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When it Rains The Dual Impact of Rainfall on Child Survival in Rural Senegal

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When it Rains
The Dual Impact of Rainfall on Child Survival in Rural Senegal

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Abstract

Using 37 years of longitudinal data on over 60,000 children, we examine how rainfall affects child survival in rural Senegal. Two contrasting effects are likely to be at play: a beneficial effect from increased rainfall stemming from improved income and nutrition, and a detrimental effect resulting from a more adverse disease environment. To assess the effects of rainfall on child survival rates, we use high-resolution rainfall data matched with discrete-time event data at the person-month level. Our analysis uses two distinct measures of rainfall deviations: one representing rainfall deviations during the previous rainy season, and another for current rainfall deviations. Additionally, we explore the heterogeneity of the impact over different groups. Next, we make use of causes of death data to try and support the interpretation of our main results and, finally, present some tentative simulation results. Our results confirm that the rates of child mortality are influenced by fluctuations in income and nutrition related to rainfall, as well as by the seasonality of the burden of disease. This burden escalates notably during the rainy season, compounded by food scarcity in lean periods. The severity of this stress amplifies when rainfall in the preceding rainy season has been insufficient. We also present simulations of child mortality under different rainfall scenarios, providing a policy-relevant perspective on how future climate variability may affect child survival in semi-arid, rain-fed agricultural settings.

***JEL* Classification: I15, J16, Q54.**
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Introduction

Climatologists predict that climate change will increase precipitation variability and the occurrence of extreme rainfall events (IPCC 2018). In West Africa, climate model projections indicate that both the total amount of precipitation and the duration of dry periods are likely to increase (Sylla et al. 2015; Diedhiou et al. 2018). Although considerable uncertainty remains, this suggests that rain events are likely to become more intense. Some studies have shown an increase in precipitation with strong spatial and interannual variations in the Sahel and Senegal over the last two decades (Ali and Lebel 2009; Bodian 2014). These environmental changes impact a wide range of outcomes such as agricultural yields, household income and consumption, human capital, health, and child mortality, particularly in the poorest regions of the world (Dell, Jones, and Olken 2014). According to the United Nations Office for Disaster Risk Reduction (UNISDR 2015), low- and middle-income countries experienced more than 40% of the total number of weather-related disasters occurring between 1995 and 2015, for a cost 358,000 lives lost.

The potentially harmful effects of climate shocks on human health have led researchers to try and understand how extreme climate events such as droughts, floods, or extreme temperatures affect child mortality. While there is evidence of the impact of climate shocks on health outcomes and mortality, there is no consensus on the main pathways through which these shocks operate. One potentially important channel, economists say, is income and nutrition (Maccini and Yang 2009; Kim 2010; Burgess et al. 2011; Flatø and Kotsadam 2014; Kumar, Molitor, and Vollmer 2016; Dinkelman 2017; Shah and Steinberg 2017; Hyland and Russ 2019). In developing countries, particularly in rural areas, the majority of the population still derives its livelihood from agricultural activities, which rely to a large extent on rain-fed agriculture. In these settings, inadequate rainfall is likely to decrease crop yields, raise food prices, and worsen nutritional outcomes. Additionally, several papers in the economics literature focus on the fetal origins hypothesis which indicates that nutritional deprivation *in utero* can have long-term detrimental effects on a wide range of outcomes in adulthood (Almond and Currie 2011). Another channel is linked to what is called the disease burden. Indeed, a wet year is associated with increased mosquito breeding and is expected to increase the prevalence of malaria, leading to a higher risk of child mortality (Ndiaye et al. 2001; Kudamatsu, Persson, and Strömberg 2012; WHO 2015). Instead, droughts could reduce water- and vector-borne diseases and reduce the risk of death (Henry and Dos Santos 2013; Rabassa, Skoufias, and Jacoby 2014). However, in some areas, a lack of rainfall can also lead to water scarcity and reduce the availability of drinking water, thereby increasing the prevalence of infectious diseases (Bandyopadhyay, Kanji, and Wang 2012; Rocha and Soares 2015).

Overall, the available evidence on the impact of rainfall on child mortality is mixed, and findings in the literature vary by context. Furthermore, examining this relationship requires good quality longitudinal data over sufficiently long periods, and, in developing countries, analysis is limited due to the lack of good

quality vital registration systems (Geruso and Spears 2018), especially in rural areas. Given the lack of administrative data, analysts turn to survey data. However, births and deaths are often under reported in poor countries (UNISDR 2015), which can affect the quality of data collected in national-level surveys and therefore the reliability of research results.

We study the impact of rainfall on neonatal, infant, and child mortality over the period 1983-2019 using data from the Niakhar Health and Demographic Surveillance System (HDSS). Located in the Senegalese countryside, the Niakhar HDSS is the oldest HDSS in sub-Saharan Africa. Demographic events such as births, deaths, and migrations have been recorded at least twice a year since 1962, resulting in very high-quality demographic data, which is relatively rare in an African context. The sample of children who resided in the area over the period contains more than 60,000 observations. In this article, this dataset is combined with rainfall data observed over the period 1983-2019 to measure the impact of rainfall on neonatal, infant, and child mortality. We also examine the heterogeneous effects of precipitation anomalies along different characteristics and simulate the impact of diverse rainfall scenarios on mortality.

This paper contributes in several ways to the existing literature that addresses the causal relationship between climate change and health outcomes. First, we use a relatively large sample of high-quality demographic data collected over four decades. This type of data is seldom available in an African context and cannot be matched by the pooling of DHS data. Secondly, the link between mortality and rainfall deviation is estimated using linear probability models (LPM) which are straightforward to interpret, relatively flexible, and allow us to match mortality and rainfall data at the monthly level. To the best of our knowledge, this type of approach has not yet been implemented to study the relationship between climate shocks and mortality. Thirdly, the flexibility of LPMs allows examining the heterogeneity of the impact of rainfall deviations across different dimensions. Finally, a dataset of recorded causes of death is used to support the interpretation of our results. Data on causes of death are not available in most studies in the literature and, therefore, interpretation of specific channels linking precipitation variability and health outcomes is often tentative.

Several results stand out. Our baseline results indicate that positive deviations in rainfall during the preceding rainy season affect mortality rates negatively among infants and children under five, but have no significant effect on neonatal mortality. This pattern suggests that economic factors related to income predominantly influence the mortality of infants and young children. Additionally, the magnitude of this impact fluctuates across the year and is more pronounced during the rainy season. In contrast, while neonatal mortality rates are notably higher during the rainy season, they do not appear to be significantly influenced by variations in rainfall. Essentially, higher rainfall compared to historical averages during the rainy season does not correlate with increased neonatal deaths for children born in that period. Our results indicate that both the income-nutrition and the disease burden channels are at play but while

the first is driven by seasonal and inter-annual rainfall variability, the second channel is mainly driven by rainfall seasonality.

The rest of the article is organized as follows. Section 2 reviews the existing literature on the impact of precipitation on health outcomes and child mortality. Section 3 introduces the Niakhar HDSS. Section 4 describes the data, the key variables, and presents some descriptive statistics. Section 5 explains the empirical strategy. Section 6 presents the main results and section 7 concludes.

How is rainfall expected to affect health outcomes and child mortality?

The impact of rainfall on children's health and child mortality is likely to manifest through various potential pathways. The literature has so far identified two main channels: the income-nutrition effect and the disease-burden effect. We present in turn the empirical literature associated with these two channels.

