workers engaged in outdoor occupations (Graff Zivin and Neidell 2014). Moreover, temperatures can affect human capital formation, as (life-long) learning outcomes may be attenuated in warmer environments (e.g. Graff Zivin et al. 2018; Park 2022). As such, weather conditions have been directly connected to lowered earnings (Fishman et al. 2019), with depressed (pre-natal) child health (Deschênes and Moretti 2009; Kudamatsu et al. 2012; Flückiger and Ludwig 2022) or educational attainment (Maccini and Yang 2009) as mediating channels.

Relatedly, climatic conditions may affect physical health outcomes (for an overview see Deschênes 2014; Heal and Park 2016). Next to directly affecting mortality (Deschênes and Greenstone 2011; Barreca et al. 2016), increased temperatures and weather shocks have been associated with increased morbidity and may spur the prevalence of infectious diseases (Wu et al. 2016). For instance, increased weather variability has been associated with epidemic malaria periods in East Africa (Zhou et al. 2004). At the same time, there is evidence that temperature increases may also attenuate the spread of disease vectors, hence why yellow fever may ultimately vanish from the African continent (Wu et al. 2016) and malaria could find new homes (Peterson 2009; Béguin et al. 2011). A similar beneficial effect of warmer climates was also observed in the recent COVID-19 pandemic (e.g. Wang et al. 2020; Prata et al. 2020). As endemic diseases have plagued economic development in Africa through various ways, i.e. directly via productivity limits (Gallup et al. 1999) or indirectly, e.g. via lasting institutional effects of colonial rule (Acemoglu et al. 2001), this channel presents another reason why exploring the effect of climatic conditions on individual living standards is relevant.

Another channel through which effects of climate change may be particularly pronounced in Africa pertains to conflict and political stability. In Africa, evidence for this channel is particularly vast, as variations in rainfall (Miguel et al. 2004), temperatures (Burke et al. 2009) as well as droughts (Couttenier and Soubeyran 2014) have all been shown to spur the incidence of conflict to relevant degrees (for an overview of this literature see Burke et al. 2015a). For example, Burke et al. (2009) estimate a 49 percent increase in violent conflict for every 1°C increase in ambient temperatures. Moreover, increased temperature has been associated with political instability in the form of coups (Dell et al. 2012), but may also improve upon democracy given the subsequent economic plights (e.g. Burke and Leigh 2010; Brückner and Ciccone 2011). One particular way to cope with increased prevalence of conflict is outmigration, which may put additional strains on (local) economic potential (Dreher et al. 2011; Abel et al. 2019). More generally, migration has been associated with climate change (Bohra-Mishra et al. 2014; Beine and Parsons 2015), particularly so in Africa, where increasing temperatures have been argued to move highly skilled individuals abroad or put additional strain on already growing urbanities (Barrios et al. 2006; Marchiori et al. 2012; Henderson et al. 2014). Notably, the poorest of the poor may be unable to migrate given (increased) budget constraints (see e.g. Cattaneo and Peri 2016), putting further strain on (those) individual livelihoods.

Given these aspects, it is to no surprise that particularly Sub-Saharan African economies have long been regarded as the countries with one of the highest levels of vulnerability due to climate change (see e.g. Brooks et al. 2005; Eriksen and Kelly 2007). In addition, potential adaptation to higher temperatures is likely far more challenging in regions burdened with economic, fiscal, and institutional difficulties compared to relatively richer regions (Mortreux and Barnett 2017; Cinner et al. 2018; Siders 2019). Hence, investigating the potential impact of an unfavourable climate on individual Sub-Saharan livelihoods is relevant to the understanding what future temperature increases may imply for the subcontinent.

## Data and Empirical Strategy

We use geo-referenced household survey data from the Afrobarometer to retrieve indicators of individual living standards and match these observations with daily weather data from CPC Global Unified Temperature provided by the Climate Prediction Centre of the National Oceanic and Atmospheric Administration (NOAA) (CPC 2024) as well as long-term average climate information (1970-2000) from WorldClim 2.1 by Fick and Hijmans (2017).

### Afrobarometer

Our primary unit of observation is individuals, respectively their corresponding household information, which were collected across six rounds of the repeated cross-sectional Afrobarometer survey.[[8]](#footnote-8) Afrobarometer surveys are nationally representative cross-sectional surveys of all voting age citizens, i.e. 18 and above. The survey has been undertaken at periodic intervals since 1999 with 12 countries in the first wave and gradually increasing to a total of 39 countries. Our analysis relies on survey samples from 2002–2004, 2005–2006, 2008–2009, 2011–2013, 2014–2015, and 2016–2018 for which all variables necessary to test the relationship between temperatures and individual subjective deprivation is consistently available.[[9]](#footnote-9)  Depending on the year, each country sample consists of 1,200 or 2,400 respondent cases, with around eight individuals surveyed within a unique enumeration area (EA). The survey includes individual and household-level questions on living conditions and a rich set of socio-demographic characteristics and perceptions. It thereby provides additional information on respondents’ opinions and attitudes towards the economy, institutions, democracy, and governance. Importantly, the Afrobarometer provides a unique latitude-longitude combination to each EA. In the earlier rounds (2-6), respondents’ geographic coordinates were not directly recorded during data collection and coordinates were attached by post-survey geocoding (BenYishay et al. 2017).[[10]](#footnote-10)

As our main outcome of interest, we consider individual-, respectively household deprivation as the capability to meet the basic needs for food, water, medical care, as well as a cash income. The corresponding survey questions read: “*Over the past year, how often, if ever, have you or a member of your household gone without any of the following essentials [‘Enough food to eat’, ‘Medicines or medical treatment’, ‘Enough clean water for home use’, and ‘A cash income’]*.” The possible answers range from never, just once or twice, several times, many times and always, which we code in this precise order using integer values from zero to four. We look at each of these deprivation indicators separately as well as jointly. For the joint analysis, we construct a *deprivation index* by taking the simple average of each individual’s response to the four questions such that the *deprivation index* also has a range from zero to four. These measures of deprivation capture the recall of individual experiences with drought situations, naturally reflecting subjective influences as well. We consider this an advantage of our data and approach, as well as a contribution to the literature, highlighting the relevance of temperature and climate change, which may also affect individual livelihoods in this dimension.

Ein Bild, das Text, Karte enthält.

Automatisch generierte Beschreibung

###### : Yearly average temperatures and Afrobarometer survey locales

### Climate Data

We draw on two sources to match ambient temperatures to households of the Afrobarometer. In either case, we attach the respective temperature value of a grid-cell to all households of an enumeration area falling within this geographical delineation.

