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Estimating the relationship between prolonged weather variability and accelerated marriage in Bangladesh

Livia Elisa Ortensi, Francesca Tosi *, Rosella Rettaroli

University of Bologna, Department of Statistical Sciences "Paolo Fortunati", Via delle Belle Arti, 41, 40126 Bologna, Italy

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A B S T R A C T

Marrying as a child is a severe violation of human rights, with far-reaching consequences for young girls' lives. Despite having declined in the last decades, the practice of early marriage is still pervasive globally, especially in South Asia. It is increasingly evident that climate change affects the timing and patterns of life course transitions, including the transition into unions for women and girls of all ages. This study focuses on the case of Bangladesh, where both extreme weather and child marriage prevalence are among the highest worldwide. We estimate the relationship between the two phenomena by applying multilevel survival modelling to integrated data based on the Bangladesh Demographic and Health Survey and the climatic information conveyed by the Standardized Precipitation and Evapotranspiration Index. Analyzing marriages between 1990 and 2016, we find that the risk of marrying before turning 18 and at any age increases when dry and wet weather conditions depart from the near normality for a medium and prolonged timespan, both in rural and urban areas. We interpret such evidence as a response of demographic behaviors to prolonged, severe climatic alterations rather than to single extreme climate events. These findings carry important implications for studies on family formation dynamics and the protection of women's rights under the threat of global climate change.

1. Introduction

Climate change-induced natural disasters have substantial and adverse effects on human survival, especially for populations living in vulnerable areas (Muttarak, 2021). These effects go beyond the biophysical impact on the local environment, influencing demographic, economic, institutional, and socio-cultural dimensions of human life (Hoffmann et al., 2022), and exacerbating the general level of population vulnerability, particularly among poorer social classes (Ainul et al., 2022; Jiang & Hardee, 2011; Otto et al., 2017; Tsaneva, 2020).

When considering the demographic consequences of climate change, natural disasters such as heat waves, droughts, floodings, and cyclones have been found to have a profound impact on mortality patterns, particularly child mortality (Bunyavanich et al., 2003; Dasgupta, 2018), and malnutrition (Dimitrova & Muttarak, 2020; Muttarak & Dimitrova, 2019). Climate change is also linked to morbidity and migration (Best et al., 2022; Carrico & Donato, 2019; Kartiki, 2011; Piguet et al., 2011). In this context, a body of literature highlights the disproportionately adverse effects of climate change on women compared to men, including higher death rates during natural disasters and greater household and caregiving burdens (Awiti, 2022; Patel et al., 2020).

One further consequence of climate change on human life is its impact on the timing and outcomes of life course transitions, including the transition to first marriage among young girls (Andriano & Behrman, 2020), a phenomenon also referred to as female early marriage. According to the definition provided by the United Nations Children's Fund (UNICEF), the term early marriage refers to both formal and informal unions where an individual under the age of 18 years is involved as a partner. Marrying early, even in childhood, has significant consequences, particularly for young girls. It often leads to risky early pregnancy (Irani & Roudsari, 2019), social isolation, reduced access to education (Amin et al., 2017; Glinski et al., 2015), increased risk of domestic violence, and physical, sexual, and psychological abuse (Ahmed et al., 2019; Nasreen, 2009; Yount et al., 2016). Additionally, early marriage contributes to school dropout (Mudavanhu, 2014; Psaki et al., 2019) and severe limitations in career and vocational advancement opportunities (Alston et al., 2014; North, 2010).

Although the prevalence of early marriage has declined in recent decades, it remains widespread globally. South Asia currently has the highest proportion of girls and women married in childhood

* Corresponding author.
E-mail addresses: livia.ortensi@unibo.it (L.E. Ortensi), francesca.tosi12@unibo.it (F. Tosi), rosella.rettaroli@unibo.it (R. Rettaroli).

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(Bangladesh Bureau of Statistics (BBS) and UNICEF, 2023a), with Bangladesh exhibiting the highest prevalence in the region. In Bangladesh, 34.6 million women entered their first union before the age of 18, and 13.4 million girls before the age 15, meaning nearly one in two young women married as children. While the mean age at marriage in the country has been rising over time, progress in combating early marriage is often hindered by shocks originating from both economic and environmental factors. Increasingly, international observers are highlighting climate change and extreme weather events as potential contributors of this persistence (UNFPA, 2021).

Exposed to cyclones, tidal surges, floods, and droughts causing damage to human lives and properties each year, Bangladesh can be considered a disaster-prone country. It ranks among the top 10 countries most affected by climate change globally, has been labelled an 'impact hotspot' by the World Bank, and is regarded as one of the most vulnerable countries to climate change by the Intergovernmental Panel on Climate Change (Khatun & Saadat, 2021). In the environmental and climatological literature there is substantial consensus – Brammer (2016) being an exception – that the frequency and intensity of extreme events in the country have increased significantly in recent decades due to climate change (Dastagir, 2015; Dewan, 2015; Khatun & Saadat, 2021). Recent research has shown that Bangladesh experienced significant and above-average warming during 1970–2010, accompanied by increasing severity and frequency of meteorological droughts. At the same time, total precipitation has risen since 1960, along with an increased flood risk throughout the country (Ainul et al., 2022; McLeod et al., 2019; Mondol et al., 2021; Rahman & Lateh, 2016). As a result, the number of households affected by natural disasters has increased from around 550 thousand in 2009 to nearly 2 million in 2014, accounting for 44 % of all households in the country (Bangladesh Bureau of Statistics (BBS), 2016). Given these figures, it is clear that Bangladesh's increasing vulnerability to climatic risks, combined with the widespread prevalence of early marriage, makes it an emblematic setting to study the relationship between climate change and the transition into union.

This paper studies the effect of prolonged weather anomalies on the likelihood of marriage for women of all ages, including those under 18, in Bangladesh. It employs multilevel discrete-time survival modelling to integrated data based on six waves of the Bangladesh Demographic and Health Surveys (BDHS), conducted between 1990 and 2018, and the corresponding climatic information at the district level provided by the Standardized Precipitation and Evapotranspiration Index (SPEI) (Vicente-Serrano et al., 2010).

Our study contributes to the existing literature in several ways. First, by focusing on prolonged periods of both wet and dry weather conditions, our approach aims to assess the impact of different types of weather events. This is particularly important in a geographical context like Bangladesh, which is increasingly affected by severe droughts and heavy rainfalls, cyclones, and floodings. Conceptually, capturing a wide range of weather variability is meaningful, as both wet and dry conditions have severe consequences for human life and significantly impact life course events, particularly when their frequency increases over time, amplifying and cumulating their effects (Ahmed, 2018; Ainul et al., 2022; Andriano & Behrman, 2020; Tsaneva, 2020).

Second, it considers the cumulative effects of significant variations in water accumulation – both excess and deficit – for prolonged periods, a perspective that has been less explored in the scholarly literature. In this regard, the advantage of using the SPEI is twofold: (i) it is expressed in units of standard deviation from the average value for each observation, allowing for the consideration of cumulative variations in both excess and deficit of water, with different degrees of severity indicated by significant departures from the mean (which is zero by construction); and (ii) it can be measured over different timespans, up to 48 months. As a result, the index captures the effect of drought periods linked to prolonged water deficits (hydrological droughts) as well as extended flooding intervals associated with persistently abnormal humidity levels. This enables the assessment of the cumulative effects of prolonged climate variability on early marriage over the medium and long term, helping to capture the impact of prolonged and cumulated climate variations rather than the immediate effects of weather shocks.

Third, by utilizing fine-grained geographical data that distinguishes between urban and rural contexts, as well as disaster-prone areas, we explicitly consider the diversity in the frequency and intensity of these phenomena at the district and division levels, according to the 2015 definition. This adds to the existing literature, which has mostly focused on specific regions, such as coastal Bangladesh (Carrico, Donato, Best, & Gilligan, 2020), or particular settings, such as rural areas (Tsaneva, 2020). In contrast, our paper focuses on the entire population of the country while considering interregional differences in terms of prevalent weather conditions and climatic risk proneness. Besides offering a more comprehensive framework for Bangladesh, this approach also has the potential to be extended to other countries adhering to the DHS protocol.

While maintaining the specific focus on the impact of climate variability on early marriage, we extend the analysis to women of all ages. This broader perspective, which enables us to assess of the wider impact of persistent climate variability on the life of Bangladeshi women, is unprecedented in the literature, and carries important implications for family formation dynamics, and the protection of fundamental rights in the context of global climate change.

In the following sections, we review the international literature on the relationship between climate change and life course transitions, with an emphasis on the transition into the first union for girls and women, especially in developing countries. We then turn to the case study of Bangladesh, examining the evolution of the mean age at first marriage and analyzing its socioeconomic and territorial distribution across the population. Next, we introduce our empirical investigation, outlining the data and methods used to test the relationship between prolonged climate variability and the timing of the transition into first marriage, both as a child and at any age, for women living in urban or rural areas, as well as according to the classification of Bangladeshi districts into disaster-prone areas. After presenting our findings, the paper concludes by discussing their key implications for human development, highlighting how climate change can hinder the modernization of demographic behaviors in vulnerable contexts and pose a significant threat to the advancement of girls' and women's rights and empowerment.

2. Theoretical background

2.1. Climate change and the transition to marriage

It is becoming increasingly clear that climate change influences life course transition patterns, including the transition into unions. Recently, scholarly attention has turned to the relationship between extreme weather events and the timing of female unions, with a particular focus on how such events may increase the incidence of child marriages (Pope et al., 2022). This link has been well-documented in qualitative and ethnographic studies (see Ahmed et al., 2019; Alston et al., 2014; McLeod et al., 2019, for the case of Bangladesh). However, assessing this phenomenon using quantitative data and methods presents significant challenges. The interactions between climate conditions and demographic behavior are complex and difficult to model, as establishing a direct link requires both individual-level and climatic data that can be unequivocally connected. Moreover, establishing causality is even more difficult, as it typically requires longitudinal data, either retrospective or collected through a panel design. Such kind of longitudinal data is rarely available, meaning researchers must either collect primary data or apply appropriate techniques to integrate suboptimal datasets, employing methods that minimize the risks associated with such analyses. Nevertheless, recent quantitative studies have made important strides in addressing these challenges (Ainul et al., 2022; Alston, 2015; Asadullah et al., 2021; Carrico, Donato, Best, & Gilligan, 2020; Tsaneva, 2020).

The anticipation of marriage before the age of 18 is widely regarded as an event with far-reaching and persistent negative consequences for women's lives. Early marriage is known to have detrimental effects on children, families, and societies at large (Ahmed et al., 2019; Bates et al., 2004). Furthermore, early partnership formation is closely associated with early pregnancy, which in turn leads to adverse socioeconomic outcomes for the children of young mothers, such as lower levels of education, poorer health, and the intergenerational transmission of poverty (Branson et al., 2015; Chari et al., 2017; Lee et al., 2023). Early childbearing also correlates with higher rates of sexually transmitted infections, intimate partner violence, domestic abuse, and depression (Ahmed et al., 2019; Felten-Bierman, 2006; Nasreen, 2009; Nour, 2009). Taken together, this body of evidence highlights the critical concerns regarding the impacts of climate change on human-centered sustainable development, particularly with respect to child protection.

The increased intensity and frequency of weather shocks exacerbate endemic poverty in many contexts, with women consistently found to be disproportionately more vulnerable than men to such adverse effects (Kümbetoğlu & User, 2010; Nasreen, 2009). The literature suggests that adolescent girls are particularly exposed to the negative consequences of climate change due to the compounded socioeconomic vulnerability arising from the intersection of their gender and age (Patel & Rajak, 2022; Van der Gaag, 2013). Dowry and bride price practices may provide a lens through which the economic effects of environmental crises shape early marriage decisions (Alston et al., 2014; Chowdhury, 2010), as younger girls often require smaller dowries or command higher bride prices. Recent studies focusing on sub-Saharan African countries have shown that, where bride price is common, the effects of climate change manifest as marriage market effects, with droughts tending to accelerate the transition into unions (Corno & Voena, 2023; Corno et al., 2020; Hoogeveen et al., 2011). Nielsen (2009) finds that child marriage and droughts are interconnected in Burkina Faso through a livelihood strategy analysis, while North (2010) discusses the potential use of 'famine brides' to mitigate drought-induced poverty in Uganda. Andriano and Behrman (2020) systematize knowledge in the African context by proposing a broader conceptual framework distinguishing between the direct and indirect impacts of weather shocks on human well-being. The authors identify the transition into union and childbearing as indirect effects of climate vulnerability, triggered by both resource constraints and psychosocial stress. Analyzing data from Malawi, they find that, even in the absence of bride price, young women and their families have both direct and indirect financial incentives to accelerate daughters' transition into union, as it alleviates the financial burden of securing their livelihoods on the parental household (Ahmed et al., 2019), irrespective of the payment structure.

Findings from different regional and cultural contexts such as South Asia, where dowry practices are more common, do not always confirm the same relationship between climate variability and the marriage market (Corno et al., 2020). However, in developing countries, early marriage is strongly associated with poor living conditions and is more prevalent among the poorest families (Hoq, 2013; Hossain & Islam, 2013; Otoo-Oyortey & Pobi, 2003; Parsons et al., 2015). Other factors that increase the likelihood of girls marrying at a young age include low levels of education, low women's employment status, religious factors, and living in rural areas (Alston et al., 2014; Hossain et al., 2016; M.K. Islam et al., 2016; M.M. Islam et al., 2016; Kamal et al., 2014; Streatfield et al., 2015).

While much of the literature considers the effects of weather shocks to be largely idiosyncratic and simultaneous with behavioral responses, it is plausible that these shocks may become cumulative and more regular as the intensity, frequency, and duration of extreme weather events increase. In this context, responses to environmental shocks may be delayed due to the cumulative negative effects over time. Prolonged and frequent adverse events, such as extended droughts or waterlogging, can exacerbate resource scarcity at the household level, amplifying their impact on the timing of transitions. These cumulative effects can be far more significant than isolated, sudden events like floods or cyclones. Within this framework, demographic responses, such as changes in marriage patterns due to drought or extremely wet conditions, may vary depending on the nature of the weather shock and its prolonged impact on community and household resources.

The literature on this topic, particularly in rural settings, presents mixed findings. Repeated droughts or heatwaves often correlate with trends toward earlier ages at first marriage and childbirth (Andriano & Behrman, 2020; Carrico, Donato, Best, & Gilligan, 2020; Tsaneva, 2020). Similarly, slow-onset environmental factors such as waterlogging and riverine erosion caused by frequent and repeated flooding appear to increase the risk of child marriage, in contrast to rapid-onset events like cyclones or flash floods (Ainul et al., 2022; Asadullah et al., 2021).

In sum, the persistence and duration of weather shocks, whether in the form of drought or excess humidity, seem to significantly influence resource availability and, consequently, the timing of female marriages. This dynamic is further shaped by the hydrogeological characteristics of the region, which may selectively retain populations depending on their level of vulnerability. Additionally, the anticipated impacts of weather shocks may depend on their historical prevalence in the region. In areas where such events are common, their disruptive economic effects may be mitigated by preventive measures such as irrigation systems, water reservoirs, or rainfall insurance schemes. These measures help improve preparedness and reduce the adverse impacts on household income and well-being, thereby influencing decisions related to transitions, such as marriage (Andriano & Behrman, 2020).

The type of climatic event experienced also plays a crucial role. Extremely dry or prolonged dry weather conditions may accelerate the entry into unions for financial reasons by affecting livelihoods, which form the foundation of social relationships and networks, particularly in rural agrarian and low-income rural contexts (Andriano & Behrman, 2020). This occurs when agricultural families, hit by negative weather shocks, face short-term budget constraints and, due to an inability to save or borrow, are forced to sell assets to mitigate income losses caused by reduced yields (Tsaneva, 2020). Similar weather conditions, however, might have different consequences for urban households, which rely less directly on agricultural livelihoods and can resort to a wider range of coping strategies to mitigate the negative impacts of droughts.

Evidence on excess humidity, on the other hand, is more scattered and provides mixed results. Qualitative and ethnographic research has linked extremely wet weather conditions to an increased tendency to marry early, as a strategy used by households in areas affected by flooding and cyclones to manage the economic effects of property loss and income shortages (Ahmed et al., 2019; McLeod et al., 2019). In quantitative research, the relationship between excess humidity and marriage during the growing season is not always clearly established in rural contexts (Andriano & Behrman, 2020). However, in coastal regions prone to waterlogging and salinity, girls facing prolonged out-of-normal weather conditions are found to be at greater risk of entering marriage at a young age due to the degradation of local biodiversity, livelihood, and social disruption (Ainul et al., 2022) compared to girls experiencing near-normal conditions. This finding is supported by evidence suggesting that recurrent floods which dissipate within a month or two have a much less significant impact on the risk of transitioning into unions. This indicates that cumulative climatic variations might have more lasting effects on transitions to marriage compared to sudden, short-term events.

2.2. *Marriage trends in Bangladesh*

In Bangladesh, as in many other developing countries in Asia and Africa (Brouwer et al., 2007; Peduzzi et al., 2009), extreme weather events, both expected and unexpected, heavily affect individuals' livelihoods (Philip & Rayhan, 2004). As a result, households often resort to a range of coping strategies to mitigate the effects of these shocks (Van der Geest & Warner, 2015). One such strategy is accelerating daughters' transition to marriage, which can help alleviate the shortage of household resources (Ahmed et al., 2019; Ainul & Amin, 2013) and reduce household consumption by transferring daughters' maintenance costs to the groom's family (Hossain & Islam, 2013; Parsons et al., 2015). Moreover, marriage and wifehood, as governed by normative and social practices, provide women with security and social status within their communities (Amin, 1998, Bates et al., 2004; Bajracharya & Amin, 2012; Chowdhury, 2010; Kabeer, 2011; Jensen & Thornton, 2003; Zaman, 1999). However, in a context where unions are typically arranged by the families of the spouses according to local laws, customs, and traditions (Ahmed, 1986), girls often have little say in the process and must accept the terms and outcomes of the negotiations (Bhuiya et al., 2005; Schuler et al., 2006). This includes agreeing on the dowry amount and the financial contribution each family must make for the ceremony (Chowdhury, 2010).[1]

Despite early marriage being illegal since almost a century[2], Bangladeshi authorities rarely intervene to prevent child marriages, and parents continue to marry off their daughters well before they reach the legal age of 18. For decades, the median age at first marriage for women has fluctuated around 15 years, with those marrying at age 18 or older commonly considered mature or late brides. Census data from the Bangladesh Bureau of Statistics (Bangladesh Bureau of Statistics (BBS), 2015) shows that the long-term trend in the age at first marriage for women has steadily increased since 1961, at a faster pace than for men. The percentage of never-married women across all age groups has risen from 10.6 % in 1961 to 41.6 % in 2011. Notably, this proportion increased by more than 14 percentage points between 1961 and 1974, with the highest growth observed among girls aged 10–14 years (+23.1 %) and 15–19 years (+16.2 %). However, the mean age at first marriage of Bangladeshi women remains one of the lowest in the world, at 16.4 years, as does the mean age at first birth (Bosch et al., 2008; Hoq, 2013).

