Extreme Weather and Marriage among Girls and Women in Bangladesh

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Abstract. Climate change interacts with social, economic, and political forces in ways that can shape demographic behavior. Yet, the link between environmental stress and marriage has received limited attention. Using survey data from 615 Bangladeshi households, we examine the relationship between extreme weather in the form of heat waves and dry spells, and the risk of marriage over the period from 1989 to 2013. We find that girls and women are at an increased risk of marrying in the year of or following heat waves. The link is strongest for women aged 18 to 23, and weakest for those 11 to 14. We also explore the hypothesis that extreme weather leads families to accept less desirable marriage proposals for daughters. We find that those who wed during periods of extreme heat married into poorer households and to husbands with less education. Similarly, those who married during abnormally dry periods married men man with less education and who were more supportive of intimate partner violence. Together these results suggest that, when Bangladeshi families face environmental shocks, they cope by hastening the marriage of daughters or accepting less desirable marriage proposals. Such practices are likely to have long-term impacts on the health and well-being of women and children, and underscore the unique vulnerabilities faced by women as climate change intensifies.

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1. Introduction

Growing evidence reveals that climate change interacts with social, economic, and political forces to shape demographic trends, including morbidity (McMichael et al., 2006; Smith et al., 2014), mortality (Diboulo et al., 2012; Huang et al., 2011), and migration (Bohra-Mishra et al., 2014; Carrico and Donato, 2019; Nawrotzki et al., 2013; Nawrotzki and DeWaard, 2016). Substantially less attention has been paid to how climate conditions influence other demographic behaviors such as marriage and fertility, which also have systemic effects on population growth and well-being (e.g., Alston et al., 2014; Bartlett, 2009; Bongaarts and O'Neill, 2018; Grace, 2017). In this paper, we examine how extreme weather conditions, in the form of heat waves and dry spells, interact with marriage patterns in the environmentally vulnerable region of southwest Bangladesh. We focus specifically on girls and women, who are disproportionately more likely to experience early or forced marriage in response to economic insecurity (Bajracharya et al., 2019; Schuler et al., 2006; UNICEF, 2011; Walker, 2012). Prior work reveals that changes in living standards in the wake of an environmental shock have the potential to both delay or hasten the timing of marriage. Yet, only a handful of studies consider the relationship between extreme weather and marriage behavior (see e.g., Ahmed et al., 2019; Alston et al., 2014; Corno et al., 2016; Jennings and Gray, 2017). Using survey data from 615 Bangladeshi households, we examine the relationship between heat waves, dry spells, and the risk of marriage from 1989 to 2013. To gain insight about how climate change may influence the opportunities available to women, we pay special attention to the extent to which extreme weather correlates with early marriage, as well as the social and economic conditions of a woman's married home.

1.1. Economic security, marriage, and well-being. Marriage is a socially and legally significant institution worldwide, often marking an individual's entry into adulthood. However, the conditions under which marriage begins can have lasting impacts on the health and well-being of individuals and families, especially girls and women (Field and Ambrus, 2008; Jensen and Thornton, 2003; Mobarak et al., 2013). Marriage often triggers the end of a woman's education and marks her entry into adult roles. In particular, early marriage (also child marriage)—defined by the United Nations as a union before the age of 18 (OHCHR, 2019)—is linked to lower educational attainment and economic opportunity (Brien and Lillard, 1994; Field and Ambrus, 2008; Wodon et al., 2016). Child marriage also exposes girls to earlier, more numerous, and more rapid childbirths (Godha et al., 2013; Nour, 2009; Raj et al., 2009). Furthermore, pregnancies during adolescence are at higher risk for complications that may compromise the long-term health of infants and mothers (Adeyinka et al., 2010; Raj et al., 2010; Santhya, 2011; United Nations, 2001). The conditions leading up to marriage—e.g., the payment of a dowry and the economic motivations for pursuing a marriage—also correlate with women's well-being such as exposure to domestic violence and participation in household decision-making (Bloch and Rao, 2002; Hallman, 2000; Mobarak et al., 2013; Quisumbing and Maluccio, 2003; Suran et al., 2004).

It is well known that marrying a daughter is one means by which households throughout the world cope with economic insecurity (Ahmed et al., 2019; Alston et al., 2014; Jensen and Thornton, 2003). Throughout South Asia, marriage is used as both an *ex ante* and *ex post* adaptation strategy. As an ex ante strategy, families are motivated to marry daughters when they are young, both to lock in a lower dowry and to avoid the reputational risks that young unmarried women accumulate as they age (Ahmed et al., 2019; Alston, 2014; Arends-Kuenning and Amin, 2001; Islam and Rashid, 2011; Schuler et al., 2006). Younger brides are often considered more desirable and, therefore, command smaller dowries (Arends-Kuenning and Amin, 2001; Field and Ambrus, 2008; Kamal et al., 2014). Unmarried adolescent girls are also considered vulnerable to sexual harassment and abuse (Alston et al., 2014), and girls who are perceived as impure or promiscuous have the potential to jeopardize future marriage prospects (Alston et al., 2014; Schuler et al., 2006). Therefore, families often speak of marrying a daughter at a young age as an opportunity to leverage scarce resources and ensure that she is settled into a good home (Arends-Kuenning and Amin, 2001; Huda, 2006). Recent qualitative work reveals that recurrent natural disasters may exacerbate these concerns. In Bangladesh, many families spend time in public shelters during cyclones or severe floods, where the reputations of their unmarried daughters are especially vulnerable

(Ahmed et al., 2019). Similarly, families who are at risk of losing their land to riverbank erosion report the desire to marry daughters as soon as possible, before they lose their remaining assets and are forced to migrate to a new community (Human Rights Watch, 2015).

As an ex post response to economic shocks, a daughter's marriage reduces household consumption demands, as a new bride typically joins her husband's home immediately after the union. Because many South Asian women have few economic opportunities outside of the home, daughters may be considered a liability during times of resource scarcity, whereas sons have relatively more economic earning potential (Alston et al., 2014; Das Gupta et al., 2003; Diamond-Smith et al., 2008; Human Rights Watch, 2015; Schuler et al., 2006). Given that dowry payments by the bride's family to the groom's is common practice in many parts of South Asia, many theorize that poor families will delay the marriage of a daughter when resources are most constrained. Consistent with this theory, Corno and colleagues (2016) found that droughts reduced the risk of marriage by 4% among Indian girls aged 12 to 17. Alternatively, others find that immediate economic constraints are commonly cited as a reason to pursue, rather than delay, the marriage of a daughter (Ahmed et al., 2019; Alston et al., 2014; Human Rights Watch, 2015; Schuler et al., 2006). It may be that families employ both strategies; some may choose to delay marriage and others may accept a less desirable marriage partner—therefore reducing dowry cost while simultaneously decreasing household consumption. Importantly, dowries are often used to secure a women's marriage to a desirable partner, avoiding a husband who is much older, unhealthy, violent, or poor (Rastogi and Therly, 2006; Schuler et al., 2006). Some families may commit to a dowry that they are ultimately unable to pay, potentially jeopardizing a women's well-being in her married home, as unpaid dowries are associated with higher rates of domestic violence post-marriage (Naved and Persson, 2010).

1.2. Climate variability and marriage. There is some evidence that the social norms and economic conditions favoring the early and forced marriage of girls in South Asia are beginning to erode (Schuler, 2007; Schuler et al., 2006). Yet, climate change threatens to undermine recent progress (Alston et al., 2014; Human Rights Watch, 2015). In addition to concerns about the welfare of women, early marriages are associated with lower educational attainment and empowerment—both of which predict resilience to climate-related disasters (Adhikari and Sawangdee, 2011; Bhuiya and Streatfield, 1991; Chakraborty et al., 2003; Fantahun et al., 2007; Henry et al., 2015; Hurt et al., 2004; Lutz et al., 2014; Striessnig et al., 2013). A woman's age at marriage is also tightly linked to fertility and population growth, with younger age at first marriage associated with higher fertility (Audrey Harwood-Lejeune, 2000; Bongaarts, 1978; Raj et al., 2009). Scholars have speculated that climate-related disruptions may contribute to higher fertility via increases in poverty and reduced access to education and contraception (Bremner et al., 2010; Casey et al., 2019; Mcleod et al., 2019). Other work reveals that abnormally high temperatures are associated with a decline in reproductive health (Barreca et al., 2018; Lam and Miron, 1996), and are correlated with a smaller ideal family size (Eissler et al., 2019; Sellers and Gray, 2019). Yet, few studies have considered how climate change might influence fertility via the number of years a woman is exposed to reproduction by virtue of her age of marriage (see e.g., Corno et al., 2016).

1.3. The Bangladeshi Context. As a densely populated developing nation, Bangladesh is an important context for understanding demographic responses to environmental stress. It is widely regarded as one of the most environmentally vulnerable regions of the world and a hot spot of climate change impacts (Benneyworth et al., 2016; Khan et al., 2014; Wong et al., 2014). Approximately 70% of Bangladeshis live in a low-lying river basin—the Ganges-Brahmaputra delta—that is vulnerable to erosion, waterlogging, flooding, and sea level rise. Still dominated by smallholding farmers, Bangladesh's economically important agricultural sector is also vulnerable to extreme weather, particularly drought and heat waves (Basak et al., 2010; Karim et al., 1996; Krishnan et al., 2007; Pathak et al., 2003; Ruane et al., 2013; Sarker et al., 2012). Despite pervasive environmental vulnerabilities, Bangladesh is rapidly developing. The nation's gross domestic product increased by approximately 6.5% per year over the last decade, and the proportion of people living below the poverty line declined from 44% in 1991 to less than 15% in 2017 (The World Bank, 2019). Economic development has translated into measurable improvements in health and well-being. For example, infant mortality has been cut in half since 2000 and the proportion of women completing a secondary education or higher rose from 15% in 1994 to nearly 50% in 2014 (The DHS Program, 2020).

Traditional marriages in Bangladesh are arranged by parents as daughters approach puberty and sons leave adolescence. When daughters marry, they typically relocate to the husband's household. Although the payment of a dowry is a post-colonial phenomenon in Bangladesh (Alston et al., 2014; Amin and Cain, 1997; Nasrin, 2011), it remains common today (Suran et al., 2004). Naved and Persson (2010) report that a groom's family demanded a dowry in nearly 50% of rural marriages. In some situations, families pay a dowry in installments or entirely after the marriage occurs, and in a minority of cases the dowry is never paid in full (Naved and Persson, 2010). Brides in high demand (i.e., those who are young, from a respected family, and perceived as virtuous or attractive) may command smaller dowries (Arends-Kuenning and Amin, 2001; Kamal et al., 2014). Likewise, grooms who hold high social status, are well-educated, or are expected to treat a wife well may receive higher dowries (Bates et al., 2011; Nasrin, 2011; Suran et al., 2004; Verma and Collumbien, 2003).

