The effects of growing-season drought on young adult women's life course transitions in a sub-Saharan context

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Abstract:

In spite of the vast importance of weather shocks for population processes, there is limited work that investigates the micro-level processes through which weather shocks influence the transition into adulthood in low-income contexts. This paper provides a conceptual overview and empirical investigation of how weather shocks impact the timing, sequencing, and characteristics of young adult women's life course transitions in low-income rural settings. Drawing on the case of Malawi, we combine repeated cross-sections of georeferenced Demographic and Health Survey data with georeferenced climate and calendar crop data to assess how drought shocks affect young women's life course transitions. Discrete-time event history analyses indicate that in this context, exposure to growing-season drought in adolescence has an accelerating effect on young adult women's transitions into first unions—including both marriage and cohabitation—and an accelerating effect on transitions into first births within union.

Keywords: drought, weather shocks, marriage, fertility, Africa.

Introduction

Climate change will affect population processes and wellbeing in unprecedented dimensions in coming decades. As a consequence of climate change, the intensity and frequency of weather shocks are expected to grow which will have tremendous implications for key demographic processes including mortality, fertility, migration, and health (Lam and Miron 1996; Costello, Grant, and Horton 2008; Gray and Mueller 2012; Gray and Bilsborrow 2013; Barreca, Deschenes, and Guldi 2015; Entwisle et al. 2016; Nawrotzki and DeWaard 2016; Barreca, Deschenes, and Guldi 2018). The ramifications of climate change and the corresponding increase in weather shocks will be felt especially strongly among young people who will experience the effects of weather shocks at all stages of their life course.

At present, about 20% of the world's population (e.g. 1.2 billion people) are currently between the ages of 10 and 19 and living in low- and middle-income countries (Anderson et al. 2014). In spite of the vast importance of weather shocks for population processes, there is limited work that investigates the micro-level processes through which weather shocks influence the transition into adulthood. This type of research is especially important in rural agrarian settings where weather shocks disrupt agricultural livelihoods that form the basis of important economic and social networks that in turn may influence young people's transitions into family formation. At present, 55% of the global youth population lives in rural areas where local livelihoods may be particularly vulnerable to weather shocks (FAO 2020). In what follows, we develop a conceptual framework of how and why weather shocks might influence young women's life course transitions in low-income rural contexts. We focus on young women (as opposed to men) because the risk of pregnancy for young women makes them of particular interest, as does their (often) lower position in bargaining in relationships in many low-income settings that may put them at higher risk of entering into relationships for financial reasons.

We go onto empirically investigate the effects of drought shocks on young adult women's transitions into unions and first births using a case study from Malawi. Malawi makes an interesting case study because the country is largely rural agrarian and highly vulnerable to weather shocks, in addition to having a large youth population and low ages of first marriage and births. Furthermore, the longstanding history of matrilineal kinship in the country allows us to identify a large sample of female respondents who are residing in the same geographic location as prior to the onset of union formation and childbearing. Our empirical analyses combine repeated cross-sections of georeferenced Malawi Demographic and Health Survey (DHS) survey data with georeferenced climate and calendar crop data to create a cutting-edge measure of drought shocks: The Standardised Precipitation Evapotranspiration Index (SPEI). Our discussion speculates how our framework and empirical approach could be applied to other low-income rural populations to better understand the linkages between weather shocks and life course transitions in other settings, which is a crucial first step in better understanding linkages between weather shocks, climate change, and young people's lives and wellbeing.

Weather shocks and young adult women's transitions to adulthood in low-income rural areas: A conceptual overview

The transition to adulthood is a pivotal point in young women's lives that is shaped by a constellation of key life cycle events which often include, but are not limited to, initiation of sexual activity, partnership formation, and childbearing (Hindin and Fatusi 2009; Juárez and Gayet 2014). While it is widely acknowledged that young people's life course transitions are shaped by social and contextual factors, limited research explores how environmental context—and particularly weather shocks—impacts the transition to adulthood in the global South. To this end, Figure 1 depicts a conceptual framework that illuminates how weather shocks might impact the life course transitions of young women in low-income rural contexts. We focus on rural agrarian contexts where people are dependent on agriculture for livelihoods because weather shocks have large and profound effects on local economies and income generation activities (Asafu-Adjaye 2010; Aggarwal and Pasricha 2011; Raga, Olivera Villarroel, and Orbe 2012). In our framework, we conceptualize shocks largely as exogenous idiosyncratic events that can have profound implications for young women's trajectories if experienced at key periods in the transition to adulthood.

As can be seen in Pathway A in the conceptual framework (top box), the direct impact of weather shocks is on crop yields, which can in turn impact crop prices (Pathway B). Weather shocks may be differentially anticipated depending on how common they are historically and it is plausible that the negative impacts of weather shocks on yields and income could be mitigated by "safeguards"—such as irrigation systems or rainfall insurance schemes—that could protect crop yields and income of households from extreme weather events (see Pathways C and D). Because irrigation in Africa is very low (Frenken 2005) and highly dependent on climate (Shiferaw et al. 2014), and the take-up of insurance products very low across different countries (Mobarak and Rosenzweig 2012), the role that these schemes can play in mediating the negative effects of weather shocks on crop yields and household income is very limited. Nonetheless, we would assume that people's abilities to invest in such schemes would depend heavily on socioeconomic background and other observable factors that could be controlled for in analyses. It is important to note that while most of the literature focuses on weather shocks that have negative ramifications for crop yields and household income, it is plausible that in some instances weather shocks—such as plentiful rains—may positively impact yields (Shah and Steinberg 2017) and income (Maccini and Yang 2009), which could also have implications for concurrent life course transitions (Pitt and Sigle 1998).

Following our conceptual framework, the direct impacts of weather shocks on crop yields and prices could lead to "secondary impacts" (represented in the second box of our framework). These include food and resource availability in families and communities (Pathway E) and also psychosocial stress that accompanies resource constraint, uncertainty, and related hardships (Pathway F). These secondary impacts on women's economic psychosocial contexts could, in turn, influence young women's transitions into unions and childbearing (we refer to these as the "tertiary impacts", which are represented by the third box in the framework). In what follows, we highlight how weather shocks might impact the timing, sequencing, and qualitative characteristics of these important life course transitions. Although a handful of studies explore linkages between weather shocks and the timing of life course transitions, we argue it is important to also consider how they affect the sequencing and characteristics of these key events to fully understand these impacts.

First of all, weather shock-related economic hardship may affect the *timing* of young adult women's transitions into unions. As can be seen in Pathway G, bride price or dowry payments may mediate the role resource constraints play in predicting marital timing because families have financial incentives to accelerate daughters marriage in the case of bride price (where daughters families receive payment upon marriage) or delay marriage in the case of dowry (where daughters families make payments upon marriage). In support of this perspective, evidence suggests negative rainfall shocks experienced in adolescence increase the probability of early marriage and births in rural Tanzania, with significantly larger effects in villages where bride price payments are more common (Corno and Voena 2016). Likewise, a comparative study of 30 African countries and India finds that in Africa—where bride price is more common—weather shocks are associated with lower female ages at first marriage, but in India—where dowry is prevalent—weather shocks are associated with higher female ages at first marriage (Corno, Hildebrandt, and Voena 2016) (for further details of how our work differs from the latter study see Appendix 1).

In contrast to the evidence that suggests weather shocks affect marital timing, a study finds rainfall has a positive—but statistically insignificant—effect on women's marriage rate in parts of rural Zimbabwe where bride price is common (Hoogeveen, van der Klaauw, and van Lomwel 2011). Hoogeveen and colleagues speculate that the rainfall effect is essentially a marriage market effect because during droughts and low rainfall periods, men's livelihoods suffer, and thus, they lack the resources to pay bride price. This raises an important point: it is also plausible that weather shocks could *delay* young women's ages at first marriage if people cannot afford to pay dowry or bride price or set up an independent household. Thus, although theoretically, a crop price impact would suggest that there should be acceleration in marriage timing in contexts with bride price, this inconclusive evidence suggests there may be countervailing factors such as lack of funds needed for a wedding ceremony or bride price payment or outmigration (discussed below).

