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Floods and maternal healthcare utilisation in Bangladesh

Hilde Orderud[1] · **Juho Härkönen**[1,2] · **Cathrine Tranberg Hårsaker**[3] · **Malin Bogren**[4]

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Abstract

Floods are a common natural hazard in Bangladesh, and climate change is expected to further increase flooding frequency, magnitude and extent. Pregnant women in flood contexts could face challenges in utilisation of maternal healthcare. The aim of this paper is to analyse associations between flood exposure and the use of maternal healthcare (antenatal care visits, birth assisted by skilled birth attendants, and giving birth in a health facility) in Bangladesh for pregnancies/births between 2004 and 2018. Bangladesh Demographic and Health Survey data from four surveys in the time period 2007–2018 and data on floods from the Emergency Events Database and the Geocoded Disasters Dataset are analysed using multilevel linear probability models. In line with previous results, we find clear bivariate associations between exposure to flooding and maternal healthcare use. These associations are largely confounded by socioeconomic and demographic variables. In general, exposure to flooding — whether measured as exposure to any floods or severe floods — does not affect maternal healthcare use, and we suggest that the lower usage of maternal healthcare in areas exposed to flooding rather relates to the characteristics of the flood-prone areas and their populations, which also relate to lower maternal healthcare use. However, we find negative associations in some supplementary analyses, which suggest that even if there is no effect of floods on average, specific floods may have negative effects on maternal healthcare use.

Keywords Maternal healthcare · Antenatal care · Delivery care · Flooding · Climate change · Bangladesh

✉ Hilde Orderud
hilde.orderud@eui.eu

1 Department of Political and Social Sciences, European University Institute, Via della Badia dei Roccettini 9, 50014 Fiesole FI, Florence, Italy

2 Department of Sociology, Stockholm University, Stockholm, Sweden

3 Norwegian Red Cross, Oslo, Norway

4 Institute of Health and Care Sciences, University of Gothenburg, Gothenburg, Sweden

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Introduction

Natural hazards are common throughout Asia and result in harmful and damaging consequences for people and property (CRED & UNDRR, 2020). Floods are the most common natural hazard-related disaster globally and a warmer climate is likely to increase the frequency, magnitude and extent of flooding (CRED & UNDRR, 2020; Mirza, 2011; Parvin et al., 2016). With a population of almost 165 million, densely populated Bangladesh is frequently affected by floods, and as much as 30 to 70% of the total land surface can be flooded in an average year (Dewan, 2015; Islam, 2013; Parvin et al., 2016; Rahman & Salehin, 2013). The impacts of flooding include loss of life, crops, properties, livelihoods, and infrastructure (Ahmed et al., 2019; Dewan, 2015; Islam, 2013; Parvin et al., 2016; Rahman & Salehin, 2013; Rentschler & Salhab, 2020).

Women and children can be especially vulnerable in disasters (Cutter, 2017; Juran & Trivedi, 2015; Sadia et al., 2016) and literature reviews have concluded that flooding is associated with compromised maternal and child health (Alderman et al., 2012; Mallett & Etzel, 2018; Partash et al., 2022). Despite some studies from low income country settings such as Bangladesh (Azad et al., 2013; Mallett & Etzel, 2018; Ahmed et al., 2019; Pinchoff et al., 2019), most research on the maternal and child health consequences of exposure to flooding has focused on contexts in wealthier countries, which are typically better prepared than poorer countries to face the consequences of flooding. Because of the high incidence of floods and disastrous events related to natural hazards in many low-income countries, which often are more vulnerable to their consequences, further research on their effects in these contexts remains a priority.

In this study, we analyse how flood exposure is associated with maternal healthcare utilisation in Bangladesh. We analyse both short-term (floods that took place during pregnancy) and long-term (up to five years) associations between floods and maternal healthcare usage, and distinguish between exposure to any floods and to severe ones. Maternal healthcare is critical for the health of pregnant women (Nove et al., 2021), and floods and related disasters can seriously disrupt access to and provision of antenatal, labour and post-partum care provided by midwives, nurses or physicians (Mallett & Etzel, 2018; Zahran et al., 2013). Disruptions to maternal healthcare usage may thus help us to understand the health consequences of flood exposure. Flooding can thus make Bangladeshi women, and especially pregnant women and their newborns, increasingly vulnerable (Islam, 2020; Naz & Saqib, 2021; Parvin et al., 2016; Pinchoff et al., 2019; Reggers, 2019) and create additional challenges in reaching the Sustainable Development Goal (SDG) 3 on health, and specifically a reduction in the maternal mortality to fewer than 70 per 100,000 by 2030 (WHO, 2019; UNFPA Bangladesh, 2020).

Previous studies from Bangladesh have highlighted worse maternal health outcomes and lower use of maternal healthcare services among women exposed to floods (Abdullah et al., 2019; Pinchoff et al., 2019; Baten et al., 2020; Haque et al., 2020). However, these studies have had their respective methodological limitations, and we aim to advance on this literature by using a multilevel design to analyse the effects of exposure to flooding on antenatal care (ANC) visits, births assisted by a skilled birth attendant (SBA) such as midwives, nurses and physicians, and giving birth in a health facility, both immediately after the flooding and in the following years. This design allows us to control for compositional differences between populations living in areas that differ by flooding exposure, as well as to make statistical inferences at the appropriate level of analysis. We use data on more than 19,000 births from the 2007, 2011, 2014 and 2017–18 Bangladesh Demographic and Health Surveys (DHS) combined with district-level data on floods from the Emergency Events Database (EM-DAT) and the Geocoded Disasters Dataset (GDIS).

Background

Women residing in areas exposed to flooding may show lower utilisation of maternal healthcare services due to immediate or mid-term consequences of the flooding, or because of the stable characteristics of areas prone to flooding and their populations.

As an immediate consequence, flooding can hamper access to maternal healthcare (Abdullah et al., 2019; Ray-Bennett et al., 2019; Baten et al., 2020; Haque et al., 2020; Loewen et al., 2021). Flooding can lead to restricted access to qualified healthcare professionals, to broken referral networks due to damaged transport infrastructures, as well as to limited access to adequate water and nutrition (Abdullah et al., 2019; Bukhari & Rizvi, 2015; Mallett & Etzel, 2018). The healthcare infrastructure may be flooded or damaged, health practitioners might struggle to access their workplaces, and necessary medical supply deliveries may be hindered or delayed due to damaged transport infrastructures. Households affected by flooding may also prioritise ensuring sufficient water and food supplies, and consequently have fewer resources to draw on in order to access and use recommended maternal healthcare.

Flooding can also have mid-term effects that persist after the immediate flooding. For example, Baten and colleagues (2020) concluded that women exposed to Bangladeshi floods between 2011 and 2014 displayed lower usage of maternal healthcare beyond the immediate period after the floods, and another report (NAWG Bangladesh, 2020) described normal recovery cycles of three to five years. Flood damage contributes to disruption of agriculture, infrastructure, employment, and food distribution systems (Islam, 2013; Parvin et al., 2016), and people whose lives and livelihoods depend directly or indirectly on land and water are especially vulnerable in these situations (Parvin et al., 2016). Living in affected areas can result in hunger and food crises, loss of income and occupation, and loss of productive assets (Parvin et al., 2016; Rosales-Rueda, 2018; Winsemius et al., 2018). Poor people are more likely to be negatively affected by disasters, and they often lose a larger proportion of their wealth, which consequently leads to poor people being less able to cope with and recover from disaster impacts (Hallegatte et al., 2020; Rahman & Salehin, 2013; Sengupta & Manik, 2020). Pregnant women suffering from poverty are less likely to utilise maternal healthcare services (Pathak et al., 2010; Nguyen et al., 2012; Pulok et al., 2018), and would consequently have even higher risk of maternal morbidity and mortality (Nove et al., 2021).