Traditional gender norms, coupled with high rates of poverty, result in Bangladesh having one of the highest rates of child marriage in the world. Although there is some evidence of decline, in 2014 it was estimated that 59% of girls marry by their 18^{th} birthday (compared to 4.5% of boys), and over 22% of girls marry by age 15 (NIPORT, 2016; UNICEF, 2011). Child marriage remains widespread despite a long-standing law specifying age 18 as the minimum age of marriage for females (Kalaivani, 2015). In practice, this law is rarely enforced and in 2017 it was formally amended to allow exceptions to the legal age of marriage when a guardian consents and it is determined to be in the child's best interest.

2. Research Overview and Hypotheses

The motivation for this analysis is the theory that climate change may exacerbate the conditions that contribute to early and forced marriage among girls and women, and the acceptance of less desirable marriage proposals for daughters, irrespective of age. In this paper, we test three hypotheses. First, we expect that girls and women are more likely to marry during the year of, or after, an extreme weather event (H1). Second, because early marriages are associated with lower economic cost, we expect that the effect of extreme weather will be strongest for younger girls (H2). Third, across all age groups, we expect that extreme weather events in the year of or before a woman's marriage will negatively correlate with her husbands' educational attainment (H3a) and wealth (H3b), and will positively correlate with her husband's support for intimate partner violence (H3c).

We test these hypotheses using data from the Bangladesh Environment and Migration Survey (Donato et al., 2016; Carrico & Donato, 2019), collected in 2014 from household heads and spouses in nine communities in southwest Bangladesh (see Figure 1 for map of study sites). Respondents reported historical information about the year and location of their birth, and the year of their first and subsequent marriages. We include annual measures of heat waves and dry spells from 1988 through 2013 (Donat et al., 2013; Peterson and Manton, 2008) derived from daily temperature and rainfall data. We focus on heat waves and dry spells because of prior research suggesting that crop yields in the region are most vulnerable to temperature spikes and rainfall deficits (relative to low temperatures, wet spells, or intense precipitation; Basak et al., 2010; Krishnan et al., 2007; Sarker et al., 2012; Shahid and Behrawan, 2008). In addition, Carrico and Donato (2019) find that both measures are correlated with out-migration in Bangladesh, particularly among those engaged in agriculture.

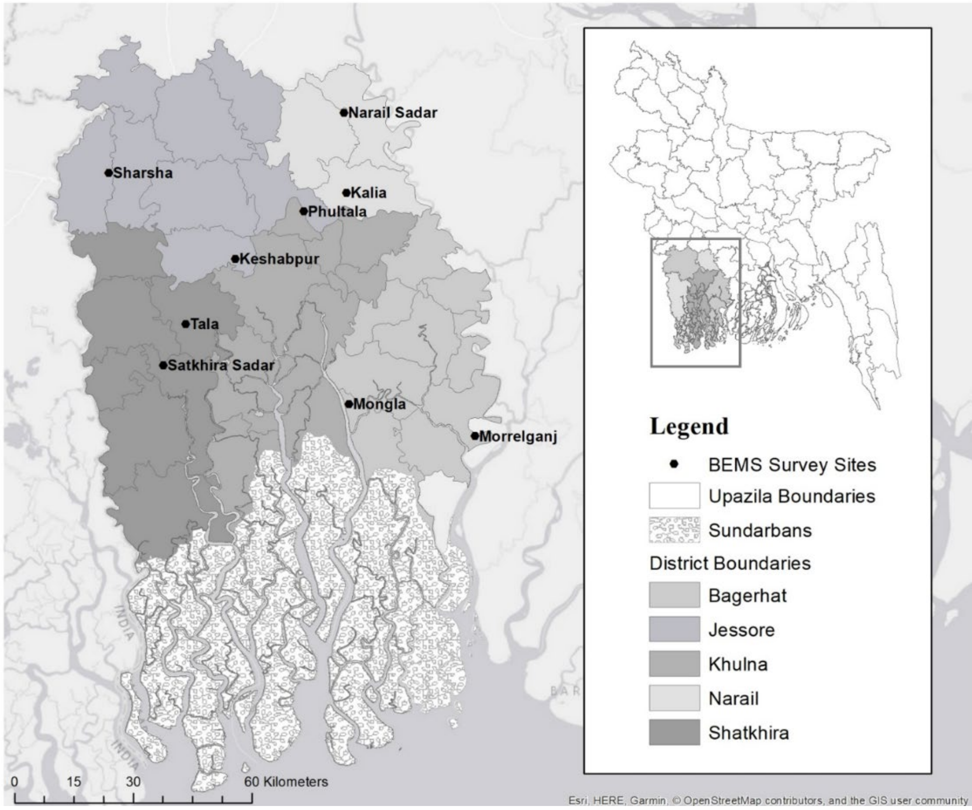

Figure 1. Map of survey sites. Black circles indicate the approximate location of each mouza. Labels represent the names of the Upazilas in which the mouzas are located. (Source: see Carrico & Donato, 2019).

3. Methods

In 2014, we administered the BEMS to 1695 randomly selected households in nine mouzas—small administrative units that typically contain one to three villages and vary in size from a few hundred to a few thousand households. A team of trained local enumerators interviewed household heads and spouses in their homes. Respondents provided demographic information about themselves and other household members, marriage and migration histories, and detailed data about current socioeconomic and environmental conditions. In the analyses presented below, we draw on retrospective data about the marriage of the female household head or female spouse of the household head (collectively referred to a female heads).

3.1. Site selection and sampling. We selected nine mouzas from all mouzas found in the five southwestern-most districts of Bangladesh (Fig 1). Using data from the Bangladesh census (Bangladesh Bureau of Statistics, 2011), we sorted the sampling frame into high and low economic development strata using a composite index comprised of adult literacy rates and the proportion of households with electricity in each mouza (using the median as a cut-off). We then randomly selected one mouza from the high and low economic development strata within each district, resulting in two mouzas in each of five districts. One site in Khulna District is excluded from this analysis because it was used to generate pilot data. In each selected mouza, we conducted a complete census of all households, and used simple random sampling to select 200 households per site. Because two of the nine communities had fewer than 200 households, we sampled all households in these locations. Almost all (99%) of the initially selected households agreed to participate in the study. We replaced those who refused with a randomly selected alternate to achieve a final household sample size of 1695. To protect anonymity, in this paper we refer to each study site using the names of the *upazilas* (i.e., subdistrict) in which the mouzas are located.

3.2. Data and measures.

Survey data. To calculate the respondent's age, we asked for her year of birth and verified this information using her government-issued identity card. The respondent reported information about all current and past marriages, including the year of the marriage and the year and cause of dissolution (if applicable). To protect the respondent's privacy, this information was collected at a time and place when other household members were not present. The enumerator probed to verify marriage dates by comparing the year reported to other known dates, such as the birth years of children or years of well-known social and political events. Respondent's also reported their religion and highest level of education completed.

Household SES is measured with a standardized index derived from a principal components analysis of a household's material assets at the time of the survey, including materials used to construct the house, vehicle holdings, and other possessions (e.g., fan, wardrobe, phone) (Vyas and Kumaranayake, 2006). Husband's directly reported their level of education, and we recoded this information to represent whether husbands completed some secondary education or higher (40.22%) or not. Finally, the husband's acceptance of intimate partner violence (IPV) was assessed with five questions developed by the Demographic Health Survey (Kishor and Johnson, 2004). Husbands were asked if they consider it acceptable for a man to beat his wife if: 1) she goes out without telling him, 2) neglects the children, 3) argues with him, 4) refuses him sex, or 5) burns the food. Men who answered yes to one or more of these questions received a one, indicating that they approve of IPV (27.88%). Those who said no to all questions received a zero.

Extreme weather data. We constructed two extreme weather variables—Warm Spell Duration Indicator (WSDI) and Consecutive Dry Days (CDD)— using the standardized approach recommended by the Expert Team on Climate Change Detection Indices (ETCCDI) (Donat et al., 2013; Peterson and Manton, 2008) that was first introduced in the IPCC Third Assessment Report. ETCCDI indicators have been employed in several studies that consider the relationship between extreme weather and demographic behavior (Carrico and Donato, 2019; Nawrotzki et al., 2015a, 2015b; Nawrotzki and DeWaard, 2016). WSDI is defined as the annual count of days during which six consecutive days exceeded the 90th percentile of temperature, where the 90th percentile is determined using a base period of 1961 – 1990. CDD is defined as the maximum number of consecutive days within a year with less than one millimeter of rainfall. To construct WSDI and CDD scores, we obtained daily measurements of maximum temperature, minimum temperature, and total precipitation from the Bangladesh Meteorology Department (BMD). These data were recorded at 34 weather stations located throughout the country. We inspected the data for implausible or unlikely values. Although data were available from 1961 to 2013, we restrict this analysis to the period from 1988 to 2013 due to missing data and quality concerns prior to 1987. The period from 1970-1987 included Bangladesh's war of independence and subsequent political and economic instability (van Schendal, 2009) that likely impacted the management of meteorological data. In addition, we dropped data from ten stations because of data quality concerns through 2013 (one station) or very high rates of missing data (nine stations).

As noted above, the period from 1961 to 1990 served as a baseline for estimating the 90th percentile temperature threshold needed to calculate WSDI values. Where baseline data overlapped in time with the data for calculating the indices (1988, 1989, 1990), thresholds were calculated with the bootstrapping method described in Zhang et al. (2005) (Zhang et al., 2005). WSDI and CDD values were calculated using the *climdex.pcic* package in R. The "quantiles" argument in the *climdexInput.raw* function was used to manually specify thresholds calculated from the 1961 to 1990 base period. Out of base thresholds and in-base thresholds calculated with the bootstrapping method were provided to the function. The resulting dataset consists of annual values of each climate index at 24 weather stations.

To spatially interpolate climate indices from station locations to the nine BEMS sites, we used ordinary kriging, a widely used method of spatial interpolation that accounts for spatial autocorrelation among measurements (Bivand et al., 2008; Gaetan and Guyon, 2010). We first used the *fit.variogram* function from the *gstat* package to fit different functional forms to the measured semivariogram for that climate index in each year. For each variable, the observed semivariograms were best described by an exponential model, in which spatial autocorrelation decreases exponentially with distance. We then used the *krige* function from the *gstat* package in R to interpolate WSDI and CDD values at each year in each of the nine research sites. This process allowed us to estimate CDD and WSDI values for each of the 20 survey sites in a given year.