For one, we use daily temperatures provided at a resolution of 30 arc minutes (~50km at the equator) of the CPC Global Unified Temperature dataset from the Climate Prediction Center of the National Oceanic and Atmospheric Administration (NOAA) (CPC 2024).[[11]](#footnote-11) With this data at hand, we consider four distinct measures of temperature with which we aim to investigate the link between temperature and individual living standards. To test the extent to which short-run weather shocks affect individual deprivation, we employ the two-week average of the daily (average) temperatures before the interview date, as well as the average temperature on the day of the interview date. Also, we compute monthly and yearly average temperatures by considering the average temperature for the month and year of the interview, respectively.

Second, we use the long-run average of monthly temperatures (1970-2000) at the enumeration area provided at a resolution of 30 arc seconds (~1km at the equator) from WorldClim 2.1 by Fick and Hijmans (2017)[[12]](#footnote-12), to provide evidence on the long-run equilibrium effect between climate and individual deprivation.

Figure 1 depicts the variation in yearly average temperature in Africa together with the unique sample enumeration areas of the Afrobarometer across our survey time frame.

### Covariates

To isolate the effect of temperatures from other, potentially correlated, influences on individual deprivation, we add covariates at the individual- as well as enumeration-area level. We thereby include age, gender, and educational level as basic socio-demographic controls, add information on the household’s locality (i.e. urban or rural), and control for further physical geographic characteristics shown to influence (local) economic output. To do this, we proceed similarly to section 3.2 and attach information on first-nature features of the respondent’s EA including precipitation (Fick and Hijmans 2017), elevation (Farr et al. 2007) ruggedness (Nunn and Puga 2012), malaria ecology (Sachs et al. 2004), land suitability (Ramankutty et al. 2002), and the number of growing days (FAO and IIASA 2019). To account for second-nature features, we control for the importance of proximity to the coast (Wild and Stadelmann 2022), as well as to major rivers and lakes (Lehner and Döll 2004; Henderson et al. 2018; Natural Earth 2019).

Table A1 in Appendix A provides summary statistics for these variables for the main sample used to produce results throughout the paper, consisting of 168,585 individuals and households sampled in 14,186 unique survey locales (EAs) from 28 Sub-Saharan African countries[[13]](#footnote-13) across 16 years.

### Empirical Strategy

We analyse a repeated cross-section of individuals surveyed by Afrobarometer to explore the effect of temperature on individual deprivation by considering the following regression model:

|  |  |  |
| --- | --- | --- |
|  | t |  |

where denotes the deprivation measure of individual living in country and sampled in year-month . is vector of individual as well as geographical control variables introduced in section 3.3. represents the temperature measurement of respondent’s enumeration area. We include country-year-month fixed effects (). Country-year-month fixed effects account for instantaneous endogenous effects such as conflict or migration concerning the short-term estimates, while past occurrences of conflict or migration due to climate, i.e. selection into specific regions are captured by individual-level controls or – in the case of the long-term equilibrium estimates, already absorbed in the estimate. Thus, is identified by differences in temperature and individual deprivation across survey clusters within a country at a specific point in time, i.e. the survey sampling year-month combination. is the idiosyncratic error term and we compute standard errors clustered at the survey enumeration area level.[[14]](#footnote-14) As such, depending on the temperature measure used, can be interpreted as either the effect of short-term weather (shocks) on individual wellbeing (for example, daily average, two-week window) or the long-run equilibrium effect of climatic conditions (for long-term (monthly) average temperature), the latter including any potential adaptation to past warming (Hsiang 2016; Kolstad and Moore 2020).

Analysing the link between temperatures and economic development from this perspective is favourable in at least three regards. First, it allows a direct comparison between short- and long-term effects of temperature on development outcomes at the individual level, going away from aggregates at the regional or country level. Second, concerning the long-run equilibrium effects of climatic conditions, it addresses issues of unobserved confounders at the local- or individual level that trouble the link between temperature and deprivation in more aggregated cross-sectional settings (see e.g. the discussion in Kolstad and Moore 2020). Lastly, it allows an assessment of *local* moderating mechanisms such as infrastructural investments or institutional quality which may have weakened negative effects of high temperatures in the longer run or may shield against short-term temperature shocks.

## Results and Discussions

### Baseline Results

Table 1 presents the baseline results estimated via (1) using the four individual deprivation indicators separately as well as the joint deprivation index as dependent variables. In the Table we also provide analyse all temperature measures. The results consistently reveal a negative relationship between each of the different measures of temperature and individual livelihoods, i.e. positive and statistically significant associations between short- as well as long-run temperature measures and individual deprivation across food, water, medicine and cash income.

##### Concerning the shorter-term impact of temperatures, we observe that an increase in the daily temperature (row 1) by one degree Celsius is associated with an increase in food deprivation (column 1) by 0.022 units. Compared to the mean food deprivation in the sample (1.12), this represents a 1.96 percent increase, and going from the 1st to the 3rd quartile of daily interview temperatures in the sample suggests a 14.89 [=(0.022\*(27.07 – 19.49))/1.12] percent increase. Similarly, a degree Celsius increase in yearly average temperature is correlated with an increase in food and cash income deprivation by 4.7 percent and 2.1 percent, respectively. Considering the long-run equilibrium effect (row 5), food deprivation increases by 3.6 percent with a 1.5 percent increase in cash income deprivation relative to the mean in the sample. The similarity in estimated effects for a given temperature measure (e.g., daily temperature) across different deprivation outcomes, such as food deprivation, medical care and income deprivation, suggests common underlying mechanisms through which temperature affects various aspects of individual living conditions. The fact that short-term and long-term measures of temperature do not vary largely in their estimated effects potentially signals lacking adjustment (possibilities) to past climate, whether through migration or other measures, which emphasizes the hurdles of agricultural based economies in Sub-Saharan Africa to adapt to temperatures (e.g. Schlenker and Roberts 2009; Hornbeck 2012; Burke and Emerick 2016). : High Temperature and Individual Deprivation in Sub-Saharan Africa