As the literature suggests, women's socioeconomic conditions play a significant role in influencing the risk of experiencing early marriage. Official data from the BBS reveals that the median and mean age at first marriage tend to be higher among women with greater educational attainment and wealth. Women with secondary education or higher marry, on average, 4.4 years later than those with no formal education (19.1 years compared to 15.5 years). Among women aged 20–24, those without education are more likely to marry before the age of 18 (75 % versus 31 %). Additionally, data from the 2011 census shows that the mean age at first marriage is higher in urban areas (24.8 years for men and 17.9 years for women), non-slum areas (23.9 years for men and 17.5 years for women), among the non-Bengali population (23.9 years for men and 18.4 years for women), and among non-Muslims (24.9 years for men and 18.2 years for women) (BBS & UNICEF, 2015). The timing of marriage varies across regions due to cultural differences. Among women aged 20–49, the median age at first marriage is higher in the eastern divisions (18.1 years in Sylhet and 16.9 years in Chattogram) and lower in the north-western divisions (15.8 years in Khulna and 15.6 years in Rajshahi and Rangpur), where poverty, illiteracy, and traditional values are more prominent (Zahangir, 2015). Therefore, while social and economic conditions favoring early marriage for girls are gradually losing their influence, particularly in urban contexts (Schuler, 2007), the phenomenon remains widespread in many rural areas of the country.

One of the most significant hypotheses underpinning this evidence is that climate shocks tend to slow down historical trends of decline in female child marriage prevalence. Carrico and colleagues (2020), using individual primary survey data and indicators of heat waves and dry spells, empirically demonstrate that the risk of marriage increases immediately after or within the same year as moderate to severe heat waves for women aged 18–23 from Southwestern coastal Bangladesh. However, they find only a weak relationship for the 11–14 age group. The authors stress that the relationship between age at first marriage and weather shocks is non-linear, with the risk of marriage increasing sharply as the number of heat days exceeds a certain threshold.

Similar evidence is described by Tsaneva (2020), who identifies three main findings. First, as the number of dry months increases each year, the probability of child marriage also rises. Second, this mechanism appears to be relevant only in rural settings, with no significant effect observed for urban populations. This suggests that child marriage functions as a short-run coping mechanism for agricultural households facing income shocks. Third, the drought effect is primarily driven by older cohorts of women, particularly those born before 1970. For younger cohorts, Tsaneva identifies two factors that have contributed to the decrease of child marriage: the inverse relationship between the persistence of dowry payments and the economic shock from prolonged climatic events, and the positive influence of the diffusion of microcredit available to women. These factors might have made early marriage less advantageous or even unnecessary (Fenton et al., 2017; Islam & Maitra, 2012).

Additional evidence shows that, whenever extreme weather events occur, affected households may be forced to undergo internal mobility, relocating to temporary shelters or refugee camps. This exacerbates resource shortages and increases personal insecurity, particularly for women, who become more vulnerable to sexual violence (Ahmed et al., 2019). In such contexts, parents may adopt suboptimal coping strategies, including encouraging their daughters to transition into formal unions at younger ages to mitigate the risk of sexual abuse or rape (McLeod et al., 2019). In these cases, marrying off underage daughters is often viewed as an acceptable solution by the population and local authorities. As a result, early female marriage remains widespread across the country, albeit with notable regional and cultural variation (M.K. Islam et al., 2016).

The relationship between child marriage and climatic shocks or variability becomes more complex when considering the different types of environmental vulnerabilities present in Bangladesh. Ainul and colleagues (2022) investigate these dynamics through discrete-time survival analysis, revealing that coastal communities experiencing prolonged waterlogging and salinity exhibit significantly higher rates of child marriage, while no increased risk is observed in areas affected by flooding. According to the authors, the impacts of rapid-onset events, such as floods and cyclones, differ markedly from those of slow-onset events like waterlogging. The latter influence marriage behaviors through prolonged effects on livelihoods and living conditions, which can exacerbate vulnerabilities over time.

3. Research questions and contribution to the literature

Based on the reviewed literature, our study aims to evaluate the effect of abnormal and prolonged climate variations – both wet and dry – on the risk of accelerating the entry into marriage at any age, and even before the age of 18, in Bangladesh. Compared to the existing literature, our approach is innovative in the following ways:

[1] The dowry system, in which the bride's family makes payments to the groom's family, is a widespread tradition that places a significant financial burden on the bride's family. This practice typically involves the transfer of various goods and may also include additional demands, such as securing employment for the groom (Bischiniotis et al., 2005; Schuler, 2006; Corno et al., 2010). However, some Bangladeshi families have observed that dowry costs tend to decrease in the immediate aftermath of environmental crises, potentially altering the impact of these practices on child marriage rates (Ahmed et al., 2019). The amount of dowry often rises with the bride's age, making child marriage a financially advantageous option for the bride's family. Additionally, recent studies report an increasing trend in love marriages (Ainul et al., 2022).

[2] The national Child Marriage Restraint Act of 1929 established the legal age for marriage as 21 years old for boys and 18 years old for girls. However, in 2017, the law was revised by the country's Parliament to allow girls under 18 to marry with parental consent and approval from the courts.

i. It focuses on the effects of both extremely wet and dry weather conditions on the probability to experience early marriage in Bangladesh.

Extreme weather conditions, both wet and dry, have severe consequences on human survival and affect the timing of life transitions. While the empirical literature on Bangladesh provides solid evidence on dry weather extremes, the impact of excess humidity remains less stable, particularly when evaluating the effects of prolonged abnormal climatic conditions.

ii. It considers the cumulative effects of significant variations in water accumulation for prolonged and exceptionally prolonged periods of time.

The literature underscores the importance of distinguishing between immediate environmental emergencies and less-visible, gradually unfolding climate-induced challenges (Ainul et al., 2022). While both sudden and protracted climate-related disruptions can shape marriage patterns, particular attention should be paid to slow-onset disasters, which, despite their subtle nature, may generate cascading effects that exacerbate vulnerabilities and increase the risk of early marriage.

iii. It develops an approach suitable for application across the entire country, accounting for regional variations in weather conditions and climatic risk proneness.

The empirical literature on Bangladesh primarily focuses on the effect of drought, high temperatures, and precipitation intensity on the probability of marrying in specific areas or regions of the country. Our approach extends this research by utilizing national data that covers the entire national territory at the district level. Recognizing the different mechanisms to which rural and urban populations are exposed in response to climatic shocks, we conduct separate analysis for rural and urban areas. Additionally, to better capture the specific climatic vulnerability of each region, we also propose an analysis by the type of disaster proneness at the district level.

4. Data and methods

4.1. Population data

The Bangladesh Demographic and Health Surveys (BDHS) are nationally representative household surveys conducted by the National Institute of Population Research and Training (NIPORT) in collaboration with ICF International as part of the global Demographic and Health Surveys (DHS) program (NIPORT, 2016, 2020). The BDHS has been conducted periodically since 1993, with the most recent survey being the 2017–2018 BDHS. These surveys are designed to provide information on several topics, including fertility, family planning, maternal and child health, nutrition, HIV/AIDS, and domestic violence. The BDHS employs a two-stage stratified cluster sampling design. In the first stage, clusters (i.e., primary sampling units) are selected from the sampling frame, and in the second stage households are selected within each cluster. For this study, data from six waves of the BDHS were used to study marriages that occurred between 1990 and 2016. The total number of women sampled in these surveys is 75,083.

All BDHS surveys are conducted on ever-married women aged between 15 and 49 years and include information about the year of marriage (V508) and age at first cohabitation (V511). Additionally, the survey collects data on mobility, allowing us to determine whether the woman was living in the same location as where she was interviewed at the time of her marriage. This enables proper linkage of the district data to the climate data. The sample composition by year and date of fieldwork, the number of women included in each survey's final sample, and the response rates are provided in Table A1 in the Appendix.

4.2. Climate data

As a source of climate-related data, we use the Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano et al., 2010). The SPEI measures drought severity considering both intensity and duration, based on the cumulative difference between precipitation and potential evapotranspiration due to temperature. This allows to capture both dry and wet climate anomalies, providing a comprehensive reflection of changes in surface water balance (Zhang et al., 2015). The SPEI is widely used in both environmental and population science (e.g., Andriano & Behrman, 2020; Muttarak & Dimitrova, 2019) and facilitates comparisons of drought severity across time and space, as it can be calculated for a broad range of climatic conditions. SPEI values indicate wet conditions for values above zero and dry conditions for those below zero, with severity categories described in Table A2 in the Appendix.

The SPEI can be calculated over periods ranging from 1 to 48 months, allowing us to capture the cumulative impact of deficient precipitation and/or excessive evapotranspiration over preceding months. While the index is widely recognized as a drought indicator, recent studies also highlight its utility in detecting floods (Bischiniotis et al., 2018; Muttarak & Dimitrova, 2019). Different timescales are useful for monitoring various types of drought conditions: a short SPEI timescale (1–12 months) is typically used to evaluate meteorological droughts, reflecting departures from normal precipitation levels over a specific period, or agricultural droughts, which are characterized by declining soil moisture during the growing season and potentially lead to crop failure. Hydrological drought, a more severe form of drought, involves a reduction in bulk water supply, including lower water levels in streams, lakes, reservoirs, and aquifers. This is best captured by the SPEI measured over a larger time scale, such as 24 months (for variations in reservoirs) or 36–48 months (for groundwater storage) (Edossa et al., 2014). Groundwater is considered one of the most valuable water resources for its quality and quantity. Around the world, agriculture, industry, and domestic usages are highly reliant on groundwater for its availability, quality, and low cost for abstraction (Bhattacharjee et al., 2019). The societal impact of groundwater resources is substantial, as they act as a buffer during times of extreme scarcity and variability. Furthermore, one of the most significant roles of groundwater is supporting ecosystems, which serve as essential links between nature and society (Esteban & Dinar, 2016). Groundwater is especially relevant in the framework of Bangladesh, where it has been the primary source of drinking water and irrigation since the 1960s. This resource is crucial for the country's food self-sufficiency: groundwater-irrigated agriculture plays a significant role in reducing poverty and has significantly increased food production (Zahid & Ahmed, 2006). Therefore, a reduction in groundwater storage is expected to have adverse effects on living conditions. Conversely, groundwater excess due to flooding and storm surges from severe tropical cyclones also has detrimental effects on agriculture and infrastructure (Becker et al., 2022) also through increased salinity (Lam et al., 2022).

In our analysis, we use SPEI values calculated over 36 and 48 months at the district level (Aadhar & Mishra, 2017) to account for prolonged climate variability within the country and its potential effects on local hydrological sub-systems (Chaturvedi et al., 2021). Using two long-term climate indices measuring the same phenomenon is not aimed at finding different trends but at assessing whether the risk of marriage increases significantly after 36 or 48 months of far-from-normal weather. Moreover, we consider consistency across different time spans (i.e., if a higher significant risk after both 36 months is also significant after 48 months) as evidence of robustness between prolonged abnormal weather conditions and the risk of marrying.

4.3. Measures

Outcome variable. The outcome variable in this study is the age at first cohabitation (V511), which refers to the age at which an individual begins living together with a partner in a sexual and conjugal relationship, irrespective of whether the partnership is formally recognized through marriage. This variable is commonly used as an indicator of the timing of sexual debut and partnership formation in populations. In Bangladesh, informal cohabitation is not widely accepted or common due to strong cultural and religious norms that emphasize marriage (Amin & Das, 2013). While some cohabitation may occur, particularly among younger generations in urban areas, it is generally considered socially and culturally unacceptable (Muniruzzaman et al., 2023; Rob & Mutahara, 2000). However, by using the broader concept of cohabitation, we can account for unregistered marriages that occur before the legal marriage age. As UNICEF (2023b) notes, a cohabiting couple – one living together as if married – raises the same human rights concerns as marriage itself. Therefore, while informal cohabitation may not be widespread in Bangladesh, we use the term 'marriage' throughout our analysis, empirically relying on the age at first cohabitation variable to assess early transitions into unions.

The BDHS data confirms that in Bangladesh the mean age at first marriage has increased over time, as demonstrated by the estimates based on marriage cohort in the pooled BDHS sample in Fig. A1 in the Appendix.

Main independent variable. As our primary independent variable, we use the SPEI, which captures cumulative climate variability within the country over prolonged timescales. Specifically, we will test the SPEI36 and SPEI48 as long-timescale weather variability indices. In contrast, SPEIs calculated over shorter time scales (between 1 and 24 months) will not be utilized nor tested as they are not suitable measures of long-term cumulative variations in climate conditions. Additionally, in our analysis we can only control for the year of marriage, not the specific month of the event. This limitation means we cannot be entirely certain that the variation in weather conditions and marriage occurred in the expected order, which could be problematic, particularly for SPEIs calculated over shorter duration.[3]

Since the distribution of minimum and maximum values of the SPEI36 and SPEI48 for Bangladesh over the past decades rarely fall outside the –2.00 to + 2.00 range (Fig. 1), we categorize the index into five classes, adapting Edossa and colleagues' (2014) classification: Severely or extremely wet (1.50 or more), Moderately wet (between 1.00 and 1.49), Near normal (between –0.99 and 0.99), Moderately dry (between –1.00 and –1.49), and Severely or extremely dry (–1.50 or less).

As shown in Fig. 2, between 2010 and 2016, minimum and maximum SPEI levels appear to be distributed in a complementary manner across districts. The eastern region and coastal Bangladesh experience a higher concentration of water in the form of river discharges and reservoir storages, while central and landlocked areas tend to experience prolonged water deficits. Moreover, eastern and northeastern districts seem to experience both severely dry and extremely wet conditions due to their vulnerability to floodings and cyclonic events, as indicated by the rather polarized minimum and maximum SPEI values observed in those areas.

Control variables. Using DHS data presents a significant challenge in the context of climate studies. While the DHS surveys collect a broad range of variables at the time of the interview, they provide only a limited set of retrospective data. For our study, some key variables necessary to control for relevant characteristics at the time of marriage are unavailable and, as a result, cannot be included in our models. To address this limitation, we selected a set of time-invariant variables that are known to influence the timing of the transition into union. These control variables are used to account for compositional aspects of the population and include:

- Religion (V130): Islam (reference), Hinduism, Buddhism, Christianity, Unsure/Does not answer, Other. This variable controls for different marriage practices related to religion (Amin & Das, 2013).
- Husband's education level (V701): None (reference), Primary, Secondary, Higher, Unsure/Does not answer. Since controlling for economic wealth at the time of marriage is not possible using DHS data, we use the education level of spouses as a proxy for family wealth, based on well-established literature linking education and wealth (Filmer & Pritchett, 2001). This helps partially mitigate the lack of information on wealth at the time of marriage.
- Type of place of residence (V025): Urban (reference), Rural. Since the models will be estimated separately by type of place of residence, this variable is only used as a control in the analysis by disaster-prone area.
- Women's birth cohort: Year of birth of respondent (V010). This variable accounts for any cohort-related shifts in the typical age at marriage.
- Division (V024): Barisal (reference), Chittagong, Dhaka, Khulna, Mymensingh, Rajshahi, Rangpur, Sylhet. This variable accounts for regional variation in marriage patterns.

Additionally, we also included a reconstructed time-variant variable to account for women's school enrollment during each year they are exposed to marriage, starting at age 10. Since the typical primary school entrance age is 6, a woman is considered to be attending school at a given age if her age is equal to or less than the highest year of education (V107), or the number of years required to complete the highest education level attended (V106), in cases where the former information is missing.

Finally, we include a control for the percentage of severely underweight children at the district level, sourced from the Global Data Lab database (2024), to account for socioeconomic deprivation. The literature for Bangladesh indicates that being severely underweight is negatively associated with wealth and parental education (Alom et al., 2012).

Table 1 summarizes the information on the variables used in the analysis.

4.4. Estimation strategy

As a modelling strategy, we employ multilevel discrete-time survival analysis to assess the risk of Bangladeshi women entering marriage before age 18 (model A) and at any age (model B). Our goal is to examine how SPEI levels influence the likelihood of marriage at different ages, while controlling for both individual-level and district-level covariates, including both observed and unobserved factors. To achieve this, we estimate a multilevel discrete-time survival model using standard logistic regression. This includes a set of covariates at the individual and district levels, as well as a random intercept at the district of residence level. By estimating the random intercept, we account for the fact that women do not behave independently of one another, given that both social norms regarding marital age and exposure to climate variability may influence one another. Therefore, we treat person-year observations as grouped by district of residence, assuming that individuals within the same district behave in a correlated manner. The multilevel discrete-time survival model is written as in equation (1):

$$log\left(\frac{h_{tij}}{1-h_{tij}}\right) = \beta_0 + \alpha_t + \beta x_{tij} + u_j \tag{1}$$

where $h_{tij} = \Pr(Y_{tij} = 1 | Y_{t-1ij} = 0)$ is the hazard that woman i in district j enters marriage at time t given that the event has not occurred yet in

[3] The DHS survey includes a question about the month of first cohabitation with a partner. However, the number of monthly observations is significantly reduced, particularly for the oldest marriage cohorts, even after pooling data from six editions of the survey. Working with such a reduced sample size would lead to unreliable estimates. Therefore, we decided to not consider the monthly information and to use only the year of first cohabitation variable in our analysis.