3.3. Analytical sample. Using the data described above, we constructed two datasets. First, we built a discrete-time person year file for the period from 1989 to 2013 in which a unit of observation represents a year in the life of a respondent. This approach is widely used in analyses that attempt to situate life events (e.g., marriage, migration, death) in time or over an individual's life course (Allison, 2010). Structuring the dataset in this way allows for the integration of time-varying variables at multiple levels (e.g., age, year, weather conditions) as well as time-invariant predictors (e.g., gender, place of birth). This dataset was used to assess the risk that a female head marries in a given year as a function of her age and extreme weather conditions (H1 and H2). The initial sample included 1,035 female heads who were not married in 1989 and who either were born in the study area or migrated into the area at least one year prior to the first marriage. Because more than 90% of marriages occurred between the ages of 11 and 23, we omitted person years that fell outside of this age range. We also excluded person years that occurred after a female head's first marriage. These criteria resulted in a final analytical sample of 3,636 person-years generated from 615 female heads. We added to these data the annual estimates of WSDI and CDD for each community.

The second dataset was used to assess the conditions of a woman's married household (H3) at the time of the survey. We restricted this sample to the 530 female heads who contributed person years to the first analysis, and who entered into a first marriage between 1989 and 2013. We excluded an additional 25 women whose first marriage ended in divorce, separation, or due to the death of a husband. This left an eligible analytical sample of N=505 women still in their first marriage at the time of the survey. In 74 of these 505 cases, the husband was unavailable at the time of the survey (primarily due to seasonal migration). Of these, 50 women provided information about the husband's level of education, leaving 24 missing cases on this variable. Because only husbands answered questions about support of intimate partner violence (IPV), 74 observations are missing for this variable. To address missing data concerns, we estimate regression models with missing cases excluded and then repeat these analyses after performing multiple imputations (see Results & Discussion).

4. Results & Discussion

Table 1 presents descriptive statistics for all model variables. Marriages were reported in 14.5% of all person-years. The probability of marrying in a given person year was 7.4% for girls aged 11 to 14, 21.2% for girls aged 15 to 17, and 24.6% for girls aged 18 to 23. This translated into 61.3% of women in the sample marrying as children, including 24.4% who married between the ages of 11 and 14 and 36.9% who married between 15 and 17.

Figure 2 shows the distribution of heat waves (WSDI) and dry spells (CDD) over time. The trend in WSDI values indicates a substantial increase in both the duration and variability of heat waves since 1988. Between 1988 and 1997, WSDI averaged 2.4 days (*standard deviation [SD]* = 2.4) across the 9 communities. After 1997, this value rose to 13.3 days (*SD* = 6.9). These data also reveal substantial community-to-community variation. On average, heat waves were most intense in Narail Sadar (*Mean [M]* = 15.2 days) and least intense in Tala (*M* = 4.0) and Shatkhira Sadar (*M* = 3.6). The average duration of dry spells also increased somewhat in the second-half of the study period. From 1988 to 1997, CDD scores averaged 59.9 compared to 79.2 days from 1998 to 2013. There was substantially less between-community variance in CDD scores, and the variability that was observed remained relatively stable throughout the study period (*SD* = 7.6 days).

Table 1. Descriptive statistics of event history model variables with person-year means and standard deviations (SDs)

Variable	Unit	Min	Max	Time-varying	Lag	Mean	SD
Marriage	0/1	0	1	Yes	No	0.145	0.353
Heat wave	Days	0	31.339	Yes	No	8.098	9.185
Heat wave, *t-1*	Days	0	31.339	Yes	1 year	8.372	8.221
Dry spell	Days	31.859	135.510	Yes	No	71.791	24.264
Dry spell, *t-1*	Days	31.859	135.510	Yes	1 year	70.910	24.054
Age							
11-14 (reference)	0/1	0	1	Yes	No	0.527	0.499
15-17	0/1	0	1	Yes	No	0.281	0.450
18-23	0/1	0	1	Yes	No	0.192	0.394
Education							
None (reference)	0/1	0	1	No	--	0.126	0.332
Some primary	0/1	0	1	No	--	0.371	0.483
Some secondary or higher	0/1	0	1	No	--	0.503	0.500
Muslim	0/1	0	1	No	--	0.910	0.287
Year							
1989-1996 (reference)	0/1	0	1	Yes	No	0.394	0.489
1997-2004	0/1	0	1	Yes	No	0.432	0.495
2005-2013	0/1	0	1	Yes	No	0.174	0.379
Community	0/1	0	1				
Mongla	0/1	0	1	No	--	0.075	0.264
Keshabpur	0/1	0	1	No	--	0.086	0.280
Sharsha	0/1	0	1	No	--	0.120	0.325
Morrelganj	0/1	0	1	No	--	0.096	0.295
Tala	0/1	0	1	No	--	0.104	0.305
Shatkhira Sadar	0/1	0	1	No	--	0.174	0.379
Narail Sadar	0/1	0	1	No	--	0.081	0.274
Kalia	0/1	0	1	No	--	0.150	0.357
Phultala	0/1	0	1	No	--	0.114	0.318
Person-years						3,636	

Person-year data generated from 615 female heads. Person-years that occur after the first marriage are removed from the analysis file. Descriptive statistics using the raw distribution are presented here. The extreme weather variables are standardized in all regression models.

4.1. Extreme weather and the probability of marriage. Table 2 presents results from a series of multivariate discrete-time event history regression models, which estimate the likelihood that a woman marries in a given person-year. Model A includes demographic covariates, including a woman's religion and age in a given person-year. Because investments in a child's education correlate with wealth, and most women cease going to school before or at the time of marriage, we include dummy indicators representing the female head's level of education at the time of the survey. We use this as a proxy for the economic conditions of the parent's household prior to a woman's marriage. We also include fixed effects for year and community to control for unobservable characteristics related to time and place. All regression models are estimated with standard errors clustered at the person-level. Results from a series of preliminary analyses and alternative specifications of the models shown in Table 2 are provided in Table S1 (Supplementary Material).

Model A explains a significant proportion of variance in the risk that girls and women aged 11 to 23 married in a given person year. Controlling for year and community fixed effects, the risk of marriage varied significantly as a function of age and education. Girls and women with some secondary education were over 30% less likely to marry in given year (*Odds Ratio [OR]* = 0.654) than those with no education. Likewise, girls aged 15 to 17 were over three times more likely to marry relative to those aged 11 to 14 (*OR* = 3.284). Women aged 18 to 23 were nearly four times more likely (*OR* = 3.898) to marry. By contrast, Muslim women were no more or less likely to marry than Hindus.

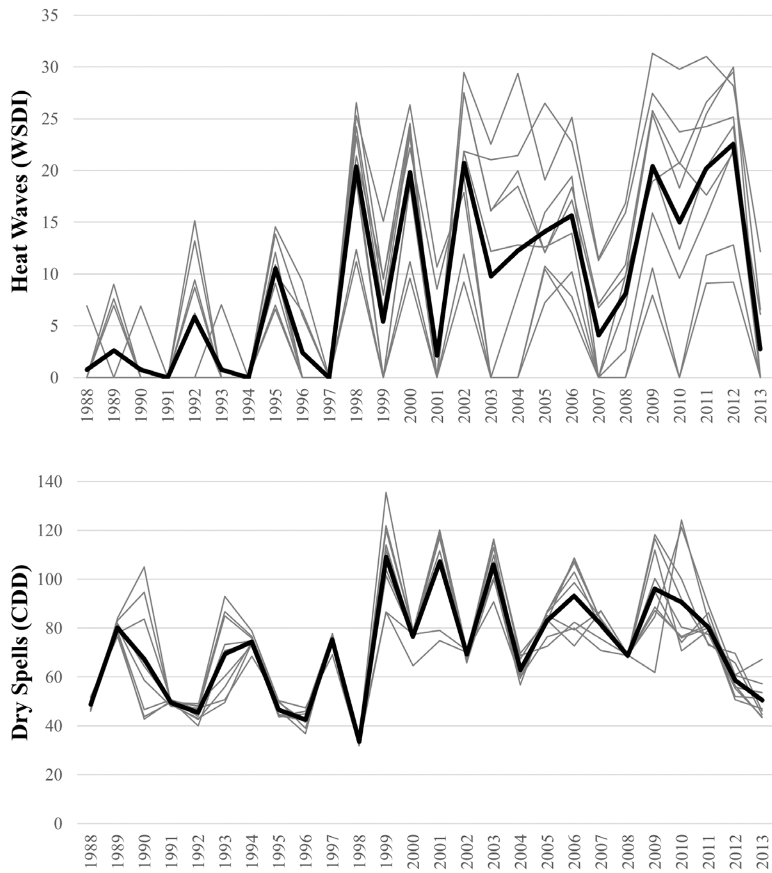

Figure 2. Heat waves (WSDI) and dry spells (CDD) over time. The grey lines represent observations for individual communities, the black lines represent the mean WSDI and CDD values across

Model B adds standardized WSDI and CDD scores specific to a given year and community. To explore delayed effects, we also include WSDI and CDD scores lagged by one year. In a set of preliminary analyses (Table S1 in the Supplementary Material), we tested for nonlinear effects of all extreme weather variables and retained only one significant effect. The inclusion of the extreme weather variables explains a significant proportion of variance, an effect that is primarily driven by extreme heat. Consistent with Hypothesis 1, as heat waves grow more intense, the probability that a woman enters into her first marriage also increases. The relationship between WSDI scores and marriage in the same year is nonlinear, with an inflection point at approximately 15 days duration (Figure 3a). When the duration of heat waves ranged from zero to 15 consecutive days, the probability that a woman marries remains relatively stable at approximately 13%. However, as the duration of heat waves exceeds 15 days, the risk of marriage rises to 19%, and heat waves longer than 25 days (which occurred 21 times between 1988 and 2013) are associated with a 23% probability that a woman marries that year. We also find a positive linear relationship between heat waves and the risk of marriage in the subsequent year (Figure 3b). A one standard deviation increase in the duration of heat waves (approximately 8 days) is associated with a 17% rise in the likelihood that a women marries in the next calendar year (*OR* = 1.167). The association between dry spells and marriage is not significant.

