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Climatic conditions and infant care: implications for child nutrition in rural Ethiopia

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Abstract

We examine the relationships between climatic conditions, breastfeeding behavior, and maternal time use in Ethiopia. Infant feeding practices are important predictors of child nutrition that may be affected by a number of factors including mother's time engaging in agricultural labor, food security, cultural beliefs, and antenatal care. We use panel data from the Living Standards Measurement Study to investigate linkages between climatic conditions during a child's first year of life and year prior to birth and duration of exclusive breastfeeding. We then explore one potential mechanism: women's agricultural labor. Results indicate that rainfall during the primary agricultural season—kiremt—in a child's first year of life plays an important role in duration of exclusive breastfeeding. Experiencing 25 cm of average monthly kiremt rainfall, versus 5 cm, is associated with a 20-percentage-point decrease in the likelihood of being exclusively breastfed for the recommended 6 months. More kiremt rainfall is associated with a greater number of days that women spend planting and harvesting, and at high levels of rainfall women with infants do not engage in significantly fewer days of agricultural labor than those without infants. Lastly, we find that during the year before birth, greater rainfall during kiremt as well as the dry season is associated with a lower likelihood of 6 months of exclusive breastfeeding, potentially due to the early introduction of complementary foods. Our findings indicate that agricultural labor demands may in part drive breastfeeding behaviors, leading to "sub-optimal" feeding practices in the short-term, but resulting in improved household food security in the longer-term.

Keywords Climate change · Ethiopia · Breastfeeding · Child nutrition · Agriculture · Time use

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Introduction

Child undernutrition is a critical population health challenge, particularly in sub-Saharan Africa. Sustained undernutrition during the first few years of life can lead to stunting—low height for age—which is the most common form of undernutrition globally, affecting over 20% of children under age five (UNICEF et al., 2017). One-third of stunted children live in Africa and 37% of children under age five in Eastern Africa are stunted (UNICEF et al., 2017). Childhood undernutrition is associated with long-term negative health and human capital outcomes including poorer cognitive development, lower educational attainment, and reduced wages (Alderman et al., 2006; Dewey & Begum, 2011; Hoddinott et al., 2008, 2013; Victora et al., 2008). In addition, stunted women are more likely to give birth to low birthweight babies who themselves are at a greater risk of becoming stunted (Victora et al., 2008). Undernutrition therefore has lasting impacts on the health and well-being of individuals across the life course as well as over generations.

Climate change has the potential to undermine future improvements in child nutrition, in part through its effects on agricultural production and food security (Porter et al., 2014). Climate change is associated with an increased frequency and intensity of droughts, floods, and heat waves, as well as a shifting seasonality of precipitation, all of which may heighten the risk of undernutrition among exposed children. Indeed, studies examining links between climatic conditions and child undernutrition have found that exposure to droughts or severe flooding in early childhood is associated with stunting, wasting (low weight for height), and slower growth (Alderman et al., 2006; Chotard et al., 2011; del Ninno & Lundberg, 2005; Hoddinott & Kinsey, 2001; Rodriguez-Llanes et al., 2011). The studies generally conclude that adverse climatic conditions lead to crop loss or to the loss of income and assets, which reduces food consumption and in turn negatively impacts child nutrition.

In addition to the effects of crop and income loss on food consumption during early childhood, another potentially important—yet understudied—pathway between climate and child nutrition is through breastfeeding behavior. The World Health Organization (WHO) recommends that infants are exclusively breastfed for the first 6 months of life, meaning that they are provided solely with breastmilk (and medicines and vitamins if necessary) (WHO, 2018). Exclusive breastfeeding (EB), particularly in low resource settings, reduces the risks of diarrheal diseases and infant mortality (Black et al., 2008; Turin & Ochoa, 2014). Further, studies in Malawi and Ethiopia have found that the duration of EB is positively associated with height for age and negatively associated with stunting in childhood (Abate & Belachew, 2017; Kamudoni et al., 2015; Kuchenbecker et al., 2015). Despite its apparent health benefits, EB in Africa is far from ubiquitous, with only 37% of infants under 6 months of age exclusively breastfed in 2017 (Bhattacharjee et al., 2019).

A number of barriers to EB exist among mothers and families in rural households in low- and middle-income countries including agricultural and domestic labor, food insecurity, cultural beliefs and practices, and lack of access to health services (Alebel et al., 2018; Burns et al., 2016; Dearden et al., 2002; Gray, 1995; Jones et al., 2012; Levine, 1988; Meehan & Roulette, 2013; Nankumbi & Muliira, 2015). For example, studies from Sub-Saharan Africa, South America, and Asia have found that mothers often leave infants in the care of others while engaging in agricultural work (Burns et al., 2016; Dearden et al., 2002; Jones et al., 2012; Levine, 1988; Meehan & Roulette, 2013). Infants cared for by relatives or community members are frequently provided with water or complementary foods instead of breastmilk, increasing the risk of diarrheal diseases and sub-optimal nutrition (Turin & Ochoa, 2014).

Additionally, in rural Uganda, domestic tasks include tending the garden, fetching water, and cooking pose barriers to EB (Nankumbi & Muliira, 2015). Further, supplementing breastmilk with complementary foods is common if a mother believes that the quality and/or quantity of her breastmilk is low as a result of food insecurity or a low-quality diet (Burns et al., 2016; Grace et al., 2017; Webb-Girard et al., 2012). Maternal undernutrition, however, has little effect on breastmilk production aside from cases in which malnutrition is severe (Black et al., 2008). In contrast, in more food secure households in Bangladesh, mothers of infants aged 3–6 months were more likely than their less food secure counterparts to introduce complementary foods such as cows' milk or juice (Saha et al., 2008). These findings suggest that cultural norms and beliefs around food in/security may motivate infant feeding practices in varying ways. Lastly, access to breastfeeding information and support during antenatal care visits has been shown to foster longer EB (Burns et al., 2016).

Climatic conditions are likely to affect the duration of EB in a number of direct and indirect ways through their impacts on mothers' time use, cultural beliefs about breastmilk and infant feeding behavior, household income and food supply, and access to health information. However, research on the links between climatic conditions and breastfeeding behavior is extremely limited. Thai and Myrskylä (2012) found that in rural Vietnam, more rainfall during the year of birth is associated with fewer months of breastfeeding, particularly in farming regions. The authors argued that this is likely due to increased demand for agricultural labor and thus a higher opportunity cost of breastfeeding. Rosales-Rueda (2018) examined the effects of severe El Niño flooding in Ecuador and found that flood exposure was associated with fewer months of EB. She argued that extreme flooding could negatively impact a mother's health or lead her to return to work, thereby reducing EB.

Two studies have examined the linkages between rainfall and breastfeeding behaviors in East Africa, with a specific focus on pastoralists. Among Turkana pastoralists in Kenya, the amount of time a mother spent away from her infant (generally to engage in livestock herding activities), as well as the amount of rainfall, were negatively associated with breastfeeding frequency (Gray, 1995). Gray argued that during the rainy season, livestock produce a greater quantity of milk, which may encourage mothers to leave infants in the care of others who can provide the infants with animal milk. Similarly, among herders in Tanzania, mothers reported introducing animal milk at the end of the rainy season due to increased milk availability and greater work demands on mothers (Sellen, 2001). The potential barriers to EB describe above were found across a variety of geographic, agricultural, and socioeconomic contexts, and we believe that many of these barriers will influence EB in an Ethiopian context.

In this paper, we use panel data from Ethiopia to understand whether climatic conditions are associated with the duration of EB. We then use detailed time use data to examine one potential mechanism: women's agricultural labor. Specifically, we examine the relationship between climatic conditions and women's time spent planting and harvesting, and then ask whether this varies by whether or not the woman has an infant. By exploring this understudied pathway between climate and child well-being, our findings will help to facilitate effective adaptation to more variable climatic conditions among rural, agricultural populations.

Breastfeeding behaviors and climatic conditions

There are a number of pathways through which climatic conditions may affect breastfeeding behaviors among rural populations in low- and middle-income countries (see conceptual model in Fig. 1). The first is through women's time use. Women in rural households play an important role in agricultural production. Labor demands during periods of planting, crop growth, and harvesting may thus compete with the time a mother has available to care for her infant. Climatic conditions could influence the extent to which a mother exclusively breastfeeds in two ways. First, more favorable temperature and rainfall conditions may lead to an increased demand for agricultural labor among mothers, which could reduce the amount of time available for breastfeeding while increasing household food production. In contrast, less favorable temperature and rainfall conditions could lead mothers to spend more time engaging in other forms of labor (e.g., non-agricultural income generation, fetching water or fuelwood), which may also limit the time available for breastfeeding. Indeed, water insecurity—often caused by drought conditions—can act as a barrier to breastfeeding if mothers must spend more time collecting water (Schuster et al., 2020).

Second, climatic effects on agricultural production could impact household income and food security. On the one hand, mothers with greater access to foods deemed appropriate for infants (e.g., animal milk) may introduce those foods earlier, thereby reducing the duration of EB (Saha et al., 2008). On the other hand, drought-related water insecurity may lead to decreased availability of food and drinking

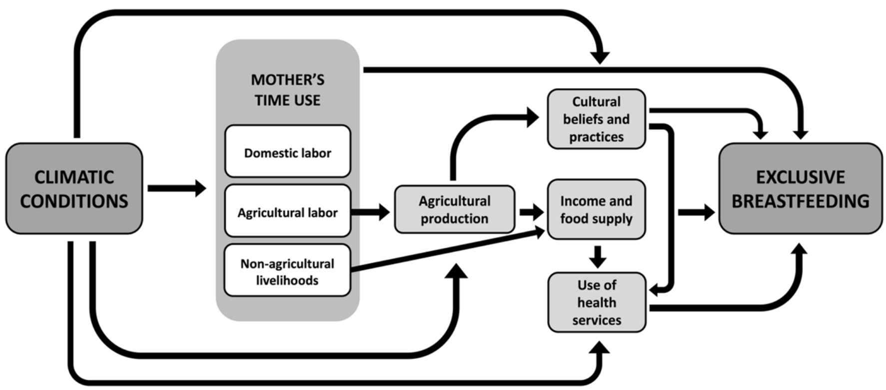

Fig. 1 Conceptual model of the linkages between climatic conditions and exclusive breastfeeding

water, leading mothers to delay the introduction of complementary foods and liquids, thereby increasing EB duration (Schuster et al., 2020).