Even in places where dowry and bride price is prevalent, there is enormous heterogeneity in the prevalence of bride price payments both between and within countries (Anderson 2007). Thus, we also provide a set of expected findings for our empirical examination of the link between weather shocks and union timing in the absence of bride price. According to our theoretical model, there should be an accelerating effect of drought on marital timing even in the absence of bride price (Pathway H). Weather shocks may lead to quicker marital transitions even in the absence of bride price because of the financial gains from marriage of a daughter. For example, young women's families may indirectly benefit financially from no longer having an additional household member to feed and support (Findley 1994). They might also directly benefit from informal cash or in-kind transfers that occur around marriages (Baird, McIntosh, and Özler 2011). In addition to the economic explanation, there could be important psychosocial reasons for acceleration in life course transition in response to weather shocks, which we highlight in Pathway F of the conceptual framework. For example, weather shocks may accelerate partnerships and childbearing because women seek out emotional support in difficult times (Silver 2002) (Pathways I and J).

As Pathway K shows, out-migration may also be a response to weather-shock related economic hardship (Henry, Schoumaker, and Beauchemin 2004; McLeman and Smit 2006; Massey, Axinn, and Ghimire 2010; Black et al. 2011), which might lead to important changes in local marriage markets (Pathway L). For example, research from Ethiopia suggests that men's labor-migration increases with drought, but women's marriage-migration decreases (Gray and Mueller 2012). If high ability men are more likely to out-migrate, women's partnership opportunities in local marriage markets may be constrained to lower ability/less educated partners (Luke and Munshi 2006). However, it is also possible that weather shocks might suppress out-migration by negatively affecting crop yields and financial resources that allow people to migrate, which may also influence marriage markets. Nonetheless, the evidence on climate-related migration is inconclusive and a recent systematic review does not find strong empirical evidence that outmigration is a common response to climate change (Borderon et al. 2019).

Partnership formation often corresponds with sexual activity and childbearing, thus weather shocks that impact marriage (via economic constraints or psychosocial stress) could lead to changes in the age at which sexual initiation and childbearing occur as well (Pathways M and N). Furthermore, weather shocks may also lead to disruption in contraceptive usage if financial resources necessary for access are diminished (Low et al. 2019) (Pathway O), which may in turn impact childbearing. There are also biological reasons why weather shocks could lead to declines in the initiation of childbearing among young women. Weather shocks that impact agricultural livelihoods may lead to poor nutritional availability, and undernutrition has been shown to delay menarche for young women and thus to delay their ability to conceive by limiting fecundity (Pathway O) (Frisch 1987; 1994).

While weather shocks often have negative ramifications for local livelihoods and economies, as discussed above there also instances when weather shocks could be positive for rural livelihoods, for example, if rainfall shocks lead to improvements in agricultural productivity (Maccini and Yang 2009; Shah and Steinberg 2017). In support of this, a study in Senegal finds that positive rainfall shocks lead to increases in fertility and decreases in infant mortality (Pitt and Sigle 1998). The authors consider this to be a positive income shock and speculate that the increased income and food supply that come from a plentiful harvest increase incentives for childbearing because of higher likelihood of child survival. Thus our conceptual framework is not limited to the case of "negative" weather shocks, but can also be used to understand how "positive" weather shocks might impact the life course transitions of young women in low-income rural contexts.

As the third box of the conceptual framework shows, weather shocks might also impact the *sequencing* of life course transitions (i.e. whether sex and childbearing occur before or after union formation). In many places in low-income countries, premarital sexual activity is often accompanied by monetary or in-kind transfers (Meekers and Calves 1997; Leclerc-Madlala 2003; Mensch, Grant, and Blanc 2006; Poulin 2007), thus young women in areas affected by weather shocks could have financial incentives to initiate sex or childbearing prior to union entry out of economic necessity. This could be particularly the case in regions where pre-marital sexual activity is less common or among young populations that have not yet initiated sexual activity.

Finally, weather shocks could further impact the *characteristics* of young adult women's life course transitions by leading them to enter into different types of relationships with different types of partners (shown by Pathways H and O). Due to resource constraints, young women might become more willing to enter romantic partnerships partly or fully for financial reasons (Meekers and Calves 1997). Women who enter partnerships in part for financial reasons may be more likely to choose a partner who is considerably older, wealthier, and/or already has another partner (Meekers and Calves 1997; Leclerc-Madlala 2003). On the other hand, if men are also under financial pressure to be independent then men may also be more likely to enter unions at earlier ages and the age gap may be unaffected (this might be particularly the case when neither bride price or dowry are practiced).

Other dimensions of partnership formation might also be impacted by drought-induced financial stress. For example, women under financial stress might be more likely to enter a polygynous union or an informal arrangement where the young woman is considered a "girlfriend" or "outside wife" to a man with an existing partner (Bledsoe 1990). It is also plausible that women may be more likely to enter a cohabiting union—rather than civil or religious wedding—if potential suitors lack the money necessary for a wedding ceremony or bride price payment (Posel, Rudwick, and Casale 2011). This could be particularly the case in Latin America or sub-Saharan Africa where cohabitation is an increasingly common alternative to marriage (Esteve, Lesthaeghe, and López-Gay 2012; Moore and Govender 2013).

Case study: Transitions to adulthood in Malawi

Contemporary Malawi is largely rural and agrarian; over 80% of the population lives in rural areas and the majority of people are engaged in small scale subsistence agriculture (ICF International 2017). The rural population depends heavily on crop production—particularly of maize—for sustenance, which are highly vulnerable to weather shocks. It is estimated that the average annual production loss of local maize due to drought in Malawi is 7.3 percent (Pauw, Thurlow, and van Seventer 2010). In cases of extreme drought, such as the those experienced in 1991/92, loss can be much more severe. For example, production loss for local maize for a drought on the magnitude of the 1991/92 event was estimated to be as high as 80% (ibid). Drought-related crop losses also have staggering impacts on price and income at the micro level (Haile 2005) and GDP at the macro level (Flatø and Kotsadam 2014; Burke, Gong, and Jones 2015). On average drought in Malawi causes direct financial losses of over 15 million dollars annually which causes GDP losses of almost 1% per year (RMSI 2009).

Given that many people in the country are dependent on agriculture for livelihoods, weather shocks will have direct impacts on the livelihoods and well-being of young adults, including the transition to adulthood. On average, young women in Malawi transition into first unions and first births at young ages (e.g. 18.2 and 18.9 years respectively) (ICF International 2017). Sexual initiation, courtship, and marriage in Malawi are often a series of interrelated processes that often involve casual sexual relations and preliminary trial relationships that may or may not evolve into marriage over time (Bledsoe 1990; Dominique Meekers 1992; Poulin 2007). Sex and birth prior to marriage are relatively prevalent, with between 20 and 30% of women born in the mid-to late 1980s reporting a premarital birth (Mensch, Grant, and Blanc 2006; Clark, Koski, and Smith-Greenaway 2017). Polygyny is also prevalent, with about 10% of women of reproductive age currently being in a polygynous union (ICF International 2017).

The practice of bride price is less common in Malawi than in other countries in the region due to the large matrilineal population (Peters 2010), however it is practiced by some patrilineal groups particularly in the Northern part of the country. Although bride price is not widely practiced, exchange of goods is still a common part of the courtship processes. For example, a qualitative study of premarital relationships formation in Southern Malawi shows that exchange cash and goods from male to female is a pre-condition to the initiation of a sexual relationship and is continued over the duration of the relationship (Peters 2010). Some authors suggest the exchange of goods between partners in Southern Africa are primarily transactional (e.g. women exchange sex for material gain often with considerably older partners) (Meekers and Calves 1997). Nonetheless, Poulin's qualitative fieldwork suggests that such exchanges are also common among younger couples and that these exchanges can also be understood as tangible symbols of love and commitment.