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Temperature Measure | Food Deprivation {0,4} | Water Deprivation {0,4} | Medical care Deprivation {0,4} | Cash Income Deprivation {0,4} | Deprivation Index [0,4] |
|  | (1) | (2) | (3) | (4) | (5) |
| (1) Daily Temperature | 0.022\*\*\* | 0.019\*\*\* | 0.020\*\*\* | 0.021\*\*\* | 0.020\*\*\* |
| (0.002) | (0.003) | (0.002) | (0.002) | (0.002) |
|  |  |  |  |  |  |
| (2) Temperature Two-weeks to Interview | 0.039\*\*\* | 0.036\*\*\* | 0.034\*\*\* | 0.037\*\*\* | 0.037\*\*\* |
| (0.003) | (0.004) | (0.003) | (0.003) | (0.002) |
|  |  |  |  |  |  |
| (3) Monthly Average Temperature | 0.041\*\*\* | 0.038\*\*\* | 0.037\*\*\* | 0.039\*\*\* | 0.039\*\*\* |
| (0.003) | (0.004) | (0.003) | (0.003) | (0.003) |
|  |  |  |  |  |  |
| (4) Yearly Average Temperature | 0.053\*\*\* | 0.047\*\*\* | 0.044\*\*\* | 0.045\*\*\* | 0.047\*\*\* |
| (0.003) | (0.005) | (0.003) | (0.003) | (0.003) |
|  |  |  |  |  |  |
| (5) Long-run Monthly Average Temperature | 0.043\*\*\* | 0.041\*\*\* | 0.036\*\*\* | 0.032\*\*\* | 0.038\*\*\* |
| (0.003) | (0.004) | (0.003) | (0.003) | (0.003) |
| Controls | No | No | No | No | No |
| Country-Year-Month FEs | Yes | Yes | Yes | Yes | Yes |
| Observations | 168,350 | 168,380 | 167,896 | 167,892 | 168,585 |
| R-Squared | 0.088 | 0.066 | 0.104 | 0.152 | 0.138 |
| Mean of Deprivation Measure | 1.117 | 1.177 | 1.242 | 2.123 | 1.414 |
| *Notes:* Results in each cell are produced by separate regressions via equation (1) and are estimated using the main sample of countries included in survey rounds 2 through 7 of the Afrobarometer. Rows (1) to (5) report the coefficient estimates of different temperature measures on the respective deprivation indicators in columns (1) to (5). Deprivation index is computed by averaging individuals’ responses to food, water, medical care and cash income indicators. Temperature is measured in degrees Celsius. Reported R-squared values are from models using daily temperature. The standard errors reported are clustered at the survey enumeration area level and reported in parentheses.  \*p < .1, \*\*p < .05, \*\*\*p < .01. | | | | | |

Table 1 checks the sensitivity of these baseline results to the inclusion of relevant individual- as well as location-specific controls by using the deprivation index as our dependent variable, only. We proceed in a stepwise fashion, assessing the robustness of the main coefficient of interest while successively adding several dimensions of relevant controls. Given that some of the controls added (e.g. education, occupation) may be channels via which temperature influences individual development outcomes, this approach has the added benefit of providing a quantitative indication of such potential mediating processes. For instance, if lower temperature lessens the incentive to invest in education, e.g. because of a location’s comparative advantage in agriculture, controlling for schooling eliminates any potential effect of temperature running via this (theoretical) channel.

First, we introduce demographic characteristics, encompassing sex, age, and age squared. Thereafter, we sequentially add individuals’ educational level, their employment status and add the household’s location type, i.e. an urban dummy.[[15]](#footnote-15) We augment the model with further geographic variables introduced in 3.3 and thereby include first-nature features such as precipitation, elevation, ruggedness, malaria ecology, land suitability, and the number of growing days. Concerning second-nature features, we enter proximity to the coast, major rivers and lakes. As shown in Table 2, temperature continues to be a statistically significant and relevant predictor of individual deprivation with the addition of controls, although the magnitude of the effect diminishes when accounting for important covariates. For instance, in column (1), an increase in the daily temperature by one-degree Celsius increases deprivation by 0.020 units when there are no covariates; the effect drops to 0.016 units when we consider socio-demographics and finally diminishes to 0.003 units when we account for first- and second nature factors. 0 in the Appendix provides individual coefficient estimates of all of the included control variables.

##### : Sensitivity Test – The Relevance of Covariates for the Deprivation Index as a Dependent Variable

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable(s) | Daily temperature | Temperature Two-weeks to Interview | Monthly Average Temperature | Yearly Average Temperature | Long-run Monthly Average Temperature |
|  | (1) | (2) | (3) | (4) | (5) |
| a = No Controls | 0.020\*\*\* | 0.037\*\*\* | 0.039\*\*\* | 0.047\*\*\* | 0.038\*\*\* |
| (0.002) | (0.002) | (0.003) | (0.003) | (0.003) |
| b = a + Demographics controls | 0.020\*\*\* | 0.036\*\*\* | 0.038\*\*\* | 0.046\*\*\* | 0.038\*\*\* |
| (0.002) | (0.002) | (0.003) | (0.003) | (0.003) |
| c = b + Level of education | 0.016\*\*\* | 0.029\*\*\* | 0.031\*\*\* | 0.039\*\*\* | 0.034\*\*\* |
| (0.002) | (0.002) | (0.002) | (0.003) | (0.002) |
| d = c + Employment status | 0.016\*\*\* | 0.028\*\*\* | 0.030\*\*\* | 0.038\*\*\* | 0.033\*\*\* |
| (0.002) | (0.002) | (0.002) | (0.003) | (0.002) |
| e = d + Urbanisation control | 0.014\*\*\* | 0.025\*\*\* | 0.027\*\*\* | 0.033\*\*\* | 0.032\*\*\* |
| (0.002) | (0.002) | (0.002) | (0.003) | (0.002) |
| f = e + First-nature geographic features | 0.003\*\* | 0.008\*\*\* | 0.009\*\*\* | 0.016\*\*\* | 0.032\*\*\* |
| (0.002) | (0.002) | (0.003) | (0.004) | (0.004) |
| g = f + Second-nature geographic features | 0.003 | 0.007\*\*\* | 0.008\*\*\* | 0.015\*\*\* | 0.038\*\*\* |
| (0.002) | (0.002) | (0.003) | (0.004) | (0.005) |
| Country-Year-Month FEs | Yes | Yes | Yes | Yes | Yes |
| Observations | 165,037 | 165,037 | 165,037 | 165,037 | 165,037 |
| R-Squared | 0.205 | 0.205 | 0.205 | 0.205 | 0.205 |
| *Notes:* Results in each cell come from separate regressions and are estimated using the main sample of countries included in survey rounds 2 through 7 of the Afrobarometer. The dependent variable is an index computed by averaging individuals’ responses to food, water, medical care and cash income indicators. Temperature is measured in degrees Celsius. Reported R-squared values and observations are from models using all covariates. The standard errors reported are clustered at the survey enumeration area level and reported in parentheses. \*p < .1, \*\*p < .05, \*\*\*p < .01. | | | | | |

We conduct additional robustness tests on our baseline results, which are reported in Table A2. (a) We include survey sampling weights (adjusted for varying sample size proportions), making the estimates representative at the national level. (b) We construct an alternative version of our deprivation index by employing principal component analysis. (c) We re-estimate our main results by replacing country-year-month fixed effects with country-year fixed effects, respectively, country-year-month-day-fixed effects. (d) We drop respondents from South Africa from the sample. (e) We allow for spatial correlation via Conley standard errors (Conley 1999) and also (f) drop respondents with a geo-precision score above 3 (precision is measured on an integer scale of 1-8, decreasing in precision).

