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

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Abstract:

This paper provides a conceptual overview and empirical investigation of how weather shocks impact young women's life course transitions. Drawing on the case of Malawi, we combine repeated cross-sections of georeferenced Demographic and Health Survey data with a cutting-edge measure of drought shocks. Discrete-time event history analyses indicate that 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 and outside of marriage (the latter is significant at $p<0.1$). Drought has a marginally significant positive impact on exchanging sex for goods/cash among unpartnered women, but exposure to extremely wet growing seasons—which are often beneficial for agricultural productivity—have a large negative impact on this outcome, which indicates that drought-related acceleration of life course transitions may be (partially) financially motivated.

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; Gray and Mueller 2012; Barreca, Deschenes, and Guldi 2015; Entwisle et al. 2016; Nawrotzki and DeWaard 2016; Gray and Bilsborrow 2013; Barreca, Deschenes, and Guldi 2018; Costello, Grant, and Horton 2008). 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 (Ragnar Anderson 2014), many of whom are particularly vulnerable to weather shocks. 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 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.

In what follows, we provide an overview of how and why weather shocks might influence young women's life course transitions in low-income rural contexts. We go onto empirically investigate the effects of drought shocks on the timing, sequencing, and characteristics of young adult women's transitions into unions and first births using a case study from Malawi. We focus on Malawi 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. We combine repeated cross-sections of georeferenced Malawi Demographic and Health Survey (DHS) survey data with a cutting-edge measure of drought shocks: The Standardised Precipitation Evapotranspiration Index (SPEI). In addition to our empirical analyses, our paper lays a framework and empirical approach for future exploration of how weather shocks impact young women's life course transitions in low-income rural contexts, 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

The transition to adulthood is a pivotal point in young women's lives that has become a focus of both researchers and policy makers interested in low-and middle-income contexts (LMIC) (Lloyd 2005). The transition to adulthood for women in LMIC 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 (Juárez and Gayet 2014; Hindin and Fatusi 2009). The sequencing in which these events occur is variable depending on the socio-cultural context (Mensch, Grant, and Blanc 2006). While it is widely acknowledged that young people's life course transitions are shaped by social and contextual factors, there has been considerably less discussion of how local environmental context—and particularly weather shocks—impacts the transition to adulthood in the global South. In what follows, we draw on available evidence from LMIC to provide an overview that helps understand how weather shocks might impact transitions to adulthood in low income rural contexts.

First, weather shocks may affect the *timing* of young adult women's life course transitions by accelerating transitions into unions and childbearing due to economic hardship. Weather shocks have large and profound effects on local economies and income generation activities, particularly in rural areas where people are dependent on agriculture for livelihoods (Asafu-Adjaye 2010; Raga, Olivera Villarroel, and Orbe 2012; Aggarwal and Pasricha 2011). Climate-related economic difficulties might lead to acceleration of partnership formation because families gain resources directly from monetary transfers that occur at union onset from husbands to wives families and indirectly from no longer having to support an additional household member (Goody 1971; Goody 2016). Partnership formation often corresponds with sexual activity and childbearing, thus by extension weather shocks could also lead to acceleration in the age at which these events occur as well.

Existing work on weather shocks and transitions to marriage in low-income contexts has focused on bride price and dowry payments as the dominant explanation for why marital timing might be affected by weather shocks. 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). On the other hand, 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). The authors 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.

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 and/or directly from informal cash or in-kind transfers that occur around marriages. Understanding how weather shocks impact unions in the absence of bride price is important because even in regions where bride-price is more prevalent (e.g. parts of sub-Saharan Africa, North Africa and Central and East Asia), there is enormous heterogeneity in the prevalence of bride price payments both between and within countries (Anderson 2007a).[i]

In addition to the economic explanation, there could be important psycho-social reasons for acceleration in life course transition in response to weather shocks. Weather shocks may accelerate partnerships and/or childbearing because women seek out emotional support in difficult times (Silver 2002). For example, following the 2004 Indonesian Tsunami, childless women transitioned into motherhood more quickly in communities with higher levels of mortality which suggests childbearing was a psychosocial response to being in a community context of high mortality (Nobles, Frankenberg, and Thomas 2015).

However, it is also plausible that weather shocks actually *delay* young women's ages at first sex, birth, marriage because people put off making important transitions in times of economic hardship. In contexts where monetary transfers at unions flow from wives to husbands family (e.g. dowry), young women's entrance to marriage may be delayed due to resource constraints (Corno, Hildebrandt, and Voena 2016). Even in places where bride price is practiced, if men's livelihoods are also affected by weather shocks they may lack the resources necessary to pay for bride prices (Hoogeveen, van der Klaauw, and van Lomwel 2011), leading to a delay in partnership formation. There also might be delays in transitions into unions in contexts where people establish their own home upon marriage if young people lack the resource to set up an independent household. There are also biological reasons why weather shocks could lead to declines in the initiation of childbearing. 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 (Frisch 1987; Frish 1994).

Weather shocks might also impact the *sequencing* of life course transitions, for example, by increasing the likelihood of sexual initiation (and correspondingly births) prior to union formation. In many places in low-income countries, premarital sexual activity is often accompanied by monetary or in-kind transfers (Mensch, Grant, and Blanc 2006; Poulin 2007; Meekers and Calves 1997; Leclerc-Madlala 2003), thus young women in areas affected by weather shocks could have financial incentives to initiate sex or childbearing prior to union entry. This could be particularly the case since pre-marital sex and childbearing are already increasingly becoming common practices in many parts of Latin America and Africa (Esteve and Lesthaeghe 2012; Clark, Koski, and Smith-Greenaway 2017; Mensch, Grant, and Blanc 2006).

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. 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). In the latter case, this could take the form of a polygynous union—particularly in sub-Saharan Africa where polygyny remains common—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 and Lesthaeghe 2012; Moore and Govender 2013). There could be important changes in the local marriage market for women in affected areas because out-migration is a common response to climate change (McLeman and Smit 2006). 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) and/or older men (if younger men are more likely to leave).

While weather shocks often have negative ramifications for local livelihoods and economies, there are also instances when weather shocks could be positive for rural livelihoods, for example, if rainfall shocks lead to improvements in agricultural productivity. In support of this, a study in Senegal finds that 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.

Case study: Transitions to adulthood in Malawi

We empirically investigate how droughts affect the transition to adulthood using a case study from 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 smallholder subsistence agriculture (ICF International 2017). The rural population depends heavily on crop production—particularly of maize—for sustenance. The country is highly vulnerable to weather shocks which disrupt agricultural production of maize and other staple crops (Pauw, Thurlow, and van Seventer 2010). Pauw and colleagues estimate that droughts currently cause GDP losses of almost 1% per year in Malawi and contribute heavily to food insecurity and poverty. Likewise, floods (which tend to be concentrated in the Southern region of the country) contribute to GDP loss of about 0.7 annually. In 2016, the president of Malawi declared a state of emergency after an ongoing drought contribution to food productivity loss that contributed to food insecurity for almost 20% of the population (AlJazeera 2019).

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; Poulin 2007; Meekers 1992). 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 (Clark, Koski, and Smith-Greenaway 2017; Mensch, Grant, and Blanc 2006). 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 (Poulin 2007). 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 1 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. 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-run analyses with the entire DHS sample of young adult women ages 15–24.

