A Comparative Analysis of the Relationship between Climate Change, Agricultural Specialization and Children's Health: Evidence from Kenya and Mali

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Abstract

Kenya and Mali have already begun experiencing severe weather anomalies leading to scarce rainfall and heat waves. Climate change research has increasingly focused attention on the ways that changing temperature and rainfall patterns impact people. A particular focus has been on how changes in the amount and distribution of rainfall will change agricultural production in poor countries (Solomon et al., 2007; Brown et al. 2015). These changes are particularly dire among farmers who are dependent on rainfall rather than irrigation (NEPAD, 2013). Households in Mali and Kenya are typically engaged in one or more of the following production strategies: livestock rearing, cash crop production (like tea or coffee) as well as staple food production (like maize) (FEWS NET, 2016). Households specializing in either cash or food crop production may exhibit different levels of vulnerability to weather shocks. Specialization in cash crop cultivation may provide households with ready cash to purchase food and other necessary items even in the years of bad harvests as opposed to food crop cultivation, where most of the harvest is consumed within the household. Here, we combine detailed information on agricultural specialization and climate change to investigate in what ways agricultural specialization in either cash crop or food crop production influences children's health and impacts fertility. This study will provide detailed evidence about how Africa's colonial legacy and the anticipated climate trends will impact some of the poorest and most vulnerable people in the world.

Introduction

A growing body of research acknowledges the immense toll climate change is taking on human health, especially in developing countries (Bernstein & Myers, 2011; Grace, Davenport, Hanson, Funk, & Shukla, 2015; Grace, Nagle, & Husak, 2016; Shea & Comm Environm, 2007). Even though African countries have started to show declines in fertility, fertility rates on the continent are still high relatively to other developing regions (Bongaarts & Casterline, 2013). High fertility coupled with climate change results into a large number of children born into households with undermined food and economic security. Within these households affected by climate change, young children are the most vulnerable. Our first goal in this project is to investigate the influence of climate change on children's weight at birth, specifically the prevalence of Low Birth Weight (LBW) babies (less than 2500 grams), an important indicator of children's health later in life. Currently, about 15 % of all births in Africa are LBW (Wardlaw, 2004). Another important fertility metric is the interval between births, reflecting couples' fertility desires, contraceptive use, the ability to conceive, and environmental factors. As prior research has indicated, the impact of the changing natural environment on conceptions may be greater than previously anticipated and has been understudied (Grace et al., 2015; Panter-Brick, 1996; Bongaarts, 1993). In this project, we examine whether climate change contributes to increasing intervals between births in Kenya and Mali – a well-documented phenomenon in the literature (Bongaarts & Casterline, 2013; Casterline & Odden, 2016).

Mali and Kenya represent developing countries with significant portions of their populations relying on agriculture, yet the two countries differ in terms of their socio-economic development. We chose Kenya and Mali to analyze how climate change differentially affects households in a relatively more developed country in East Africa, in the case of Kenya, and a less developed and more reliant on agriculture country in West Africa, in the case of Mali. Agriculture is the main occupation sector in Mali, employing 80% of Mali's labor force (CIA, 2016). Agriculture in Mali is also the main economic sector, contributing 39% to Mali's Gross Domestic Product (GDP) (CIA, 2016). Even though a similar percentage of Kenya's labor force is employed in agriculture – 75% – only 30% of Kenya's GDP comes from agriculture, whereas the main economic sector is services (CIA, 2016). Kenya and Mali are ranked 145^{th} and 179^{th} on the Human Development Index (HDI) – the index is strikingly low in both countries, but Kenya is still more than 30 countries ahead (UNDP, 2016). Besides economic differences, Mali and Kenya exhibit differences in fertility: Mali's fertility is still high and is not showing signs of decline across surveys whereas Kenya has been demonstrating declining trends (Shapiro & Gebreselassie, 2009).