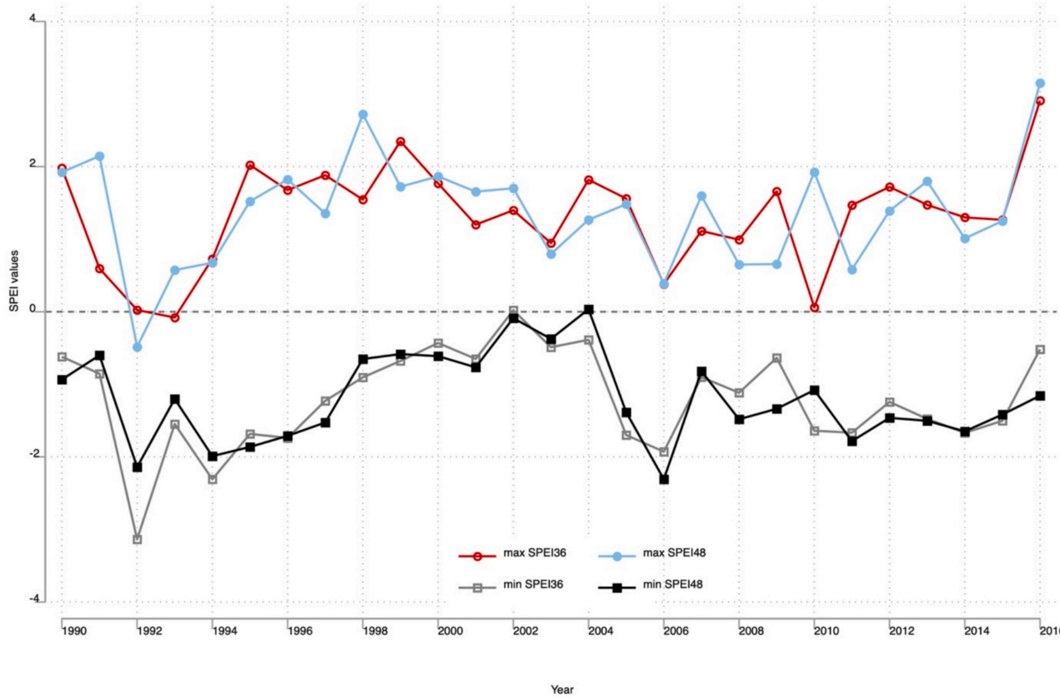

Fig. 1. Minimum and maximum SPEI36 and SPEI48 values in Bangladesh by year (1990–2016).
Source: Own elaborations of SPEI data retrieved from Aadhar and Mishra (2017)

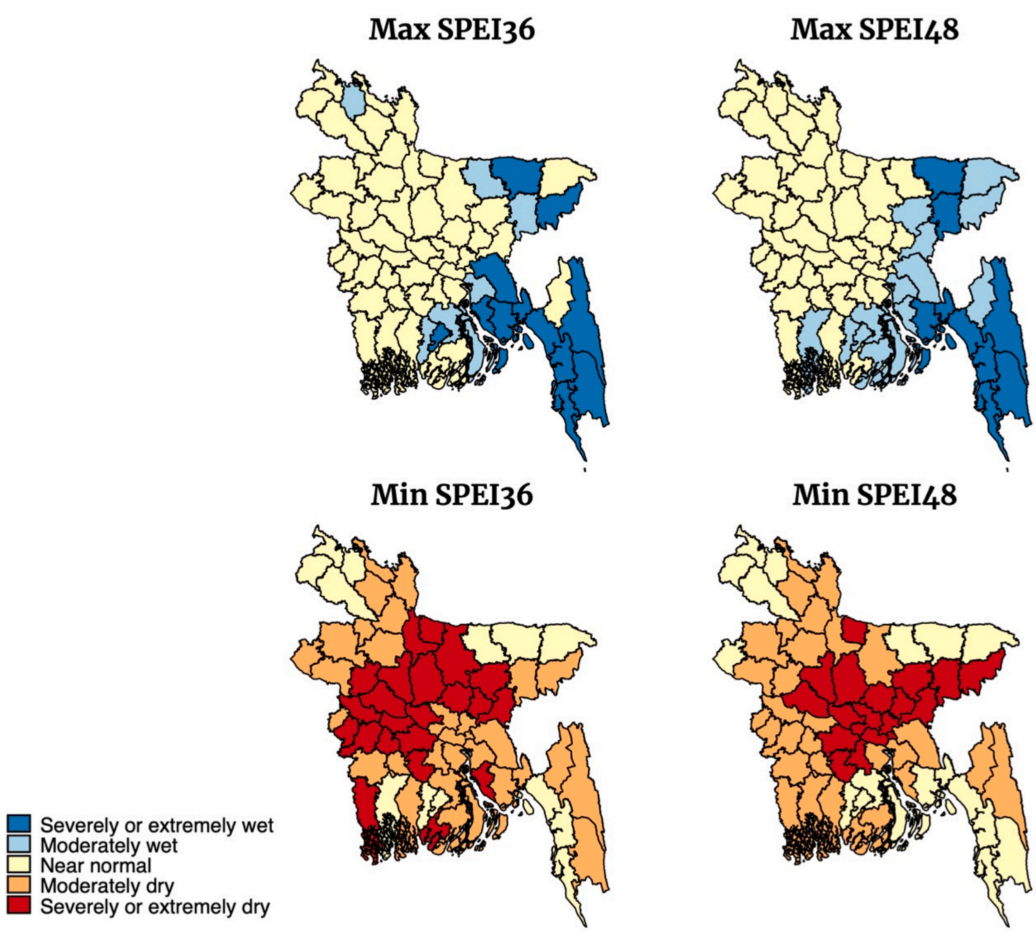

Fig. 2. Minimum and maximum SPEI36 and SPEI48 values in Bangladesh districts (mean 2010–2016).
Source: Own elaborations of SPEI data retrieved from Aadhar and Mishra (2017)

Table 1
Summary statistics.

	Mean	SD	%
Dependent Variable			
Age at first cohabitation	16.20	0.112	
Key Control Variables			
Religion: Islam			89.8
Religion: Hinduism			9.5
Religion: Buddhism			0.4
Religion: Christianity			0.2
Religion: Other			0.0
Religion: Unsure/Does not answer			0.0
Husband's education level: No education			24.7
Husband's education level: Primary			28.1
Husband's education level: Secondary			30.2
Husband's education level: Higher			16.8
Husband's education level: Does not know			0.2
Husband's education level: Unsure/Does not answer			0.0
Type of place of residence: rural			64.6
Type of place of residence: urban			35.4
Women's birth cohort	1985	0.026	
Percentage of severely underweight children (district level)	16.95	0.026	
Division: Barisal			11.4
Division: Chattogram			16.7
Division: Dhaka			18.1
Division: Khulna			14.0
Division: Mymensingh			14.5
Division: Rajshahi			13.0
Division: Rangpur			9.6
Division: Sylhet			2.7

Notes: Models were fitted using data reshaped in long form. Descriptive statistics in this table are calculated using the wide form.
Source: Own elaborations of BDHS pooled data.

time $t-1$; β_0 is the constant; α_t is a function of time, β is a vector of parameters representing the effects of covariates x_{tij} on the probability of event occurrence, and u_j is the district-level random effect. Risk exposure begins at age 10 in both models. Since our working sample consists of ever-married women aged between 15 and 49 years, the data is not affected by right censoring.

To ensure accurate spatial matching between environmental exposure and the transition to marriage, we use the information provided by item V104, which corresponds to the question: "*How long have you been living continuously in the town/village?*". As noted in the literature (Grace et al., 2021), this question serves as a filter to select the subsample of women whose current place of residence is the same as the location where they lived at least 36 (or 48) months before their marriage. We therefore control for women's internal mobility by linking climate data (SPEI) only to women who report having lived in the same location for at least n months before their marriage. For example, in models using SPEI36, women are included in the analysis only if they report having lived in the place of the interview for at least 36 months before marriage. If the marriage took place 10 years before the survey, the woman is included only if she reported living in the place for at least 13 years. In the case of post-marriage migration, women are excluded from the analysis, as the number of years spent in the place of the interview would be less than the number of years since their first marriage or union.

Finally, to account for within-country variability in the relationship between climatic conditions and the transition to marriage, we conduct a second analysis distinguishing districts by their type of disaster proneness, following the classification proposed by the Government of Bangladesh in 2012. The categories include districts prone to (i) cyclones, (ii) waterlogging, floods, and flash floods, and (iii) drought (Fig. 3). A residual category is used to represent districts that do not fall into any of these groups, identifying them as the least disaster-prone areas. Given the variation in the number of districts across clusters – ranging from 2 in the drought-prone cluster to 44 in the least disaster-prone cluster – we opted to forgo the multilevel framework for this analysis and instead employed discrete-time survival regressions with clustered standard errors at the district level.

5. Results

This section presents the main results from the multilevel discrete-time survival model estimates, which assess the risk of entering marriage before age 18 (model A) and at any age (model B), conditioned on climate variability as measured by the SPEI at 36 and 48 months for each observational year.[4] To account for differing exposures to climate vulnerability, the results are separated by urban and rural areas and clustered based on the disaster-prone area of residence.

Our analysis confirms that both prolonged wet and dry conditions are linked to an accelerated transition to marriage, particularly for women and girls residing in rural areas. Table 2 shows that, in rural areas, the risk of entering marriage before 18 years of age increases after prolonged abnormal weather conditions (36 months), with this effect persisting also when longer timespans are considered (48 months). This applies to both extreme wet and dry conditions. In urban areas, however, the risk of early marriage after 36 months of cumulative weather abnormalities appears to increase only in cases of persistent droughts. When longer durations (48 months) are examined, the risk of marrying before the legal age rises again, with statistically significant effects for both moderate to severe droughts and excess humidity.

When we expand the analysis to include the risk of entering marriage for women of all ages, the relationship between prolonged climatic variations and transition into unions becomes even more evident. Table 3 shows a significant increase in the hazard of entering marriage at any age in association with cumulative (36 and 48 months) extreme wet and dry conditions, in both urban and rural areas. Additionally, when weather conditions deviate even moderately from the near-normal for at least 48 months, the likelihood of marriage appears to rise, as indicated by statistically significant and greater-than-1 exponentiated hazard ratios for all SPEI48 categories in both urban and rural areas. For women living in rural areas, this effect is also observed when similar conditions persist for 36 months.

Although hazard ratios are not directly comparable across models and sub-populations, we observe that, when considering marriages of any age, the exponentiated coefficients associated with abnormal weather conditions tend to be generally higher than those related to marriages before the age of 18, regardless of the spell duration. This seems plausible, as young adult women experiencing heightened socioeconomic vulnerability due to adverse climate conditions may be more likely to expedite entering unions that were already anticipated. In contrast, child marriage may be viewed as a last-resort response for families coping with prolonged climatic instability.

To account for within-country variability in the relationship between climatic conditions and the transition to marriage, we reran our models, distinguishing by the type of disaster proneness at the district level, following the classification proposed by the Government of Bangladesh (2012). This analysis also helps control for the level of preparedness among populations living in disaster-prone areas, based on the hypothesis that populations exposed to extreme weather conditions over time may be better equipped to handle their consequences. As a result, these populations may be less likely to resort to suboptimal coping strategies, such as early or accelerated female marriage, compared to populations with less experience in managing such climate-related shocks.

[4] In the main text we only show and comment the main explanatory variables for conciseness. Estimates associated to control variables confirm the relationships between individual characteristics and the transition to marriage in Bangladesh expected based on the relevant literature. The complete set of estimates for all models, including those who consider all women regardless of the place of residence, is provided in the Appendix to this article (please see Tables A3-A12).

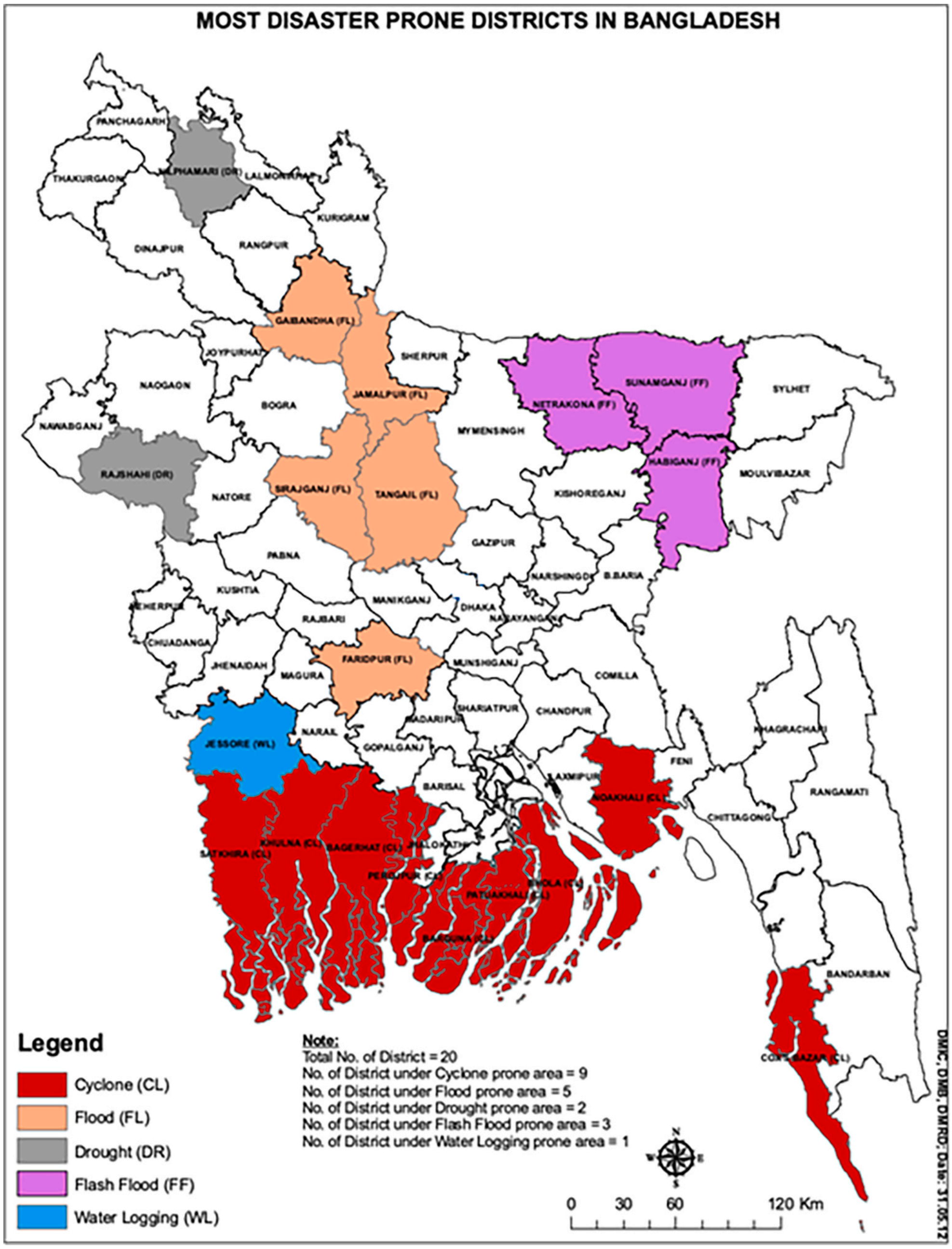

Fig. 3. Most disaster-prone districts in Bangladesh (Govt. of Bangladesh, 2012).
Source: https://reliefweb.int/map/bangladesh/most-disaster-prone-districts-Bangladesh

Fig. 4 plots the exponentiated hazard ratios for the risk of early marriage by disaster-prone area of residence, showing that severely or extremely wet weather triggers the transition to early marriage in all district clusters. In the least disaster-prone districts, the likelihood of marrying before reaching the legal age is influenced by almost any weather conditions deviating from normal, particularly drought. In cyclone-prone districts, the likelihood of early marriage responds to both moderate and excess humidity, similarly to drought-prone areas, especially when dry weather conditions persist for at least 48 months. Lastly, districts prone to waterlogging, floods, and flash floods show higher vulnerability to both severely or extremely wet conditions and moderately dry ones.

Fig. 5 illustrates the exponentiated hazard ratios for the risk of marrying at any age, categorized by disaster-proneness of the district of residence. In the least disaster-prone areas, which include the largest group of districts (44 out of 64), both severely or extremely wet weather conditions and moderately dry conditions are significantly associated with increased odds of marriage, as indicated by both the SPEI36 and SPEI48. Additionally, the SPEI48 shows a positive association between extremely dry weather and the transition to marriage in these districts. Focusing on the cyclone-prone cluster, which includes the coastal districts of Bagerhat, Barguna, Bhola, Cox's Bazar, Khulna, Noakhali, Patuakhali, Pirojpur, and Satkhira, exceptionally severe or extreme wet weather shows the most significant positive association with the risk of marriage, according to both climate variability indices. In districts prone to waterlogging, floods, and flash floods, such as Faridpur, Gaibandha, Habiganj, Jamalpur, Jessore, Netrakona, Sirajganj, Sunamganj, and Tangail, vulnerability is observed to both severely or extremely wet conditions and moderately dry ones. Drought-prone districts, including Nilphamari and Rajshahi, show vulnerability to both severely or

Table 2
Multilevel discrete-time survival model estimates of the risk of entering marriage before age 18 (model A) by cumulative climatic conditions (SPEI36-48) and place of residence (urban vs. rural areas).

SPEI (ref. Near normal)	**Urban areas**					
	SPEI36			**SPEI48**		
	HR	**p-value**	**CI**	**HR**	**p-value**	**CI**
Severely or extremely wet	1.01	0.906	[0.92–1.10]	1.13***	0.003	[1.04–1.23]
Moderately wet	0.96	0.202	[0.90–1.02]	1.02	0.546	[0.95–1.10]
Moderately dry	1.03	0.454	[0.95–1.13]	1.13**	0.002	[1.04–1.22]
Severely or extremely dry	1.14**	0.007	[1.04–1.25]	1.15**	0.008	[1.04–1.28]
lnsig2u	− 2.60		[− 3.08–− 2.12]	− 2.59		[− 3.06–− 2.11]
sigma_u	0.27		[0.21–0.35]	0.27		[0.22–0.35]
rho	0.02		[0.01–0.04]	0.02		[0.01–0.04]
Observations	107,689			107,867		
Number of districts	63			63		
	Rural areas					
SPEI (ref. Near normal)	**SPEI36**			**SPEI48**		
	HR	**p-value**	**CI**	**HR**	**p-value**	**CI**
Severely or extremely wet	1.18***	0.000	[1.11–1.25]	1.13***	0.000	[1.07–1.19]
Moderately wet	1.04	0.073	[1.00–1.08]	1.04	0.144	[0.99–1.08]
Moderately dry	1.13***	0.000	[1.07–1.20]	1.16***	0.000	[1.10–1.22]
Severely or extremely dry	1.13***	0.000	[1.06–1.20]	1.08*	0.031	[1.01–1.16]
lnsig2u	− 2.16		[− 2.57–− 1.76]	− 2.16		[− 2.56–− 1.76]
sigma_u	0.34		[0.28–0.41]	0.34		[0.28–0.42]
rho	0.03		[0.02–0.05]	0.03		[0.02–0.05]
Observations	232,987			212,774		
Number of districts	64			64		

Notes: *HR* is the exponentiated hazard ratio estimated from the random intercept discrete-time survival model, while *CI* is the confidence interval. Statistically significant p-values are marked as follows ***: $p < 0.001$; **: $p < 0.01$; *: $p < 0.05$. Estimates are robust to internal mobility. Controls for years at risk, religion, husband's educational level, birth cohort, percentage of severely underweight children, and school attendance are applied.
Source: Own elaborations of BDHS and SPEI data (1990–2016).

Table 3
Multilevel discrete-time survival model estimates of the risk of entering marriage at any age (model B) by cumulative climatic conditions (SPEI36-48) and place of residence (urban vs. rural areas).

SPEI (ref. Near normal)	**Urban areas**					
	SPEI36			**SPEI48**		
	HR	**p-value**	**CI**	**HR**	**p-value**	**CI**
Severely or extremely wet	1.09*	0.038	[1.07–1.19]	1.18***	0.000	[1.10–1.27]
Moderately wet	0.96	0.151	[0.91–1.02]	1.08***	0.010	[1.02–1.14]
Moderately dry	1.10**	0.008	[1.02–1.17]	1.17***	0.000	[1.10–1.25]
Severely or extremely dry	1.10*	0.029	[1.01–1.20]	1.16**	0.001	[1.06–1.27]
lnsig2u	− 2.96		[− 3.46–− 2.47]	− 2.91		[− 3.4 –− 2.41]
sigma_u	0.23		[0.18–0.29]	0.23		[0.18–0.30]
rho	0.02		[0.01–0.03]	0.02		[0.01–0.03]
Observations	124,750			124,942		
Number of districts	63			63		
	Rural areas					
SPEI (ref. Near normal)	**SPEI36**			**SPEI48**		
	HR	**p-value**	**CI**	**HR**	**p-value**	**CI**
Severely or extremely wet	1.26***	0.000	[1.19–1.33]	1.20***	0.000	[1.14–1.26]
Moderately wet	1.06**	0.005	[1.02–1.10]	1.07***	0.001	[1.03–1.11]
Moderately dry	1.16***	0.000	[1.10–1.22]	1.17***	0.000	[1.12–1.23]
Severely or extremely dry	1.11**	0.001	[1.04–1.17]	1.09**	0.006	[1.03–1.17]
lnsig2u	− 2.26		[− 2.67–− 1.85]	−2.25		[− 2.65–− 1.84]
sigma_u	0.32		[0.26–0.40]	0.32		[0.27–0.40]
rho	0.03		[0.02–0.05]	0.03		[0.02–0.05]
Observations	232,677			232,987		
Number of districts	64			64		

Notes: *HR* is the exponentiated hazard ratio estimated from the random intercept discrete-time survival model, while *CI* is the confidence interval. Statistically significant p-values are marked as follows ***: $p < 0.001$; **: $p < 0.01$; *: $p < 0.05$. Estimates are robust to internal mobility. Controls for years at risk, religion, husband's educational level, birth cohort, percentage of severely underweight children, and school attendance are applied.
Source: Own elaborations of BDHS and SPEI data (1990–2016).

extremely wet climate conditions and prolonged, exceptionally dry conditions, as measured by the SPEI48.

