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Extreme weather and migration: evidence from Bangladesh

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Abstract
Using retrospective migration history data collected in southwestern Bangladesh, we examine the relationship between extreme weather conditions—warm spells, dry spells, wet spells, and intense precipitation—and the likelihood that male household heads make a first internal or international migrant trip. We also investigate whether and how agricultural livelihoods and having a close migrant relative are associated with migration in response to extreme weather. Findings reveal that dry spells are most consistently associated with increased migration, although we see some evidence that first trips also increase after warm spells and above average rainfall. Associations between dry spells and warm spells are more pronounced among household heads with agricultural livelihoods. We find little evidence that having migrant relatives is associated with migration after extreme weather events, but some evidence that the presence of migrant networks at the community level is associated with international migration after an environmental shock.

Keywords Migration · Environment · Climate · Bangladesh · Livelihoods · Social Networks

Introduction

As the global climate changes in the twenty-first century, patterns of migration are also likely to shift (Hunter et al. 2015; IPCC 2014). When and why climate-related stressors influence migration is a matter of intense interest for researchers and policymakers (Black et al. 2011b; Gemenne 2011; Rigaud et al. 2018; Stapleton et al. 2017).

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Predictions of large-scale climate-induced migration range from tens of millions to over 1 billion (Christian Aid, 2007; Gemenne 2011; Jacobson, 1988; Myers, 2002). These forecasts have attracted much attention, in part, because migrations of this magnitude could have far-reaching social and political consequences. In reality, predictions are speculative and based on incomplete data (Gemenne 2011; Lilleør & Van den Broeck, 2011; Tacoli, 2009). Prior work suggests that environmental conditions can both trigger and inhibit migration (Findley 1994; Henry et al. 2004; Feng et al. 2010; Nawrotzki et al. 2013), but the conditions that govern these relationships are complex and not well understood.

In this paper, we use new migration history data collected from Bangladeshi households in 2014 to advance understanding of the relationship between environmental conditions and mobility. Extreme weather is likely to increase in intensity and duration as the climate changes (Mirza 2003). Our research examines the relationship between extreme rainfall and temperature and the likelihood of making a first internal or international migrant trip. We also consider two factors that may interact with environmental conditions to influence migration. Recognizing that the agricultural sector is particularly vulnerable to environmental shocks, we assess whether and how the relationship between extreme weather and migration varies between agricultural and non-agricultural households. In addition, because prior work suggests that having social ties to other migrants is a source of resilience but may also facilitate new migration trips, we consider whether having such ties is associated with the likelihood of making a first migrant trip for those who experience an environmental shock.

Theoretical framework

In much of the developing world, pursuing multiple and diverse livelihood strategies is essential to social and economic security. The Sustainable Livelihoods Framework (SLF) has been applied extensively to the context of smallholding agricultural communities (Adato et al. 2007; Bebbington 1999; Chambers 1997; Scoones 2009), and considers how households draw on several assets (i.e., capitals) to build livelihood strategies that can withstand external political, economic, and environmental changes (Bebbington 1999). The SLF is more holistic in its understanding of resilience and vulnerability than traditional approaches, and typically considers access to natural, physical, financial, human, and social capital. Drawing from this approach, livelihoods are dynamic, multifaceted, and often coordinated at the household rather than individual level.

Prior work finds that a household's or community's access to capital assets is important for the adoption of particular livelihood strategies (Adato et al. 2007; Bilsborrow 2002). For example, livelihood strategies often vary by season to compensate for intra-annual fluctuations in natural capital or to exploit particular forms of human capital (Ellis 2010; Marschke and Berkes 2006; Newton et al. 2012). Similarly, sending a migrant is an important strategy to diversify livelihoods in response to the local vulnerability context. In this analysis, we consider how the mobilization of social capital in the form of ties to other migrants offsets natural capital shocks. As discussed below, prior work suggests a strong link between social networks and migration—having ties to other migrants is an important factor that contributes to the decision to migrate (Fussell 2010; Lindstrom and Lauster 2001; Kuhn 2000, 2003; Massey and Riosmena 2010). Prior work has also established a link between migration and natural capital (i.e., favorable or unfavorable environmental conditions), although this relationship varies across contexts (Call et al. 2017; Hunter et al. 2015; Hunter et al. 2013a). Yet, relatively little work has empirically examined the intersection between natural and social capital in relation to migration (for exceptions, see Nawrotzki, Riosmena, & Hunter, 2013; Nawrotzki et al. 2015). We aim to fill this gap for the case of Bangladesh.

Meteorological conditions and migration

In this study, we focus on environmental shocks that stem from extreme weather events. The association between meteorological conditions and migration has received increased attention in recent years. Findings suggest that this association varies geographically and across household and community contexts (Black et al. 2011a; Gray and Wise 2016; Hunter et al. 2015). Nonetheless, some patterns have emerged. Studies show that, compared to labor migration, environmentally induced migration often takes the form of short-distance internal trips (Findley 1994; Gray and Mueller 2012b; Henry et al. 2004). In addition, high temperatures are associated with an increase in outmigration across multiple contexts (e.g., Bohra-Mishra et al. 2014; Dillon et al. 2011; Mueller et al. 2014; Nawrotzki et al. 2015). To our knowledge, only one study examines the effect of temperature on migration in Bangladesh. Using high-frequency surveillance data, Call et al. (2017) find that, like in other parts of the world, high temperatures are associated with an increase in outmigration.

Studies that examine the effect of rainfall on migration report mixed results. In some cases, below average rainfall is associated with an increase in outmigration (Barrios et al. 2006; Nawrotzki et al. 2015); in others, it is associated with a decline (Call et al. 2017). Clearer patterns exist within national or regional contexts. For example, rainfall deficits in Mexico are associated with increased outmigration to the USA (Feng et al. 2010; Hunter et al. 2013a; Munshi 2003; Nawrotzki et al. 2013, 2015). In contrast, drought conditions in Africa suppress international trips (Findley 1994; Henry et al. 2004), but may increase short distance and temporary moves (Findley 1994; Gray and Mueller 2012a; Roncoli et al. 2001). In Asia, the patterns are less clear. In Pakistan and the Philippines, studies find no robust effects of precipitation on migration (Bohra-Mishra et al. 2014; Mueller et al. 2014). Bohra-Mishra et al. (2014) find a curvilinear relationship in Indonesia, such that migration increases during periods of abnormally low and high precipitation. On the other hand, Call et al. (2017) find the reverse pattern in Bangladesh; periods of abnormally high and low rainfall are associated with less migration in the two years following the event.

Although migration analyses routinely incorporate meteorological data, most consider the effects of mean temperature and total rainfall. Although these data are important to consider, extremes may affect human and natural systems more than averages (Alexander et al. 2006; Katz and Brown 1992; Meehl et al. 2000; Parmesan et al. 2000; Peterson and Manton 2008; Walther et al. 2002). For example, consecutive days of extreme heat have a more negative impact on human health than high-temperature days distributed throughout a month or year (Gasparrini and Armstrong 2012; Yin and Wang 2017). Several studies report a significant decline in crop yields for every day that the temperature exceeds a given threshold (Lobell et al. 2011; Schlenker and Roberts 2009). Extreme rainfall in the form of consecutive days with heavy or no rainfall can also lead to significant impacts. It is for these reasons that environmental scientists have urged for more research into the effects of extreme events on social and economic systems (Katz and Brown 1992; Meehl et al. 2000).

Agricultural livelihoods

There are some clear associations between meteorological conditions and migration, but less is known about the mechanisms involved. Scholars theorize that disruptions to agricultural livelihoods is a primary pathway (Cai et al. 2016; Feng and Oppenheimer 2012; Nawrotzki and Bakhtsiyarava 2017). As temperature or rainfall anomalies reduce yields, households use a variety of strategies to cope, including adopting alternative enterprises (i.e., fishing, foraging), selling assets, reducing consumption, or sending a household member to migrate (Habiba et al. 2012; Jülich 2011; Penning-Rowsell et al. 2013). Migration is often used as a last (or late) resort to cope with environmental shocks (Jülich 2011; Sakdapolrak et al. 2014), and when it is used it often takes the form of relatively short-distance and short-duration moves (Findley 1994; Gray and Mueller 2012b; Henry et al. 2004; Hunter et al. 2013a, 2013b). Consistent with the agricultural pathway explanation, prior work suggests that environmental shocks more strongly predict migration in regions more dependent on agriculture (Nawrotzki et al. 2015) or when a shock is experienced during a growing season (Nawrotzki and Bakhtsiyarava 2017). Similarly, Feng et al. (2010) found a direct relationship between crop yields and Mexico–US migration.

Nevertheless, more research is needed to understand when disruptions in agriculture lead to migration and for whom. Households not directly engaged in agriculture may be impacted if declines in agricultural production cause the price of food and fiber to rise or regional household expenditures to drop. Mueller et al. (2014) report that heat stress negatively affected both agricultural and non-agricultural incomes in Pakistan, although impacts to agricultural incomes were 2–3 times greater. Disruptions to agriculture may also undermine the resources needed to execute a migrant trip, therefore suppressing migration particularly among the poor and those most dependent on crop yields (Henry et al. 2004; Gray and Mueller 2012a, 2012b). Data that can connect a particular livelihood strategy to an individual's risk of migrating is needed to complement existing work that often relies on regional aggregate data.

Social ties

Migrant social ties constitute linkages with other individuals who have migrated to destinations outside of their community of origin. Prior work reveals strong empirical evidence that having social ties to other migrants is positively associated with rates of migration across the globe (Akcapar 2009; Alvarado and Massey 2010; Fussell 2010; Klvanova 2009; Korinek et al. 2005; Lindstrom and Lauster 2001; Massey and Espinosa 1997; Massey and Riosmena 2010; Takenaka and Pren 2010). Those with ties to family or friends with migration experience have the potential to access valuable information and assistance that can reduce the cost of migration and increase expected benefits (Curran, 2002). Yet, how social ties contribute to migration streams vary (Fussell 2010). For example, Curran and Rivero-Fuentes (2003) report that migrant networks are more important for international than internal migrant trips because international moves are more expensive and entail greater risk. Lindstrom and Lauster (2001) show that having social ties to current internal or international migrants positively influences that same type of migration.

Few studies consider how social ties affect out-migration as a means of coping with environmental shocks (Curran, 2002). Because social ties and exposure to some environmental shocks are independently associated with an increased propensity to migrate, it is theoretically intuitive that, after experiencing such a shock, those having social ties may be even more likely to migrate (i.e., an amplification effect, Nawrotzki et al. 2015). In other words, a loss of natural capital may provide an impetus to move in search of alternative livelihood strategies, whereas social ties offer important information and support to execute a move. Consistent with this hypothesis, Kartiki (2011) and Mallick and Vogt (2012) report that Bangladeshis often cited the presence of social ties outside of their village as the reason why they migrated after Cyclone Aila in 2009. On the other hand, Nawrotzki et al. (2015) theorized that social ties may also suppress the effects of environmental stress on migration. For example, access to remittances from a migrant with earnings insulated from environmental shocks in the origin community may compensate for abrupt losses of natural capital, therefore reducing migration (i.e., suppression effect). Households may also benefit from past remittances that are invested into assets to reduce vulnerability (Bohra-Mishra 2013; De Haas 2006; Kuhn 2006; Stark and Bloom 1985). Consistent with a suppression mechanism, Nawrotzki et al. (2015) demonstrated that extreme heat is less predictive of international migration when households have a prior history of sending migrants (i.e., last trips vs. first trips) and within communities with stronger migration networks.