The influence of climate change on economic sectors sets the stage for the development of demographic processes in a country. Previous research has established agriculture as an important link between the negative influence of climate change and children's health (Lloyd, Kovats, & Chalabi, 2015). When crop yields are low and households generate too little profits from selling crops or have too little for their own consumption, they may lack resources to provide adequate nutrition for their children or expectant women, putting mother's and baby's lives at risk. In this project, we add depth to the understanding of how the climate change – agriculture nexus affects children's weight at birth by taking into account household's livelihood strategies, or agricultural specialization. Livelihood strategies represent activities through which people obtain income and food (FEWSNET, 2016). Agricultural specialization matters because some agricultural activities and crops are less susceptible to climate change than others and thus can protect households from climate change, resulting into better birth weight outcomes for children. The main livelihood strategy in Kenya and Mali is agriculture. Cash cropping, food cropping and pastoralism are the three dominant agricultural specializations in Kenya and Mali (FEWSNET, 2016). In this project we use detailed information on agricultural specialization and climate change to investigate in what ways agricultural specialization influences children's health.

1.1. Food and cash crops

In view of extremely limited irrigation, African agriculture is vulnerable to droughts and heat waves, which can substantially undermine food security (Grace, Davenport, Funk, & Lerner, 2012; Grace, Husak, & Bogle, 2014). The colonial past of sub-Saharan Africa determined its reliance on cash crops for export. Cash crops – cotton, tea, coffee, and others – are intended for international export (Maxwell & Fernando, 1989) as opposed to food crops that are mostly grown for domestic food consumption. Tea and cotton are the main cash crops in Kenya and Mali, respectively, while corn and millet are the main food crops (CIA, 2016). While ubiquitous in African agriculture, cash crops are a source of ongoing debates about their effect on the local populations and the environment. Cash crops have been praised as sources of economic growth and innovation as they allowed African nations to occupy a specialization niche on the international markets (Maxwell & Fernando, 1989). Despite these positive contributions, the instability of international and national markets raised concerns about the dangers of reliance on cash crops for livelihoods. At the household level, food crop growers are believed to have more resilience because they "live on what they grow" (Reutlinger, 1984) as opposed to cash crop farmers whose income depends on the international markets and exchange rates. Cash crops are often blamed for exacerbating social inequalities because of barriers to enter the cash crop agriculture, and gender inequalities due to the transformation and modernization of cropping techniques, which results into the rising role of men

(Maxwell & Fernando, 1989; Tosh, 1980). From the environmental point of view, existing research has documented that cash crops are often cultivated on better and more fertile soils, while food crops are moved to less fertile soils (Maxwell & Fernando, 1989). Taken together, these factors indicate that households cultivating cash and food crops may exhibit differential patterns of vulnerability to food insecurity.

1.2. Low birth weight

In this study we aim to evaluate the differential impacts of community livelihood strategies on children's birth weight and fertility. Specifically, we evaluate the differences in children's weight at birth and birth intervals by comparing cash crop dominant communities to food crop dominated communities. We theorize that cash crop dominated communities are less vulnerable to climate variability as compared to the food crop dominated communities because monetary profits from cash crop agriculture provide resources to purchase food and other necessities even during years of poor harvests. However, we also posit that cash crop communities may be more vulnerable to the crises on the international agricultural markets.

Numerous studies have investigated the relationship between weather conditions, food security and children's health (de Sherbinin, 2011; Funk & Brown, 2009; Grace et al., 2012; Grace et al., 2015; Grace et al., 2016). These studies conclude that as temperatures are rising, rainfall is becoming scarcer, and food security is compromised, children in developing countries will bear the burden of malnutrition, stunting, and increased vulnerability to infectious diseases (Bernstein & Myers, 2011; Deschenes, Greenstone, & Guryan, 2009; Grace et al., 2012; Grace et al., 2015; Thompson, Matamale, & Kharidza, 2012). These negative health outcomes in children persist later in life: stunted and malnourished girls are at risk for giving birth to stunted children (Victora, Adair, Fall, & Maternal, 2008), and malnourished children are more likely to develop disabilities and behavioral problems and less likely to have education and incomes comparable to children with normal birth weights (Grace et al., 2015). Even though there is a rich literature on climate change and food security, the existing studies do not explore possible differential vulnerability arising from agricultural specialization in either food crops or cash crops (Lloyd et al., 2015; Parry, Rosenzweig, Iglesias, Livermore, & Fischer, 2004). This study attempts to investigate differential vulnerability to changes in rainfall and temperature by taking into account specialization in agricultural production.