The theoretical justification for the effect of rainfall on mortality through income and nutrition is based on the observation that rural populations are largely dependent on rain-fed agriculture as access to irrigation is rare. When precipitation levels decrease, agricultural yields fall, incomes fall and food prices rise. The production shock is likely to lead to a reduction in the nutritional intake of children, thereby increasing the risk of infant mortality. Several empirical studies support the existence of an income-nutrition effect. Using the Indonesian Family Life Survey (2000) linked to rainfall by district and year of birth, Maccini and Yang (2009) analyzes the long-term effects of rainfall on the health of women and men born between 1953 and 1974 in rural areas. One of the main findings is that a positive deviation of precipitation from the historical district average during the year of birth increases the probability of reporting very good health for adult women but not for men. According to the authors, gender bias in the allocation of household resources could explain this result. For rural India, Burgess et al. (2011) and Kumar, Molitor, and Vollmer (2016) show that negative rainfall shocks such as droughts lead to higher mortality rates. Burgess et al. (2011) uses vital statistics data from 1957 to 2000 combined with district-level temperature and precipitation data to assess the impact of weather shocks on mortality. The authors find that the occurrence of drought significantly increases mortality rates in rural areas. However, they point out that mortality rates are likely underestimated due to underreporting of births and deaths, highlighting the limitations of civil registration and vital statistics (CRVS) systems for accurately measuring vital events in developing countries. Also in India, Shah and Steinberg (2017) analyze the relationship between early exposure to rainfall shocks and human capital outcomes later in life. Using the Indian Human Development Survey, the authors find that a positive rainfall shock in

the year of birth or the previous year significantly increases weight-for-age z-scores for children aged 1 to 5 years in rural areas due to the higher level of precipitation, nutrient intake, and consumption and therefore leads to greater educational investment and higher levels of human capital later in life. In the sub-Saharan region, several studies have highlighted the effect of income and nutrition as a potential channel between rainfall and health outcomes early in life. Using data from the 1996 South African census combined with rainfall data, Dinkelman (2017) examines the impact of exposure to drought from *in utero* at age four on the likelihood of having a disability later in life. The author calculates the standardized precipitation index (SPI) to define a dry year. Results indicate that early exposure to drought increases the probability of declaring a disability by 3.5%. Results also show that while negative rainfall shocks significantly affect both men and women, the magnitude of the effect is twice as large for men. According to the author, this could be explained by the fact that men are more vulnerable to drought-induced nutritional and health shocks during early childhood. Hyland and Russ (2019) draws on demographic and health surveys (DHS) conducted in nineteen countries in sub-Saharan Africa, combined with meteorological data. It reveals that exposure to drought during early childhood has a strong negative intergenerational effect on health. These effects are explained by the fact that extreme droughts cause an income shock and significant nutritional deprivation during early childhood, which negatively affects physical and cognitive development, reduces years of schooling later in life, and therefore leads to worse health and economic conditions.

Another channel through which precipitation is likely to affect mortality is the so-called disease burden effect. Indeed, several studies highlight that this channel plays an important role in developing countries where vector-borne diseases such as malaria are significant causes of death. According to the World Health Organization (WHO 2015), Africa has the highest malaria prevalence and approximately 90% of all malaria deaths worldwide in 2013. Additionally, 78% of Malaria deaths occur in children under 5 years of age. Kudamatsu, Persson, and Strömberg (2012) use DHS data from twenty-eight African countries and find that higher rainfall in epidemic or seasonal malaria regions significantly increases the likelihood that pregnant women will be infected with malaria and that this increases the likelihood that their child dies before the age of one. Indeed, pregnant women who live in these regions lack immunity and therefore develop symptoms of fever and anemia which lead to a higher probability of premature delivery and infant death. Another likely mechanism, the authors say, is the positive correlation between malaria during pregnancy and the likelihood of low birth weight, linked to increased infant mortality. Using two waves of data from the Nigerian DHS, Rabassa, Skoufias, and Jacoby (2014) shows that higher rainfall has a negative contemporary effect on the weight-for-height z-scores (WHZ) of children aged 0-35 months in rural areas. Furthermore, they report that a positive rainfall shock during the wet season *before* birth increases WHZ, suggesting that the positive effect on income dominates the contemporaneous negative effect of waterborne diseases. The authors find no indication of gender bias in intra-household

resource allocation, as the impact of rainfall shocks is similar for boys and girls. Focusing on semi-arid regions of Brazil, Rocha and Soares (2015) constructs a panel of municipal data for 1996-2010 combined with rainfall data to examine the impact of precipitation variability during the gestation period on birth outcomes. They find that a one standard deviation increase in precipitation during the 12 months before birth reduces the infant mortality rate by 1.53 points and show that this effect is due to improved access to drinking water. According to the authors, a positive rainfall shock during the gestation period reduces water scarcity, which significantly improves the health status of pregnant women and therefore improves both birth outcomes and the immunological protection of the newborn. Analyzing data on causes of death, they show that experiencing higher rainfall in the 12 months before birth significantly reduces deaths caused by intestinal infections and malnutrition. Furthermore, they analyze the heterogeneity of the effect by gender and report that girls have a higher infant mortality rate than boys, indicating that girls are more sensitive to rainfall shocks during the gestation period than boys. They interpret the difference between the sexes as a likely combination of biological and social factors. Finally, Buchner and Rehfuess (2015) provides proof of the existence of an indoor air pollution channel. Using DHS data from eighteen countries in sub-Saharan Africa, they find that the risk of suffering from acute respiratory infections (ARI) for under-five children is higher during the rainy season due to indoor air pollution[1]. The authors show that during the rainy season, outdoor cooking is replaced by indoor cooking using coal, charcoal, and wood, which increases indoor air pollution and, therefore, the risk of ARI for kids. Although they do not study the impact of shocks, their results highlight an interesting channel through which precipitation is likely to affect health outcomes.

To sum up, the various findings reported here are heterogeneous and appear somewhat specific to the setting. While the income-nutrition effect is expected to play a role in most rural settings, the disease-environment effect is likely to be more context-dependent. Our paper contributes to the literature by using high-quality demographic data as well as high resolution rainfall data to try and understand the link between rainfall and child survival in rural Senegal more thoroughly.

Background

The Health and Demographic Surveillance System (HDSS) of Niakhar, the oldest HDSS in Africa, was established in 1962 by the French National Research Institute for Sustainable Development (IRD) (Delaunay et al. 2013). It is located in rural Senegal in the district of Fatick, 135 km East of the capital Dakar. The size of the area is about 203 km^2 (Figure 1). Since 1983, the HDSS covers all 30 villages located in 2 *communes* (fourth territorial division in Senegal) Ngayokheme and Diarrere (Figure 1). In

[1] A child with ALRI is defined as someone who has had a cough, short, rapid breathing, chest problems, or a stuffy or runny nose during two weeks preceding the investigation.

these villages, the population is surveyed at least twice a year and demographic events such as births, deaths, and migrations are recorded.

Between 1983 and 2019, the population of the HDSS has increased more than two-fold from 23,130 to 52,772[2]. The area's climate is typical of the Sahel with a single rainy season from June to October and a dry season from November to May. Agriculture is the main source of income for households in the district and employs about 90% of the active population (ANSD 2016). The two major crops grown in the area are millet for household food consumption and groundnut for cash.

Malaria is endemic in the region and is one of the leading causes of death among children, accounting for 19% of deaths among children under five years (0-59 months) over the period 1983-2019. Following the emergence of Chloroquine resistance in the malaria parasite *Plasmodium falciparum* during the 1990s (Trape et al. 1998), the treatment of malaria was considerably improved. Two new antimalarial drugs were introduced into the national health system for first-line treatment: Amodiaquine plus Sulfadoxine-pyrimethamine (AQ+SP) in November-December 2003 and Artesunate plus Amodiaquine (AS+AQ) in May 2006 (Trape et al. 2012). Additionally, following the Roll Back Malaria initiative, the Senegalese government launched a national malaria program in 2005 to reduce malaria prevalence and associated under-five mortality. Thanks to this program, 6 million insecticide-treated mosquito nets (ITNs) were distributed between 2006 and 2010 nationally. In the Niakhar HDSS, mass distribution of ITNs began in June 2008 and the coverage rate reached 40% whereas it was less than 5% before 2008 (Trape et al. 2012). Thwing et al. (2011) reports that large-scale free distribution of ITNs began in 2008 at the subnational level and resulted in a significant increase in the coverage rate from 36.3% in 2006 to 60.4% in 2008. This likely contributed to the decrease in the under-five mortality rate in the region, from 293.9 per 1000 livebirths in 1983 to 16.4 per 1000 livebirths in 2019.