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[ii], 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 looking at a number of partnership characteristics for partnered respondents. First, we look at the partner's educational attainment with a continuous measure of partner's years of education. 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. 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 their first union formation and birth. 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 2). 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 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, 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:

$$\mathrm{gs\_drought\_}ei_{\mathrm{g,d}} = \omega_{\mathrm{g,t}} * \mathrm{gs\_drought\_}ei_{1}^{\mathrm{g,d}} + \left(1-\omega_{\mathrm{g,d}}\right) * \mathrm{gs\_drought\_}ei_{2}^{\mathrm{g,d}} \quad \text{Eq. (1)}$$

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 $\omega_{g,d} = \frac{t-h^{g,d}}{12}$, 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.

The growing-season drought variable is a $[0; 1]$ continuous variable where 0 indicates that the woman did not experience any drought event prior to the event (e.g. union formation or conception) and 1 indicates that the woman experienced droughts for the whole growing-season period prior to the event.

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 marriage 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. 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 first birth. 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.

Finally, 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 asses the effects of drought on types of unions, we run 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. Second, to assess the effects of drought on partnership characteristics we run a series of linear regression models with additional outcomes including partner's educational attainment, age difference between the respondent and partner, and polygyny. For this analysis, we consider the presence of drought in the two growing seasons prior to the union onset and exclude women who have never been in a union, separated and widowed women, and women who have been in multiple unions. 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.

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).

Results

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

Malawian women in our sample initiated union formation and childbearing at young ages. 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).

To show descriptively how young adult women's transition into first unions and first births differ depending on exposure to drought we present a series of Kaplan-Meier survival function graphs. We categorise the growing-season drought variable as 0 for no drought during last two growing seasons, 1 for low exposure (drought for up to 20% of the months of the last two growing seasons), 2 for medium exposure (drought for 20% to 35% of the months of the last two growing seasons), and 3 for high exposure (drought for greater than 35% of the months of the last two growing seasons). The Kaplan-Meier survivor function graphs show that women who were highly exposed to growing-season drought in adolescence transition into both first births and first unions at earlier ages than those who were not exposed to any growing-season drought in adolescence (Fig. 1). On the other hand, there is less of a pronounced difference in transitions into first births and first unions between young women who were less highly exposed (e.g. low or medium exposure) to growing-season drought in adolescence compared to women who were not exposed to any growing-season drought. In total, the prevalence of drought was 2.2% of all person-years observed in our samples, thus highlighting that severe growing-season drought was a rare occurrence.

[Fig. 1 here]

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 2). Model 1 shows that exposure to growing-season drought significantly increases young adult women's transitions into first unions. Specifically, a one-unit increase in exposure to growing-season drought in adolescence—in other words 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. The transition into first unions is often closely related to initiation of childbearing in Malawi, thus we also look at whether exposure to growing-season drought in adolescence has impacts on young adult women's transitions into first births. We find that a one-unit increase in exposure to growing-season drought in adolescence increases the log-odds of young women's first birth by 0.32 (p<0.10), although this result is only significant at unconventional 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 conditions increases the log-odds of young women's first birth by 0.63 (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.

[Table 2 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 and first births. 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 3 presents discrete-time logistic regression models where no birth by survey end, 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 leads to a 0.53 increase in the log-odds of 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). We also find that exposure to growing-season drought in adolescence leads to a 0.56 increase in the log-odds of first births conceived outside of unions (compared to having no births), although this finding is only unconventionally significant at $p<0.10$. This increase in births conceived outside of unions could be because drought-related economic hardships make young women more inclined to enter sexual relationships for gifts or cash (Meekers and Calves 1997) and many women do not use reliable contraception until after a first birth in Malawi (Behrman et al. 2018). Alternatively, women may be more inclined to initiate romantic partnership as a form of emotional support if droughts are associated with psychosocial stress in the family and community.

In addition to our drought variable, we also find that going from no exposure to extremely wet growing seasons to full exposure to extremely wet growing seasons in adolescence leads to an increase in the log-odds of young adult women's first births conceived in unions by 1.82 (compared to having no births by survey), though there is no significant effect of full exposure to extremely wet growing seasons in adolescence on births conceived outside of unions (compared to having no births by survey). 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).

[Table 3 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 4 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 growing-season drought to full exposure to growing-season drought leads to a 0.88 increase in the log-odds of young women's transition into marriage (compared to no union formation) ($p<0.001$). Model 2 shows that, compared with no exposure to growing-season drought, full exposure to growing-season drought leads to an increase in the log-odds of young women's transitions into cohabitation by 2.13 (compared to no union formation) ($p<0.001$). The marriage and cohabitation coefficients are statistically different at $p<0.05$, 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 4 here]

As a next step, we explore the effects of droughts on partnership characteristics because drought may impact local marriage markets due to outmigration. 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 5). In particular, going from zero drought exposure during growing seasons to drought to exposure for the full growing-season period leads to a one-year reduction in the partner's years of education, which is a sizeable impact when we consider the overall low levels of education in the sample (for example on average women in the sample have about 6 years of education (Table1)). This finding suggests that women exposed to growing-season drought are more likely to end up in relationships with less educated men than they would have in the absence of drought, which could be because of drought-related out-migration of more educated men (Luke and Munshi 2006). On the other hand, we do not find any significant effects of exposure to growing-season drought on the age difference between the respondent and her partner or on the presence of other wives (e.g. polygyny) (Models 2–4).

[Table 5 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. We find that, compared with no exposure to growing-season drought, full exposure to growing-season drought leads to a 13-percentage point increase in the probability of exchanging sex for goods/cash, although this finding is only statistically significant at the $p<0.10$ level (Table 6). Nonetheless, this finding lends some support to the notion that exchange of sex for material resources can be a financial coping strategy in hard times. At the same time, exposure to extremely wet growing-season conditions is significantly associated with reductions in the probability of exchanging sex for goods/cash ($p<0.001$). The magnitude of this coefficient is particularly striking, suggesting that going from no extremely wet growing-season conditions to extremely wet conditions for the full growing-season period leads to a 52-percentage point reduction in the probability of exchanging sex for cash/goods. The very large magnitude of this coefficient likely reflects that the prevalence of extremely wet growing-season conditions for the full growing season was extremely rare (0.02% of person-years). Nonetheless, this finding suggests that women are less likely to engage in sex (at least partly) for financial gain when both food and income resources are abundant after a wet growing season.

[Table 6 here]

Supplementary analyses

One limitation of our analysis was 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. It is also plausible that more educated women were more likely to out-migrate either in response to weather shocks or in search of economic opportunities. As a supplement, we run our analyses on the full sample of women ages 15 to 24 from the Malawi DHS and show that our main findings are similar to those generated using the fall sample of DHS women (Table S1, Supplementary Material)[iii].

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[iv] 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 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

Although weather-related shocks affect the livelihoods of people around the world, there is limited work on how shocks impact life course transitions among young people in low-income rural contexts. Drawing on this research gap, we provided an overview of the reasons why weather shocks might impact the timing, sequencing, and characteristics of young people's life course transitions in low-income countries. Next, using the case of Malawi we explored the effects of plausibly exogenous drought shocks on the timing, sequencing, and characteristics of young adult women's life-course transitions. As a supplement, we also looked at whether exposure to extremely wet conditions during growing seasons—which can be viewed as a "positive" shock for agricultural productivity—impacted these same transitions.