Our results are robust, and the main interpretations of the baseline findings remain unchanged: there is a systematic and statistically significant association between our different temperature measures and our indicators individual deprivation. However, the quantitative effect is relatively small, particularly when accounting for individual controls and geographic covariates. Moreover, daily temperature becomes a less robust predictor once geographic controls are included and in other robustness checks. Nevertheless, elevated temperatures are clearly statistically associated with increased difficulties in meeting essential needs such as food, water, healthcare, and income, as reported by individuals. These challenges arise whether temperature increases manifest as sudden shocks or persist as long-term climate change.

### Heterogeneity

Given the substantial variation in reported effects of climatic conditions across regions (e.g. Dell et al. 2012; Burke et al. 2015b; Cruz and Rossi-Hansberg 2024), the negative coefficient on temperature reported in our main results may not materialise (to the same degree) for all individuals in our sample; regardless of where they are located, which occupation they carry out, etc. Such within-region heterogeneities may exist even in sub-Saharan Africa, a region which has consistently been reported to experience negative effects of high temperatures and global warming. As such, we conduct heterogeneity analysis along individuals’ locality, i.e. urban vs. rural, as well as their occupational category, i.e. agriculture vs. non-agricultural work.

##### : The Link between High Temperature and Individual Deprivation by Sub-Sample

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | | **Deprivation Index [0,4]** | | | | |  |
|  | Locality Type | | |  |  | Employment Sector | |  |
| Temperature Measure | Urban | Rural | | CI Overlap |  | Agriculture Activity | Non-Agriculture Activity | CI Overlap |
|  | (1) | (2) | |  |  | (3) | (4) |  |
| Daily Temperature | -0.001 | 0.003 | | Yes |  | 0.007\*\* | -0.0003 | Yes |
| (0.003) | (0.002) | |  |  | (0.004) | (0.002) |  |
| Temperature Two-weeks to Interview | 0.005 | 0.008\*\* | | Yes |  | 0.016\*\*\* | 0.003 | Yes |
| (0.005) | (0.003) | |  |  | (0.006) | (0.004) |  |
| Monthly Average Temperature | 0.006 | 0.009\*\* | | Yes |  | 0.020\*\*\* | 0.007 | Yes |
| (0.005) | (0.004) | |  |  | (0.006) | (0.004) |  |
| Yearly Average Temperature | 0.012\* | 0.015\*\*\* | | Yes |  | 0.029\*\*\* | 0.012\*\* | Yes |
| (0.007) | (0.005) | |  |  | (0.008) | (0.005) |  |
| Long-run Monthly Average Temperature | 0.026\*\*\* | 0.033\*\*\* | | Yes |  | 0.039\*\*\* | 0.037\*\*\* | Yes |
| (0.008) | (0.006) | |  |  | (0.010) | (0.007) |  |
| Socio-demographic Controls | Yes | Yes | |  |  | Yes | Yes |  |
| Geographic Controls | Yes | Yes | |  |  | Yes | Yes |  |
| Country-Year-Month FEs | Yes | Yes | |  |  | Yes | Yes |  |
| Observations | 56,615 | 108,422 | |  |  | 32,054 | 48,467 |  |
| Mean of Deprivation Measure | 1.114 | 1.570 | |  |  | 1.644 | 1.206 |  |
| *Notes:* Results in each cell come from separate regressions and are estimated using the main sample of countries included in survey rounds 2 through 7 of the Afrobarometer. The dependent variable is an index computed by averaging individuals’ responses to food, water, medical care and cash income indicators. Temperature is measured in degrees Celsius. The standard errors reported are clustered at the survey enumeration area level and reported in parentheses. The column CI Overlap indicates whether 95% confidence intervals for the respective coefficients overlap or not. \*p < .1, \*\*p < .05, \*\*\*p < .01. | | | | | | | | |

The results indicate that ignoring sub-sample heterogeneity may underestimate differences in susceptibility to temperature increases across occupation and location. For one, the effects seem to be somewhat more pronounced among individuals living in rural areas, consistent across all deprivation indicators (see Table A4 in the Appendix for results on each of the deprivation indicators). For urban areas, we tend to have statistically insignificant effects which are close to zero apart from long-run monthly average temperature. Second, concerning sectoral differences, the link between temperatures and individual deprivation is starkly strengthened among individuals engaged in agricultural-related activities, consistent with the large support of decreased agricultural productivity as one of the main channels in how (higher) temperatures may affect living standards.[[16]](#footnote-16) For activity in non-agricultural-related sectors, we tend to have statistically insignificant effects which are close to zero. These findings corroborate evidence from the existing literature that both rural areas and agricultural households are subject to higher losses in the face of rising temperatures, and this may also in part be due to their limited adaptive capacities (Wheeler & Von Braun, 2013; Burke and Emerick, 2016; Onyutha, 2019).

### Evidence on Coping Strategies

Of course, geography – or in this case climate – need not be destiny, and certain provisions may be able to mitigate some of the negative effects of increasing temperatures. For one, strong institutions have been shown to influence the extent to which relief is provided in droughts (Besley and Burgess 2002) or natural disasters (Kahn 2005), and may safeguard against high temperature more generally (Meierrieks and Stadelmann 2024). Second, infrastructural endowments such as dams, irrigation, roads, sewage, clinics, banks, electricity grids have all been associated with mitigation of both the short and long-term effects of weather shocks and climatic change (e.g. Duflo and Pande 2007; Kurukulasuriya et al. 2011; Burgess et al. 2017; Tack et al. 2017).