1.3. Birth spacing

We also examine whether and how climate variability, as acting through crop production, contributes to longer intervals between marriage and the first birth as well as following births. We consider birth intervals as a proxy measure of a failed reproductive experience – either in terms of miscarriage/stillbirth or failed conceptions. When the stability of livelihoods is undermined by bad yields and food shortages, household nutrition may be impacted in a negative way, leading to an increase in stillbirths, miscarriages, and failed conceptions (Basu, Malig, & Ostro, 2010).

Large ideal family size and the Total Fertility rate (TFR) twice the replacement level are indicative of pronatalist behaviors in Africa (Bongaarts & Casterline, 2013). However, birth intervals in Africa are longer than in other developing regions with comparable levels of fertility, with the median birth interval totaling 35 months (Bongaarts & Casterline, 2013; Casterline & Odden, 2016). Longer birth intervals are theorized to be caused by abstinence and postpartum amenorrhea (Bongaarts & Casterline, 2013). However, mother's health and inability to conceive in the face of food insecurity and heat stress may lead to longer birth intervals, and this aspect has rarely been studied in contemporary contexts. In such a case, longer birth spacing is not a desired outcome but rather represents a failed reproductive outcome – a couple wanted to have children but could not conceive, henceforth increased birth spacing. While it may be difficult to disentangle the effect of climate change on second and later births because biological factors and fertility desires that were not there immediately after marriage kick in, we are using the interval between marriage and first birth to investigate how increased climate change contributes to the growing intervals between marriage and the first birth.

This study is guided by the following research questions:

1) Do variations in seasonal growing conditions have different effects on children's birth weights depending on the community livelihood strategy (specialization in the type of crop harvested in the area: cash vs. food crops)?
2) How is fertility affected by weather variations: can longer intervals between marriage and first birth be explained by variations in rainfall, temperatures and harvests?
3) How do these patterns vary in East and West Africa in countries with different levels of socioeconomic development and different fertility patterns (Kenya vs. Mali)?

Data and Methods

2.1. Health and Demographic Data

Our health and sociodemographic data come from the Demographic Health Surveys data (DHS, 2016). We will use the following samples: Kenya 2014 and 2008, and Mali 2012-2013. These data are combined with spatial information from the DHS, at the level of the community cluster, to create a spatial data set containing detailed information on reproductive health outcomes.

The first dependent variable in our analysis reflects whether a baby was low birth weight (LBW) (birth weight under 2,500 grams – low birth weight). This variable is constructed from the continuous variable of birthweight in the DHS. Previous research has established that mother's age, education, breastfeeding practices, and birth order are significantly associated with children's weight at birth (Grace et al., 2012; Grace et al., 2015). We are going to use these variables as control variables in our models. Besides mother's demographic characteristics, we are also going to adjust for the following household characteristics: wealth index, water source and floor material, and whether or not the household is located in an urban area. To ensure that every birth record in the survey is matched to the appropriate environmental data, we only conduct analysis for women who gave birth in their current place of residence.

The time period between births, or from marriage to birth for the first birth, will serve as our second dependent variable. We evaluate birth intervals because they can serve as a measure of a "failed" reproductive outcome. In other words, a low birth weight baby is one outcome from a conception, other outcomes are miscarriage or stillbirth, but neither of these are well measured in the DHS. As such, we assume that a longer than average birth interval is an indication of a failed reproductive experience. Similar to the low birth weight analysis, we aim to evaluate whether birth intervals change following periods of heat waves, droughts and bad yields. Further, we will consider the way that the dominant livelihood strategies of the area – cash cropping versus food cropping – influence low birth weight outcomes and birth spacing.

2.2. Environmental Data

Our climate measures represent high resolution (0.5 x 0.5 degrees) monthly temperature and precipitation data available through Terra Populus (Kugler et al., 2015). Livelihood zone data come from the USAID's Famine Early Warning System Network (FEWS NET) which uses local experts and geophysical data to identify areas dominated by a specific livelihood strategy. Livelihoods zones are widely used in food security research as they allow researchers to observe differential vulnerabilities based on how people produce their food (Grace, et al., 2012). Based on the information provided in FEWS NET country reports, we aggregated livelihood zones by the prevailing livelihood strategy. Figures 1 and 2 depict DHS clusters nested within livelihood zones in Kenya and Mali.

Rainfall and temperature data for a given year are linked to the demographic data by locating each DHS cluster within the livelihood zone boundaries. The dynamic spatial data – rainfall and temperature – are temporally matched with the birth interval and the birth weight data to ensure that the relevant season is matched to the health outcome of interest.