The Bangladeshi context

As an environmentally vulnerable region of the world, Bangladesh is an important context to explore the relationship between the environment and migration. About 70% of the population lives in the low-lying Ganges–Brahmaputra delta and is regularly affected by flooding (Cash et al. 2013), erosion (Siddiqui 2003), and severe cyclones (MoEF 2009). Bangladesh's demography exacerbates these challenges. It is the 10th most densely populated country in the world and has high rates of poverty (World Bank 2017). Yet, Bangladesh is in a state of transition. Since 2010, its gross national income per capita has grown by an annual rate of at least 3% and the share of Gross Domestic Product (GDP) derived from agriculture has dropped to less than 15% (World Bank 2016). In tandem, life expectancy at birth has improved dramatically, and infant and under 5 mortality has strongly declined (World Bank 2017).

Since the early 2000s migration from Bangladesh to other parts of the world has also grown (Bangladesh Bureau of Statistics 2011; BMET 2018). In 2017 alone, more than one million Bangladeshis left for foreign employment (BMET 2018). Neighboring

India has historically been an important destination (Alam 2003; Donato et al. 2016), and reports suggest that unauthorized migration has increased in recent years. In response, India has strengthened its border control, leading to concern about human rights violations at the border (Ganguly and Alffram 2010). Furthermore, the international community has grown increasingly anxious that climate change will trigger an influx of environmentally induced migrants into India, which could have a destabilizing effect on the region (Alam 2003; Friedman 2009; Population Council 2010; Vijayaraghavan and Somani 2016)).

Although international migration is increasing, most Bangladeshis migrate to internal destinations. Donato et al. (2016) estimate that the cumulative chance that a man will make a first domestic migrant trip by age 44 is as much as four to seven times greater than the chance of making a first international trip. Seasonal and temporary internal migration is most common (Afsar 2003; Kuhn 2000). Call et al. (2017) report that 7% of household members in the Matlab region of Bangladesh participated in a temporary migrant trip between 1996 and 2003, and that most migrants reported taking one or two temporary trips with an average duration of 2 years. In addition, estimates suggest that internal migration rates have increased. Using national data, Afsar (2003) reports that the proportion of people who have migrated in their lifetime tripled from roughly 3% in 1974 to over 10% in 1991. Although migration among women is common, a majority of their moves are from rural to rural destinations for the purpose of marriage (Afsar 2003; Kuhn, 2005). Consistent with other areas of the world, labor migrants are disproportionately unmarried men between 15 and 35 who move temporarily (Afsar 2003; Call et al. 2017; Kuhn 2000, 2003, 2005).[1] Because most men assume the role of household head when they marry, unmarried men are 2–3 times more likely to migrate than married men (Kuhn 2005). Nevertheless, family migration is also common. Using data collected in the 1990s from Matlab, Kuhn (2000, 2005) finds that of the approximately 9% of married men who migrated, 55% moved with an immediate family member.

Prior work also suggests that social networks are important to facilitating migrant trips. Social contacts in the destination reduce the cost of moving by providing temporary shelter, financial assistance, and help finding work (Afsar 2000; Kuhn 2000, 2003). Afsar (1999, Alam 2003) estimates that three-quarters of rural-to-urban migrants secured their first job in a destination with assistance of a friend or family member. Kuhn (2003) found that close patrilineal relatives are especially important, but extended networks are also widely used. This is especially prevalent in origin communities with less overall migration experience.

Research objectives and hypotheses

The analyses presented below examine the extent to which extreme rainfall and temperature are associated with the likelihood that Bangladeshi men make a first internal or international migrant trip. We leverage daily temperature and rainfall data from a meteorological station in our study area to construct an historical record of four

[1] However, women make up an increasing share of labor migrants, largely due to emergence of the ready-made garment industry in Bangladesh in the 1980s (Ward et al. 2004).

indicators of extreme weather—warm spells, dry spells, wet spells, and intense precipitation. Drawing on the literature reviewed above, we predict the following:

> H1a: Extreme weather is positively related to the likelihood of making a first migrant trip.
> H1b: The relationship between temperature extremes and migration is stronger than that between precipitation extremes and migration.

We also theorize that agricultural livelihoods amplify the relationship between extreme weather and migration:

> H2: The positive association between extreme weather and migration is stronger for agricultural than for non-agricultural households.

We test two competing hypotheses about the relationship between extreme weather and migrant social ties. First, drawing on the idea that social ties lower costs and increase information and resources needed to execute a first trip (i.e., an amplification effect):

> H3a: We predict that the association between extreme weather and risk of making a first migrant trip is more positive among those with migrant social ties relative to those without.

Second, based on the idea that migrant social ties offer access to resources that support households and reduce the impetus to move (i.e., a suppression effect):

> H3b: We expect that the relationship between extreme weather and risk of making a first migrant trip is less positive among those with migrant social ties relative to those without.

Data and methods

We use data collected in 2014 from 1695 households in the southwest region of Bangladesh as part of the Bangladesh Environment and Migration Survey (BEMS). The BEMS collects detailed information about up to nine migration trips, including the first, last, and second-to-last to internal destinations, India,[2] and other international destinations. We collect information about the year, origin, destination, and duration of all trips. We use these data to estimate discrete-time event history models that assess relationships among extreme weather, livelihoods, and social ties in a given person-year and the risk of making a first internal or international (including India or other destinations) migration trip in the subsequent year. Following the recommendation of King and Skeldon (2010), we present and compare findings from separate models that predict internal and international moves.

[2] Given the high prevalence of migration to India, we collected migration histories for this destination separately from other international destinations.

Sampling The BEMS was carried out in nine *mouzas*—small rural administrative units that typically contain one to three villages varying in size from a few hundred to a few thousand households (see map in Fig. 1).[3] In each of the nine study sites, we conducted a complete census of all households and then randomly selected a sample of 200 (see the Appendix for a description of site selection procedures). Because two sites had populations less than 200, we enumerated all households in these locations. Consistent with other survey research in Bangladesh, we achieved a high response rate (99%) (Bangladesh Multiple Indicator Cluster Survey 2012–2013, 2015; Garcia-Moreno et al. 2006; NIPORT 2017). We replaced households that refused or were not available with a randomly selected alternate to meet our target sample size. To protect the confidentiality of respondents, we refer to study sites using the names of the *upazilas* (i.e., subdistrict) in which the mouzas are located.

Analytical sample We generated a discrete-time person-year file to assess patterns of mobility. We focus on male household heads because the sample size of female heads is too small to sustain an analysis of the type we present here. Furthermore, we focus only on first trips given prior work suggesting that environmental stress more strongly predicts migration for those with no prior migration experience (Nawrotzki et al. 2015).

The vast majority of domestic and international trips occurred between the ages of 11 and 44; therefore, we consider this subsample to be at risk of migration. Furthermore, we include only respondents born in one of the nine sites, and exclude those born elsewhere because they were not fully exposed to the extreme weather conditions in the models. We excluded two respondents who did not know the location of their birthplace, but reported migrating into the community. Another respondent did not know his birthplace, but because he indicated no migration experience, we assumed his birthplace was the origin community. Although our migration histories span from 1928 to 2014, we limit these analyses to 1973–2012, the time after which Bangladesh obtained independence until 2012, the period when daily meteorological data are available for the region. The criteria described above resulted in the exclusion of 195 female (11.5%) and 286 male (16.3%) respondents from our original sample of 1695 households.[4] This final analytical sample includes 26,129 person-years generated from 1214 respondents.

Variable definitions Similar to the Mexican Migration Project, we define a migrant trip as any trip outside of the upazila (subdistrict) during which the migrant set up a household in the destination for three months or longer.[5] A person-year received a 1

[3] The BEMS was part of a larger project that investigated coastal dynamics, environmental change, and migration in the low-lying southwestern region of Bangladesh, which was heavily affected by tidal processes (Auerbach et al. 2015). The BEMS is closely modeled on the sampling design and ethnosurvey used in the Mexican Migration Project (see http://mmp.opr.princeton.edu/).

[4] Of the 286 male household heads who were excluded, most (72.0%) were born outside of the study region, two (0.7%) assumed the role of household head after 2012, and another 78 (27.3%) completed a first trip before 1973.

[5] The average duration of trips for domestic moves was 3.3 years and, for international moves, 6.4 years.

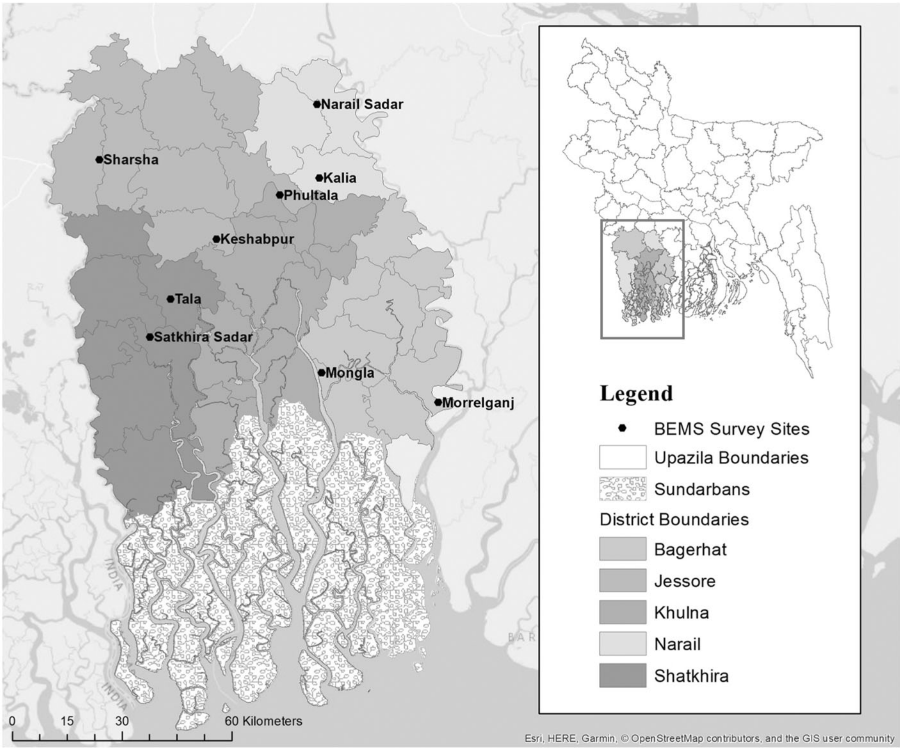

Fig. 1 Map of survey sites. Black circles indicate the location of each mouza. Labels represent the names of the upazilas in which the mouzas are located. Source: GADM (2018), Zhang et al. 2017

for an internal (or international) migrant trip if respondents made a trip in a given person-year, and 0 otherwise.

Upazilas are the second smallest administrative unit in Bangladesh and are roughly equivalent to US counties. There are 492 upazilas in the country, with an average size of approximately 300 km^2. We refer to the upazila boundary in our definition of a migration trip because it is a widely used geographic unit throughout the country and represents a relatively small area. This ensures that we accurately record the location of destinations and capture relatively short distance moves (Findley 1994; Henry et al. 2004; Gray and Mueller 2012a, 2012b).