Our results indicated that exposure to growing-season drought in adolescence accelerated young adult women's transitions into first unions—including both cohabitation and marriage. This was a striking finding given bride price was not common in Malawi, which meant that drought accelerated young adult women's transitions into unions even in the absence of financial incentives for bride price, which has been the focus of existing literature on the topic in Africa. We speculated that even in the absence of bride price young women and their families had 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. Alternatively, the accelerating effect of drought on union formation could be due to comfort seeking or other psychosocial explanations for why young women form partnerships in stressful situations.

In addition to accelerating union formation, growing-season drought had an accelerating effect on initiation of childbearing both outside of and within unions (though the former was only significant at unconventional levels). It was likely that the accelerating effects of drought on childbearing within marriage and cohabitation corresponded with the quicker transitions into unions since childbearing often follows the initiation of marriage in Malawi. We also speculated that the (marginally significant) increase in births conceived outside of unions could be because drought-related economic hardships make young women more inclined to enter sexual relationships for gifts or cash. In support of this, we found that exposure to growing-season drought led to a (marginally significant) increase in reports of exchanging sex for cash or goods among unpartnered women. Although this finding was only statistically significant at unconventional levels, it was dramatic in comparison to the findings that exposure to extremely wet growing-season conditions—which often corresponded with a positive food and income shock—led to large and significant reductions in unpartnered women exchanging sex for cash or goods.

Taken together, our findings suggested that growing-season drought have large and important impacts on key dimensions of young women's life course transitions.

Nonetheless, the cross-sectional nature of the DHS led to several 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. 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 had a positive impact on exchanging sex for goods/money—but extremely wet growing seasons had the opposite effect—suggested that resource-constrained women entered unions partly as a coping strategy. 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 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. Given the heterogeneity in transitions to adulthood across contexts, it would be important to explore these issues in other contexts as well. We would expect that drought might have different impacts on the timing, sequencing, or life course transitions of young women in other contexts. 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.

Supplementary Material

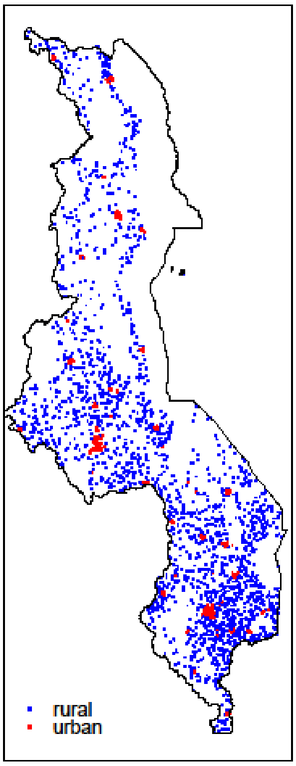
Appendix 1. Detailed discussion of sample creation

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) climate data on Malawi from the European Centre for Medium-Term Weather Forecasting (ECMWF); and (3) calendar crop data for Malawi from the Global Monthly Irrigated and Rainfed Crop Areas (MIRCA2000). Combing these data sources allows us to calculate a measure of drought shocks based on the SPEI index, and link this measure to young adult women's life course information (described in further detail in the section on treatment in the main text).

In what follows we describe each of the data sources used in our analysis in detail and also describe the climate parameters we take to create the SPEI index.

First, the individual-level data come from four Malawi Demographic and Health Surveys: 2000, 2004, 2010, 2015–16. The DHS is cross-sectional publicly available data that is nationally representative of women of reproductive age (e.g. 15-49), collected by ICF international in collaboration with host country governments. The DHS includes detailed information about union and family formation, reproductive health, fertility, and georeferenced information (i.e. latitude and longitude) on the woman's location (Fig. S1).

Fig. S1 Spatial distribution of the DHS cluster across Malawi by type of residence (rural/urban).



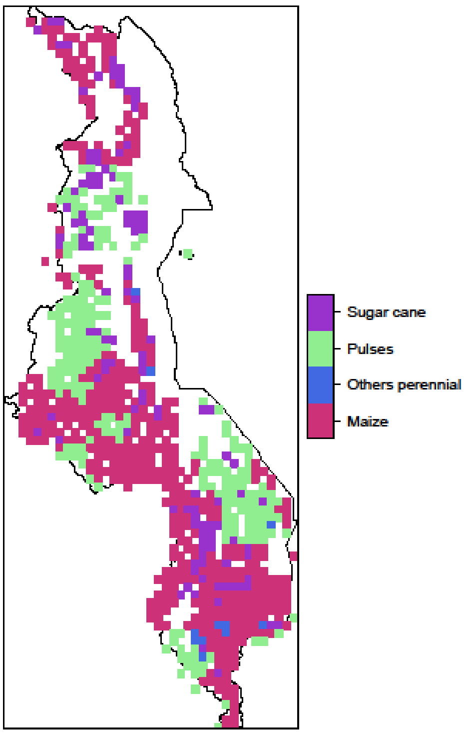
Because we are interested in union and family transitions in early adulthood, we focus our analysis on a sample of young adult women aged 15–24. The DHS uses a stratified random sampling design, where the primary geographic sampling unit is the cluster (also known as the primary sampling unit). We limit our sample to young adult women who report living in the same cluster 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. This is an important step since 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. For example, women may have migrated in response to a weather shock or to marriage, so that based on their current location it appears that they were unaffected by weather shocks when in fact the reverse is true. This has been a limitation of other work on weather shocks and marriage, which have relied upon cross-sectional information about current location to assess the effect of exposure to droughts in adolescence on marital transitions (Corno and Voena 2016).

We take advantage of the fact that matrilineal lineage is common in Malawi (Peters 2010) which means that there are very 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). Because bride price is less common in Malawi, this allows us to explore whether weather shocks impact young adult women's marital and life-course transitions even largely in the absence of bride price payments. Although existing studies have focused on bride price as the main reason weather shocks might impact transitions to marriage in Africa (Corno and Voena 2016; Corno, Hildebrandt, and Voena 2016; Hoogeveen, van der Klaauw, and van Lomwel 2011), weather shocks might still affect marriage because of the indirect financial gains from marriage. Given that the prevalence of bride price is highly heterogenous in Africa (Anderson 2007b), there is a need for a broader understanding of how weather shocks impact young people's life course transitions even in the absence of bride price payments.

Second, the climate data is taken from the ERA-Interim archive produced by the European Centre for Medium-Term Weather Forecasting (ECMWF). Weather outcomes are available for every six hours from 1 January 1979 to 31 August 2016, on a global grid of parallels and meridians at a 0.75 × 0.75-degree resolution (Dee et al. 2011). We use data on monthly mean daily net solar radiation, daily maximum and minimum air temperature, monthly mean daily wind speeds at 10 m height, monthly mean daily dewpoint temperature, and elevation above sea level.

Third, calendar crop data is used to identify the growing-season months of the main crop grown (ranked by harvested area) in a given cell. We use the Global Monthly Irrigated and Rainfed Crop Areas (MIRCA2000), which is a data set of monthly growing seasons of 26 irrigated and rainfed crops at different latitudes and longitudes, with a spatial resolution of 5 arc-minute grids (Portmann et al. 2010). We select the crop with the greatest value in each cell, in other words the main crop grown in the cell. The growing-seasons months are defined as those between the last month of the planting period and the first month of the harvesting period. Fig. S2 provides a full picture of the cultivation pattern across Malawi and shows variation in the crop spatial distribution. 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.

Fig. S2 Spatial distribution of main crop across Malawi.