Finally, women residing in flood-prone areas may also utilise maternal healthcare less for reasons that do not result from the immediate or mid-term effects of floods on healthcare facilities and personnel, or livelihoods. Populations residing in flood-prone areas may differ from those in less flooded areas in their sociodemographic profiles, and families with more resources may locate to areas where the risk of flooding is lower (Rahman & Salehin, 2013; Hallegatte et al., 2018). Riverine flooding is the most common flood type in Bangladesh, which contributes to an increased vulnerability for rural populations in the agricultural sector (Rahman & Salehin, 2013; Huq et al., 2019). Also pointing to such stable features of some flood-prone areas, Abdullah and colleagues (2019) concluded in their qualitative investigation that a reason for the low level of maternal healthcare usage in Netrokona district in northern Bangladesh, which is flooded every year, was the lack of education and knowledge about maternal healthcare. As importantly, flood-prone areas often suffer from restricted accessibility and provision of maternal healthcare, such as transport difficulties (often by boat and/or food), longer distance to local healthcare facilities (increased travel costs), challenges to cover the cost for healthcare (especially for displaced populations), damaged and destroyed local health facilities, and lack of skilled healthcare professionals (Abdullah et al., 2019; Haque et al., 2019, 2020). In support of this proposition, there are reports of poor geographic targeting of public health resources in Bangladesh (Mani & Wang, 2014). Although access can be further limited during disaster periods, flood-prone areas may receive less investment in maternal healthcare facilities partly as a consequence of an underlying expectation that flooding will damage or disrupt such services.

Previous research on the effects of exposure to floods in the Bangladeshi context has been limited to a few studies, which have concluded that pregnant women exposed to flooding show lower usage of maternal healthcare (Abdullah et al., 2019; Baten et al., 2020; Haque et al., 2020). Abdullah and colleagues (2019), who conducted a qualitative study in Netrokona district, reported in-depth results of perceived reasons behind flood-related, low maternal healthcare usage in this district. Haque and colleagues (2020) focused on an important group of women impacted by climate related hazards such as floods, namely those who have been displaced as a consequence, and found lower levels of maternal healthcare usage among women recurrently displaced. While providing important results, their population-level generalisability may be limited due to a focus on a specific mechanism linking floods and maternal healthcare use (Haque et al., 2020) and a lack of a comparison group (Abdullah et al., 2019). Overcoming these limitations, Baten and colleagues (2020) estimated logistic regression models on maternal and newborn healthcare with 2014 Bangladeshi DHS which was matched to information on floods from the EM-DAT, thus with very similar data to ours, and reported associations between flood exposure — both in the short- and medium-term — and a range of maternal healthcare use outcomes. However, because they did not use multilevel models to estimate the association between (area-level) flooding and (individual-level) healthcare usage, their results may be subject to erroneous (Type I error) statistical inference. These results, and their potential limitations, warrant further analysis of whether flooding exposure impacts maternal healthcare usage in Bangladesh.

The setting: Bangladesh

Bangladesh is divided into eight divisions and 64 districts. The flat topography, heavy rainfall, geographical location, transboundary flows, and global warming, combined with the socioeconomic conditions, make the country and its population especially vulnerable to floods (Islam, 2013). The Bengal river delta combines waters of several rivers, primarily from the major rivers the Brahmaputra (known as the Jamuna in Bangladesh), the Ganges (known as the Padma in Bangladesh) and the Meghna (Rahman & Salehin, 2013). These rivers pass through multiple countries affected by southwest monsoon precipitation, which accounts for the majority of annual rainfall in the region (Mirza, 2011; Rahman & Salehin, 2013). With precipitation as an important contributor to floods in this region (Mirza, 2011; Rahman & Salehin, 2013), instances of excessive rainfall in these three river basins lead to riverine flooding when their capacity is exceeded (Rahman & Salehin, 2013). Riverine flooding is therefore the most common flood-type (Rahman & Salehin, 2013), and a possible change in monsoon precipitation, as a consequence of climate change, can therefore lead to increased flood-related disasters in Bangladesh (Mirza, 2011).

In addition to riverine flooding, manmade and natural features of Bangladesh's topography contribute to flood risk in certain other areas of the country. This includes the seasonally flooded, bowl-shaped floodplain depressions (so-called haors) located in the wetlands in the north-eastern part of the country (Rahman et al., 2018; Hoq et al., 2021), the hilly districts in the southeast where smaller streams flash flood during intense rainfall events (Adnan et al., 2019a; Sarker & Rashid, 2013), and the southwestern districts of Jessore and Sathkira, where damage to protective embankments has led to sustained water-logging of polders (low-lying land inside the embankment) (Nowreen et al., 2014; Adnan et al., 2019b).

Maternal healthcare is provided both by public and private actors. In the most recent DHS report (2020), 44% of the clusters had a government facility within their village and 9% had a private facility. Individual patients are often charged a small user fee to access public healthcare facilities, while relatively large costs are required to access maternal healthcare services from any private actor (Mahmood et al., 2019; Sarker et al., 2021). In 2016, a total of 43% of women received the complete continuum of maternal care (ANC, childbirth, and postnatal care from medically trained professionals) (NIPORT & ICF, 2019). Normal childbirth services are offered by 6 in 10 healthcare facilities, which is assessed according to a less restrictive and Bangladesh-context-appropriate version of the World Health Organization (WHO) measure of childbirth services, which include, e.g. trained staff and availability of medicines and commodities. Almost all Bangladeshi healthcare facilities offer ANC services. However, the quality of these services differs between the centres, with only 4% covering all six services recommended by the WHO (NIPORT & ICF, 2019). These maternal healthcare services are more likely to be given in urban than rural areas (NIPORT & ICF, 2020), whereas the most flood-vulnerable populations live in rural areas.

Data and analysis

Demographic and health surveys

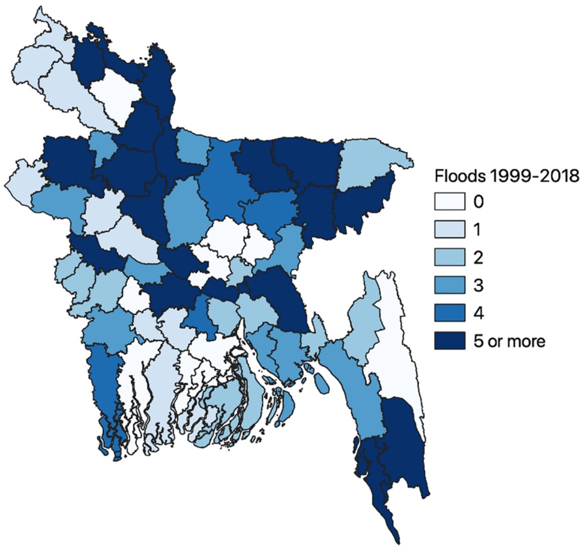
We used nationally representative data from Bangladesh DHS conducted in 2007, 2011, 2014, and 2017–18 to analyse maternal healthcare utilisation. DHS are cross-sectional household surveys, which collect accurate data on various indicators related to maternal and child health, among other information. The data used in this paper consist of information from ever-married women of reproductive age ranging from 15 to 49 years. Non-marital childbearing is rare in Bangladesh (DaVanzo et al., 2013), and is not likely to bias our results. The DHS provide information on ANC for women who had a live birth three years before the survey interview, while the variables on births assisted by SBA and births taking place in healthcare facilities include all births in the three years prior to the interview. We limited the sample to respondents with a valid response to all questions of the dependent variables, and in addition we excluded 87 respondents who did not provide information on the husband's occupation. Our sample covers 19,519 pregnancies/births occurring from 2004 to 2018.