To assess migrant social ties, we constructed two time-varying dichotomous variables that represent the presence of familial ties to one or more domestic (domestic ties) or international migrants (international ties) in a given person-year.[6] If siblings or parents of household heads migrated to an internal or international destination, respondents received a 1 for that person-year. If no parents or siblings migrated, respondents received a 0. In the analyses described below, we lag these variables by 1 year to ensure that the presence of social ties precedes a first migrant trip. However, similar to other measures of migrant social

[6] Although we wanted to construct a continuous measure of the number of family members who had migrated, we were unable to do so because it was rare to have more than one migrant in the household (1.9% of all person years). Thus, we use a dichotomous variable.

ties (e.g., Curran and Rivero-Fuentes 2003; Lindstrom and Lauster 2001), these two variables do not capture ties to migrants outside of one's immediate family, a point we raise in the discussion section below. We also include a dichotomous variable that represents whether household heads engaged in an agricultural livelihood (e.g., farmer, agricultural worker, raising livestock) in a given person-year. Because migration often corresponds to livelihood shifts, we lag this variable by one year. In addition, we include time-varying predictors that represent age and marriage of respondents in a given person-year, and a covariate indicating the household head's religion at the time of the survey. We also include a series of dummy variables that represent the head's origin community and fixed effects for year.

Extreme weather To assess extreme weather, we add to the BEMS four measures of temperature and rainfall extremes. Prior studies suggest that climate extremes may have more severe health and socioeconomic impacts than averages; however, many indicators of extreme weather require daily meteorological data that are difficult to access in much of the developing world. In these analyses, we leverage daily temperature and precipitation data from 1961 to 2012 recorded at a meteorological station in Jessore (Bangladesh Agricultural Research Council 2017), which is within a radius of approximately 100 km (~ 60 miles) of all BEMS study sites and the most complete historical record of meteorological data in the region. From these data, we derive four roughly orthogonal indicators[7] developed by the Expert Team on Climate Change Detection Indices (ETCCDI; Peterson and Manton 2008), and directly relevant to the tropical and agricultural context of Bangladesh (see Table 1 for definitions). These include the duration of warm spells (Warm Spell Duration Indicator, WSDI), dry spells (Consecutive Dry Days, CDD), wet spells (Consecutive Wet Days, CWD), and the intensity of rainfall (Simple Daily Intensity Index, SDII).

The ETCCDI calculations rely on daily precipitation and temperature data to generate annual indices. Some missing data can be tolerated, but annual values cannot be estimated if data are missing for more than 3 consecutive days within a month or more than 15 days in a year. Approximately 3–4% of daily observations were missing or flagged as errors on each of the three daily variables (daily precipitation, and minimum and maximum temperature), resulting in missing annual observations for 1978 and 1979. To recover the missing observations, we cannot use multivariate imputation approaches that rely on covariation between multiple vectors because the majority of missing daily observations occurred on all three variables simultaneously. We, therefore, used a seasonally decomposed missing value imputation (SEADEC) algorithm in the imputeTS package in *R* (Moritz and Bartz-Beielstein 2017) that leverages both seasonality and long-term trends for imputing time series data (Moritz and Bartz-Beielstein 2017; Moritz et al. 2015).[8] This imputed daily record generated a complete set of

[7] The zero-order correlations range from −0.02 to 0.19.

[8] We also considered a seasonally splitted missing value imputation algorithm (SEASPLIT), which produced nearly identical regression results as those reported below. We decided to use the SEADEC algorithm because it generated an imputed dataset with fewer outliers and best matched the seasonal and temporal trends within the raw data.

Table 1 Description of climate indicators used in analysis

Variable	Description
Warm spells	Warm Spell Duration Indicator (WSDI)—annual count of days during which 6 consecutive days exceeded the 90th percentile of temperature. A base period of 1961–1990 is used to determine the 90th percentile threshold.
Dry spells	Consecutive Dry Days (CDD)—maximum number of consecutive days within a year with less than 1 mm (mm) of rainfall.
Wet spells	Consecutive Wet Days (CWD)—maximum number of consecutive days within a year with more than 1 mm of rainfall.
Rainfall intensity	Simple Daily Intensity Index (SDII)—total precipitation divided by the number of wet days, in a year.

Values derived from daily precipitation and temperature data obtained from the Bangladesh Agricultural Research Council (2017), Jessore Station

annual WSDI, CDD, CWD, and SDII indices from 1973 to 2012. These four continuous extreme weather variables are lagged by 1 year, and standardized in the regression models below.

Findings

Table 2 presents descriptive statistics for all study variables (represented in person-years). Of the 26,129 person-years that refer to male household heads aged 11 to 44, approximately 1.3% had a first domestic trip and 0.4% had a first international trip. This corresponds to 29.4% of respondents making a first domestic trip and 8.9% making a first international trip. Most domestic moves were to urban centers (73.6%), and 62.0% of those moves were to the capital of Dhaka. Although the proportion of person-years with migrant trips is small, it is in line with other research from Bangladesh (Kuhn 2000) and reflects the fact that we capture migration only in a given year and then censor person-years that occur after a trip. Figure 2 describes trends in first domestic and international trips over time. For the former, the share grew from a low of 1.1% in 1973 to over 3% in 2010. The trend is relatively flat before the mid-1990s, but then rises rapidly over the last 20 years. The rate of international trips ranges from zero in 1973 to 0.9% in 1994 and declined thereafter, but since 2000 has remained fairly stable.

Figure 3 plots the four extreme weather indicators over time. Warm spells have increased sharply since the late 1990s. During 1972–1999, the duration of warm spells averaged 3.46 days; after 1999, the average was 18.75 days. Average durations for dry spells and wet spells have also increased somewhat since the late 1990s. From 2000 to 2011, the average duration of dry spells was 82.25 and wet spells was 12.92, up from 70.64 consecutive dry days and 10.04 consecutive wet days from 1972 to 1999. Although there is substantial year-to-year variability in intense precipitation, there are no detectable changes in these variables over time.

Table 2 Descriptive statistics of all model variables with person-year means and standard deviations (SDs)

Variable	Unit	Time-varying	Lag	Mean	SD
Dependent variables					
First domestic migrant trip	1/0	Yes[1]	No	0.013	0.113
First international migrant trip	1/0	Yes[1]	No	0.004	0.062
Predictor variables					
Climate variables[2]					
Warm spells (WSDI)	0–32	Yes	1 year	7.614	9.766
Dry spells (CDD)	32–135	Yes	1 year	72.472	27.418
Wet spells (CWD)	5–22	Yes	1 year	10.885	3.152
Rainfall intensity (SDII)	7.3–22.2	Yes	1 year	15.411	3.039
Social capital and livelihood variables					
Domestic migrant social ties	1/0	Yes	1 year	0.009	0.096
International migrant social ties	1/0	Yes	1 year	0.005	0.068
Employed in agriculture	1/0	Yes	1 year	0.362	0.480
Controls					
Age					
Under 15 (reference)	1/0	Yes	No	0.141	0.348
15–24	1/0	Yes	No	0.365	0.482
25–34	1/0	Yes	No	0.296	0.457
35–44	1/0	Yes	No	0.198	0.398
Married	1/0	Yes	No	0.532	0.499
Muslim	1/0	No	–	0.805	0.396
Year					
1973–1982 (reference)	1/0	Yes	No	0.184	0.387
1983–1992	1/0	Yes	No	0.278	0.448
1993–2002	1/0	Yes	No	0.314	0.464
2003–2012	1/0	Yes	No	0.224	0.417
Community					
Mongla	1/0	No	–	0.089	0.285
Keshabpur	1/0	No	–	0.155	0.362
Sharsha	1/0	No	–	0.098	0.297
Morrelganj	1/0	No	–	0.073	0.259
Tala	1/0	No	–	0.151	0.359
Satkhira Sadar	1/0	No	–	0.132	0.338
Narail Sadar	1/0	No	–	0.083	0.276
Kalia	1/0	No	–	0.145	0.352
Phultala	1/0	No	–	0.075	0.263
Person-years; respondents				26,129; 1214	

[1] Person-years that occur after the year of the first trip are removed from the analysis file

[2] Descriptive statistics using the raw distribution are presented here. The four extreme weather variables are standardized in all regression models

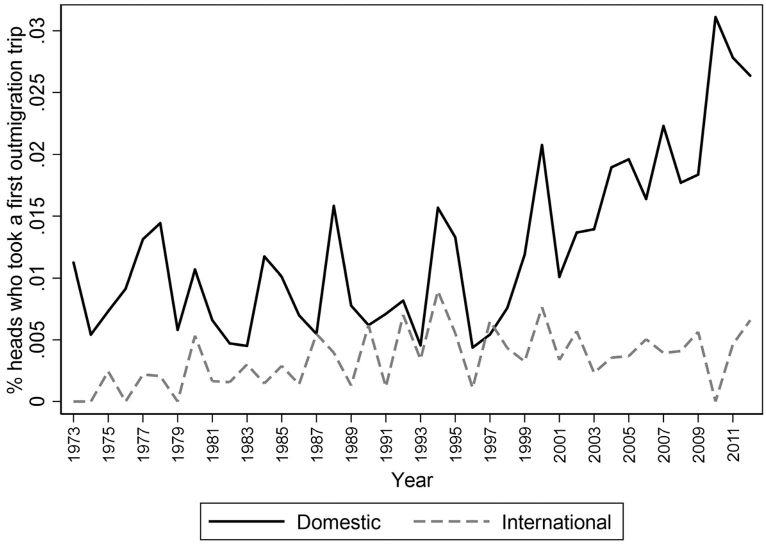

Fig. 2 Rate of household heads who took a first outmigration trip in given year

Likelihood of making a first domestic trip Table 3 presents results from multivariate discrete-time logistic regression models that estimate the likelihood of making a first domestic migrant trip in a given person-year.[9] Model A includes the demographic covariates, fixed effects for decade and community, and variables representing livelihood type and domestic social ties. Model B adds the extreme weather variables. Model C adds eight interaction terms: four interactions between having an agricultural livelihood and extreme weather and four between domestic social ties and extreme weather.

Model A reveals significant effects of several control variables. First, age significantly predicts making a first trip—the likelihood of migrating is nearly three to four times higher for those aged 15 to 34 relative to those under age 15, but the risk declines among those aged 35–44. Muslims are more than twice as likely to make a first domestic trip, and year covariates suggest that the rate of domestic migration grew from 1993 to 2012 relative to the reference period (1973–1982). Model A also suggests that the risk of domestic migration is lower for those engaged in agricultural livelihoods and higher for those with social ties to other migrants, but neither reached the conventional threshold for statistical significance (engaged in agriculture, $p = 0.358$; domestic social ties, $p = 0.127$).

Model B adds the main effects of lagged extreme weather. The four variables jointly explain a small but significant proportion of variance in the risk of domestic migration (Δchi-square [$\Delta\chi^2$] = 11.89, $p = 0.018$). Consistent with H1a, we find that three of the four extreme weather indicators are positively associated with making a first domestic trip. Dry spells are most strongly and reliably associated with migration; a one standard deviation increase in the duration of dry spells is associated with a 20% increased risk in the odds of making a first domestic trip. The odds ratios associated with warm and

[9] We also estimated multinomial models in which domestic and international trips are modeled as competing risks. These findings are presented in Table 5 of the Appendix.