To investigate whether such factors moderate our established link between temperature and deprivation, we interact in (1) with a measure of local institutional quality as well as a dummy variable signalling the presence of (basic) infrastructural endowments at an individual’s survey locale. To the latter, we measure the presence of infrastructure by considering the availability of essential services such as an electricity grid, pipe-borne water, sewerage, schools, and health clinics in a respondent’s EA. From these binary values we construct an “infrastructure score” ranging between 0 and 1 higher values indicating the presence of (more) infrastructural endowments. For the measure of local institutional quality, we follow Mitton (2016) and average the responses to a total of 21 questions which include individuals' trust (in the local government, police, court), their experiences with corruption or bribery, as well as assessments of e.g. the ease of handling administrative matters and enforcement of crimes.[[17]](#footnote-17) This “institutional score” ranges from 0 to 4 with lower values indicating worse judgments of (local) institutions.

The results from this investigation are presented in Table 4. To aid the interpretation of coefficients, we have centred both the temperature measure as well as the respective moderator at their mean value. As expected, temperature is still positively related to individual deprivation for average levels of local institutional quality as well as infrastructural endowment. Considering the moderating power of these influences, we identify a significantly lower negative influence of temperature for higher scores of local infrastructures. For instance, moving from the mean level of local infrastructural endowments (0.528) to the maximum diminishes the influence of a one-degree Celsius increase in the yearly *(long-run monthly)* average temperature from 0.013 *(0.037)* to 0.003 [=0.013+(-0.018\*0.528)] (*0.027 ([=0.037+(-0.019\*0.528)])).*

Importantly, our findings highlight the general role of quality institutions and essential infrastructure in economic development, consistently showing significant and sizeable negative effects on levels of individual deprivation. What is more, they trump the quantitative effect of temperatures up to an order of magnitude. As such, establishing quality institutions and fundamental infrastructural provisions may not only help safeguard against any potential effect of rising temperatures, but their establishment may be more important to development than rising temperatures alone.

##### : Temperature and Individual Deprivation: Moderating Role of Institutions and Infrastructures

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | |  | |  | |  |  | |
|  | **Deprivation Index [0,4]** | | | | | | | | |
| Variable(s) | Daily temperature | Temperature Two-weeks to Interview | | Monthly Average Temperature | | Yearly Average Temperature | | | Long-run Monthly Average Temperature |
|  | (1) | (2) | | (3) | | (4) | | | (5) |
| **Panel (a): Institutional Quality** |  |  | |  | |  | | |  |
| Temperature Measure | 0.003 | 0.008\*\*\* | | 0.009\*\*\* | | 0.015\*\*\* | | | 0.036\*\*\* |
| (0.002) | (0.003) | | (0.003) | | (0.004) | | | (0.005) |
| Institutional Quality | -0.169\*\*\* | -0.169\*\*\* | | -0.169\*\*\* | | -0.170\*\*\* | | | -0.169\*\*\* |
| (0.005) | (0.005) | | (0.005) | | (0.005) | | | (0.005) |
| Temperature Measure \* Institutional Quality | -0.003\* | 0.001 | | 0.001 | | 0.003\*\*\* | | | 0.003\*\* |
| (0.001) | (0.001) | | (0.001) | | (0.001) | | | (0.001) |
| *Observations* | 164,758 | 164,758 | | 164,758 | | 164,758 | | | 164,758 |
| *R-Squared* | 0.215 | 0.215 | | 0.215 | | 0.215 | | | 0.216 |
| **Panel (b): Local Infrastructure** |  |  | |  | |  | | |  |
| Temperature Measure | 0.002 | 0.006\*\* | | 0.007\*\* | | 0.013\*\*\* | | | 0.037\*\*\* |
| (0.002) | (0.003) | | (0.003) | | (0.004) | | | (0.005) |
| Local Infrastructure | -0.413\*\*\* | -0.414\*\*\* | | -0.414\*\*\* | | -0.413\*\*\* | | | -0.412\*\*\* |
| (0.015) | (0.015) | | (0.015) | | (0.015) | | | (0.015) |
| Temperature Measure \* Local Infrastructure | -0.003 | -0.012\*\*\* | | -0.013\*\*\* | | -0.018\*\*\* | | | -0.019\*\*\* |
| (0.003) | (0.002) | | (0.002) | | (0.003) | | | (0.003) |
| *Observations* | 163,874 | 163,874 | | 163,874 | | 163,874 | | | 163,874 |
| *R-Squared* | 0.213 | 0.213 | | 0.213 | | 0.214 | | | 0.214 |
| Socio-demographic Controls | Yes | Yes | | Yes | | Yes | | | Yes |
| Geographic Controls | Yes | Yes | | Yes | | Yes | | | Yes |
| Country-Year-Month FEs | Yes | Yes | | Yes | | Yes | | | Yes |
| *Notes:* Results in each cell come from separate regressions and are estimated using the main sample of countries included in survey rounds 2 through 7 of the Afrobarometer. The dependent variable is an index computed by averaging individuals’ responses to food, water, medical care and cash income indicators. Temperature is measured in degrees Celsius. The standard errors reported are clustered at the survey enumeration area level and reported in parentheses. \*p < .1, \*\*p < .05, \*\*\*p < .01. | | | | | | | | | |  |

## Conclusion

Given its structural features, Sub-Saharan Africa is expected to face particularly harsh impacts from progressing climate change. Next to its temperature already twice the global average, the persistent reliance on agricultural output, underdeveloped human capital, as well as recurring conflict and weak institutions are expected to amplify the negative consequences and hinder its ability to cope with climate change.

In this paper, we provide a systematic investigation into the short- and long-run effects of temperature and climatic conditions in sub-Saharan Africa by analyzing 168,585 individual-level responses sampled in 28 African countries across 14,186 unique geo-referenced survey locales. Our results show that higher temperatures are consistently associated with lower living standards, as measured by deprivation in food, water, medicine or cash income, whether identified short-term fluctuations or long-run equilibrium effects.

Our findings are robust to an array of individual and geographical control variables and withstand other specification checks such as stringent clustering of standard errors and dropping imprecise geo-locales. Importantly, our results also show a disproportionally strong effect of temperatures on rural and agrarian households. We also evaluate the role of mitigating factors suggested in the literature and find that having fundamental infrastructure shaves a large portion of the negative effect of temperatures and may effectively safeguard against any potential effect of rising temperatures.

In sum, our results provide support the suggested negative effect of temperature on development in hot as well as poor settings. While the relationship between temperature and individual living standards in Sub-Saharan Africa is robustly negative, the quantitative relevance of higher temperatures on deprivation is comparatively small. Importantly, our results also provide direct policy implications concerning adaptation, i.e. investing in essential infrastructure, speaking directly to Goal 13 of the Sustainable Development Goals (SDGs) in taking urgent action to combat climate change and its impacts.