DHS are collected using a two-stage cluster sampling procedure, whereby enumeration areas (EAs) (survey clusters) are selected in the first stage and a systematic sample of an average of 25–30 households per cluster is selected in the second stage (NIPORT & ICF, 2020). All ever-married women age 15–49 who are usual members of the selected households or who spent the night before the survey in the selected household are eligible to be interviewed. EAs cover the entire country and are based on a list prepared by the Bangladesh Bureau of Statistics from the 2001 and 2011 population censuses of the People's Republic of Bangladesh. In a rural area, a cluster can be an entire village, a part of a village or a group of small villages, while in urban areas a cluster is usually a city block (ICF International, 2012). The DHS datasets also contain geographic data on the clusters (Croft et al., 2018). Clusters are geomasked to protect the respondents' confidentiality. This implies that urban clusters are displaced by a distance of up to two kilometres and rural clusters are displaced by a distance of up to five kilometres, and additionally a randomly selected 1% of rural clusters are displaced by a distance of up to 10 km (Burgert et al., 2013). The file with the geocoded DHS clusters is prepared with the software QGIS and GADM maps (https://gadm.org/) to identify the 2,229 clusters according to the 64 districts in Bangladesh.

The emergency events database

Data on floods in Bangladesh were prepared with data from the EM-DAT (https://www.emdat.be/) and the GDIS (https://sedac.ciesin.columbia.edu/data/set/pend-gdis-1960-2018) (Rosvold & Buhaug, 2021). EM-DAT is a database on mass disasters f rom 1900 to the present, while GDIS is a geocoded extension of a selection of EM-DAT these disasters between 1960 and 2018. For disasters to be included in the EM-DAT database, at least one of the following criteria needs to be fulfilled: (1) death of 10

Fig. 1 Floods per district in Bangladesh 1999–2018



or more people, (2) 100 or more people affected/injured/homeless, or (3) declaration by the country of a state of emergency and/or an appeal for international assistance. The dataset, therefore, entails floods that have had a major impact on the population living in the affected districts.

A total of 233 district level floods between 1999 and 2018 were identified. Missing information on district level for floods already listed at the division level was identified in the dataset. The missing information was imputed based on information from secondary sources for floods in 2002, 2007 (June), 2007 (July), 2009, 2012, and 2015 (Appendix, Table 5). This resulted in 41 additional district flood specifications. A total of 274 district level floods were included in the analyses. Additionally, to assess the severity of each flood, we used estimates provided by EM-DAT of the number of people affected by each flood provided. In supplementary analyses, we also used estimates of the number of people who lost their lives due to the flood.

Figure 1 shows the number of floods for each district between 1999 and 2018.

Variables

We used four binary variables of maternal healthcare utilisation as our dependent variables. The first two dependent variables measured whether the woman had at least one ANC visit and four ANC visits, respectively. Attending ANC visits as recommended reduces maternal and perinatal morbidity and mortality through detection and treatment of pregnancy related complications, as well as through the promotion of health-seeking behaviour and birth preparedness (Nove et al., 2021; WHO, 2016). Four or more ANC visits were chosen based on the focused ANC model from the 1990s, despite the current recommendation of at least eight visits (WHO, 2016). Uptake of four ANC visits in Bangladesh has improved from 6% in 1993–94 to 47% in 2017–18, and the aim is to reach 50% coverage of at least four ANC visits

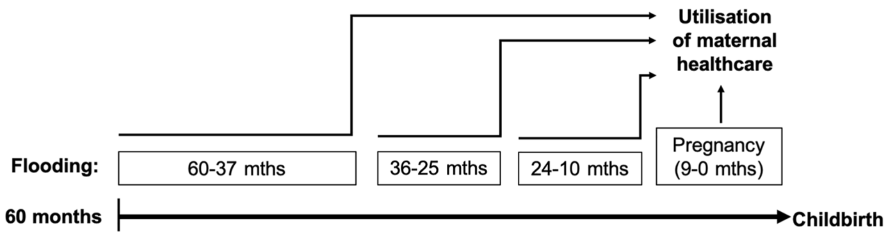


Fig. 2 Illustration of the time periods of flooding ranging from 60 months prior to childbirth to month of childbirth

by 2022 (NIPORT & ICF, 2020). Women receive most ANC visits (2017–18) from the private sector (64%), followed by public sector healthcare facilities or at home (36% each) and by nongovernmental organisations (9%) (women may visit more than one type of facility for ANC during the same pregnancy, so the facility categories are not mutually exclusive and do not total 100%) (NIPORT & ICF, 2020). There has been a 20% increase from 2014 (16%) to 2017–18 (36%) in the proportion of women receiving ANC at home (NIPORT & ICF, 2020). The other two dependent variables measured conditions around childbirth. We measured whether the birth was assisted by an SBA — a qualified doctor, nurse, midwife or paramedic (NIPORT & ICF, 2020) — and whether the birth took place in a healthcare facility. Paramedics[1] in the Bangladesh DHS dataset include family welfare visitors (FWVs), community skilled birth attendants (CSBAs), and sub-assistant community medical officers (SACMOs). Birth assistance by SBA in healthcare facilities reduces the risk of neonatal and maternal morbidity and mortality (Nove et al., 2021). The presence of an SBA during childbirth is crucial in reducing maternal and child deaths.

We combined the DHS data with the disaster data to identify women's exposure to flooding. We constructed two main measures. The first one measured exposure to all floods at the district level, using information on the year and month of childbirth reported by the women, as well as on her cluster and respective district of residence during the interview, and the year and month of each flood in each district. With this information, we created four dummy variables that measure flood exposure (a) during pregnancy (0–9 months prior to childbirth), (b) 10 to 24 months prior to childbirth, (c) 25 to 36 months prior to childbirth and (d) 37 to 60 months prior to childbirth (Fig. 2). These time periods are intended to capture the potential time-varying effects of floods on maternal healthcare utilisation. The second measure assessed exposure to severe floods, which we defined as floods that were estimated in the EM-DAT database to have affected over one million people. The database identified 11 such floods at country level. The severe flood measure was otherwise constructed

[1] FWVs have 18 months of training (after training entitled to provide routine antenatal, delivery, and postnatal care), CSBAs have 6 months of training, SACMOs have 4 years of education (3 years Medical Diploma and 12 months internship) and are all qualified to provide antenatal and delivery care (Chowdhury et al., 2010; Khan et al., 2018; Rawal et al., 2016; Ministry of Health and Family Welfare (MOHFW), 2018).

in the same way as the first measure, with four dummy variables across the same time periods. As supplementary measures, we identified severe floods as four floods (occurring in 2004, 2007, 2012 and 2017) that were estimated to have affected five million people or more, and floods due to which over 100 people died ($N=7$).

Control variables included the year of childbirth, age of the woman at childbirth, birth order, the place of residence (rural or urban), maternal education, and husband's occupation (agriculture/farming or other). These variables vary between the pregnancies of mothers living in the same cluster and district and with the exception of the three last ones, between pregnancies of the same mother. These variables were adjusted in order to control for different exposure to flooding as well as resources that may affect the responses to flooding. The variables were measured at time of interview and are used in the cross-sectional analyses. Descriptive information on the variables is shown in Table 1.