Besides its high quality, a notable feature of the data collected at the Niakhar HDSS is the availability of data on causes of death through verbal autopsy. For each death, a postmortem interview is conducted using a standardized questionnaire which is then independently reviewed by two physicians who assign the probable underlying cause of death. Discordant diagnoses are discussed by a panel of physicians (Etard et al. 2004; Duthé et al. 2008). This procedure ensures the reliability and high quality of the data on probable causes of death collected in the Niakhar HDSS.

[2]This increase corresponds to an average population growth of 2.3% per year, very close to the national figure.

Data and key variables

Mortality/Survival outcomes

The mortality data utilized in this study comes from the record of demographic events collected by the Niakhar HDSS presented above. The most recent version of the dataset contains 3,340,654 events recorded for 100,278 individuals. Leveraging this dataset, we construct a database of over 60,000 children under the age of 5 who resided in the HDSS area at some point during the period from 1983 to 2020. We then transform individual-level data into event data. In this format, each observation corresponds to a specific month of an individual's life in the area. This allows dating each month of survival and matching it to a time and village-specific climate event.

Our analysis focuses on three outcomes: neonatal mortality, infant mortality, and child mortality. Neonatal mortality refers to deaths occurring during the first month of life; infant mortality refers to deaths occurring before 12 months of age; child mortality refers to deaths before 60 months (or 5 years).

Compared to Demographic and Health Survey (DHS) data, the high frequency of demographic surveys in the HDSS reduces recall bias for demographic events. Each demographic event occurring in individuals in HDSS is reported and dated within 6 months (the longest intervals between two rounds of data collection), allowing for high quality and accuracy in dating events. This is an important dimension of our contribution, as misreporting has been shown to distort the results of early childhood health studies (Larsen, Headey, and Masters 2019). Also, the database only includes children who are observed as they reside in the area, which strengthens the spatial accuracy of the analysis. Last, the length of the observation period allows for observing and collecting precise information on the survival status of several generations of individuals.

To try and support the interpretation of our results, we also use the cause of death data presented above.

Measuring rainfall deviation

Rainfall deviations are estimated as the difference between average rainfall during a given interval and the historical average of rainfall during the same interval, divided by the historical standard deviation of rainfall during the same interval. This writes as follows:

$$RD_t = \frac{R_t - R^{av}}{R^{sd}} \tag{1}$$

where R_t is the average rainfall at time t, R^{av} is the historical average rainfall and R^{sd} is the historical standard deviation of rainfall over 1981–2020. Thus, an increase by one unit of RD_t corresponds to a one standard deviation increase in rainfall at time t relative to the historical average.

To account for rainfall deviations in a setting characterized by unequal distribution of rain over the year, we construct two variables using monthly rainfall data extracted from the CHIRPS (Climate Hazards group Infrared Precipitation with Stations) dataset (Funk et al. 2015). The first variable, RD_t^{past}, represents the deviation during the *past* rainy season compared to the historical average of rainy season precipitations. We expect this variable to capture the delayed impact that rainy season rainfall will likely have over subsequent months on the livelihoods and nutrition of individuals. The second variable, RD_t^{curr}, reflects *current* rainfall deviations. It is computed for each month of the rainy season and corresponds to the deviation of cumulative rainfall since the start of the rainy season from the historical average of rainfall during the corresponding interval. Unlike RD_t^{past}, RD_t^{curr} is only defined during the rainy season. Figure A1 in Appendix presents how these variables are defined for each month. Through these two variables, we expect to capture both the delayed and current impact of rainfall on child mortality [3].

Descriptive statistics

Table 1 reports some summary statistics for our three mortality outcomes of interest while Figure 2 shows their evolution over the period 1983-2019. Three important stylized facts stand out. First, as shown in Figure 2 mortality rates have declined dramatically over the period, from 58.3 to 1.2 per 1000 livebirths, 134.4 to 7.0 per 1000 livebirths, and 293.9 to 16.4 per 1000 livebirths for neonatal, infant, and under 5 children respectively. This decline is similar to what has been observed at the national level and can be attributed to several drivers (Brar et al. 2020). The clear declining trend is broken over the period by two important peaks that can be linked to two dramatic epidemic outbreaks: measles and pertussis in 1985 and meningitis in 1998-1999 during which infant and under five mortality rates reached 108.5 and 322.6 respectively. Second, the mortality of boys appears higher than that of girls - by 28%, 17%, and 13% for neonatal, infant, and under 5 mortality respectively. The survival advantage of girls is consistent with findings at the regional level (Garenne 2003). The last important stylized fact is that child mortality is much higher during the rainy season than during the dry season - by 23%, 47%, and 75% for neonatal, infant, and under 5 mortality respectively. The seasonality of health outcomes has been documented in the Sahel region, in particular in semi arid zones (Venkat et al. 2023). It suggests that the disease burden, in particular malaria, plays an important role as a driver of child mortality and that we should expect positive rainfall deviations to exacerbate this role.

Concerning precipitations, the annual average recorded in the area between 1981 and 2020 is 484 mm, with high variability throughout the period: the lowest amount of rainfall was recorded in 1983 at

[3]Given the small size of the area, we use a single rainfall series. To support this specification choice, we tested that, when considering village specific rainfall time series, village fixed effects do not explain a significant share of the total variance.

309 mm and the highest in 2012 at 725 mm. Consistently with what has been observed at the national level (Bodian 2014), average rainfall exhibits a positive trend over the period. Figure 3 presents the yearly precipitations in the Niakhar HDSS area over the period 1981-2020. The first two decades (80s and 90s) were characterized by a lower level of rainfall, 447 mm on average while the last two decades (2000s and 2010s) are characterized by a higher level of rainfall, 526 mm on average. Both periods are equally marked by significant inter-annual variability.

Empirical strategy

Taking advantage of the exogenous variation of rainfall across villages and over time, we measure the impact of rainfall deviations on neonatal, infant, and under 5 mortality at the individual level. The unequal distribution of rain over the year, which characterizes semi-arid regions, leads us to specify two different equations: one for the dry season (November to May), and one for the rainy season (June to October). The equations are specified as follows:

$$D_{ivt} = \beta^{dry} RD_t^{past} + \alpha.t + \gamma_m + \delta_v + \epsilon_{ivt} \quad \text{if} \quad \text{rainy==0} \tag{2}$$

$$D_{ivt} = \beta^{rain} RD_t^{past} + \beta^{curr} RD_t^{curr} + \alpha.t + \gamma_m + \delta_v + \epsilon_{ivt} \quad \text{if} \quad \text{rainy==1} \tag{3}$$

where D_{ivt} is a dummy that indicates whether child i in village v died at time t, RD_t^{past} is the past rainfall deviation variable, RD_t^{curr} is the current rainfall deviation variable, t is a time trend, γ_m is a month fixed effect, and δ_v is a village fixed effect.

β^{dry}, β^{rain}, and β^{curr} are the coefficients of interest that capture the impact of delayed and current rainfall deviations on the probability of dying. According to the main channels identified in the literature review, we expect the βs to be negative if the income-nutrition effect dominates. Instead, if the disease burden effect dominates, we expect the βs to be positive, with excess rainfall leading to a more adverse disease environment and increased mortality.

The unbiased identification of a causal link between rainfall deviations and infant mortality raises several questions. First, the estimate could be biased if high-risk villages from a child mortality perspective experience more rainfall deviations. This is unlikely given the small size of the area and, hence, its homogeneity in terms of climate. However, village fixed effects are included in the baseline specification to prevent such bias. They control for initial conditions and persistent elements of history, climate, culture, and political institutions as well as for village-specific time-invariant sources of measurement error. A second problem is related to the presence of time-varying unobservables. As presented above, over the 40 years of the study, the HDSS area has been marked by two remarkable evolutions. On the

one hand, child mortality rates declined significantly. On the other hand, rainfall was characterized by a positive trend with a marked discontinuity around 2000: average annual rainfall is 526 mm after 2000 vs 447 mm before, equivalent to a 17.7% increase. We include a time trend in our baseline specification to capture the decline in mortality rates and prevent bias arising from long-term concurrent rainfall trends. Finally, as shown in the section above, child mortality rates are notably higher during the rainy season. To account for this pattern, month fixed-effects are included in our baseline specification.