Data & Methods

We combine data from three different sources in order to explore the effects of weather shocks on young adult women's transitions to adulthood in Malawi: (1) georeferenced individual-level data from the Malawi Demographic and Health Surveys 2000, 2004, 2010, 2015–16; (2) georeferenced climate data on Malawi from the European Centre for Medium-Term Weather Forecasting (ECMWF); and (3) georeferenced calendar crop data for Malawi from the Global Monthly Irrigated and Rainfed Crop Areas (MIRCA2000). The unit of analysis is young adult women aged 15–24 from the Demographic and Health Surveys. See Appendix 2 for further details.

We limit our sample to young adult women who report living in the same cluster (e.g. primary sampling unit) since the age of 9 years old to ensure that we know where the woman was residing in early adulthood and thus have the correct spatial ordering between drought shocks and life course transitions. We do this because migration in response to a weather shock and/or marriage is common in Malawi (Beegle and Poulin 2012), thus women's current residence may not accurately reflect the location and climatic conditions of their adolescence prior to the shock. We identify these women using a variable about how long the respondent has lived in the current cluster; this allows us to identify the childhood location of women who have never migrated, but does not provide information about residence in childhood for women who have migrated (who we drop from our analytical sample). Note that visitors, i.e. women surveyed but not resident in the household, are also excluded.

Because matrilineal lineage is prevalent in Malawi (Peters 2010), there are high rates of young adult women still living in their natal communities. In total, 55.8% of young women aged 15–24 have been living in the same DHS cluster since the age of 9 years old, giving us a total sample of 17,033 women living in 2,680 clusters (Table 1 for summary statistics). Although this analytical choice limits our abilities to generalize beyond our sample, it is an essential step to ensure that we have correct information on climatic conditions prior to transitions into family formation. As a robustness check, we re-estimate analyses with the entire DHS sample of young adult women ages 15–24.

[Table 1 here]

We construct two different types of datasets for our analysis. The first type of dataset is a panel dataset where the unit of analysis is person-years. This dataset is used for the Event History Analyses where the outcomes are related to timing of union formation and conception. We use 11 years of age as the data entry point, the age at first union and at first conception as the data exit point, and the survey month/year as the end of observation. The data are right-censored because some women may not have experienced the event by the time of the survey, and are organized so that each woman contributes multiple person-years to the analysis. The second type of dataset is a cross sectional dataset where the unit of analysis is each individual respondent. This dataset is used to estimate linear probability models for outcomes related to partnership characteristics.

Measures

Timing outcomes: Age at first union and first birth

The main outcome variables of interest are age at first union—defined as either marriage or cohabitation—and age at first conception that resulted in a live birth (referred to as first birth throughout the paper for reasons of parsimony)—calculated as first birth minus nine months—which are constructed out of detailed DHS questions about the month and year of first union and first birth.

Partnership characteristics outcomes

We also explore whether drought impacts partnership characteristics by using a number of partnership characteristics for partnered respondents. First, we examine the partner's educational attainment with two variables, one continuous measure of partner's years of education and one binary variable that specifies if the difference between the partner's and the woman's years of education is positive (i.e., the woman's partner has more education than the woman). Next, we explore the age difference between the respondent and her partner with a binary variable that equals one if the difference between the partner's and the woman's age is positive (i.e., the woman's partner is older than the woman). Finally, we investigate the presence of other wives (e.g. polygyny) with two binary variables, one that specifies if the male partner has more than one wife and another that equals one if the respondent is the second (or third or fourth etc.) wife in a polygynous union and zero if she is the only wife or the first wife in a polygynous union. Among unpartnered women, we also explore whether the respondent reports that she has engaged in sex for cash or goods in the last 12 months. Because the measure of exchanging sex or goods for cash is only collected in the most recent DHS survey for women not in unions, this analysis is limited to unpartnered women in this later round only (DHS 2015–16).

Treatment: Exposure to growing-season drought

Our main treatment is whether or not the respondent was exposed to drought during the last and second-to-last growing seasons prior to any given month of exposure. We measure drought exposure with the Standardised Precipitation Evapotranspiration Index (SPEI), which has been identified as the most complete and robust agricultural drought index in Africa (WMO 2012). The SPEI presents an improved measure of drought intensity, severity, and duration that includes climate indicators other than just precipitation because increases in evaporation from soil and vegetation—in addition to decreases in precipitation—play a role in droughts (WMO 1975). We focus on whether the drought occurred during the last and second-to-last growing seasons because crops are most vulnerable to drought during growing season. This is preferred to using monthly or year rainfall averages which average climatic conditions over a relatively long timeframe, thereby masking important short-term shocks that are devastating to staple crops. Calendar crop data is used to identify the growing-season months of the main crop grown (ranked by harvested area) in a given woman's grid cell of residence. Using georeferenced data in the DHS, each woman in our sample is matched to the weather (ERA-I) and calendar crop (MIRCA) grid cell in which she resides.

Using the weather data, we calculate the 3-month SPEI (SPEI3) for each cell and month from Jan 1979 to Aug 2016 (for further details about the construction of

SPEI see Appendix 3). SPEI3 is expressed in units of standard deviation from the cell average of SPEI and has mean 0 by construction. In accordance with the World Meteorological Organization (WMO), we designate a severe and extreme drought, which, for shorthand, we refer to as severe drought, when SPEI3 is smaller than –1.5 (WMO 2012). Then, for each cell g and woman w observed in month/year d we define the independent variable, severe growing-season drought (which is used interchangeably with growing-season drought), as the proportion of months during the last and second-to-last completed growing seasons in which a severe drought (i.e. SPEI3 below –1.5) occurs prior d. Then, we construct the growing-season drought variable as:

$$gs\_drought\_ei_{g,d} = \omega_{\mathrm{g,d}} * gs\_drought\_ei_{1}^{\mathrm{g,d}} + \left(1 - \omega_{\mathrm{g,d}}\right) * gs\_drought\_ei_{2}^{g,d},$$

Eq. (1)

where $gs\_drought\_ei_{1}^{g,d}$ and $gs\_drought\_ei_{2}^{g,d}$ are the growing-season drought during the last and second-to-last completed growing seasons preceding date d for location g. Weight $\omega_{g,d}$ is given by $\omega_{g,d} = \frac{d-h^{g,d}}{12}$, where $h^{g,d}$ is the running month of the last harvest preceding date d in location g, and accounts for how many months in the year before the event a young woman was exposed to droughts. We demonstrate that our main results do not depend on the definition of $\omega_{g,d}$ (see Appendix 4 for further details). The growing-season drought variable is a $[0; 1]$ continuous variable where 0 indicates that the woman did not experience any drought event prior d and 1 indicates that the woman experienced droughts for the whole growing-season period prior d.

Additional explanatory variables

In accordance with WMO designation of extremely wet conditions, we use a symmetric variable to control for events in which SPEI3 exceeded normal levels by 2 standard deviations (i.e., extremely wet conditions). In both samples, the correlation between exposure to growing-season drought and exposure to extremely wet growing-season events is very low (i.e., –0.05).