Statistical analysis

We estimated four-level multilevel linear probability models, in which pregnancies were nested within households, households within survey clusters, and survey clusters within districts. Linear probability models are linear regression models estimated on binary outcome variables, which estimate the effects of an independent variable on the outcome on the percentage point scale. We estimated linear probability rather than logistic regression models, because the former allows us to estimate marginal effects whereas estimates of the latter are group-specific and have a more complex interpretation (Rabe-Hesketh & Skrondal, 2012). Not accounting for the multilevel structure may lead to biased standard errors and erroneous inference. We estimated cluster robust standard errors at the district level. The random effects multilevel model is written as

$$y_{ijkl} = \alpha + \beta_1 \text{flooding}_l + \beta_2 X_{ijk} + \pi_l + \omega_{kl} + v_{jkl} + \varepsilon_{ijkl} \tag{1}$$

y_{ijkl} is the outcome for birth i in household j, cluster k and district l. flooding_l is the main independent variable (either measures as all floods or severe floods, as specified above), and X_{ijk} are the control variables. Finally, π_l captures the district level error term, ω_{kl} captures the cluster level error term, v_{jkl} captures the household level error, and ε_{ijkl} is the pregnancy level (residual) error term.

We also estimated models with fixed effects at the district level, to account for any unmeasured district level features (such as in economic development and government investment in maternal health care) that may also correlate with flooding exposure. Hausman tests, which compared estimates between the fixed and the random effects models, rejected for each outcome the hypothesis that the random effects estimates would have been biased due to unmeasured district level confounding. We therefore present results from the random effects models, which are statistically more efficient. Likewise, the results remained robust when including fixed effects at the survey cluster or household levels, as well as when using the number of floods experienced within the time unit. All analyses were conducted with the software Stata 16.1.

Table 1 Descriptive statistics of variables used in the analysis based on sample of children born 2004–2018 where a response to all survey questions on ANC visits, birth assisted by SBA and birth in a healthcare facility was given. Weights applied

Variable	Category	Mean
One ANC visit	1 ≥ ANC visits	0.75
Four or more ANC visits	4 ≥ ANC visits	0.32
Assisted by SBA	Yes	0.32
Birth location	Institutional delivery	0.35
Birth year of the child	Year	2011.1
Maternal age at childbirth	Years	23.4
Highest maternal educational level	No education	0.16
	Primary	0.29
	Secondary	0.44
	Higher:	0.11
Husband occupation	Farmer/Agriculture	0.22
Place of residence	Urban	0.25
Birth order	1	0.35
	2	0.30
	3	0.17
	4	0.17
Divisions	Barisal	0.06
	Chittagong	0.22
	Dhaka	0.33
	Khulna	0.09
	Rajshahi	0.12
	Rangpur	0.11
	Sylhet	0.08
Proportion one flood or more	0–9 mths, prior to childbirth	0.16
	10–24 mths. prior to childbirth	0.23
	25–36 mths. prior to childbirth	0.19
	37–60 mths. prior to childbirth	0.32
Proportion survey years	2007	0.14
	2011	0.37
	2014	0.23
	2017–18	0.25

Total sample without weights: 19,519

Sensitivity analysis

We performed four sensitivity analyses. First, we estimated the multilevel models on the original EM-DAT dataset without the imputed floods. Second, we estimated models which, instead of measuring exposure to floods at different time points prior to delivery, measured the cumulative number of floods during the five years preceding delivery. Third, we estimated the number of ANC visits as a count variable, using multilevel Poisson regression analysis. Finally, we investigated the possibility of biased results due to migration and displacement due to the flood exposure (e.g. Mallett & Etzel, 2018) by analysing the 2007 and 2017–18 survey data which contain questions about migration. In this sensitivity analysis, we included women from the 2007 survey and the 2017–18 survey who had lived eight years or more in the same place of residence, here understood as same division. A time period of eight years was chosen since maternal healthcare variables are asked for up to three years prior to interview, and the longest time period at flood exposure considered is five years prior to childbirth.

Ethical considerations

In this study, we analyse secondary data from DHS and EM-DAT. The data use is in line with the rules and regulations of the databases. Data from EM-DAT include aggregated data from country reports and do not contain any data on individuals. Questionnaires and procedures for the DHS surveys are reviewed and approved by the ICF Institutional Review Board (IRB) and a host country IRB. Informed consent is given by all participating respondents.

Results

Descriptive results

As Fig. 3 suggests, women living in areas that were flooded at least once use maternal healthcare less than women in non-flooded areas. The 95% confidence intervals do not overlap in any of the comparisons, indicating that these differences are statistically significant at the 5% level.

Maternal healthcare usage is clearly lower in areas that were exposed to floods compared to those that were not. Yet areas exposed to flooding differ also in other respects from non-exposed areas. Before we turn to our regression analysis, we provide descriptive information on the characteristics of areas by flood exposure in Table 2. The data show that flooded areas are likely to be rural with a large proportion of mothers with no education, husband's occupation in farming and agriculture, and households in the lowest wealth quintile.

Regression analysis

Table 3 shows results from multilevel linear probability models — where pregnancies/births are clustered within households, survey clusters and districts — on the conditional associations between flood exposure and maternal healthcare utilisation. Only one of the estimates of flood exposure is statistically significant at the 5% level: having been exposed to flooding 25–36 months prior to birth is associated with a 2.1 percentage point

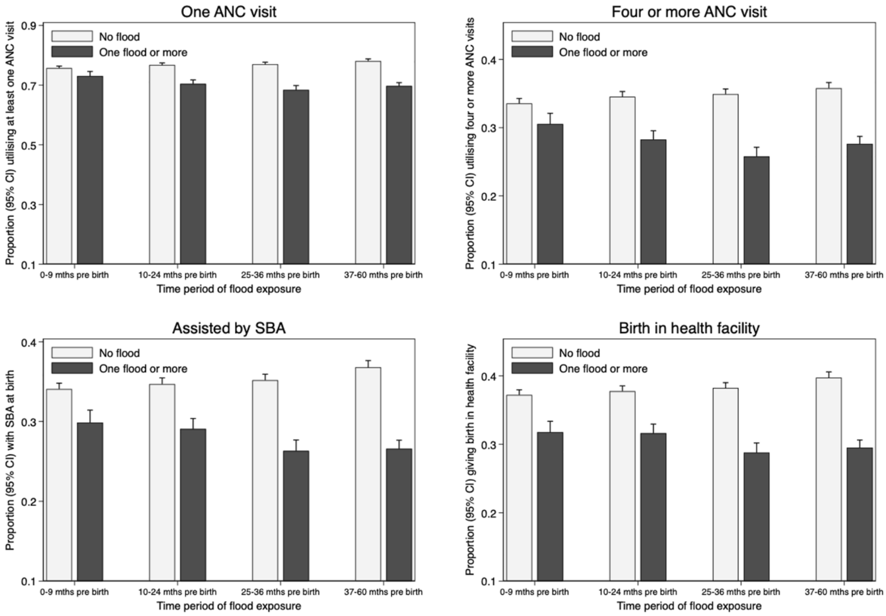


Fig. 3 Living in a flood exposed area and maternal healthcare use among Bangladeshi pregnant women

reduction in the probability of having any ANC visits. This effect is small in size, given that 75% of the overall population was estimated to have at least one visit, as shown in Table 1. None of the other estimates are statistically significant, and they too are small in size, varying between 0 and 0.02 (i.e. 2 percentage points) in absolute value. As mentioned above, the results were robust when we controlled for district level fixed effects (which additionally control for unobserved district level variation) as well as a continuous measure of the number of floods during each pre-pregnancy time period.