Results

In this section, we present estimates of the impact of rainfall deviations on child mortality at different ages. We then investigate whether the impact varies across different groups. Finally, we examine causes of death data to try and provide credible interpretations of our findings.

The impact of rainfall deviations on child mortality

As presented above, the impact of rainfall deviations on child mortality is captured through two variables: a variable that measures *past* rainfall deviation and a variable that captures *current* rainfall deviation. We estimate two equations for each mortality outcome. The model specified for the dry season includes the past rainfall deviation variable only. Instead, the rainy season model includes both the past and current rainfall deviation variables. In both models, we control for village fixed effects, month fixed effects, and a time trend. We also report the coefficient for being female to provide a reference against which to assess the magnitude of the estimated impacts.

The first two lines of table 2 report the coefficients related to the impact of one standard rainfall deviation on mortality outcomes at each season. The first three columns present estimates of the impact on mortality during the dry season (from November to May). Results show that the impact of *past* rainfall deviation on neonatal mortality during the dry season is negative. In other words, a positive deviation of past rainfall drives child mortality rates during the dry season *down*. While the impact is not significant for neonatal mortality, it is for infant and under-5 mortality. For infants, the point estimate of the impact of past rainfall conditions on mortality during the dry season is -0.336 percentage points which, compared to the average seasonal infant mortality risk of 3.78 per 1,000 livebirths, corresponds to a -8.8% impact. For under-5 mortality, one standard rainfall deviation is found to reduce mortality during the dry season by -0.179 percentage points which corresponds to a -10.2% impact.

When considering child mortality during the rainy season (from June to October), the impact of *past* rainfall conditions remains negative and appears to be bigger in absolute value. While the impact remains not significantly different from zero for neonatal mortality, it increases (in absolute value) to -0.403 for infant mortality, and to -0.404 for under-5 mortality. Given that the onset of the rainy season coincides

with the beginning of the lean season, this could reflect the increased stress on nutrition, exacerbated when the preceding harvest has been poor in a context where the disease burden is higher (Venkat et al. 2023). Concerning *current* rainfall conditions, we find that its impact on mortality is also negative but much smaller in absolute value than past rainfall deviation and significant for under-5 mortality only. As mentioned above, current rainfall conditions influence the disease burden in opposite ways. While a wet year is usually associated with an increased prevalence of malaria, a lack of rainfall can also increase the prevalence of infectious diseases through its impact on the availability of drinking water. Our results suggest that the net impact is positive. This result either reflects a net positive disease burden effect or the fact that more rainfall is beneficial at the end of the rainy season when harvesting time comes and this offsets the detrimental effect of the increased disease burden.

Results in table 2 also indicate that the coefficient associated with the female dummy variable is significant and negative - consistent with the descriptive statistics -, and of the same magnitude as the impact of past rain conditions.

To sum up, our baseline results show that past rainfall has a significant and negative impact on child mortality rates at all ages and all seasons. This supports the role of income and nutrition as substantial drivers of child mortality in a context where access to irrigation is rare and households' living conditions are largely dependent on rain-fed agriculture. When precipitations increase, agricultural yields increase as well which leads to better incomes and better nutrition, thereby decreasing the risk of infant mortality. The impact is stronger on mortality during the rainy season, which also coincides with the lean season when production stocks from the previous season are low and nutritional stress increases. The surprise comes from the fact that, while rainy season child mortality is higher, inter annual rainfall deviations during the rainy season do not seem to make things significantly worse. Instead, as for past deviations, the impact of current rainfall deviations is negative, meaning that more rain during the rainy season compared to the historical average, leads to less mortality.

Heterogeneity

This section examines whether our main findings are consistent across different groups.

Firstly, we consider the variable survival rates between genders. Since girls have a differential survival advantage, it raises the question of whether boys and girls are differently affected by variations in rainfall. The data presented in Panel A of Table 3 show significant differences in the effects of past rainfall variations on the sexes, though current variations seem to impact both genders similarly. Notably, boys experience a greater absolute impact from past rainfall deviations during the dry season. More specifically, results suggest that while the impact of rainfall deviations is negative and significant for boys, it is much closer to zero for girls. In other words, when past rainfall has been relatively abundant, boys benefit more from it than girls; when rainfall has been scarce, they suffer more from it than girls.

This could result either from a greater susceptibility of boys to food stress or from differential feeding practices between boys and girls.

In parallel to the dramatic decline of mortality risks, the Niakhar HDSS area has experienced a very significant increase in education (Delaunay, Desclaux, and Sokhna 2018), consistently with the trend observed at the national trend. This improvement has particularly enhanced primary education achievements among mothers in our dataset, as detailed in Figure A2 of the Appendix. Interestingly, as shown in Table A1, children of uneducated mothers face substantially higher mortality risks — by 44% for neonatal, 74% for infant, and 70% for under-five mortality. To determine if educational levels of mothers influence the impact of rainfall deviations, we include an interaction between rainfall variables and an indicator of maternal primary-level achievement. Results from Panel B of Table 3 indicate that rainfall deviation effects are similar regardless of maternal education levels.

Thirdly, the analysis extends to the size of the villages. By dividing our dataset evenly, we compare mortality and rainfall impact between bigger and smaller villages. Smaller villages, as shown in Table A1, exhibit higher mortality rates— by 19% for neonatal, 14% for infant, and 7.5% for under-five mortality. According to the regression results in Panel C of Table 3, smaller villages experience more pronounced negative impacts from rainfall deviations on mortality during the rainy season. This suggests that the income-nutrition channel, which is crucial in these predominantly agrarian communities, plays a significant role in mediating the effects of rainfall on mortality.

Robustness checks

In this section, we implement several checks to test the robustness of our main results. First, following Bhalotra (2010), we test whether the impact is robust to the inclusion of mother fixed effects to control for the possibility that the characteristics of women giving birth vary with rainfall deviations. For instance, if high-risk mothers are more likely than low-risk mothers to give birth when rainfall is relatively abundant, then the impact will be - at least in part - biased by this selection. We find that our main results hold when controlling for mother fixed effects (see Panel B in Table A2 in Appendix), suggesting that there is no relevant selection of characteristics in the timing of births.

Second, we test whether our results hold when accounting for specific events that had an important impact on child mortality such as the meningitis epidemic and the mass distribution of ITNs. If these events coincide with rainfall extremes then this could bias our results. Results in Panel C in table A2 suggest that controlling for these events does not change our baseline (Panel A) results significantly.

Last, relatedly, we test whether the way we control for time trends has an impact on our baseline results. More specifically we include decadal fixed-effects in our specification. Results in Panel D in table A2 suggest that controlling for these events does not change our baseline results significantly[4].

[4]On top of these robustness checks, we tested 3 alternative specifications: (1) adding heat waves

Causes of death

To support the interpretation of our findings, we present some evidence on mortality by cause of death and by month. The results presented in Figure 4 confirm the clear seasonal pattern of child mortality which peaks during the wet season (in September for neonatal mortality, in October for infant and under 5 mortality). For neonatal mortality, the main cause of death is perinatal conditions which appear to be slightly exacerbated during the rainy season. For infant and under 5 mortality, the main causes are diarrhea, malaria, and respiratory infections. While diarrhea is more evenly distributed over the year, both malaria and respiratory infections exhibit a clear seasonal pattern. This is consistent with seasonal malaria playing an important role in child health and with the documented higher risk of suffering from acute respiratory infections (ARI) for children during the rainy season due to indoor air pollution. These patterns confirm that the disease burden plays an important role during the rainy season.