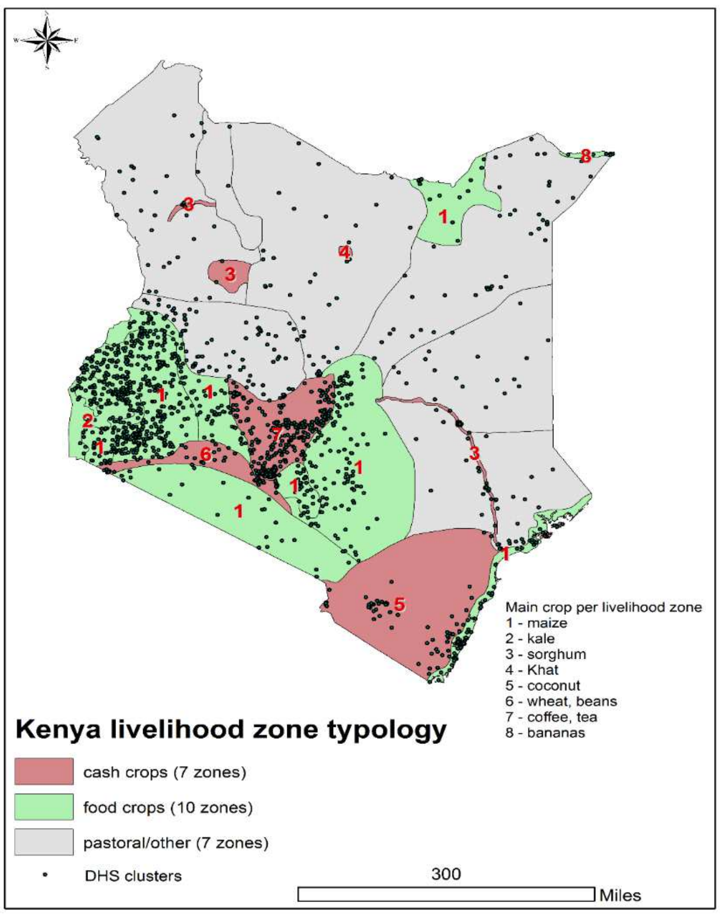

Figure 1. Livelihood zones typology and DHS cluster coverage in Kenya (2014 clusters)