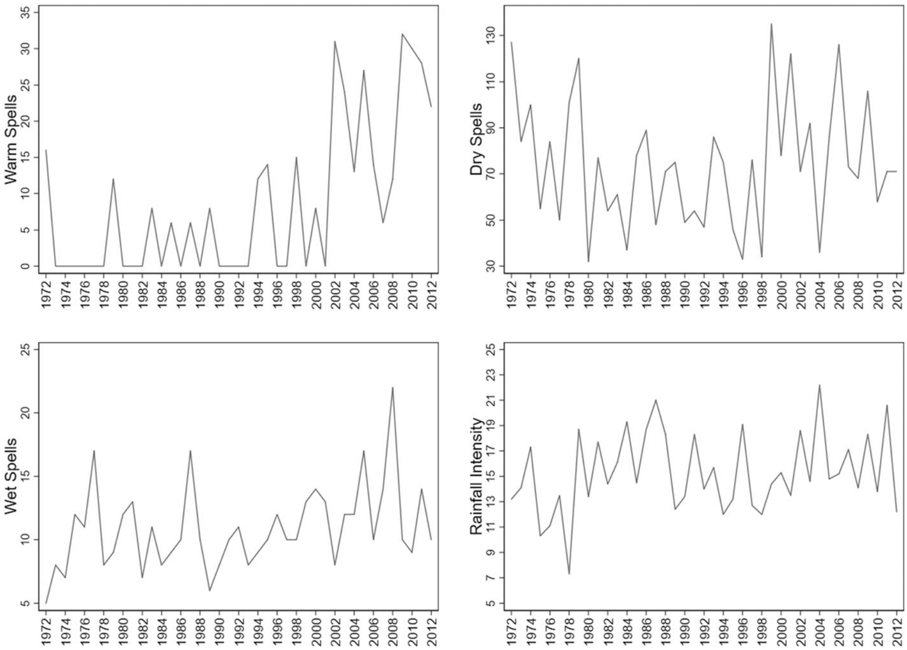

Fig. 3 Observed values of four ETCCDI indicators, 1972–2012

wet spells do not reach the conventional threshold for statistical significance (warm spells, $p = 0.169$, wet spells, $p = 0.062$), but the direction and magnitude of effects are consistent with that of dry spells. However, in contrast to H1b, we find no evidence that temperature extremes are more strongly related to migration than precipitation extremes.

Adding eight interaction terms in model C reveals that the variables are jointly significant. The four interactions with livelihood type jointly explain a greater proportion of variance ($\Delta\chi^2 = 16.26$, $p = 0.003$) than the four interactions with social ties ($\Delta\chi^2 = 8.45$, $p = 0.076$). Focusing first on the livelihood-extreme weather interactions, consistent with H3 we find positive and significant interactions for both warm spells and dry spells. We plot both interactions in Fig. 4 using the coefficients from model C to estimate the predicted probability of making a first domestic trip. The top panel reveals the relationship between livelihood type and warm spells. A one standard deviation increase in the duration of warm spells is associated with a 0.3% increase in the odds of making a first trip for those engaged in agriculture, but warm spells are unrelated to migration for those with other livelihoods. The lower panel of Fig. 4 shows a nearly identical, yet slightly stronger, pattern for dry spells. Again, for those not engaged in agriculture there is no relationship between dry spells and domestic moves. For agriculturalists, a one standard deviation increase in dry spells is associated with a 0.5% increase in the risk of making a domestic trip. Finally, model C in Table 3 reveals that although the interaction between precipitation intensity and livelihood is in the positive direction, it is not significant ($p = 0.381$).

Table 3 Logistic regression models predicting first domestic trip by male household heads

	Model A			Model B			Model C		
	OR		SE	OR		SE	OR		SE
Age (ref = under 15)									
15–24	4.044	***	1.144	3.965	***	1.120	4.162	***	1.170
25–34	2.976	**	0.937	2.923	**	0.920	3.090	***	0.971
35–44	1.446		0.498	1.411		0.485	1.483		0.510
Married	0.927		0.142	0.909		0.139	0.929		0.143
Muslim	2.101	**	0.450	2.092	**	0.449	2.068	**	0.444
Year (ref = 1973–1982)									
1983–1992	0.981		0.199	1.099		0.232	1.103		0.233
1993–2002	1.388	^	0.265	1.403	^	0.275	1.397	^	0.273
2003–2012	3.464	***	0.667	2.516	**	0.683	2.507	**	0.678
Community (ref = Phultala)									
Mongla	0.569		0.204	0.571		0.205	0.559		0.201
Keshabpur	1.027		0.270	1.036		0.273	0.990		0.261
Sharsha	0.632		0.188	0.637		0.190	0.625		0.186
Morrelganj	2.260	**	0.579	2.297	**	0.589	2.242	**	0.572
Tala	0.849		0.220	0.852		0.221	0.816		0.212
Satkhira Sadar	1.278		0.321	1.281		0.322	1.236		0.311
Narail Sadar	1.648	^	0.430	1.664	^	0.435	1.615	^	0.418
Kalia	0.683		0.186	0.689		0.188	0.663		0.180
Engaged in agriculture	0.895		0.108	0.895		0.108	0.752	*	0.102
Domestic migrant social ties	1.801		0.694	1.795		0.699	1.914		1.061
Extreme weather									
Warm spells (WSDI)				1.133		0.103	1.043		0.103
Dry spells (CDD)				1.196	**	0.072	1.072		0.079
Wet spells (CWD)				1.120	^	0.068	1.118		0.081
Intense precipitation (SDII)				1.060		0.071	1.032		0.083
Interaction terms									
WSDI*engaged in agriculture							1.258	*	0.137
CDD*engaged in agriculture							1.432	**	0.175
CWD*engaged in agriculture							1.005		0.109
SDII*engaged in agriculture							1.129		0.157
WSDI*social ties							0.880		0.304
CDD*social ties							0.474		0.271
CWD*social ties							1.212		0.436
SDII*social ties							0.522		0.236
Constant	0.002	***	0.001	0.002	***	0.001	0.002	***	0.001
Chi-square	202.26***			214.89***			249.04 ***		
Δchi-square				11.89*			21.88**		
Pseudo *R*-squared	0.061			0.064			0.070		
Person-years; respondents	26,129; 1214			26,129; 1214			26,129; 1214		

ΔChi-square tests the joint effect of the variables added to this model relative to the previous model. Statistical significance is based on *t*-tests where $^{\wedge}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, and $^{***}p < 0.001$. The four extreme weather variables are standardized

OR odds ratio, *SE* robust standard errors

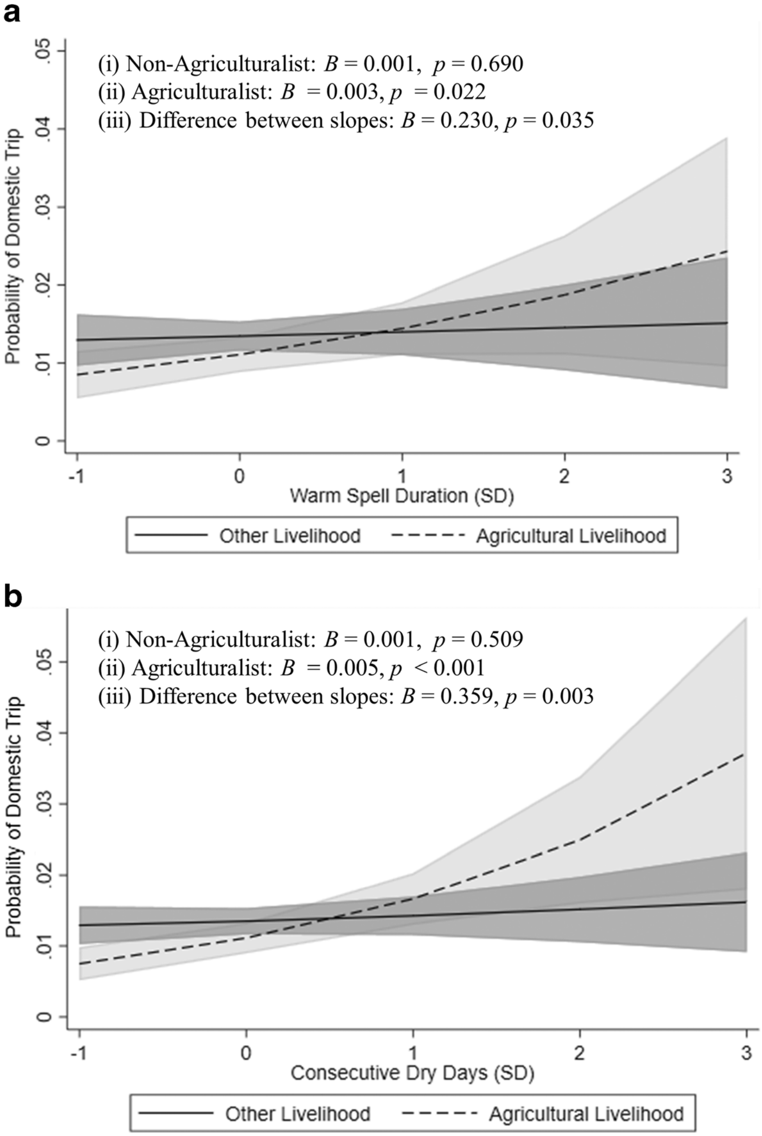

Fig. 4 Predicted probability of a first domestic trip as a function of livelihood and **a** warm spells or **b** dry spells (derived from Table 3, model C). Unstandardized coefficients associated with the simple slopes are denoted as *i* and *ii*. The associated *p* values reflect differences from zero. Line *iii* is the unstandardized coefficient associated with the interaction term; the *p* value reflects the difference between slopes

Turning to the interactions with domestic social ties in model C, we find little evidence that social ties amplify (H3a) or suppress (H3b) the relationship between extreme weather and migration. Three of the four odds ratios are below 1, suggesting that the risk of migration may be lower among those with domestic social ties. However, none reach the threshold for significance (warm spells, $p = 0.711$, dry spells, $p = 0.192$, and intense precipitation, $p = 0.151$). The remaining odds ratio (wet spells) is small and positive ($p = 0.593$).

Table 4 Logistic regression models predicting a first international trip in four communities where international migration is prevalent

	Model A			Model B			Model C		
	OR		SE	OR		SE	OR		SE
Age (ref = under 15)									
15–24	1.014		0.445	0.992		0.436	1.017		0.447
25–34	0.711		0.362	0.715		0.365	0.727		0.372
35–44	0.632		0.349	0.625		0.345	0.636		0.353
Married	2.286	*	0.764	2.216	*	0.738	2.250	*	0.748
Muslim	2.058		1.242	2.036		1.228	1.993		1.203
Year (ref = 1973–1982)									
1983–1992	2.301	^	1.085	2.240	^	1.096	2.266	^	1.115
1993–2002	4.370	***	1.939	4.826	***	2.105	4.881	***	2.148
2003–2012	4.152	**	1.927	4.606	*	2.903	4.712	*	3.009
Community (vs. Tala)									
Morrelganj	6.280	***	2.749	6.325	***	2.775	6.450	***	2.857
Satkhira Sadar	1.789		0.807	1.793		0.808	1.810		0.818
Kalia	4.356	***	1.802	4.369	***	1.809	4.427	***	1.843
Engaged in agriculture	0.560	*	0.137	0.556	*	0.137	0.584	*	0.149
International migrant social ties	3.668		3.007	3.651		3.108	3.749		3.166
Extreme weather									
Warm spells (WSDI)				0.853		0.154	0.749		0.146
Dry spells (CDD)				1.270	*	0.132	1.377	*	0.170
Wet spells (CWD)				0.979		0.136	0.943		0.158
Intense precipitation (SDII)				1.324	^	0.201	1.399	^	0.243
Interaction terms									
WSDI*engaged in agriculture							1.487		0.368
CDD*engaged in agriculture							0.753		0.172
CWD*engaged in agriculture							1.123		0.317
SDII*engaged in agriculture							0.835		0.236
Constant	0.000	***	0.000	0.000	***	0.000	0.000	***	0.000
Chi-square	74.57***			85.75***			93.47***		
ΔChi-square				8.03^			3.45		
Pseudo R-squared	0.079			0.088			0.092		
Person-years; respondents	13,073; 620			13,073; 620			13,073; 620		

ΔChi-square tests the joint effect of the variables added to this model relative to the previous model. Statistical significance is based on t-tests where $^{\wedge}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, and $^{***}p < 0.001$. The four extreme weather variables are standardized

OR odds ratio, *SE* robust standard errors

Likelihood of making a first international trip Table 4 summarizes results from regression models predicting a first international trip. The vast majority (86%) of international trips in the BEMS are made by household heads in four communities: Morrelganj, Tala, Satkhira Sadar, and Kalia. Household heads that report having international migrant social ties are also exclusively found in the same four communities.[10] Therefore, in Table 4 we constrain the analytic sample to household heads from these four locations, which permits us to examine the relationship between extreme weather and international moves in communities where international migration is prevalent. We adopt this approach because the very uneven distribution of international migrants across communities results in most of the variation being explained by community fixed effects. As a result, if we use the entire BEMS sample of communities, the models overfit the data. Thus, the results presented in this section do not generalize to all BEMS communities. (See Table 6 to view the regression results for the full sample.) In addition, because we observe a low rate of international migrant social ties in these data (0.5% of person-years), we have also omitted interactions between having social ties and extreme weather and focus instead on the direct effects of having migrant social ties.[11]

Model A in Table 4 shows no significant correlation between age and the risk of making a first international trip. Married men are more than twice as likely as unmarried men to migrate, and the year fixed effects reveal that first international trips have increased in recent decades. Model A also reveals that, net of other factors, those engaged in agriculture are between 40 and 50% less likely to make a first international trip compared to those in other sectors. Finally, the odds ratio associated with having familial ties to an international migrant is large and positive but not statistically significant.

