The effects of growing-season drought on young adult women's life course transitions: Evidence from Malawi

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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 as part of a broader investigation of the demographic implications of climate change. Drawing on the case, of Malawi we combine repeated cross-sections of geo-referenced 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, but rainfall shocks—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 extreme 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 will be felt especially strongly among young people who will experience the effects of climatic weather shocks at all stages of their life course. This is particularly relevant since the largest ever cohort of youth is currently entering adulthood (UNFPA 2014), the majority of whom are living in low- and middle-income countries that are particularly vulnerable to weather shocks. In spite of the vast importance of climate change for population processes, there is limited work that investigates the micro-level processes through which weather shocks influence the transition into adulthood. It is highly plausibly that weather shocks impact the timing, sequencing, and characteristics of key life course transitions—such as union formation—by altering the economic and social contexts of young adult's lives. This could be particularly the case in rural agrarian settings where weather shocks disrupt agricultural livelihoods that form the basis of important economic and social networks.

Drawing on this research gap, the paper explores the association between drought-related weather shocks and young adult women's life course transitions using a case study from Malawi in South Eastern Africa. Malawi provides an interesting case study because the country has a large youth population and low ages of first marriage and birth (ICF International 2017). At the same time, the country is largely rural and agrarian and highly vulnerable to weather shocks which will have direct impacts on the livelihoods and well-being of many young adults and their families (Pauw, Thurlow, and van Seventer 2010). For methodological purposes, Malawi has a major advantage because the longstanding history of matrilineal kinship in the country (Peters 2010) allows us to identify a large sample of female respondents who are residing in the same geographic location as prior to the onset of marriage and childbearing. This is essential to our empirical strategy because it allows us to know women's geographic location in adolescence, and thus assess whether exposure to a weather shock in adolescence is associated with onset of key life course events. In the absence of this information we could not adequately identify the correct geo-spatial ordering of weather shocks and young women's life course transitions.

In the following sections, we develop a framework to explicate how and why weather shocks might influence you women's life course transitions in Malawi and other low-income contexts, particularly for rural populations. We go on to investigate empirically the effects of drought shocks on young adult women's life course transitions by combining repeated cross-sections of geo-referenced Malawi Demographic and Health Survey (DHS) survey data with a cutting-edged measure of drought shocks: The Standardised Precipitation Evapotranspiration Index (SPEI). The SPEI is widely viewed by agricultural scientists as the most complete and robust agricultural drought index (Sivakumar et al. 2010) and our analysis represents the first time it is combined with data on young people's life course transitions. We hypothesize that exposure to drought shocks in adolescence may impact the timing, sequencing, and characteristics of union formation and first birth. We explore this topic empirically using discrete time event history analysis, including models that explore competing risks. Our analyses lay a framework and empirical approach for future exploration of how weather shocks impact young women's life course transitions to better understand the demographic implications of climate change.

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 an increasing focus of both researchers and policy makers interested in low- and middle-income contexts (LMIC) (Lloyd 2005). At present, about 20 percent of the world's population (e.g. 1.2 billion people) are currently between the ages of 10 and 19 and living in LMIC (Ragnar Anderson 2014), thus providing a strong demographic rationale for better understanding the life course transitions of young people in the global South.

Typically, 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 highly variable depending on the socio-cultural context; for example in South Asia sexual activity prior to marriage is rare, but it is much more common in many parts of Africa (Mensch, Grant, and Blanc 2006). Young people's life course transitions are shaped by social and contextual factors such as family instability, schooling availability, reproductive healthcare and health service provision, and peer networks (Goldberg 2012; Marteleto, Lam, and Ranchhod 2008; Bongaarts, Mensch, and Blanc 2017; Hindin and Fatusi 2009; Clark and Mathur 2012; Grant 2015; Mensch, Grant, and Blanc 2006; Blanc et al. 2009). Nonetheless, 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 to lay out a framework to help understand how weather shocks might impact transitions to adulthood in key three dimensions. First, we hypothesize that weather shocks might affect the *timing* of life course transitions, in other words, the ages at which young women initiate marriage, childbearing etc. Second, we hypothesize that weather shocks might affect the *sequencing* of life course transitions, for example whether young women initiate sexual activity and childbearing before or after marriage. Finally, we hypothesize that weather shocks might affect the *characteristics* of life course transitions, such as the types of partners women choose (e.g. age and education), and also the types of relationships (e.g. polygynous versus monogamous). Though the case study from our paper is from a primarily rural country in sub-Saharan Africa, the themes we develop in our framework should be applicable to other contexts in the global South, particularly in rural areas. There are both economic and psychosocial explanations on why we might expect changes in life course transitions as a response to weather shocks, and we elaborate on these below.

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 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 rainfall shocks experienced in adolescence increased 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 shocks had a positive but insignificant effect on women's marriage rate in parts of rural Zimbabwe where bride price is common, although economic shocks (e.g. loss of livestock) had a significant positive effect on the marriage rate (Hoogeveen, van der Klaauw, and van Lomwel 2011). The authors suggest that the null effects of rainfall on marriage could be because during periods of heavy rainfall men's livelihoods suffer as well, and thus, they lack the resources to pay bride price.

While bride price has been identified as the primary mechanism through which weather shocks impact union formation in existing literature, 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). Likewise, the 1995 Oklahoma City Bombing (a man-made disaster with low levels of mortality) led to a fertility increase in surrounding areas which likely was a coping strategy to deal with the stress of the event (Rodgers, John, and Coleman 2005).

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 husband's family (e.g. dowry), young women's entrance to marriage may be delayed due to resource constraints. In support of this, a comparative study of India and 30 African countries finds that in India—where dowry is common (e.g. wealth transfers from the wives to husbands' family at marriage)—rainfall shocks are associated with higher female ages at first marriage, but the opposite is true in African countries where bride wealth is prevalent (e.g. wealth transfers from the husbands to the wives family at marriage). Even in places where bride price is practiced, if men's livelihoods are also affected by weather shocks they may also 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). Likewise, high temperatures led to postponement of pregnancy in the United States (Lam and Miron 1996; Barreca, Deschenes, and Guldi 2018), which is attributed to the fact that extreme heat reduces fecundity (and also changes preferences if couples prefer to wait for cooler weather).