To assess if the relationship between heat waves and marriage is conditional on age, Model C in Table 2 adds interaction terms between WSDI and a woman's age in a given year Contrary to Hypothesis 2, we find that the association between heat waves and marriage in the same year is stronger for women aged 18 to 23 relative to those under 18 (overall interaction effect: X^2=8.50, p = 0.014). The estimated marginal probabilities associated with this interaction effect are provided in Table S2 and plotted in Figure 4. Again, we see a nonlinear relationship—the likelihood that women aged 18-23 enter into a first marriage rises as heat waves increase; however, the risk accelerates more rapidly as WSDI values exceed

10-12 days. The longest heat waves recorded during this period (approximately 30 days) were associated with a 51% probability that women aged 18-23 marry that year, relative to a 19% probability in years with no heat wave. The effect of heat waves is weaker for girls aged 15 to 17, and weaker still for those 11 to 14. For both younger age groups, the risk of marriage declines slightly during years with moderate heat waves (~6 to 18 days), suggesting that families may delay the marriage of their younger daughters during periods of moderate stress. However, the risk of marriage rises above baseline as the duration of heat waves exceed approximately 24 days in duration. The most extreme heat waves are associated with a 29% probability that girls aged 15-17 marry in that year, and a 14% chance for girls aged 11-14. This is relative to a 22% and 7% probability, respectively, during years with no heat wave.

Table 2. Logistic regression predicting first marriages of females aged 11-23 (1989-2013)

	Model A			**Model B**			**Model C**		
	OR	***SE***	***p***	***OR***	***SE***	***p***	***OR***	***SE***	***p***
Controls									
Year (ref=1989-1996)									
1997-2004	1.132	0.131	0.285	0.925	0.157	0.646	0.928	0.158	0.660
2005-2013	1.615	0.212	0.000	1.249	0.242	0.251	1.271	0.247	0.217
Education (ref=none)									
Some primary	0.787	0.132	0.154	0.782	0.133	0.147	0.776	0.134	0.143
Some secondary or higher	0.654	0.113	0.014	0.642	0.112	0.011	0.634	0.115	0.012
Muslim	1.058	0.159	0.706	1.061	0.160	0.695	1.067	0.160	0.665
Age (ref= 11-14)									
15-17	3.284	0.364	0.000	3.268	0.363	0.000	3.318	0.372	0.000
18-23	3.898	0.510	0.000	3.972	0.519	0.000	3.806	0.506	0.000
Extreme Weather									
Heat wave				1.047	0.094	0.609	1.012	0.115	0.917
Heat wave – squared				1.136	0.066	0.027	1.141	0.067	0.025
Heat wave – *t-1*				1.167	0.077	0.020	1.087	0.114	0.424
Dry spell				0.928	0.064	0.276	0.924	0.064	0.250
Dry spell – *t-1*				1.012	0.060	0.838	1.013	0.061	0.824
Interactions									
Heat wave X age 15-17							0.906	0.102	0.378
Heat wave X age 18-23							1.273	0.155	0.047
Heat wave *t-1* X age 15-17							1.112	0.131	0.368
Heat wave *t-1* X age 18-23							1.105	0.137	0.421
Constant	0.087	0.019	0.000	0.077	0.019	0.000	0.076	0.019	0.000
Chi-square	212.08, $p < 0.001$			234.44, $p < 0.001$			239.20, $p < 0.001$		
Δ Chi-square				16.47, $p = 0.006$			9.28, $p = 0.055$		
Pseudo R-squared	0.068			0.074			0.078		

N = 3,636 person-years derived from 615 female heads; OR = Odds Ratio, SE = Clustered Standard Errors, *p* = Alpha (significance level). Δ Chi-square tests the joint effect of the variables added to each model relative to the previous model. The heat wave and dry spell variables are standardized. All models include fixed effects of community (coefficients not shown). Alternative specifications of these models are shown in Table S1.

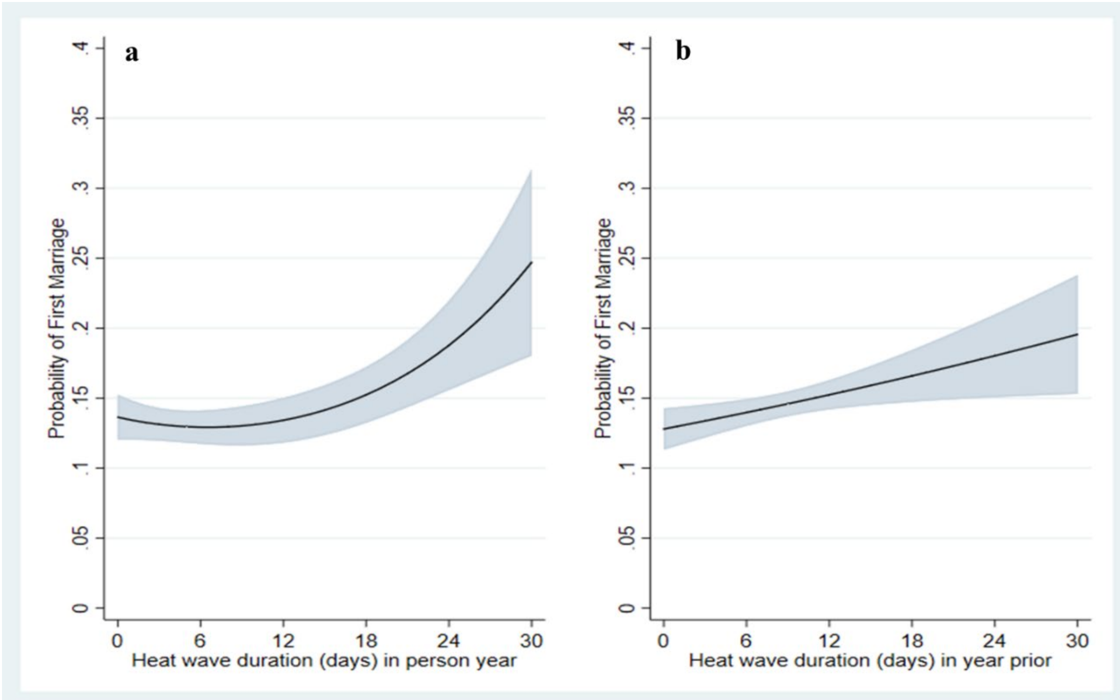

Figure 3. Relationship between the intensity of heat waves in the year of (a) and year prior (b), and the risk that a woman enters into her first marriage. Shaded area represents the 90% confidence interval. Derived from Table 2, Model B.

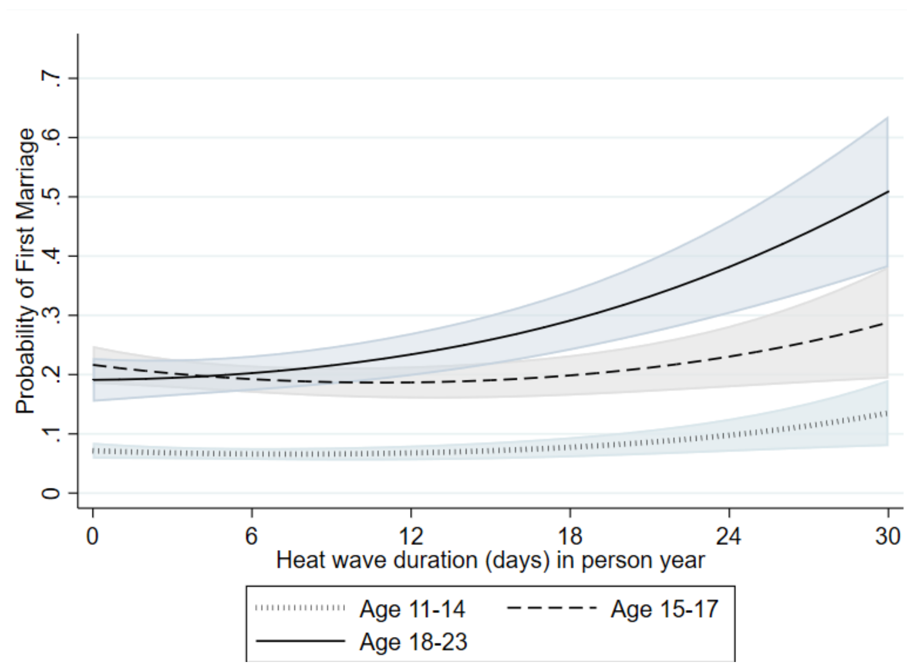

Figure 4. The probability of first marriage as a function of age and heat wave duration (WSDI) in the same year. The shaded area represents the 90% confidence interval. Derived from Table 2, Model C.

4.2. Extreme weather and the conditions of marriage. Next, we consider the relationship between extreme weather at the time of a woman's first marriage and the conditions of her married household. As noted above, we limit this analysis to a subset of 505 women who entered into a first marriage between 1989 and 2013 and were still married to their first husband at the time of the survey. Table 3 presents Model A, predicting household SES; Model B, predicting husband's level of education; and Model C, predicting husband's approval of IPV. We estimate Model A using ordinary least squares regression and Models B and C using logistic regression. All models include predictors that represent extreme weather conditions in the year of and year before a woman marries. We also include covariates that represent a woman's age at marriage, her educational attainment, the year she married, and fixed effects associated with community. Like before, we test for nonlinear effects of all extreme weather variables and retain quadratic terms when appropriate. When the main effects of extreme weather are significant, we estimate a subsequent model that includes age x weather interaction terms. Because no interactions terms are significant, we present only results from the baseline models in Table 3.

As noted above, information about the husband's education was missing for 24 respondents and the husband's approval of spouse abuse was missing for 74 respondents. To preserve these cases, we generated five imputed datasets using multiple imputation. We performed the analyses described above on each imputed data set and summarized the results using Rubin's combination rule (Little and Rubin, 2019; Rubin, 2004). Results from the un-imputed data are provided in the supplementary materials (Table S3); however, the two sets of results point to the same substantive conclusions.