Model B adds the four extreme weather variables. Consistent with H1a, we see evidence that dry spells and intense precipitation are positively associated with the risk of making a first international trip. Similar to domestic trips, the effect of dry spells is most robust. A one standard deviation increase in the duration of dry spells is associated with a 27% increase in the probability of making a first international move. In addition, although the odds ratio associated with intense precipitation is only marginally significant ($p = 0.065$), the direction and magnitude is nearly equivalent to that of dry spells. However, this pattern does not hold for warm spells and wet spells; both are slightly negative and not significant (p values: warm spells = 0.378, wet spells = 0.878). Therefore, again, we find no support for H1b that associations between temperature and migration are stronger than rainfall and migration.

Results presented in model C reveal no clear support for H2, that agricultural livelihoods strengthen the relationship between extreme weather and international migration. The joint effect of the four interactions explains a small and non-significant proportion of variance in international migration, and the pattern across interaction terms is mixed. However, the interaction between livelihood type and warm spells is strong and positive ($p = 0.108$) suggesting that, like domestic migration, longer warm spells may be associated with an increased propensity for those engaged in agriculture to move. Finally, when comparing

[10] The distribution of migrant social ties is roughly equivalent across the four communities; mean person-years with social ties are 0.018, 0.012, 0.019, and 0.010 for Morrelganj, Tala, Satkhira Sadar, and Kalia, respectively. Mean person years with a first international trip for the same communities are 0.015, 0.002, 0.004, and 0.011.

[11] We included these interactions in a preliminary model; however, the standard errors associated with the interactions are very large making interpretation difficult.

the results from Table 4 to those from the full sample in Table 6, we can see that the odds ratios associated with extreme weather, livelihoods, and social ties are largely consistent. Thus, when we limit the sample to locations with international migration, the joint effect of the four extreme weather variables is stronger, which is primarily driven by the effects of dry spells and intense precipitation.

Discussion

In this paper, we examine the relationship between extreme weather and the risk of making a first domestic or international trip, paying special attention to how agricultural livelihoods and social ties to other migrants interact with environmental conditions. Consistent with the sustainable livelihoods framework, we conceptualize migration as an important livelihood strategy that households may draw on to cope with disruptions associated with extreme weather. These findings provide several insights that advance our understanding of the environment–migration association, and point to fruitful avenues for future research.

We predicted that, net of other factors, extreme weather would be positively associated with an increased risk of making a first trip (H1a). For both domestic and international moves, we consistently find that dry spells are associated with increased migration of male household heads. Findings associated with heavy rainfall are less robust, although we see some evidence that domestic and international trips also increase in the year after an extended wet spell (as with domestic trips) or intense precipitation (as with international trips in a subset of communities). These findings add to an existing literature that has generated inconsistent results regarding the relationship between rainfall and migration (e.g., Barrios et al. 2006; Bohra-Mishra et al. 2016; Call et al. 2017; Mueller et al. 2014; Nawrotzki et al. 2015). Yet, relatively few studies have examined rainfall extremes rather than or in addition to total precipitation. That we find migration increases after periods with abnormally high and low rainfall may suggest a curvilinear relationship (see Bohra-Mishra et al. 2014).

We find no support in this context for the hypothesis (H1b) that warm spells are more strongly related to migration than precipitation. Rather, these data suggest that the relationship between extreme heat and migration is largely a function of livelihood type. This is most evident for domestic migration, where we find that the risk of making a first migrant trip rises after warm spells, but only for those employed in the agricultural sector. We observe a nearly identical pattern for international migration, although the reliability of this relationship is less certain and should be explored in future work. The importance of agriculture is also evident in the association between dry spells and domestic migration, where we find that agriculturalists are 40% more likely to migrate after a dry spell relative to their peers engaged in other livelihoods.

In sum, these data contribute to growing evidence of at least a partial “agricultural pathway” (Call et al. 2017; Nawrotzki et al. 2015), in which environmental shocks influence migration through disruptions to agricultural livelihoods. That extreme heat and rainfall deficits (relative to wet spells and intense precipitation) are the most clearly associated with this pathway is intuitive. Prior evidence suggests that crop yields in Bangladesh and Eastern India are more sensitive to temperature than precipitation (Basak et al. 2010; Karim et al. 1996; Krishnan et al. 2007; Lobell and Burke 2008; Pathak et al. 2003; Sarker et al. 2012). In addition, drought more so than flooding is associated with crop failures and widespread losses in agricultural production (Sarker et al. 2012; Shahid and Behrawan 2008). Therefore, our findings are consistent with the theory that environmental shocks to agriculture stimulate migration as a means of diversifying livelihoods to offset economic losses (Cai et al. 2016; Feng and Oppenheimer 2012; Nawrotzki and Bakhtsiyarava 2017; Jülich 2011; Sakdapolrak et al. 2014).

These data also raise unanswered questions about when and why heavy rainfall influences migration. As noted above, the associations between above average rainfall and domestic or international migration are weaker and less robust than associations with heat and rainfall deficits. Nevertheless, we see some indication that wet spells and intense precipitation are associated with internal and international migration. Moreover, these trends appear unrelated to whether a household is engaged in agriculture. Although rice crops are most sensitive to hot and dry conditions, Zhu and Troy (2018) find that yields also negatively correlate with wet spells and intense precipitation. Yet, the mechanisms by which these shocks relate to migration appear different than for heat and drought. In Bangladesh, Gray and Mueller (2012a) find evidence that floods are minimally related to population mobility but when migration does occur, it tends to be among the poor. One possibility is that the worst impacts of heavy rainfall are concentrated among households living in or farming land more prone to flooding or water logging, whereas impacts of heat and drought are more widespread.

Hypotheses 3a and 3b tested competing predictions regarding whether social ties amplify or suppress the relationship between environmental stress and migration. Within the context of domestic trips, we find little evidence to support either H3a (amplification) or H3b (suppression). Like Nawrotzki et al. (2015), the prevailing trend is one of suppression—the direction of effects suggests that those with social ties to other domestic migrants may be less likely to move after a warm spell, dry spell, or year of intense precipitation. However, wet spells trended in the other direction, and none of the interactions were statistically significant. In short, these findings suggest that social ties as measured by having a parent or sibling that has migrated internally is—at best—weakly associated with first domestic trips irrespective of the presence of environmental shocks.

Although we are unable to explore interactions between having international social ties and extreme weather, these analyses provide some evidence of the importance of migrant networks. We find that the vast majority of international migrants and all respondents with international migrant social ties come from four communities. When we compare results from this subset with the full sample, several interesting patterns emerge. First, we find no robust relationship between having familial ties to an international migrant and making a first trip. However, that international migrants and social ties are clustered in a subset of communities suggests that living in a place with a history of international migration may be more important to the odds of making a first trip than having a migrant relative. In fact, prior studies report that both strong and weak social ties to other migrants are important to facilitating new migrant trips (Dolfin and Genicot 2010; Kuhn 2003; McKenzie and Rapoport 2007; Munshi 2003; Orrenius and Zavodny 2005). In some contexts, community-level networks are more pivotal to facilitating a new migrant trip than close personal relationships (Wilson 1998; Winters et al. 2001).

Furthermore, we find that in locations where international migrant networks exist, relationships between extreme weather and making a first international trip strengthen. This offers some suggestive evidence that migrant networks may facilitate the use of international migration after extreme weather events. We caution readers to remember that this finding derives from models that include only those communities where international migration is most prevalent. Nevertheless, it offers some evidence that men are making a first international trip as a response to extreme weather. Because having a parent or sibling that has migrated in this sample is rare, we are also limited in our ability to precisely assess the role of familial ties. We encourage more research that examines this association and also considers whether and how access to broader migrant networks represent a pathway to environmentally induced migration.

We caution readers to keep in mind several other limitations of this study. First, these data were collected in a small geographic area and, therefore, do not capture spatial variation in environmental conditions. Furthermore, international migration is relatively rare in this region of Bangladesh. As a result, our analyses of international trips are underpowered. In a newly funded project,[12] we are collecting comparable data in 20 new research sites across a wider geographic region that will permit us to capture considerably more spatial variability and migration histories. This new data collection effort collects more detailed information about migrant social ties, including matrilineal ties and having friends or extended relatives who have migrated. We will also collect retrospective information about the receipt of remittances, which we are unable to consider in this paper. With a wider set of communities, the new data will also permit us to explore the relative importance of community-level migrant networks vs. individual and household level social ties.

Second, although the BEMS methodology generates a rich historical record of migration and livelihood activities, it has several weaknesses that should be addressed in future studies. Most importantly, the BEMS fails to capture entire households that have migrated from their origin communities and have not returned. As a consequence, we may be underestimating the rate of migration and failing to capture the attributes that lead to permanent outmigration (Hamilton and Savinar 2015). Although we cannot completely address this selection issue without panel data, our future work will improve our ability to assess differences between those households who no longer exist in origins vs. those who remain by tracking a small sample of households that have left.

[12] Socioecological System Dynamics Related to Livelihood, Human Migration, and Landscape Evolution (Grant # CNH-1716909)

Finally, because we capture information about migrant trips across more than 30 years, these data may be prone to recall error. More specifically, respondents may fail to recall information about past livelihood activities or migrant trips (including trips by relatives), resulting in measurement error on key variables. To gain some leverage on this issue, we performed a sensitivity analysis by re-estimating models after narrowing the window for observations from 1973 to 2012 to 1983–2012 and 1993–2012. The results are substantively the same as those presented here, providing some reassurance that recall error is not a major source of bias in these results.[13] Some respondents may also be reluctant to report unauthorized international trips, although prior work suggests that the ethnosurvey produces more accurate estimates of unauthorized migration than some other approaches (Massey 1987; Massey and Zenteno 2000). Despite these various concerns, past research finds that the ethnosurvey methodology when used in Mexico was accurate at capturing the characteristics of international migrants, despite errors in estimating the rate of migration across geographic regions (Massey and Capoferro 2004; Massey and Zenteno 2000).