Third, cultural beliefs and practices related to climatic conditions and breastfeeding may affect duration of EB. For example, in the Democratic Republic of Congo, it is a common practice to provide infants with water during periods of hot weather (Burns et al., 2016). In addition, beliefs that food insecurity reduces the quantity or quality of breastmilk may lead mothers to introduce complementary foods earlier in response to poor agricultural production (Burns et al., 2016; Grace et al., 2017; Webb-Girard et al., 2012).

Fourth, greater access to breastfeeding information and antenatal services is correlated with a longer duration of EB (Burns et al., 2016; Egata et al., 2013). Extreme weather events such as floods may impede access to health facilities by damaging roads, with the greatest adverse effects on pregnant women or new mothers in remote, rural areas without a nearby hospital or health post. In addition, poor climatic conditions may reduce agricultural income, thereby limiting a woman's ability to afford travel costs to health facilities. Lastly, pregnant women spending more time on agricultural labor during periods of favorable climatic conditions may have less available time to seek antenatal care, particularly if reaching a health center necessitates substantial travel time.

The Ethiopian context

The landscape and climate of Ethiopia are highly variable, with deserts in the east, tropical rainforests in parts of the south, and highland mountainous areas throughout the central and northern regions. Annual rainfall ranges from 300 mm in arid, lowland areas to 2000 mm in the highlands (Viste et al., 2013). Temperature conditions vary greatly as well, with highland areas experiencing maximum daily temperatures averaging 20–25 °C (68–77 °F) and lowland areas experiencing maximum daily temperatures of 30–35 °C (86–95 °F) (Fazzini et al., 2015). Agriculture is central to Ethiopia's economy. Smallholder farmers produce 95% of the country's agricultural products, and crop production is highly dependent on rainfall conditions, as only 3% of cropland is irrigated (FAO, 2019; Machado Mendes & Paglietti, 2015). The majority of the country's population lives in the cooler highlands, where agricultural production focuses on crops including teff, maize, wheat, and coffee (Evangelista et al., 2013). Arid and semiarid regions are home to pastoralists and agro-pastoralists, who raise livestock or rely on a mixture of livestock keeping and crop production.

There are two rainy seasons in much of Ethiopia: kiremt, which typically runs between June and September, and belg, which extends from February to May (Seleshi & Zanke, 2004). The dry season, bega, occurs from October through January. Crops grown during kiremt account for 90–95% of total annual production, while belg crops comprise the remainder (Bezabih & Di Falco, 2012). Kiremt crops are typically planted between April and July and harvested in October through December, while belg crops are planted between January and March and harvested in June and July (FEWS NET, 2013). See Appendix Fig. 4 for a timeline of seasonal rainfall and agricultural activities.

Ethiopia periodically experiences droughts and dry spells, with a recent severe drought occurring throughout much of the country in 2015 and 2016 (Philip et al., 2018; Viste et al., 2013). Further, belg and kiremt rains have declined by 15–20% in southern Ethiopia since the 1970s (Funk et al., 2012) and poor belg rainy seasons now occur two-to-three times more frequently than in the 1980s and early 1990s (Funk et al., 2019). Ethiopia is projected to experience an annual warming of 2.2 °C by the 2050s, which will lead to higher rates of evaporation (Conway & Schipper, 2011). Further, kiremt precipitation is predicted to increase in the central Highlands and northern Great Rift Valley and decrease in southern Ethiopia (Li et al., 2016).

Women play an important role in agricultural production in rural Ethiopia, providing 29% of the total amount time spent on crop production, with the remainder provided by male household members and/or hired or exchanged labor (Palacios-Lopez et al., 2017). Women's contributions to agricultural labor ranges from 26% for land preparation, planting, and weeding to 37% for harvesting. Agricultural labor, coupled with domestic work including cooking, fetching water, and gathering fuelwood, can therefore take up a significant portion of a woman's day. While men are more likely than women to engage in agricultural and wage labor, domestic tasks are predominantly performed by women. As such, Ethiopian women tend to spend more time than men performing work activities (Arora & Rada, 2013; Robles, 2010).

Overall, the rates of EB in Ethiopia are relatively high compared with other Sub-Saharan African countries, with 58% of infants under 6 months of age exclusively breastfed (Bhattacharjee et al., 2019). However, sub-national rates vary substantially (Bhattacharjee et al., 2019). For example, the data used in this study indicate that the percentage of rural children aged 12–35 months who were exclusively breastfed for 6 months ranged from 75% in the Amhara region to 35% in Dire Dawa.

Consistent with longstanding cultural practices, Ethiopian mothers and other care providers often introduce foods like butter or milk (mixed with water) to otherwise breastfed infants under 6 months of age (Rogers et al., 2011). Providing young infants with water or complementary foods can lead to diarrheal diseases and sub-optimal nutrition, thereby negatively impacting growth and development. Indeed, a study in a coffee farming region of southwest Ethiopia discovered that children who were exclusively breastfed for less than 6 months were four times more likely to be stunted than those exclusively breastfed longer (Abate & Belachew, 2017). The authors argued that in a cash cropping economy, mothers may have less time to devote to infant care due to increased market participation, which in turn affects infant feeding practices and nutritional outcomes. Research also shows that when Ethiopian mothers receive educational and health/medical support, they are more likely to adhere to breastfeeding guidelines and engage in EB of their infants (Asemahagn, 2016; Egata et al., 2013; Horii et al., 2011).

Two other notable findings emerge from Ethiopian research on infant care and feeding practices. Mothers without partners are less likely to exclusively breastfeed their infants, and infants of unemployed mothers are more likely to be exclusively breastfed (Asemahagn, 2016; Egata et al., 2013). These findings may indicate that when women face increased demands on their time to secure resources for their families—single mothers likely must take on at least some of the tasks of a male partner—breastfeeding behaviors, and consequently, child health outcomes are impacted. Climatic conditions influence daily life in agriculturally dependent households, changing workloads, food/resource availability, and impacting local markets and mobility practices (see Grace et al., 2017). In Ethiopia when mothers' workloads and time demands change, breastfeeding practices may change in response. This suggests that climatic conditions may shift breastfeeding practices in this setting. The role of climatic conditions in breastfeeding behavior and infant care in rural Ethiopia is a key unexplored pathway that is critical for better understanding how climate change may impact child undernutrition.

Methods

Data

We use longitudinal household survey data from the World Bank's Living Standards Measurement Study—Integrated Surveys on Agriculture (LSMS-ISA) program. The World Bank assisted Ethiopia's Central Statistical Agency in conducting three rounds of data collection with approximately 4000 households in 2011–2012, 2013–2014, and 2015–2016 (Central Statistical Agency of Ethiopia (CSA), 2012, 2014, 2016). The data were collected in 290 rural and 43 small town enumeration areas (EAs), and the sample was designed to be representative of rural areas and small towns in Ethiopia. Data on duration of EB were collected in rounds two (2013/2014) and three (2015/2016). We use the first round (2011/2012) for baseline household socioeconomic, demographic, and environmental data, and data from rounds two and three on duration of EB as well as child and mother characteristics. We restrict this sample to children aged 12 to 35 months at the time of the survey (the children were born between 2011 and 2015). If a child was between 12 and 35 months during both rounds of the survey and thus appeared in the dataset twice, we use data from the earlier round. For analyses on women's time use, we use data from all three rounds. We restrict the women's sample to those of reproductive age (15 to 49 years) and determine whether the woman has an infant during the most recent planting or harvesting season. Specifically, we determine whether a woman has an infant under 12 months of age during the middle of the kiremt planting season in June or during the middle of the kiremt harvest season in November.

During each survey round, a post-planting questionnaire was implemented in September and October followed by post-harvest and household questionnaires the following February through April (January through March during the first round) (see Appendix Fig. 4 for a timeline of data collection). Household demographic and socioeconomic information and data on EB duration were collected in the household questionnaire. The post-planting and post-harvest questionnaires collected data on household members' time spent engaging in agricultural activities during the most recent kiremt season. Recalling time spent on farm labor has been shown to be relatively accurate with a month-long recall period; however, recalling labor for an entire season may lead respondents to underestimate time spent on agricultural activities (Bell et al., 2019).

To account for known variation, we incorporate a number of control variables at the child level (age in months, sex, whether he/she is the child of the household head), mother level (mother's age, whether mother has ever attended school), household-level (number of household members at baseline, whether household engaged in agricultural activities at baseline, and food insecurity at baseline, defined as whether the household reported at least 1 month of inadequate food provision in the past year), and community level (whether the community is rural or a small town). Lastly, to further account for differences in baseline climatic conditions and livelihoods, we control for agro-ecological zone, agricultural production seasons, and altitude.