How do we reconcile this interpretation with the finding that *current* rainfall deviations seem to have little or no impact on mortality rates during the wet season compared to *past* rainfall deviations? Our proposed narrative is as follows: child mortality rates are driven by income and nutrition shocks as well as the disease burden. The disease burden has a strong seasonal pattern and is significantly worse during the rainy season. This is aggravated by the food stress during the lean season. This stress is higher when rainfall during the past rainy season has been relatively poor. In sum, the income-nutrition channel is driven by both seasonal and inter annual rainfall variability while the disease burden channel is mainly driven by seasonality.

Simulating the impact of climate change on child mortality

This section provides some tentative answers to the question of how child mortality is likely to evolve with climate change. To answer this, we focus on *past* rainfall deviation. We first examine its distribution over the period which provides five statistics for rainfall deviation: three average values are computed over the 2000s, before, and after 2000; two extreme values are its minimum and maximum over the period. These five values provide the input for five scenarios. In each scenario, using our baseline estimate of the coefficient of interest, we simulate child mortality levels over the period under the assumption that rainfall takes the corresponding value.

Table 4 shows the results. Not surprisingly, when rainfall is higher, child mortality falls. Symmetrically, child mortality increases when rainfall deviation is negative. More precisely, if rainfall over the whole period had been stable and equal to that observed during the 2000s, 320 children deaths would

- measured as the number of days when temperature is over 40 degrees Celsius per month - as an additional control variable ; (2) using local rain station rainfall series instead of CHIRPS data ; (3) using the Standardized Precipitation Index (SPI) instead of standardized deviations. These tests, available upon request, show that our results are robust to alternative specifications

have been avoided, corresponding to a reduction by almost 5%. In contrast, if rainfall over the whole period had been equal to the minimum value registered in 1983, 1,448 more child deaths (i.e. 22.4%) would have been incurred over the period.

Conclusion

The relationship between rainfall and child mortality is a complex one. Several channels over different time scales are at play and the impact varies both across groups and across time. In this paper, we investigate the relationship between rainfall and mortality in semi-arid rural Senegal over 40 years. For that purpose, we exploit the exogenous variation of rainfall over time between 1983 and 2020 and link the recorded variations with high-quality demographic data collected by the Health and Demographic Surveillance System (HDSS) of Niakhar.

We find that a positive rainfall deviation during the past rainy season has a significant negative impact on child mortality over the following year. More specifically, our estimates show that the average impact of one standard positive rainfall deviation corresponds to a reduction of under five mortality by -10% during the dry rainy and by -13% during the rainy season. This pattern suggests that economic factors related to income predominantly influence the mortality of infants and young children.

While this average impact is not trivial, it hides some dimensions of heterogeneity. In particular, for under 5 mortality, we find that the impact is stronger for boys as well as for children living in relatively smaller villages.

In contrast, while neonatal mortality rates are higher *during* the rainy season, they do not appear to be significantly influenced by rainfall *deviations*. In other words, more rain during the rainy season is not associated with more neonatal mortality for children born in that season.

The analysis of causes of death is consistent with our findings and help clarifies the narrative on the impact of rainfall on child mortality. The rates of child mortality are influenced by fluctuations in income and nutrition, as well as by the seasonality of the burden of disease. This burden escalates notably during the rainy season, compounded by food scarcity in lean periods. The severity of this stress amplifies when rainfall in the preceding rainy season has been insufficient. To sum up, the income-nutrition channel is driven by both seasonal and inter annual rainfall variability while the disease burden channel is mainly driven by seasonality.

What can we expect from future climate variations? Our simulation results show that the impact of rainfall deviations is not trivial. If the area had experienced the minimum levels of rainfall recorded locally over the whole period - and corresponding to a standard deviation of -1.84 - 22% more deaths would have been incurred.

What is the external validity of our results? We believe our results are relevant for semi arid climates

in context where access to irrigation is rare and households' living conditions are largely dependent on rain-fed agriculture. In these settings, child mortality is likely to be affected by rainfall, mainly through the income-nutrition channel.

References

Ali, Abdou and Thierry Lebel (2009). "The Sahelian standardized rainfall index revisited". *International Journal of Climatology: A Journal of the Royal Meteorological Society* 29.12, pp. 1705–1714.

Almond, Douglas and Janet Currie (2011). "Killing me softly: The fetal origins hypothesis". *Journal of economic perspectives* 25.3, pp. 153–72.

ANSD (2016). *Situation Economique et Sociale de la Région de Fatick*.

Bandyopadhyay, Sushenjit, Shireen Kanji, and Limin Wang (2012). "The impact of rainfall and temperature variation on diarrheal prevalence in Sub-Saharan Africa". *Applied Geography* 33, pp. 63–72.

Bhalotra, Sonia (2010). "Fatal fluctuations? Cyclicality in infant mortality in India". *Journal of Development Economics* 93.1, pp. 7–19.

Bodian, Ansoumana (2014). "Caractérisation de la variabilité temporelle récente des précipitations annuelles au Sénégal (Afrique de l'Ouest)". *Physio-Géo. Géographie physique et environnement* Volume 8, pp. 297–312.

Brar, Samanpreet et al. (2020). "Drivers of stunting reduction in Senegal: a country case study". *The American journal of clinical nutrition* 112, 860S–874S.

Buchner, Hannes and Eva A Rehfuess (2015). "Cooking and season as risk factors for acute lower respiratory infections in African children: a cross-sectional multi-country analysis". *PloS one* 10.6.

Burgess, Robin et al. (2011). "Weather and death in India". *Cambridge, United States: Massachusetts Institute of Technology, Department of Economics. Manuscript* 19.

Delaunay, Valérie, Alice Desclaux, and Cheikh Sokhna (2018). *Niakhar, mémoires et perspectives: recherches pluridisciplinaires sur le changement en Afrique*.

Delaunay, Valerie et al. (2013). "Profile: the Niakhar health and demographic surveillance system". *International journal of epidemiology* 42.4, pp. 1002–1011.

Dell, Melissa, Benjamin F Jones, and Benjamin A Olken (2014). "What do we learn from the weather? The new climate-economy literature". *Journal of Economic Literature* 52.3, pp. 740–98.

Diedhiou, Arona et al. (2018). "Changes in climate extremes over West and Central Africa at 1.5 C and 2 C global warming". *Environmental Research Letters* 13.6, p. 065020.

Dinkelman, Taryn (2017). "Long-run Health Repercussions of Drought Shocks: Evidence from South African Homelands". *The Economic Journal* 127.604, pp. 1906–1939.

Duthé, Géraldine et al. (2008). "La détermination des causes de décès par autopsie verbale: étude de la mortalité palustre en zone rurale sénégalaise". *INED, Paris,(Documents de travail no 150)* 35.

Etard, Jean-François et al. (2004). "Childhood mortality and probable causes of death using verbal autopsy in Niakhar, Senegal, 1989–2000". *International Journal of Epidemiology* 33.6, pp. 1286–1292.

Flatø, Martin and Andreas Kotsadam (2014). *Droughts and gender bias in infant mortality in Sub-Saharan Africa*. Tech. rep. Memorandum.

Funk, Chris et al. (2015). "The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes". *Scientific data* 2.1, pp. 1–21.

Garenne, Michel (2003). "Sex differences in health indicators among children in African DHS surveys". *Journal of biosocial science* 35.4, pp. 601–614.

Geruso, Michael and Dean Spears (2018). *Heat, Humidity, and Infant Mortality in the Developing World*. Tech. rep. National Bureau of Economic Research.

Henry, Sabine JF and Stéphanie Dos Santos (2013). "Rainfall variations and child mortality in the Sahel: results from a comparative event history analysis in Burkina Faso and Mali". *Population and Environment* 34.4, pp. 431–459.

Hyland, Marie and Jason Russ (2019). "Water as destiny–The long-term impacts of drought in sub-Saharan Africa". *World Development* 115, pp. 30–45.