Table 4 presents estimates when using exposure to a severe flood — defined as a flood that affected at least one million people — as the main independent variable. None of the estimates are statistically significant and they are close to zero. We found similar results when using at least five million affected, or at least 100 deaths as indicators of severe floods. We thus conclude based on these analyses that exposure to flooding does not predict maternal healthcare usage in Bangladesh.

Table 2 Descriptive statistics of population which had none and one or more floods during the time periods at interest

	Place of residence		Husband's occupation		Maternal education		Wealth	
Flood	Urban	Rural	Farm., Agri.[a]	Prof./ techn.[b]	None	Sec./ higher	Poorest	Richest
0	34.31	65.69	19.97	6.48	13.48	58.98	16.59	26.08
≥ 1	16.59	83.41	24.46	4.67	18.50	51.44	25.99	13.26

[a]Farming or agriculture

[b]Professional/technical: Doctor, lawyer, dentist, accountant, teacher, nurse, family welfare visitor

Table 3 Multilevel linear probability regression results for maternal health indicators according to no floods or one or more floods 0–9, 10–24, 25–36, 37–60 months prior to childbirth

Variables	Maternal healthcare outcomes							
	At least 1 ANC visit		4 or more ANC visits		Birth with SBA		Birth in healthcare facility	
	Coeff	(95% CI)	Coeff	(95% CI)	Coeff	(95% CI)	Coeff	(95% CI)
Flood exposure (=0)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Flood exposure 0–9 mths (≥1)	0.008	(−0.011, 0.027)	0.013	(−0.007, 0.033)	0.009	(−0.009, 0.028)	−0.001	(−0.020, 0.018)
Flood exposure 10–24 mths (≥1)	−0.012	(−0.033, 0.009)	0.001	(−0.016, 0.018)	0.018	(0.000, 0.035)	0.014	(−0.003, 0.031)
Flood exposure 25–36 mths (≥1)	−0.021*	(−0.042, −0.001)	−0.014	(−0.034, 0.005)	0.003	(−0.014, 0.020)	−0.002	(−0.020, 0.016)
Flood exposure 37–60 mths (≥1)	−0.007	(−0.028, 0.014)	0.004	(−0.019, 0.027)	−0.013	(−0.032, 0.006)	−0.010	(−0.028, 0.008)
Birth year	0.020***	(0.017, 0.023)	0.014***	(0.011 0.017)	0.017***	(0.015, 0.019)	0.018***	(0.016, 0.020)
Mother age at birth	0.006***	(0.005, 0.008)	0.007***	(0.005, 0.009)	0.013***	(0.011, 0.015)	0.013***	(0.011, 0.015)
Education (None)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Primary	0.138***	(0.113, 0.163)	0.063***	(0.044, 0.082)	0.045***	(0.031, 0.059)	0.053***	(0.038, 0.069)
Secondary	0.257***	(0.229, 0.286)	0.187***	(0.159, 0.215)	0.178***	(0.150, 0.205)	0.190***	(0.159, 0.221)
Higher	0.299***	(0.268, 0.330)	0.370***	(0.340, 0.400)	0.389***	(0.352, 0.426)	0.394***	(0.355, 0.434)
Occupation (Other/ unknown)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Farmer/ Agriculture	−0.058***	(−0.075, −0.041)	−0.052***	(−0.066, −0.038)	−0.060***	(−0.077, −0.043)	−0.063***	(−0.079, −0.046)

Table 3 (continued)

Variables	Maternal healthcare outcomes							
	At least 1 ANC visit		4 or more ANC visits		Birth with SBA		Birth in healthcare facility	
	Coeff	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**
Place of residence (Rural)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Urban	0.085***	(0.068, 0.102)	0.120***	(0.099, 0.141)	0.125***	(0.101, 0.148)	0.134***	(0.108, 0.161)
Birth order (1)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
2	−0.061***	(−0.077, −0.046)	−0.055***	(−0.075, −0.034)	−0.118***	(−0.140, −0.096)	−0.126***	(−0.148, −0.104)
3	−0.096***	(−0.118, −0.074)	−0.096***	(−0.123 −0.069)	−0.172***	(−0.199, −0.145)	−0.187***	(−0.215, −0.159)
4	−0.164***	(−0.193, −0.136)	−0.159***	(−0.195, −0.123)	−0.259***	(−0.288, −0.231)	−0.272***	(−0.301, −0.243)
Random Effects								
District (dis)	0.004	(0.002, 0.007)	0.008	(0.005, 0.012)	0.006	(0.004, 0.010)	0.009	(0.005, 0.016)
Cluster (cl)	0.013	(0.010, 0.016)	0.017	(0.014, 0.021)	0.012	(0.010, 0.016)	0.014	(0.011, 0.019)
Household (hh)	0.019	(0.011, 0.033)	0.030	(0.021, 0.044)	0.017	(0.008, 0.036)	0.017	(0.008, 0.037)
Residual	0.114	(0.100, 0.130)	0.129	(0.118, 0.142)	0.138	(0.126, 0.151)	0.138	(0.125, 0.153)
Wald chi square	1894.17		1636.58		3468.93		5098.62	
Prob > chi2	0.0000		0.0000		0.0000		0.0000	
Log pseudolikelihood	−8694.6872		−10,516.811		−10,100.704		−10,239.425	
N (dis/cl/hh)	64/ 2,229/ 18,567		64/ 2,229/ 18,567		64/ 2,229/ 18,567		64/ 2,229/ 18,567	

Total sample: 19,519. Weights not applied

*$p<0.05$; **$p<0.01$; ***$p<0.001$

Table 4 Multilevel linear probability regression results for maternal health indicators according to flood severity with one million or more affected in the time periods 0–9, 10–24, 25–36, 37–60 months prior to childbirth

Variables	Maternal healthcare outcomes							
	At least 1 ANC visit		4 or more ANC visits		Birth with SBA		Birth in healthcare facility	
	Coeff	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**
Flood exposure (=0)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Flood exposure 0–9 mths (≥1)	0.022	(−0.001, 0.045)	0.006	(−0.023, 0.034)	0.003	(−0.024, 0.031)	−0.008	(−0.037, 0.022)
Flood exposure 10–24 mths (≥1)	−0.008	(−0.038, 0.023)	0.006	(−0.025, 0.038)	0.000	(−0.033, 0.033)	−0.003	(−0.035, 0.029)
Flood exposure 25–36 mths (≥1)	−0.007	(−0.027, 0.013)	−0.012	(−0.045, 0.021)	−0.005	(−0.025, 0.014)	−0.004	(−0.025, 0.017)
Flood exposure 37–60 mths (≥1)	−0.009	(−0.043, 0.024)	0.016	(−0.012, 0.045)	0.014	(−0.008, 0.035)	0.013	(−0.010, 0.036)
Birth year	0.020***	(0.017, 0.023)	0.014***	(0.011, 0.017)	0.017***	(0.015, 0.019)	0.018***	(0.016, 0.020)
Mother age at birth	0.006***	(0.005, 0.008)	0.007***	(0.005, 0.009)	0.013***	(0.011, 0.015)	0.013***	(0.011, 0.015)
Education (None)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Primary	0.138***	(0.113, 0.164)	0.063***	(0.044, 0.082)	0.045***	(0.031, 0.058)	0.053***	(0.038, 0.068)
Secondary	0.257***	(0.229, 0.286)	0.187***	(0.158, 0.215)	0.177***	(0.150, 0.205)	0.190***	(0.159, 0.221)
Higher	0.299***	(0.268, 0.330)	0.370***	(0.340, 0.400)	0.389***	(0.352, 0.426)	0.395***	(0.355, 0.434)
Occupation (Other/ unknown)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Farmer/ Agriculture	−0.058***	(−0.075, −0.041)	−0.052***	(−0.065, −0.038)	−0.060***	(−0.077, −0.043)	−0.063***	(−0.079, −0.046)