Table 3. Regressions models predicting conditions of marriage

	Model A: Household SES			**Model B: Husband education is > primary**[a]			**Model C: Husband endorses IPV**[a]		
	B	***SE***	***p***	***OR***	***SE***	***p***	***OR***	***SE***	***p***
Controls									
Education (ref=none)									
Some primary	0.241	0.092	0.009	4.610	2.382	0.005	0.607	0.208	0.146
Above primary	0.731	0.095	0.000	38.517	20.390	0.000	0.387	0.139	0.001
Muslim	-0.003	0.112	0.978	0.532	0.231	0.162	1.792	0.918	0.256
Age (ref= 11-14									
15-17	-0.141	0.075	0.060	0.893	0.282	0.721	1.197	0.391	0.584
18-23	0.045	0.079	0.570	1.126	0.356	0.707	1.312	0.432	0.413
Extreme Weather									
Heat wave	0.010	0.051	0.851	0.739	0.112	0.046	1.227	0.175	0.151
Heat wave - squared	-0.073	0.034	0.031						
Heat wave – *t-1*	-0.073	0.046	0.113	1.036	0.185	0.844	1.045	0.183	0.803
Dry spell	-0.029	0.042	0.486	0.520	0.089	0.000	1.388	0.210	0.030
Dry spell – *t-1*	-0.034	0.049	0.483	1.055	0.204	0.781	1.112	0.208	0.573
Constant	0.027	0.220	0.901	0.136	0.102	0.008	0.233	0.161	0.036
F	20.50, $p < 0.001$			5.51, $p < 0.001$			1.59, $p = 0.042$		
Joint effect of extreme weather variables	2.13, $p = 0.060$			4.57, $p = 0.001$			1.56, $p = 0.182$		
# of imputed observations	0			24			74		
Adj / Pseudo R-Squared[b]	0.460			0.255 – 0.283			0.073 – 0.093		

Note. N= 505 female heads still engaged in their first marriage at the time of the survey. Model A is estimated using multiple linear regression. Models B and C are estimated using logistic regression. OR = Odds Ratio, SE = Standard Errors, *p* = Alpha (significance level). All models control for year and community fixed effects (coefficients not shown). [a]Results are derived from five imputed datasets. Summary statistics are generated using Rubin's (1987) combination rules. [b]Pseudo R-squared estimates represent the highest and lowest values from analyses on the five imputed datasets.

Table 3 reveals that, across the three outcomes, women's educational attainment emerges as the strongest and most consistent predictor. More educated women tended to marry into wealthier households and to more educated husbands; and are less likely to marry a man who endorses spouse abuse. Above and beyond education, the extreme weather variables explain a significant proportion of variance for all three outcome variables. Model A (predicting household SES) reveals a significant nonlinear effect of heat waves in the year of marriage. The marginal probabilities plotted in Figure 5a again reveal an inflection point at approximately 15 days duration. When heat waves in the year of marriage are longer than 15 days, the socioeconomic condition of a woman's married household declines. The average household SES of women who married during an extreme heat wave (25 days or longer) is approximately one-third of a standard deviation lower than similar women who married when there was no heat wave.

Model B in Table 3 suggests that extreme weather in the year of marriage is also associated with the likelihood that a woman marries a man with no secondary education. Again, we see a significant effect of heat waves—for every one standard deviation increase in heat wave duration during the year of marriage, there is a corresponding 26% lower probability that a woman marries a man with at least some secondary education (Figure 5b). We observe a similar, though stronger, effect of dry spells (Figure 5c). With each standard deviation increase in the duration of dry spells (approximately 24 days), there is a 48% lower likelihood that a woman marries a man with some secondary schooling.

Model C reveals a similar pattern as Models A and B, although the effects of extreme weather are somewhat weaker. Again, there is some suggestion that heat waves are associated with an increased likelihood that a woman marries a man who endorses intimate partner violence; however, this effect does not reach the threshold for statistical significance ($p = 0.15$). Like in Model B, we also find a significant relationship between dry spells and the risk of marrying a man who supports IPV (Figure 5d). On average, 28% of husbands report that it is acceptable for a man to beat his wife. Yet, for women who married in the year of a moderate (one SD above the mean) to severe (two SD's above the mean) dry spell; this rate rises to 35% and 41%, respectively.

5. Conclusions

A growing literature reveals the complex ways that climate shocks impact demographic processes and major life events, including fertility (Eissler et al., 2019; Sellers and Gray, 2019), migration (Call et al., 2017; Carrico and Donato, 2019; Mastrorillo et al., 2016), and mortality (Diboulo et al., 2012; Huang et al., 2011). Yet, we know surprisingly little about how climate variability shapes transitions to marriage. In this paper we integrate annual indicators of heat waves and dry spells from 1989 to 2013 with survey data from 615 women living in southwestern Bangladesh. Our data reveal that girls and women between the ages of 11 and 23 were at an increased risk of marrying in the year of, or after, moderate to severe heat waves. We also find that the relationship between extreme heat and the risk of marriage in the same year was nonlinear. The probability that a girl or woman married in a given year remained stable until heat waves reached approximately 15 days in duration. Above this threshold, the likelihood of marriage grew sharply. Nearly one in four females married in years with extreme heat waves, compared to 13% in years with moderate or no heat waves (15 days or less). Moreover, the risk of marriage remained elevated in the year after a heat wave occurred, suggesting a delayed coping response for some households.

These data also reveal that, relative to women of comparable age and education, those who wed during a year with a heat wave married poorer and less educated husbands. Likewise, women who married in years with an extended dry spell married husbands who, on average, had less education and were more supportive of domestic violence. That we see evidence of an increase in the rate of marriage during heat waves and a simultaneous decrease in the social standing of husbands points to the possible explanation that families seek out or accept proposals from less desirable marriage partners in order to reduce the cost dowries or to hasten the timing of a marriage. Although these data do not provide insight into the specific strategies at play, this interpretation is consistent with prior qualitative work suggesting that when families face economic hardship, many seek out marriage opportunities for daughters to reduce household consumption by moving them out of the home (Ahmed et al., 2019; Alston et al., 2014).

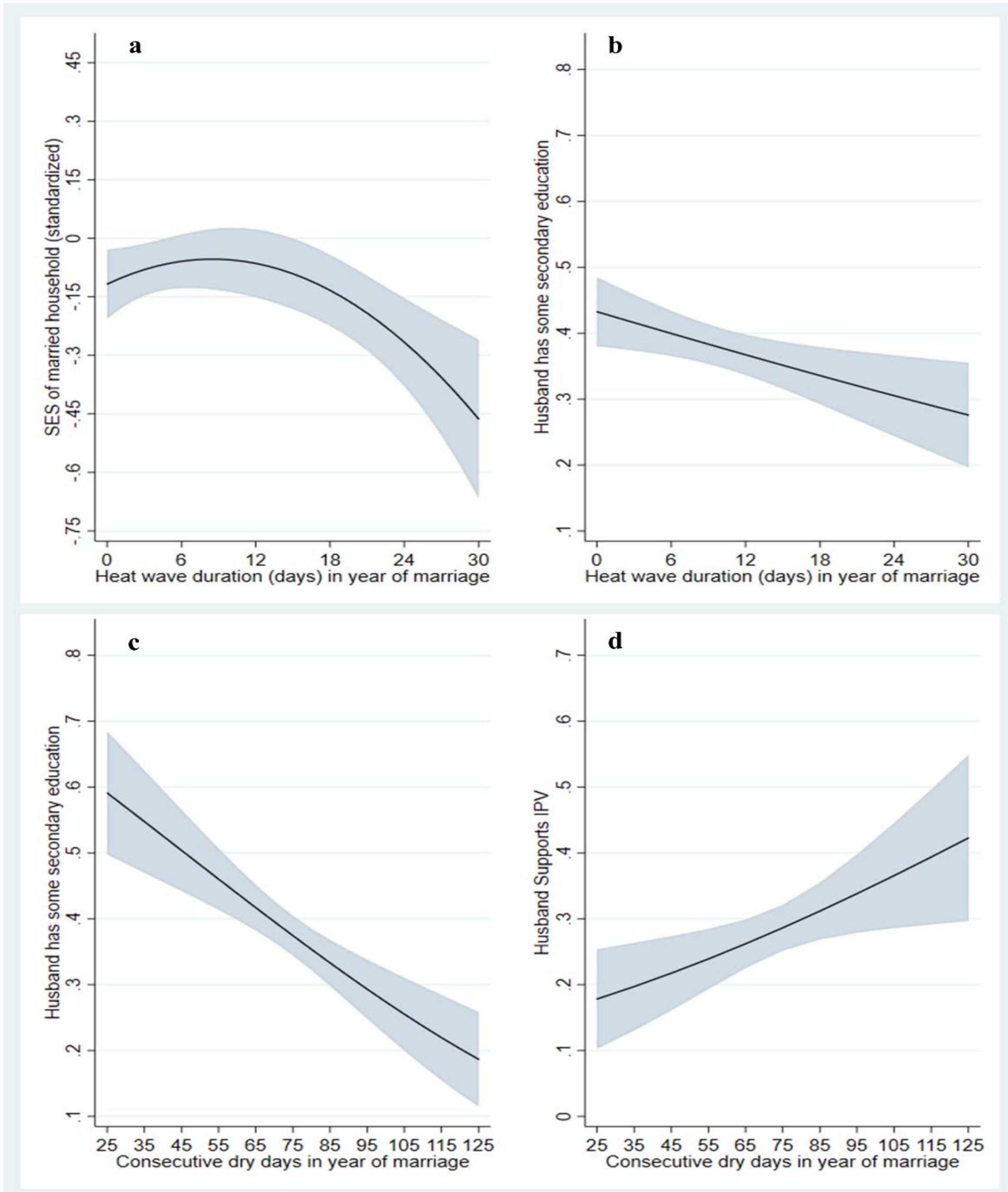

Figure 5. Relationship between extreme weather in the year of marriage and the conditions of a woman's home at the time of the survey (2014). Panel A shows the SES of a woman's household as a function of heat wave duration (WSDI). The probability that the husband completed primary school as function of heat waves is shown in Panel B, and dry spells (CDD) in Panel C. Panel D shows the probability that her husband supports intimate partner violence as a function of dry spells. The shaded area represents the 90% confidence interval. All estimates are derived from Table 3.

Prior work examining the use of marriage as an economic coping strategy has emphasized the implications of this practice for girls under the age of 18. Persistent poverty and periods of short-term economic stress place girls at higher risk for child marriage (Field and Ambrus, 2008; Godha et al., 2013; Nour, 2009; Wodon et al., 2016). This recognition has led to growing concern that climate change may exacerbate the conditions that lead to early marriage. These data reinforce that concern. Among girls aged

11 to 17, the risk of marriage remained stable during years with moderate heat waves. Yet, as heat waves approached 18 days in duration, the risk of marriage increased. In years with extreme heat waves of nearly 30 days in duration, girls aged 11 to 14 were twice as likely to marry relative to normal years, and those aged 15 to 17 were over 30% more likely to marry. As discussed above, early marriage is associated with lower educational attainment, larger family size, and adverse health outcomes for girls and their children. Despite some indications that child marriage may be declining, these data provide additional evidence that climate change has the potential to undermine recent trends.