Despite some limitations, the evidence presented in this paper advances our understanding of internal and international migration processes and adaptation to environmental stress in southwest Bangladesh. Dry spells are most clearly associated with increases in moves among male household heads, and associations of extreme heat and rainfall deficits with domestic migrations are moderated by agricultural livelihoods. In contrast, we find little evidence that having close migrant relatives is associated with migration after extreme weather events, but some evidence that the presence of migrant networks at the community level is associated with rates of international migration after an environmental shock. In our future work, we will further investigate these and other related questions with more robust data.

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Appendix

BEMS site selection

To select the nine BEMS research sites, we constructed a sampling frame of all mouzas in the five southwestern-most districts (Jessore, Narail, Satkhira, Khulna, and Bagerhat). We stratified the sampling frame by district to ensure variability in proximity to the Indian border (to the east) and to the coast (south), where there is greater exposure to salinity, storm surges, and cyclones. We also stratified by economic development using an index that sums the adult literacy rate and share of households with access to electricity in each mouza, using data from the Bangladesh census (Bangladesh Bureau of Statistics 2011). We then divided the sampling frame of mouzas

[13] Available from the authors on request.

into high and low economic development strata using a median split. Within each district, we selected one mouza from each stratum, resulting in two study sites in each of the five districts. We omitted one study site in Khulna District from this analysis because it was our pilot data collection site.

Table 5 Multinomial logistic regression models predicting first domestic or international trips by male household heads

	Model A				Model B			
	Domestic		International		Domestic		International	
	RRR	SE	RRR	SE	RRR	SE	RRR	SE
Age (ref = under 15)								
15–24	3.833 ***	1.084	1.186	0.469	4.043 ***	1.138	1.213	0.480
25–34	2.838 **	0.894	0.885	0.420	3.016 **	0.951	0.908	0.431
35–44	1.296	0.447	0.800	0.407	1.367	0.471	0.816	0.417
Married	0.921	0.142	1.798 ^	0.556	0.943	0.147	1.816 ^	0.562
Muslim	2.093 **	0.449	1.520	0.729	2.069 **	0.445	1.497	0.716
Year (ref = 1973–1979)								
1983–1992	1.110	0.239	1.810	0.797	1.119	0.241	1.830	0.808
1993–2002	1.408 ^	0.283	3.704 **	1.438	1.406 ^	0.282	3.735 **	1.452
2003–2012	2.475 **	0.694	3.311 *	1.944	2.472 **	0.692	3.303 *	1.955
Community (ref = Phultala)								
Mongla	0.594	0.214	1.142	1.597	0.580	0.209	1.126	1.578
Keshabpur	1.082	0.288	1.918	2.240	1.031	0.274	1.858	2.177
Sharsha	0.635	0.192	4.843	5.300	0.622	0.189	4.769	5.225
Morrelganj	2.330 **	0.607	37.186 **	38.593	2.269 **	0.588	36.874 **	38.304
Tala	0.888	0.233	5.397	5.801	0.848	0.222	5.230	5.642
Satkhira Sadar	1.335	0.340	9.701 *	10.253	1.286	0.327	9.468 *	10.022
Narail Sadar	1.708 *	0.453	3.036	3.505	1.652 ^	0.433	3.000	3.467
Kalia	0.725	0.199	24.862 **	25.424	0.695	0.190	24.398 **	24.992
Engaged in agriculture	0.893	0.108	0.555 *	0.128	0.756 *	0.103	0.551 *	0.133
Social ties	1.712	0.566	1.769	1.332	1.786	0.767	1.874	1.408
Warm spells (WSDI)	1.143	0.106	0.867	0.148	1.048	0.105	0.802	0.147
Dry spells (CDD)	1.204 **	0.073	1.193 ^	0.117	1.075	0.080	1.292 *	0.148
Wet spells (CWD)	1.123 ^	0.069	1.067	0.139	1.128 ^	0.082	1.003	0.160
Intense precipitation (SDII)	1.055	0.071	1.207	0.164	1.025	0.082	1.197	0.183
WSDI*engaged in agriculture					1.266 *	0.138	1.344	0.327
CDD*engaged in agriculture					1.441 **	0.178	0.742	0.165
CWD*engaged in agriculture					0.987	0.111	1.223	0.314

Table 5 (continued)

	Model A				Model B			
	Domestic		International		Domestic		International	
	RRR	SE	RRR	SE	RRR	SE	RRR	SE
SDII*engaged in agriculture					1.129	0.157	1.036	0.262
WSDI*social ties					0.902	0.303	0.687 ^	0.139
CDD*social ties					0.463	0.266	0.992	0.156
CWD*social ties					1.237	0.438	0.860	0.190
SDII*social ties					0.520	0.235	0.794	0.126
Constant	0.002 ***	0.001	0.000 ***	0.000	0.002 ***	0.001	0.000 ***	0.000
Chi-square	327.87***				447.00***			
ΔChi-square	18.55*				31.80*			
Pseudo R-squared	0.078				0.083			
	26,129; 1214				26,129; 1214			

ΔChi-square tests the joint effect of the four extreme weather variables in model A and the eight interaction effects in model B. Statistical significance is based on *t*-tests where $^{\wedge}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, and $^{***}p < 0.001$. The four extreme weather variables are standardized. The results associated with making a first domestic move presented in this table are nearly identical to those presented in Table 3. The results associated with first international moves in this table are most comparable to those presented in Table 6, which models the risk of a first international trip in the full sample. The primary substantive differences in these results have to do with the odds ratios associated with social ties. The social ties variable used in these models is a single variable that includes both social ties to domestic and international migrants. Due to the distribution of domestic vs. international social ties in these data, this variable captures substantially more domestic social ties than international. As a consequence, the relationship between social ties and international trips is weaker in these models than what is presented in Table 4 and the supplemental model in Table C

RRR relative risk ratio, *SE* robust standard errors

Table 6 Logistic regression models predicting a first international trip by male household heads in the full sample

	Model A			Model B			Model C		
	OR		SE	OR		SE	OR		SE
Age (ref = under 15)									
15–24	1.192		0.472	1.168		0.462	1.197		0.473
25–34	0.887		0.423	0.883		0.421	0.902		0.430
35–44	0.821		0.418	0.804		0.410	0.818		0.418
Married	1.863	*	0.580	1.821	*	0.566	1.844	*	0.573
Muslim	1.623		0.808	1.607		0.799	1.581		0.784
Year (ref = 1973–1982)									
1983–1992	1.961		0.809	1.925		0.849	1.957		0.869
1993–2002	3.737	**	1.432	3.917	***	1.514	3.972	***	1.539
2003–2012	3.178	**	1.300	3.505	*	2.008	3.532	*	2.039
Community (ref = Phultala)									
Mongla	1.179		1.648	1.181		1.651	1.163		1.629
Keshabpur	1.939		2.259	1.962		2.286	1.904		2.223
Sharsha	4.756		5.206	4.836		5.291	4.777		5.231
Morrelganj	34.768	**	36.039	35.513	**	36.863	35.183	**	36.550
Tala	5.329		5.727	5.393		5.797	5.242		5.654
Satkhira Sadar	9.484	*	10.024	9.602	*	10.151	9.442	*	9.991
Narail Sadar	2.961		3.415	3.000		3.464	2.956		3.415
Kalia	24.100	**	24.626	24.505	**	25.064	24.096	**	24.691
Engaged in agriculture	0.559	*	0.129	0.556	*	0.128	0.552	*	0.133
International migrant social ties	3.531		2.842	3.515		2.936	3.571		2.940
Extreme weather									
Warm spells (WSDI)				0.850		0.143	0.779		0.140
Dry spells (CDD)				1.177	^	0.115	1.274	*	0.144
Wet spells (CWD)				1.075		0.137	1.013		0.157
Intense precipitation (SDII)				1.206		0.166	1.194		0.185
Interaction terms									
WSDI*engaged in agriculture							1.351		0.331
CDD*engaged in agriculture							0.744		0.165
CWD*engaged in agriculture							1.208		0.302
SDII*engaged in agriculture							1.030		0.261
Constant	0.000	***	0.000	0.000	***	0.000	0.000	***	0.000
Chi-square	112.63***			118.86***			127.01***		
ΔChi-square				5.93			3.95		
Pseudo *R*-squared	0.109			0.114			0.118		
Person-years; respondents	26,129; 1214			26,129; 1214			26,129; 1214		

ΔChi-square tests the joint effect of the variables added to this model relative to the previous model. Statistical significance is based on *t*-tests where $^{\wedge}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, and $^{***}p < 0.001$. The four extreme weather variables are standardized

OR odds ratio, *SE* robust standard errors

References

Adato, M., Meinzen-Dick, R., Hazell, P., & Haddad, L. (2007). Integrating social and economic analyses to study impacts on livelihoods and poverty: Conceptual frameworks and research methods. In M. Adato & R. Meinzen-Dick (Eds.), *Agricultural research , livelihoods, and poverty: Studies of economic and social impacts in six countries* (pp. 20–55). Baltimore: Johns Hopkins University Press.

Afsar, R. (1999). Rural-urban dichotomy and convergence: Emerging realities in Bangladesh. *Environment and Urbanization, 11*(1), 235–246.

Afsar, R. (2000). *Rural urban migration in Bangladesh: Causes consequences and challenges.* Dhaka: University Press.

Afsar, R. (2003). Internal migration and the development nexus: The case of Bangladesh. Regional conference on migration, Development and Pro-Poor Policy Choices in Asia. https://assets.publishing.service.gov.uk/media/57a08d16e5274a31e0001632/WP-CP2.pdf.

Akcapar, S. K. (2009). Re-thinking migrants' networks and social capital: A case study of Iranians in Turkey. *International Migration, 48*(2). https://doi.org/10.1111/j.1468-2435.2009.00557.x.

Alam, S. (2003). Environmentally induced migration from Bangladesh to India. *Strategic Analysis, 27*(3), 422–438.

Alexander, L. V., Zhang, X., Peterson, T. C., et al. (2006). Global observed changes in daily climate extremes of temperature and precipitation. *Journal of Geophysical Research-Atmospheres, 111*(5), 1–22. https://doi.org/10.1029/2005JD006290.

Alvarado, S. E., & Massey, D. S. (2010). In search of peace: Structural adjustment, violence, and international migration. *The Annals of the American Academy of Political and Social Science, 630*(July), 137–161. https://doi.org/10.1177/0002716210368107.

Auerbach, L. W., Goodbred, S. L., Mondal, D. R., Wilson, C. A., Ahmed, K. R., Roy, K., … Ackerly, B. A. (2015). Flood risk of natural and embanked landscapes on the Ganges-Brahmaputra tidal delta plain. *Nature Climate Change, 5*(2), 153–157. https://doi.org/10.1038/nclimate2472.

Bangladesh Agricultural Research Council. (2017). Climatic Information Management System. Retrieved August 1, 2017 from http://climate.barcapps.gov.bd/index.php .

Bangladesh Bureau of Statistics. (2011). Population and housing census 2011: Socio-economic and demographic report. *National Series, Volume-4*. Dhaka. Retrieved from http://203.112.218.66/WebTestApplication/userfiles/Image/BBS/Socio_Economic.pdf.

Bangladesh Multiple Indicator Cluster Survey 2012-2013. (2015). United Nations Children Fund, Bangladesh Bureau of Statistics. https://file:/C:/Users/amca3032/Downloads/ddi-documentation-english_microdata-2533%20(1).pdf

Barrios, Bertinelli, & Strobl. (2006). Climatic change and rural-urban migration: The case of sub-Saharan Africa. *Journal of Urban Economics, 60*, 357–371.