The samples consist of women and children living in eight agro-ecological zones, but due to small numbers of households in some of the zones, we combined them into five categories: tropic-warm/arid and semiarid, tropic-cool/arid and semiarid, tropic-warm/humid and subhumid, tropic-cool/humid, and tropic-cool/subhumid (see map in Fig. 2). These categories capture differences in general rainfall and temperature conditions as well as differences in livelihood strategies. The warm arid and semiarid areas of the country's northeast, south, and southwest rely predominantly on livestock production. The cool humid areas in the west engage in the production of cereals (e.g., wheat, maize, teff) as well as perennials including coffee, while the other areas rely on the production of cereal, oilseeds (e.g., sesame, flax), and/or pulses (e.g., chickpeas, lentils) (USAID & Government of Ethiopia, 2010). Lastly, agricultural seasons vary spatially, with western areas dependent entirely on kiremt rainfall, northeastern and central regions dependent primarily on kiremt rainfall but also engaging in a secondary belg cropping season, and pastoral areas in the country's south and east relying primarily on

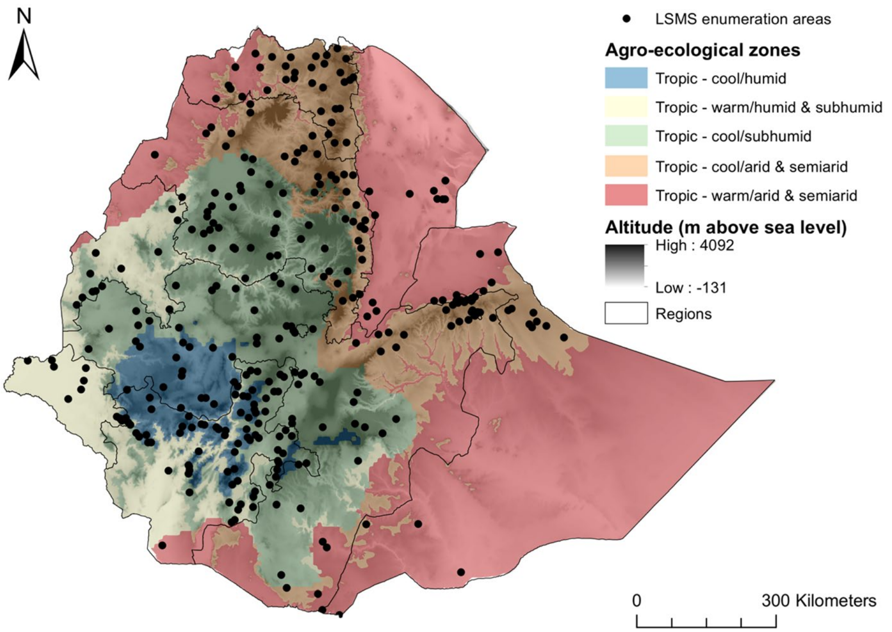

Fig. 2 Map of LSMS enumeration areas including agro-ecological zones, altitude, and region boundaries

belg rainfall (see map in Appendix Fig. 5) (USAID & Government of Ethiopia, 2010). Data on agro-ecological zone and altitude were provided for each household by the LSMS program. Agricultural seasons were derived from USAID and Government of Ethiopia (2010). Indicators of baseline household size, engagement in agriculture, and food insecurity status were constructed from the raw LSMS data by the Evans School Policy Analysis and Research Group (2019) at the University of Washington.

We link the LSMS data to climate data using village-level GPS points to measure exposure to rainfall and temperature conditions during the child's early life as well as during the most recent kiremt season. We use precipitation data from the Climate Hazards group Infrared Precipitation with Stations (CHIRPS). CHIRPS provides 0.05° (~ 5 km) daily gridded precipitation data from 1981 to present using a combination of weather station and satellite data (Funk et al., 2015). CHIRPS data are widely used by international and governmental organizations to monitor the agricultural and food security situation in Ethiopia and in sub-Saharan Africa (see fews.net).

Temperature data are derived from the Global Meteorological Forcing Dataset for land surface modeling developed by the Terrestrial Hydrology Research Group at Princeton University. Available at 0.25° (~ 27 km at the equator) spatial resolution at daily and monthly intervals, these temperature data are created from a blend of reanalysis data and observations from meteorological stations for 1948–2016 (Sheffield et al., 2006). While the temperature data is notably coarser than the rainfall data, this is generally not considered to be problematic as temperature is much less spatially variable than rainfall and therefore the coarser grid is adequate.

Our climate measures consist of mean maximum daily temperature (°C) and mean monthly rainfall (cm). We include maximum daily temperature as our metric because high temperatures can increase evaporation and prolong droughts, leading to poor harvests, and heat stress can reduce yields of cereal crops by affecting plant flowering and growth (Hadgu et al., 2015). The climate variables vary spatially and are adjusted temporally to match each person's exposure. For the children's sample, we use month of birth to calculate averages for each season (kiremt, bega, and belg) during the child's first year of life as well as during each season in the year before birth (see Appendix Table 5 for details on linking children to climate data). For the women's sample, we calculate averages for the most recent kiremt season prior to the household survey (e.g., the 2015 kiremt season for the 2015/2016 survey round). To ensure confidentiality, the LSMS randomly displaces the GPS locations of small town EAs by between 0 and 2 km and rural EAs by between 0 and 5 km (with 1% of clusters displaced by up to 10 km). To account for this, we create a 10-km buffer around each cluster and average the climatic conditions for all grid cells contained within that buffer. The spatial merging approach that we use is consistent with the recommended use for similar surveys (see Grace et al., 2019; Perez-Heydrich et al., 2013).

Analysis

We estimate a set of multivariate regression models that account for the LSMS's stratified two-stage sampling design by adjusting for the selection of households within EAs, regional stratification, and sampling weights. In the children's models, we use logistic regressions to model the likelihood of EB for less than 6 months based on seasonal climatic conditions in (1) the first year of life and (2) the year before birth. The model is formally described by the following equation:

$$\begin{aligned}\ln(Y_{ij}) = \beta_0 &+ \beta_1\left(\text{kiremt rain}_i\right) + \beta_2\left(\text{kiremt temp}_i\right) \\ &+ \beta_3\left(\text{bega rain}_i\right) + \beta_4\left(\text{bega temp}_i\right) \\ &+ \beta_5\left(\text{belg rain}_i\right) + \beta_6\left(\text{belg temp}_i\right) \\ &+ \beta_c\left(X_{\text{cn}}\right) + u_k + v_z + \gamma_t + e_i\end{aligned} \tag{1}$$

In Eq. 1, a logit link function is used to estimate the odds of being exclusively breastfed for less than 6 months for child i. Parameter β_0 represents intercept, whereas parameters $\beta_1 - \beta_6$ represent estimates of the following climatic conditions during the child's first year of life on the odds of being breastfed for less than 6 months: average monthly rainfall and average maximum daily temperature during the kiremt, bega, and belg seasons. The model controls for the effects β_c of various control variables (X_{cn}) described above.

Finally, we use fixed effects to account for underlying differences in rates of EB between Ethiopia's ten regions (the survey excluded Addis Ababa) and across time and birth seasons. We include u_k, v_z, and γ_t as fixed effects for the child's region of residence, birth season, and survey round, respectively. The error term is represented by e_i. We estimate a similar model for the likelihood of less than 6 months of EB based on seasonal climatic conditions in the year before birth. The model specification is the same as in Eq. 1, except the parameters $\beta_1 - \beta_6$ represent estimates of the climatic conditions in the year before child's birth.

In the women's models, we first use multilevel mixed-effects binary logit models to estimate whether a woman engaged in (1) planting activities and (2) harvest activities during the most recent kiremt season. The model can be specified as:

$$\ln(Y_{ij}) = \beta_0 + \beta_1\left(\text{kiremt rain}_{ij}\right) + \beta_2\left(\text{kiremt temp}_{ij}\right) + \beta_3\left(\text{infant}_{ij}\right) + \beta_c\left(X_{\text{cn}}\right) + w_i + u_k + e_{ij} \tag{2}$$

In Eq. 2, a logit link function is used to model the odds of woman i engaging in planting activities at time j. The model includes variables representing prior year's kiremt rainfall $\left(\text{kiremt rain}_{ij}\right)$ and prior year's kiremt temperature (kiremt temp_{ij}), and accounts for whether the woman had an infant under 12 months old during the middle of planting season (infant_{ij}). Coefficients β_1 and β_2 represent the effects of kiremt rainfall and temperature on the odds of engaging in planting at time j. Parameter β_3 represents the effect of having an infant during the planting season on the odds of engaging in planting. The model controls for the effects (β_c) of various control variables (X_{cn}). Woman-specific random intercept is represented by w_i and accounts for multiple observations per woman. Region-level fixed effects are noted by u_k, and e_{ij} is the error term. We used the same model specification to estimate the odds of engaging in harvesting activities.

Finally, for the women who engaged in planting and/or harvesting activities, we used mixed-effects Generalized Linear Models (GLM) with a log link to estimate the number of days spent on planting and harvesting (separate models for planting and harvesting). The models can be formally specified as:

$$\ln(Y_{ij}) = \beta_0 + \beta_1(\text{kiremt rain}_{ij}) + \beta_2(\text{kiremt temp}_{ij}) + \beta_3(\text{infant}_{ij}) + \beta_c(X_{\text{cn}}) + w_i + u_{k+}e_{\text{it}} \tag{3}$$

In Eq. 3, we estimate $\ln(Y_{ij})$, which is the logged number of days woman i spent on planting activities at time j. The model includes variables $(\text{kiremt rain}_{ij})$ and $(\text{kiremt temp}_{ij})$, representing average monthly kiremt rainfall and average maximum daily kiremt temperature from the year prior to the household interview, respectively. The model also accounts for whether a woman had an infant under 12 months old during the middle of planting (harvesting) season (infant_{ij}). Coefficients β_1 and β_2 represent the effects of kiremt temperature and rainfall from the year prior to the household interview on the number of days a woman engaged in planting at time j. Parameter β_3 represents the effect of having an infant during the planting season on the number of days spent on planting activities. The model controls for the effects (β_c) of various control variables (X_{cn}). Woman-specific random intercept is represented by w_i and accounts for multiple observations per woman. Region-level fixed effects are noted by u_k, and e_{ij} is an error term. We used the same specification to model the number of days a woman spent on harvesting activities.

We then estimate models of the number of days spent planting and harvesting including an interaction term between kiremt rainfall and whether the woman has an infant in order to determine whether differences exist in the relationship between rainfall and agricultural labor between women with and without infants. Lastly, to examine the extent to which mother's agricultural labor mediates the link between climatic conditions and EB, we estimate a set of binary logit models predicting whether a child was exclusively breastfed for less than 6 months based on kiremt rainfall and temperature conditions and mother's agricultural labor. We use a sample of children aged 6–15 months at the time of the second and third household survey rounds who were born during the year prior to the survey (born in 2013 or 2015), as these children were under a year of age during the time points at which mother's agricultural labor was measured.