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: Summary Statistics

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |
| Variable | *Obs.* | *Mean* | *Std. dev.* | *Min.* | *Max.* |
| **Dependent Variable** |  |  |  |  |  |
| Food deprivation | 168,350 | 1.117 | 1 | 0 | 4 |
| Water deprivation | 168,380 | 1.177 | 1 | 0 | 4 |
| Medical care deprivation | 167,896 | 1.242 | 1 | 0 | 4 |
| Cash income deprivation | 167,892 | 2.123 | 1 | 0 | 4 |
| Deprivation Index | 168,585 | 1.414 | 1 | 0 | 4 |
| **Temperature Measure** |  |  |  |  |  |
| Daily temperature | 168,585 | 23.156 | 5 | 2.458 | 39.464 |
| Temperature two-weeks before interview date | 168,585 | 23.134 | 5 | 4.332 | 36.386 |
| Monthly average temperature | 168,585 | 23.112 | 5 | 6.191 | 35.715 |
| Yearly average temperature | 168,585 | 23.349 | 4 | 10.134 | 32.122 |
| Long-run monthly average temperature | 168,585 | 24.748 | 4 | 6.858 | 32.583 |
| **Covariates** |  |  |  |  |  |
| Sex | 168,578 | 1.501 | 1 | 1 | 2 |
| Age | 166,869 | 36.700 | 15 | 18 | 130 |
| Level of Education | 168,085 | 2.195 | 1 | 0 | 4 |
| Employment status | 167,921 | 0.335 | 0 | 0 | 1 |
| Locality Type | 168,585 | 1.659 | 0 | 1 | 2 |
| Precipitation | 167,842 | 2.121 | 6 | 0 | 109.643 |
| Elevation | 168,585 | 0.817 | 1 | 0.001 | 3.914 |
| Ruggedness | 168,585 | -0.005 | 1 | -0.640 | 10.757 |
| Land suitability | 168,537 | 0.462 | 0 | 0.001 | 0.999 |
| Malaria ecology | 168,537 | 11.690 | 10 | 0 | 38.081 |
| Number of growing days | 168,577 | 214.636 | 86 | 0 | 365 |
| Proximity to the coast | 168,529 | 516.539 | 354 | 0.158 | 1971.552 |
| Distance to major rivers | 168,585 | 239.535 | 198 | 0.266 | 1165.896 |
| Distance to lakes | 168,585 | 712.337 | 619 | 0.128 | 2746.362 |
| Institutional Quality | 168,257 | 2.192 | 0.661 | 0 | 4 |
| Local Infrastructure | 167,398 | 0.528 | 0.304 | 0 | 1 |

: High Temperature and Individual Deprivation - Robustness Checks

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Deprivation Index [0,4]** | | | | |
| Variable(s) | Daily temperature | Temperature Two-weeks to Interview | Monthly Average Temperature | Yearly Average Temperature | Long-run Monthly Average Temperature |
|  | (1) | (2) | (3) | (4) | (5) |
| (1) Baseline Model | 0.003 | 0.007\*\*\* | 0.008\*\*\* | 0.015\*\*\* | 0.038\*\*\* |
|  | (0.002) | (0.002) | (0.003) | (0.004) | (0.005) |
|  |  |  |  |  |  |
| (2) Applying Sample Weights | 0.003 | 0.008\*\* | 0.008\*\* | 0.014\*\*\* | 0.026\*\*\* |
| (0.002) | (0.003) | (0.003) | (0.004) | (0.005) |
|  |  |  |  |  |  |
| (3) Using Principal Computed Analysis to construct Index | 0.004\* | 0.011\*\* | 0.012\*\* | 0.022\*\*\* | 0.058\*\*\* |
| (0.002) | (0.004) | (0.005) | (0.006) | (0.007) |
|  |  |  |  |  |  |
| (4) Applying Conley Standard Errors | 0.003 | 0.007\* | 0.008\*\* | 0.015\*\*\* | 0.038\*\*\* |
| (0.002) | (0.003) | (0.003) | (0.004) | (0.005) |
|  |  |  |  |  |  |
| (5) Accounting for Country-Year FEs | 0.002 | 0.006\*\* | 0.006\*\* | 0.015\*\*\* | 0.038\*\*\* |
|  | (0.002) | (0.003) | (0.003) | (0.004) | (0.005) |
|  |  |  |  |  |  |
| (5) Accounting for Country-Year-Month-Day FEs | 0.005\* | 0.013\*\*\* | 0.012\*\*\* | 0.019\*\*\* | 0.039\*\*\* |
| (0.002) | (0.003) | (0.003) | (0.004) | (0.005) |
| *Observations* | *165,037* | *165,037* | *165,037* | *165,037* | *165,037* |
|  |  |  |  |  |  |
| Considering Geo-precision Score of at least 3 | *0.003* | *0.007\*\** | *0.009\*\** | *0.014\*\*\** | *0.040\*\*\** |
| (0.002) | (0.003) | (0.004) | (0.005) | (0.006) |
| *Observations* | *125,795* | *125,795* | *125,795* | *125,795* | *125,795* |
|  |  |  |  |  |  |
| Excluding South Africa from Sample | 0.003 | 0.008\*\*\* | 0.008\*\* | 0.012\*\*\* | 0.034\*\*\* |
| (0.002) | (0.003) | (0.003) | (0.004) | (0.005) |
| *Observations* | *154,582* | *154,582* | *154,582* | *154,582* | *154,582* |
|  |  |  |  |  |  |
| *Socio-demographic Controls* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| *Geographic Controls* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |
| *Notes:* Results in each cell come from separate regressions and are estimated using the main sample of countries included in survey rounds 2 through 7 of the Afrobarometer. All Models account for county-year-month fixed effects except for model accounting for country-year and country-year-month-day fixed effects. The dependent variable is an index computed by averaging individuals’ responses to food, water, medical care and cash income indicators. The standard errors reported except for the model with Conley SE are clustered at the survey enumeration area level and reported in parentheses. In row (2) we apply the combined-country weighting factor “combwt” to account for variation in sampling sizes across country-round tuples Refer to https://www.afrobarometer.org/surveys-and-methods/sampling/ for details. \*p < .1, \*\*p < .05, \*\*\*p < .01. | | | | | |