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 marriage. 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 marriage. 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). Even in parts of the world where sexual activity prior to marriage is still uncommon, such as South Asia, there is evidence of rising incidences of pre-marital sex in certain contexts (Santhya et al. 2011), which indicates premarital sexual activity could be a response to economic hardship in diverse contexts.

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).

Throughout the discussion thus far we have assumed that weather shocks have negative ramifications for local livelihoods and economies, particularly in rural areas. However, there are instances when weather shocks could actually 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.

The transition to adulthood in Malawi in the context of changing climate

Contemporary Malawi is largely rural and agrarian; over 80 percent 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 percent 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 percent of the population (AlJazeera 2019). There is scientific consensus that this type of weather shocks will only be exacerbated by climate change in the coming decades (Morton 2007).

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 many young adults and their families (Stringer et al. 2009). This includes the transition to adulthood, although there has been little exploration of how weather shocks will influence these processes. In what follows, we highlight key topics in in the transitions to adulthood in Malawi that could potentially be influenced by weather shocks along the lines discussed in the proceeding section.

On average, young women in Malawi transition into first unions and first births at young ages and there has been limited change over time in these trends. Between 1992 and 2015 the median age of first marriage increased only marginally from 17.8 to 18.2 years and the median age at first birth was relatively stable at 18.9 years (ICF International 2017). Although child marriage has been outlawed since 1994 (the minimum age of marriage was raised from 15 with parental consent to 18 in 2017), approximately 1 in 2 girls were married by the age of 18 in 2015 (UNICEF, 2016). The lack of change in ages of first marriage and births may be related to the poor quality of education and minimal opportunities for non-agricultural employment (Grant 2015).

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; Johnson-Hanks 2006; Meekers 1992; van de Walle 1965; Bledsoe and Pison 1994; Poulin 2007). First sex might take place within or outside of marriage, with some evidence of the latter arrangement becoming increasingly common (Mensch, Grant, and Blanc 2006). Premarital births are also increasingly prevalent, with 20–30 percent of women born in the mid-to late 1980s reporting a premarital birth (Clark, Koski, and Smith-Greenaway 2017).

Relatively few marriages in Malawi are civil (e.g. registered with the state), but they may involve a religious ceremony, a customary or traditional ceremony which may correspond transfer of good between families, or they may entail cohabitation without any of the above (Meekers 1992). Young women may try out several different partnership arrangements before settling on a more permanent option (Bledsoe 1990). For example, cohabitation may evolve into a marriage over time if people decide to have a religious or more formal ceremony. Alternatively, a monogamous union may become polygynous eventually, given that polygyny is relatively common, with about

10 percent of women of reproductive age currently being in a polygynous union (ICF International 2017).

In total, about 75 percent of the population of Malawi is matrilineal, including the three largest ethnic groups (Chewa, Yao, and Lomwe) (Berge et al. 2014). 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.

Taken together, the trends highlighted in this section underlie that partnership formation and affiliated life course transitions are complex and multifaceted in the contemporary Malawian context. Understanding the complexity of courtship and partnership formation in Malawi is important for any investigation of how these key social processes are influenced by environmental processes such as weather shocks.

Data

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. The data sources include: (1) georeferenced individual-level data from the Malawi Demographic and Health Surveys; (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 cutting-edge 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 estimation below).

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 marriage and family formation, reproductive health, fertility, and georeferenced information (i.e. latitude and longitude) on the woman's location (Fig. 1).

[Fig. 1 here]

Because we are interested in marriage 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 percent 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.

[Table 1 here]

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. 2 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. 2 here]

Methods

Measures

Exposure to growing season droughts

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[ii] 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 growing-season months in which a severe drought occurs in the months prior d during the last and second-to-last completed growing seasons. Then, we construct the growing-season drought variable as:

$$\text{gs\_drought\_e}i_{\text{g,d}} = \omega_{\text{g,t}} * \text{gs\_drought\_}ei_1^{\text{g,d}} + \left(1 - \omega_{\text{g,d}}\right) * \text{gs\_drought\_}ei_2^{\text{g,d}} \text{Eq. (1)}$$

where $gs\_drought\_ei_1^{g,d}$ and $gs\_drought\_ei_2^{g,d}$ are the proportions of growing-season months during the last and second-to-last completed growing seasons preceding date d for location g in which SPEI3 is below –1.5. 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).

Exposure to extremely wet growing season conditions

Although the focus of our analysis is on exposure to growing season drought, we also control for exposure to extremely wet growing season conditions. 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). This measure captures extremely wet conditions that we speculate may actually be beneficial for agricultural productivity (in other words, a positive shock, as in Sigle and Pitt 1998). In both samples, the correlation between $\text{gs\_drought\_e}i_{\text{g,d}}$ and $\text{gs\_wet\_e}i_{\text{g,d}}$ is very low (i.e., –0.05).

Additional explanatory variables

We control for other explanatory variables that may also be associated with transitions to marriage and birth including exposure to extremely wet growing season conditions (described above), years of education and religion (indicators for Catholic, Protestant, Muslim, Other/None). We control for ethnicity (indicators Chewa, Tumbuka, Lomwe, Yao, Ngoni, Other) because there may be important differences in marriage between matrilineal and patrilineal tribes. The Chewa, Lomwe, Yao, and Ngoni tribes are all matrilineal whereas the Tumbuka tribe is patrilineal (the Ngoni are patrilineal in Mzimba) (Berge et al. 2014). 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 life course transitions. First, we explore the effects of growing-season drought shocks on the *timing* of young adult women's life course transitions. To this end, we conduct a discrete time event history analysis (EHA) of the effect of drought on young adult women's transitions to unions and childbearing. Although EHA is most commonly used with longitudinal datasets, the DHS includes detailed retrospective information about the month and year of first union and first birth, thus allowing us to apply this method with cross-sectional data. We use 11 years of age as the data entry point[iii], the age at first union—defined as either marriage or cohabitation—and at first conception – calculated as first birth minus nine months – 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. Robust standard errors are calculated using the Huber-White method.