Importantly, and counter to our expectations, we find that the link between extreme heat and marriage was strongest for women between the ages of 18 and 23. For this age group, the risk of marriage increases even in years with relatively short heat waves, and rises to nearly 50% when heat waves are most intense (relative to 19% in average years). This finding may suggest that when experiencing an environmental shock, families with older daughters resort more quickly to marriage as a coping mechanism, whereas those with younger daughters may look to other coping strategies before considering marriage as an option. It is also noteworthy that only heat waves were associated with the risk of marriage. Although we observe a relationship between dry spells and the conditions of a woman's marriage, dry spells were not associated with a detectable change in the probability of marriage.

These data shed new light on the ways in which climate shocks might lead to socioeconomic and demographic change; however, there are several limitations of this research that should be considered. First, these data come from nine communities in the southwestern-most area of the country, a region that faces relatively high rates of poverty and environmental stress. Although these data come from a random sample of households in these communities, our sample is not representative of Bangladesh as a whole. These analyses are further constrained by the fact that we have relatively little information about women's households prior to marriage. As a result, we are unable to explore the conditions that lead families to seek out or delay marriage during periods of environmental stress. Importantly, future work should consider how the socioeconomic conditions of households, or the availability of alternative adaptation strategies, influence whether a household marries a daughter as a means of coping with environmental stress. Further, although we theorize that the economic cost of dowries contributes to the pattern of results observed here, we do not have data from this sample about dowries paid and, therefore, we are unable to explicitly test this mechanism. Our second set of analyses predicting the conditions of a woman's married household may also be biased due to missing data. Approximately 5% (n=25) of respondents were no longer engaged in their first marriage at the time of the survey; and, therefore, we were unable to gather information about the conditions of this marriage. As a consequence, findings from this set of analyses reflect the characteristics of marriages that persisted through 2019. Because this issue applied to a small fraction of the women in our sample, we feel that any bias that was introduced is likely small. We were also unable to collect data about husbands' educational attainment or support for intimate partner violence from a subset of husbands (4.8% and 14.7%, respectively), because they were unavailable at the time of the survey. We attempted to mitigate this constraint using multiple imputation procedures and found no substantive differences between the results based on analyses with and without imputed data. However, readers should consider these concerns when interpreting the findings reported here.

Despite these limitations, we believe that these findings offer a rare glimpse into how the lives of girls and women are intimately tied to environmental conditions. Climate change threatens the health, well-being, and prosperity of people around the world, irrespective of age and gender. Yet, the forms that these impacts take are likely to vary substantially within and across communities. Given the clear policy relevance of these findings, we encourage further work in this area.

6. Bibliography

Adeyinka, D.A., Oladimeji, O., Adekanbi, T.I., Adeyinka, F.E., Falope, Y., Aimakhu, C., 2010. Outcome of adolescent pregnancies in southwestern Nigeria: A casecontrol study. J. Matern. Neonatal Med. 23, 785–789. https://doi.org/10.3109/14767050903572166

Adhikari, R., Sawangdee, Y., 2011. Influence of women's autonomy on infant mortality in Nepal. Reprod. Health 8, 1–8. https://doi.org/10.1186/1742-4755-8-7

Ahmed, K.J., Haq, S.A., Bartiaux, F., 2019. The nexus between extreme weather events, sexual violence, and early marriage: A study of vulnerable populations in Bangladesh. Popul. Environ. 40, 303–324.

Allison, P. D. (2010). *Survival analysis using SAS: a practical guide*. SAS Institute, Cary, USA.

Alston, M., 2014. Gender mainstreaming and climate change. Womens. Stud. Int. Forum 47, 287–294. https://doi.org/10.1016/j.wsif.2013.01.016

Alston, M., Whittenbury, K., Haynes, A., Godden, N., 2014. Are climate challenges reinforcing child and forced marriage and dowry as adaptation strategies in the context of Bangladesh? Womens. Stud. Int. Forum 47, 137–144. https://doi.org/10.1016/j.wsif.2014.08.005

Amin, S., Cain, M., 1997. The rise of dowry in Bangladesh, in: Jones, G., Douglas, R., Caldwell, J., D'Souza, R. (Eds.), The Continuing Demographic Transition. Clarendon Press, Oxford, UK, pp. 290–306.

Arends-Kuenning, M., Amin, S., 2001. Women's Capabilities and the Right to Education in Bangladesh. Int. J. Polit. Cult. Soc. 15, 125–142.

Audrey Harwood-Lejeune, 2000. Rising Age at Marriage and Fertility in Southern and Eastern Africa. Eur. J. Popul. 17, 261–280.

Bajracharya, A., Psaki, S.R., Sadiq, M., 2019. Child marriage, adolescent pregnancy and school dropout in South Asia. Kathmandu, Nepal.

Bangladesh Bureau of Statistics, 2011. Population and housing census 2011: Socio-economic and demographic report. National Series, Volume-4. Dhaka, Bangladesh.

Barreca, A., Deschenes, O., Guldi, M., 2018. Maybe Next Month? Temperature Shocks, Climate Change, and Dynamic Adjustments in Birth Rates. Demography 55, 1269–1293. https://doi.org/10.1007/s13398-014-0173-7.2

Bartlett, S., 2009. Children in the Context of Climate Change: A Large and Vulnerable Population, in: Guzman, J.M., Martine, G., McGarnahan, G., Schensul, D., Tacoli, C. (Eds.), Population Dynamics and Climate Change. UNFPA & IIED, New York, pp. 133–148.

Basak, J.K., Ali, M.A., Islam, N., 2010. Assessment of the effect of climate change on boro rice production in Bangladesh using DSSAT model. J. Civ. Eng. (IEB), 38, 95–108.

Bates, L.M., Schuler, S.R., Islam, F., Islam, M.K., 2011. Socioeconomic Factors and Processes Associated With Domestic Violence in Rural Bangladesh. Int. Fam. Plan. Perspect. 30, 190–199. https://doi.org/10.1363/3019004

Benneyworth, L., Gilligan, J., Ayers, J., Goodbred, S., George, G., Carrico, A.R., Karim, M.R., Akter, F., Fry, D., Donato, K.M., Piya, B., 2016. Drinking water insecurity: water quality and access in coastal Southwestern Bangladesh. Int. J. Environ. Health Res. 3123. https://doi.org/10.1080/09603123.2016.1194383

Bhuiya, A., Streatfield, K., 1991. Mothers' education and survival of female children in a rural area of Bangladesh. Popul. Stud. (NY). 45, 253–264. https://doi.org/10.1080/0032472031000145426

Bivand, R.S., Edzer, J.P., Gomez-Rubio, V., 2008. Applied Spatial Data Analysis with R: By. Springer, New York. https://doi.org/10.1007/BF03354901

Bloch, F., Rao, V., 2002. Terror as a Bargaining Instrument: A Case Study of Dowry Violence in Rural India. Am. Econ. Rev. 92, 1029–1043. https://doi.org/10.1257/00028280260344588

Bohra-Mishra, P., Oppenheimer, M., Hsiang, S.M., 2014. Nonlinear permanent migration response to climatic variations but minimal response to disasters. Proc. Natl. Acad. Sci. 1–6. https://doi.org/10.1073/pnas.1317166111

Bongaarts, J., 1978. A Framework for Analyzing the Proximate Determinants of Fertility. Popul. Dev. Rev. 4, 105. https://doi.org/10.2307/1972149

Bongaarts, J., O'Neill, B.C., 2018. Population policies offer options to lessen climate risks. Science (80-.). 361, 650–652. https://doi.org/10.1126/science.aat8680

Bremner, J., Carr, D.L., Suter, L., Davis, J., 2010. Population, poverty, environment, and climate dynamics in the developing world. Interdiscip. Environ. Rev. 11, 112–126.

https://doi.org/10.1504/ier.2010.037902
Brien, M.J., Lillard, L.A., 1994. Education, marriage, and first conception in Malaysia. J. Hum. Resour. 29, 1167–1204. https://doi.org/10.2307/146137
Call, M.A., Gray, C.L., Yunus, M., Emch, M., 2017. Disruption, not displacement: Environmental variability and temporary migration in Bangladesh. Glob. Environ. Chang. 46, 157–165. https://doi.org/https://doi.org/10.1016/j.gloenvcha.2017.08.008
Carrico, A.R., Donato, K., 2019. Extreme weather and migration: evidence from Bangladesh. Popul. Environ. 41, 1–31. https://doi.org/10.1007/s11111-019-00322-9
Casey, G., Shayegh, S., Moren-Cruz, J., Bunzl, M., Galor, O., Caldeira, K., 2019. The Impact of Climate Change on Fertility. Environ. Res. Lett. 14, 1–9. https://doi.org/10.1016/j.tree.2018.12.002
Chakraborty, N., Islam, M.A., Chowdhury, R.I., Bari, W., Akhter, H.H., 2003. Determinants of the use of maternal health services in rural Bangladesh. Health Promot. Int. 18, 327–337. https://doi.org/10.1093/heapro/dag414
Corno, L., Hildebrandt, N., Voena, A., 2016. Age of marriage, weather shocks, and the direction of marriage payments (No. 23604), National Bureau of Economic Research, Working Paper. https://doi.org/10.3386/w23604
Das Gupta, M., Jiang, Z., Li, B., Xie, Z., Woojin, C., Bae, H.O., 2003. Why is son preference so persistent in East and South Asia? A cross-country study of China, India and the Republic of Korea. J. Dev. Stud. 40, 153–187. https://doi.org/10.1080/00220380412331293807
Diamond-Smith, N., Luke, N., McGarvey, S., 2008. "Too many girls, too much dowry": Son preference and daughter aversion in rural Tamil Nadu, India. Cult. Heal. Sex. 10, 697–708. https://doi.org/10.1080/13691050802061665
Diboulo, E., Sié, A., Rocklöv, J., Niamba, L., Yé, M., Bagagnan, C., Sauerborn, R., 2012. Weather and mortality: A 10 year retrospective analysis of the nouna health and demographic surveillance system, Burkina Faso. Glob. Health Action 5, 6–13. https://doi.org/10.3402/gha.v5i0.19078
Donat, M.G., Alexander, L. V., Yang, H., Durre, I., Vose, R., Caesar, J., 2013. Global land-based datasets for monitoring climatic extremes. Bull. Am. Meteorol. Soc. 94, 997–1006. https://doi.org/10.1175/BAMS-D-12-00109.1
Eissler, S., Thiede, B.C., Strube, J., 2019. Climatic variability and changing reproductive goals in Sub-Saharan Africa. Glob. Environ. Chang. 57, 101912. https://doi.org/10.1016/j.gloenvcha.2019.03.011
Fantahun, M., Berhane, Y., Wall, S., Byass, P., Högberg, U., 2007. Women's involvement in household decision-making and strengthening social capital - Crucial factors for child survival in Ethiopia. Acta Paediatr. Int. J. Paediatr. 96, 582–589. https://doi.org/10.1111/j.1651-2227.2007.00147.x
Field, E., Ambrus, A., 2008. Early marriage, age of menarche, and female schooling attainment in Bangladesh. J. Polit. Econ. 116, 881–930.
Gaetan, C., Guyon, X., 2010. Spatial Statistics and Modeling. Springer, New York. https://doi.org/10.1007/978-0-387-92257-7
Godha, D., Hotchkiss, D.R., Gage, A.J., 2013. Association between child marriage and reproductive health outcomes and service utilization: A multi-country study from south asia. J. Adolesc. Heal. 52, 552–558. https://doi.org/10.1016/j.jadohealth.2013.01.021
Grace, K., 2017. Considering climate in studies of fertility and reproductive health in poor countries. Nat. Clim. Chang. 7, 479–485. https://doi.org/10.1038/nclimate3318
Hallman, K.K., 2000. Mother-Father Resource Control, Marriage Payments, and Girl-Boy Health in Rural Bangladesh, FCND Discussion Paper, Food Consumption and Nutrition Division. Washington D.C.
Henry, E.G., Lehnertz, N.B., Alam, A., Ali, N.A., Williams, E.K., Rahman, S.M., Ahmed, S., El Arifeen, S., Baqui, A.H., Winch, P.J., 2015. Sociocultural factors perpetuating the practices of early marriage and childbirth in Sylhet District, Bangladesh. Int. Health 7. https://doi.org/10.1093/inthealth/ihu074
Huang, C., Barnett, A.G., Wang, X., Vaneckova, P., Fitzgerald, G., Tong, S., 2011. Projecting Future heat-related mortality under climate change scenarios: A systematic review. Environ. Health Perspect. 119, 1681–1690. https://doi.org/10.1289/ehp.1103456
Huda, S., 2006. Dowry in Bangladesh: Compromizing Women's Rights. South Asia Res. 26, 249–268.