6. Discussion and conclusions

This paper aimed to quantitatively assess the relationship between prolonged, abnormal weather conditions and the risk of transitioning into marriage in Bangladesh for women of all age, including those under 18. We applied multilevel discrete-time survival analysis to a dataset combining six editions of the Bangladesh Demographic and Health Survey with annual observations of the Standardized Precipitation-Evapotranspiration Index (SPEI) from 1990 to 2016. By modelling the

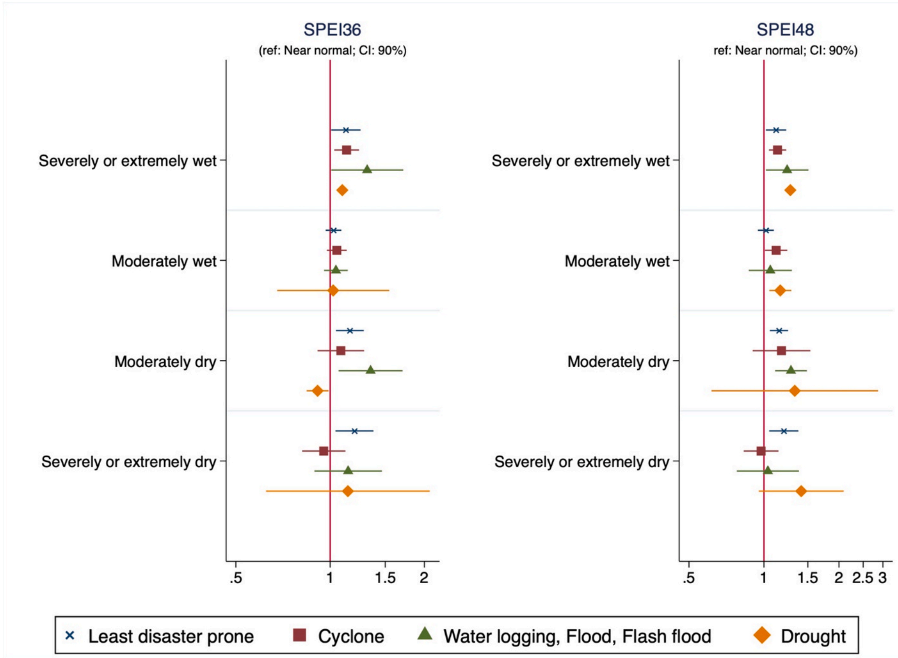

Fig. 4. Risk of entering marriage before 18 years by disaster-prone area (plot of hazard ratios and CI). Notes: Estimates are robust to internal mobility. Controls for years at risk, religion, husband's educational level, residence in a rural/urban area, birth cohort, percentage of severely underweight children, and school attendance are applied.
Source: Own elaborations of BDHS and SPEI data (1990–2016)

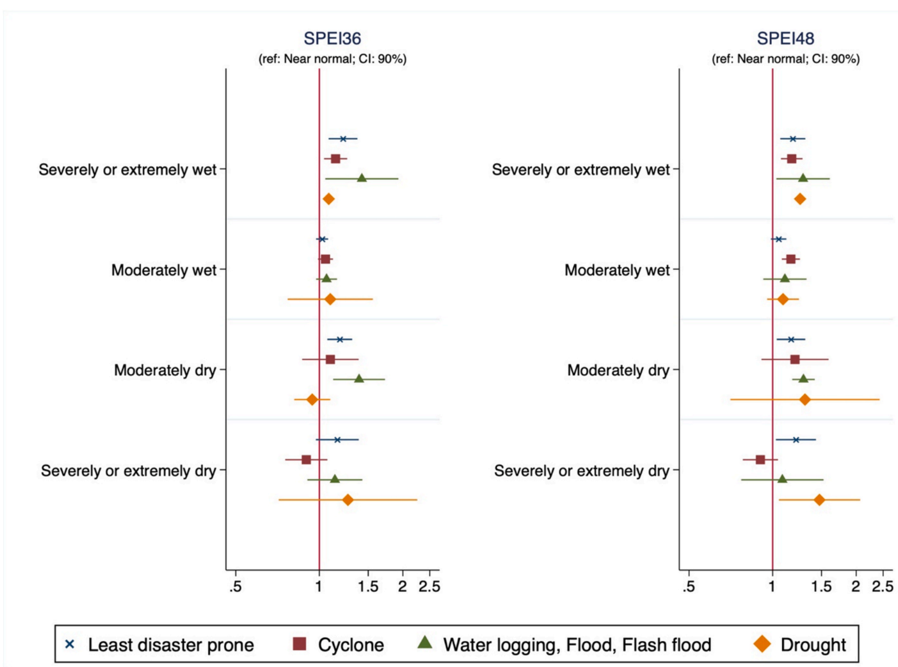

Fig. 5. Risk of entering marriage at any age by disaster-prone area (plot of hazard ratios and CI). Notes: Estimates are robust to internal mobility. Controls for years at risk, religion, husband's educational level, residence in a rural/urban area, birth cohort, percentage of severely underweight children, and school attendance are applied.
Source: Own elaborations of BDHS and SPEI data (1990–2016)

effect of SPEI calculated over 36- and 48-month timespans, we assessed the cumulative effects of water deficits or excess over long timescales. Focusing on climate variability indicators that capture variations in the longer term represents an improvement in the literature, which primarily focuses on the short-term interplay between human adaptation and global warming. Moreover, using national-level and large-scale survey data, our analytical approach enabled us to draw conclusions with country-wide representativeness, while also controlling for demographic and climate variability at the district level. Our findings indicate that the risk of entering marriage, even before the age of 18, increases following prolonged periods of far-from-normal weather conditions, both in urban and rural areas, providing key insights into the relationship between climate variability and marriage timing.

First, both abnormal wet and dry weather increase the risk of accelerated entry into marriage in Bangladesh for women living in both urban and rural areas, even after controlling for individual and contextual (district-level) heterogeneity. Extreme humidity generally has a stronger effect on marriage timing than drought, in both urban and rural areas. For girls under 18 living in rural areas, the risk of early marriage significantly increases following prolonged abnormal weather conditions. In urban areas, the risk of early marriage due to excessive wet weather becomes significant only when the climatic alteration persists for at least 48 months.

Second, when considering disaster-proneness at the district level, prolonged severe or extreme wet weather triggers the transition to marriage, including early marriage, in all disaster-prone clusters (cyclone-, waterlogging-, flood-, and flash-flood-prone areas), where populations are generally better equipped to cope with such climate-related extremes. Interestingly, nearly any prolonged deviation from near-normal weather increases the risk of entering marriage in the least disaster-prone areas. In contrast, the effects are less systematic in other areas, especially those vulnerable to drought.

Concerning wet weather conditions, our findings expand existing knowledge by going beyond what is currently understood about how sudden and violent wet weather impacts the population in Bangladesh by generating displacement and immediate damage to living beings, roads, and buildings (Dewan, 2015; Doocy et al., 2013; French et al., 1983; Jonkman & Kelman, 2005). We show that persisting or slow-onset environmental factors associated with excess humidity, like water-logging and riverine erosion caused by frequent and repeated flooding, also play a role in increasing the risk of marriage at all ages. This is likely due to the amplification of negative climate effects on human survival and livelihoods (Ainul et al., 2022). One further interpretation is that, in addition to causing crop failure and resulting agricultural income shocks, excess rainfall leading to flooding and destruction could also negatively impact the rural non-farm employment market if it disrupts production activities of firms (Emran & Shilpi, 2018), potentially having more lasting effects on individual economic security.

Regarding dry weather, as established in previous research (Carrico, Donato, Best, & Gilligan, 2020; Tsaneva, 2020), droughts contribute to the increased risk of accelerating the transition to marriage for women and girls of all ages, particularly in rural agricultural households that experience negative income shocks following periods characterized by below-average precipitation. While the relevant literature indicate that this effect holds only in the short term (Tsaneva, 2020), our findings show that dry weather conditions accelerate marriage transitions not only through meteorological and agricultural droughts but also in cases of long-term groundwater storage variations. This suggests that cumulative water deficits over extended periods can further intensify the pressure to marry at younger ages.

Our study also provides new insights into the effects of cumulative abnormal weather on urban women. We find that the latter are similarly affected by the climate-induced risk of accelerated marriage as rural women, even without direct reliance on agricultural incomes. As discussed in the literature, the mechanisms linking urban women's exposure to climate hardships and marriage are primarily economic. Prolonged excess humidity, which leads to property loss, non-farm economic disruption, and asset depletion, may prompt income shortages, incentivizing women to enter marriage earlier than planned (Ahmed et al., 2019; McLeod et al., 2019). Additionally, urban households, often net food buyers, are also susceptible to food price shocks resulting from crop failures and decreased agricultural yields caused by droughts or rainfall fluctuations (Akter & Basher, 2014). Furthermore, rural-to-urban migration in response to income shocks could place downward pressure on wages for urban and non-agricultural workers, particularly women, who are overrepresented in these sectors in Bangladesh (Sen et al., 2021).

There are some limitations in our analysis that should be acknowledged. First, marriage data likely exhibit seasonality, which could only be accounted for by modelling the month of first marriage. However, this was not feasible due to the small sample sizes, especially for older cohorts. Additionally, several key individual characteristics, such as women's socioeconomic conditions during their upbringing and their participation in the workforce prior to marrying their first partner, are not available in the data and could not be included in our analysis. While we mitigate this limitation by controlling for the education level of both the bride and the groom, longitudinal data would provide a more comprehensive understanding of the factors influencing marriage timing. Income at the time of marriage, for example, plays a relevant role in mediating the relationship between climate shocks and marriage timing (Tsaneva, 2020), but detailed retrospective information on these factors is unavailable in the DHS. Despite these limitations, the high quality, comprehensive geographical coverage, and implementation regularity of the DHS allowed us to establish a robust and replicable methodology that can be extended to other countries included in the survey agreement, enabling comparisons with other contexts.

In conclusion, our findings provide important new evidence on how populations adapt their demographic behaviors in response to long-term climate changes, rather than single extreme climate events, to mitigate their adverse impacts on human life. Particularly in vulnerable contexts, these adaptations may take the form of suboptimal coping strategies, such as accelerating the transition to marriage, even at very young ages. In Bangladesh, where child marriage has long been a societal norm, this exacerbates the risks of school dropout for girls, early childbearing, higher lifetime fertility, and an increased likelihood of experiencing sexual violence (Psaki et al., 2019; Yount et al., 2016). Marrying earlier than intended may result in poorer outcomes also for adult women in the marriage market, potentially leading to social downgrading (Tsaneva, 2020). In all cases, this contributes to a slowdown in the country's modernization processes and represents a threaten to women's and girls' rights and emancipation.

CRediT authorship contribution statement

Livia Elisa Ortensi: Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Francesca Tosi:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Rosella Rettaroli:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Table A1
Description of the sample composition.

Year	DHS programme phase	Dates of Fieldwork	Number of women	Response rate among eligible women
2017–2018	DHS-VII	10/2017–03/2018	17,392	98.9 %
2014	DHS-VII	06/2014–11/2014	28,318	97.9 %
2011	DHS-VI	07/2011–12/2011	12,915	97.9 %
2007	DHS-V	03/2007–08/2007	6,592	98.4 %
2004	DHS-IV	01/2004–05/2004	5,854	97.2 %
1999–2000	DHS-IV	11/1999–03/2000	4,012	96.9 %

Source: DHS reports.

Table A2
Categories of the Standardized Precipitation Evapotranspiration Index (SPEI).

Categories	SPEI values
Extremely wet	2.00 or more
Severely wet	1.50 to 1.99
Moderately wet	1.00 to 1.49
Near normal	− 0.99 to 0.99
Moderately dry	− 1.00 to − 1.49
Severely dry	− 1.50 to − 1.99
Extremely dry	− 2.00 or less

Source: Vicente–Serrano et al. (2010).

Table A3
Multilevel Discrete-time survival logit estimates of the risk of entering marriage before age 18.

	Risk of entering marriage before age 18					
	SPEI36			SPEI48		
	HR	p-value	CI	HR	p-value	CI
Years at risk (ref. 8)						
1	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]
2	0.01	0.000	[0.01–0.01]	0.01	0.000	[0.01–0.01]
3	0.02	0.000	[0.02–0.02]	0.02	0.000	[0.02–0.02]
4	0.17	0.000	[0.16–0.18]	0.17	0.000	[0.16–0.18]
5	0.31	0.000	[0.30–0.32]	0.31	0.000	[0.30–0.32]
6	0.48	0.000	[0.46–0.49]	0.47	0.000	[0.46–0.49]
7	0.74	0.000	[0.71–0.76]	0.74	0.000	[0.71–0.76]
Religion (ref. Islam)						
Hinduism	0.71	0.000	[0.68–0.74]	0.71	0.000	[0.68–0.73]
Buddhism	0.38	0.000	[0.29–0.48]	0.38	0.000	[0.29–0.48]
Christianity	0.33	0.000	[0.24–0.45]	0.33	0.000	[0.24–0.45]
Unsure/Does not answer	5.73	0.011	[1.86–17.60]	5.70	0.011	[1.85–17.60]
Other	0.41	0.106	[0.16–1.02]	0.39	0.093	[0.16–0.98]
Husband/Partner's education (ref. None)						
Primary	0.87	0.000	[0.85–0.90]	0.88	0.000	[0.85–0.90]
Secondary	0.72	0.000	[0.70–0.74]	0.72	0.000	[0.70–0.74]
Higher	0.34	0.000	[0.33–0.36]	0.34	0.000	[0.33–0.36]
Don't know	1.13	0.504	[0.83–1.55]	1.15	0.460	[0.84–1.57]
Unsure/Does not answer	0.56	0.163	[0.29–1.11]	0.56	0.162	[0.29–1.11]
At school	0.61	0.000	[0.59–0.62]	0.61	0.000	[0.59–0.62]
Lives in a rural area	1.14	0.000	[1.12–1.17]	1.14	0.000	[1.12–1.17]
Birth cohort	1.03	0.000	[1.02–1.03]	1.03	0.000	[1.02–1.03]
SPEI (ref. Near normal)						
Severely or extremely wet	1.12	0.000	[1.07–1.17]	1.13	0.000	[1.09–1.17]
Moderately wet	1.01	0.461	[0.98–1.04]	1.03	0.121	[1.00–1.06]
Moderately dry	1.10	0.000	[1.06–1.14]	1.15	0.000	[1.11–1.19]
Severely or extremely dry	1.13	0.000	[1.08–1.18]	1.10	0.001	[1.05–1.16]
Percentage of severely underweight children	1.02	0.000	[1.01–1.02]	1.02	0.000	[1.01–1.02]
Division (ref. Barisal)						
Chattogram	0.71	0.038	[0.54–0.93]	0.71	0.035	[0.54–0.93]
Dhaka	1.22	0.191	[0.95–1.55]	1.22	0.193	[0.95–1.55]
Khulna	1.39	0.057	[1.04–1.84]	1.37	0.065	[1.03–1.82]
Mymensingh	0.97	0.836	[0.76–1.24]	0.96	0.806	[0.75–1.23]
Rajshahi	0.78	0.100	[0.61–1.00]	0.78	0.092	[0.61–0.99]
Rangpur	0.61	0.001	[0.48–0.78]	0.61	0.001	[0.47–0.78]

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Table A3 (*continued*)

	Risk of entering marriage before age 18					
	SPEI36			SPEI48		
	HR	p-value	CI	HR	p-value	CI
Sylhet	0.44	0.000	[0.34–0.57]	0.44	0.000	[0.34–0.57]
Constant	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]
lnsig2u	0.11	0.000	[0.08–0.15]	0.11	0.000	[0.08–0.15]
Observations	320,185			320,665		
Number of districts	64			64		

Source: Own elaborations of BDHS and SPEI data (1990–2016).

Table A4
Multilevel Discrete-time survival logit estimates of the risk of entering marriage at any age.