Results

Table 1 presents descriptive statistics for the children's sample, which consists of 1678 children. The weighted sample is representative of 6.7 million children throughout rural areas and small towns in Ethiopia. Thirty-five percent of children were exclusively breastfed for less than 6 months. Nearly one-third of mothers had any education, and 30% of children came from food insecure households at baseline. Ninety-three percent of children came from households that engaged in agriculture at baseline, with 51% living in cool/subhumid regions. Lastly, 53% of children lived in areas dependent solely on kiremt crop production and 40% of children lived in areas dependent on a primary kiremt season and secondary belg season.

Table 2 presents descriptive statistics for the women's sample, which consists of 12,406 woman-years and 5846 women. On average, each woman

Table 1 Descriptive statistics for children's sample

	Mean	SD	Min	Max
Outcome variable:				
Exclusively breastfed for less than 6 months	0.35		0	1
First year of life climatic conditions:				
Kiremt rainfall	16.93	7.51	0.06	37.5
Bega rainfall	3.85	2.74	0.35	14.96
Belg rainfall	7.95	4.25	0.47	24.79
Kiremt temperature	25.94	3.59	15.39	39.77
Bega temperature	27.16	3.04	18.38	38.69
Belg temperature	29.13	3.24	20.79	41.83
Year before birth climatic conditions:				
Kiremt rainfall	17.58	7.60	0.06	37.50
Bega rainfall	3.39	2.61	0.33	15.15
Belg rainfall	8.11	4.34	0.47	24.79
Kiremt temperature	25.74	3.57	15.47	38.48
Bega temperature	27.11	3.07	18.07	38.69
Belg temperature	28.95	3.24	20.41	42.08
Child characteristics:				
Age in months	22.87	6.69	12	35
Sex [1 = female]	0.49		0	1
Child of household head	0.94		0	1
Household characteristics:				
Mother's age	30.16	6.70	13	67
Mother has any education	0.31			
Number of household members at baseline	5.41	2.20	1	14
Food insecure at baseline	0.30		0	1
Engaged in agricultural activities at baseline	0.93		0	1
Community characteristics:				
Household lives in rural area	0.94		0	1
Agro-ecological zone:				
Tropic-warm/arid-semiarid	0.06		0	1
Tropic warm/humid-subhumid	0.01		0	1
Tropic-cool/arid-semiarid	0.23		0	1
Tropic-cool/subhumid	0.51		0	1
Tropic-cool/humid	0.18		0	1
Agricultural seasons:				
Kiremt dependent	0.53		0	1
Primary kiremt, secondary belg	0.40		0	1
Primary belg	0.07		0	1
Altitude (m above sea level)	1939.17	549.35	204	3434
N	1,678			

Rainfall is measured in centimeters, and temperature is measured in degrees Celsius was interviewed in 2.5 of the three survey rounds. Fifty-seven percent of women engaged in planting activities during the prior season, with an average of 34 days spent on planting among those who participated in any planting activities. Sixty-eight percent engaged in harvest activities during the prior season, with an average of 29 days spent harvesting among those who participated in any harvesting activities. Eleven percent of women had an infant during the middle of planting season and 10% had an infant during the middle of harvest season.

Table 2 Descriptive statistics for women's sample

	Mean	SD	Min	Max
Outcome variables:				
Spent any time engaging in planting activities	0.57		0	1
Days planting among women who planted ($N=5909$)	33.56	37.08	1	184
Spent any time engaging in harvest activities	0.68		0	1
Days harvesting among women who harvested ($N=7029$)	29.01	30.03	1	122
Climate variables:				
Kiremt rainfall	17.40	7.29	0.07	36.68
Kiremt temperature	25.83	3.42	15.57	39.77
Woman characteristics:				
Has infant during the middle of planting season	0.11		0	1
Has infant during the middle of harvest season	0.10		0	1
Age	28.75	9.66	15	49
Any education	0.44		0	1
Number of household members at baseline	5.85	2.27	1	15
Food insecure at baseline	0.31		0	1
Engaged in agricultural activities at baseline	0.92		0	1
Community characteristics:				
Household lives in rural area	0.94		0	1
Agro-ecological zone:				
Tropic-warm/arid-semiarid	0.04		0	1
Tropic warm/humid-subhumid	0.01		0	1
Tropic-cool/arid-semiarid	0.21		0	1
Tropic-cool/subhumid	0.56		0	1
Tropic-cool/humid	0.18		0	1
Agricultural seasons:				
Kiremt dependent	0.59		0	1
Primary kiremt, secondary belg	0.38		0	1
Primary belg	0.04		0	1
Altitude (m above sea level)	2010	513.20	201	3434
Number of woman-years	12,406			
Number of women	5846			

Rainfall is measured in centimeters, and temperature is measured in degrees Celsius

Table 3 presents results from models predicting the likelihood that a child is exclusively breastfed for less than 6 months based on seasonal rainfall and temperature during the first year of life as well as during the year before birth. In Model 1, we find that more rainfall during the kiremt rainy season in the first year of life is associated with a reduced likelihood of being exclusively breastfed for 6 months ($p<0.05$). Indeed, each additional centimeter of average monthly rainfall is associated with a 5% greater odds of being breastfed for less than 6 months. Further, the likelihood of being exclusively breastfed for 6 months increases among children whose mothers have any education ($p<0.05$). EB also varies by environmental conditions, with children from warm arid/semiarid areas the least likely to exclusively breastfeed for 6 months and those from regions solely dependent on the kiremt cropping season the most likely. In Model 2, we discover that greater rainfall during the kiremt season before birth ($p<0.1$) and greater rainfall during the bega dry season before birth ($p<0.05$) are associated with a lower likelihood of being exclusively breastfed for 6 months.

Table 4 presents results from models predicting the likelihood of participation in planting and harvesting activities, as well as number of days engaged in planting and harvesting among women who engaged in these activities. In Model 3, we do not find a significant relationship between kiremt rainfall or temperature and the likelihood that a woman engages in planting, while in Model 5, we find that greater kiremt rainfall is associated with a higher likelihood that a woman engages in harvesting ($p<0.1$). However, as Models 4 and 6 indicate, among women involved in these activities, more kiremt rainfall is associated with a greater number of days both planting ($p<0.05$) and harvesting ($p<0.001$). Women with infants are more likely to engage in planting ($p<0.1$), while having an infant is negatively associated with the number of days spent harvesting ($p<0.01$).

We then examine whether the relationship between kiremt rainfall and women's agricultural labor varies by whether a woman has an infant by including an interaction term between rainfall and infant status. Results are presented in Appendix Table 6 We find no evidence to suggest that the relationship between greater kiremt rainfall and time spent planting varies between women with and without infants. However, the results do indicate a relationship between rainfall and time spent harvesting among women with infants ($p<0.1$). At low levels of rainfall women with infants spend fewer days harvesting than those without infants, yet this difference decreases with increasing rainfall. Lastly, we examine the extent to which mother's agricultural labor mediates the link between rainfall and EB among children who were infants during the year prior to the second and third household survey rounds. Results, presented in Appendix Table 7, suggest that increased time spent harvesting, but not planting, may mediate the link between greater rainfall and a reduced likelihood of 6 months of EB. However, due to small sample sizes and limited temporal variation in rainfall conditions, these results should be interpreted with caution.

Figure 3 presents predicted probabilities of being exclusively breastfed for less than 6 months based on average monthly kiremt rainfall in the first year of life, as well as predicted days spent planting and harvesting based on average monthly kiremt rainfall during the prior season. A child who experiences average monthly kiremt rainfall of 5 cm during their first year of life has a 23% likelihood of having been exclusively breastfed for less than 6 months, whereas the likelihood increases to 43% for a child who experiences

Table 3 Models predicting the likelihood of being exclusively breastfed for less than 6 months based on seasonal rainfall and temperature conditions during the first year of life as well as during the year prior to birth

	Model 1		Model 2	
	OR	SE	OR	SE
First year of life climatic conditions:				
Kiremt rainfall	1.047*	(0.020)		
Bega rainfall	1.082	(0.053)		
Belg rainfall	0.999	(0.037)		
Kiremt temperature	0.996	(0.091)		
Bega temperature	1.016	(0.197)		
Belg temperature	0.953	(0.154)		
Year before birth climatic conditions:				
Kiremt rainfall			1.033+	(0.020)
Bega rainfall			1.103*	(0.054)
Belg rainfall			0.985	(0.034)
Kiremt temperature			0.950	(0.095)
Bega temperature			1.106	(0.215)
Belg temperature			0.924	(0.160)
Child characteristics:				
Age in months	0.994	(0.014)	1.006	(0.013)
Sex [1 = female]	0.911	(0.139)	0.925	(0.142)
Child of household head	1.261	(0.403)	1.298	(0.408)
Household characteristics:				
Mother's age	0.984	(0.016)	0.983	(0.017)
Mother has any education	0.689*	(0.123)	0.695*	(0.123)
Number of household members at baseline	0.950	(0.041)	0.955	(0.041)
Food insecure at baseline	1.317	(0.277)	1.290	(0.279)
Engaged in agriculture at baseline	1.301	(0.486)	1.335	(0.483)
Community characteristics:				
Household lives in rural area	1.487	(0.598)	1.366	(0.541)
Agro-ecological Zone [tropic-cool/subhumid is baseline]				
Tropic-warm/arid-semiarid	4.852**	(2.477)	4.686**	(2.369)
Tropic warm/humid-subhumid	1.868	(0.720)	1.821	(0.664)
Tropic-cool/arid-semiarid	1.755	(0.642)	1.898+	(0.715)
Tropic-cool/humid	1.215	(0.384)	1.340	(0.414)

Table 3 (continued)

	Model 1		Model 2	
	OR	SE	OR	SE
Agricultural seasons [Kiremt dependent is baseline]				
Primary belg	5.026*	(3.763)	4.014+	(3.026)
Primary kiremt, secondary belg	2.174**	(0.624)	2.168**	(0.627)
Altitude	1.0004	(0.0003)	1.0004	(0.0003)
Wald test:				
Kiremt rainfall and temperature	3.74*		2.30	
Bega rainfall and temperature	1.29		2.20	
Belg rainfall and temperature	0.04		0.15	
All seasons rainfall and temperature	2.02+		1.87+	
N	1678		1678	

Standard errors in parentheses. Models include fixed effects for region, birth season, and survey round

+$p<0.1$; *$p<0.05$; **$p<0.01$

25 cm of rainfall. Similarly, a woman who experiences average monthly rainfall of 5 cm during the prior kiremt season is predicted to spend 27 days engaged in planting activities, which increases to 37 days at 25 cm of rainfall. Lastly, a woman who experiences average monthly rainfall of 5 cm during the prior kiremt season is predicted to spend 20 days harvesting, which increases to 35 days at 25 cm of rainfall.