Basak, J. K., Ali, M. A., & Islam, N. (2010). Assessment of the effect of climate change on boro rice production in Bangladesh using DSSAT model. *Journal of Civil Engineering (IEB), 38*(2), 95–108.

Bebbington, A. (1999). Capitals and capabilities, a framework for analyzing and rural livelihoods. *World Development, 27*(12), 2021–2044. https://doi.org/10.1016/S0305-750X(99)00104-7.

Bilsborrow, R. E. (2002). *Migration, population change, and the rural environment.* (Woodrow Wilson International Center for Scholars, Environmental Change and Security Project; ECSP Report No. Issue 8).

Black, R., Adger, W. N., Arnell, N. W., Dercon, S., Geddes, A., & Thomas, D. (2011a). The effect of environmental change on human migration. *Global Environmental Change-Human and Policy Dimensions, 21*, S3–S11. https://doi.org/10.1016/j.gloenvcha.2011.10.001.

Black, R., Stephen, R., Bennett, G., Thomas, S. M., & Beddington, J. R. (2011b). Migration as adaptation: Mobility can bring opportunities for coping with environmental change. *Nature, 478*, 447–449.

BMET. (2018). Overseas employment and remittances from 1976–2018. Dhaka. Retrieved May 25, 2018 from http://www.old.bmet.org.bd/BMET/stattisticalDataAction.

Bohra-Mishra, P. (2013). Labour migration and investments by remaining households in rural Nepal. *Journal of Population Research, 30*, 171–192.

Bohra-Mishra, P., Oppenheimer, M., & Hsiang, S. M. (2014). Nonlinear permanent migration response to climatic variations but minimal response to disasters. *Proceedings of the National Academy of Sciences, 111(27),* 9780-9785.https://doi.org/10.1073/pnas.1317166111 .

Bohra-Mishra, P., Oppenheimer, M., Cai, R., Feng, S., & Licker, R. (2016). Climate variability and migration in the Philippines. *Population and Environment, 38*(3), 1–23. https://doi.org/10.1007/s11111-016-0263-x.

Cai, R., Feng, S., Oppenheimer, M., & Pytlikova, M. (2016). Climate variability and international migration: The importance of the agricultural linkage. *Journal of Environmental Economics and Management, 79*, 135–151. https://doi.org/10.1016/j.jeem.2016.06.005.

Call, M. A., Gray, C., Yunus, M., & Emch, M. (2017). Disruption, not displacement: Environmental variability and temporary migration in Bangladesh. *Global Environmental Change, 46*(August), 157–165. https://doi.org/10.1016/j.gloenvcha.2017.08.008.

Cash, R. A., Halder, S. R., Husain, M., Islam, M. S., Mallick, F. H., May, M. A., et al. (2013). Reducing the health effect of natural hazards in Bangladesh. *Lancet, 382*(9910), 2094–2103. https://doi.org/10.1016/S0140-6736(13)61948-0.

Chambers, R. (1997). *Whose reality counts? Putting the last first*. London: Intermediate Technology Publications.

Christian Aid. (2007). Human tide: The real migration crisis. https://www.christianaid.org.uk/sites/default/files/2017-08/human-tide-the-realmigration-crisis-may-2007.pdf.

Curran, S. (2002). Migration, Social Capital, and the Environment: Considering Migrant Selectivity and Networks in Relation to Coastal Ecosystems. *Population and Development Review, 28*, 89–125.

Curran, S. R., & Rivero-Fuentes, E. (2003). Engendering migrant networks: The case of Mexican migration. *Demography, 40*(2), 289–307.

De Haas, H. (2006). Migration, remittances and regional development in Southern Morocco. *Geoforum, 37*(4), 565–580. https://doi.org/10.1016/j.geoforum.2005.11.007.

Dillon, A., Mueller, V., & Salau, S. (2011). Migratory responses to agricultural risk in northern Nigeria. *American Journal of Agricultural Economics, 93*(4), 1048–1061. https://doi.org/10.1093/ajae/aar033.

Dolfin, S., & Genicot, G. (2010). What do networks do? The role of networks on migration and “coyote” use. *Review of Development Economics, 14*(2), 343–359.

Donato, K. M., Carrico, A. R., Sisk, B., & Piya, B. (2016). Migration, social capital, and the environment in Bangladesh. In *Population Association of America, Annual Meeting*. Washington D.C.

Ellis, F. (2010). The determinants of rural livelihood diversification in developing countries. *Journal of Agricultural Economics, 51*(2), 289–302. https://doi.org/10.1111/j.1477-9552.2000.tb01229.x.

Feng, S., & Oppenheimer, M. (2012). Applying statistical models to the climate-migration relationship. *Proceedings of the National Academy of Sciences, 109*(43), E2915–E2915. https://doi.org/10.1073/pnas.1212226109.

Feng, S., Krueger, A. B., & Oppenheimer, M. (2010). Linkages among climate change, crop yields and Mexico-US cross-border migration. *Proceedings of the National Academy of Sciences, 107*(32), 14257–14262. https://doi.org/10.1073/pnas.1002632107.

Findley, S. E. (1994). Does drought increase migration? A study of migration from rural Mali during the 1983–1985 Drought. *International Migration Review, 28*(3), 539–553.

Friedman, L. (2009). Climate Change Makes Refugees in Bangladesh. Scientific American. Retrieved from https://www.scientificamerican.com/article/climate-change-refugees-bangladesh/.

Fussell, E. (2010). The cumulative causation of international migration in Latin America. *The Annals of the American Academy of Political and Social Science, 630*(July), 162–177. https://doi.org/10.1177/0002716210368108.

GADM. (2018). GADM database of Global Administrative Areas, version 3.6. www.gadm.org.

Ganguly M, Alffram H (2010) Trigger happy: Excessive use of force by Indian troops at the Bangladesh border. New York. https://www.hrw.org/sites/default/files/reports/bangladesh1210Web.pdf.

Garcia-Moreno, C., Jansen, H. A., Ellsberg, M., Heise, L., & Watts, C. H. (2006). Prevalence of intimate partner violence: Findings from the WHO multi-country study on women’s health and domestic violence. *Lancet, 368*, 1260–1269. https://doi.org/10.1016/S0140-6736(06)69523-8.

Gasparrini, A., & Armstrong, B. (2012). UKPMC Funders Group: The impact of heat waves on mortality. *Epidemiology, 22*(1), 68–73. https://doi.org/10.1097/EDE.0b013e3181fdcd99.The.

Gemenne, F. (2011). Why the numbers don’t add up: A review of estimates and predictions of people displaced by environmental changes. *Global Environmental Change-Human and Policy Dimensions, 21S*, S41–S49. https://doi.org/10.1016/j.gloenvcha.2011.09.005.

Gray, C., & Mueller, V. (2012a). Drought and population mobility in rural Ethiopia. *World Development, 40*(1), 134–145. https://doi.org/10.1016/j.worlddev.2011.05.023.

Gray, C., & Mueller, V. (2012b). Natural disasters and population mobility in Bangladesh. *Proceedings of the National Academy of Sciences, 109(16),* 6000-6005. https://doi.org/10.1073/pnas.1115944109 .

Gray, C., & Wise, E. (2016). Country-specific effects of climate variability on human migration. *Climatic Change*, 1–14. https://doi.org/10.1007/s10584-015-1592-y.

Habiba, U., Shaw, R., & Takeuchi, Y. (2012). Farmer's perception and adaptation practices to cope with drought: Perspectives from Northwestern Bangladesh. *International Journal of Disaster Risk Reduction, 1*(1), 72–84. https://doi.org/10.1016/j.ijdrr.2012.05.004 .

Hamilton, E. R., & Savinar, R. (2015). Two sources of error in data on migration from Mexico to the United States in Mexican household-based surveys. *Demography, 52*, 1345–1355. https://doi.org/10.1007/s13524-015-0409-y.

Henry, S., Schoumaker, B., & Beauchemin, C. (2004). The impact of rainfall on the first out-migration: A multi-level event-history analysis in Burkina Faso. *Population and Environment, 25*(5), 423–460.

Hunter, L. M., Murray, S., & Riosmena, F. (2013a). Rainfall patterns and U.S. migration from rural Mexico. *International Migration Review, 47*(4), 874–909. https://doi.org/10.1111/imre.12051.

Hunter, L. M., Nawrotzki, R. J., Leyk, S., Maclaurin, G. J., Twine, W., Collinson, M., & Erasmus, B. (2013b). Rural outmigration, natural capital, and livelihoods in South Africa. *Population, Space and Place, 20*(5), 402–420. https://doi.org/10.1002/psp.1776.

Hunter, L. M., Luna, J. K., & Norton, R. M. (2015). Environmental dimensions of migration. *Annual Review of Sociology, 41*, 377–397. https://doi.org/10.1146/annurev-soc-073014-112223.

IPCC. (2014). Summary for policymakers. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1–33). Cambridge and New York: Cambridge University Press. https://doi.org/10.1017/CBO9781107415324.

Jacobson, J. L. (1988). Environmental refugees: A yardstick of habitability. Worldwatch Paper 86. Washington, D.C. https://doi.org/10.1177/027046768800800304.

Jülich, S. (2011). Drought triggered temporary migration in an East Indian village. *International Migration, 49*, e189–e199.

Karim, Z., Hussain, S. G., & Ahmed, M. (1996). Assessing the impact of climatic variations on foodgrain production in Bangladesh. In L. Erda, W. C. Bolhofer, S. Huq, S. Lenhart, S. K. Mukherjee, J. B. Smith, & J. Wisniewski (Eds.), Climate change vulnerability and adaptation in Asia and the Pacific (pp. 53–62). Manila. Retrieved from https://link.springer.com/chapter/10.1007/978-94-017-1053-4_5.

Kartiki, K. (2011). Climate change and migration: A case study from rural Bangladesh. *Gender and Development, 19*(1), 23–38. https://doi.org/10.1080/13552074.2011.554017.

Katz, R. W., & Brown, B. G. (1992). Extreme events in a changing climate: Variability is more important than averages. *Climatic Change, 21*(3), 289–302. https://doi.org/10.1007/BF00139728.

King, R., & Skeldon, R. (2010). 'Mind the gap!' Integrating approaches to internal and international migration. *Journal of Ethnic and Migration Studies, 36*(10), 1619–1646.

Klvanova, R. (2009). Moving through social networks: The case of Armenian migrants in the Czech Republic. *International Migration, 48*(2), 104–132. https://doi.org/10.1111/j.1468-2435.2009.00565.x.

Korinek, K., Entwisle, B., & Jampaklay, A. (2005). Through thick and thin: Layers of social ties and urban settlement among Thai migrants. *American Sociological Review, 70*, 779–800.

Krishnan, P., Swain, D. K., Chandra Bhaskar, B., Nayak, S. K., & Dash, R. N. (2007). Impact of elevated CO2 and temperature on rice yield and methods of adaptation as evaluated by crop simulation studies. *Agriculture, Ecosystems and Environment, 122*(2), 233–242. https://doi.org/10.1016/j.agee.2007.01.019.

Kuhn, R. S. (2000). *The logic of letting go: Family and individual migration from Bangladesh* (RAND Labor and Population Program, Working Paper Series No. 0–9). Santa Monica, CA.

Kuhn, R. (2003). Identities in motion: Social exchange networks and rural-urban migration in Bangladesh. *Contributions to Indian Sociology, 37*(1–2), 311–337.

Kuhn, R. S. (2005). The determinants of family and individual migration: A case-study of rural Bangladesh. Working Paper, Institute of Behavioral Science.

Kuhn, R. (2006). The effects of fathers' and siblings' migration on children's pace of schooling in rural Bangladesh. *Asian Population Studies, 2*(1), 69–92.