	Risk of entering marriage at any age					
	SPEI36			SPEI48		
	HR	p-value	CI	HR	p-value	CI
Years at risk (ref. 8)						
1	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]
2	0.01	0.000	[0.01–0.01]	0.01	0.000	[0.01–0.01]
3	0.02	0.000	[0.02–0.02]	0.02	0.000	[0.02–0.02]
4	0.17	0.000	[0.17–0.18]	0.17	0.000	[0.17–0.18]
5	0.32	0.000	[0.31–0.33]	0.32	0.000	[0.31–0.33]
6	0.48	0.000	[0.47–0.50]	0.48	0.000	[0.46–0.50]
7	0.74	0.000	[0.72–0.77]	0.74	0.000	[0.72–0.77]
9	1.63	0.000	[1.57–1.69]	1.62	0.000	[1.56–1.69]
10	1.78	0.000	[1.70–1.86]	1.78	0.000	[1.70–1.87]
11	1.82	0.000	[1.72–1.93]	1.82	0.000	[1.72–1.92]
12	1.73	0.000	[1.62–1.86]	1.75	0.000	[1.63–1.88]
13	1.75	0.000	[1.61–1.91]	1.75	0.000	[1.61–1.91]
14	2.14	0.000	[1.94–2.37]	2.15	0.000	[1.95–2.38]
15	2.17	0.000	[1.92–2.44]	2.21	0.000	[1.96–2.49]
16	2.59	0.000	[2.25–2.99]	2.61	0.000	[2.26–3.00]
17	3.18	0.000	[2.68–3.78]	3.25	0.000	[2.73–3.87]
18	2.79	0.000	[2.23–3.49]	2.84	0.000	[2.26–3.55]
19	3.12	0.000	[2.36–4.13]	3.17	0.000	[2.39–4.19]
20	2.11	0.001	[1.44–3.08]	2.10	0.000	[1.44–3.06]
21	3.15	0.000	[2.00–4.98]	3.14	0.000	[2.00–4.93]
22	3.85	0.000	[2.11–7.03]	3.91	0.000	[2.14–7.16]
23	1.25	0.697	[0.49–3.22]	1.28	0.671	[0.49–3.30]
24	0.55	0.468	[0.14–2.13]	0.54	0.451	[0.14–2.09]
25	3.12	0.112	[0.96–10.13]	3.10	0.114	[0.95–10.07]
26	7.71	0.032	[1.60–36.99]	8.09	0.029	[1.68–38.90]
27	–	–	[–]	–	–	[–]
28	–	–	[–]	–	–	[–]
Religion (ref. Islam)						
Hinduism	0.76	0.000	[0.73–0.78]	0.75	0.000	[0.73–0.78]
Buddhism	0.51	0.000	[0.43–0.61]	0.51	0.000	[0.43–0.61]
Christianity	0.55	0.000	[0.44–0.67]	0.55	0.000	[0.44–0.67]
Unsure/Does not answer	5.55	0.012	[1.82–16.92]	5.49	0.012	[1.79–16.81]
Other	0.41	0.033	[0.21–0.82]	0.40	0.028	[0.20–0.79]
Husband/Partner's education (ref. None)						
Primary	0.88	0.000	[0.85–0.90]	0.88	0.000	[0.86–0.90]
Secondary	0.72	0.000	[0.70–0.74]	0.72	0.000	[0.70–0.74]
Higher	0.37	0.000	[0.36–0.38]	0.37	0.000	[0.36–0.38]
Don't know	0.97	0.875	[0.72–1.31]	0.98	0.913	[0.73–1.32]
Unsure/Does not answer	0.69	0.240	[0.42–1.16]	0.69	0.229	[0.41–1.15]
At school	0.64	0.000	[0.63–0.66]	0.64	0.000	[0.63–0.66]
Lives in a rural area	1.15	0.000	[1.12–1.17]	1.14	0.000	[1.12–1.17]
Birth cohort	1.04	0.000	[1.04–1.04]	1.04	0.000	[1.04–1.05]
SPEI (ref. Near normal)						
Severely or extremely wet	1.20	0.000	[1.15–1.24]	1.19	0.000	[1.15–1.23]
Moderately wet	1.02	0.131	[1.00–1.05]	1.07	0.000	[1.04–1.10]
Moderately dry	1.14	0.000	[1.10–1.18]	1.18	0.000	[1.14–1.22]
Severely or extremely dry	1.10	0.000	[1.06–1.15]	1.12	0.000	[1.07–1.17]
Percentage of severely underweight children	1.02	0.000	[1.02–1.03]	1.02	0.000	[1.02–1.03]
Division (ref. Barisal)						
Chattogram	0.76	0.074	[0.59–0.98]	0.76	0.074	[0.58–0.98]
Dhaka	1.24	0.134	[0.98–1.56]	1.24	0.128	[0.98–1.57]
Khulna	1.29	0.114	[0.99–1.69]	1.29	0.124	[0.98–1.69]
Mymensingh	0.97	0.854	[0.77–1.23]	0.97	0.837	[0.77–1.23]
Rajshahi	0.74	0.034	[0.59–0.94]	0.74	0.034	[0.58–0.93]
Rangpur	0.58	0.000	[0.46–0.74]	0.58	0.000	[0.46–0.73]
Sylhet	0.46	0.000	[0.36–0.58]	0.45	0.000	[0.35–0.58]

(*continued on next page*)

Table A4 (*continued*)

	Risk of entering marriage at any age					
	SPEI36			**SPEI48**		
	HR	**p-value**	**CI**	**HR**	**p-value**	**CI**
Constant	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]
lnsig2u	0.10	0.000	[0.07–0.14]	0.10	0.000	[0.07–0.14]
Observations	357,436			357,938		
Number of districts	64			64		

Source: Own elaborations of BDHS and SPEI data (1990–2016).

Table A5

Discrete-time survival logit estimates of the risk of entering marriage before age 18 by disaster-prone area (SPEI36).

	Risk of entering marriage before age 18											
	Least disaster prone			**Cyclone**			**Water logging, flood, flash flood**			**Drought**		
	HR	**p-value**	**CI**	**HR**	**p-value**	**CI**	**HR**	**p-value**	**CI**	**HR**	**p-value**	**CI**
Years at risk (ref. 8)												
1	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.01]
2	0.01	0.000	[0.01–0.01]	0.01	0.000	[0.01–0.01]	0.01	0.000	[0.00–0.02]	0.01	0.000	[0.00–0.01]
3	0.03	0.000	[0.02–0.03]	0.02	0.000	[0.02–0.03]	0.03	0.000	[0.02–0.04]	0.02	0.000	[0.01–0.02]
4	0.18	0.000	[0.16–0.20]	0.16	0.000	[0.14–0.19]	0.22	0.000	[0.17–0.28]	0.18	0.000	[0.10–0.33]
5	0.33	0.000	[0.30–0.36]	0.32	0.000	[0.27–0.38]	0.36	0.000	[0.29–0.44]	0.32	0.001	[0.18–0.58]
6	0.49	0.000	[0.46–0.53]	0.50	0.000	[0.44–0.57]	0.52	0.000	[0.45–0.59]	0.47	0.067	[0.24–0.93]
7	0.74	0.000	[0.70–0.79]	0.81	0.002	[0.73–0.91]	0.75	0.000	[0.66–0.86]	0.71	0.402	[0.37–1.39]
Religion (ref. Islam)												
Hinduism	0.70	0.000	[0.65–0.76]	0.66	0.000	[0.61–0.71]	0.76	0.001	[0.67–0.87]	0.85	0.000	[0.79–0.91]
Buddhism	0.34	0.000	[0.24–0.49]	0.48	0.063	[0.25–0.92]	1.03	0.808	[0.82–1.30]	–	–	[–]
Christianity	0.35	0.000	[0.20–0.63]	0.31	0.002	[0.16–0.58]	–	–	[–]	0.49	0.000	[0.40–0.60]
Unsure/Does not answer	5.64	0.034	[1.48–21.57]	6.21	0.000	[5.20–7.43]	4.34	0.000	[3.68–5.12]	–	–	[–]
Other	0.39	0.051	[0.18–0.86]	–	–	[–]	–	–	[–]	–	–	[–]
Husband/Partner's education (ref. None)												
Primary	0.86	0.000	[0.82–0.90]	0.97	0.588	[0.87–1.07]	0.84	0.000	[0.80–0.89]	0.93	0.501	[0.78–1.11]
Secondary	0.72	0.000	[0.67–0.76]	0.72	0.002	[0.61–0.86]	0.72	0.000	[0.64–0.81]	0.69	0.000	[0.63–0.75]
Higher	0.35	0.000	[0.32–0.39]	0.38	0.000	[0.33–0.43]	0.36	0.000	[0.32–0.41]	0.26	0.000	[0.25–0.26]
Don't know	0.93	0.762	[0.64–1.36]	1.86	0.078	[1.04–3.33]	2.50	0.039	[1.21–5.18]	2.65	0.000	[2.08–3.38]
Unsure/Does not answer	0.33	0.222	[0.07–1.47]	1.11	0.496	[0.86–1.44]	0.82	0.890	[0.08–8.46]	–	–	[–]
At school	0.60	0.000	[0.58–0.62]	0.72	0.000	[0.64–0.79]	0.65	0.000	[0.60–0.71]	0.52	0.000	[0.49–0.55]
Lives in a rural area	1.19	0.000	[1.13–1.25]	1.13	0.001	[1.06–1.20]	1.16	0.001	[1.08–1.26]	1.38	0.190	[0.92–2.06]
Birth cohort	1.02	0.004	[1.01–1.04]	1.01	0.242	[1.00–1.02]	0.98	0.105	[0.97–1.00]	1.08	0.000	[1.07–1.10]
SPEI48 (ref. Near normal)												
Severely or extremely wet	1.12	0.037	[1.02–1.23]	1.13	0.009	[1.05–1.22]	1.31	0.044	[1.05–1.64]	1.09	0.000	[1.06–1.13]
Moderately wet	1.03	0.401	[0.98–1.08]	1.05	0.185	[0.99–1.12]	1.04	0.335	[0.97–1.12]	1.02	0.914	[0.72–1.45]
Moderately dry	1.16	0.006	[1.06–1.26]	1.08	0.367	[0.94–1.25]	1.35	0.013	[1.11–1.64]	0.91	0.026	[0.85–0.98]
Severely or extremely dry	1.20	0.012	[1.06–1.34]	0.95	0.565	[0.83–1.09]	1.14	0.294	[0.93–1.41]	1.14	0.671	[0.69–1.89]
Percentage of severely underweight children	1.01	0.106	[1.00–1.02]	1.00	0.821	[0.98–1.01]	0.97	0.009	[0.95–0.99]	1.07	0.000	[1.04–1.11]
Division (ref. Barisal)												
Chattogram	0.78	0.017	[0.65–0.92]	0.73	0.001	[0.63–0.85]	–	–	[–]	–	–	[–]
Dhaka	0.95	0.521	[0.84–1.08]	–	–	[–]	1.04	0.675	[0.88–1.23]	–	–	[–]
Khulna	1.59	0.000	[1.42–1.77]	1.10	0.033	[1.02–1.18]	0.88	0.354	[0.69–1.11]	–	–	[–]
Mymensingh	1.38	0.000	[1.20–1.59]	–	–	[–]	0.94	0.569	[0.79–1.12]	–	–	[–]
Rajshahi	1.27	0.005	[1.10–1.45]	–	–	[–]	0.98	0.820	[0.85–1.13]	0.71	0.001	[0.60–0.84]
Rangpur	0.67	0.014	[0.51–0.87]	–	–	[–]	0.51	0.000	[0.46–0.58]	0.61	0.000	[0.53–0.71]
Sylhet	0.38	0.000	[0.30–0.48]	–	–	[–]	0.38	0.000	[0.34–0.44]	–	–	[–]
Constant	0.00	0.004	[0.00–0.00]	0.00	0.246	[0.00–911.75]	3.52e + 13	0.103	[0.76–1.63e + 27]	0.00	0.000	[0.00–0.00]
Observations	209,229			48,719			50,489			11,748		

Source: Own elaborations of BDHS and SPEI data (1990–2016).

Table A6
Discrete-time survival logit estimates of the risk of entering marriage at any age by disaster-prone area (SPEI36).

	Risk of entering marriage at any age											
	Least disaster prone			Cyclone			Water logging, flood, flash flood			Drought		
	HR	p-value	CI	HR	p-value	CI	HR	p-value	CI	HR	p-value	CI
Years at risk (ref. 8)												
1	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.01]
2	0.01	0.000	[0.01–0.01]	0.01	0.000	[0.01–0.01]	0.01	0.000	[0.00–0.02]	0.01	0.000	[0.00–0.01]
3	0.03	0.000	[0.02–0.03]	0.02	0.000	[0.02–0.03]	0.03	0.000	[0.02–0.04]	0.02	0.000	[0.01–0.02]
4	0.19	0.000	[0.17–0.21]	0.16	0.000	[0.14–0.19]	0.22	0.000	[0.17–0.29]	0.19	0.000	[0.10–0.35]
5	0.34	0.000	[0.31–0.37]	0.33	0.000	[0.28–0.39]	0.36	0.000	[0.29–0.45]	0.33	0.002	[0.18–0.60]
6	0.50	0.000	[0.46–0.54]	0.51	0.000	[0.44–0.58]	0.52	0.000	[0.45–0.59]	0.49	0.074	[0.25–0.94]
7	0.75	0.000	[0.70–0.79]	0.82	0.002	[0.73–0.91]	0.75	0.000	[0.66–0.86]	0.72	0.419	[0.37–1.40]
9	1.61	0.000	[1.52–1.71]	1.64	0.000	[1.41–1.92]	1.55	0.000	[1.33–1.80]	1.42	0.059	[1.05–1.94]
10	1.74	0.000	[1.58–1.92]	1.42	0.005	[1.16–1.75]	1.86	0.000	[1.68–2.05]	1.88	0.000	[1.53–2.31]
11	1.82	0.000	[1.63–2.03]	1.32	0.054	[1.04–1.67]	1.84	0.000	[1.39–2.43]	1.30	0.111	[0.99–1.69]
12	1.64	0.000	[1.43–1.87]	1.67	0.001	[1.29–2.16]	1.40	0.028	[1.09–1.80]	2.49	0.006	[1.45–4.29]
13	1.78	0.000	[1.50–2.13]	1.17	0.261	[0.93–1.48]	1.30	0.357	[0.82–2.06]	1.95	0.000	[1.52–2.51]
14	2.15	0.000	[1.73–2.67]	1.55	0.004	[1.21–2.00]	1.64	0.054	[1.08–2.50]	1.34	0.501	[0.65–2.76]
15	2.26	0.000	[1.79–2.84]	1.42	0.160	[0.94–2.16]	1.47	0.039	[1.08–2.01]	1.51	0.664	[0.32–7.15]
16	2.36	0.000	[1.66–3.35]	2.70	0.000	[1.76–4.14]	1.96	0.039	[1.15–3.34]	3.11	0.039	[1.26–7.66]
17	3.88	0.000	[2.79–5.40]	0.86	0.807	[0.33–2.29]	1.50	0.522	[0.53–4.22]	1.84	0.454	[0.48–7.05]
18	2.64	0.000	[1.80–3.89]	2.58	0.118	[0.95–7.02]	1.10	0.894	[0.35–3.42]	12.72	0.000	[11.36–14.24]
19	3.62	0.003	[1.77–7.39]	1.36	0.811	[0.16–11.24]	1.65	0.316	[0.73–3.73]	3.19	0.642	[0.05–191.70]
20	2.38	0.040	[1.19–4.76]	0.85	0.864	[0.17–4.21]	1.76	0.430	[0.54–5.75]	–	–	[–]
21	3.47	0.044	[1.26–9.61]	3.20	0.316	[0.48–21.46]	2.64	0.273	[0.62–11.35]	–	–	[–]
22	3.90	0.069	[1.14–13.33]	1.24	0.847	[0.19–7.97]	4.87	0.013	[1.71–13.85]	6.27	0.000	[5.03–7.80]
23	1.78	0.484	[0.46–6.94]	–	–	[–]	4.54	0.323	[0.37–56.51]	–	–	[–]
24	–	–	[–]	–	–	[–]	–	–	[–]	–	–	[–]
25	2.40	0.381	[0.46–12.46]	–	–	[–]	–	–	[–]	–	–	[–]
26	4.94	0.290	[0.41–59.04]	–	–	[–]	–	–	[–]	–	–	[–]
27	–	–	[–]	–	–	[–]	–	–	[–]	–	–	[–]
28	–	–	[–]	–	–	[–]	–	–	[–]	–	–	[–]
Religion (ref. Islam)												
Hinduism	0.75	0.000	[0.71–0.81]	0.71	0.000	[0.65–0.78]	0.81	0.002	[0.73–0.91]	0.85	0.000	[0.81–0.90]
Buddhism	0.47	0.000)	[0.37–0.61]	0.38	0.005	[0.22–0.67]	1.03	0.854	[0.81–1.31]	–	–	[–]
Christianity	0.53	0.000	[0.41–0.68]	0.55	0.000	[0.42–0.71]	–	–	[–]	1.10	0.248	[0.96–1.27]
Unsure/Does not answer	6.14	0.020	[1.70–22.20]	5.64	0.000	[4.75–6.69]	4.37	0.000	[3.58–5.34]	–	–	[–]
Other	0.43	0.002	[0.27–0.67]	–	–	[–]	–	–	[–]	–	–	[–]
Husband/Partner's education (ref. None)												
Primary	0.85	0.000	[0.81–0.89]	1.01	0.884	[0.92–1.11]	0.85	0.000	[0.81–0.90]	0.90	0.005	[0.84–0.96]
Secondary	0.71	0.000	[0.67–0.76]	0.74	0.000	[0.66–0.83]	0.75	0.000	[0.68–0.82]	0.67	0.000	[0.60–0.74]
Higher	0.37	0.000	[0.35–0.40]	0.42	0.000	[0.39–0.46]	0.39	0.000	[0.34–0.44]	0.30	0.000	[0.29–0.30]
Don't know	0.84	0.512	[0.54–1.31]	1.33	0.647	[0.48–3.74]	2.60	0.025	[1.29–5.23]	–	–	[–]
Unsure/Does not answer	0.50	0.054	[0.27–0.90]	1.05	0.691	[0.86–1.29]	1.11	0.919	[0.21–5.85]	2.93	0.000	[2.16–3.96]
At school	0.63	0.000	[0.61–0.66]	0.75	0.000	[0.69–0.82]	0.67	0.000	[0.62–0.73]	0.56	0.000	[0.55–0.57]
Lives in a rural area	1.18	0.000	[1.13–1.24]	1.14	0.001	[1.07–1.22]	1.12	0.049	[1.02–1.23]	1.32	0.191	[0.93–1.88]
Birth cohort	1.03	0.000	[1.02–1.05]	1.02	0.054	[1.00–1.03]	1.00	0.787	[0.98–1.03]	1.32	0.191	[0.93–1.88]
SPEI36 (ref. Near normal)												
Severely or extremely wet	1.22	0.001	[1.10–1.35]	1.14	0.006	[1.06–1.24]	1.42	0.023	[1.10–1.84]	1.08	0.000	[1.08–1.09]
Moderately wet	1.02	0.367	[0.98–1.07]	1.05	0.108	[1.00–1.11]	1.06	0.176	[0.99–1.14]	1.09	0.615	[0.81–1.47]
Moderately dry	1.18	0.001	[1.09–1.29]	1.10	0.444	[0.90–1.33]	1.39	0.003	[1.16–1.67]	0.94	0.440	[0.83–1.07]
Severely or extremely dry	1.16	0.102	[1.00–1.35]	0.90	0.225	[0.78–1.04]	1.14	0.267	[0.94–1.38]	1.27	0.419	[0.78–2.05]
Percentage of severely underweight children	1.01	0.056	[1.00–1.03]	1.00	0.944	[0.98–1.02]	0.98	0.105	[0.95–1.00]	1.08	0.008	[1.03–1.13]
Division (ref. Barisal)												
Chattogram	0.79	0.005	[0.68–0.91]	0.80	0.016	[0.69–0.93]	–	–	[–]	–	–	[–]
Dhaka	0.90	0.083	[0.82–0.99]	–	–	[–]	1.08	0.444	[0.91–1.28]	–	–	[–]
Khulna	1.43	0.000	[1.31–1.57]	1.01	0.763	[0.94–1.09]	0.92	0.588	[0.72–1.18]	–	–	[–]
Mymensingh	1.28	0.003	[1.11–1.47]	–	–	[–]	0.95	0.676	[0.79–1.15]	–	–	[–]
Rajshahi	1.16	0.019	[1.05–1.29]	–	–	[–]	1.01	0.861	[0.88–1.17]	0.70	0.001	[0.59–0.84]
Rangpur	0.65	0.001	[0.52–0.81]	–	–	[–]	0.58	0.000	[0.52–0.65]	0.61	0.000	[0.50–0.73]
Sylhet	0.44	0.000	[0.38–0.51]	–	–	[–]	0.46	0.000	[0.42–0.50]	–	–	[–]
Constant	0.00	0.000	[0.00–0.00]	0.00	0.055	[0.00–0.01]	0.00	0.796	[0.00–1.13e + 16]	0.00	0.000	[0.00–0.00]
Observations	235,062			53,369			55,954			13,023		

Source: Own elaborations of BDHS and SPEI data (1990–2016).

Table A7
Discrete-time survival logit estimates of the risk of entering marriage before age 18 by disaster-prone area (SPEI48).