Next, we investigate impacts on the *sequencing* of young adult women's life course event by exploring the effects of droughts on a young woman's probability of having a birth inside or outside of a union (including both cohabitation and marriage). We analyse these processes within the framework of a discrete time logistic regression competing risk model 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. We do not explicitly explore whether growing season droughts shocks impact the timing and/or sequencing of young women's transition into first sex because the DHS does not collect information on both the month and year the first sex occurred (whereas this information is available for first unions and first births). We nonetheless gain some insights into whether sex is occurring before or after union formation by looking at the competing risk analysis of first childbearing within or outside unions, particularly since many young women in Malawi do not use contraception regularly until after a first birth (Behrman et al. 2018).

Finally, we explore the effects of growing-season droughts on the *characteristics* of women's partnerships. Growing season drought might impact whether women are in cohabiting unions rather than marriages if the local resources needed for marriage ceremonies are adversely affected by droughts. To explore this empirically 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. To conduct this analysis, we use a DHS question about whether the respondent's first union is a marriage or cohabiting union, though we recognise that there may be reporting bias in responses given that marriage in Africa is often a set of processes rather than a discrete event (Meekers 1992). 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.

Next, we run a series of linear regression models with additional outcomes about partnership characteristics, which may be affected by drought if local marriage markets change (due to out-migration), or if partnership decisions are increasingly financially motivated following a drought. 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. The analysis of partnership and relationship characteristics is restricted to women who have only been in a union one time because the DHS only asks about timing indicators (e.g. age of first union) for the first partner and only about the partner characteristics for the current partner. For this analysis, we exclude women who have never been in a union, separated and widowed women, and women who have been in more than one union.

Because drought-related resource scarcity may lead women to enter into unions that are (partly) financially motivated, we look at whether recent experiences of drought are associated with 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 women from the most recent DHS only. Using the month and year of survey as date d in Eq. (1), we calculate the exposure to droughts during the last growing season for each woman from the most recent DHS and estimate the net relationship between exchanging sex for goods/cash and growing season drought using a linear probability model.

Results

Descriptive overview of drought in Malawi using the SPEI

We start by validating our measure of droughts. In particular, we check that it reflects past droughts by comparing it with evidence of droughts available from past studies. We do this in two ways. First, 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. 1, Supplementary Material). Second, we show the time trend in drought prevalence by plotting the same proportions over time across the country (Fig. 2, 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. In Fig. 1, we can identify areas where drought was longer (red squares) or shorter (yellow squares). For example, consistent with past evidence we find that Southern areas were most affected by the 1992 drought (Giertz et al. 2015). Fig. 2 further shows both that drought is a rare event and that variation over time in drought prevalence was high (e.g. for example in 2015 the whole country was highly affected by droughts as opposed to the year 1982 when no droughts seem to have occurred). Finally, our findings are in line with past work and show evidence of the droughts that affected Malawi in 1992, 1995, 2005, and 2015 (Giertz et al. 2015). In total, the prevalence of drought was 2.2 percent of all person-years observed in our samples, thus highlighting that severe drought was a rare occurrence with large implications for rural livelihoods and wellbeing.

Descriptive overview of union formation and childbearing in our sample

Union formation and childbearing were common among our analytical sample of women aged 15–24. On average, 46 percent of respondents had experienced a union and 47 percent 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). Education was also overall low in our sample, with young women completing on average about 6 years of school.

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 droughts variable as 0 for no exposure, 1 for low exposure (0–0.2], 2 for medium exposure (0.2–0.35], and 3 for high exposure (0.35–1]. These categories correspond with how many months of the last two completed growing seasons there was drought, for example 0 corresponds with no drought at all during the growing season, 1 corresponds with drought for up to 20 percent of the months of the growing season, 2 corresponds with drought for 20 percent to 35 percent of the months of the growing season, and 3 corresponds with drought for greater than 35 percent of the months of the growing season.

The Kaplan-Meier survivor function graphs show that women who were highly exposed to growing season droughts in adolescence transition into both first births and first unions at earlier ages than those who were not exposed to any growing season droughts in adolescence (Fig. 3). 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.

[Fig. 3 here]

Discrete time event history analysis of the effect of growing season droughts on the timing of first unions and first births among young adult women

Growing season droughts may accelerate young women's transitions into first unions and births if families benefit financially (either directly or indirectly) from union formation and/or if young women seek out psychosocial support in the form of partnerships or offspring. At the same time, drought could deaccelerate young women's transitions into these key life events if destruction to livelihoods impedes the finances necessary for weddings and/or alters marriage markets.

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 droughts significantly increases young adult women's transitions into first unions. Specifically, a one-unit increase in exposure to growing season droughts in adolescence—in other words going from no drought exposure to drought exposure for all of growing season—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. These results are particularly interesting since we focus on a country where bride price is less common, thus suggesting that drought accelerates young adult women's union formation transitions even in the absence of financial incentives for bride price (which has been the focus of existing literature on the topic).

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 droughts 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. We also find that exposure to extremely wet growing season conditions has a sizeable positive effect on transitions into first births. In particular, exposure to extremely wet growing conditions increases the log odds of young women's first birth by 0.63 ($p<0.05$), although there are no significant effects of exposure to extremely wet conditions on union transitions. This finding is similar to a study from Senegal which suggests that positive rainfall shocks increase fertility (Pitt and Sigle 1998). The authors attribute this finding to increased anticipated income from a plentiful harvest, 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.