Table 4 (continued)

Variables	Maternal healthcare outcomes							
	At least 1 ANC visit		4 or more ANC visits		Birth with SBA		Birth in healthcare facility	
	Coeff	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**
Place of residence (Rural)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Urban	0.085***	(0.068, 0.102)	0.120***	(0.099, 0.141)	0.125***	(0.102, 0.149)	0.135***	(0.108, 0.161)
Birth order (1)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
2	−0.062***	(−0.077, −0.046)	−0.055***	(−0.075, −0.034)	−0.118***	(−0.140, −0.096)	−0.126***	(−0.148, −0.104)
3	−0.096***	(−0.118, −0.074)	−0.096***	(−0.123, −0.069)	−0.172***	(−0.199, −0.145)	−0.187***	(−0.215, −0.158)
4	−0.165***	(−0.193, −0.137)	−0.159***	(−0.195, −0.122)	−0.258***	(−0.287, −0.229)	−0.271***	(−0.301, −0.242)
Random Effects								
District (dis)	0.004	(0.002, 0.007)	0.008	(0.005, 0.012)	0.006	(0.004, 0.010)	0.009	(0.005, 0.016)
Cluster (cl)	0.013	(0.010, 0.016)	0.017	(0.014, 0.021)	0.013	(0.010, 0.016)	0.014	(0.011, 0.019)
Household (hh)	0.019	(0.011, 0.034)	0.030	(0.021, 0.044)	0.017	(0.008, 0.036)	0.017	(0.008, 0.037)
Residual	0.114	(0.100, 0.130)	0.129	(0.118, 0.141)	0.138	(0.126, 0.151)	0.139	(0.125, 0.153)
Wald chi square	1786.27		1660.69		3803.58		5460.13	
Prob > chi2	0.0000		0.0000		0.0000		0.0000	
Log pseudolikelihood	−8696.2887		−10,517.058		−10,103.174		−10,240.921	
N (dis/cl/hh)	64/2,229/18,567		64/2,229/18,567		64/2,229/18,567		64/2,229/18,567	

Total sample: 19,519. Weights not applied

*$p<0.05$; **$p<0.01$; ***$p<0.001$

Sensitivity analysis

In the first sensitivity analysis, we estimated the multilevel models on the dataset without the imputed district-level flood data (Appendix, Table 6). Contrary to expectations, we find a positive relationship between flood exposure 10–24 months before delivery and births assisted by SBA as well as births in a healthcare facility. This result may reflect selective missingness of information of the flood data based on characteristics of the districts which correlate with maternal healthcare usage.

The next sensitivity analyses use continuous measures of flood exposure (Appendix, Table 7). Appendix Table 7 shows that our results remained robust when we used a single indicator of the number of floods during the 60-month window before birth. Table 8 (Appendix) presents results from a Poisson model, where the two binary indicators of the number of ANC visits were replaced by a count measure of the number of visits as the dependent variable and the exposure variables are continuous measures of the number of incidents of flood exposure in each of the periods. We find that women who were exposed to flooding 25 to 36 months prior to delivery had fewer ANC visits than non-exposed women. We likewise find a negative estimate of being exposed 10–24 months before pregnancy, but the estimate is not statistically significant.

Finally, we investigated whether migration could affect our results by estimating the random effects models for women who had lived eight years or more in the same place of residence using data from 2007 (84.7% of original sample included) and 2017–18 (82.0% of original sample included) DHS (Appendix, Table 9). This analysis produced more significant estimates. Women who had stably lived in the same place of residence and were exposed to floods 10–24 and 25–36 months before pregnancy were less likely to have any or the recommended four ANC visits. Furthermore, women exposed to flooding 25–36 months before birth were less likely to have assistance by a skilled birth attendant or to give birth at a healthcare facility. The point estimates suggest a four to six percentage point reduction in the respective maternal healthcare usages, which correspond up to a 10–15% reduction when compared to the average levels (Table 1). However, since information on migration was only included in two of the four DHS waves, we estimated the same models with all women — including those who relocated — from the two DHS waves with migration data (Appendix, Table 10). The estimates remained significant, although often weaker. Overall, this suggests that the results were specific to certain waves and possibly, specific floods such as the major flood in 2004.

Discussion and conclusion

We analysed the effects of flood exposure on maternal healthcare utilisation in Bangladesh with multilevel linear probability models. Previous research has found a negative association between flooding and healthcare usage in Bangladesh (Adnan et al., 2019a; Baten et al., 2020; Haque et al., 2020). This research has highlighted the challenges faced by pregnant women exposed to flooding and that flooding can affect their access to and use of maternal healthcare, but by focusing on specific groups (Haque et al., 2020), not including control groups (Abdullah et al., 2019), or not considering the multilevel structure of the data (Baten et al., 2020), which leads to uncertainties whether the findings can be generalised to the population level. Our study, which used data from four waves of the DHS covering the whole of Bangladesh over 1999–2018 and used multilevel techniques, has addressed these limitations.

Our findings concur with previous research in indicating that maternal healthcare usage is clearly lower among pregnant women who live in areas that are exposed to flooding. However, our multilevel models that controlled for a range of measured variables find no average effect of exposure to floods during pregnancy or the years prior to it. This result was robust to using severe floods (defined as floods that affected at least one million people) rather than all floods as the indicator of flood exposure. These results suggest that the generally lower usage of maternal healthcare in areas exposed to flooding is not caused by the women's exposure to the flooding itself, but rather relates to the compositional characteristics of the flood-prone areas which also relate to lower maternal healthcare use. Yet, despite not finding an average effect of flood exposure, we did find statistically significant associations between flood exposure and maternal healthcare usage in some of the models and in particular, in data from the 2007 and 2017/18 waves which we used to assess whether migration patterns may have affected our findings. These findings may point to negative effects in the case of specific floods, even if the average flood — even when severe — does not have major effects.

Not finding an average effect of exposure to flooding — even to severe flooding — on maternal healthcare use in Bangladesh may seem surprising, given the clearly documented negative repercussions it has on health, infrastructure and livelihood (Mallett & Etzel, 2018). The result may reflect adaptation to recurrent floods, which characterise the area we study. Recurrent flooding, or the risk thereof, may encourage households and communities to build dwellings in locations that are secured from the most damage, and communities which have experienced flooding may develop mitigation measures to protect health and livelihood against future flooding (Rahman & Salehin, 2013). Public authorities may also plan health infrastructures in ways that make them less exposed in the occurrence of flooding. Yet the findings that we interpreted as potentially reflecting the effects of some specific floods suggest that, despite the apparent success in adaptation, floods may at least under certain circumstances have negative effects which disrupt pregnant women's access to maternal healthcare services and that these effects may be long-lasting. Further examination of these circumstances was beyond the scope of this study and we encourage future research to look into the conditions which increase vulnerability to floods, as well as resilience in the face of them.