Discussion and conclusions

In this paper, we explore an understudied pathway between climate and child undernutrition by examining infant care. We focus on Ethiopia, which is heavily dependent on smallholder rainfed agriculture, has high rates of child undernutrition, and has substantial regional variation in the duration of EB (Bhattacharjee et al., 2019; FAO, 2019; Machado Mendes & Paglietti, 2015; USAID, 2014). The WHO recommends EB for the first 6 months of life in order to prevent early exposure to contaminated water and less-nutritious complementary foods (WHO, 2018). However, a number of factors have been shown to limit EB including competing demands on women's time due to agricultural and domestic labor, cultural beliefs and practices, income and food security, and access to health services (Burns et al., 2016; Egata et al., 2013;

Table 4 Results from multilevel logit and mixed-effects generalized linear models on participation in and days of planting and harvesting during the last *kiremt* season

	Engaged in planting		Days of planting		Engaged in harvesting		Days of harvesting	
	Model 3		Model 4		Model 5		Model 6	
	OR	SE	Coefficient	SE	OR	SE	Coefficient	SE
Climate variables:								
Kiremt rainfall	1.012	(0.016)	0.015*	(0.007)	1.034+	(0.018)	0.027***	(0.007)
Kiremt temperature	0.985	(0.042)	0.025	(0.021)	0.969	(0.034)	0.009	(0.019)
Woman characteristics:								
Woman has infant during planting season	1.205+	(0.122)	– 0.037	(0.066)				
Woman has infant during harvest season					0.978	(0.120)	– 0.153*	(0.060)
Age	1.061***	(0.006)	0.008**	(0.003)	1.055***	(0.007)	0.012***	(0.003)
Any education	0.861	(0.094)	– 0.023	(0.052)	0.890	(0.099)	– 0.039	(0.053)
Household characteristics:								
Number of household members at baseline	0.908***	(0.021)	0.021+	(0.011)	0.927**	(0.022)	0.028*	(0.011)
Food insecure at baseline	1.011	(0.158)	– 0.106	(0.070)	0.965	(0.131)	– 0.075	(0.061)
Engaged in agriculture at baseline	10.960***	(2.658)	0.494**	(0.149)	9.075***	(2.320)	0.110	(0.112)
Community characteristics:								
Rural area	5.447***	(1.515)	0.702***	(0.140)	6.597***	(1.786)	0.797***	(0.178)
Agro-ecological zone [tropic-cool/subhumid is baseline]								
Tropic-warm/arid-semiarid	0.160**	(0.098)	– 0.724***	(0.193)	0.314*	(0.174)	– 0.789***	(0.208)

Table 4 (continued)

	Engaged in planting		Days of planting		Engaged in harvesting		Days of harvesting	
	Model 3		Model 4		Model 5		Model 6	
	OR	SE	Coefficient	SE	OR	SE	Coefficient	SE
Tropic warm/humid-subhumid	1.452	(0.890)	− 0.410+	(0.222)	0.853	(0.385)	0.318	(0.224)
Tropic-cool/arid-semiarid	0.336***	(0.109)	− 0.253+	(0.149)	0.548+	(0.171)	− 0.197	(0.146)
Tropic-cool/humid	2.022*	(0.576)	− 0.348*	(0.157)	1.888**	(0.448)	0.267*	(0.119)
Agricultural seasons [Kiremt dependent is baseline]								
Primary belg	0.684	(0.382)	− 0.591*	(0.270)	0.780	(0.447)	− 0.072	(0.203)
Primary kiremt, secondary belg	0.455***	(0.107)	− 0.125	(0.105)	1.052	(0.236)	0.195+	(0.107)
Altitude	0.999	(0.0003)	0.00004	(0.0001)	0.999	(0.0003)	0.0001	(0.0001)
Wald test:								
Kiremt rainfall and temperature	0.39		2.41+		2.83+		7.46***	
Number of woman-years	12,406		5,951		12,406		7,081	
Number of women	5846		3260		5846		3742	

Standard errors in parentheses. Models include fixed effects for region

$+p<0.1$; $*p<0.05$; $**p<0.01$; $***p<0.001$

Grace et al., 2017; Jones et al., 2012; Levine, 1988; Nankumbi & Muliira, 2015; Saha et al., 2008; Schuster et al., 2020; Webb-Girard et al., 2012). We examine linkages between climatic conditions and infant care practices by exploring the relationship between climatic conditions and duration of EB as well as one potential barrier: women's time use on agricultural activities.

Results indicate that rainfall during kiremt—the primary agricultural season—in a child's first year of life plays an important role in duration of EB. Wetter conditions during kiremt are associated with a lower probability of being exclusively breastfed for the recommended 6 months. Indeed, experiencing 25 cm of average monthly kiremt rainfall, versus 5 cm, is associated with a 20-percentage-point decrease in the likelihood of being exclusively breastfed for 6 months. When examining conditions during the year prior to a child's birth, we find positive associations between kiremt and bega rainfall and less than 6 months of EB. Further, more kiremt rainfall is associated with a greater number of days that women of childbearing age participate in planting and harvesting activities. Lastly, we discover that when kiremt rainfall is high, and thus growing conditions are favorable, women with infants do not engage in significantly fewer days of agricultural labor than those without infants.

Similar to research by Thai and Myrskylä (2012) in rural Vietnam, we argue that greater rainfall during the primary agricultural season in a child's first year of life likely increases demand for agricultural labor, which is often filled by mothers of young children. Better growing conditions—and the expectation of larger harvests—may encourage households to invest more in labor inputs for land preparation, planting, and harvesting. These time intensive investments may in turn compete with the time a mother has available to breastfeed her infant, particularly if she must leave the child in the care of relatives or community members. This suggests that agricultural labor demands may affect infant care behaviors, leading to "sub-optimal" feeding practices, but may actually be a part of a larger strategy to produce and store food for the household.

Indeed, Randell et al. (2020) discovered that greater kiremt rainfall during a child's early life is positively associated with height for age. This suggests that while greater rainfall could lead to a shorter duration of EB, the returns of rainfall to food availability in later infancy and early childhood may outweigh the potential risks associated with non-EB in early infancy. Despite the global WHO recommendation of 6 months of EB, women are likely making strategic decisions about time use to ensure greater agricultural production and income for the household. Behaviors that appear sub-optimal may in fact lead to more positive nutritional outcomes for children over the longer term, and thus, recommendations about breastfeeding should consider the complex tradeoffs inherent within household health behaviors, livelihoods, and food production strategies.

Examining linkages between climatic conditions during the year prior to birth and EB enables us to explore the extent to which additional pathways—such as income/food security and access to antenatal healthcare—may be relevant in this context. Kiremt rainfall in year *t*-1 is an important indicator

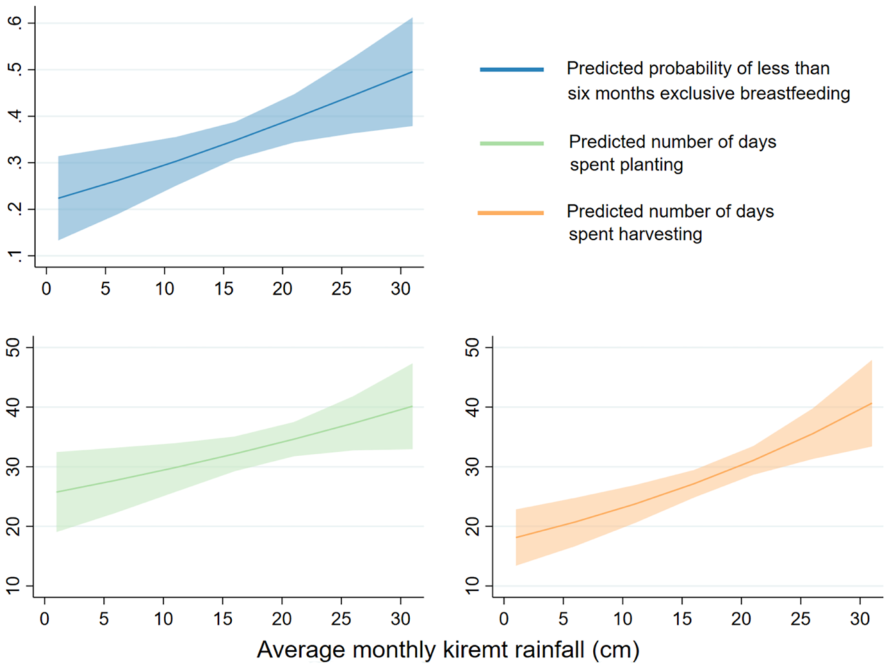

Fig. 3 Predicted probabilities of less than 6 months of exclusive breastfeeding, and predicted days women spent planting and harvesting, based on rainfall during the kiremt season and including 95% confidence intervals

of food security and income in year *t*, as households depend on income and harvests from *t*-1 until year *t*'s crops are harvested. The marginally significant positive relationship between year before birth kiremt rainfall and less than 6 months of EB may therefore reflect that households with greater food security during a child's first year of life are more likely to introduce culturally-valued complementary foods, such as butter or animal milk, to infants under 6 months (Rogers et al., 2011; Saha et al., 2008). Another potential mechanism concerns access to healthcare. When kiremt rainfall is more favorable for agricultural production, pregnant women may spend more time engaged in agricultural labor and may in turn have less time available to seek antenatal care. This could limit the amount of information they receive about optimal breastfeeding behaviors, thereby potentially decreasing EB duration.