A number of other variables in the model are also important predictors of the transition into first unions and births. For example, education is negatively associated with the transition into both unions and birth, which is largely expected given a large literature on education leading to delays in family formation. There is minimal evidence of differences in these life course transitions depending on matrilineal or patrilineal background; there is no significant difference in either type of transition between the Tumbuka, who are patrilineal, and the Chewa, who are matrilineal (and also the largest tribe). On the other hand, the Lomwe (matrilineal) and Ngogni (largely matrilineal) are both associated with quicker transitions into first births compared to the Chewa, and the Lomwe are also associated with quicker transitions into first unions compared to the Chewa. Contrary to what might be expected, living in rural areas is associated with delays in first unions and first births, however this could be because the drought variable is absorbing the negative effects of rurality because rural areas are most affected by droughts.

[Table 2 here]

Competing risk discrete time logistic regression analysis of the effects of growing season drought on the sequencing of young adult women's life course transitions

The results from the proceeding section suggested that exposure to growing season drought in adolescence had 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 getting pregnant prior to or after union formation, thus we also explore the impact of growing season drought on the sequencing of whether childbearing occurs inside or outside of unions. 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 droughts 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).

Exposure to growing season drought in adolescence also 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 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 months is actually a "positive" shock because it 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]

Competing risk discrete time logistic regression analysis and linear regression analyses of the effects of growing season drought on young adult women's relationship characteristics

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. To explore this empirically 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. Table 4 Model 1 shows that, going from no exposure to growing season droughts to full exposure to growing season droughts leads to a 0.88 increase in the log odds of young women's transition into marriage (compared to no union formation) ($p<0.001$). Table 4 Model 2 shows that, compared with no exposure to growing season droughts, full exposure to growing season droughts 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 more common than marriage because young people and their families lack the resources for marriage ceremonies. 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 decisions about partnership and/or local marriage markets in important dimensions. To do this, we use the dataset built to estimate the age at first marriage and focus on the sample on women who are married and/or cohabiting for the first time (e.g. women who are currently partnered). We find that exposure to growing season droughts 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 season to drought to exposure for the full growing season 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 droughts 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 droughts 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, because they are more likely to be partly motivated by the financial aspects of relationships. 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). We find that, compared with no exposure to growing season droughts, full exposure to growing season droughts 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 conditions to extremely wet conditions for the full growing season leads to a 52-percentage point reduction in the probability of exchanging sex for cash/goods. In this sample, the prevalence of extremely wet growing conditions was 0.02 percent which highlights the rarity of extreme wet growing seasons events. If wet growing season conditions are a positive income shock due to increased agricultural productivity, then this could suggest that women are less likely to engage in sex (at least partly) for financial gain when both food and income resources are abundant.

[Table 6 here]

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 a conceptual 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-related weather shocks on young adult women's life-course transitions by combining repeated cross-sections of geo-referenced Malawi Demographic and Health Survey (DHS) data with an improved georeferenced measure of drought shocks: the SPEI Index. As a supplement, we also looked at whether exposure to extremely wet conditions—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 less 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). We speculated that this could be because young women and their families nonetheless had financial incentives for young women's partnerships either directly 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 suggest that psychosocial explanations about why young women form partnerships in stressful situations are more important than have previously been considered in the literature on weather shocks and union formation.

In addition to accelerating union formation, there was also evidence of growing season drought significantly increasing both births outside of unions, and births within unions (though the former was only significant at unconventional levels). There was also evidence of exposure of growing seasons drought leading women to partner with less educated men, and leading non-partnered women to be more likely to exchange sex for cash or goods. Although the latter finding was only statistically significant at unconventional levels, it was dramatic in comparison to the findings that exposure to extremely wet growing conditions—which likely corresponded with a positive food and income shock—lead to large and significant reductions in unpartnered women exchanging sex for cash or goods. Taken together, these findings suggested that growing season droughts have large and important impacts on key dimensions of young women's life course transitions.

Although our paper made an important advancement in exploring the linkages between weather shocks and young adult women's life course transitions, the cross-sectional nature of the DHS led to several limitations. First, we relied upon retrospective information on women's age of first marriage 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 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, thus raising questions about the generalizability of our findings to patrilineal tribes. Our results may have also been biased by out-migration if more educated women were likely to migrate out of rural areas either in response to weather shocks or in search of economic opportunities.

A further 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 rainfall 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.

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, since the findings from Malawi are not generalized to elsewhere. Our analysis also emphasized the importance of contextualizing union and family formation as a broad set of processes that are often complex and interwoven. This is important given that marriage and family formation in Malawi and many other African countries are complicated social processes that often involves multiple steps and a long-time horizon. 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 better understanding of the relationship between climatic processes and the demographic outcomes, lives, and livelihoods of young people.

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.” Oxford.

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.

Berge, Erling, Daimon Kambewa, Alister Munthali, and Henrik Wiig. 2014. “Lineage and Land Reforms in Malawi: Do Matrilineal and Patrilineal Landholding Systems Represent a Problem for Land Reforms in Malawi?.” *Land Use Policy* 41 (November): 61–69. doi:10.1016/j.landusepol.2014.05.003.

Blanc, Ann K, Amy O Tsui, Trevor N Croft, and Jamie L Trevitt. 2009. “Patterns and Trends in Adolescents' Contraceptive Use and Discontinuation in Developing Countries and Comparisons with Adult Women.” *International Perspectives on Sexual and Reproductive Health* 35 (02): 063–071. doi:10.1363/3506309.

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.

Bledsoe, Caroline H, and Gilles Pison. 1994. *Nuptiality in Sub-Saharan Africa*. Oxford University Press, USA.

Bongaarts, John, Barbara S Mensch, and Ann K Blanc. 2017. “Trends in the Age at Reproductive Transitions in the Developing World: the Role of Education.” *Population Studies* 71 (2). Taylor & Francis: 139–54. doi:10.1080/00324728.2017.1291986.

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.

Clark, Shelley, and Rohini Mathur. 2012. “Dating, Sex, and Schooling in Urban Kenya.” *Studies in Family Planning* 43 (3). Wiley Online Library: 161–74.