: Effect of High Temperature on Individual Deprivation – Results of Covariates

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variables | Food Deprivation {0,4} | Water Deprivation {0,4} | Medical care Deprivation {0,4} | Cash Income Deprivation {0,4} | Deprivation Index [0,4] |
|  | (1) | (2) | (3) | (4) | (5) |
| Long-run Monthly Average Temperature | 0.033\*\*\* | 0.055\*\*\* | 0.033\*\*\* | 0.032\*\*\* | 0.038\*\*\* |
| (0.006) | (0.008) | (0.006) | (0.006) | (0.005) |
| Female | -0.016\*\*\* | -0.054\*\*\* | -0.056\*\*\* | -0.026\*\*\* | 0.038\*\*\* |
|  | (0.005) | (0.006) | (0.005) | (0.006) | (0.004) |
| Age | 0.014\*\*\* | 0.011\*\*\* | 0.018\*\*\* | 0.015\*\*\* | 0.015\*\*\* |
|  | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Age squared | -0.0001\*\*\* | -0.0001\*\*\* | -0.0002\*\*\* | -0.0001\*\*\* | -0.0001\*\*\* |
|  | (0.00001) | (0.00001) | (0.00001) | (0.00001) | (0.00001) |
| Informal education | -0.110\*\*\* | -0.099\*\*\* | -0.081\*\*\* | -0.105\*\*\* | -0.098\*\*\* |
|  | (0.017) | (0.021) | (0.018) | (0.017) | (0.014) |
| Basic education | -0.208\*\*\* | -0.190\*\*\* | -0.154\*\*\* | -0.160\*\*\* | -0.178\*\*\* |
|  | (0.011) | (0.013) | (0.011) | (0.011) | (0.008) |
| Secondary education | -0.445\*\*\* | -0.276\*\*\* | -0.294\*\*\* | -0.383\*\*\* | -0.349\*\*\* |
|  | (0.012) | (0.014) | (0.012) | (0.012) | (0.009) |
| Tertiary education | -0.684\*\*\* | -0.426\*\*\* | -0.512\*\*\* | -0.697\*\*\* | -0.579\*\*\* |
|  | (0.014) | (0.016) | (0.014) | (0.016) | (0.011) |
| Employed | -0.167\*\*\* | -0.087\*\*\* | -0.124\*\*\* | -0.244\*\*\* | -0.155\*\*\* |
|  | (0.007) | (0.009) | (0.008) | (0.008) | (0.006) |
| Rural | 0.185\*\*\* | 0.269\*\*\* | 0.284\*\*\* | 0.263\*\*\* | 0.250\*\*\* |
|  | (0.010) | (0.013) | (0.010) | (0.010) | (0.008) |
| Precipitation | -0.0001 | -0.001\* | -0.0010 | -0.002\*\* | -0.001\* |
|  | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Elevation | 0.015 | 0.230\*\*\* | 0.102\*\*\* | 0.137\*\*\* | 0.121\*\*\* |
|  | (0.033) | (0.044) | (0.032) | (0.035) | (0.028) |
| Ruggedness | 0.006 | -0.010 | 0.0002 | 0.014\*\* | 0.002 |
|  | (0.007) | (0.011) | (0.009) | (0.006) | (0.007) |
| Land suitability | -0.057\*\* | 0.254\*\*\* | 0.074\*\*\* | 0.075\*\*\* | 0.087\*\*\* |
|  | (0.027) | (0.038) | (0.028) | (0.026) | (0.023) |
| Malaria ecology | 0.004\*\*\* | 0.005\*\* | 0.006\*\*\* | 0.008\*\*\* | 0.006\*\*\* |
|  | (0.001) | (0.002) | (0.001) | (0.001) | (0.001) |
| Number of growing days | -0.0001 | -0.001\*\*\* | -0.001\*\*\* | -0.0004\*\*\* | -0.0005\*\*\* |
| (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Proximity to the coast | -0.0001\*\*\* | -0.00004 | 0.00002 | 0.00001 | -0.00003 |
|  | (0.003) | (0.005) | (0.003) | (0.003) | (0.003) |
| Distance to major rivers | -0.0001\* | 0.0004\*\*\* | 0.0001\*\* | 0.0001\*\* | 0.0001\*\*\* |
| (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Distance to lakes | 0.00005\* | 0.0001 | -0.0001\* | -0.00001 | 0.00001 |
|  | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Controls | Yes | Yes | Yes | Yes | Yes |
| Country-Year-Month FEs | Yes | Yes | Yes | Yes | Yes |
| Observations | 164,822 | 164,854 | 164,390 | 164,434 | 165,037 |
| R-Squared | 0.136 | 0.092 | 0.142 | 0.202 | 0.205 |

*Notes:* Results in each cell come from separate regressions and are estimated using the main sample of countries included in survey rounds 2 through 7 of the Afrobarometer. The standard errors reported are clustered at the survey enumeration area level and reported in parentheses. Results regarding all other measures of temperature can be obtained from the authors. \*p < .1, \*\*p < .05, \*\*\*p < .01.

: High Temperature and Individual Deprivation by Rural and Agricultural Households

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Deprivation Indicators** | | | | | | | | |
|  | **Rural** | | | |  | **Agricultural Activities** | | | |
| Temperature Measure | Food Deprivation {0,4} | Water Deprivation {0,4} | Medical care Deprivation {0,4} | Cash Income Deprivation {0,4} |  | Food Deprivation {0,4} | Water Deprivation {0,4} | Medical care Deprivation {0,4} | Cash Income Deprivation {0,4} |
| Daily Temperature | 0.004 | 0.001 | 0.001 | 0.006\*\*\* |  | 0.009\*\* | 0.008 | 0.006 | 0.008\* |
| (0.002) | (0.003) | (0.003) | (0.002) |  | (0.005) | (0.006) | (0.005) | (0.004) |
| Temperature Two-weeks to Interview | 0.007\* | 0.009 | 0.004 | 0.011\*\*\* |  | 0.025\*\*\* | 0.022\*\* | 0.011 | 0.007 |
| (0.004) | (0.005) | (0.004) | (0.004) |  | (0.007) | (0.009) | (0.007) | (0.006) |
| Monthly Average Temperature | 0.007 | 0.011\* | 0.006 | 0.011\*\*\* |  | 0.027\*\*\* | 0.026\*\*\* | 0.018\*\* | 0.009 |
| (0.004) | (0.006) | (0.005) | (0.004) |  | (0.008) | (0.010) | (0.008) | (0.007) |
| Yearly Average Temperature | 0.020\*\*\* | 0.019\*\* | 0.009 | 0.013\*\* |  | 0.041\*\*\* | 0.039\*\*\* | 0.016 | 0.019\*\* |
| (0.006) | (0.008) | (0.006) | (0.005) |  | (0.010) | (0.012) | (0.010) | (0.009) |
| Long-run Monthly Average Temperature | 0.031\*\*\* | 0.036\*\*\* | 0.037\*\*\* | 0.029\*\*\* |  | 0.040\*\*\* | 0.046\*\*\* | 0.044\*\*\* | 0.028\*\* |
| (0.008) | (0.010) | (0.008) | (0.007) |  | (0.012) | (0.016) | (0.012) | (0.011) |
| Socio-demographic Controls | Yes | Yes | Yes | Yes |  | Yes | Yes | Yes | Yes |
| Geographic Controls | Yes | Yes | Yes | Yes |  | Yes | Yes | Yes | Yes |
| Country-Year-Month FEs | Yes | Yes | Yes | Yes |  | Yes | Yes | Yes | Yes |
| Observations | 108,289 | 108,288 | 108,039 | 108,038 |  | 32,020 | 32,016 | 31,988 | 31,935 |
| Mean of Deprivation Measure | 1.253 | 1.305 | 1.406 | 2.318 |  | 1.300 | 1.353 | 1.512 | 2.410 |