We also control for other explanatory variables that may also be associated with transitions to union formation and birth including years of education, religion (indicators for Catholic, Protestant, Muslim, Other/None), and ethnicity (indicators Chewa, Tumbuka, Lomwe, Yao, Ngoni, Other). To account for the fact that women's marital transitions may be influenced by birth order and the number of other siblings in the family (Hoogeveen, van der Klaauw, and van Lomwel 2011), we also include a binary variable indicating if the respondent is the oldest sibling and number of siblings (indicators for 0–2, 3–5, 6–8, 9 and more). We also control for the passage of time at the individual level by using a set of dummy variables indicating the woman's age in completed years. Our measure of historical time is a set of dummy variables indicating the woman's year of birth which control for unobserved factors that vary by year of birth. Additionally, we add ERA-I cell fixed effects to compare women living in the same location, and year of survey fixed effects to capture potential differences between surveys.

Estimation strategy

Our analysis largely follows the framework we laid out in the literature review where we explore the effects of growing-season drought shocks on the timing, sequencing, and characteristics of young women's transitions into unions and childbearing. First, we explore the effects of growing-season drought shocks on the *timing* of young adult women's life course transitions by conducting a discrete-time event history analysis of how drought affects ages at first union formation and birth. The model reads as:

$$log\left(\frac{p_{itkgs}}{1-p_{itkgs}}\right) = \boldsymbol{\alpha}_t + \lambda \text{gs\_drought\_e}i_{\text{it}} + \gamma \text{gs\_wet\_e}i_{\text{it}} + \boldsymbol{x}_i'\boldsymbol{\beta} + \boldsymbol{\theta}_k + \boldsymbol{\pi}_g + \boldsymbol{\rho}_s, \text{ Eq. (2)}$$

where p_{itkgs} is the probability that woman i born in year k residing in cell g and interviewed in survey s experiences the event at age t, given that the event has not already occurred. $\boldsymbol{\alpha}_t$ is the baseline hazard function that captures changes in p_{itkgs} with t, i.e. vector of age fixed effects. gs_drought_ei_{it} is the drought variable that woman i has experienced during the last and second-to-last completed growing season prior to age t. gs_wet_ei_{it} is the extremely wet variable that woman i has experienced during the last and second-to-last completed growing season prior to age t. The vector $\boldsymbol{x}_i$ contains time-invariant characteristics of woman i, specifically years of education, religion, ethnicity, oldest sibling, and number of siblings. The vector of woman's year of birth fixed effects is $\boldsymbol{\theta}_k$, the vector of ERA-I cell fixed effects is $\boldsymbol{\pi}_g$, and the vector of survey fixed effects is $\boldsymbol{\rho}_s$. Robust standard errors are calculated using the Huber-White method.

Next, we investigate how drought impacts the *sequencing* of young adult women's life by conducting a discrete-time logistic regression competing risk analysis that recognises three different "risks": (i) no birth over the period of study; (ii) first birth conceived outside of a union; and (iii) first birth conceived within a union. Women who get pregnant outside of a union, but subsequently form a union before the child is born, are coded in the second category. The model reads as:

$$log\left(\frac{p_{itkgs}^{(r)}}{1-p_{itkgs}^{(r)}}\right) = \boldsymbol{\alpha}_t^{(r)} + \lambda^{(r)} gs\_drought\_ei_{it}^{(r)} + \gamma^{(r)} gs\_wet\_ei_{it}^{(r)} + \boldsymbol{x}_i^{(r)\prime}\boldsymbol{\beta}^{(r)} + \boldsymbol{\theta}_k^{(r)} + \boldsymbol{\pi}_g^{(r)} + \boldsymbol{\rho}_s^{(r)}, \text{ Eq. (3)}$$

where r is the type of event: first birth conceived outside of a union or first birth conceived within a union; $p_{itkgs}^{(r)}$ is the probability that woman i born in year k residing in cell g and interviewed in survey s experiences event r at age t, given that the event has not already occurred. Robust standard errors are calculated using the Huber-White method.

Then, we explore the effects of growing-season drought on the *characteristics* of women's partnerships including both qualitative types of union (e.g. marriage versus cohabitation) and characteristics of partners. First, to assess the effects of drought on types of unions, we estimate a discrete-time logistic regression competing risk model that recognises three different "risks": (i) no union formation over the period of study; (ii) marriage; and (iii) cohabitation. For this analysis, we exclude young women who were separated or widowed and young women who were in a union more than once because we do not have detailed information on past unions that have ended. The estimated model is as in Eq. (3), where r in this case is marriage or cohabitation.

Second, to assess the effects of drought on partnership characteristics we estimate a series of linear regression models with additional outcomes including partner's educational attainment, educational difference between the respondent and partner, age difference between the respondent and partner, and polygyny. For this analysis, we exclude women who have never been in a union, separated and widowed women, and women who have been in multiple unions. The model is as follows:

$$y_{ikgs} = \alpha_0 + \alpha_1 gs\_drought\_ei_i + \alpha_2 gs\_wet\_ei_i + \boldsymbol{x}_i'\boldsymbol{\beta} + \boldsymbol{\theta}_k + \boldsymbol{\pi}_g + \boldsymbol{\rho}_s, \text{ Eq. (4)}$$

where y_{ikgs} is the characteristic of woman i's partnership, and $gs\_drought\_ei_i$ and $gs\_wet\_ei_i$ are exposure to drought and exposure to extremely wet events during the last and second-to-last completed growing seasons prior to the union onset, respectively. Standard errors are clustered by ERA-I cell level and woman's year of birth.

Finally, we also explore whether exposure to drought in the last growing season leads to increases in the probability that non-partnered women have engaged in sex for cash or goods in the last 12 months. This question is asked in the most recent survey only (DHS 2015–16) to women who are not currently in unions, thus this sub-analysis is limited to these women. Note that visitors are excluded. The model is as follows:

$$y_{ikg} = \alpha_0 + \alpha_1 gs\_drought\_ei_{1i} + \alpha_2 gs\_wet\_ei_{1i} + \boldsymbol{x}_i'\boldsymbol{\beta} + \boldsymbol{\theta}_k + \boldsymbol{\pi}_g, \text{ Eq. (5)}$$

where y_{ikg} is a binary variable equal to 1 if woman i has engaged in sex for cash or goods in the last 12 months. The vector of time-invariant characteristics of woman i, $\boldsymbol{x}_i$, also includes age at first sex. $gs\_drought\_ei_{1i}$ and $gs\_wet\_ei_{1i}$ are exposure to drought and exposure to extremely wet events during the last completed growing seasons prior to the survey, respectively. Standard errors are clustered by ERA-I cell level and woman's year of birth.

Due to the plausibly exogenous nature of drought we use the language of causality (e.g. effects and impacts throughout the paper); for similar see Harari and La Ferrara (2018), and von Uexkull et al. (2016). The key characteristic of our model is the use of short-run random variation of weather to assess how climate change affects young adult women's transitions to adulthood. Thus, identification exploits the within location (i.e., ERA-I cell) variation of climate parameters, after controlling for time invariant heterogeneity and individual-level characteristics. Failure to do so will introduce a bias in the estimate of growing-season drought, and weather shocks in general. This is particularly true when weather shocks and its effects are most likely different in space. In conclusion, the fixed-effect strategy allows to identify variation as temporal change within location and should be employed to estimate causal effects of weather shocks.

Results

The effect of growing-season drought on the *timing* of young women's life course transitions

On average, 46% of respondents aged 15–24 had experienced a union and 47% had experienced a first birth by year of survey (Table 1). The average ages of first union and birth were 16.7 and 17.5 respectively, which are largely consistent with national averages reported elsewhere for a similar time period (ICF International 2017). In total, the prevalence of drought was 2.2% of all person-years (Table 2, Columns 1–3) and between 2.2% and 2.6% of observations (Table 2, Columns 4–8), thus highlighting that severe growing-season drought was a rare occurrence. The same is true for wet growing season events, where the prevalence of extremely wet (SPEI $\geq +2$) and very wet (SPEI $\geq +1.5$) events is respectively less than 0.8% and 6.2%.