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.

Goldberg, Rachel E. 2012. “Family Instability and Early Initiation of Sexual Activity in Western Kenya.” *Demography* 50 (2): 725–50. doi:10.1007/s13524-012-0150-8.

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.

Grant, M. 2015. “The Demographic Promise of Expanded Female Education: Trends in the Age at First Birth in Malawi.” *Population and Development Review* 41 (3): 409–38. doi:10.1111/j.1728-4457.2015.00066.x.

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 .”

Johnson-Hanks, Jennifer. 2006. *Uncertain Honor: Modern Motherhood in an African Crisis*. Chicago, IL, USA: University of Chicago Press.

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.

Marteleto, Letícia, David Lam, and Vimal Ranchhod. 2008. “Sexual Behavior, Pregnancy, and Schooling Among Young People in Urban South Africa.” *Studies in Family Planning* 39 (4). Wiley Online Library: 351–68.

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.

Morton, J F. 2007. “The Impact of Climate Change on Smallholder and Subsistence Agriculture.” *Proceedings of the National Academy of Sciences* 104 (50). National Academy of Sciences: 19680–85. doi:10.1073/pnas.0701855104.

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.
Rodgers, Joseph Lee, Craig A St John, and Ronnie Coleman. 2005. “Did Fertility Go Up After the Oklahoma City Bombing? an Analysis of Births in Metropolitan Counties in Oklahoma, 1990–1999.” *Demography* 42 (4). Springer: 675–92.
Santhya, K G, Rajib Acharya, Shireen J Jejeebhoy, and Usha Ram. 2011. “Timing of First Sex Before Marriage and Its Correlates: Evidence From India.” *Culture, Health & Sexuality* 13 (3): 327–41. doi:10.1080/13691058.2010.534819.
Silver, Roxane Cohen. 2002. “Nationwide Longitudinal Study of Psychological Responses to September 11.” *Jama* 288 (10): 1235. doi:10.1001/jama.288.10.1235.
Sivakumar, M, R P Motha, D A Wilhite, and D A Wood. 2010. “Agricultural Drought Indices: Summary and Recommendations.” *Proceedings of the WMO/UNISDR Expert Group Meeting on Agricultural Drough*. Switzerland.
Stringer, Lindsay C, Jen C Dyer, Mark S Reed, Andrew J Dougill, Chasca Twyman, and David Mkwambisi. 2009. “Adaptations to Climate Change, Drought and Desertification: Local Insights to Enhance Policy in Southern Africa.” *Environmental Science & Policy* 12 (7): 748–65. doi:10.1016/j.envsci.2009.04.002.
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.
UNFPA. 2014. “The Power of 1.8 Billion: Adolescents, Youth and the Transformation of the Future.” New York : UNFPA.
van de Walle, Etienne. 1965. “The Relation of Marriage to Fertility in African Demographic Inquiries.” *Demography* 2: 302. doi:10.2307/2060120.
WMO. 1975. “Drought and Agriculture: Report of the CAgM Working Group on the Assessment of Drought.” Technical Note No. 138.

Fig. 1 Spatial distribution of the DHS cluster across Malawi by type of residence (rural/urban).

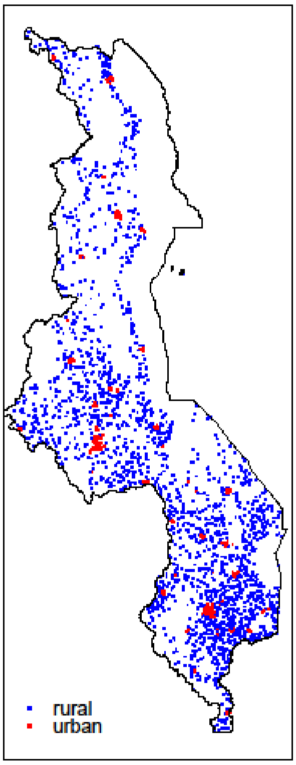


Fig. 2 Spatial distribution of main crop across Malawi.

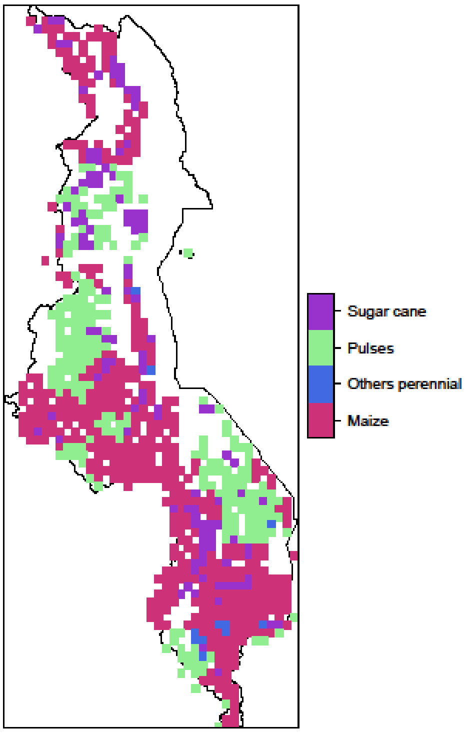
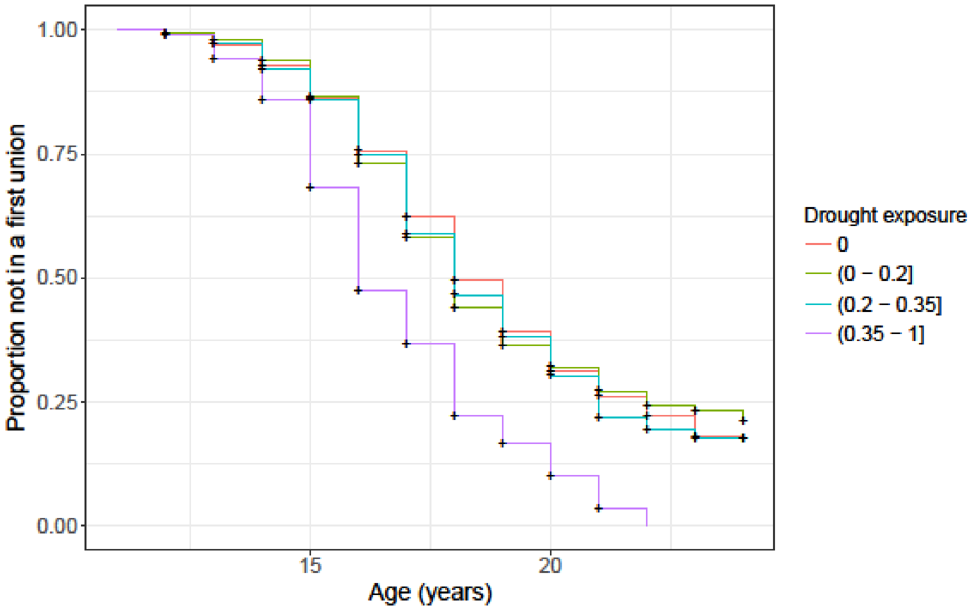