*Notes:* Results in each cell are produced by separate regressions via equation (1) and are estimated using the main sample of countries included in survey rounds 2 through 7 of the Afrobarometer. Temperature is measured in degrees Celsius. Reported R-squared values are from models using daily temperature. The standard errors reported are clustered at the survey enumeration area level and reported in parentheses. \*p < .1, \*\*p < .05, \*\*\*p < .01.

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2. Surveys of the literature providing similar insights have proliferated over the years (see, e.g. Dell et al. 2014, Carleton and Hsiang 2016, Nordhaus and Moffat 2017, Howard and Sterner 2017, as well as Tol 2018). [↑](#footnote-ref-2)
3. The sources of heterogeneity stem, among others, from the different empirical specifications, mainly the dichotomy between cross-sectional approaches identifying long-term (climatic) effects (e.g. Mendelsohn et al. 1994) and panel settings that identify shorter-term climatic fluctuations, i.e. weather shocks (see e.g. Dell et al. 2012). There are also hybrid approaches, such as regressing on non-linear specifications of temperature in a panel, or long-differences specification recovering “medium-term” effects (Burke and Emerick 2016). For an empirical investigation using all three approaches, see Kalkuhl and Wenz (2020). For more on these empirical caveats see Hsiang (2016) and Kolstad and Moore (2020). Other (methodological) discussions revolve around whether to employ (economic) outcomes, such as GDP, in growth or levels (see Newell et al. 2021). [↑](#footnote-ref-3)
4. In effect, some regions may experience positive effects of climate change (see e.g. Kalkuhl and Wenz 2020; Cruz and Rossi-Hansberg 2024). [↑](#footnote-ref-4)
5. Of course, many of the hottest countries on the planet are poor, but there is evidence of independent non-linear effects for wealthy countries (Burke et al. 2015b), and linear effects in poor countries (see Letta and Tol 2019). As a region, Sub-Saharan Africa is a particular case in point which may suffer exceptionally due to progressing climate change (e.g. Lanzafame 2014). [↑](#footnote-ref-5)
6. Most studies focussing on individuals mentioned above make use of the Demographic and Health Surveys (DHS). Studies employing the Afrobarometer have focused on assessing climate change literacy (Helbling et al. 2021) or trust and democratic attitudes (Aboyadana and Alfano 2021; Cerkez 2024; Ahlerup et al. 2024). We could only identify one study (Bukari and Aluko 2023) which explores living standards using a single round of the Afrobarometer and focusses on droughts and floods. We exploit a total of six survey rounds to assess short-term weather and long-run climate effects. [↑](#footnote-ref-6)
7. While improved irrigation and water storage may alleviate effects of droughts or flooding (e.g. Duflo and Pande 2007), most of the negative impact on agriculture is, in fact, due to increased temperatures. [↑](#footnote-ref-7)
8. For more details, refer to to <https://www.afrobarometer.org/surveys-and-methods/>. [↑](#footnote-ref-8)
9. We exclude the first round due to inconsistencies in the questionnaire and coding between the first and subsequent rounds. [↑](#footnote-ref-9)
10. Following the granularity scale, precision is measured as an integer ranging from 1 to 8 (coordinates referring to the country). The latter categories (5-8) account for approximately 1 percent of the respondents. However, from round 7 onwards, all respondent locations were marked via GPS tracking by the interviewer, putting them entirely into category 1. [↑](#footnote-ref-10)
11. This dataset provides a gridded analysis of daily surface air temperature, including daily maximum and minimum temperatures, from 1979 to date. The data is presented on 0.5-degree latitude/longitude grids. Refer to https://psl.noaa.gov/data/gridded/data.cpc.globaltemp.html for more details. [↑](#footnote-ref-11)
12. This data serves as a historical baseline to assess long-term temperature patterns and help us explore how long-term climate patterns affect deprivation outcomes. Refer to https://www.worldclim.org/data/worldclim21.html for details on data. [↑](#footnote-ref-12)
13. Benin, Botswana, Burkina Faso, Burundi, Cameroon, Côte d'Ivoire, Gabon, Gambia, Ghana, Guinea, Kenya, Lesotho, Liberia, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Senegal, Sierra Leone, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe. [↑](#footnote-ref-13)
14. We also adjust model (1) with sample weights and include other robustness tests such as Conley standard errors in robustness tests. [↑](#footnote-ref-14)
15. Sex is binary, whether the individual is male or female; locality type is the place of residence, either urban or rural. Educational level is the highest level of education an individual has attained. We recoded the level of education into no education, basic education, secondary education, tertiary education and informal education. The employment status has been categorised into two groups: "unemployed" for individuals who answered "no" to the employment status question, regardless of whether they are actively seeking employment or not, and "employed" for those who are either full-time or part-time employed. [↑](#footnote-ref-15)
16. Importantly, the evidence on a differentially stronger effect on rural (agrarian) households also holds in a sub-sample of agrarian (urban) households. Results can be obtained from the authors. [↑](#footnote-ref-16)
17. For instance, respondents are asked if they had to pay the bride to avoid taxes or avoid going to court, and the responses are ordered ranging from “not at all” to “very likely”. Other questions such as corruption of public officials have ordered responses from “none” to “all of them”. [↑](#footnote-ref-17)