Appendix 2. Detailed discussion of creation of SPEI

Drought shocks have become one of the major manifestations of climate change in contemporary Malawi, with far reaching implications for livelihoods and population wellbeing. Exposure to growing-season drought is measured by construction of the Standardised Precipitation Evapotranspiration Index (SPEI). The Standardised Precipitation Evapotranspiration Index (SPEI) has been identified as the most complete and robust agricultural drought index in Africa (WMO 2012). The SPEI presents an improved measure of drought that includes climate indicators other than just precipitation. This is relevant because increases in evaporation from soil and vegetation—in addition to decreases in precipitation—play a role in droughts. Specifically, agricultural droughts are associated with a shortage of water for plant growth and are assessed as insufficient soil moisture to replace evapotranspirative losses (WMO 1975), which in turn affects crop yields and variability. The SPEI measures drought severity, intensity and duration, and allows for comparisons of drought severity through space and time (Vicente-Serrano et al. 2010). The SPEI at a 3 month-time scale reflects short and medium-term moisture conditions, thus providing a seasonal estimation of precipitation as it is relevant for agriculture.

A further benefit of our approach is that we focus on climatic conditions during the growing seasons—when crops are most vulnerable to drought— rather than using monthly or year rainfall averages as in Corno et al. (2016). The latter approach is problematic because it averages climatic conditions over a relatively long timeframe, which can mask important short-term shocks that are devastating to key crops. The SPEI index has been used to look at the effects of agricultural shocks on conflict (Harari and Ferrara 2018; Uexkull et al. 2016) and the effects of drought shocks on child mortality (Andriano 2018), however our analysis represents the first time it is combined with data on young people's life course transitions.

For this analysis, we calculate the potential evapotranspiration (PET) based on the FAO-56 Penman-Monteith estimation[v] and the 3-month SPEI (SPEI3) for each cell and month from Jan 1979 to Aug 2016. 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 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, 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:

$$\mathrm{gs\_drought\_e}i_{\mathrm{g,d}} = \omega_{\mathrm{g,t}} * \mathrm{gs\_drought\_}ei_{1}^{\mathrm{g,d}} + \left(1 - \omega_{\mathrm{g,d}}\right) * \mathrm{gs\_drought\_}ei_{2}^{\mathrm{g,d}} \quad \text{Eq. (1)}$$

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 $\omega_{g,d} = \frac{t-h^{g,d}}{12}$, 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. The growing-season drought variable is a $[0; 1]$ continuous variable where 0 indicates that the woman did not experience any drought event prior to the event and 1 indicates that the woman experienced droughts for the whole growing-season period prior to the event.

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).

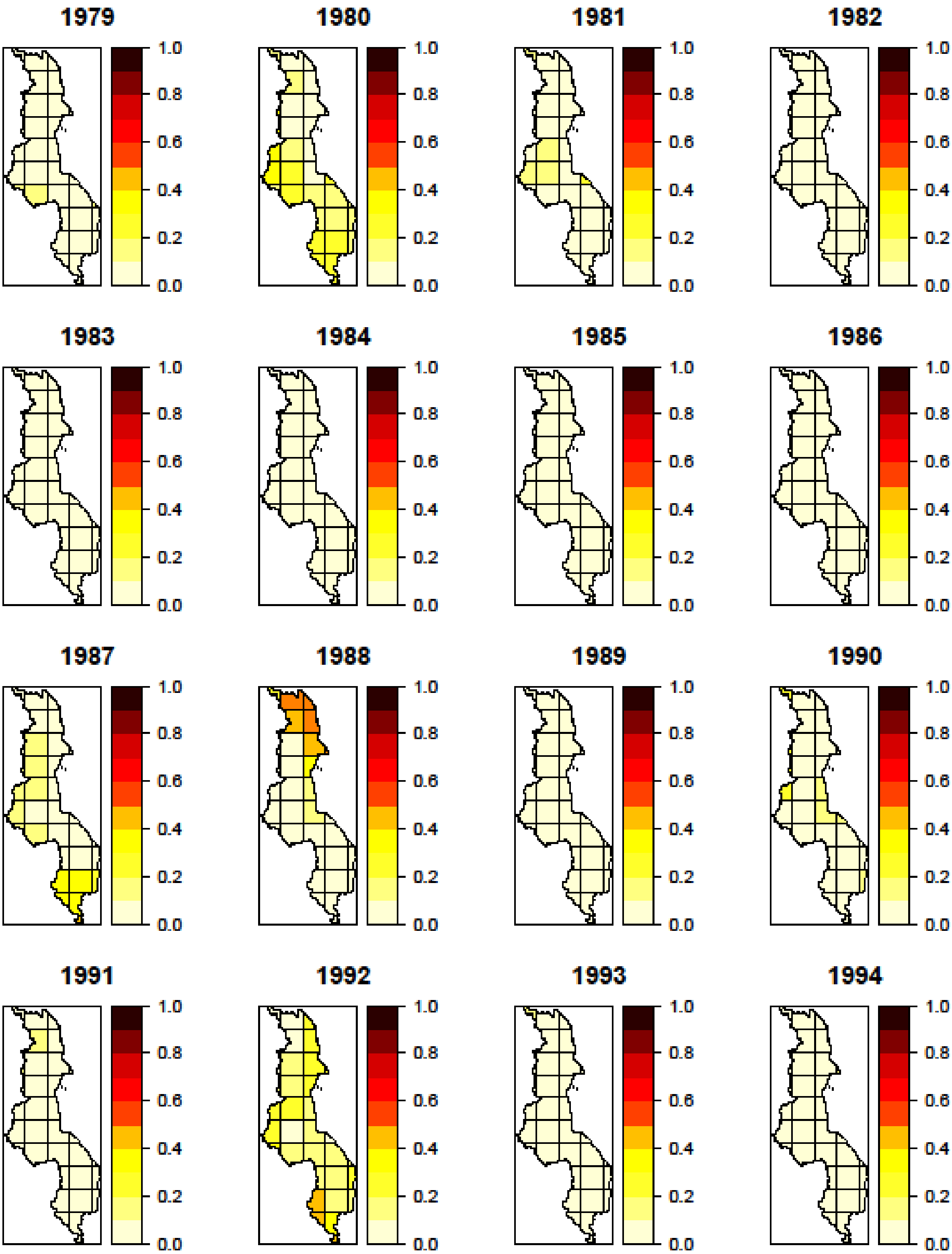
Table S1 Discrete-time logit models first union and birth (log-odds ratios) – full sample.