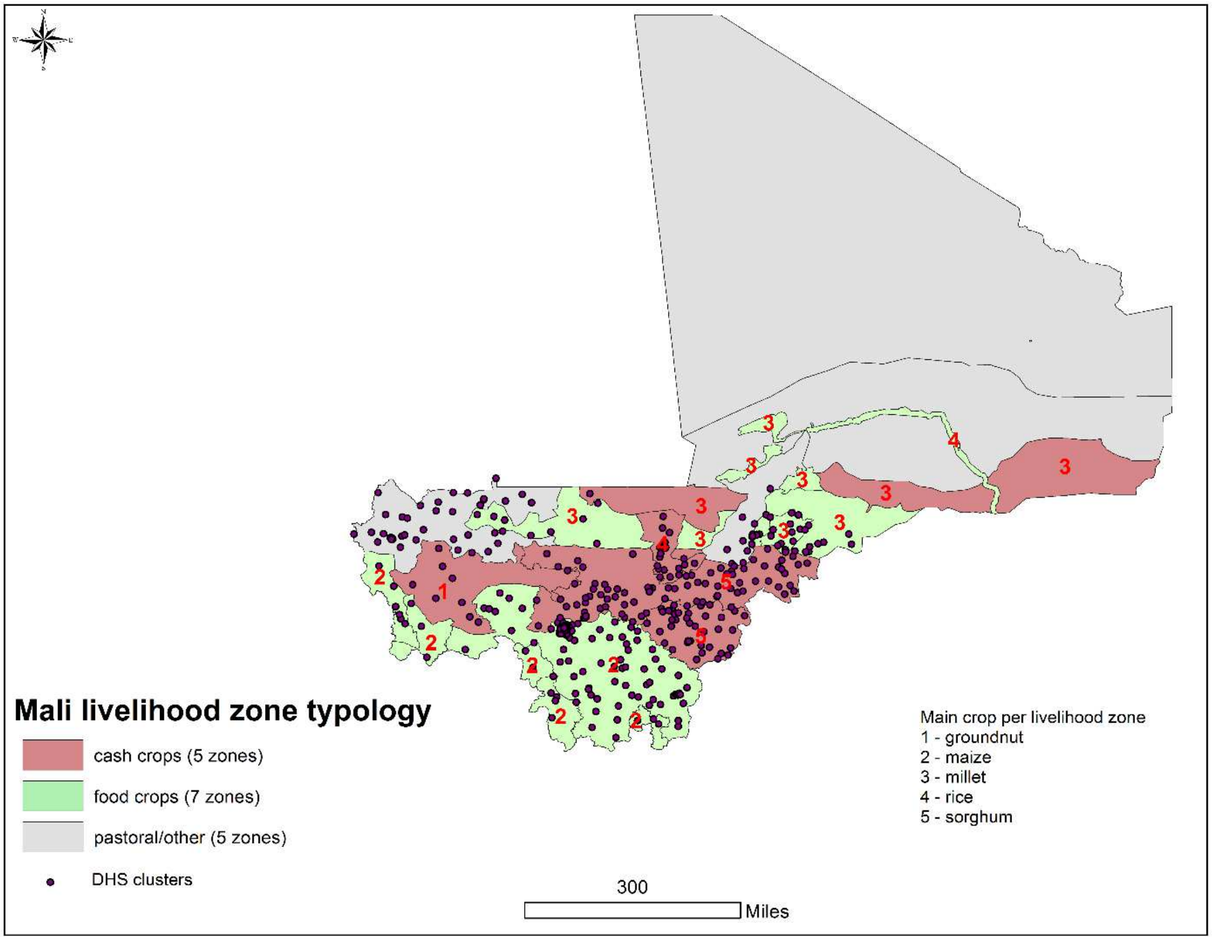

Figure 2. Livelihood zones typology and DHS cluster coverage in Mali

Preliminary results

Tables 1 represents summary statistics for the combined DHS samples for Kenya from 2008 and 2014. In this sample 8% of babies were born LBW (under 2500 grams). Summary statistics for the Mali 2012-2013 sample are presented in Table 2, and 15% of babies from that sample were LBW. Both samples represent single births. The 2008 Kenya sample was restricted to mothers who gave birth in their current residence to ensure that each birth record is matched to appropriate environmental data. We could only apply the residence restriction to the 2008 Kenya sample because DHS stopped collecting the variable on the duration of stay after 2010. Based on this residence restriction, we dropped 6106 births from the 2008 sample.

Table 1. Summary statistics for the variables used in the analysis (Kenya)

Variables	**Count**	**Mean**	**SD**	**Min**	**Max**
Child's sex	Boys 4169; Girls 3940				
Birth order		2.9	2	1	15
Mother's age (years)	2344	28	6.38	15	49
Mother's weight (kg)		60.7	12.8	33.6	168
Mother's height (in cm)		160	6.7	88.7	206
Mother's education	None 808; Primary 4336; Secondary and beyond 2965				
Type of residence	Urban 3469; Rural 4640				
Electricity in a household	No 5743; Yes 2449; NA 185				
Floor type	Natural 4029; Rudimentary 15; Finished 3871; Other 186				
Livelihood zones	Cash crops 2736; Food crops 4525; Pastoralists 848				
Birth weight (kg)	NA 89998	3.33	0.6	0.6	6.9
Low Birth Weight	Yes 487; No 7622				
Source of birth weight	Written card 4077; Mother’s recall 4032				

Table 2. Summary statistics for the variables used in the analysis (Mali)

Variables	**Count**	**Mean**	**SD**	**Min**	**Max**
Child's sex	Boys 1661; Girls 1552				
Birth order		3.4	2.12	1	13
Mother's age (years)	2344	28.2	6.7	15	49
Mother's weight (kg)		62.2	13.7	33	179
Mother's height (in cm)		161.4	13.4	140	183
Mother's education	None 2142; Primary 403; Secondary and beyond 668				
Type of residence	Urban 1645; Rural 1568				
Electricity in a household	No 5743; Yes 2449; NA 185				
Floor type	Natural 1674; Rudimentary 25; Finished 1494; Other 20				
Livelihood zones	Cash crops 684; Food crops 831; Pastoralists 1698				
Birth weight (kg)		3.29	0.995	0.5	9
Low Birth Weight	Yes 86; No 2727				
Source of birth weight	Written card 1049; Mother’s recall 2276				