IPCC (2018). *Global warming of 1.5°C Report, Summary for Policymakers (http://www.ipcc.ch/report/sr15/)*.

Kim, Yeon Soo (2010). "The impact of rainfall on early child health". *Unpublished manuscript*.

Kudamatsu, Masayuki, Torsten Persson, and David Strömberg (2012). "Weather and infant mortality in Africa". *CEPR Discussion Paper No. DP9222*.

Kumar, Santosh, Ramona Molitor, and Sebastian Vollmer (2016). "Drought and early child health in rural India". *Population and Development Review*, pp. 53–68.

Larsen, Anna Folke, Derek Headey, and William A Masters (2019). "Misreporting month of birth: diagnosis and implications for research on nutrition and early childhood in developing countries". *Demography* 56.2, pp. 707–728.

Maccini, Sharon and Dean Yang (2009). "Under the weather: Health, schooling, and economic consequences of early-life rainfall". *American Economic Review* 99.3, pp. 1006–26.

Ndiaye, Ousmane et al. (2001). "Variations climatiques et mortalité attribuée au paludisme dans la zone de Niakhar, Sénégal, de 1984 à 1996". *Cahiers d'études et de recherches francophones/Santé* 11.1, pp. 25–33.

Rabassa, Mariano, Emmanuel Skoufias, and Hanan Jacoby (2014). "Weather and Child Health in Rural Nigeria". *Journal of African Economies* 23.4, pp. 464–492.

Rocha, Rudi and Rodrigo R Soares (2015). "Water scarcity and birth outcomes in the Brazilian semiarid". *Journal of Development Economics* 112, pp. 72–91.

Shah, Manisha and Bryce Millett Steinberg (2017). "Drought of opportunities: Contemporaneous and long-term impacts of rainfall shocks on human capital". *Journal of Political Economy* 125.2, pp. 527–561.

Sylla, Mouhamadou Bamba et al. (2015). "Projected changes in the annual cycle of high-intensity precipitation events over West Africa for the late twenty-first century". *Journal of Climate* 28.16, pp. 6475–6488.

Thwing, Julie I et al. (2011). "Success of Senegal's first nationwide distribution of long-lasting insecticide-treated nets to children under five-contribution toward universal coverage". *Malaria Journal* 10.1, pp. 1–8.

Trape, Jean-François et al. (1998). "Impact of chloroquine resistance on malaria mortality". *Comptes Rendus de l'Académie des Sciences-Series III-Sciences de la Vie* 321.8, pp. 689–697.

Trape, Jean-François et al. (2012). "New malaria-control policies and child mortality in senegal: reaching millennium development goal 4". *Journal of Infectious Diseases* 205.4, pp. 672–679.

UNISDR (2015). *Weather Disasters Report: The human cost of weather related disasters 1995-2015.*

Venkat, Aishwarya et al. (2023). "Seasonality of Acute Malnutrition in African Drylands: Evidence From 15 Years of SMART Surveys". *Food and Nutrition Bulletin* 44.2_suppl, S94–S108. DOI: 10.1177/03795721231178344.

WHO (2015). *World Health Statistics 2015.*

Table 1: Descriptive statistics

	Mean	SD	Min	Max	N
Neonatal	18.76	135.66	0	1,000	51,609
Infant	4.58	67.55	0	1,000	602,931
Under 5	2.34	48.35	0	1,000	2,751,057
	mean	sd	min	max	count
Panel A: Boys					
Neonatal	21.02	143.45	0	1,000	26,309
Infant	4.93	70.02	0	1,000	305,868
Under 5	2.48	49.77	0	1,000	1,392,317
	mean	sd	min	max	count
Panel B: Girls					
Neonatal	16.40	127.02	0	1,000	25,300
Infant	4.23	64.91	0	1,000	297,063
Under 5	2.20	46.85	0	1,000	1,358,740
	mean	sd	min	max	count
Panel C: Dry season					
Neonatal	17.04	129.42	0	1,000	30,281
Infant	3.81	61.64	0	1,000	352,393
Under 5	1.77	42.03	0	1,000	1,610,663
	mean	sd	min	max	count
Panel D: Rainy season					
Neonatal	21.19	144.03	0	1,000	21,328
Infant	5.67	75.07	0	1,000	250,538
Under 5	3.15	56.07	0	1,000	1,140,394

Table 2: Baseline model results

	Dry season			Rainy season		
	(1) Neonatal	(2) Infant	(3) Under 5	(4) Neonatal	(5) Infant	(6) Under 5
Past	-0.160	-0.331***	-0.178***	-0.650	-0.392**	-0.404***
	(-0.20)	(-3.02)	(-5.08)	(-0.61)	(-2.45)	(-7.22)
Current				-0.558	-0.0509	-0.104*
				(-0.57)	(-0.34)	(-1.94)
Girl	-5.088***	-0.807***	-0.321***	-4.065**	-0.593**	-0.264**
	(-3.43)	(-3.89)	(-4.84)	(-2.07)	(-1.98)	(-2.52)
Time trend	-0.944***	-0.222***	-0.117***	-1.371***	-0.352***	-0.203***
	(-13.02)	(-21.84)	(-36.12)	(-13.90)	(-23.47)	(-38.71)
Constant	38.45***	8.728***	4.377***	49.90***	12.97***	7.465***
	(21.58)	(34.81)	(53.63)	(21.40)	(35.85)	(57.84)
N	30,281	352,393	1,610,663	21,328	250,538	1,140,394

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 1: Location of the Niakhar HDSS area