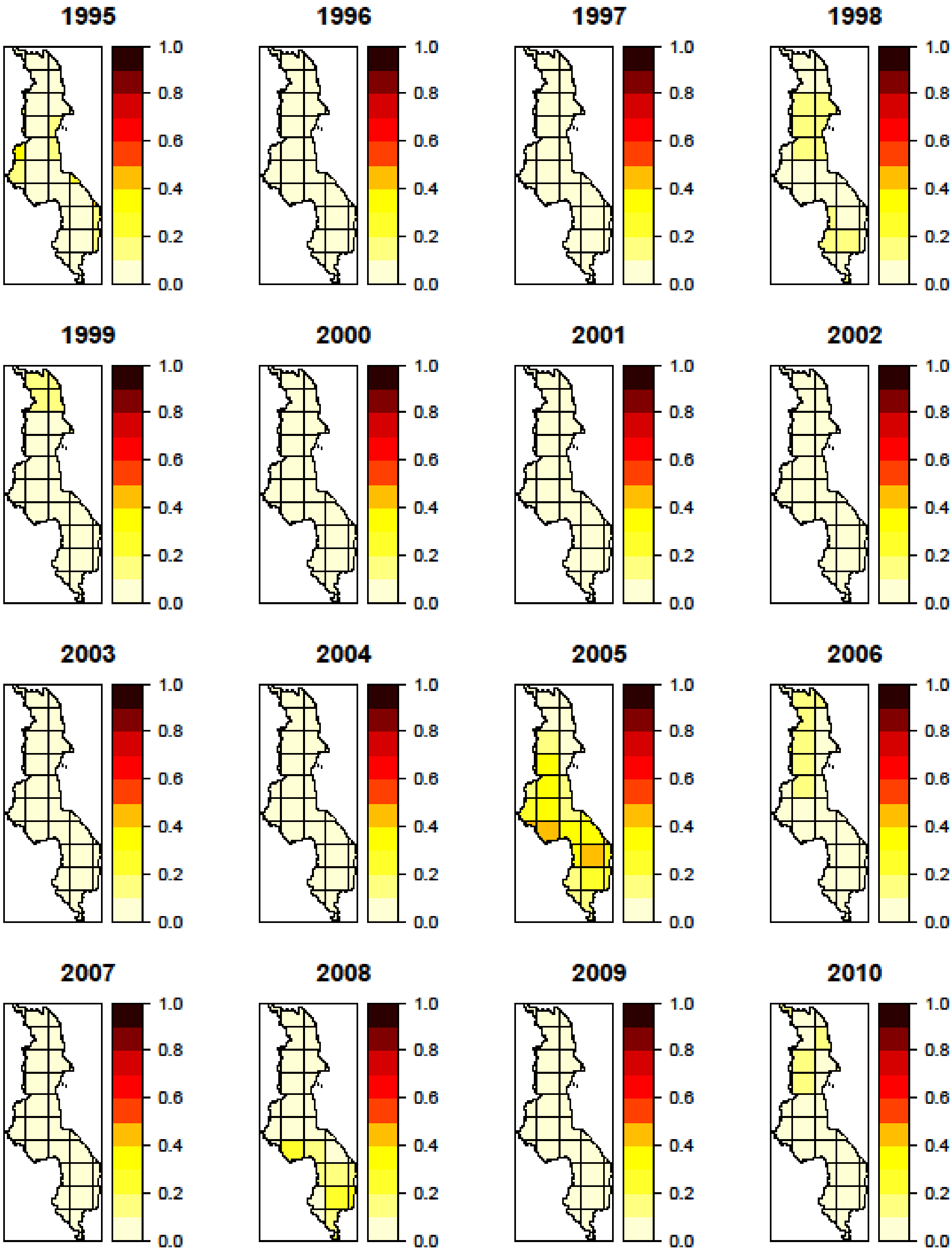
	Union Model 1	Birth Model 2
Exposure to growing-season drought	0.39**	0.04
	(0.12)	(0.13)
Oldest	-0.002	-0.01
	(0.02)	(0.02)
Siblings (2,5]	0.02	-0.03
	(0.03)	(0.03)
Siblings (5,8]	0.03	-0.01
	(0.03)	(0.03)
Siblings 8+	0.0001	0.03
	(0.04)	(0.04)
Exposure to extremely wet growing season	-0.22	0.30
	(0.20)	(0.20)
Rural	-0.23***	-0.17***
	(0.03)	(0.03)
Years of education	-0.17***	-0.14***
	(0.003)	(0.003)
Muslim	0.18***	0.16***
	(0.05)	(0.05)
Other/None	0.21***	0.15***
	(0.02)	(0.03)
Protestant	-0.06*	-0.04
	(0.03)	(0.03)
Lomwe	0.24***	0.21***
	(0.04)	(0.04)
Ngoni	0.09**	0.17***
	(0.04)	(0.04)
Other	0.09*	0.08*
	(0.04)	(0.04)
Tumbuka	0.10*	0.11*
	(0.05)	(0.05)
Yao	0.05	0.03
	(0.05)	(0.05)
Person-Years of Observation	186,584	201,245
AIC	92,587.36	86,504.68

+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.

Fig. S3 Spatial distribution of droughts across Malawi, 1979–2016.




1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
1.0
0.8
0.6
0.4
0.2
0.0

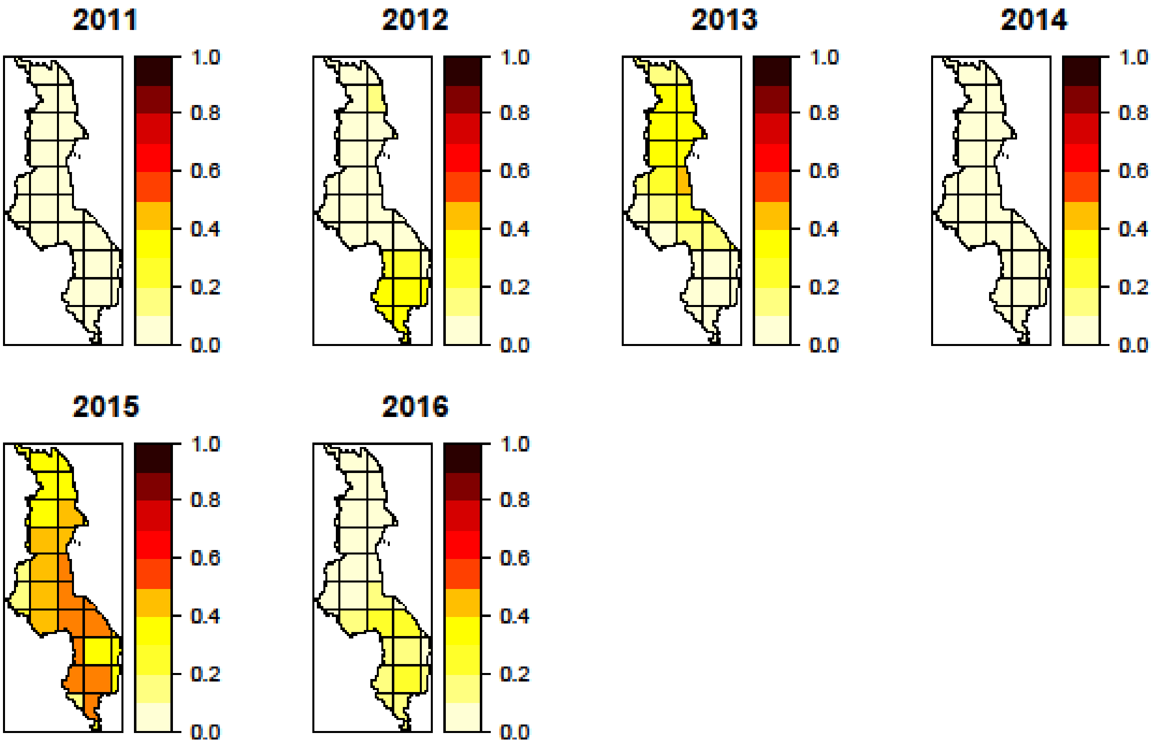
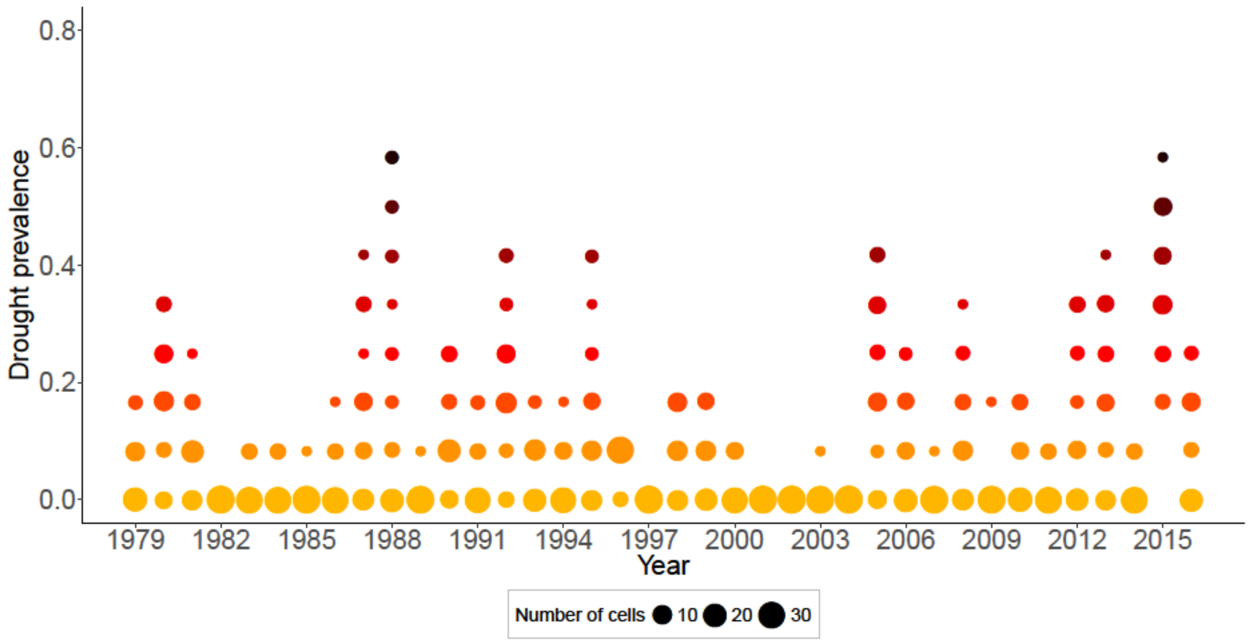