Fig. 3 Kaplan-Meier survival estimate of young women's transition to first union[v] (top) and first birth[vi] (bottom) by exposure to growing season drought.



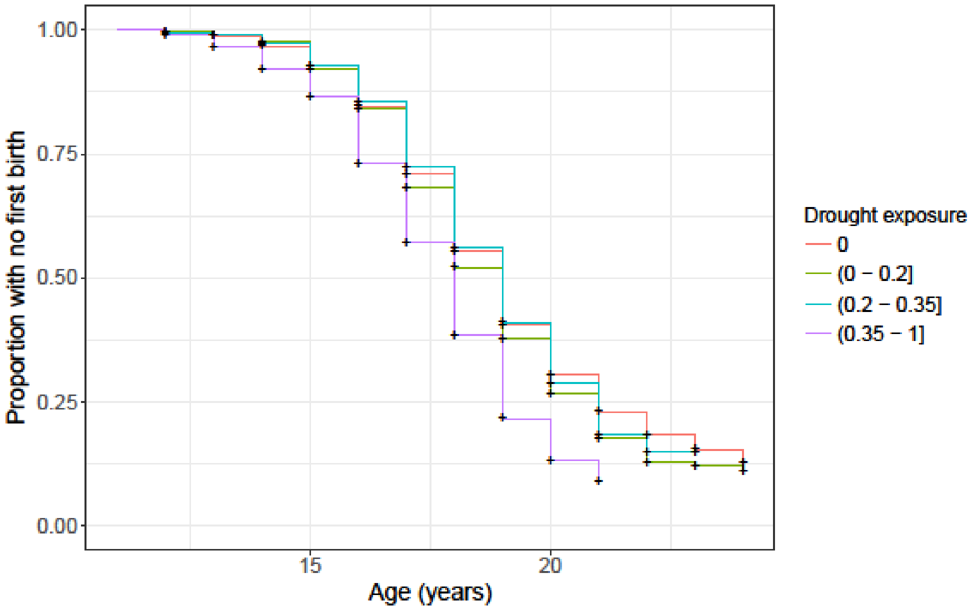


Table 1 Summary statistics.

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 droughts	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 growing season wet events	-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 droughts	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 growing season wet events	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 droughts	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 growing season wet events	-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 Model 1	Age difference Model 2	Polygynous parntership Model 3	Wife's ranking Model 4
Exposure to growing season droughts	-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 growing season wet events	-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	0.3	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.

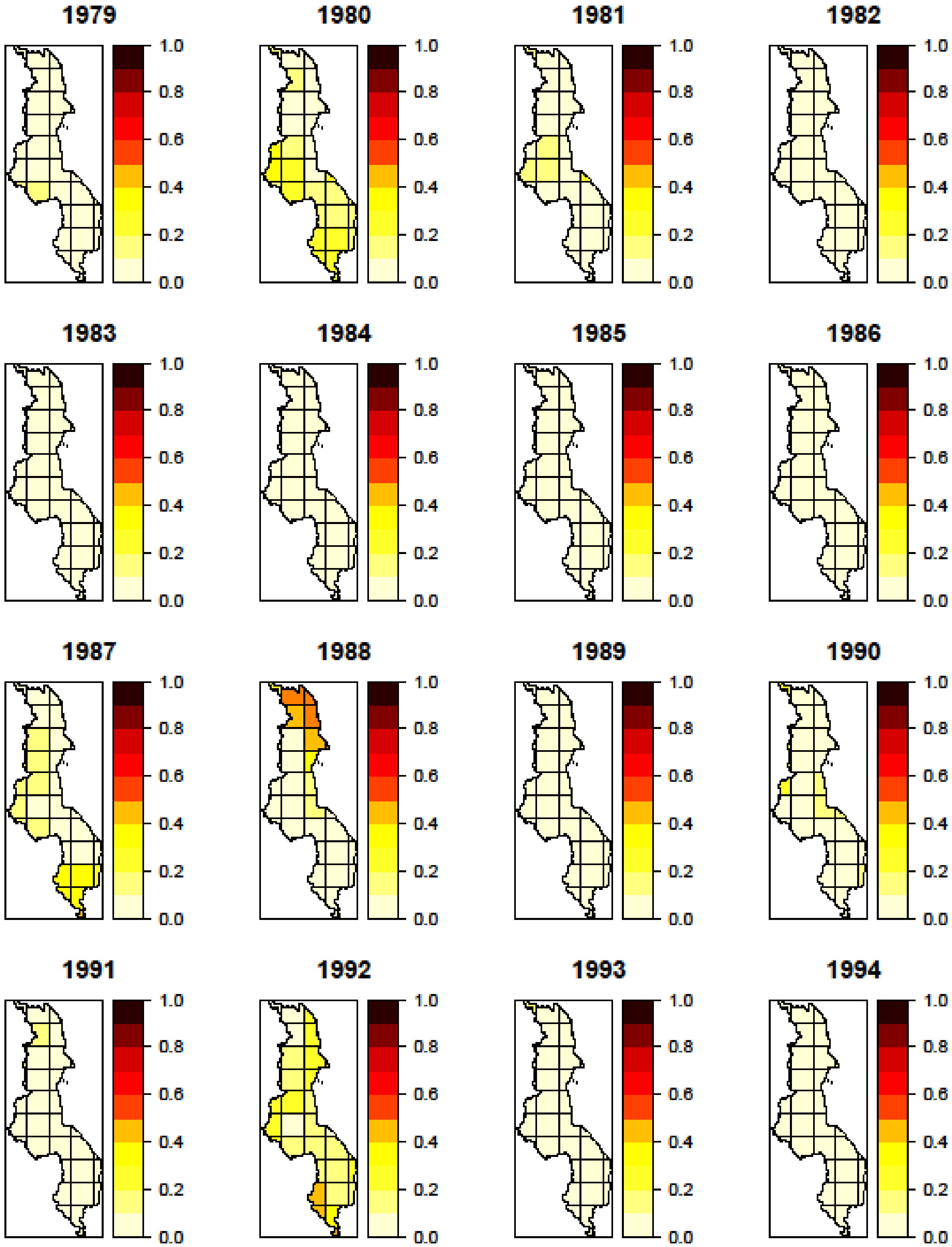
	Sex in exchange for cash/goods
Exposure to growing season droughts (t-1)	0.13^{+}
	(0.07)
Oldest	-0.01
	(0.01)
Siblings (2,5]	-0.02
	(0.01)
Siblings (5,8]	-0.001
	(0.01)
Siblings 8+	-0.02
	(0.03)
Exposure to growing season wet events (t-1)	-0.52***
	(0.12)
Rural	-0.02^{+}
	(0.01)
Years of education	-0.004^{+}
	(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