	Risk of entering marriage before age 18											
	Least disaster prone			Cyclone			Water logging, flood, flash flood			Drought		
	HR	p-value	CI	HR	p-value	CI	HR	p-value	CI	HR	p-value	CI
Years at risk (ref. 8)												
1	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.01]
2	0.01	0.000	[0.01–0.01]	0.01	0.000	[0.01–0.01]	0.01	0.000	[0.00–0.02]	0.01	0.000	[0.01–0.01]
3	0.03	0.000	[0.02–0.03]	0.02	0.000	[0.02–0.03]	0.03	0.000	[0.02–0.04]	0.02	0.000	[0.01–0.02]
4	0.18	0.000	[0.16–0.20]	0.16	0.000	[0.14–0.19]	0.22	0.000	[0.17–0.28]	0.19	0.000	[0.11–0.33]
5	0.33	0.000	[0.30–0.36]	0.32	0.000	[0.28–0.38]	0.36	0.000	[0.29–0.44]	0.33	0.002	[0.18–0.59]
6	0.49	0.000	[0.45–0.53]	0.50	0.000	[0.44–0.57]	0.52	0.000	[0.45–0.60]	0.48	0.064	[0.25–0.92]
7	0.74	0.000	[0.70–0.79]	0.81	0.002	[0.72–0.90]	0.76	0.000	[0.67–0.86]	0.73	0.425	[0.38–1.40]
Religion (ref. Islam)												
Hinduism	0.70	0.000	[0.65–0.76]	0.66	0.000	[0.61–0.71]	0.77	0.001	[0.67–0.87]	0.84	0.000	[0.82–0.87]
Buddhism	0.34	0.000	[0.24–0.49]	0.49	0.067	[0.25–0.93]	1.09	0.570	[0.85–1.39]	–	–	[–]
Christianity	0.35	0.003	[0.20–0.63]	0.30	0.002	[0.16–0.57]	–	–	[–]	0.48	0.000	[0.43–0.54]
Unsure/Does not answer	5.60	0.038	[1.43–22.04]	6.11	0.000	[5.00–7.47]	4.70	0.000	[4.05–5.46]	–	–	[–]
Other	0.38	0.047	[0.17–0.84]	–	–	[–]	–	–	[–]	–	–	[–]
Husband/Partner's education (ref. None)												
Primary	0.86	0.000	[0.82–0.90]	0.97	0.609	[0.87–1.07]	0.84	0.000	[0.80–0.89]	0.91	0.214	[0.80–1.03]
Secondary	0.72	0.000	[0.67–0.76]	0.73	0.002	[0.61–0.86]	0.72	0.000	[0.64–0.81]	0.68	0.000	[0.62–0.75]
Higher	0.35	0.000	[0.32–0.39]	0.38	0.000)	[0.33–0.43]	0.36	0.000	[0.32–0.41]	0.25	0.000	[0.25–0.25]
Don't know	0.95	0.809	[0.65–1.38]	1.88	0.069	[1.06–3.32]	2.40	0.046	[1.17–4.93]	2.50	0.002	[1.53–4.08]
Unsure/Does not answer	0.33	0.222	[0.07–1.47]	1.11	0.517	[0.85–1.44]	0.82	0.888	[0.08–8.59]	–	–	[–]
At school	0.60	0.000	[0.58–0.62]	0.72	0.000	[0.65–0.79]	0.65	0.000	[0.60–0.71]	0.52	0.000	[0.48–0.57]
Lives in a rural area	1.18	0.000	[1.12–1.24]	1.12	0.003	[1.05–1.19]	1.17	0.001	[1.08–1.26]	1.41	0.146	[0.96–2.08]
Birth cohort	1.02	0.002	[1.01–1.04]	1.01	0.208	[1.00–1.02]	0.99	0.140	[0.97–1.00]	1.07	0.000	[1.05–1.10]
SPEI48 (ref. Near normal)												
Severely or extremely wet	1.12	0.021	[1.03–1.21]	1.13	0.002	[1.06–1.21]	1.24	0.033	[1.05–1.46]	1.28	0.000	[1.27–1.28]
Moderately wet	1.02	0.644	[0.96–1.08]	1.12	0.031	[1.03–1.22]	1.06	0.564	[0.90–1.25]	1.16	0.004	[1.07–1.27]
Moderately dry	1.15	0.001	[1.07–1.23]	1.18	0.234	[0.94–1.47]	1.28	0.001	[1.13–1.45]	1.33	0.469	[0.70–2.54]
Severely or extremely dry	1.20	0.008	[1.07–1.34]	0.97	0.746	[0.85–1.11]	1.04	0.805	[0.81–1.32]	1.41	0.086	[1.01–1.96]
Percentage of severely underweight children	1.01	0.083	[1.00–1.02]	1.00	0.891	[0.98–1.01]	0.97	0.019	[0.95–0.99]	1.05	0.003	[1.02–1.08]
Division (ref. Barisal)												
Chattogram	0.78	0.015	[0.66–0.92]	0.72	0.000	[0.62–0.84]	–	–	[–]	–	–	[–]
Dhaka	0.96	0.562	[0.85–1.08]	–	–	[–]	1.05	0.639	[0.89–1.23]	–	–	[–]
Khulna	1.59	0.000	[1.43–1.77]	1.10	0.053	[1.01–1.18]	0.90	0.481	[0.70–1.15]	–	–	[–]
Mymensingh	1.38	0.000	[1.19–1.59]	–	–	[–]	0.93	0.541	[0.77–1.13]	–	–	[–]
Rajshahi	1.27	0.004	[1.11–1.46]	–	–	[–]	0.99	0.944	[0.86–1.15]	0.72	0.000	[0.62–0.83]
Rangpur	0.67	0.013	[0.51–0.87]	–	–	[–]	0.51	0.000	[0.46–0.58]	0.66	0.001	[0.53–0.82]
Sylhet	0.38	0.000	[0.30–0.48]	–	–	[–]	0.38	0.000	[0.33–0.44]	–	–	[–]
Constant	0.00	0.002	[0.00–0.00]	0.00	0.210	[0.00–351.13]	3.62e + 11	0.138	[0.06–2.36e + 24]	0.00	0.000	[0.00–0.00]
Observations	209,279			48,871			50,500			12,015		

Source: Own elaborations of BDHS and SPEI data (1990–2016).

Table A8
Discrete-time survival logit estimates of the risk of entering marriage at any age by disaster-prone area (SPEI48).

	Risk of entering marriage at any age											
	Least disaster prone			Cyclone			Water logging, flood, flash flood			Drought		
	HR	p-value	CI	HR	p-value	CI	HR	p-value	CI	HR	p-value	CI
Years at risk (ref. 8)												
1	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.01]
2	0.01	0.000	[0.01–0.01]	0.01	0.000	[0.01–0.01]	0.01	0.000	[0.00–0.02]	0.01	0.000	[0.01–0.01]
3	0.03	0.000	[0.02–0.03]	0.02	0.000	[0.02–0.03]	0.03	0.000	[0.02–0.04]	0.02	0.000	[0.02–0.02]
4	0.19	0.000	[0.17–0.21]	0.16	0.000	[0.14–0.19]	0.22	0.000	[0.17–0.29]	0.20	0.000	[0.12–0.34]
5	0.33	0.000	[0.30–0.37]	0.33	0.000	[0.28–0.38]	0.36	0.000	[0.29–0.45]	0.34	0.002	[0.19–0.61]
6	0.49	0.000	[0.46–0.53]	0.51	0.000	[0.44–0.57]	0.52	0.000	[0.45–0.60]	0.50	0.073	[0.26–0.94]
7	0.74	0.000	[0.70–0.79]	0.81	0.002	[0.73–0.91]	0.76	0.000	[0.67–0.86]	0.74	0.440	[0.39–1.41]
9	1.61	0.000	[1.52–1.70]	1.64	0.000	[1.40–1.92]	1.54	0.000	[1.32–1.80]	1.43	0.018	[1.11–1.83]
10	1.74	0.000	[1.58–1.91]	1.43	0.007	[1.15–1.78]	1.86	0.000	[1.69–2.06]	1.85	0.000	[1.64–2.10]

(*continued on next page*)

Table A8 (*continued*)

	Risk of entering marriage at any age											
	Least disaster prone			Cyclone			Water logging, flood, flash flood			Drought		
	HR	p-value	CI	HR	p-value	CI	HR	p-value	CI	HR	p-value	CI
11	1.81	0.000	[1.62–2.02]	1.32	0.052	[1.04–1.68]	1.85	0.000	[1.39–2.45]	1.27	0.261	[0.90–1.78]
12	1.65	0.000	[1.44–1.88]	1.69	0.001	[1.30–2.19]	1.42	0.018	[1.11–1.82]	2.44	0.003	[1.49–3.98]
13	1.77	0.000	[1.49–2.11]	1.19	0.246	[0.93–1.52]	1.31	0.334	[0.83–2.08]	1.89	0.001	[1.37–2.62]
14	2.16	0.000	[1.74–2.68]	1.57	0.004	[1.21–2.03]	1.66	0.047	[1.09–2.53]	1.28	0.534	[0.66–2.48]
15	2.31	0.000	[1.82–2.93]	1.44	0.149	[0.95–2.17]	1.49	0.043	[1.08–2.06]	1.40	0.699	[0.34–5.81]
16	2.38	0.000	[1.66–3.39]	2.76	0.000	[1.76–4.34]	1.94	0.038	[1.15–3.29]	2.83	0.014	[1.41–5.65]
17	3.97	0.000	[2.86–5.51]	0.86	0.796	[0.32–2.29]	1.58	0.451	[0.58–4.26]	1.67	0.466	[0.52–5.33]
18	2.69	0.000	[1.83–3.95]	2.56	0.118	[0.95–6.91]	1.13	0.860	[0.36–3.57]	11.92	0.000	[11.06–12.84]
19	3.71	0.002	[1.82–7.56]	1.39	0.796	[0.17–11.13]	1.66	0.316	[0.72–3.83]	2.98	0.658	[0.05–172.88]
20	2.37	0.040	[1.19–4.72]	0.83	0.846	[0.17–4.01]	1.83	0.420	[0.53–6.28]	–	–	[–]
21	3.67	0.030	[1.37–9.82]	2.94	0.338	[0.46–18.73]	2.38	0.317	[0.57–9.92]	–	–	[–]
22	3.98	0.062	[1.18–13.50]	1.25	0.844	[0.20–7.94]	4.98	0.010	[1.78–13.96]	5.64	0.000	[4.43–7.19]
23	1.87	0.481	[0.43–8.01]	–	–	[–]	4.68	0.315	[0.37–58.62]	–	–	[–]
24	–	–	[–]	–	–	[–]	–	–	[–]	–	–	[–]
25	2.42	0.377	[0.47–12.55]	–	–	[–]	–	–	[–]	–	–	[–]
26	5.30	0.278	[0.42–66.73]	–	–	[–]	–	–	[–]	–	–	[–]
27	–	–	[–]	–	–	[–]	–	–	[–]	–	–	[–]
28	–	–	[–]	–	–	[–]	–	–	[–]	–	–	[–]
Religion (ref. Islam)												
Hinduism	0.75	0.000	[0.70–0.80]	0.71	0.000	[0.65–0.77]	0.81	0.001	[0.73–0.90]	0.85	0.000	[0.84–0.86]
Buddhism	0.48	0.000	[0.37–0.61]	0.39	0.005	[0.22–0.68]	1.07	0.642	[0.83–1.39]	–	–	[–]
Christianity	0.53	0.000	[0.41–0.68]	0.54	0.000	[0.42–0.70]	–	–	[–]	1.10	0.153	[0.99–1.24]
Unsure/Does not answer	6.02	0.025	[1.61–22.46]	5.45	0.000	[4.52–6.59]	4.76	0.000	[3.95–5.75]	–	–	[–]
Other	0.41	0.002	[0.26–0.66]	–	–	[–]	–	–	[–]	–	–	[–]
Husband/Partner's education (ref. None)												
Primary	0.85	0.000	[0.81–0.89]	1.01	0.873	[0.92–1.10]	0.85	0.000	[0.81–0.90]	0.88	0.000	[0.86–0.90]
Secondary	0.71	0.000	[0.67–0.76]	0.74	0.000	[0.66–0.83]	0.75	0.000	[0.68–0.82]	0.66	0.000	[0.59–0.74]
Higher	0.37	0.000	[0.35–0.40]	0.42	0.000	[0.39–0.45]	0.39	0.000	[0.35–0.44]	0.29	0.000	[0.29–0.29]
Don't know	0.85	0.549	[0.54–1.33]	1.33	0.656	[0.46–3.82]	2.48	0.031	[1.24–4.96]	2.67	0.002	[1.58–4.49]
Unsure/Does not answer	0.50	0.051	[0.27–0.90]	1.04	0.763	[0.83–1.30]	1.12	0.914	[0.21–5.93]	–	–	[–]
At school	0.63	0.000	[0.61–0.66]	0.75	0.000	[0.69–0.82]	0.67	0.000	[0.62–0.73]	0.56	0.000	[0.55–0.57]
Lives in a rural area	1.18	0.000	[1.13–1.24]	1.13	0.001	[1.07–1.20]	1.12	0.040	[1.02–1.23]	1.34	0.168	[0.95–1.91]
Birth cohort	1.04	0.000	[1.02–1.05]	1.02	0.020	[1.00–1.03]	1.01	0.644	[0.99–1.03]	1.09	0.001	[1.04–1.13]
SPEI36 (ref. Near normal)												
Severely or extremely wet	1.18	0.002	[1.08–1.29]	1.17	0.001	[1.09–1.26]	1.29	0.025	[1.07–1.55]	1.26	0.000	[1.24–1.27]
Moderately wet	1.05	0.128	[1.00–1.11]	1.16	0.000	[1.09–1.24]	1.11	0.266	[0.95–1.29]	1.09	0.200	[0.98–1.22]
Moderately dry	1.16	0.011	[1.05–1.29]	1.20	0.192	[0.95–1.52]	1.29	0.000	[1.19–1.40]	1.31	0.395	[0.78–2.20]
Severely or extremely dry	1.21	0.023	[1.05–1.39]	0.90	0.173	[0.80–1.02]	1.08	0.643	[0.81–1.44]	1.48	0.024	[1.11–1.96]
Percentage of severely underweight children	1.02	0.052	[1.00–1.03]	1.00	0.991	[0.98–1.02]	0.98	0.159	[0.95–1.00]	1.06	0.022	[1.02–1.10]
Division (ref. Barisal)												
Chattogram	0.79	0.007	[0.69–0.91]	0.79	0.010	[0.68–0.92]	–	–	[–]	–	–	[–]
Dhaka	0.92	0.163	[0.83–1.02]	–	–	[–]	1.09	0.388	[0.93–1.27]	–	–	[–]
Khulna	1.46	0.000	[1.33–1.60]	1.01	0.827	[0.93–1.10]	0.94	0.700	[0.72–1.22]	–	–	[–]
Mymensingh	1.29	0.003	[1.12–1.49]	–	–	[–]	0.95	0.630	[0.78–1.15]	–	–	[–]
Rajshahi	1.18	0.011	[1.06–1.32]	–	–	[–]	1.03	0.736	[0.89–1.19]	0.72	0.001	[0.62–0.84]
Rangpur	0.66	0.001	[0.53–0.81]	–	–	[–]	0.58	0.000	[0.51–0.65]	0.66	0.005	[0.51–0.84]
Sylhet	0.44	0.000	[0.38–0.51]	–	–	[–]	0.45	0.000	[0.42–0.50]	–	–	[–]
Constant	0.00	0.000	[0.00–0.00]	0.00	0.028	[0.00–0.00]	0.00	0.654	[0.00–6.51e + 12]	0.00	0.001	[0.00–0.00]
Observations	235,111			53,538			55,971			13,290		

Source: Own elaborations of BDHS and SPEI data (1990–2016).

Table A9
Discrete-time survival logit estimates of the risk of entering marriage at any age for women living in urban areas.

	Risk of entering marriage at any age					
	SPEI36			**SPEI48**		
	HR	**p-value**	**CI**	**HR**	**p-value**	**CI**
Years at risk (ref. 8)						
1	0.00	0.000	[0.00–0.00]	0,00	0.000	[0.00–0.00]
2	0.01	0.000	[0.01–0.01]	0,01	0.000	[0.01–0.01]
3	0.03	0.000	[0.02–0.03]	0,03	0.000	[0.02–0.03]
4	0.18	0.000	[0.17–0.20]	0,18	0.000	[0.17–0.20]
5	0.31	0.000	[0.29–0.33]	0,31	0.000	[0.29–0.33]
6	0.46	0.000	[0.43–0.50]	0,46	0.000	[0.43–0.49]
7	0.70	0.000	[0.65–0.75]	0,70	0.000	[0.65–0.75]
9	1.63	0.000	[1.51–1.77]	1,63	0.000	[1.51–1.76]
10	1.76	0.000	[1.61–1.93]	1,78	0.000	[1.63–1.95]
11	2.03	0.000	[1.83–2.25]	2,04	0.000	[1.84–2.26]
12	1.76	0.000	[1.55–2.00]	1,77	0.000	[1.56–2.01]
13	1.92	0.000	[1.66–2.22]	1,93	0.000	[1.67–2.24]
14	2.43	0.000	[2.06–2.87]	2,44	0.000	[2.07–2.89]
15	2.73	0.000	[2.25–3.32]	2,81	0.000	[2.31–3.42]
16	2.84	0.000	[2.25–3.59]	2,89	0.000	[2.29–3.65]
17	3.54	0.000	[2.69–4.67]	3,66	0.000	[2.77–4.82]
18	3.11	0.000	[2.19–4.43]	3,17	0.000	[2.23–4.50]
19	3.39	0.000	[2.21–5.20]	3,49	0.000	[2.27–5.35]
20	3.01	0.000	[1.75–5.19]	3,01	0.000	[1.75–5.18]
21	4.70	0.000	[2.46–8.99]	4,71	0.000	[2.47–8.99]
22	5.79	0.000	[2.39–14.02]	5,88	0.000	[2.42–14.27]
23	1.92	0.360	[0.47–7.78]	2,03	0.318	[0.51–8.19]
24	2.02	0.414	[0.37–10.95]	2,12	0.382	[0.39–11.49]
25	6.50	0.034	[1.15–36.76]	6,72	0.031	[1.19–37.86]
26	–	–	[–]	–	–	[–]
27	–	–	[–]	–	–	[–]
28	–	–	[–]	–	–	[–]
Religion (ref. Islam)						
Hinduism	0.78	0.000	[0.73–0.83]	0.78	0.000	[0.73–0.83]
Buddhism	0.52	0.000	[0.34–0.80]	0.52	0.003	[0.34–0.80]
Christianity	0.59	0.000	[0.42–0.82]	0.59	0.002	[0.42–0.82]
Unsure/Does not answer	–	–	[–]	–	–	[–]
Other	–	–	[–]	–	–	[–]
Husband/Partner's education (ref. None)						
Primary	0.86	0.000	[0.81–0.91]	0.86	0.000	[0.81–0.91]
Secondary	0.67	0.000	[0.63–0.72]	0.68	0.000	[0.64–0.72]
Higher	0.34	0.000	[0.31–0.36]	0.34	0.000	[0.31–0.36]
Don't know	0.82	0.526	[0.45–1.51]	0.83	0.561	[0.45–1.54]
Unsure/Does not answer	0.36	0.114	[0.10–1.28]	0.35	0.103	[0.10–1.24]
At school	0.59	0.000	[0.59–0.65]	0.62	0.000	[0.59–0.65]
Birth cohort	1.05	0.000	[1.04–1.06]	1.05	0.000	[1.04–1.06]
SPEI (ref. Near normal)						
Severely or extremely wet	1.13	0.000	[1.07–1.19]	1.18	0.000	[1.10–1.27]
Moderately wet	0.96	0.151	[0.91–1.02]	1.08	0.010	[1.02–1.14]
Moderately dry	1.10	0.008	[1.02–1.17]	1.17	0.000	[1.10–1.25]
Severely or extremely dry	1.10	0.029	[1.01–1.20]	1.16	0.000	[1.06–1.27]
Percentage of severely underweight children	1.02	0.000	[1.02–1.03]	1.03	0.000	[1.02–1.03]
Division (ref. Barisal)						
Chattogram	0.70	0.005	[0.55–0.90]	0.76	0.006	[0.54–0.90]
Dhaka	0.99	0.900	[0.78–1.24]	1.24	0.969	[0.79–1.27]
Khulna	1.19	0.174	[0.93–1.53]	1.29	0.183	[0.92–1.54]
Mymensingh	0.97	0.759	[0.77–1.21]	0.97	0.805	[0.77–1.22]
Rajshahi	0.76	0.016	[0.60–0.95]	0.74	0.021	[0.60–0.96]
Rangpur	0.64	0.000	[0.50–0.81]	0.58	0.000	[0.50–0.82]
Sylhet	0.43	0.000	[0.33–0.57]	0.45	0.000	[0.33–0.57]
Constant	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]
lnsig2u	− 2.96		[− 3.46–− 2.47]	− 2.91		[− 3.4–− 2.41]
sigma_u	0.23		[0.18–0.29]	0.23		[0.18–0.30]
rho	0.02		[0.01–0.03]	0.02		[0.01–0.03]
Observations	124,750			124,942		
Number of districts	63			63		

Source: Own elaborations of BDHS and SPEI data (1990–2016).