Despite not finding average effects of exposure to floods in themselves, we did find bivariate associations between flooding exposure and maternal healthcare use. Together these results suggest that the bivariate differences in maternal healthcare use between women living in areas that were exposed to floods and those in areas not experiencing flooding therefore reflect other characteristics of the populations in these areas. Populations with and without exposure to flooding have different socioeconomic profiles, such as lower maternal education and a higher proportion of poverty among flood exposed populations, as indicated in our descriptive analysis. Poor populations, which often live in areas more exposed to natural hazards (Rahman & Salehin, 2013; Hallegatte et al., 2018), have fewer resources to reduce risk or cope with the lasting consequences of disasters (Hallegatte et al., 2020). Repeated flooding could lead to poverty traps, whereby especially poor households have difficulties in sustaining their pre-disaster income levels and are locked into poverty in the long term (Guha-Sapir et al., 2013; Rentschler, 2013). Households located in areas with frequent flooding might therefore have limited financial resources, leading to constraints on spending priorities with potentially less money to use on healthcare not considered to be essential. These populations may also have, partly reflecting their lower socioeconomic positioning, less knowledge of maternal healthcare and its importance (Abdullah et al., 2019). Pregnant women in these areas may therefore be less likely to utilise maternal healthcare services due to their more limited resources. Our multilevel linear probability models controlled for a range of sociodemographic variables that can be related to lower access to and use of maternal healthcare, and the results from these models, which mostly showed no statistically significant effects of exposure to floods, suggest that the sociodemographic profiles of populations in flood-affected areas largely explain the lower use of these services.

An additional, area-level, difference between areas affected by flooding and those that are not affected may be the provision of healthcare services in these areas. Disadvantaged populations may lack understanding and knowledge of their rights to public services and be less able to exert pressure on governments to invest in extensive healthcare infrastructures in areas that are at risk of flood damage (Paul & Islam, 2015). Limited or no availability of medical doctors in areas vulnerable to flooding has been reported in previous studies (Haque et al., 2020). Some of the free public health facilities close to flood prone areas do not provide antenatal care in line with WHO recommendations, while private-sector providers of ANC services are less likely to be present in such areas due to disaster risk and poverty among local populations (Haque et al., 2020). Limited access to maternal healthcare services may therefore additionally contribute to women not being able to utilise such services in flood exposed areas. If this is the case, this lack of access affects populations with lower socioeconomic status, who are also disadvantaged by exposure to flooding. We are not aware of detailed data on access to quality maternal healthcare services by proximity to flood-prone areas, and analysing its potential implications is an important task for future research.

We acknowledge that our study has limitations. Firstly, our study is based on floods listed at district level in EM-DAT. This means that we have not accounted for differences between the sub-districts, which may lead to measurement error in flood exposure. Secondly, our measures of the severity of the flooding were arguably crude and future research should attempt to develop and use more precise measures. Thirdly, Bangladesh is frequently affected by other natural hazards, which could affect our results. If more than one disaster strikes an area in the same time period, a more severe impact on the utilisation of maternal healthcare services would be expected. Addressing these limitations is a task for future research.

Finally, the maternal healthcare data are based on self-reporting, which could create recall bias. However, we have no reason to believe that such recall bias will differ by flood exposure. It is therefore unlikely to have had an impact on our results. Future research should extend into analyses on flooding and maternal morbidity and mortality, since there is currently limited knowledge on this association in the Bangladeshi context. Finally, future research should aim to better understand which characteristics of flood prone areas specifically lead to lower use of maternal healthcare services in them.

As climate change proceeds, the flooding in Bangladesh is likely to worsen and an expansion of the currently known flood-prone areas is likely. Consideration of access to and provision of maternal healthcare services should be incorporated into climate change adaptation policies and programmes, to ensure safe pregnancies and births for all women, regardless of their geographical location.

Appendix

Table 5 Secondary sources for imputations of district-level floods according to division-level floods identified through EM-DAT

Year of flood	Source
2002	https://reliefweb.int/report/bangladesh/bangladesh-appeal-no-212002-monsoon-floods-final-report
2007 (June)	https://reliefweb.int/report/bangladesh/bangladesh-landslides-and-flash-flood-12-jun-2007
2007 (July)	https://modmr.portal.gov.bd/sites/default/files/files/modmr.portal.gov.bd/publications/8e731b3d_479f_4ea1_b1c3_f3af17d263b4/Executive%20Summary-Flood%20Report.pdf
2009	https://reliefweb.int/sites/reliefweb.int/files/resources/CB12138F4CAE32F34925764E00105A66-Full_Report.pdf and https://reliefweb.int/map/bangladesh/bangladesh-flood-situation-27-aug-2009
2009	Barisal was listed as affected division in EMDAT, but the districts could not be identified through secondary sources
2012	https://reliefweb.int/map/bangladesh/bangladesh-daily-disaster-report-18-july-2012 and http://www.ffwc.gov.bd/images/annual12.pdf
2015	https://reliefweb.int/sites/reliefweb.int/files/resources/Monthly%20Disaster%20Incidence%20Report_July%202015.pdf

Table 6 Multilevel linear probability regression results for maternal health indicators according no floods or one or more floods 0–9, 10–24, 25–36, 37–60 months prior to childbirth. Original EMDAT dataset without the imputed data on flooded districts

Variables	Maternal healthcare outcomes							
	At least 1 ANC visit		4 or more ANC visits		Birth with SBA		Birth in health facility	
	Coeff	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**
Flood exposure (=0)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Flood exposure 0–9 mths (≥ 1)	0.016	(−0.003, 0.035)	0.012	(−0.009, 0.033)	0.016	(−0.005, 0.037)	0.010	(−0.009, 0.030)
Flood exposure 10 – 24 mths (≥ 1)	−0.010	(−0.037, 0.018)	0.011	(−0.010, 0.031)	0.022*	(0.004, 0.040)	0.020*	(0.004, 0.036)
Flood exposure 25 – 36 mths (≥ 1)	−0.015	(−0.036, 0.006)	−0.007	(−0.028, 0.014)	0.005	(−0.012, 0.021)	−0.001	(−0.019, 0.017)
Flood exposure 37 – 60 mths (≥ 1)	−0.013	(−0.034, 0.009)	0.005	(−0.019, 0.029)	−0.001	(−0.019, 0.016)	−0.004	(−0.022, 0.013)
Birth year	0.020***	(0.017, 0.022)	0.014***	(0.011, 0.017)	0.018***	(0.016, 0.020)	0.018***	(0.016, 0.020)
Mother age at birth	0.006***	(0.005, 0.008)	0.007***	(0.005, 0.009)	0.013***	(0.011, 0.015)	0.013***	(0.011, 0.015)
Education (None)	Ref.	(–)	Ref.	(–)	Ref.	(–)	Ref.	(–)
Primary	0.138***	(0.113, 0.164)	0.063***	(0.044, 0.082)	0.045***	(0.031, 0.059)	0.053***	(0.038, 0.069)
Secondary	0.258***	(0.229, 0.286)	0.187***	(0.159, 0.215)	0.178***	(0.150, 0.205)	0.190***	(0.159, 0.221)
Higher	0.299***	(0.268, 0.330)	0.370***	(0.340, 0.400)	0.389***	(0.352, 0.426)	0.394***	(0.355, 0.434)
Occupation (Other/unknown)	Ref.	(–)	Ref.	(–)	Ref.	(–)	Ref.	(–)

Table 6 (continued)