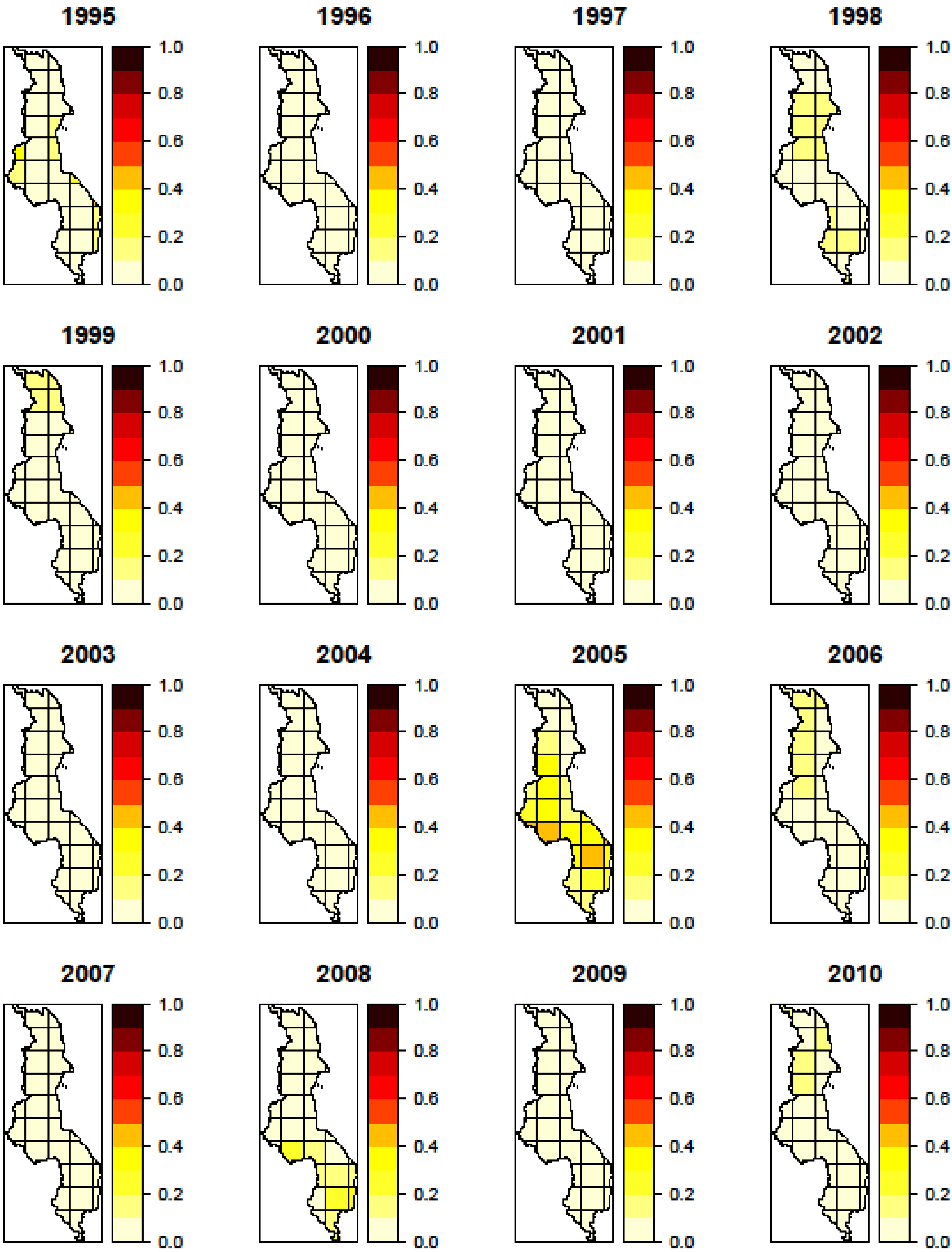
+p<.1; *p<.05; **p<.01; ***p<.001

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.