To investigate the effect of droughts on timing of first unions and first birth, we estimate discrete-time logistic regression models of transition into first union and first birth with coefficients expressed as log-odds ratios (Table 3). Model 1 shows that exposure to growing-season drought significantly increases young adult women's transitions into first unions. More specifically going from no drought exposure to drought exposure for the whole growing-season period increases the log-odds of union formation by 0.68 ($p<0.001$). To put the magnitude of this finding into context, a one-year increase in education is associated with a 0.17 decrease in the log-odds of union formation, which is significantly different in magnitude from 0.68. Likewise, going from no drought exposure to drought exposure for 15% of the months of the last two growing seasons (the mean drought prevalence across Malawi over 1979–2016) increases the log-odds of union formation by 0.10.

The transition into first unions is often closely related to initiation of childbearing in Malawi, thus we also test whether exposure to growing-season drought in adolescence has impacts on young adult women's transitions into first births. Although exposure to growing-season drought in adolescence is positively associated with young women's first birth, this result is not significant at conventional levels.

As a supplement, we also explore the effects of exposure to extremely wet growing conditions on transitions into unions and births. We find there are no significant effects of exposure to extremely wet conditions during growing seasons on young women's transitions into unions. On the other hand, exposure to extremely wet growing-season conditions increases young women's transitions into first births ($p<0.05$). If positive rainfall shocks during growing seasons are good for harvests, then a fertility increase in response to wet periods could reflect that couples see this as an advantageous moment to start a family due to bountiful conditions (Pitt and Sigle 1998). Thus, it could be that the mechanisms underlying fertility responses to drought and extremely wet conditions operate differently, even if both result in fertility increases. On the other hand, in supplementary analyses (available upon request), we find no significant effects of exposure to very wet and moderately wet growing-season conditions on transitions into unions and births.

[Table 3 here]

The effect of growing-season drought on the *sequencing* of young women's life course transitions

The results from the proceeding section suggested that exposure to growing-season drought in adolescence has an accelerating effect on young adult women's transitions into first unions. Nonetheless, these models do not parse out whether women are conceiving prior to or after union formation, thus we also explore the impact of growing-season drought on the sequencing of conception and union formation. Table 4 presents discrete-time logistic regression models where no birth by survey time, first birth conceived prior to union formation, and first birth conceived after union formation are all treated as competing risks (no birth is the reference category).

Model 1 shows that exposure to growing-season drought in adolescence is associated with a significant acceleration in young adult women's first birth conceived following union formation (compared to having no births by time of survey). This finding is perhaps expected given that drought accelerates transitions into unions, and childbearing often follows the initiation of unions in Malawi (ICF International 2017). Nonetheless, there is no statistically significant effect of growing-season drought on first births conceived outside of unions (Model 2, Table 4).

In addition, we find that exposure to extremely wet growing seasons leads to an acceleration in young adult women's first births conceived in unions, but there is no significant effect of exposure to extremely wet growing seasons on births conceived outside of unions. If exposure to extremely wet growing seasons functions as a "positive" shock that is good for agricultural production, then this could explain why we see an increase of births conceived inside of unions (which may be more likely to be planned), but not births conceived outside of unions (which may be more likely to be unplanned). In supplementary analyses (available upon request), we find that exposure to very wet, but not moderately wet, growing-seasons also leads to an increase in the log-odds of young adult women's first births conceived in unions (compared to having no births by survey). At the same time, we find that exposure to both very wet and moderately wet growing-season conditions leads to a significant reduction in the log-odds of young adult women's first births conceived outside of unions (compared to having no births by survey).

[Table 4 here]

The effect of growing-season drought on the *characteristics* of young women's life course transitions

The previous analyses showed that exposure to growing-season drought in adolescence affected both the timing and sequencing of young adult women's union formations and birth transitions. In the next step of analyses, we explore whether drought also impacts the characteristics of union formation, including the types of partnerships women enter and partner characteristics.

First, we hypothesize that drought might alter the types of partnerships that women enter, for example women may be more likely to enter cohabiting unions than marriages if their families and their partners lack the resources necessary for a wedding ceremony. Table 5 presents discrete-time logistic regression models where no union formation over the period of study, marriage, and cohabitation are treated as competing risks (no union formation is the reference category). Model 1 shows that, going from no exposure to full exposure to growing-season drought leads to a 0.88 increase in the log-odds of young women's transition into marriage ($p<0.001$) and going from no exposure to drought exposure for 15% of the months of the last two growing seasons leads to a 0.13 increase in the log-odds of young women's transition into marriage. Model 2 shows that, going from no exposure to full exposure to growing-season drought leads to a 2.13 increase in the log-odds of young women's transitions into cohabitation ($p<0.001$) and going from no exposure to drought exposure for 15% of the months of the last two growing seasons leads to a 0.32 increase in the log-odds of young women's transition into cohabitation. The marriage and cohabitation coefficients are statistically different at 5% level, which could indicate that cohabitation is becoming an alternative to marriage. Nonetheless, these results should be interpreted with some caution since there may be some measurement error in whether a union gets reported as marriage or cohabitation.

[Table 5 here]

As a next step, we explore the effects of droughts on partnership characteristics. Among currently partnered women, we find that exposure to growing-season drought in adolescence has a negative statistically significant effect on the respondent's partner's years of education ($p<0.05$) (Model 1, Table 6). In particular, going from no exposure to full drought exposure leads to a one-year reduction in the partner's years of education and going from no exposure to drought exposure for 15% of the months of the last two growing seasons leads to a 0.16 reduction in partners years of education. This is a sizeable impact when we consider the overall low levels of education in the sample (on average, women in the sample have about 6 years of education (Table1)). On the other hand, we do not find any significant effects of exposure to growing-season drought on the education difference between the respondent and her partner, on the age difference between the respondent and her partner, or on the presence of other wives or the respondent's ranking (e.g. polygyny) (Models 2–5).

[Table 6 here]

Finally, we explore the possibility that women exposed to drought might be more likely to enter into relationships where goods or cash are exchanged for sex using a question collected in the 2015–16 DHS (Table 7). Although the coefficient on this term is positive, we find that exposure to growing season drought is not significantly associated with exchanging sex for goods or cash at 5% level.

[Table 7 here]

Supplementary analyses

One limitation of our analysis is that we had to limit our sample to respondents who were living in the same cluster since age 9 to get the correct geospatial ordering between weather shocks and key life course transitions using cross sectional data. As a result, we ended up limiting our sample to women primarily from matrilineal tribes who did not migrate upon marriage. This limited our abilities to generalize findings to the young women outside of our sample, who may have been more likely to be from patrilineal tribes. As a supplement, we estimate our analyses on the *full* sample of women aged 15 to 24 (i.e., including both migrants and non-migrants) from the Malawi DHS and show that our main findings are similar to those generated using the full sample of DHS women (Table S2, Supplementary Material). As a further supplement, we examine if drought predicts the probability of marrying outside the location of residence during childhood. We find that women's marriage-migration decreases with exposure to growing season droughts (Table S3, Supplementary Material) and this suggests that the women in our sample are less likely to marry out because of drought, thus indicating another way drought might influence women's marriage patterns. For further details about these supplementary analyses, see Appendix 5.

As a further supplement, we validate our drought measure against historical records of drought in Malawi. We show the prevalence of droughts within Malawi by mapping the proportions of months in the calendar year where SPEI3 was below –1.5 across grid cells for each year from 1979 to 2016 (Fig. S3, Supplementary Material). Drought prevalence ranges from 0, that is no severe drought in the year, to 1, that is severe drought in every month of the year. The figure shows areas where drought was longer (red squares) or shorter (yellow squares) and is largely consistent with the historical trajectory of droughts in Malawi. For example, we find that Southern areas were most affected by the 1992 drought, as has been noted in the historical record (Giertz et al. 2015). We also show the time trend in drought prevalence by plotting the same proportions over time across the country (Fig. S4, Supplementary Material). Fig. S4 shows both that drought is a rare event—the share of areas experiencing drought varies from 0 in 1982, 1997, 2001, 2002, and 2004 to over 80% in 1992, 1996, and 2015—and that variation over time in drought prevalence was high. For example, in 2015 the whole country was highly affected by droughts as opposed to the year 1982 when no droughts occurred. These supplementary analyses support that our measure of drought shocks is in line with historical documentation of droughts that affected Malawi in 1992, 1995, 2005, and 2015 (Giertz et al. 2015).