https://doi.org/10.1177/0262728006071707
Human Rights Watch, 2015. Marry before your house is swept away: Child marriage in Bangladesh. New York, New York.
Hurt, L.S., Ronsmans, C., Saha, S., 2004. Effects of education and other socioeconomic factors on middle age mortality in rural Bangladesh. J. Epidemiol. Community Health 58, 315–320. https://doi.org/10.1136/jech.2003.007351
Islam, M.D.F., Rashid, A.N.M.B., 2011. Riverbank erosion displacees in Bangladesh: Need for institutional response and policy intervention. Bangladesh J. Bioeth. 2, 4–19. https://doi.org/10.3329/bioethics.v2i2.9540
Jennings, J.A., Gray, C.L., 2017. Climate and marriage in the Netherlands, 1871–1937. Popul. Environ. 38, 242–260. https://doi.org/10.1007/s11111-016-0266-7
Jensen, R., Thornton, R., 2003. Early female marriage in the developing world. Gend. Dev. 11, 9–19. https://doi.org/10.1080/741954311
Kalaivani, R., 2015. Child Marriage Restraint Act (1929) - A Historical Review. Int. J. Humanit. Soc. Sci. Invent. 4, 14–18.
Kamal, S.M.M., Hassan, C.H.E.H., Alam, G.M., Ying, Y., 2014. Child marriage in Bangladesh: Trends and determinants. J. Biosoc. Sci. 1–20. https://doi.org/10.1017/S0021932013000746
Karim, Z., Hussain, S.G., Ahmed, M., 1996. Assessing the impact of climatic variations on foodgrain production in Bangladesh, in: Erda, L., Bolhofer, W.C., Huq, S., Lenhart, S., Mukherjee, S.K., Smith, J.B., Wisniewski, J. (Eds.), Climate Change Vulnerability and Adaptation in Asia and the Pacific. Manila, Philippines, pp. 53–62.
Khan, A.E. hmar, Scheelbeek, P.F. ranka D., Shilpi, A.B. egum, Chan, Q., Mojumder, S.K. umar, Rahman, A., Haines, A., Vineis, P., 2014. Salinity in drinking water and the risk of (pre)eclampsia and gestational hypertension in coastal Bangladesh: a case-control study. PLoS One 9, e108715. https://doi.org/10.1371/journal.pone.0108715
Kishor, S., Johnson, K., 2004. Profiling domestic violence: A multi-country study. Calverton, Maryland.
Krishnan, P., Swain, D.K., Chandra Bhaskar, B., Nayak, S.K., Dash, R.N., 2007. Impact of elevated CO2 and temperature on rice yield and methods of adaptation as evaluated by crop simulation studies. Agric. Ecosyst. Environ. 122, 233–242. https://doi.org/10.1016/j.agee.2007.01.019
Lam, D.A., Miron, J.A., 1996. The Effects of Temperature on Human Fertility. Demography 33, 291–305.
Little, R.J.A., Rubin, D.B., 2019. Statistical analysis with missing data. John Wiley & Sons, New York.
Lutz, W., Muttarak, R., Striessnig, E., 2014. Universal education is key to enhanced climate adaptation. Science (80-.). 346, 1061–1062. https://doi.org/10.1126/science.1257975
Mastrorillo, M., Licker, R., Bohra-Mishra, P., Fagiolo, G., D. Estes, L., Oppenheimer, M., 2016. The influence of climate variability on internal migration flows in South Africa. Glob. Environ. Chang. 39, 155–169. https://doi.org/10.1016/j.gloenvcha.2016.04.014
Mcleod, C., Barr, H., Rall, K., 2019. Does climate change increase the risk of child marriage? A look at what we know - and what we don’t - with lessons from Bangladesh and Mozambique. Columbia J. Gend. Law 38, 96–145.
McMichael, A.J., Woodruff, R.E., Hales, S., 2006. Climate change and human health: present and future risks. Lancet 367, 859–69. https://doi.org/10.1016/S0140-6736(06)68079-3
Mobarak, A.M., Kuhn, R., Peters, C., 2013. Consanguinity and Other Marriage Market Effects of a Wealth Shock in Bangladesh. Demography 50, 1845–1871. https://doi.org/10.1007/s13524-013-0208-2
Nasrin, S., 2011. Crime or custom? Motivations behind dowry practice in rural Bangladesh. Indian J. Gend. Stud. 18, 27–50. https://doi.org/10.1177/097152151001800102
Naved, R.T., Persson, L.A., 2010. Dowry and spousal physical violence against women in Bangladesh. J. Fam. Issues 31, 830–856. https://doi.org/10.1177/0192513X09357554
Nawrotzki, R.J., DeWaard, J., 2016. Climate shocks and the timing of migration from Mexico. Popul. Environ. 38, 72–100. https://doi.org/10.1007/s11111-016-0255-x

Nawrotzki, R.J., Hunter, L.M., Runfola, D.M., Riosmena, F., 2015a. Climate change as a migration driver from rural and urban Mexico. Environ. Res. Lett. 10, 114023. https://doi.org/10.1088/1748-9326/10/11/114023

Nawrotzki, R.J., Riosmena, F., Hunter, L.M., 2013. Do Rainfall Deficits Predict U.S.-Bound Migration from Rural Mexico? Evidence from the Mexican Census. Popul. Res. Policy Rev. 32, 129–158. https://doi.org/10.1007/s11113-012-9251-8

Nawrotzki, R.J., Riosmena, F., Hunter, L.M., Runfola, D.M., 2015b. Amplification or suppression: Social networks and the climate change-migration association in rural Mexico. Glob. Environ. Chang. 35, 463–474. https://doi.org/10.1016/j.gloenvcha.2015.09.002

NIPORT, 2016. Bangladesh: Demographic and Health Survey. Dhaka, Bangladesh and Rockville, USA.

Nour, N.M., 2009. Child marriage: A silent health and human rights issue. Rev. Obstet. Gynecol. 2, 51–56. https://doi.org/10.3909/riog0109

OHCHR (2019). Child, early and forced marriage, including in humanitarian settings. United Nations Office of the High Commissioner on Human Rights. Retrieved December 6, 2019 from https://www.ohchr.org/EN/Issues/Women/WRGS/Pages/ChildMarriage.aspx

Pathak, H., Ladha, J.K., Aggarwal, P.K., Peng, S., Das, S., Singh, Y., Singh, B., Kamra, S.K., Mishra, B., Sastri, A.S.R.A.S., Aggarwal, H.P., Das, D.K., Gupta, R.K., 2003. Trends of climatic potential and on-farm yields of rice and wheat in the Indo-Gangetic Plains. F. Crop. Res. 80, 223–234. https://doi.org/10.1016/S0378-4290(02)00194-6

Peterson, T.C., Manton, M.J., 2008. Monitoring changes in climate extremes: A tale of international collaboration. Bull. Am. Meteorol. Soc. 89, 1266–1271. https://doi.org/10.1175/2008BAMS2501.1

Quisumbing, A.R., Maluccio, J.A., 2003. Resources at marriage and intrahousehold distribution: evidence from Bangladesh, Ethiopia, Indonesia, and South Africa. Oxf. Bull. Econ. Stat. 65, 283–327.

Raj, A., Saggurti, N., Balaiah, D., Silverman, J.G., 2009. Prevalence of child marriage and its effect on fertility and fertility-control outcomes of young women in India: a cross-sectional, observational study. Lancet 373, 1883–1889. https://doi.org/10.1016/S0140-6736(09)60246-4

Raj, A., Saggurti, N., Winter, M., Labonte, A., Decker, M.R., Balaiah, D., Silverman, J.G., 2010. The effect of maternal child marriage on morbidity and mortality of children under 5 in India: Cross sectional study of a nationally representative sample. BMJ 340, 353. https://doi.org/10.1136/bmj.b4258

Rastogi, M., Therly, P., 2006. Dowry and its link to violence against women in India: Feminist psychological perspectives. Trauma, Violence, Abus. 7, 66–77. https://doi.org/10.1177/1524838005283927

Ruane, A.C., Major, D.C., Yu, W.H., Alam, M., Hussain, S.G., Khan, A.S., Hassan, A., Hossain, B.M.T. Al, Goldberg, R., Horton, R.M., Rosenzweig, C., 2013. Multi-factor impact analysis of agricultural production in Bangladesh with climate change. Glob. Environ. Chang. 23, 338–350. https://doi.org/10.1016/j.gloenvcha.2012.09.001

Rubin, D.B., 2004. Multiple Imputation for Nonresponse in Surveys. Johm Wiley & Sons, New York.