Supplementary Material

Fig. 1 Spatial distribution of drought 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

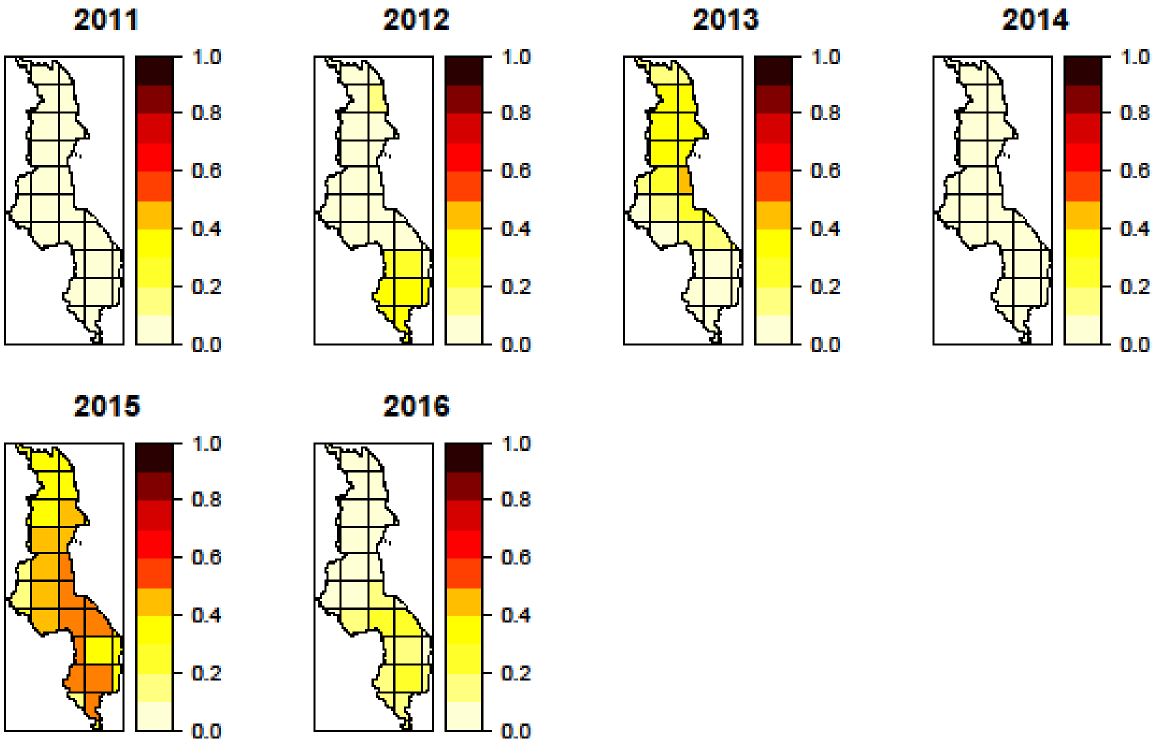
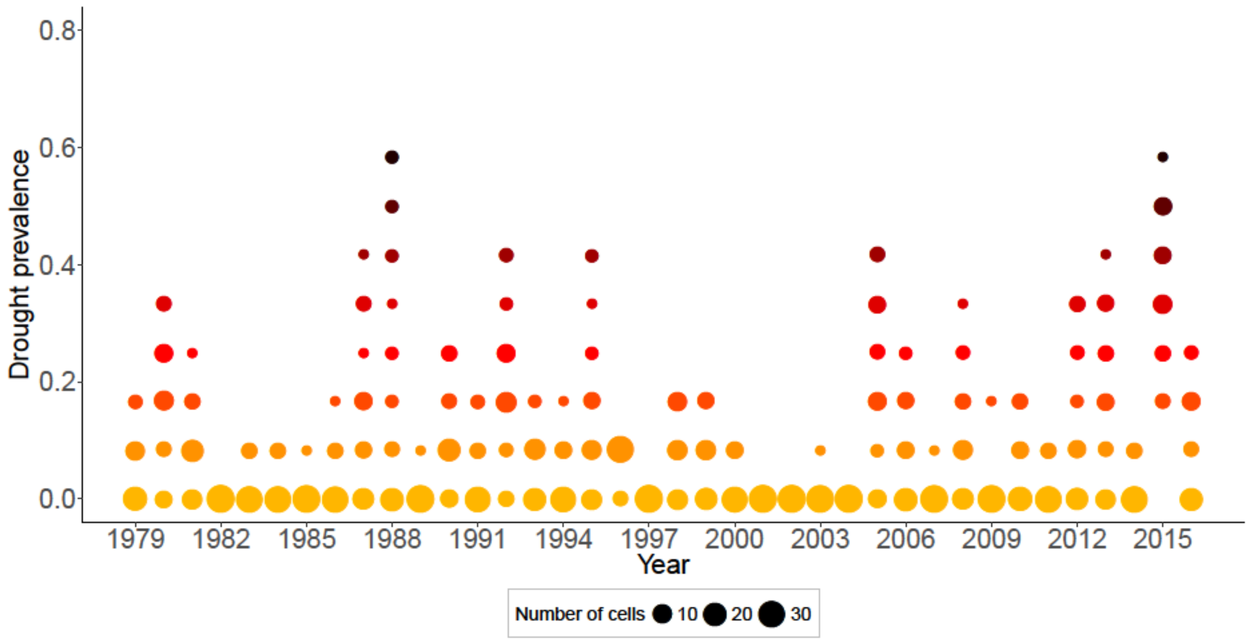

2011
2012
2013
2014
2015
2016
1.0
0.8
0.6
0.4
0.2
0.0

Fig. 2 Drought prevalence in Malawi over time, 1979–2006.



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[i] For example, in the mid 1990s in Uganda, a country where bride price remains widespread, about 46 percent of urban residents and 65 percent 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] The PET is the amount of water that could be evaporated and transpired if a sufficient water source were available.

[iii] 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.

[iv] 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 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]).

[vi] 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]).