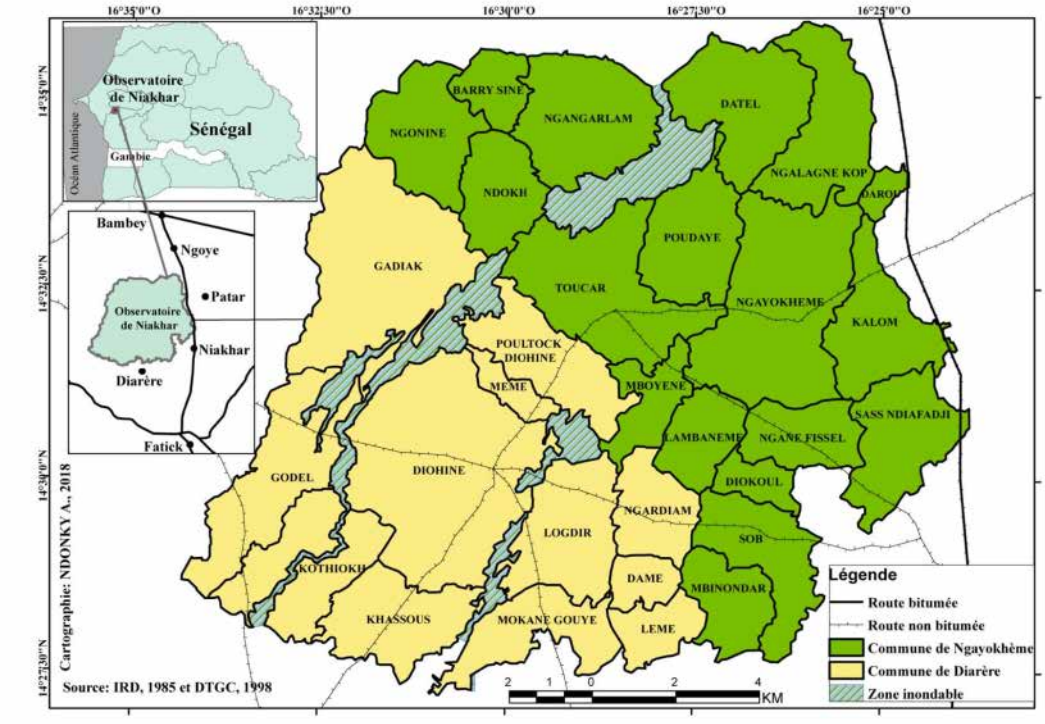


Table 3: Heterogeneity

	Dry season			Rainy season		
	(1)	(2)	(3)	(4)	(5)	(6)
	Neonatal	Infant	Under 5	Neonatal	Infant	Under 5
Panel A: By sex						
Past	-1.370	-0.540***	-0.273***	-2.239	-0.506**	-0.441***
	(-1.27)	(-3.59)	(-5.65)	(-1.55)	(-2.31)	(-5.74)
Girl=1 × Past	2.442	0.424**	0.192***	3.273	0.231	0.0749
	(1.63)	(2.02)	(2.85)	(1.64)	(0.76)	(0.70)
Current				-2.115	-0.265	-0.136*
				(-1.57)	(-1.25)	(-1.81)
Girl=1 × Current				3.229*	0.435	0.0645
				(1.67)	(1.44)	(0.61)
Girl=1	-5.197***	-0.835***	-0.334***	-4.511**	-0.625**	-0.272***
	(-3.50)	(-4.01)	(-5.04)	(-2.29)	(-2.08)	(-2.58)
N	30,281	352,393	1,610,663	21,328	250,538	1,140,394
Panel B: By mothers's education						
Past	-0.0333	-0.346***	-0.184***	-0.222	-0.385**	-0.428***
	(-0.04)	(-2.88)	(-4.81)	(-0.19)	(-2.19)	(-7.01)
Primary=1 × Past	-0.691	0.0855	0.0358	-2.293	-0.0423	0.141
	(-0.34)	(0.30)	(0.39)	(-0.87)	(-0.10)	(0.97)
Current				-0.131	-0.0962	-0.135**
				(-0.12)	(-0.58)	(-2.33)
Primary=1 × Current				-2.768	0.264	0.204
				(-1.04)	(0.64)	(1.37)
Primary=1	0.906	-0.112	-0.0180	3.423	-0.585	-0.262*
	(0.44)	(-0.39)	(-0.19)	(1.23)	(-1.39)	(-1.74)
N	30,281	352,393	1,610,663	21,328	250,538	1,140,394
Panel C: By village size						
Past	-0.636	-0.257	-0.180***	-2.776*	-0.859***	-0.571***
	(-0.57)	(-1.63)	(-3.57)	(-1.84)	(-3.77)	(-7.13)
Big=1 × Past	0.895	-0.136	0.00421	4.002**	0.875***	0.311***
	(0.60)	(-0.65)	(0.06)	(2.00)	(2.89)	(2.92)
Current				-0.408	-0.0188	-0.0910
				(-0.28)	(-0.08)	(-1.16)
Big=1 × Current				-0.265	-0.0602	-0.0236
				(-0.14)	(-0.20)	(-0.22)
Big=1	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
N	30,281	352,393	1,610,663	21,328	250,538	1,140,394

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Simulation results for under 5 mortality over the 1983-2020 period

	Rainfall (mm)	Number of deaths	Difference with observed	Percent change
Observed values	486	6,460		
Rainfall Scenarios				
(1) 2000s average	545	6,140	-320	-4.9
(2) 1981-2000 average	445	6,846	386	6.0
(3) 2000-2020 average	526	6,247	-213	-3.3
(4) Minimum (1983)	307	7,908	1,448	22.4
(5) Maximum (2012)	724	4,663	-1,797	-27.8

Figure 2: Evolution of mortality in the Niakhar HDSS, 1983-2020

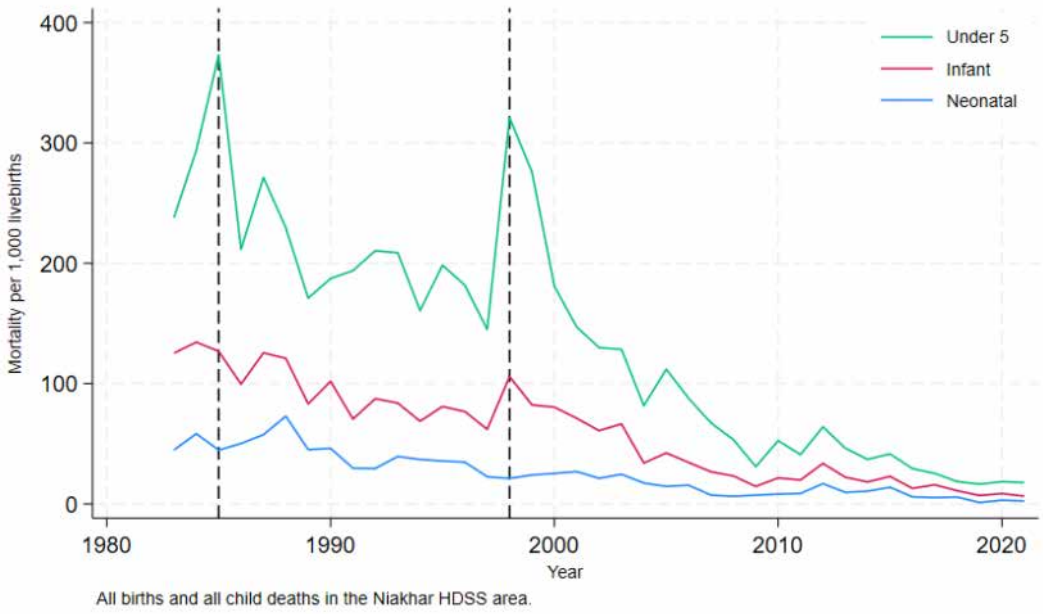


Figure 3: Annual rainfall in the Niakhar HDSS area, 1981-2020

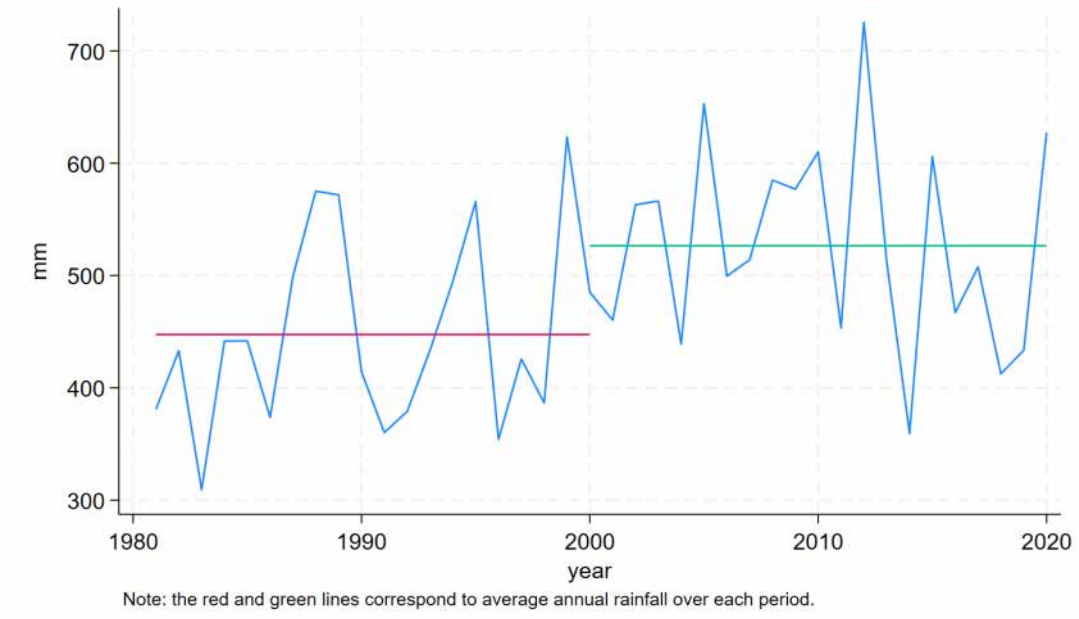
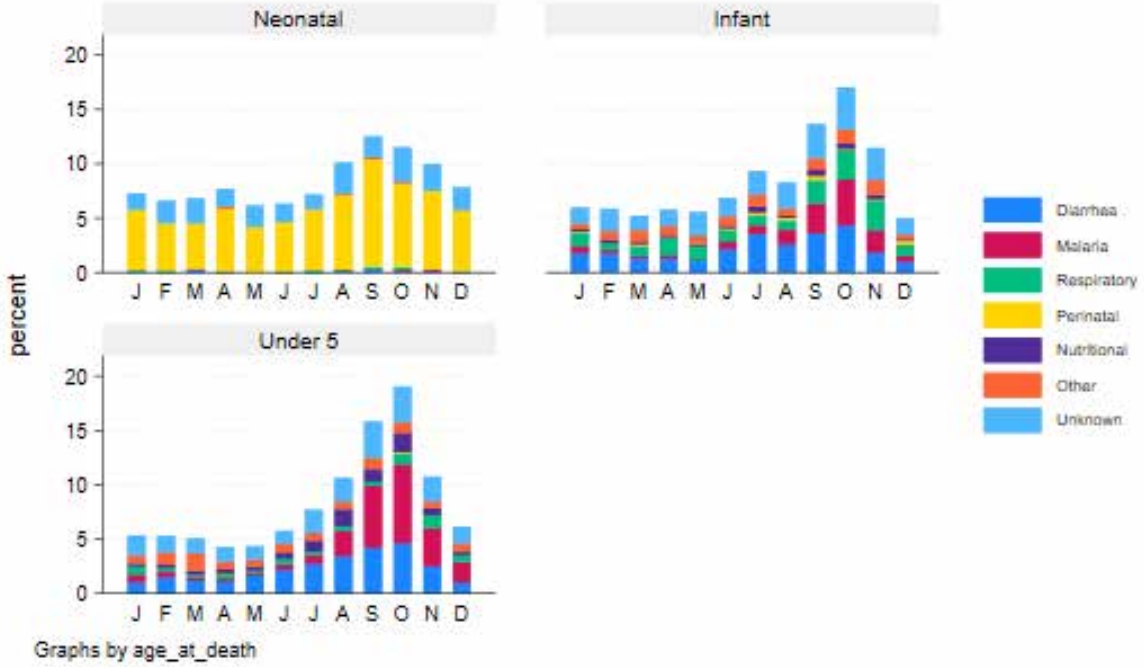