Santhya, K.G., 2011. Early marriage and sexual and reproductive health vulnerabilities of young women: A synthesis of recent evidence from developing countries. Curr. Opin. Obstet. Gynecol. 23, 334–339. https://doi.org/10.1097/gco.0b013e32834a93d2

Sarker, M.A.R., Alam, K., Gow, J., 2012. Exploring the relationship between climate change and rice yield in Bangladesh: An analysis of time series data. Agric. SySarker, M. A. R., Alam, K., Gow, J. (2012). Explor. Relatsh. between Clim. Chang. rice yield Bangladesh An Anal. time Ser. data. Agric. Syst. 112, 11–16. https//doi.org/10.1016/j.agsy.2012.06.004stems 112, 11–16. https://doi.org/10.1016/j.agsy.2012.06.004

Schuler, S.R., 2007. Rural Bangladesh: Sound policies, evolving gender norms, and family strategies., in: Exclusion, Gender and Education: Case Studies from the Developing World. Washington D.C., pp. 179–204.

Schuler, S.R., Bates, L.M., Islam, F., Islam, M.K., 2006. The timing of marriage and childbearing among rural families in Bangladesh: Choosing between competing risks. Soc. Sci. Med. 62, 2826–2837.

https://doi.org/10.1016/j.socscimed.2005.11.004
Sellers, S., Gray, C., 2019. Climate shocks constrain human fertility in Indonesia. World Dev. 117, 357–369. https://doi.org/10.1016/j.worlddev.2019.02.003
Shahid, S., Behrawan, H., 2008. Drought risk assessment in the western part of Bangladesh. Nat. Hazards 46, 391–413. https://doi.org/10.1007/s11069-007-9191-5
Smith, K.R., Woodward, A., Campbell-Lendrum, D., Chadee, D.D., Honda, Y., Liu, Q., Olwoch, J.M., Revich, B., Sauerborn, R., 2014. Human health: Impacts, adaptation, and co-benefits, in: Field, C.B., V.R.B., D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C.G., B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.W. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, USA, pp. 709–754.
Striessnig, E., Lutz, W., Patt, A.G., 2013. Effects of educational attainment on climate risk vulnerability. Ecol. Soc. 18, 39–52. https://doi.org/10.5751/ES-05252-180116
Suran, L., Amin, S., Huq, L., Chowdury, K., 2004. Does dowry improve life for brides? A test of the bequest theory of dowry in rural Bangladesh (No. 195), Policy Research Division Working Paper Series. New York.
The DHS Program, 2020. Demographic and Health Surveys. Country Quickstats: Bangladesh [WWW Document]. USAID.
The World Bank, 2019. The World Bank in Bangladesh: Overview [WWW Document]. URL https://www.worldbank.org/en/country/bangladesh/overview (accessed 2.1.20).
UNICEF, 2011. State of the World's Children. Adolescence: An Age of Opportunity. New York City.
United Nations, 2001. We the Children: End-Decade Review of the Follow-Up to the World Summit for Children. New York.
Verma, R., Collumbien, M., 2003. Wife beating and the link with poor sexual health and risk behavior among men in urban slums in India. J. Comp. Fam. Stud.
Vyas, S., Kumaranayake, L., 2006. Constructing socio-economic status indices: how to use principal components analysis. Health Policy Plan. 21, 459–68. https://doi.org/10.1093/heapol/czl029
Walker, J., 2012. Early Marriage in Africa – Trends, Harmful Effects and Interventions. Afr. J. Reprod. Health 16, 231–240.
Wodon, Q., Nguyen, M.C., Tsimpo, C., 2016. Child Marriage, Education, and Agency in Uganda. Fem. Econ. 22, 54–79. https://doi.org/10.1080/13545701.2015.1102020
Wong, P.P., Losada, I.J., Gattuso, J.-P., Hinkel, J., Khattabi, A., McInnes, K.L., Saito, Y., Sallenger, A., 2014. Coastal Systems and Low-Lying Areas, in: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kisse, E.S., Levy, A.N., MacCracken, S., Mastrandree, P.R., White, L.L. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York, pp. 361–409. https://doi.org/10.1017/CBO9781107415379.010
Zhang, X., Hegerl, G., Zwiers, F.W., Kenyon, J., 2005. Avoiding inhomogeneity in percentile-based indices of temperature extremes. J. Clim. 18, 1641–1651. https://doi.org/10.1175/JCLI3366.1

Supplementary Materials

Table S1. Alternate specifications of the logistic regression models shown in Table 2

	1			2			3		
	OR	***SE***	***p***	***OR***	***SE***	***p***	***OR***	***SE***	***p***
Controls									
Year (ref=1989-1996)									
1997-2004	1.001	0.173	0.994	0.939	0.159	0.709	0.933	0.158	0.683
2005-2013	1.212	0.236	0.323	1.292	0.250	0.186	1.288	0.249	0.190
Education (ref=none)									
Some primary	0.815	0.136	0.220	0.801	0.137	0.197	0.805	0.138	0.207
Some secondary or higher	0.671	0.116	0.021	0.659	0.118	0.020	0.661	0.119	0.021
Muslim	1.047	0.158	0.759	1.045	0.157	0.767	1.062	0.158	0.686
Age (ref= 11-14)									
15-17	3.213	0.356	0.000	3.316	0.375	0.000	2.889	0.526	0.000
18-23	3.844	0.499	0.000	3.735	0.498	0.000	3.717	0.720	0.000
Extreme Weather									
Heat wave	1.034	0.093	0.713	0.994	0.121	0.960	1.040	0.145	0.777
Heat wave, *squared*	1.134	0.066	0.029	1.145	0.067	0.021	1.087	0.117	0.435
Heat wave – *t-1*	1.197	0.111	0.053	1.141	0.143	0.291	1.069	0.112	0.522
Heat wave – *t-1, squared*	0.970	0.050	0.551						
Dry spell	0.932	0.068	0.332	0.831	0.096	0.108	0.931	0.064	0.303
Dry spell, *squared*	0.980	0.051	0.695						
Dry spell – *t-1*	1.049	0.069	0.465	0.970	0.093	0.753	1.017	0.061	0.780
Dry spell – *t-1, squared*	0.911	0.048	0.076						
Interactions									
Heat wave X age 15-17				0.909	0.120	0.470	0.816	0.138	0.229
Heat wave X age 18-23				1.296	0.186	0.071	1.313	0.236	0.129
Heat wave *t-1* X age 15-17				1.026	0.155	0.867	1.116	0.131	0.350
Heat wave *t-1* X age 18-23				1.041	0.175	0.812	1.120	0.139	0.359
Dry spell X age 11-14				1.184	0.169	0.238			
Dry spell X age 15-17				1.149	0.181	0.376			
Dry spell *t-1* X age 11-14				1.090	0.141	0.508			
Dry spell *t-1* X age 15-17				1.053	0.148	0.715			
Heat wave, *squared* X age 15-17							1.131	0.156	0.371
Heat wave, *squared* X age 18-23							0.986	0.139	0.922
Constant	0.087	0.023	0.000	0.076	0.019	0.000	0.079	0.021	0.000
Chi-square	233.67, $p < 0.001$			235.86, $p < 0.001$			239.27, $p < 0.001$		
Δ Chi-square	3.39, $p = 0.335$			2.45, $p = 0.654$			1.49, $p = 0.475$		
Pseudo R-squared	0.073			0.077			0.076		

OR = Odds Ratio, SE = Clustered Standard Errors. Δ Chi-square tests the joint effect of the variables added to each model relative to Model B in Table 2 of the main text. The heat wave and dry spell variables are standardized. All models include fixed effects of community (coefficients not shown).

Table S2. Marginal probability of entering into a first marriage as a function of heat waves in the same year and a woman's age.

WSDI (days) same year	Age 11-14 Prob	Age 11-14 95% CI	Age 15-17 Prob	Age 15-17 95% CI	Age 18-23 Prob	Age 18-23 95% CI
0	0.072	0.055 , 0.088	0.217	0.179 , 0.254	0.191	0.147 , 0.235
6	0.066	0.054 , 0.078	0.192	0.165 , 0.220	0.203	0.167 , 0.238
12	0.068	0.053 , 0.083	0.187	0.155 , 0.219	0.234	0.191 , 0.277
18	0.077	0.057 , 0.098	0.199	0.158 , 0.239	0.291	0.231 , 0.351
24	0.098	0.064 , 0.131	0.230	0.169 , 0.292	0.382	0.288 , 0.476
30	0.135	0.069 , 0.202	0.288	0.176 , 0.400	0.509	0.357 , 0.661

Marginal probabilities are derived using point estimates based on the logistic regression model shown in Model C of Table 2.

Table S3. Logistic regressions predicting conditions of marriage with un-imputed, raw data

	Model B: Husband education is > primary[a]			**Model C: Husband endorses spouse abuse**		
	OR	***SE***	***p***	***OR***	***SE***	***p***
Education (ref=none)						
Some primary	4.492	2.325	0.004	0.607	0.204	0.138
Above primary	38.240	20.200	0.000	0.405	0.148	0.014
Muslim	0.548	0.238	0.167	1.895	0.952	0.203
Age (ref= 11-14						
15-17	0.866	0.266	0.638	1.269	0.372	0.417
18-23	1.120	0.362	0.728	1.330	0.415	0.361
Heat wave	0.731	0.111	0.040	1.231	0.181	0.158
Heat wave – *t-1*	1.042	0.192	0.825	1.036	0.187	0.845
Dry spell	0.528	0.091	0.000	1.378	0.218	0.043
Dry spell – *t-1*	1.055	0.207	0.786	1.147	0.215	0.465
Constant	0.131	0.099	0.007	0.240	0.240	0.038
Chi-square	171.87, $p < 0.001$			41.78, $p = 0.005$		
Δ Chi-square	17.41, $p = 0.002$			5.87, $p = 0.209$		
Pseudo R-squared	0.269			0.081		
N	481			431		

OR = Odds Ratio, SE = Standard Errors; ^p<0.10, *p<0.05, **p<0.01, ***p<0.001.
All models control for year and community fixed effects (coefficients not shown).