As can be seen from Table 3, we observe a significant difference in the prevalence of LBW babies among three dominant livelihood strategies in both countries. We now turn to examining demographic and health characteristics of low birth weight children. (Tables 4 & 5). In a sample of 487 LBW babies for Kenya, more than a half were girls – 287. Low Birth Weight babies represented 15% of Mali sample, and more than a half of these LBW babies were girls (227 boys vs. 259 girls). We observe that mothers who gave birth to LBW babies weighed less and were shorter as opposed to those mothers who gave birth to children with normal weight. Educational attainment between the mothers of LBW babies and healthy babies was different as well. In our subset of low birth weight children for Kenya, 58 and 29% of babies were born to mothers with only primary and at least secondary education, respectively, compared to 53 and 37% in the healthy birth subset. In Mali, 67 and 13% of babies were born to mothers with only primary and at least secondary education, respectively, compared to 69 and 13% in the healthy birth subset. In addition, in Mali 21% of babies in the healthy birth weight subset were born to mothers with secondary education and beyond, compared with 17% in the LBW subsample. In both countries most of the LBW babies were born in rural households.

Table 3. Preliminary results

Sample	Variables	Cash croppers	Food croppers	Pastoralists	P-value
Kenya	Weight (Mean* ± SE)	3.208 ± 0.012	3.380 ± 0.010	3.205 ± 0.021	<0.0001***
Mali	Weight (Mean* ± SE)	3.201 ± 0.035	3.346 ± 0.033	3.289 ± 0.024	0.0131 *

Note: * Weight is in kg

Table 4. Summary statistics for LBW children (Kenya)

Variables	Count	Mean	SD	Min	Max
Child's sex	Boys 200; Girls 287				
Birth order		3	2.07	1	15
Mother's age (years)	162	27	6.98	15	48
Mother's weight (kg)		59.9	14.5	33.6	166
Mother's height (in cm)		158	6.5	117	187
Mother's education	None 62; Primary 283; Secondary and beyond 141				
Type of residence, total	Urban 226; Rural 261				
Electricity in a household	No 322; Yes 141; NA's 14				
Floor type	Natural 234; Rudimentary 1; Finished 238; Other 14				
Livelihood zones	Cash crops 201; Food crops 224; Pastoralists 62				

Table 5. Summary statistics for LBW children (Mali)

Variables	Count	Mean	SD	Min	Max
Child's sex	Boys 227; Girls 259				
Birth order		3	2.1	1	11
Mother's age (years)	162	27.5	6.9	15	47
Mother's weight (kg)		60.2	14	30	159
Mother's height (in cm)		160	14.8	140	180
Mother's education	None 337; Primary 64; Secondary and beyond 85				
Type of residence, total	Urban 239; Rural 247				
Electricity in a household	No 231; Yes 253; NA's 2				
Floor type	Natural 270; Rudimentary 7; Finished 1205; Other 4				
Livelihood zones	Cash crops 123; Food crops 110; Pastoralists 253				

2.3. Methods

In our next step we will use multi-level models for continuous and categorical outcomes to examine the association between rainfall, temperature, livelihood zones and our outcome variables. DHS observations are nested within clusters, and using multi-level models will account for grouping of cases within the clusters. We will then fit the models to examine whether the odds of giving birth to a low birth weight baby or the birth intervals are different for areas relying on cash or food crops given different seasonal experiences. From the preliminary results we have already seen that agricultural specialization plays a significant role in the prevalence of LBW babies. Our analyses will be conducted with a particular focus on livelihood strategies and possible differences between the outcomes observed in the two countries of interest.

Contribution and innovation

Food and cash crops, climate variability, children's health and fertility behaviors are closely intertwined and their interplay shapes the health and economic development of future generations. Analyzing the effects of weather conditions on health outcomes while accounting for specialization in food and cash crops will provide detailed evidence about how Africa's colonial legacy and the anticipated climate trends will impact some of the poorest and most vulnerable people in the world. The scale of this study will reveal how these patterns vary in West and East Africa in countries experiencing different fertility patterns and who are exposed to different types of climate related risks. This study is innovative because it aims to evaluate reproductive health outcomes with attention to agricultural characteristics in the context of climate change.

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