Discussion

Poor nations—and often the poorest citizens of those nations—are disproportionately vulnerable to weather shocks, which are expected to increase in intensity, frequency, and duration in the coming decades due to climate change. Although we know that weather shocks affect the livelihoods and well-being of people around the world, scant research explores how weather shocks influence the transition to adulthood upon the largest ever cohort of young people. Throughout low-income countries there have been dramatic increases in important life course transitions among young adult women's over the last decade—including delays in age at first sex, marriage, and birth (Pesando and GFC Team 2018)—all of which could be impacted in the future by weather shocks and other climate events.

Our paper provided a conceptual overview of the reasons why and how weather shocks might impact young women's life course transitions in low-income rural contexts and explored the model empirically using the case of drought in Malawi. Consistent with the expectation that a price impact would accelerate union formation even in the absence of bride price, we find that that exposure to growing-season drought in adolescence accelerated young adult women's transitions into first unions—including both cohabitation and marriage—and had an accelerating effect on initiation of childbearing within unions. This was a striking finding suggesting that even in the absence of bride price young women and their families might have financial incentives for young women's union formation in the form of exchange of goods at union onset, or indirectly because the family will have less people to feed in the household (Findley 1994). It also points to the importance of the direct link between food and resources to union formation (Pathway H in our conceptual framework). This finding is also in line with existing evidence from Malawi that indicates how the income of the brides' household plays a dominant role in determining the timing of marriage (Baird, McIntosh, and Özler 2011). Nevertheless, there could be alternative explanations for this impact, for example weather shocks may accelerate union formation because women view it as a way to reduce the psychosocial stress that accompanies resource constraint, uncertainty, and related hardships.

Taken together, our findings suggested that growing-season drought have large and important impacts on key dimensions of young women's life course transitions. Although in the context of our paper we treated shocks as idiosyncratic, it is plausible that idiosyncratic shocks might become cumulative and more regular as the intensity, frequency, and duration of extreme weather events increases with climate change. This might lead to more long-lasting changes in family formation and transitions to adulthood in low-income countries. For example, in the case of Malawi, if extreme drought events were to become increasingly common there could be an overall trend towards lower ages of first union and first birth. Given the already low ages of first marriage and birth in Malawi, this would be a case of substantial concern for policymakers.

While our conceptual framework and empirical analysis focused exclusively on young adult women, in future research it would also be interesting to explore these issues in more detail with young men as well. We might expect that our main pathways of impact—economic and psychosocial stress—would have differential (perhaps even opposite) impacts on young men because of gender-based differences in productive activities and social norms. For example, in societies where bride price is practiced, women have a financial incentive to accelerate marriage formation, but men have a financial incentive to delay marriage formation, which may also contribute to an increase in the age gap between spouses (the opposite would be true for a society where dowry is practiced). At the same time, we might expect different dynamics in a place like Malawi where neither bride price or dowry is common. For example, we find women's age at marriage is accelerating but the age gap is not significantly affected, which suggests that men's age at marriage may also be deaccelerating. In a context without bride price, the pathways laid out in our conceptual framework may apply to men as well (i.e. men may also be under pressure to set up independent households and/or view marriage as a means for psycho-social coping). There is a need for further empirical work that focuses on men that explores this in more detail.

In many places weather shocks such as drought and flooding may be differentially anticipated depending on how common they are historically, which potentially provides an important intervention point for policy makers. It is plausible that the impacts of weather shocks could be mitigated, for example, by irrigation systems or rainfall insurance schemes that could protect crop yields and household income from extreme weather events. Because implementation of these systems will likely depend on the resource availability of the individuals at hand—meaning that higher resource individuals will be better protected—support for irrigation (or agricultural systems designed to safeguard yields) or rainfall insurance schemes among poorer populations could present a promising way to protect against the negative impacts of weather shocks. On the one hand, policy makers should consider that agricultural investments may have effects that go far beyond just agricultural productivity, actually impacting the lives and wellbeing of young people's life course transitions. On the other hand, because water resources are influenced by climate (Shiferaw et al. 2014), the positive impacts of investments in such schemes to manage droughts in particular may still be limited. This has led scholars to suggest alternative complementary measures to reduce vulnerability to climate change, including strategic food reserves as well as social protection policies.

It is important to acknowledge that the cross-sectional nature of the DHS data led to several analytical limitations. First, we relied upon retrospective information on women's age of first union and birth, which may be subject to measurement error. Furthermore, we had to limit our sample to respondents who were living in the same cluster since age 9 to ensure the correct geospatial ordering of climate conditions and life course transitions, which limited our ability to generalize findings to the entire population of young women in Malawi (although we find similar results when we estimate the same set of models on the entire population). A final limitation of our analysis was that we could not fully illuminate the mechanisms behind why drought shocks led to acceleration in life course transitions. The fact that drought was positively (though only marginally significantly at $p<.10$) associated with exchanging sex for goods/money suggested that resource-constrained women may have entered unions partly as a financial coping strategy; and this is consistent with previous research highlighting that decisions about sexual behaviour and marriage among adolescent girls in Malawi are driven by poverty (Baird et al. 2011). Nonetheless, there could be other possible explanations, for example women might have entered partnerships for social and emotional support in difficult times, although this is not possible to assess in our data and would be a fruitful area of research for future qualitative work.

Ultimately, our analysis provided a conceptual framework that could be used to guide an analysis in other settings and showed how a cutting-edge measure of weather shocks can be combined with widely available georeferenced DHS data to better understand the linkages between weather shocks and young people's life course transitions. Sub-Saharan African countries are highly diverse in terms of ethnicity, religion and socioeconomic status, and there is considerable diversity in marriage practices and transitions to adulthood across different contexts. The effects of drought on life course transitions could depend on variables such as the type and intensity of the weather shock, the predominant system of resource transfer at marriage (bride price vs. dowry vs. other arrangements), the availability of non-agricultural employment in urban areas that might induce migration, and the prevalence of social norms around the acceptability of pre-marital sexual activity. Our analysis highlights the need for more context specific work because we suspect that these relationships may differ across contexts in important dimensions.

Throughout our analyses, we engaged with a growing literature that combined insights from agricultural economics and environmental studies with key demographic measures and concepts. Given that weather shocks will increase in coming decades as a consequence of climate change, there is a crucial need for a better understanding of the relationship between climatic processes and the demographic outcomes, lives, and livelihoods of young people.

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Fig. 1 Transition to adulthood among women in LMICs.