2011
2012
2013
2014
2015
2016
1.0
0.8
0.6
0.4
0.2
0.0

Fig. S4 Drought prevalence in Malawi over time, 1979–2006.



Works Cited

Aggarwal, Deepika, and J S Pasricha. 2011. “Climate Change and Its Impacts on Indian Agriculture.” *The International Journal of Climate Change: Impacts and Responses* 2 (3): 163–72. doi:10.18848/1835-7156/CGP/v02i03/37060.

AlJazeera. 2019. “Malawi Declares State of Emergency Over Drought .” AlJazeera.

Anderson, Siwan. 2007a. “The Economics of Dowry and Brideprice.” *Journal of Economic Perspectives* 21 (4): 151–74. doi:10.1257/jep.21.4.151.

Anderson, Siwan. 2007b. “The Economics of Dowry and Brideprice.” *The Journal of Economic Perspectives*. JSTOR, 151–74.

Andriano, Liliana. 2018. “The Effect of Weather Shocks During Conception and Pregnancy on Under-Five Mortality in Sub-Saharan Africa: the Role of Maternal Education.” Oxforod.

Asafu-Adjaye, John. 2010. “The Economic Impacts of Climate Change in Sub-Saharan Africa.” *The International Journal of Climate Change: Impacts and Responses* 2 (1): 103–18. doi:10.18848/1835-7156/CGP/v02i01/37294.

Barreca, Alan, Olivier Deschenes, and Melanie Guldi. 2015. “Maybe Next Month? Temperature Shocks, Climate Change, and Dynamic Adjustmetns in Birth Rates .” *NBER Working Paper*. Vol. 21681.

Barreca, Alan, Olivier Deschenes, and Melanie Guldi. 2018. “Maybe Next Month? Temperature Shocks and Dynamic Adjustments in Birth Rates.” *Demography* 55 (4). Springer US: 1269–93. doi:10.1007/s13524-018-0690-7.

Beegle, Kathleen, and Michelle Poulin. 2012. “Migration and the Transition to Adulthood in Contemporary Malawi.” *Working Paper*, September, 1–24.

Behrman, Julia Andrea, Kelsey Quinn Wright, M Grant, and Erica Soler-Hampejsek. 2018. “Trends in Modern Contraceptive Use Among Young Adult Women in Sub-Saharan Africa 1990 to 2014.” *Studies in Family Planning* 49 (4): 319–44. doi:10.1111/sifp.12075.

Bledsoe, Caroline. 1990. “Transformations in Sub-Saharan African Marriage and Fertility.” *The ANNALS of the American Academy of Political and Social Science* 510 (1): 115–25. doi:10.1177/0002716290510001009.

Clark, Shelley, Alissa Koski, and Emily Smith-Greenaway. 2017. “Recent Trends in Premarital Fertility Across Sub-Saharan Africa.” *Studies in Family Planning* 48 (1): 3–22. doi:10.1111/sifp.12013.

Corno, L, N Hildebrandt, and A Voena. 2016. “Weather Shocks, Age of Marriage and the Direction of Marriage Payments.”

Corno, Lucia, and A Voena. 2016. “Selling Daughters: Age of Marriage, Income Shocks and the Bride Price Tradition.” IFS. doi:10.1920/wp.ifs.2016.1608.

Costello, Anthony, Malcolm Grant, and Richard Horton. 2008. “The Lancet–UCL Commission: Health Effects of Climate Change.” *The Lancet* 371 (9619): 1145–47. doi:10.1016/S0140-6736(08)60502-4.

Entwisle, Barbara, Nathalie E Williams, Ashton M Verdery, Ronald R Rindfuss, Stephen J Walsh, George P Malanson, Peter J Mucha, et al. 2016. “Climate Shocks and Migration: an Agent-Based Modeling Approach.” *Population and Environment* 38 (1). Springer Netherlands: 47–71. doi:10.1007/s11111-016-0254-y.

Esteve, A, and R Lesthaeghe. 2012. “The Latin American Cohabitation Boom, 1970–2007.” *Population and Development Review* 38 (1): 55–81. doi:10.1111/j.1728-4457.2012.00472.x/abstract.

Goody, Jack. 1971. “Class and Marriage in Africa and Eurasia.” *American Journal of Sociology* 76 (4): 585–603. doi:10.1086/224973.