Lastly, the bega dry season is the period during which kiremt crops are harvested and grains are stored. Rainfall during bega can damage crops, hinder harvesting activities, and lead to outbreaks of pests (National Meteorological Services Agency, 2005). Greater bega rainfall prior to birth may thus negatively impact household food security during a child's first year of life, leading mothers to introduce complementary foods if they believe that the quality or quantity of their breastmilk is compromised due to poor nutrition (Burns et al., 2016; Grace et al., 2017; Webb-Girard et al., 2012).

As a result of climate change, kiremt rainfall is predicted to increase in the central Highlands and northern Great Rift Valley and decrease in southern Ethiopia (Li et al., 2016). Climate change is therefore likely to affect breastfeeding behaviors and child nutrition in Ethiopia in complex ways. For example, in areas with declining kiremt rainfall, mothers may have more time during the kiremt season to devote to infant care and feeding; however, lower agricultural productivity may simultaneously threaten household food security and children's health over the longer term. In areas with increasing kiremt rainfall, rates of EB may decline because of the growing demand for agricultural labor, decreased time available to seek antenatal care, or earlier introduction of complementary foods. However, the greater rainfall may ultimately benefit children's nutritional outcomes over the longer term.

This study is subject to a few primary limitations. First, while we were able to examine one potential mechanism—the linkages between climatic conditions and women's time expenditures on agricultural production—the LSMS data did not enable us to explore additional mechanisms including access to antenatal care and breastfeeding information, or cultural beliefs and practices about breastfeeding and complementary foods. Exploring relationships between climatic conditions and other factors such as these would facilitate a more comprehensive understanding of the complex relationships between climatic conditions and EB. Second, while quantitative data are critical for establishing relationships between climate and health outcomes, they are rarely able to capture the contextual factors, decision-making processes, and cultural norms that shape behaviors (Grace & Mikal, 2019). Qualitative research that explores how mothers in different contexts make decisions about EB—and how climatic conditions may shape those decisions—are key for developing effective policies to promote optimal infant feeding practices amidst a changing climate.

Appendix

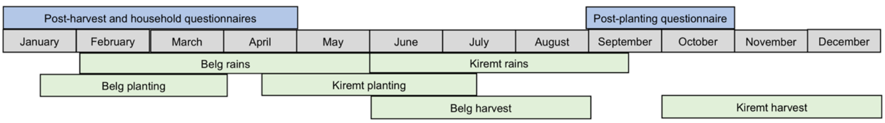

Fig. 4 General timeline of seasonal rainfall, agricultural activities, and LSMS data collection

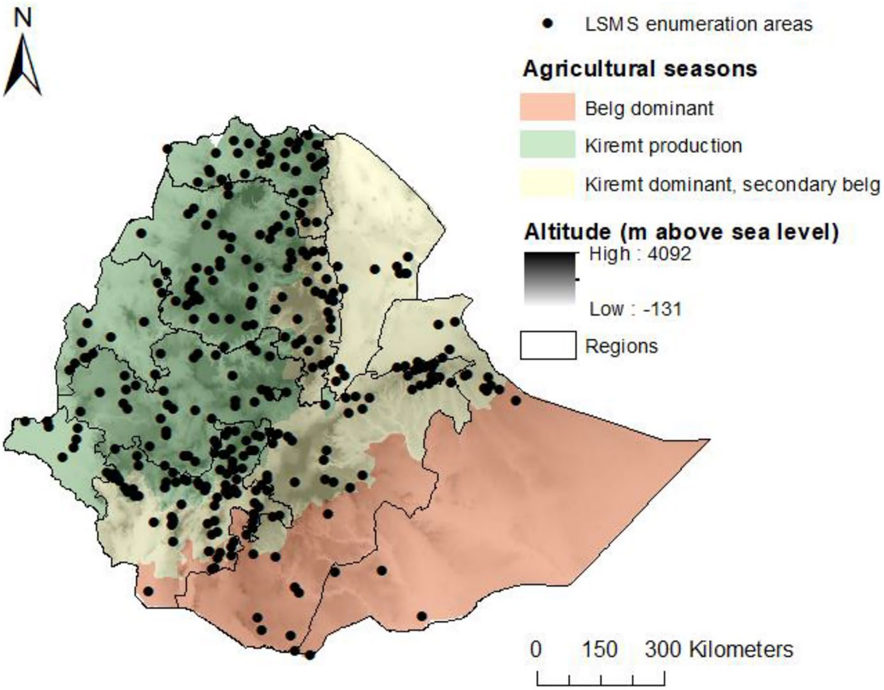

Fig. 5 Map of Ethiopia including LSMS enumeration areas, agricultural seasons, altitude, and regional boundaries

Table 5 Linking children to rainfall and temperature data based on birth month

Birth month	Birth year -2			Birth year - 1												Birth year												Birth year + 1								
January	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
		bega t-1				belg t-1				kiremt t-1				bega t				belg t				kiremt t														
February	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
						belg t-1				kiremt t-1				bega t-1				belg t				kiremt t				bega t										
March	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
						belg t-1				kiremt t-1				bega t-1				belg t				kiremt t				bega t										
April	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
						belg t-1				kiremt t-1				bega t-1				belg t				kiremt t				bega t										
May	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
						belg t-1				kiremt t-1				bega t-1				belg t				kiremt t				bega t										
June	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
										kiremt t-1				bega t-1				belg t-1				kiremt t				bega t				belg t						
July	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
										kiremt t-1				bega t-1				belg t-1				kiremt t				bega t				belg t						
August	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
										kiremt t-1				bega t-1				belg t-1				kiremt t				bega t				belg t						
September	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
										kiremt t-1				bega t-1				belg t-1				kiremt t				bega t				belg t						
October	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
														bega t-1				belg t-1				kiremt t-1				bega t				belg t				kiremt t		
November	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
														bega t-1				belg t-1				kiremt t-1				bega t				belg t				kiremt t		
December	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
														bega t-1				belg t-1				kiremt t-1				bega t				belg t				kiremt t		
t = first year of life																																				
t-1 = year before birth																																				

The black boxes indicate the first six months of a child's life. Belg t, kiremt t, and bega t correspond to seasons during the child's first year of life, while belg t-1, kiremt t-1, and bega t-1 correspond to seasons during the year before birth. We link seasonal rainfall and temperature data to each child based on their month of birth using the above chart. For example, if a child was born June 2014, seasons corresponding to the first year of life are kiremt 2014, bega 2014-2015, and belg 2015. Seasons corresponding to the year before birth are kiremt 2013, bega 2013-2014, and belg 2014

Table 6 Results from mixed-effects generalized linear models on days of planting and harvesting during the last *kiremt* season, including rainfall-infant interactions

	Days of planting		Days of harvesting	
	Coefficient	SE	Coefficient	SE
Climate variables:				
Kiremt rainfall	0.015*	(0.007)	0.026***	(0.007)
Kiremt temperature	0.025	(0.021)	0.009	(0.019)
Woman has infant during planting season	− 0.064	(0.159)		
Woman has infant during harvest season			− 0.411*	(0.172)
Interactions				
Rainfall X infant during planting season	0.001	(0.008)		
Rainfall X infant during harvest season			0.014+	(0.008)
Woman characteristics:				
Age	0.008**	(0.003)	0.012***	(0.003)
Any education	− 0.023	(0.052)	− 0.039	(0.053)
Household characteristics:				
Number of household members at baseline	0.021+	(0.011)	0.028**	(0.011)
Food insecure at baseline	− 0.105	(0.069)	− 0.076	(0.061)
Engaged in agriculture at baseline	0.494**	(0.149)	0.108	(0.112)
Community characteristics:				
Rural area	0.701***	(0.140)	0.796***	(0.178)
Agro-ecological zone [tropic-cool/sub-humid is baseline]				
Tropic-warm/arid-semiarid	− 0.724***	(0.193)	− 0.797***	(0.208)
Tropic warm/humid-subhumid	− 0.410+	(0.222)	0.319	(0.223)
Tropic-cool/arid-semiarid	− 0.254+	(0.149)	− 0.199	(0.146)
Tropic-cool/humid	− 0.349*	(0.157)	0.261*	(0.119)
Agricultural seasons [Kiremt dependent is baseline]				
Primary belg	− 0.589*	(0.269)	− 0.046	(0.201)
Primary kiremt, secondary belg	− 0.125	(0.105)	0.196+	(0.107)
Elevation	0.00004	(0.0001)	0.0001	(0.0001)
Number of woman-years	5951		7081	
Number of women	3260		3742	

Table 7 Models predicting whether child was exclusively breastfed for less than 6 months based on *kiremt* rainfall and temperature conditions and mother's agricultural labor, for children aged 6–15 months who were born during the year prior to the second and third survey rounds (born in 2013 and 2015)