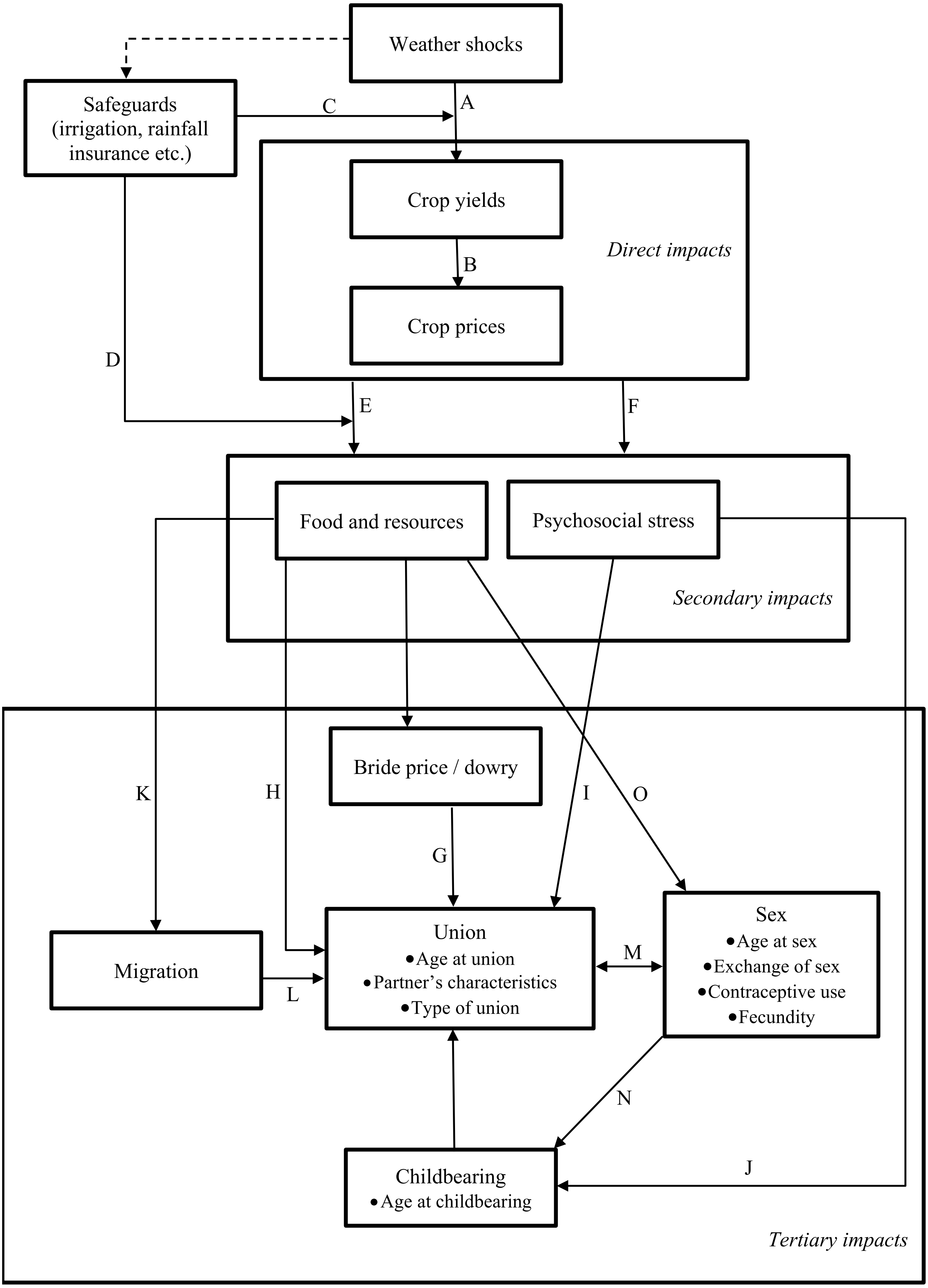

Table 1 Summary statistics.

Variable	Mean
First union (%)	0.46
First birth (%)	0.47
Age at first union	16.70
	(2.10)
Age at first birth	17.53
	(1.98)
Years of education	5.85
	(3.15)
Year of birth	1990
	(6.36)
Oldest	0.20
	(0.40)
Religion (%)	
Catholic	0.22
Protestant	0.26
Muslim	0.15
Other/None	0.37
Ethnicity (%)	
Chewa	0.33
Tumbuka	0.07
Lomwe	0.20
Yao	0.16
Ngoni	0.12
Other	0.12
Number of siblings (%)	
[0,2]	0.12
(2,5]	0.41
(5,8]	0.37
8+	0.11
Year of survey (%)	
2000	0.17
2004	0.14
2010	0.31
2015	0.38
N	17,033

Proportions and means are based on weighted data, standard errors in parenthesis; *N* is unweighted.

Table 2 Summary statistics of the climate variables across samples.

Variable	Outcome							
	Union	Birth	Marriage vs Cohabitation	Education	Age difference	Polygynous partnership	Wife's ranking	Sex in exchange for cash/goods[a]
Exposure to severe growing-season drought (SPEI ≤ –1.5)	2.21	2.25	2.18	2.26	2.26	2.25	2.22	2.63
	(0.07)	(0.07)	(0.07)	(0.08)	(0.08)	(0.08)	(0.08)	(0.10)
Exposure to extremely wet growing season (SPEI ≥ +2)	0.75	0.79	0.71	0.82	0.80	0.82	0.82	0.02
	(0.04)	(0.05)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.01)
Exposure to very wet growing season (SPEI ≥ +1.5)	5.79	5.99	5.68	6.15	6.13	6.17	6.18	0.08
	(0.13)	(0.13)	-0.12	(0.13)	(0.13)	(0.13)	(0.13)	(0.01)
Exposure to moderately wet growing season (SPEI ≥ +1)	21.04	21.33	20.95	21.97	21.86	21.93	22.06	3.33
	(0.23)	(0.23)	(0.23)	(0.24)	(0.24)	(0.24)	(0.24)	(0.13)
Person-Years of Observation	100,260	106,987	89,334	–	–	–	–	–
N	–	–	–	5,924	5,968	5,967	5,872	1,857

Means are based on weighted data and are expressed as percentages, standard errors in parenthesis; person-years of observation and *N* are unweighted.

[a] The variables for this outcome refer to the last growing season only.

Note: Moderately wet events correspond to SPEI ranging from +1 and +1.49, very wet events correspond to SPEI ranging from +1.5 and +1.99, extremely wet events correspond to SPEI greater than +2, thus SPEI ≥ +1 encompasses moderately wet, very wet, and extremely wet events, and SPEI ≥ +1.5 encompasses very wet and extremely wet events.

Table 3 Discrete-time logit models of transition into first union and birth (log-odds ratios).

	Union Model 1	Birth Model 2
Exposure to growing-season drought	0.68^{***}	0.32^{+}
	(0.18)	(0.18)
Exposure to extremely wet growing season	-0.05	0.63^{*}
	(0.28)	(0.27)
Oldest	-0.02	-0.06^{+}
	(0.03)	(0.03)
Siblings (2,5]	-0.05	-0.08^{+}
	(0.04)	(0.04)
Siblings (5,8]	-0.06	-0.08^{+}
	(0.04)	(0.04)
Siblings 8+	-0.08	-0.04
	(0.05)	(0.06)
Rural	-0.31^{***}	-0.09^{+}
	(0.05)	(0.05)
Years of education	-0.17^{***}	-0.15^{***}
	(0.004)	(0.004)
Muslim	0.23^{***}	0.21^{**}
	(0.07)	(0.07)
Other/None	0.24^{***}	0.18^{***}
	(0.04)	(0.04)
Protestant	-0.05	-0.04
	(0.04)	(0.04)
Lomwe	0.21^{***}	0.14^{**}
	(0.05)	(0.05)
Ngoni	0.04	0.14^{*}
	(0.05)	(0.05)
Other	0.004	0.01
	(0.06)	(0.06)
Tumbuka	0.10	0.12
	(0.09)	(0.09)
Yao	-0.01	-0.05
	(0.06)	(0.07)
Person-Years of Observation	100,260	106,987
AIC	45,082.66	43,209.27

+p<.1; *p<.05; **p<.01; ***p<.001

Controls: age fixed effects, year of birth fixed effects, survey fixed effects, ERA-I cell fixed effects.

Table 4 Discrete-time logit models of transition into first birth within union and first birth outside of union (log-odds ratios).