Goody, Jack. 2016. “Inheritance, Property, and Marriage in Africa and Eurasia.” *Sociology* 3 (1): 55–76. doi:10.1177/003803856900300104.
Gray, Clark, and Richard Bilsborrow. 2013. “Environmental Influences on Human Migration in Rural Ecuador.” *Demography* 50 (4). Springer US: 1217–41. doi:10.1007/s13524-012-0192-y.
Gray, Clark, and Valerie Mueller. 2012. “Drought and Population Mobility in Rural Ethiopia.” *World Development* 40 (1): 134–45. doi:10.1016/j.worlddev.2011.05.023.
Harari, Mariaflavia, and Eliana La Ferrara. 2018. “Conflict, Climate, and Cells: a Disaggregated Analysis.” *The Review of Economics and Statistics* 100 (4). MIT Press: 594–608. doi:10.1162/rest_a_00730.
Hindin, Michelle J, and Adesegun O Fatusi. 2009. “Adolescent Sexual and Reproductive Health in Developing Countries: an Overview of Trends and Interventions.” *International Perspectives on Sexual and Reproductive Health* 35 (2). JSTOR: 58–62. http://sparky.guttmacher.org/pubs/journals/3505809.pdf.
Hoogeveen, Johannes, Bas van der Klaauw, and Gijsbert van Lomwel. 2011. “On the Timing of Marriage, Cattle, and Shocks.” *Economic Development and Cultural Change* 60 (1): 121–54. doi:10.1086/661215.
ICF International. 2017. “Malawi Demographic and Health Survey 2015-16 .”
Juárez, Fatima, and Cecilia Gayet. 2014. “Transitions to Adulthood in Developing Countries.” *Annual Review of Sociology* 40 (1): 521–38. doi:10.1146/annurev-soc-052914-085540.
Lam, D A, and J Miron. 1996. “The Effects of Temperature on Human Fertility.” *Demography* 33 (3): 291–305.
Leclerc-Madlala, Suzanne. 2003. “Transactional Sex and the Pursuit of Modernity.” *Social Dynamics* 29 (2): 213–33. doi:10.1080/02533950308628681.
Lloyd, Cynthia. 2005. *Growing Up Global: the Changing Transitions to Adulthood in Developing Countries*. Edited by Cynthia Lloyd. Washington, D.C.: National Academies Press. doi:10.17226/11174.
Luke, Nancy, and Kaivan Munshi. 2006. “New Roles for Marriage in Urban Africa: Kinship Networks and the Labor Market in Kenya.” *The Review of Economics and Statistics* 88 (2). The MIT Press: 264–82. doi:10.1162/rest.88.2.264.
McLeman, R, and B Smit. 2006. “Migration as an Adaptation to Climate Change.” *Climatic Change* 76 (1-2). Springer Netherlands: 31–53. doi:10.1007/s10584-005-9000-7.
Meekers, D, and A-E Calves. 1997. “‘Main’Girlfriends, Girlfriends, Marriage, and Money: the Social Context of HIV Risk Behaviour in Sub-Saharan Africa.” *Health Transition Review* Supp 7: 361–75.
Meekers, Dominique. 1992. “The Process of Marriage in African Societies: a Multiple Indicator Approach.” *Population and Development Review* 18 (1): 61. doi:10.2307/1971859.
Mensch, Barbara S, M Grant, and Ann K Blanc. 2006. “The Changing Context of Sexual Initiation in Sub-Saharan Africa.” *Population and Development Review* 32 (4). Wiley Online Library: 699–727.
Moore, Elena, and Rajen Govender. 2013. “Marriage and Cohabitation in South Africa: an Enriching Explanation?.” *Journal of Comparative Family Studies* 44 (5). Dr. George Kurian: 623–39. doi:10.2307/23644622?refreqid=search-gateway:b8244f79b04259e49df54cefefdfdbd2.
Nawrotzki, Raphael J, and Jack DeWaard. 2016. “Climate Shocks and the Timing of Migration From Mexico.” *Population and Environment* 38 (1). Springer Netherlands: 72–100. doi:10.1007/s11111-016-0255-x.

Nobles, Jenna, Elizabeth Frankenberg, and Duncan Thomas. 2015. “The Effects of Mortality on Fertility: Population Dynamics After a Natural Disaster.” *Demography* 52 (1). Springer US: 15–38. doi:10.1007/s13524-014-0362-1.
Pauw, K, J Thurlow, and D van Seventer. 2010. “Droughts and Floods in Malawi.” International Food Policy Reserach Institute.
Peters, Pauline E. 2010. “‘Our Daughters Inherit Our Land, but Our Sons Use Their Wives' Fields’: Matrilineal-Matrilocal Land Tenure and the New Land Policy in Malawi.” *Journal of Eastern African Studies* 4 (1). Taylor & Francis Group : 179–99. doi:10.1080/17531050903556717.
Pitt, Mark, and Wendy Sigle. 1998. “Seasonality, Weather Shocks, and the Timing of Births and Child Mortlaity in Senegal .” Providence, Rhode Island.
Posel, Dorrit, Stephanie Rudwick, and Daniela Casale. 2011. “Is Marriage a Dying Institution in South Africa? Exploring Changes in Marriage in the Context of Ilobolopayments.” *Agenda* 25 (1). Taylor & Francis Group: 102–11. doi:10.1080/10130950.2011.575589.
Poulin, Michelle. 2007. “Sex, Money, and Premarital Partnerships in Southern Malawi.” *Social Science & Medicine* 65 (11): 2383–93. doi:10.1016/j.socscimed.2007.05.030.
Raga, Graciela Binimelis, S Marcelo Olivera Villarroel, and Roberto Orbe. 2012. “The Economic Effects of Intense Rainfall in Central States of the Pacific Coast of Mexico: Global Warming Impacts on Agriculture.” *The International Journal of Climate Change: Impacts and Responses* 3 (1): 89–108. doi:10.18848/1835-7156/CGP/v03i01/37090.
Ragnar Anderson, Christine Panchaud Susheela Singh and Katherine Watson. 2014. “Demystifying Data: a Guide to Using Evidence to Improve Young People's Sexual Health and Rights.” New York: Guttmacher Instittue and International Planned Parenthood Federation.
Silver, Roxane Cohen. 2002. “Nationwide Longitudinal Study of Psychological Responses to September 11.” *Jama* 288 (10): 1235. doi:10.1001/jama.288.10.1235.
Uexkull, von, Nina, Mihai Croicu, Hanne Fjelde, and Halvard Buhaug. 2016. “Civil Conflict Sensitivity to Growing-Season Drought.” *Proceedings of the National Academy of Sciences* 113 (44): 12391–96. doi:10.1073/pnas.1607542113.
WMO. 1975. “Drought and Agriculture: Report of the CAgM Working Group on the Assessment of Drought.” Technical Note No. 138.

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 Discrete-time logit models 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)
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)
Exposure to extremely wet growing season	-0.05	0.63*
	(0.28)	(0.27)
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 3 Discrete-time logit models of first birth within union and first birth outside of union (log-odds ratios).

	Birth within union[a]	Birth outside of union[b]
	Model 1	Model 2
Exposure to growing-season drought	0.53*	0.56+
	(0.23)	(0.32)
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)
Exposure to extremely wet growing season	1.82***	0.03
	(0.30)	(0.52)
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.

Table 4 Discrete-time logit models of 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)
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)
Exposure to extremely wet growing season	-0.38	0.74
	(0.35)	(1.19)
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 5 Linear effects of droughts on partnership characteristics.