	Kiremt rainfall and temperature		Kiremt rainfall and temperature plus days planting		Kiremt rainfall and temperature plus days harvesting	
	OR	SE	OR	SE	OR	SE
Climate variables:						
Kiremt rainfall	1.042+	(0.023)	1.091**	(0.036)	1.043	(0.028)
Kiremt temperature	1.102+	(0.056)	1.133	(0.095)	1.020	(0.066)
Total days planting			0.994	(0.007)		
Total days harvesting					0.9995	(0.004)
Child characteristics:						
Age in months	0.947	(0.075)	0.930	(0.125)	0.900	(0.090)
Sex [1=female]	1.417+	(0.277)	1.800*	(0.490)	1.566+	(0.380)
Child of household head	1.330	(0.456)	0.995	(0.526)	1.334	(0.584)
Mother characteristics:						
Age	0.955*	(0.018)	0.961	(0.027)	0.956+	(0.022)
Any education	0.693+	(0.152)	0.760	(0.262)	0.655	(0.182)
Household characteristics:						
Number of household members at baseline						
Food insecure at baseline	1.037	(0.046)	1.088	(0.090)	1.025	(0.067)
Engaged in agriculture at baseline	0.694	(0.165)	0.609	(0.238)	0.546*	(0.161)
Community characteristics:	1.916*	(0.597)	1.814	(1.127)	1.948	(0.911)
Rural area	0.643	(0.243)	1.026	(0.818)	0.959	(0.709)
Agro-ecological zone [tropic-cool/subhumid is baseline]						
Tropic-warm/arid-semiarid	1.380	(0.898)	9.568*	(9.096)	5.584*	(3.756)
Tropic warm/humid-subhumid	3.032+	(1.958)	8.197**	(5.911)	7.026**	(4.492)
Tropic-cool/arid-semiarid	1.149	(0.548)	1.551	(1.129)	1.051	(0.576)

Table 7 (continued)

	Kiremt rainfall and temperature		Kiremt rainfall and temperature plus days planting		Kiremt rainfall and temperature plus days harvesting	
	OR	SE	OR	SE	OR	SE
Tropic-cool/humid	1.089	(0.396)	0.701	(0.437)	1.101	(0.510)
Agricultural seasons [Kiremt dependent is baseline]						
Primary belg	2.441+	(1.223)	4.983*	(3.610)	3.319*	(1.845)
Primary kiremt, secondary belg	1.627	(0.497)	2.184+	(0.955)	2.034*	(0.698)
Altitude	1.001*	(0.0003)	1.001*	(0.0005)	1.001	(0.0004)
Wald test:						
Kiremt rainfall and temperature	2.82+		8.50*		2.56	
N	563		273		383	

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References

Abate, K. H., & Belachew, T. (2017). Care and not wealth is a predictor of wasting and stunting of 'The Coffee Kids' of Jimma Zone, Southwest Ethiopia. *Nutrition and Health, 23*(3), 193–202. https://doi.org/10.1177/0260106017706253.

Alderman, H., Hoddinott, J., & Kinsey, B. (2006). Long term consequences of early childhood malnutrition. *Oxford Economic Papers, 58*(3), 450–474. https://doi.org/10.1093/oep/gpl008.

Alebel, A., Tesma, C., Temesgen, B., Ferede, A., & Kibret, G. D. (2018). Exclusive breastfeeding practice in Ethiopia and its association with antenatal care and institutional delivery: a systematic review and meta-analysis. *International Breastfeeding Journal BioMed Central Ltd*. https://doi.org/10.1186/s13006-018-0173-x.

Arora, D., & Rada, C. (2013). Gender differences in time and resource allocation in rural households in Ethiopia. Pap Prep Annu Conf Am Econ Assoc Retrieved 25 July 2015, 1970, 1–23. http://www.aeaweb.org/aea/2014conference/program/retrieve.php?pdfid=421.

Asemahagn, M. A. (2016). Determinants of exclusive breastfeeding practices among mothers in azezo district, northwest Ethiopia. *International Breastfeeding Journal, 11*(1), 1–7. https://doi.org/10.1186/s13006-016-0081-x.

Bell, A., Ward, P., Tamal, M. E. H., & Killilea, M. (2019). Assessing recall bias and measurement error in high-frequency social data collection for human-environment research. *Population and Environment, 40*(3), 325–345. https://doi.org/10.1007/s11111-019-0314-1.

Bezabih, M., & Di Falco, S. (2012). Rainfall variability and food crop portfolio choice: evidence from Ethiopia. *Food Secur, 4*(4), 557–567. https://doi.org/10.1007/s12571-012-0219-7.

Bhattacharjee, N. V., Schaeffer, L. E., Marczak, L. B., Ross, J. M., Swartz, S. J., Albright, J., et al. (2019). Mapping exclusive breastfeeding in Africa between 2000 and 2017. *Nature Medicine, 25*(8), 1205–1212. https://doi.org/10.1038/s41591-019-0525-0.

Black, R. E., Allen, L. H., Bhutta, Z. A., Caulfield, L. E., de Onis, M., Ezzati, M., et al. (2008). Maternal and child undernutrition: global and regional exposures and health consequences. *Lancet*. https://doi.org/10.1016/S0140-6736(07)61690-0.

Burns, J., Emerson, J. A., Amundson, K., Doocy, S., Caulfield, L. E., & Klemm, R. D. W. (2016). A qualitative analysis of barriers and facilitators to optimal breastfeeding and complementary feeding practices in South Kivu, Democratic Republic of Congo. *Food and Nutrition Bulletin, 37*(2), 119–131. https://doi.org/10.1177/0379572116637947.

Central Statistical Agency of Ethiopia (CSA). (2012). Ethiopia Rural Socioeconomic Survey.

Central Statistical Agency of Ethiopia (CSA). (2014). Ethiopia Socioeconomic Survey 2013–2014.

Central Statistical Agency of Ethiopia (CSA). (2016). Ethiopia Socioeconomic Survey,Wave 3 (ESS3) 2015–2016. Public Use Dataset.

Chotard, S., Mason, J. B., Oliphant, N. P., Mebrahtu, S., & Hailey, P. (2011). Fluctuations in wasting in vulnerable child populations in the Greater Horn of Africa. *Food and Nutrition Bulletin, 32*(3 SUPPL.), S219–S233. https://doi.org/10.1177/15648265100313S302.

Conway, D., & Schipper, E. L. F. (2011). Adaptation to climate change in Africa: challenges and opportunities identified from Ethiopia. *Global Environmental Change, 21*(1), 227–237.

Dearden, K. A., Quan, L. N., Do, M., Marsh, D. R., Pachón, H., Schroeder, D. G., & Lang, T. T. (2002). Work outside the home is the primary barrier to exclusive breastfeeding in rural Viet Nam: insights from mothers who exclusively breastfed and worked. *Food and Nutrition Bulletin, 23*(4 SUPP), 101–108. https://doi.org/10.1177/15648265020234s214.

del Ninno, C., & Lundberg, M. (2005). Treading water. The long-term impact of the1998 flood on nutrition in Bangladesh. *Economics and Human Biology, 3*(1), 67-96. https://doi.org/10.1016/j.ehb.2004.12.002.

Dewey, K. G., & Begum, K. (2011). Long-term consequences of stunting in early life. *Maternal and Child Nutrition, 7*(SUPPL. 3), 5–18. https://doi.org/10.1111/j.1740-8709.2011.00349.x.

Egata, G., Berhane, Y., & Worku, A. (2013). Predictors of non-exclusive breastfeeding at 6 months among rural mothers in east Ethiopia: a community-based analytical cross-sectional study. *International Breastfeeding Journal, 8*(1), 1–8. https://doi.org/10.1186/1746-4358-8-8.

Evangelista, P., Young, N., & Burnett, J. (2013). How will climate change spatially affect agriculture production in Ethiopia? Case studies of important cereal crops. *Climatic Change*. http://link.springer.com/article/. https://doi.org/10.1007/s10584-013-0776-6.

Evans School Policy Analysis and Research Group. (2019). Agricultural Development Data Curation. https://evans.uw.edu/policy-impact/epar/agricultural-development-data-curation.

Ethiopia at a glance. http://www.fao.org/ethiopia/fao-in-ethiopia/ethiopia-at-a-glance/en/.

Fazzini, M., Bisci, C., & Billi, P. (2015). The climate of Ethiopia. In P. Billi (Ed.), Landscapes Landforms Ethiop (pp. 65–87). New York: Springer. https://doi.org/10.1007/978-94-017-8026-1_3.

FEWS NET. (2013). Ethiopia—seasonal calendar. http://www.fews.net/east-africa/ethiopia/seasonal-calendar/december-2013.

Funk, C., Pedreros, D., & Korecha, D. (2019). Declines in Ethiopia's Belg growing season rainfall and length of season. *Climate Hazards Center Blog*. http://blog.chg.ucsb.edu/?p=615.

Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., & Shukla, S. (2015). The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. *Scientific Data, 2,* 150066. https://doi.org/10.1038/sdata.2015.66.

Funk, C., Rowland, J., Eilerts, G., Kebebe, E., Biru, N., White, L., & Galu, G. (2012). *A climate trend analysis of Ethiopia*. Washington, DC.

Grace, K., Lerner, A. M., Mikal, J., & Sangli, G. (2017). A qualitative investigation of childbearing and seasonal hunger in peri-urban Ouagadougou, Burkina Faso. *Population Environment, 38*(4), 369–380. https://doi.org/10.1007/s11111-016-0268-5.

Grace, K., & Mikal, J. (2019). Incorporating qualitative methodologies and fieldwork into large scale, quantitative analyses of climate health in low-income countries. *Lancet Planet Heal, 3*(12), e496–e498. https://doi.org/10.1016/S2542-5196(19)30240-2.

Grace, K., Nagle, N. N., Burgert-Brucker, C. R., Rutzick, S., Van Riper, D. C., Dontamsetti, T., & Croft, T. (2019). Integrating environmental context into DHS analysis while protecting participant confidentiality: a new remote sensing method. *Population and Development Review, 45*(1), 197–218. https://doi.org/10.1111/padr.12222.

Gray, S. J. (1995). Correlates of breastfeeding frequency among nomadic pastoralists of Turkana, Kenya: a retrospective study. *American Journal of Physical Anthropology, 98*(3), 239–255. https://doi.org/10.1002/ajpa.1330980302.

Hadgu, G., Tesfaye, K., & Mamo, G. (2015). Analysis of climate change in Northern Ethiopia: implications for agricultural production. *Theoretical and Applied Climatology, 121*(3–4), 733–747. https://doi.org/10.1007/s00704-014-1261-5.