Table A10
Discrete-time survival logit estimates of the risk of entering marriage at any age for women living in rural areas.

	Risk of entering marriage at any age					
	SPEI36			SPEI48		
	HR	p-value	CI	HR	p-value	CI
Years at risk (ref. 8)						
1	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]
2	0.01	0.000	[0.01–0.01]	0.01	0.000	[0.01–0.01]
3	0.02	0.000	[0.02–0.02]	0.02	0.000	[0.02–0.02]
4	0.17	0.000	[0.16–0.18]	0.17	0.000	[0.16–0.18]
5	0.32	0.000	[0.31–0.34]	0.32	0.000	[0.30–0.34]
6	0.49	0.000	[0.47–0.52]	0.49	0.000	[0.47–0.52]
7	0.77	0.000	[0.73–0.81]	0.76	0.000	[0.73–0.80]
9	1.63	0.000	[1.54–1.73]	1.62	0.000	[1.53–1.72]
10	1.79	0.000	[1.67–1.93]	1.79	0.000	[1.67–1.93]
11	1.67	0.000	[1.53–1.83]	1.67	0.000	[1.53–1.83]
12	1.74	0.000	[1.55–1.94]	1.76	0.000	[1.58–1.97]
13	1.64	0.000	[1.42–1.89]	1.63	0.000	[1.42–1.88]
14	1.92	0.000	[1.62–2.28]	1.94	0.000	[1.64–2.30]
15	1.71	0.000	[1.38–2.12]	1.74	0.000	[1.40–2.15]
16	2.41	0.000	[1.88–3.10]	2.41	0.000	[1.88–3.09]
17	2.90	0.000	[2.11–3.97]	2.95	0.000	[2.15–4.05]
18	2.58	0.000	[1.70–3.92]	2.62	0.000	[1.72–3.98]
19	3.12	0.000	[1.82–5.34]	3.10	0.000	[1.81–5.32]
20	1.28	0.542	[0.58–2.82]	1.26	0.562	[0.57–2.79]
21	1.72	0.275	[0.65–4.54]	1.73	0.260	[0.67–4.47]
22	2.47	0.137	[0.75–8.13]	2.54	0.128	[0.77–8.42]
23	0.98	0.982	[0.16–5.93]	0.94	0.950	[0.15–5.76]
24	–	–	[–]	–	–	[–]
25	1.52	0.696	[0.19–12.23]	1.44	0.729	[0.18–11.46]
26	–	–	[–]	–	–	[–]
27	–	–	[–]	–	–	[–]
28	–	–	[–]	–	–	[–]
Religion (ref. Islam)						
Hinduism	0.73	0.000	[0.70–0.76]	0.73	0.000	[0.69–0.76]
Buddhism	0.50	0.000	[0.39–0.63]	0.50	0.000	[0.39–0.63]
Christianity	0.49	0.000	[0.33–0.72]	0.49	0.000	[0.33–0.72]
Unsure/Does not answer	4.28	0.052	[0.97–18.87]	4.25	0.058	[0.95–18.89]
Other	0.39	0.023	[0.17–0.88]	0.38	0.021	[0.17–0.86]
Husband/Partner's education (ref. None)						
Primary	0.88	0.000	[0.85–0.91]	0.88	0.000	[0.85–0.92]
Secondary	0.74	0.000	[0.71–0.77]	0.74	0.000	[0.71–0.77]
Higher	0.40	0.000	[0.38–0.42]	0.40	0.000	[0.38–0.42]
Don't know	1.08	0.735	[0.70–1.66]	1.08	0.731	[0.73–0.70]
Unsure/Does not answer	0.91	0.979	[0.45–1.84]	0.91	0.802	[0.45–1.84]
At school	0.66	0.000	[0.64–0.68]	0.66	0.000	[0.64–0.68]
Birth cohort	0.00	0.000	[0.00–0.00]	1.03	0.000	[1.03–1.04]
SPEI (ref. Near normal)						
Severely or extremely wet	1.26	0.000	[1.19–1.33]	1.20	0.000	[1.14–1.26]
Moderately wet	1.06	0.005	[1.02–1.10]	1.07	0.000	[1.03–1.11]
Moderately dry	1.16	0.000	[1.10–1.22]	1.17	0.000	[1.12–1.23]
Severely or extremely dry	1.11	0.001	[1.04–1.17]	1.09	0.006	[1.03–1.17]
Percentage of severely underweight children	1.02	0.000	[1.01–1.02]	1.02	0.000	[1.01–1.03]
Division (ref. Barisal)						
Chattogram	0.78	0.125	[0.57–1.07]	0.78	0.119	[0.57–1.07]
Dhaka	1.29	0.088	[0.96–1.71]	1.28	0.090	[0.96–1.72]
Khulna	1.33	0.095	[0.95–1.85]	1.32	0.104	[0.94–1.84]
Mymensingh	1.04	0.784	[0.78–1.39]	1.03	0.822	[0.78–1.38]
Rajshahi	0.81	0.149	[0.61–1.08]	0.80	0.143	[0.60–1.08]
Rangpur	0.61	0.001	[0.45–0.81]	0.60	0.001	[0.45–0.81]
Sylhet	0.50	0.000	[0.37–0.68]	0.50	0.000	[0.37–0.67]
Constant	0.00	0.450	[–0.45]	0.00	0.000	[0.00–0.00]
lnsig2u	− 2.26	0.000	[− 2.67–− 1.85]	− 2.25	0.000	[− 2.65–− 1.84]
sigma_u	0.32		[0.26–0.40]	0.32		[0.27–0.40]
rho	0.03		[0.02–0.05]	0.03		[0.02–0.05]
Observations	232,677			232,987		
Number of districts	64			64		

Source: Own elaborations of BDHS and SPEI data (1990–2016).

Table A11
Discrete-time survival logit estimates of the risk of entering marriage before age 18 for women living in urban areas.

	Risk of entering marriage before age 18					
	SPEI36			SPEI48		
	HR	p-value	CI	HR	p-value	CI
Years at risk (ref. 8)						
1	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]
2	0.01	0.000	[0.01–0.01]	0.01	0.000	[0.01–0.01]
3	0.03	0.000	[0.02–0.03]	0.03	0.000	[0.02–0.03]
4	0.17	0.000	[0.16–0.19]	0.17	0.000	[0.16–0.19]
5	0.30	0.000	[0.28–0.32]	0.30	0.000	[0.28–0.32]
6	0.45	0.000	[0.42–0.49]	0.45	0.000	[0.42–0.49]
7	0.69	0.000	[0.64–0.74]	0.69	0.000	[0.64–0.74]
Religion (ref. Islam)						
Hinduism	0.73	0.000	[0.68–0.80]	0.73	0.000	[0.67–0.80]
Buddhism	0.18	0.000	[0.08–0.42]	0.18	0.000	[0.08–0.42]
Christianity	0.18	0.000	[0.09–0.35]	0.18	0.000	[0.09–0.34]
Unsure/Does not answer	–	–	[–]	–	–	[–]
Other	–	–	[–]	–	–	[–]
Husband/Partner's education (ref. None)						
Primary	0.87	0.000	[0.81–0.93]	0.87	0.000	[0.81–0.93]
Secondary	0.67	0.000	[0.62–0.71]	0.67	0.000	[0.62–0.71]
Higher	0.30	0.000	[0.27–0.32]	0.30	0.000	[0.27–0.33]
Don't know	0.74	0.368	[0.38–1.43]	0.75	0.398	[0.39–1.46]
Unsure/Does not answer	–	–	[–]	–	–	[–]
At school	0.58	0.000	[0.55–0.62]	0.58	0.000	[0.55–0.61]
Birth cohort	1.03	0.000	[1.02–1.04]	1.03	0.000	[1.02–1.04]
SPEI (ref. Near normal)						
Severely or extremely wet	1.01	0.906	[0.92–1.10]	1.13	0.000	[1.04–1.23]
Moderately wet	0.96	0.202	[0.90–1.02]	1.02	0.546	[0.95–1.10]
Moderately dry	1.03	0.454	[0.95–1.13]	1.13	0.002	[1.04–1.22]
Severely or extremely dry	1.14	0.007	[1.04–1.25]	1.15	0.018	[1.04–1.28]
Percentage of severely underweight children	1.02	0.000	[1.01–1.03]	1.02	0.000	[1.01–1.03]
Division (ref. Barisal)						
Chattogram	0.68	0.013	[0.51–0.92]	0.69	0.015	[0.51–0.93]
Dhaka	0.98	0.884	[0.75–1.29]	0.99	0.950	[0.75–1.31]
Khulna	1.30	0.087	[0.96–1.75]	1.29	0.100	[0.95–1.74]
Mymensingh	0.96	0.760	[0.73–1.25]	0.96	0.779	[0.74–1.26]
Rajshahi	0.80	0.104	[0.61–1.05]	0.80	0.111	[0.61–1.05]
Rangpur	0.65	0.003	[0.49–0.86]	0.66	0.004	[0.49–0.87]
Sylhet	0.38	0.000	[0.27–0.54]	0.38	0.000	[0.27–0.54]
Constant	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]
lnsig2u	− 2.60		[− 3.08–− 2.12]	− 2.59		[− 3.06–− 2.11]
sigma_u	0.27		[0.21–0.35]	0.27		[0.22–0.35]
rho	0.02		[0.01–0.04]	0.02		[0.01–0.04]
Observations	107,689			107,867		
Number of districts	64			64		

Source: Own elaborations of BDHS and SPEI data (1990–2016).

Table A12
Discrete-time survival logit estimates of the risk of entering marriage before age 18 for women living in rural areas.

	Risk of entering marriage before age 18					
	SPEI36			SPEI48		
	HR	p-value	CI	HR	p-value	CI
Years at risk (ref. 8)						
1	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]
2	0.01	0.000	[0.01–0.01]	0.01	0.000	[0.01–0.01]
3	0.02	0.000	[0.02–0.02]	0.02	0.000	[0.02–0.02]
4	0.17	0.000	[0.16–0.18]	0.17	0.000	[0.16–0.18]
5	0.31	0.000	[0.30–0.33]	0.31	0.000	[0.30–0.33]
6	0.49	0.000	[0.46–0.51]	0.48	0.000	[0.46–0.51]
7	0.76	0.000	[0.72–0.80]	0.76	0.000	[0.72–0.80]
Religion (ref. Islam)						
Hinduism	0.69	0.000	[0.65–0.73]	0.69	0.000	[0.65–0.72]
Buddhism	0.42	0.000	[0.31–0.58]	0.42	0.000	[0.31–0.58]
Christianity	0.46	0.001	[0.29–0.73]	0.46	0.001	[0.29–0.73]
Unsure/Does not answer	–	–	[–]	–	–	[–]
Other	–	–	[–]	–	–	[–]
Husband/Partner's education (ref. None)						
Primary	0.87	0.000	[0.84–0.91]	0.88	0.000	[0.84–0.91]
Secondary	0.74	0.000	[0.71–0.77]	0.74	0.000	[0.71–0.77]
Higher	0.38	0.000	[0.36–0.41]	0.38	0.000	[0.36–0.41]

(*continued on next page*)

Table A12 (*continued*)

	Risk of entering marriage before age 18					
	SPEI36			SPEI48		
	HR	p-value	CI	HR	p-value	CI
Don't know	1.42	0.126	[0.91–2.22]	1.42	0.121	[0.91–2.23]
Unsure/Does not answer	–	–	[–]	–	–	[–]
At school	0.62	0.000	[0.60–0.65]	0.62	0.000	[0.60–0.65]
Birth cohort	1.02	0.000	[1.02–1.03]	1.02	0.000	[1.02–1.03]
SPEI (ref. Near normal)						
Severely or extremely wet	1.18	0.000	[1.11–1.25]	1.13	0.000	[1.07–1.19]
Moderately wet	1.04	0.073	[1.00–1.08]	1.03	0.144	[0.99–1.08]
Moderately dry	1.13	0.000	[1.07–1.20]	1.16	0.000	[1.10–1.22]
Severely or extremely dry	1.13	0.000	[1.06–1.20]	1.08	0.031	[1.01–1.16]
Percentage of severely underweight children	1.02	0.000	[1.01–1.02]	1.02	0.000	[1.01–1.02]
Division (ref. Barisal)						
Chattogram	0.71	0.043	[0.51–0.99]	0.70	0.037	[0.50–0.98]
Dhaka	1.26	0.140	[0.93–1.70]	1.25	0.151	[0.92–1.69]
Khulna	1.40	0.058	[0.99–1.98]	1.39	0.065	[0.98–1.97]
Mymensingh	1.03	0.864	[0.76–1.39]	1.02	0.916	[0.75–1.37]
Rajshahi	0.83	0.236	[0.61–1.13]	0.82	0.214	[0.61–1.12]
Rangpur	0.62	0.002	[0.46–0.85]	0.62	0.002	[0.45–0.84]
Sylhet	0.48	0.000	[0.34–0.66]	0.47	0.000	[0.34–0.65]
Constant	0.00	0.000	[0.00–0.00]	0.00	0.000	[0.00–0.00]
lnsig2u	− 2.16		[− 2.57–− 1.76]	− 2.16		[− 2.56–− 1.76]
sigma_u	0.34		[0.28–0.41]	0.34		[0.28–0.42]
rho	0.03		[0.02–0.05]	0.03		[0.02–0.05]
Observations	232,987			212,774		
Number of districts	64			64		

Source: Own elaborations of BDHS and SPEI data (1990–2016).

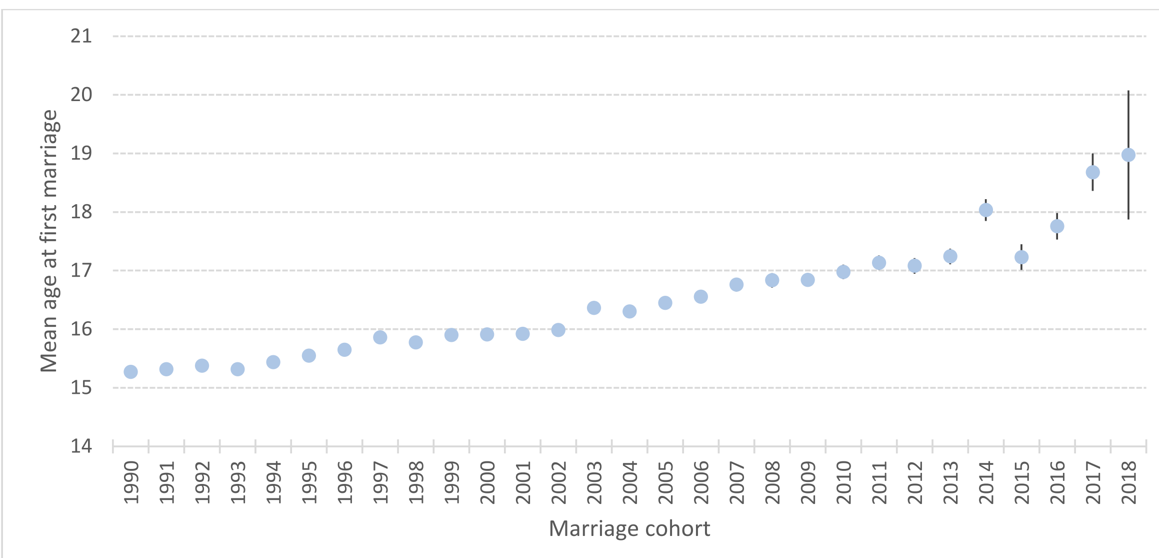

Fig. A1. Mean age at first marriage by marriage cohort. Source: Own elaborations of BDHS pooled data.

Data availability

Data will be made available on request.

References

Aadhar, S., & Mishra, V. (2017). High-resolution near real-time drought monitoring in South Asia. *Scientific Data, 4*(1), 1–14.

Ahmed, A. U. (1986). Marriage and its transition in Bangladesh. *International Journal of Sociology of the Family, 16*(1), 49–59.

Ahmed, K. J., Haq, S. M. A., & Bartiaux, F. (2019). The nexus between extreme weather events, sexual violence, and early marriage: A study of vulnerable populations in Bangladesh. *Population and Environment, 40*, 303–324.

Ahmed, R. (2018). The impact of flooding on marriage: Evidence from Pakistan. *Disaster Prevention and Management, 27*(1), 115–128.

Akter, S., & Basher, S. A. (2014). The impacts of food price and income shocks on household food security and economic well-being: Evidence from rural Bangladesh. *Global Environmental Change, 25*, 150–162.

Ainul, S., & Amin, S. (2013). *Environmental Vulnerability and Early Marriage in Southern Bangladesh*. Population Council.

Ainul, S., Saha, J., Hossain, M. I., & Amin, S. (2022). Climate change and child marriage. *The Bangladesh Development Studies, 45*(1/2), 1–26.

Alom, J., Quddus, M. A., & Islam, M. A. (2012). Nutritional status of under-five children in Bangladesh: A multilevel analysis. *Journal of Biosocial Science, 44*(5), 525–535.

Alston, M. (2015). *Women and Climate Change in Bangladesh*. London: Routledge.

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? *Women's Studies International Forum, 47*, 137–144.

Amin, S. (1998). Family structure and change in rural Bangladesh. *Population Studies, 52* (2), 201–213.

Amin, S., & Das, M. B. (2013). Marriage continuity and change in Bangladesh. In R. Kaur, & R. Palriwala (Eds.), *Marrying in South Asia: Shifting concepts, changing practices in a globalising world* (pp. 89–115). Telangana: Orient Blackswan.

Amin, S., Asadullah, M. N., Hossain, S., & Wahhaj, Z. (2017). Eradicating child marriage in the commonwealth: Is investment in girl's education sufficient? *The Round Table, 106*(2), 221–223.

Andriano, L., & Behrman, J. (2020). The effects of growing-season drought on young women's life course transitions in a sub-Saharan context. *Population Studies, 74*(3), 331–350.