Figure 4: Causes of death by decade



Appendix

Figure A1: Definition of past and current rainfall deviation variables

Year	Month		Season	Past rainfall deviation	Current rainfall deviation
N	Jun	J	RAINY	RD(JJASO, N-1)	RD(J, N)
	Jul	J		RD(JJASO, N-1)	RD(JJ, N)
	Aug	A		RD(JJASO, N-1)	RD(JJA, N)
	Sep	S		RD(JJASO, N-1)	RD(JJAS, N)
	Oct	O		RD(JJASO, N-1)	RD(JJASO, N)
	Nov	N	DRY	RD(JJASO, N)	
	Dec	D		RD(JJASO, N)	
N+1	Jan	J		RD(JJASO, N)	
	Feb	F		RD(JJASO, N)	
	Mar	M		RD(JJASO, N)	
	Apr	A		RD(JJASO, N)	
	May	M		RD(JJASO, N)	
	Jun	J	RAINY	RD(JJASO, N)	RD(J, N+1)
	Jul	J		RD(JJASO, N)	RD(JJ, N+1)
	Aug	A		RD(JJASO, N)	RD(JJA, N+1)
	Sep	S		RD(JJASO, N)	RD(JJAS, N+1)
	Oct	O		RD(JJASO, N)	RD(JJASO, N+1)

Figure A2: Evolution of mother's primary level achievement in the Niakhar HDSS

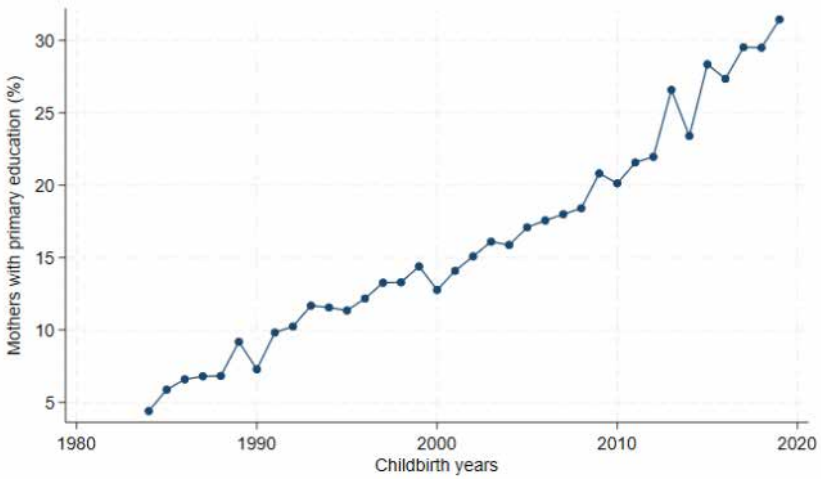


Table A1: Additionnal descriptive statistics

	Mean	SD	Min	Max	N
Neonatal	18.8	135.7	0.0	1000.0	51,609
Infant	4.6	67.6	0.0	1000.0	602,931
Under 5	2.3	48.4	0.0	1000.0	2,751,057
	mean	sd	min	max	count
Panel A: Non educated mother					
Neonatal	19.7	139.1	0.0	1000.0	42,891
Infant	4.9	70.1	0.0	1000.0	501,343
Under 5	2.5	50.0	0.0	1000.0	2,313,369
	mean	sd	min	max	count
Panel B: Primary educated mother					
Neonatal	13.9	117.0	0.0	1000.0	8,718
Infant	2.9	53.4	0.0	1000.0	101,588
Under 5	1.5	38.6	0.0	1000.0	437,688
	mean	sd	min	max	count
Panel C: Small village					
Neonatal	20.6	142.0	0.0	1000.0	24,101
Infant	4.9	69.8	0.0	1000.0	281,469
Under 5	2.4	49.3	0.0	1000.0	1,280,965
	mean	sd	min	max	count
Panel D: Big village					
Neonatal	17.2	129.9	0.0	1000.0	27,508
Infant	4.3	65.5	0.0	1000.0	321,462
Under 5	2.3	47.5	0.0	1000.0	1,470,092

Table A2: Robustness

	Dry season			Rainy season		
	(1)	(2)	(3)	(4)	(5)	(6)
	Neonatal	Infant	Under 5	Neonatal	Infant	Under 5
Panel A: Baseline						
Past	-0.160	-0.331***	-0.178***	-0.650	-0.392**	-0.404***
	(-0.20)	(-3.02)	(-5.08)	(-0.61)	(-2.45)	(-7.22)
Current				-0.558	-0.0509	-0.104*
				(-0.57)	(-0.34)	(-1.94)
N	30,281	352,393	1,610,663	21,328	250,538	1,140,394
Panel B: With mother fixed-effects						
Past	0.300	-0.394***	-0.159***	1.044	-0.274	-0.354***
	(0.31)	(-3.25)	(-4.39)	(0.70)	(-1.53)	(-6.13)
Current				-0.742	-0.0221	-0.120**
				(-0.55)	(-0.14)	(-2.21)
N	26,087	352,217	1,610,540	16,917	250,192	1,140,115
Panel C: With year dummies						
Past	-0.547	-0.370***	-0.174***	-0.356	-0.266	-0.346***
	(-0.65)	(-3.16)	(-4.62)	(-0.31)	(-1.56)	(-5.78)
Current				-0.376	0.0574	-0.0563
				(-0.36)	(0.35)	(-0.97)
N	30,281	352,393	1,610,663	21,328	250,538	1,140,394
Panel D: With decadal fixed-effects						
Past	0.107	-0.278**	-0.139***	-0.455	-0.315*	-0.337***
	(0.13)	(-2.42)	(-3.80)	(-0.41)	(-1.89)	(-5.77)
Current				-0.370	0.0593	-0.0246
				(-0.36)	(0.37)	(-0.43)
N	30,281	352,393	1,610,663	21,328	250,538	1,140,394

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$