Hoddinott, J., Behrman, J. R., Maluccio, J. A., Melgar, P., Quisumbing, A. R., Ramirez-Zea, M., et al. (2013). Adult consequences of growth failure in early childhood. *American Journal of Clinical Nutrition, 98*(5), 1170–1178. https://doi.org/10.3945/ajcn.113.064584.

Hoddinott, J., & Kinsey, B. (2001). Child growth in the time of drought. *Oxford Bulletin of Economics and Statistics, 63*(4), 409–436. https://doi.org/10.1111/1468-0084.t01-1-00227.

Hoddinott, J., Maluccio, J. A., Behrman, J. R., Flores, R., & Martorell, R. (2008). Effect of a nutrition intervention during early childhood on economic productivity in Guatemalan adults. *Lancet, 371*(9610), 411–416. https://doi.org/10.1016/S0140-6736(08)60205-6.

Horii, N., Guyon, A. B., & Quinn, V. J. (2011). Determinants of delayed initiation of breastfeeding in rural Ethiopia: programmatic implications. *Food and Nutrition Bulletin, 32*(2), 94–102. https://doi.org/10.1177/156482651103200203.

Jones, A. D., Cruz Agudo, Y., Galway, L., Bentley, J., & Pinstrup-Andersen, P. (2012). Heavy agricultural workloads and low crop diversity are strong barriers to improving child feeding practices in the Bolivian Andes. *Social Science and Medicine, 75*(9), 1673–1684. https://doi.org/10.1016/j.socscimed.2012.06.025.

Kamudoni, P., Maleta, K., Shi, Z., & Holmboe-Ottesen, G. (2015). Exclusive breastfeeding duration during the first 6 months of life is positively associated with length-for-age among infants 6–12 months old, in Mangochi district, Malawi. *European Journal of Clinical Nutrition, 69*(1), 96–101. https://doi.org/10.1038/ejcn.2014.148.

Kuchenbecker, J., Jordan, I., Reinbott, A., Herrmann, J., Jeremias, T., Kennedy, G., et al. (2015). Exclusive breastfeeding and its effect on growth of malawian infants: results from a cross-sectional study. *Paediatr Int Child Health, 35*(1), 14–23. https://doi.org/10.1179/2046905514Y.0000000134.

Levine, N. E. (1988). Women's work and infant feeding: a case from Rural Nepal. *Ethnology, 27*(3), 231. https://doi.org/10.2307/3773519.

Li, L., Li, W., Ballard, T., Sun, G., & Jeuland, M. (2016). CMIP5 model simulations of Ethiopian Kiremt-season precipitation: current climate and future changes. *Climate Dynamics, 46*(9–10), 2883–2895. https://doi.org/10.1007/s00382-015-2737-4.

Machado Mendes, D., & Paglietti, L. (2015). *Ethiopia irrigation market brief*. Rome. www.fao.org/investment/en.

Meehan, C. L., & Roulette, J. W. (2013). Early supplementary feeding among central African foragers and farmers: a biocultural approach. *Social Science and Medicine, 96,* 112–120. https://doi.org/10.1016/j.socscimed.2013.07.029.

Nankumbi, J., & Muliira, J. K. (2015). Barriers to infant and child-feeding practices: a qualitative study of primary caregivers in Rural Uganda. *Journal of Health, Population and Nutrition*, 33(1), 106–16. http://www.ncbi.nlm.nih.gov/pubmed/25995727.

National Meteorological Services Agency. (2005). *Seasonal agro meteorological bulletin, Bega, 2004/05*. Addis Ababa.

Palacios-Lopez, A., Christiaensen, L., & Kilic, T. (2017). How much of the labor in African agriculture is provided by women? *Food Policy, 67,* 52–63. https://doi.org/10.1016/j.foodpol.2016.09.017.

Perez-Heydrich, C., Warren, J. L., Burget, C. R., Emch, M. E., On, G., Use, T. H. E., & Data, D. H. S. G. P. S. (2013). *Guidelines on the use of DHS GPS data. Spatial Analysis Reports No. 8*. www.measuredhs.com.

Philip, S., Kew, S. F., Jan van Oldenborgh, G., Otto, F., O'Keefe, S., Haustein, K., et al. (2018). Attribution analysis of the Ethiopian drought of 2015. *Journal of Climate, 31*(6), 2465–2486. https://doi.org/10.1175/JCLI-D-17-0274.1.

Porter, J. R., Xie, L., Challinor, A. J., Cochrane, K., Howden, S. M., & Iqbal, M. M. (2014). Food security and food production systems. In L. L. W. Field, C. B., V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea (Eds.), Clim Chang 2014 Impacts, Adapt Vulnerability Part A Glob Sect Asp Contrib Work Gr II to Fifth Assess Rep Intergov Panel Clim Chang (pp. 485–533). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. https://books.google.com/books?hl=en&lr=&id=aJ-TBQAAQBAJ&oi=fnd&pg=PA1142&dq=Climate+Change+2014:+Impacts,+Adaptation,+and+Vulnerability&ots=v0RAQL9dHz&sig=dDMX2bOnwcZ3zOrWKGZP9RUAGUg.

Randell, H., Gray, C., & Grace, K. (2020). Stunted from the Start: early life weather conditions and child undernutrition in Ethiopia. *Social Science & Medicine, 261*.

Robles, P. (2010). Gender disparities in time allocation, time poverty, and labor allocation across employment sectors in Ethiopia. In J. S. Arbache, A. Kolev, & E. Filipiak (Eds.), Gend Disparities Africa's Labor Mark. Washington, DC: The World Bank.

Rodriguez-Llanes, J. M., Ranjan-Dash, S., Degomme, O., Mukhopadhyay, A., & Guha-Sapir, D. (2011). Child malnutrition and recurrent flooding in rural eastern India: a community-based survey. *British Medical Journal Open, 1*(2), e000109–e000109. https://doi.org/10.1136/bmjopen-2011-000109.

Rogers, N. L., Abdi, J., Moore, D., & Nd'Iangui, S., Smith, L. J., Carlson, A. J., & Carlson, D. (2011). Colostrum avoidance, prelacteal feeding and late breast-feeding initiation in rural Northern Ethiopia. *Public Health Nutrition, 14*(11), 2029–2036. https://doi.org/10.1017/S1368980011000073.

Rosales-Rueda, M. (2018). The impact of early life shocks on human capital formation: evidence from El Niño floods in Ecuador. *Journal of Health Economics, 62,* 13–44. https://doi.org/10.1016/j.jhealeco.2018.07.003.

Saha, K. K., Frongillo, E. A., Alam, D. S., Arifeen, S. E., Persson, L. Å., & Rasmussen, K. M. (2008). Household food security is associated with infant feeding practices in rural Bangladesh. *Journal of Nutrition, 138*(7), 1383–1390. https://doi.org/10.1093/jn/138.7.1383.

Schuster, R. C., Butler, M. S., Wutich, A., Miller, J. D., & Young, S. L. (2020). "If there is no water, we cannot feed our children": the far-reaching consequences of water insecurity on infant feeding practices and infant health across 16 low- and middle-income countries. *American Journal of Human Biology, 32*(1). https://doi.org/10.1002/ajhb.23357.

Seleshi, Y., & Zanke, U. (2004). Recent changes in rainfall and rainy days in Ethiopia. *International Journal of Climatology, 24*(8), 973–983.https://doi.org/10.1002/joc.1052.

Sellen, D. W. (2001). Weaning, complementary feeding, and maternal decision making in a rural East African pastoral population. *Journal of Human Lactation, 17*(3), 233–244. https://doi.org/10.1177/089033440101700307.

Sheffield, J., Goteti, G., & Wood, E. F. (2006). Development of a 50-year high-resolution global dataset of meteorological forcings for land surface modeling. *Journal of Climate, 19*(13), 3088–3111. https://doi.org/10.1175/JCLI3790.1.

Thai, T. Q., & Myrskylä, M. (2012). Rainfall shocks, parental behavior and breastfeeding: evidence from rural Vietnam. http://www.demogr.mpg.de.

Turin, C. G., & Ochoa, T. J. (2014). The role of maternal breast milk in preventing infantile diarrhea in the developing world. *Current Tropical Medicine Reports, 1*(2), 97–105. https://doi.org/10.1007/s40475-014-0015-x.

UNICEF, WHO, & World Bank Group. (2017). Levels and trends in child malnutrition. https://www.who.int/nutgrowthdb/jme_brochoure2017.pdf.

USAID. (2014). *Ethiopia: nutrition profile background*. Washington, DC. https://www.usaid.gov/sites/default/files/documents/1864/USAID-Ethiopia-Profile.pdf.

USAID, & Government of Ethiopia. (2010). *An Atlas of Ethiopian Livelihoods*. Addis Ababa.

Victora, C. G., Adair, L., Fall, C., Hallal, P. C., Martorell, R., Richter, L., & Sachdev, H. S. (2008). Maternal and child undernutrition: consequences for adult health and human capital. *Lancet, 371*(9609), 340–357. https://doi.org/10.1016/S0140-6736(07)61692-4.

Viste, E., Korecha, D., & Sorteberg, A. (2013). Recent drought and precipitation tendencies in Ethiopia. *Theoretical and Applied Climatology, 112*(3–4), 535–551. https://doi.org/10.1007/s00704-012-0746-3.

Webb-Girard, A., Cherobon, A., Mbugua, S., Kamau-Mbuthia, E., Amin, A., & Sellen, D. W. (2012). Food insecurity is associated with attitudes towards exclusive breastfeeding among women in urban Kenya. *Maternal & Child Nutrition, 8*(2), 199–214. https://doi.org/10.1111/j.1740-8709.2010.00272.x.

WHO. (2018). Breastfeeding. WHO. World Health Organization. https://www.who.int/nutrition/topics/exclusive_breastfeeding/en/.