Asadullah, M. N., Islam, K. M. M., & Wahhaj, Z. (2021). Child marriage, climate vulnerability and natural disasters in coastal Bangladesh. *Journal of Biosocial Science, 53*(6), 948–967.

Awiti, A. O. (2022). Climate change and gender in Africa: A review of impact and gender-responsive solutions. *Frontiers in Climate, 4*, Article 895950.

Bhattacharjee, S., Saha, B., Saha, B., Uddin, S., Panna, C. H., Bhattacharya, P., & Saha, R. (2019). Groundwater governance in Bangladesh: Established practices and recent trends. *Groundwater for Sustainable Development, 8*, 69–81.

Bajracharya, A., & Amin, S. (2012). Poverty, marriage timing, and transitions to adulthood in Nepal. *Studies in Family Planning, 43*(2), 79–92.

Bangladesh Bureau of Statistics (BBS) and UNICEF. (2015). *Bangladesh Multiple Indicator Cluster Survey 2012-2013, ProgotirPathey: Final Report*. Dhaka: Bangladesh Bureau of Statistics and UNICEF Bangladesh.

Bangladesh Bureau of Statistics (BBS). (2015). *Trends, patterns and determinants of marriage in Bangladesh*. Dhaka: Bangladesh Bureau of Statistics.

Bangladesh Bureau of Statistics (BBS). (2016). *Bangladesh Disaster Related Statistics 2015: Climate Change and Natural Disaster Perspectives*. Dhaka: Bangladesh Bureau of Statistics.

Bates, L. M., Schuler, S. R., Islam, F., & Islam, M. K. (2004). Socioeconomic factors and processes associated with domestic violence in rural Bangladesh. *International Family Planning Perspectives*, 190–199.

Becker, B., Reichel, F., Bachmann, D., & Schinke, R. (2022). High groundwater levels: Processes, consequences, and management. *WIREs Water, 9*(5), Article e1605.

Best, K., Carrico, A. R., Donato, K., & Mallick, B. (2022). A multicontextual analysis of place attachment, environmental perceptions, and mobility in southwestern Bangladesh. *Translational Issues in Psychological Science, 8*(4), 461–472.

Bhuiya, A. A., Chowdhury, M. R., Momen, M., & Khatan, M. (2005). Marital disruption: Determinants and consequences on the lives of women in a rural area of Bangladesh. *Journal of Health, Population, and Nutrition, 23*(1), 82–94.

Bischiniotis, K., Van Den Hurk, B., Jongman, B., Coughlan de Perez, E., Veldkamp, T., De Moel, H., & Aerts, J. (2018). The influence of antecedent conditions on flood risk in sub-Saharan Africa. *Natural Hazards and Earth System Sciences, 18*(1), 271–285.

Bosch, A. M., Willekens, F. J., Baqui, A. H., Van Ginneken, J. K., & Hutter, I. (2008). Association between age at menarche and early-life nutritional status in rural Bangladesh. *Journal of Biosocial Science, 40*(2), 223–237.

Brammer, H. (2016). Floods, cyclones, drought and climate change in Bangladesh: A reality check. *International Journal of Environmental Studies, 73*(6), 865–886.

Branson, N., Ardington, C., & Leibbrandt, M. (2015). Health outcomes for children born to teen mothers in Cape Town, South Africa. *Economic development and cultural change, 63*(3), 589–616.

Brouwer, R., Akter, S., Brander, L., & Haque, E. (2007). Socioeconomic vulnerability and adaptation to environmental risk: A case study of climate change and flooding in Bangladesh. *Risk Analysis, 27*(2), 313–326.

Bunyavanich, S., Landrigan, C. P., McMichael, A. J., & Epstein, P. R. (2003). The Impact of Climate Change on Child Health. *Ambulatory Pediatrics, 3*(1), 44–52.

Carrico, A. R., & Donato, K. M. (2019). Extreme weather and migration: Evidence from Bangladesh. *Population and Environment, 41*, 1–31.

Carrico, A. R., Donato, K. M., Best, K. B., & Gilligan, J. (2020). Extreme weather and marriage among girls and women in Bangladesh. *Global Environmental Change, 65*, 1–12.

Chari, A. V., Heath, R., Maertens, A., & Fatima, F. (2017). The causal effect of maternal age at marriage on child wellbeing: Evidence from India. *Journal of Development Economics, 127*, 42–55.

Chaturvedi A., Pandey B., Yadav A.K., Saroj S. (2021). Chapter 5 - An overview of the potential impacts of global climate change on water resources, Editor(s): Thokchom B., Qiu P., Singh P., Iyer P.K., Water Conservation in the Era of Global Climate Change, 99-120.

Chowdhury, F. D. (2010). Dowry, women and law in Bangladesh. *International Journal of Law Policy and the Family, 24*(2), 198–221.

Corno, L., Hildebrandt, N., & Voena, A. (2020). Age of marriage, weather shocks, and the direction of marriage payments. *Econometrica: Journal of the Econometric Society, 88*(3), 879–915.

Corno, L., & Voena, A. (2023). Child marriage as informal insurance: Empirical evidence and policy simulations. *Journal of Development Economics*, Article 103047.

Dasgupta, S. (2018). Burden of climate change on malaria mortality. *International Journal of Hygiene and Environmental Health, 221*(5), 782–791.

Dastagir, M. R. (2015). Modeling recent climate change induced extreme events in Bangladesh: A review. *Weather and Climate Extremes, 7*, 49–60.

Dewan, T. H. (2015). Societal impacts and vulnerability to floods in Bangladesh and Nepal. *Weather and Climate Extremes, 7*, 36–42.

Dimitrova, A., & Muttarak, R. (2020). After the floods: Differential impacts of rainfall anomalies on child stunting in India. *Global Environmental Change, 64*.

Doocy, S., Daniels, A., Murray, S., & Kirsch, T. D. (2013). The human impact of floods: A historical review of events 1980-2009 and systematic literature review. *PLoS. Currents, 5*.

Edossa, D. C., Woyessa, Y. E., & Welderufael, W. A. (2014). Analysis of droughts in the central region of South Africa and their association with SST anomalies. *International Journal of Atmospheric Sciences, 2014*(1), Article 508953.

Emran, M. S., & Shilpi, F. (2018). Beyond dualism: Agricultural productivity, small towns, and structural change in Bangladesh. *World Development, 107*, 264–276.

Esteban, E., & Dinar, A. (2016). The Role of Groundwater-Dependent Ecosystems in Groundwater Management. *Natural Resource Modeling, 29*, 98–129.

Felten-Bierman, C. (2006). Gender and natural disaster: Sexualized violence and the tsunami. *Development, 49*(3), 82–86.

Fenton, A., Paavola, J., & Tallontire, A. (2017). The role of microfinance in household livelihood adaptation in Satkhira District, Southwest Bangladesh. *World Development, 92*, 192–202.

Filmer, D., & Pritchett, L. H. (2001). Estimating wealth effects without expenditure data—or tears: An application to educational enrollments in states of India. *Demography, 38*, 115–132.

French, J., Ing, R., Von Allmen, S., & Wood, R. (1983). Mortality from flash floods: A review of national weather service reports, 1969-81. *Public Health Reports, 98*(6), 584.

Glinski, A., Sexton, M., & Meyers, L. (2015). Child, early and forced marriage resource guide. USAID. https://www.usaid.gov/sites/default/files/documents/1 865/USAID_CEFM_Resource-Guide.PDF.

Global Data Lab (2024). Subnational Database. Online resource. https://globaldatalab.org/geos/table/.

Grace, K., Verdin, A., Dorélien, A., Davenport, F., Funk, C., & Husak, G. (2021). Exploring strategies for investigating the mechanisms linking climate and individual-level child health outcomes: An analysis of birth weight in Mali. *Demography, 58*(2), 499–526.

Hoffmann, R., Muttarak, R., Peisker, J., & Stanig, P. (2022). Climate change experiences raise environmental concerns and promote Green voting. *Nature Climate Change, 12*(2), 148–155.

Hoogeveen, J., Van Der Klaauw, B., & Van Lomwel, G. (2011). On the timing of marriage, cattle, and shocks. *Economic Development and Cultural Change, 60*(1), 121–154.

Hoq, M. N. (2013). Regional Differentials of Age at First Marriage among Women in Bangladesh. *Asian Journal of Applied Science and Engineering, 2*(2), 76–83.

Hossain, M., & Islam, R. (2013). Effects of socio-economic and demographic variables on age at first marriage in Bangladesh. *Current Research Journal of Biological Sciences, 5*(4), 149–152.

Hossain, M. G., Mahumud, R. A., & Saw, A. (2016). Prevalence of child marriage among Bangladeshi women and trend of change over time. *Journal of Biosocial Science, 48*(4), 530–538.

Irani, M., & Roudsari, R. L. (2019). Reproductive and sexual health consequences of child marriage: A review of literature. *Journal of Midwifery and Reproductive Health, 7*(1), 1491–1497.

Islam, M. K., Haque, M. R., & Hossain, M. B. (2016). Regional variations in child marriage in Bangladesh. *Journal of Biosocial Science, 48*(5), 694–708.

Islam, M. M., Islam, M. K., Hasan, M. S., & Haque, M. A. (2016). Marriage before 16 or 18 years: The effect of marital age on women's educational attainment in Bangladesh. *Journal of Population and Social Studies, 24*(1), 117–132.

Islam, A., & Maitra, P. (2012). Health shocks and consumption smoothing in rural households: Does microcredit have a role to play? *Journal of development economics, 97*(2), 232–243.

Jensen, R., & Thornton, R. (2003). Early female marriage in the developing world. *Gender and Development, 11*(2), 9–19.

Jiang, L., & Hardee, K. (2011). How do Recent Population Trends Matter to Climate Change? *Population Research and Policy Review, 30*(2), 287–312.

Jonkman, S. N., & Kelman, I. (2005). An analysis of the causes and circumstances of flood disaster deaths. *Disasters, 29*(1), 75–97.

Kabeer, N. (2011). Between affiliation and autonomy: Navigating pathways of women's empowerment and gender justice in rural Bangladesh. *Development and Change, 42*(2), 499–528.

Kamal, S. M. M., Hassan, C. H., Alam, G. M., & Ying, Y. (2014). Child marriage in Bangladesh: Trends and determinants. *Journal of Biosocial Science, 47*(1), 120–139.

Kartiki, K. (2011). Climate change and migration: A case study from rural Bangladesh. *Gender & Development, 19*(1), 23–38.

Khatun, F., & Saadat, S. Y. (2021). Implementation of the SDGs in Bangladesh: Domestic challenges and regional considerations. South and South-West Asia Development Papers 21-02, United Nations Economic and Social Commission for Asia and the Pacific (ESCAP).

Kümbetoğlu, F. B., & User, I. (2010). Gender aspects of the disaster recovery process. In S. Dasgupta, İ. Şiriner, & P. De Sarathi (Eds.), *Women's encounter with disaster* (pp. 22–51). London: Frontpage Publications Limited.

Lam, Y., Winch, P. J., Nizame, F. A., et al. (2022). Salinity and food security in southwest coastal Bangladesh: Impacts on household food production and strategies for adaptation. *Food Security, 14*, 229–248.

Lee, K. H., Chowdhury, A. I., Rahman, Q. S. U., Cunningham, S. A., Parveen, S., Bari, S., & Gurley, E. S. (2023). Child marriage in rural Bangladesh and impact on obstetric complications and perinatal death: Findings from a health and demographic surveillance system. *PLoS One1, 18*(7), Article e0288746.

McLeod, C., Barr, H., & Rall, K. (2019). Does climate change increase the risk of child marriage: Look at what we know and what we don't with lessons from Bangladesh and Mozambique. *Columbia Journal of Gender and Law, 38*(1), 96–146.

Mondol, M. A. H., Zhu, X., Dunkerley, D., & Henley, B. J. (2021). Observed meteorological drought trends in Bangladesh identified with the Effective Drought Index (EDI). *Agricultural Water Management, 255*, Article 107001.

Mudavanhu, C. (2014). The impact of flood disasters on child education in Muzarabani District, Zimbabwe. *Jàmbá: Journal of Disaster Risk Studies, 6*(1), 8.

Muniruzzaman, M., Siddiky, M. R., Akter, S., & Haque, I. E. (2023). Premarital and extramarital relationships: A study of a selected slum in Dhaka. *Bangladesh. Indonesian Journal of Social Research (IJSR), 5*(1), 1–22.

Muttarak, R. (2021). Demographic perspectives in research on global environmental change. *Population Studies, 75*(sup1), 77–104.

Muttarak, R., & Dimitrova, A. (2019). Climate change and seasonal floods: Potential long-term nutritional consequences for children in Kerala. *India. BMJ Global Health, 4*(2), Article e001215.

Nasreen, M. (2009). *Violence Against Women during flood and post-flood situations in Bangladesh*. Dhaka: Action Aid, Bangladesh.

National Institute of Population Research and Training (NIPORT), Mitra and Associates, and Macro International. (2016). *Bangladesh demographic and health survey 2014*. Calverton, MD.

National Institute of Population Research and Training (NIPORT), Mitra and Associates, and Macro International. (2020). *Bangladesh demographic and health survey 2017–2018*. Calverton, MD.

Nielsen, J. Ø. (2009). Drought and Marriage: Exploring the Interconnection Between Climate Variability and Social Chang Through a Livelihood Perspective. In K. Hastrup, (Ed). *The question of resilience: social responses to climate change.* 159–177. Historisk-filosofiske Meddelelser 106: Det Kongelige Danske Videnskabernes Selskab.

North, A. (2010). Drought, Drop Out and Early Marriage: Feeling the Effects of Climate Change in East Africa. *Beyond Access: Gender, Education & Development, 24*, 6.

Nour, N. M. (2009). Child marriage: A silent health and human rights issue. *Reviews in obstetrics and gynecology, 2*(1), 51–56.

Otoo-Oyortey, N., & Pobi, S. (2003). Early marriage and poverty: Exploring links and key policy issues. *Gender and Development, 11*(2), 42–51.

Otto, I. M., Reckien, D., Reyer, C. P. O., Marcus, R., Le Masson, V., Jones, & Serdeczny, O. (2017). Social vulnerability to climate change: A review of concepts and evidence. *Regional Environmental Change, 17*(6), 1651–1662.

Parsons, J., Edmeades, J., Kes, A., Petroni, S., Sexton, M., & Wodon, Q. (2015). Economic impacts of child marriage: A review of the literature. *The Review of Faith & International Affairs, 13*(3), 12–22.

Patel, S. K., Agrawal, G., Mathew, B., Patel, S., Mohanty, B., & Singh, A. (2020). Climate change and women in South Asia: A review and future policy implications. *World Journal of Science, Technology and Sustainable Development, 17*(2), 145–166.

Patel, S. K., & Rajak, R. (2022). Effects and resilience to climate crisis among adolescents: A narrative review on South Asian countries. *Climate and Development, 15*, 692–703.

Peduzzi, P., Dao, H., Herold, C., & Mouton, F. (2009). Assessing global exposure and vulnerability towards natural hazards: The Disaster Risk Index. *Natural hazards and earth system sciences, 9*(4), 1149–1159.

Philip, D., & Rayhan, M. I. (2004). *Vulnerability and Poverty: What are the causes and how are they related.* ZEF Bonn: Center for Development Research, University of Bonn.

Piguet, E., Pécoud, A., & De Guchteneire, P. (2011). Migration and climate change: An overview. *Refugee Survey Quarterly, 30*(3), 1–23.

Pope, D. H., McMullen, H., Baschieri, A., Philipose, A., Udeh, C., Diallo, J., & McCoy, D. (2022). What is the current evidence for the relationship between the climate and environmental crises and child marriage? A scoping review. *Global Public Health*, 1–18.

Psaki, S. R., Soler-Hampejsek, E., Saha, J., Mensch, B. S., & Amin, S. (2019). The effects of adolescent childbearing on literacy and numeracy in Bangladesh, Malawi, and Zambia. *Demography, 56*(5), 1899–1929.

Rahman, M. R., & Lateh, H. (2016). Spatio-temporal analysis of warming in Bangladesh using recent observed temperature data and GIS. *Climate Dynamics, 46*, 2943–2960.

Rob, U., & Mutahara, M. U. (2000). Premarital Sex among Urban Adolescents in Bangladesh. *International Quarterly of Community Health Education, 20*, 103–111.

Schuler, S. R., Bates, L. M., Islam, F., & Islam, K. (2006). The timing of marriage and childbearing among rural families in Bangladesh: Choosing between competing risks. *Social Science & Medicine, 62*(11), 2826–2837.

Schuler, S. R. (2007). Rural Bangladesh: Sound policies, evolving gender norms, and family strategies. In M. A. Lewis, & M. E. Lockheed (Eds.), *Exclusion, Gender and Education: Case Studies from the Developing World* (pp. 179–204). Washington, DC: Center for Global Development.

Sen, B., Dorosh, P., & Ahmed, M. (2021). Moving out of agriculture in Bangladesh: The role of farm, non-farm and mixed households. *World Development, 144*, Article 105479.

Streatfield, P. K., Kamal, N., Ahsan, K. Z., & Nahar, Q. (2015). Early marriage in Bangladesh: Not as early as it appears. *Asian Population Studies, 11*(1), 94–110.

Tsaneva, M. (2020). The effect of weather variability on child marriage in Bangladesh. *Journal of International Development, 32*(8), 1346–1359.

Unfpa. (2021). *Child Marriage and Environmental Crises: An Evidence Brief*. New York: United Nations Population Fund. Retrieved from: Https://esaro.unfpa.org/en/publications/child-marriage-and-environmental-crises-evidence-brief.

UNICEF (2023a). A profile of child marriage in South Asia. https://data.unicef.org/wp-content/uploads/2023/05/Profile_of_child_marriage_in_South_Asia.pdf.

UNICEF (2023b). *Is an End to Child Marriage Within Reach? UNICEF, 2023*.

Van der Gaag, N. (2013). Because I Am a Girl: The State of the World's Girls 2013: in Double Jeopardy: Adolescent Girls and Disasters. Plan Canada.

Van der Geest, K., & Warner, K. (2015). Vulnerability, coping and loss and damage from climate events. In J. F. Shroder, A. E. Collins, S. Jones, B. Manyena, & J. Jayawickrama (Eds.), *Hazards, risks and disasters in society* (pp. 121–144). Boston: Academic Press.

Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2010). A multiscalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index. *Journal of Climate, 23*(7), 1696–1718.

Yount, K. M., Crandall, A., Cheong, Y. F., Osypuk, T. L., Bates, L. M., Naved, R. T., & Schuler, S. R. (2016). Child marriage and intimate partner violence in rural Bangladesh: A longitudinal multilevel analysis. *Demography, 53*(6), 1821–1852.

Zahangir, M. S. (2015). Patterns in early and very early family formation in Bangladesh. *Asian Profile, 43*(2), 123–140.

Zahid, A., & Ahmed, S. R. U. (2006). Groundwater resources development in Bangladesh: contribution to irrigation for food security and constraints to sustainability, IWMI Books, Reports H039306, International Water Management Institute.

Zaman, H. (1999). Violence against women in Bangladesh: Issues and responses. *Women's Studies International Forum, 22*(1), 37–48.

Zhang, Q., Qi, T., Singh, V. P., Chen, Y. D., & Xiao, M. (2015). Regional frequency analysis of droughts in China: A multivariate perspective. *Water Resources Management, 29*, 1767–1787.