Lilleør, H. B., & Van den Broeck, K. (2011). Economic drivers of migration and climate change in LDCs. *Global Environmental Change-Human and Policy Dimensions, 21S*, S70–S81. https://doi.org/10.1016/j.gloenvcha.2011.09.002.

Lindstrom, D. P., & Lauster, N. (2001). Local economic opportunity and the competing risks of internal and U.S. migration in Zacatecas, Mexico1. *International Migration Review, 35*(4), 1232–1256. https://doi.org/10.1111/j.1747-7379.2001.tb00059.x.

Lobell, D. B., & Burke, M. B. (2008). Why are agricultural impacts of climate change so uncertain? The importance of temperature relative to precipitation. *Environmental Research Letters, 3*(3), 1–8. https://doi.org/10.1088/1748-9326/3/3/034007.

Lobell, D. B., Bänziger, M., Magorokosho, C., & Vivek, B. (2011). Nonlinear heat effects on African maize as evidenced by historical yield trials. *Nature Climate Change, 1*(1), 42–45. https://doi.org/10.1038/nclimate1043.

Mallick, B., & Vogt, J. (2012). Cyclone, coastal society and migration: Empirical evidence from Bangladesh. *International Development Planning Review, 34*(3), 217–240. https://doi.org/10.3828/idpr.2012.16.

Marschke, M. J., & Berkes, F. (2006). Exploring strategies that build livelihood resilience: A case from Cambodia. *Ecology and Society, 11*(1), 42.

Massey, D. S. (1987). The Ethnosurvey in Theory and Practice. International Migration Review, Winter, 1498–1522.

Massey, D. S., & Capoferro, C. (2004). Measuring undocumented migration. *International Migration Review, 38*, 1075–1102. https://doi.org/10.1111/j.1747-7379.2004.tb00229.x.

Massey, D. S., & Espinosa, K. E. (1997). What's driving Mexico-U.S. migration? A theoretical, empirical, and policy analysis. *The American Journal of Sociology, 102*(4), 939–999.

Massey, D. S., & Riosmena, F. (2010). Undocumented migration from Latin America in an era of rising U.S. enforcement. *The Annals of the American Academy of Political and Social Science, 630*(July), 294–321. https://doi.org/10.1177/0002716210368114.

Massey, D. S., & Zenteno, R. (2000). A validation of the ethnosurvey: The case of Mexico-U.S. migration. *International Migration Review, 37*, 766–793.

McKenzie, D., & Rapoport, H. (2007). Network effects and the dynamics of migration and inequality: Theory and evidence from Mexico. *Journal of Development Economics, 84*(1), 1–24.

Meehl, G. A., Karl, T., Easterling, D. R., et al. (2000). An introduction to trends in extreme weather and climate events: Observations, socioeconomic impacts, terrestrial ecological impacts, and model projections. *Bulletin of the Americna Meteorological Society, 81*, 413–416. https://doi.org/10.1175/1520-0477(2000)081<0413:AITTIE>2.3.CO;2.

Mirza, M. (2003). Climate change and extreme weather events: Can developing countries adapt? *Climate Policy, 3*(3), 233–248. https://doi.org/10.3763/cpol.2003.0330.

MoEF. (2009). Bangladesh climate change strategy and action plan 2009. Dhaka. Retrieved from https://www.iucn.org/downloads/bangladesh_climate_change_strategy_and_action_plan_2009.pdf.

Moritz, S., & Bartz-Beielstein, T. (2017). ImputeTS: Time series missing value imputation in R. *The R Journal, 9*(1), 207–218.

Moritz, S., Sardá, A., Bartz-Beielstein, T., Zaefferer, M., & Stork, J. (2015). *Comparison of different methods for univariate time series imputation in R.*

Mueller, V., Gray, C., & Kosec, K. (2014). Heat stress increases long-term human migration in rural Pakistan. *Nature Climate Change, 4*(3), 182–185. https://doi.org/10.1038/nclimate2103.

Munshi, K. (2003). Networks in the modern economy: Mexican migrants in the U.S. Labor Market. *The Quarterly Journal of Economics, 118*(2), 549–599. https://doi.org/10.1162/003355303321675455.

Myers, N. (2002). Environmental refugees: A growing phenomenon of the 21st century. *Philosophical Transactions of the Royal Society B: Biological Sciences, 357*(1420), 609–613. https://doi.org/10.1098/rstb.2001.0953.

Nawrotzki, R. J., & Bakhtsiyarava, M. (2017). International climate migration: Evidence for the climate inhibitor mechanism and the agricultural pathway. *Population, Space and Place, 23*(4), e2033. https://doi.org/10.1002/psp.2033.

Nawrotzki, R. J., Riosmena, F., & Hunter, L. M. (2013). Do rainfall deficits predict U.S.-bound migration from rural Mexico? Evidence from the Mexican census. *Population Research and Policy Review, 32*(1), 129–158. https://doi.org/10.1007/s11113-012-9251-8.

Nawrotzki, R. J., Hunter, L. M., Runfola, D. M., & Riosmena, F. (2015). Climate change as a migration driver from rural and urban Mexico. *Environmental Research Letters, 10*(11), 114023. https://doi.org/10.1088/1748-9326/10/11/114023.

Newton, P., Endo, W., & Peres, C. A. (2012). Determinants of livelihood strategy variation in two extractive reserves in Amazonian flooded and unflooded forests. *Environmental Conservation, 39*(2), 97–110. https://doi.org/10.1017/S0376892911000580.

NIPORT. (2017). Bangladesh - Demographic and Health Survey 2014. Retrieved from http://microdata.worldbank.org/index.php/catalog/2562/sampling.

Orrenius, P. M., & Zavodny, M. (2005). Self-selection among undocumented immigrants from Mexico. *Journal of Development Economics, 78*(1), 215–240.

Parmesan, C., Root, T. L., & Willig, M. R. (2000). Impacts of extreme weather and climate on terrestiral biota. *Bulletin of the American Meteorological Society, 81*(3), 443–450. https://doi.org/10.1175/1520-0477(2000)081<0443.

Pathak, H., Ladha, J. K., Aggarwal, P. K., Peng, S., Das, S., Singh, Y., … Gupta, R. K. (2003). Trends of climatic potential and on-farm yields of rice and wheat in the Indo-Gangetic Plains. *Field Crops Research, 80*(3), 223–234. https://doi.org/10.1016/S0378-4290(02)00194-6.

Penning-Rowsell, E. C., Sultana, P., & Thompson, P. M. (2013). The 'last report'? Population movement in response to climate-related hazards in Bangladesh. *Environmental Science & Policy, 27S*, S44–S59.

Peterson, T. C., & Manton, M. J. (2008). Monitoring changes in climate extremes: A tale of international collaboration. *Bulletin of the American Meteorological Society, 89*(9), 1266–1271. https://doi.org/10.1175/2008BAMS2501.1.

Population Council. (2010). Effects of future climate change on cross-border migration in North Africa and India. *Population and Development Review, 36*(2), 408–412. https://doi.org/10.1111/j.1728-4457.2010.00338.x.

Rigaud, K. K., de Sherbinin, A., Jones, B., Bergmann, J., Clement, V., Ober, K., et al (2018). Groundswell: Preparing for internal climate migration. Washington D.C. Retrieved from https://openknowledge.worldbank.org/handle/10986/29461.

Roncoli, C., Ingram, K., Kirshen, P., & Res, C. (2001). The costs and risks of coping with drought: Livelihood impacts and farmers' responses in Burkina Faso. *Climate Research, 19*(2), 119–132. https://doi.org/10.3354/cr019119.

Sakdapolrak, P., Promburom, P., & Reif, A. (2014). Why successful in situ adaptation with environmental stress does not prevent people from migrating? Empirical evidence from Northern Thailand. *Climate and Development, 6*(1), 38–45.

Sarker, M. A. R., Alam, K., & Gow, J. (2012). Exploring the relationship between climate change and rice yield in Bangladesh: An analysis of time series data. *Agricultural Systems, 112*, 11–16. https://doi.org/10.1016/j.agsy.2012.06.004.

Schlenker, W., & Roberts, M. J. (2009). Nonlinear severe effects indicate temperature climate damages to US crop yields under change. *Proceedings of the National Academy of Sciences, 106*(37), 15594–15598.

Scoones, I. (2009). Livelihoods perspectives and rural development. *Journal of Peasant Studies, 36*(1), 171–196. https://doi.org/10.1080/03066150902820503.

Shahid, S., & Behrawan, H. (2008). Drought risk assessment in the western part of Bangladesh. *Natural Hazards, 46*(3), 391–413.

Siddiqui, T. (2003). Migration as a livelihood strategy of the poor: The Bangladesh case. In *Regional Conference on Migration,* Development and Pro-Poor Policy Choices in Asia.

Stapleton, S. O., Nadin, R., Watson, C., & Kellett, J. (2017). *Climate change, migration, and displacement: The need for a risk-informed and coherent approach*. https://doi.org/10.1002/9781444351071.

Stark, O., & Bloom, D. E. (1985). The new economics of labor migration. *The American Economic Review, 75*(2), 173–178. http://www.jstor.org/stable/1805591.

Tacoli, C. (2009). Crisis or adaptation? Migration and climate change in a context of high mobility. *Environment and Urbanization, 21*(2), 513–525. https://doi.org/10.1177/0956247809342182.

Takenaka, A., & Pren, K. A. (2010). Leaving to get ahead: Assessing the relationship between mobility and inequality in Peruvian migration. *Latin American Perspectives, 37*(174), 29–49. https://doi.org/10.1177/0094582X10379106.

Vijayaraghavan, H., & Somani, D. (2016). As climate change worsens, India must consider formulating policy on environmental Migration. The Wire. Retrieved from https://thewire.in/75688/environmental-migration-india-need-policy/

Walther, G.-R., Post, E., Convey, P., et al. (2002). Ecological responses to recent climate change. *Nature, 416*, 389–395. https://doi.org/10.1016/j.agwat.2008.09.024.

Ward, K., Rahman, F., Islam, A. K. M. S., Akhter, R., & Kamal, N. (2004). The effects of global ecobnomic restructing on urban women's work and income-generating strategies in Dhaka, Bangladesh. *Critical Sociology, 30*(1), 63–102.

Wilson, T. D. (1998). Weak ties, strong ties: Network principles in Mexican migration. *Human Organization, 57*(4), 394–403.

Winters, P., De Janvry, A., & Sadoulet, E. (2001). Family and community networks in Mexico-US migration. *The Journal of Human Resources, 36*(1), 159–184.

World Bank. (2016). Agriculture, value added (% of GDP). Retrieved November 11, 2017, from https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=BD .

World Bank. (2017). World Development Indicators database. Retrieved from http://databank.worldbank.org/data/Views/Reports/ReportWidgetCustom.aspx?Report_Name=CountryProfile&Id=b450fd57&tbar=y&dd=y&inf=n&zm=n&country=BGD.

Yin, Q., & Wang, J. (2017). The association between consecutive days' heat wave and cardiovascular disease mortality in Beijing, China. *BMC Public Health, 17*(1), 1–9. https://doi.org/10.1186/s12889-017-4129-7.

Zhang, H. Y., Niu, Z. G., & Liu, C. (2017). Sundarbans Wetland boundary data (Bangladesh). *Journal of Global Change Dat A& Discovery, 1*(3), 368.

Zhu, X., & Troy, T. J. (2018). Agriculturally relevant climate extremes and their trends in the world's major growing regions. *Earth's Future, 6*(4), 656–672. https://doi.org/10.1002/2017EF000687.