	Years of education	Age difference	Polygynous parntership	Wife's ranking
	Model 1	Model 2	Model 3	Model 4
Exposure to growing-season drought	-1.04*	0.03	0.02	-0.01
	(0.52)	(0.03)	(0.05)	(0.03)
Oldest	-0.09	0.003	-0.01	-0.004
	(0.12)	(0.01)	(0.01)	(0.005)
Siblings (2,5]	-0.06	0.001	-0.003	0.004
	(0.13)	(0.01)	(0.01)	(0.01)
Siblings (5,8]	0.04	0.004	-0.01	0.004
	(0.13)	(0.01)	(0.01)	(0.01)
Siblings 8+	-0.10	-0.005	0.001	0.01
	(0.17)	(0.01)	(0.01)	(0.01)
Exposure to extremely wet growing season	-0.59	-0.14+	-0.005	0.002
	(0.70)	(0.08)	(0.07)	(0.03)
Rural	-1.22***	-0.02**	0.02*	0.01
	(0.16)	(0.01)	(0.01)	(0.01)
Years of education	0.52***	-0.002	-0.003**	-0.0005
	(0.01)	(0.001)	(0.001)	(0.001)
Muslim	-0.62**	-0.01	0.05**	0.02*
	(0.19)	(0.01)	(0.02)	(0.01)
Other/None	-0.67***	0.01	0.02*	0.01
	(0.12)	(0.01)	(0.01)	(0.01)
Protestant	0.18	0.01	-0.01	-0.01
	(0.13)	(0.01)	(0.01)	(0.01)
Lomwe	0.17	0.01	0.03*	0.01+
	(0.15)	(0.01)	(0.01)	(0.01)
Ngoni	0.48**	0.01	0.002	0.001
	(0.18)	(0.01)	(0.01)	(0.01)
Other	0.33+	0.01	0.01	0.01
	(0.18)	(0.01)	(0.01)	(0.01)
Tumbuka	0.31	-0.005	0.02	0.02
	(0.28)	(0.02)	(0.03)	(0.02)
Yao	0.21	0.03**	0.01	0.004
	(0.18)	(0.01)	(0.01)	(0.01)
N	5,924	5,968	5,967	5,872
R^2	0.300	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-cell level and woman's year of birth.

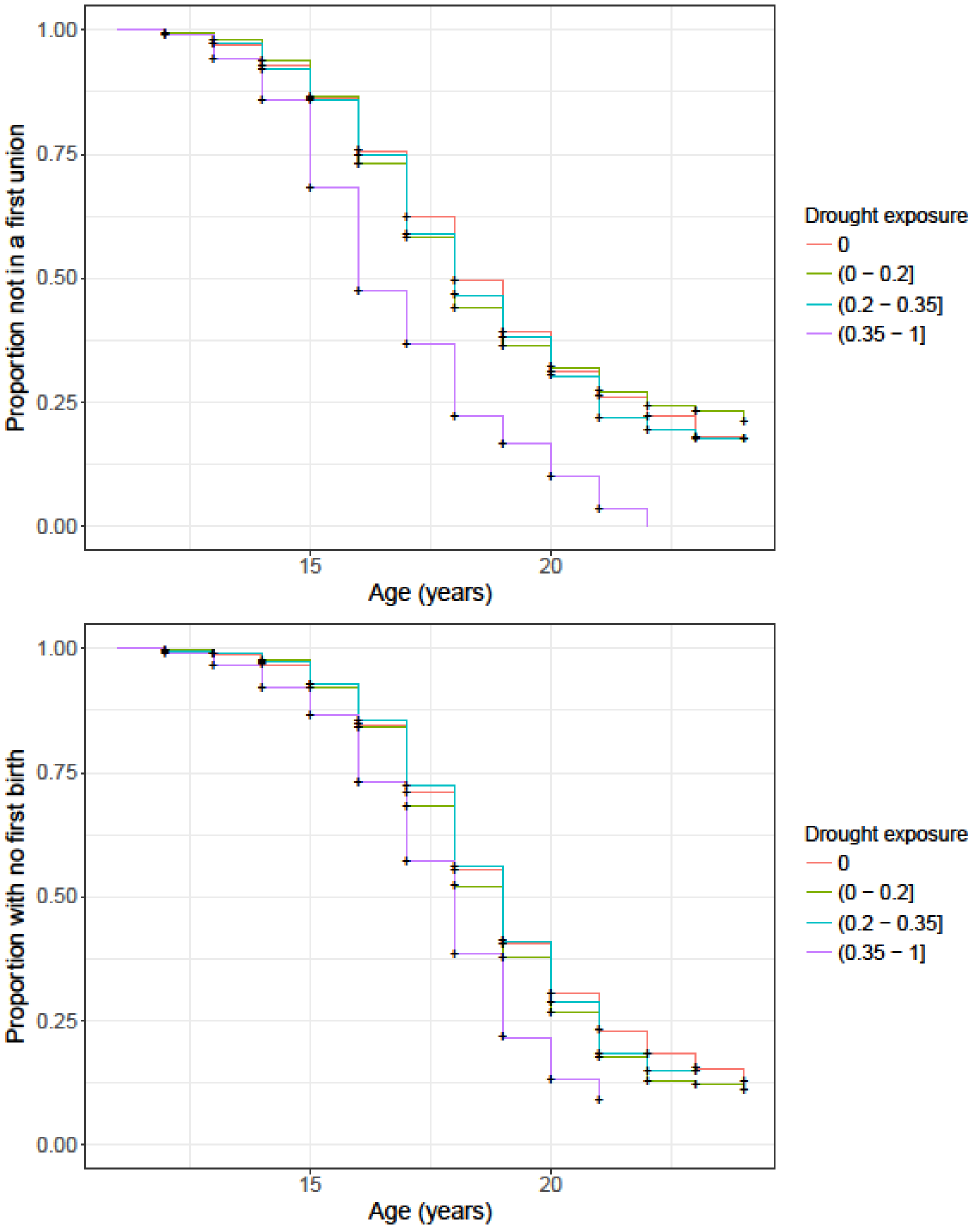
Table 6 Linear effects of droughts on sex in exchange for cash/goods.

	Sex in exchange for cash/goods
Exposure to growing-season drought (t–1)	0.13^{+}
	(0.07)
Oldest	-0.01
	(0.01)
Siblings (2,5]	-0.02
	(0.01)
Siblings (5,8]	-0.001
	(0.01)
Siblings 8+	-0.02
	(0.03)
Exposure to extremely wet growing season (t–1)	-0.52***
	(0.12)
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
	(0.02)
Yao	0.01
	(0.02)
Age at first sex	-0.01*
	(0.004)
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. Visitors, that is individuals present in the household during the survey but not usually resident, are excluded.

Fig. 1 Kaplan-Meier survival estimate of young women's transition to first union[vi] (top) and first birth[vii] (bottom) by exposure to growing-season drought.



[i] For example, in the mid 1990s in Uganda, a country where bride price remains widespread, about 46% of urban residents and 65% of rural residents paid bride price, which suggests substantial proportions of the population do not pay bride price even in a context where the practice is common.

[ii] In our sample, the minimum age at first union is 8 years old while that at first birth is 10 years old; however, most women report entering into a first union and having their first birth only after 10 and 11 years old, respectively. Thus, for consistency across models, we set 11 years old as the age when a woman is first at risk of entering into a union and childbearing.

[iii] Results from Tables 3–6 are also robust and available upon request from the authors.

[iv] For this analysis, we compute our drought measure in the calendar year for two main reasons. First, in some spatial units the main crop's growing season starts in December and ends in April of the next year, which would make it infeasible to calculate a drought measure for each year. Second, the fact that the calendar data spatial resolution differs from the weather data spatial resolution prevents us from combining these data without aggregating the calendar crop data to larger spatial units.

[v] The PET is the amount of water that could be evaporated and transpired if a sufficient water source were available.

[vi] The person-years of observation is 88,366 for no drought exposure; 6,543 for low exposure (0 – 0.2]; 4,493 for medium exposure (0.2 – 0.35]; 858 for high exposure (0.35 – 1]).

[vii] The person-years of observation is 94,201 for no drought exposure; 7,008 for low exposure (0 – 0.2]; 4,736 for medium exposure (0.2 – 0.35]; 1,042 for high exposure (0.35 – 1]).