	Birth within union[a] Model 1	Birth outside of union[b] Model 2
Exposure to growing-season drought	0.53*	0.56+
	(0.23)	(0.32)
Exposure to extremely wet growing season	1.82***	0.03
	(0.30)	(0.52)
Oldest	-0.01	-0.22***
	(0.04)	(0.06)
Siblings (2,5]	-0.08	-0.18**
	(0.06)	(0.07)
Siblings (5,8]	-0.12*	-0.19**
	(0.06)	(0.07)
Siblings 8+	-0.13+	-0.26**
	(0.07)	(0.09)
Rural	-0.49***	0.16*
	(0.07)	(0.07)
Years of education	-0.16***	-0.09***
	(0.01)	(0.01)
Muslim	0.24**	0.40***
	(0.08)	(0.11)
Other/None	0.38***	0.31***
	(0.05)	(0.06)
Protestant	-0.02	0.12+
	(0.05)	(0.07)
Lomwe	0.23***	-0.11
	(0.07)	(0.08)
Ngoni	-0.01	0.31***
	(0.07)	(0.08)
Other	0.22**	-0.16+
	(0.08)	(0.10)
Tumbuka	-0.33**	0.67***
	(0.13)	(0.15)
Yao	0.09	-0.15
	(0.08)	(0.10)
Person-Years of Observation	106,987	106,987
AIC	62,692.33	62,692.33

+p<.1; *p<.05; **p<.01; ***p<.001

Controls: age fixed effects, year of birth fixed effects, survey fixed effects, ERA-I cell fixed effects.

a Birth outside of union is treated as a competing risk.

b Birth within union is treated as a competing risk.

Note: It is important to note that although the point estimates on first births conceived following unions and on first births conceived outside of unions are very similar, the point estimate on first unions is twice as large as the point estimate on first births (Models 1–2, Table 3). When comparing point estimates across type of transition, it is important to keep in mind that those with lower count events have larger standard errors and vice-versa. In our case, first births conceived outside of union (5,909 events) are lower than births conceived within union (10,160 events). At the same time, the standard error of the point estimate on first births is also large relative to its coefficient.

Table 5 Discrete-time logit models of transition into marriage and cohabitation (log-odds ratios).

	Marriage[a] Model 1	Cohabitation[b] Model 2
Exposure to growing-season drought	0.88***	2.13***
	(0.22)	(0.60)
Exposure to extremely wet growing season	-0.38	0.74
	(0.35)	(1.19)
Oldest	-0.08+	0.23*
	(0.04)	(0.12)
Siblings (2,5]	-0.03	0.02
	(0.05)	(0.16)
Siblings (5,8]	-0.07	-0.02
	(0.05)	(0.17)
Siblings 8+	-0.06	-0.23
	(0.07)	(0.21)
Rural	-0.41***	0.14
	(0.06)	(0.17)
Years of education	-0.17***	-0.19***
	(0.01)	(0.02)
Muslim	0.22**	-0.26
	(0.08)	(0.25)
Other/None	0.26***	0.22
	(0.04)	(0.14)
Protestant	0.01	0.18
	(0.05)	(0.15)
Lomwe	0.20**	0.07
	(0.06)	(0.19)
Ngoni	-0.05	-0.39+
	(0.06)	(0.23)
Other	0.08	-0.32
	(0.07)	(0.22)
Tumbuka	-0.07	1.16***
	(0.11)	(0.25)
Yao	-0.07	-0.85***
	(0.08)	(0.26)
Person-Years of Observation	89,334	89,334
AIC	40,786.94	40,786.94

+p<.1; *p<.05; **p<.01; ***p<.001

Controls: age fixed effects, year of birth fixed effects, survey fixed effects, ERA-I cell fixed effects.

a Cohabitation is treated as a competing risk.
b Marriage is treated as a competing risk.

Table 6 Linear effects of droughts on partnership characteristics.

	Partner's years of education	Education difference	Age difference	Polygynous parntership	Wife's ranking
	Model 1	Model 2	Model 3	Model 4	Model 5
Exposure to growing-season drought	-1.04*	-0.06	0.03	0.02	-0.01
	(0.52)	(0.08)	(0.03)	(0.05)	(0.03)
Exposure to extremely wet growing season	-0.59	-0.07	-0.14+	-0.005	0.002
	(0.70)	(0.12)	(0.08)	(0.07)	(0.03)
Oldest	-0.09	-0.01	0.003	-0.01	-0.004
	(0.12)	(0.02)	(0.01)	(0.01)	(0.005)
Siblings (2,5]	-0.06	-0.03	0.001	-0.003	0.004
	(0.13)	(0.02)	(0.01)	(0.01)	(0.01)
Siblings (5,8]	0.04	-0.02	0.004	-0.01	0.004
	(0.13)	(0.02)	(0.01)	(0.01)	(0.01)
Siblings 8+	-0.10	-0.06*	-0.005	0.001	0.01
	(0.17)	(0.03)	(0.01)	(0.01)	(0.01)
Rural	-1.22***	-0.14***	-0.02**	0.02*	0.01
	(0.16)	(0.02)	(0.01)	(0.01)	(0.01)
Years of education	0.52***	-0.04***	-0.002	-0.003**	-0.0005
	(0.01)	(0.002)	(0.001)	(0.001)	(0.001)
Muslim	-0.62**	-0.08**	-0.01	0.05**	0.02*
	(0.19)	(0.03)	(0.01)	(0.02)	(0.01)
Other/None	-0.67***	-0.08***	0.01	0.02*	0.01
	(0.12)	(0.02)	(0.01)	(0.01)	(0.01)
Protestant	0.18	0.01	0.01	-0.01	-0.01
	(0.13)	(0.02)	(0.01)	(0.01)	(0.01)
Lomwe	0.17	0.02	0.01	0.03*	0.01+
	(0.15)	(0.02)	(0.01)	(0.01)	(0.01)
Ngoni	0.48**	0.05+	0.01	0.002	0.001
	(0.18)	(0.03)	(0.01)	(0.01)	(0.01)
Other	0.33+	0.01	0.01	0.01	0.01
	(0.18)	(0.03)	(0.01)	(0.01)	(0.01)
Tumbuka	0.31	0.02	-0.005	0.02	0.02
	(0.28)	(0.05)	(0.02)	(0.03)	(0.02)
Yao	0.21	0.04	0.03**	0.01	0.004
	(0.18)	(0.03)	(0.01)	(0.01)	(0.01)
N	5,924	5,924	5,968	5,967	5,872
R^2	0.3	0.075	0.016	0.042	0.027

+p<.1; *p<.05; **p<.01; ***p<.001

Controls: year of birth fixed effects, survey fixed effects, ERA-I cell fixed effects. Standard errors are clustered by ERA-I cell level and woman's year of birth.

Table 7 Linear effects of droughts on sex in exchange for cash/goods.

	Sex in exchange for cash/goods
Exposure to growing season droughts (t-1)	0.13^{+}
	(0.07)
Exposure to growing season wet events (t-1)	-0.52
	(0.52)
Oldest	-0.01
	(0.01)
Siblings (2,5]	-0.02
	(0.02)
Siblings (5,8]	-0.001
	(0.02)
Siblings 8+	-0.02
	(0.03)
Rural	-0.02
	(0.01)
Years of education	-0.004^{*}
	(0.002)
Muslim	-0.01
	(0.02)
Other/None	-0.01
	(0.01)
Protestant	-0.01
	(0.02)
Lomwe	-0.02
	(0.02)
Ngoni	-0.01
	(0.02)
Other	0.02
	(0.02)
Tumbuka	-0.01
	(0.03)
Yao	0.01
	(0.02)
Age at first sex	-0.01^{*}
	(0.003)
N	1,857
R^2	0.048

+p<.1; *p<.05; **p<.01; ***p<.001

Controls: year of birth fixed effects, ERA-I cell fixed effects. Standard errors are clustered by ERA-I cell level and woman's year of birth.