Variables	Maternal healthcare outcomes							
	At least 1 ANC visit		4 or more ANC visits		Birth with SBA		Birth in health facility	
	Coeff	(95% CI)	Coeff	(95% CI)	Coeff	(95% CI)	Coeff	(95% CI)
Farmer/ Agriculture	−0.058***	(−0.075, −0.041)	−0.052***	(−0.066, −0.038)	−0.060***	(−0.077, −0.043)	−0.063***	(−0.079, −0.046)
Place of residence (Rural)	Ref.	(–)	Ref.	(–)	Ref.	(–)	Ref.	(–)
Urban	0.085***	(0.067, 0.102)	0.120***	(0.099, 0.141)	0.125***	(0.101, 0.149)	0.134***	(0.108, 0.161)
Birth order (1)	Ref.	(–)	Ref.	(–)	Ref.	(–)	Ref.	(–)
2	−0.062***	(−0.077, −0.046)	−0.055***	(−0.075, −0.034)	−0.118***	(−0.140, −0.096)	−0.126***	(−0.148, −0.104)
3	−0.096***	(−0.118, −0.074)	−0.096***	(−0.122, −0.069)	−0.172***	(−0.199, −0.145)	−0.187***	(−0.215, −0.159)
4	−0.165***	(−0.193, −0.137)	−0.159***	(−0.195, −0.123)	−0.259***	(−0.288, −0.230)	−0.272***	(−0.301, −0.243)
Random Effects								
District (dis)	0.004	(0.002, 0.007)	0.008	(0.005, 0.012)	0.006	(0.004, 0.010)	0.009	(0.005, 0.016)
Cluster (cl)	0.013	(0.010, 0.016)	0.017	(0.014, 0.021)	0.012	(0.010, 0.016)	0.014	(0.011, 0.018)
Household (hh)	0.019	(0.011, 0.034)	0.031	(0.021, 0.044)	0.017	(0.008, 0.036)	0.017	(0.008, 0.037)
Residual	0.114	(0.100, 0.130)	0.129	(0.118, 0.141)	0.138	(0.126, 0.151)	0.138	(0.125, 0.153)
Wald chi square	1787.30		1659.73		3602.12		5135.92	
Prob > chi2	0.0000		0.0000		0.0000		0.0000	
Log pseudolikelihood	−8695.2385		−10,517.985		−10,100.873		−10,238.989	
N (dis/cl/hh)	64/2,229/18,567		64/2,229/18,567		64/2,229/18,567		64/2,229/18,567	

Total sample: 19,519. Weights not applied

*$p<0.05$; **$p<0.01$; ***$p<0.001$

Table 7 Multilevel linear probability regression results for maternal health indicators according to frequency of floods 0–60 months prior to childbirth

Variables	Maternal healthcare outcomes							
	At least 1 ANC visit		4 or more ANC visits		Birth with SBA		Birth in health facility	
	Coeff	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**
Floods 0–60 mths	−0.006	(−0.015, 0.004)	0.003	(−0.007, 0.014)	0.001	(−0.009, 0.011)	−0.002	(−0.011, 0.007)
Birth year	0.020***	(0.017, 0.023)	0.014***	(0.011, 0.017)	0.017***	(0.016, 0.019)	0.018***	(0.016, 0.020)
Mother age at birth	0.006***	(0.005, 0.008)	0.007***	(0.005, 0.009)	0.013***	(0.011, 0.015)	0.013***	(0.011, 0.015)
Education (None)	Ref.	(–)	Ref.	(–)	Ref.	(–)	Ref.	(–)
Primary	0.138***	(0.113, 0.163)	0.063***	(0.044, 0.082)	0.045***	(0.031, 0.059)	0.053***	(0.037, 0.068)
Secondary	0.257***	(0.229, 0.286)	0.187***	(0.159, 0.215)	0.177***	(0.150, 0.205)	0.190***	(0.159, 0.221)
Higher	0.299***	(0.269, 0.330)	0.370***	(0.340, 0.400)	0.389***	(0.352, 0.426)	0.394***	(0.355, 0.434)
Occupation (Other/ unknown)	Ref.	(–)	Ref.	(–)	Ref.	(–)	Ref.	(–)
Farmer/ Agriculture	−0.058***	(−0.075, −0.041)	−0.052***	(−0.066, −0.038)	−0.060***	(−0.077, −0.043)	−0.063***	(−0.079, −0.046)
Place of residence (Rural)	Ref.	(–)	Ref	(–)	Ref.	(–)	Ref.	(–)
Urban	0.085***	(0.067, 0.102)	0.120***	(0.099, 0.141)	0.125***	(0.102, 0.149)	0.135***	(0.108, 0.161)
Birth order (1)	Ref.	(–)	Ref.	(–)	Ref.	(–)	Ref.	(–)
2	−0.061***	(−0.077, −0.046)	−0.055***	(−0.076, −0.034)	−0.118***	(−0.140, −0.096)	−0.126***	(−0.148, −0.104)
3	−0.096***	(−0.118, −0.074)	−0.096***	(−0.123, −0.069)	−0.172***	(−0.199, −0.145)	−0.187***	(−0.215, −0.159)
4	−0.165***	(−0.193, −0.137)	−0.159***	(−0.195, −0.122)	−0.259***	(−0.287, −0.230)	−0.272***	(−0.301, −0.243)
Random Effects								
District (dis)	0.003	(0.002, 0.007)	0.008	(0.005, 0.012)	0.006	(0.004, 0.010)	0.009	(0.005, 0.016)

Table 7 (continued)

Variables	**Maternal healthcare outcomes**							
	At least 1 ANC visit		**4 or more ANC visits**		**Birth with SBA**		**Birth in health facility**	
	Coeff	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**
Cluster (cl)	0.013	(0.010, 0.016)	0.017	(0.014, 0.021)	0.013	(0.010, 0.016)	0.014	(0.011, 0.019)
Household (hh)	0.019	(0.011, 0.034)	0.031	(0.021, 0.044)	0.017	(0.017, 0.006)	0.017	(0.008, 0.037)
Residual	0.114	(0.100, 0.130)	0.129	(0.118, 0.141)	0.138	(0.126, 0.151)	0.138	(0.125, 0.153)
Wald chi square	1699.14		1559.51		3388.51		5057.09	
Prob > chi2	0.0000		0.0000		0.0000		0.0000	
Log pseudolikelihood	−8698.8139		−10,519.422		−10,104.446		−10,241.56	
N (dis/cl/hh)	64/ 2,229/ 18,567		64/ 2,229/ 18,567		64/ 2,229/ 18,567		64/ 2,229/ 18,567	

Total sample: 19,519. Weights not applied

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table 8 Poisson regression results for ANC visits as a continuous variable according to according to frequency of floods 0–9, 10–24, 25–36, 37–60 months prior to childbirth

ANC visits	Coeff	(95% CI)
Floods 0–9 mths	0.005	(−0.036, 0.046)
Floods 10–24 mths	−0.037	(−0.083, 0.009)
Floods 25–36 mths	−0.049*	(−0.091, −0.006)
Floods 37–60 mths	0.001	(−0.034, 0.036)
Birth year	0.045***	(0.037, 0.052)
Mother age at birth	0.020***	(0.016, 0.025)
Education (None)	Ref.	(–)
Primary	0.376***	(0.291, 0.461)
Secondary	0.703***	(0.611, 0.795)
Higher	0.944***	(0.851, 1.036)
Occupation (Other/ unknown)	Ref.	(–)
Farmer/ Agriculture	−0.177***	(−0.226, −0.129)
Place of residence (Rural)	Ref.	(–)
Urban	0.318***	(0.265, 0.372)
Birth order (1)	Ref.	(–)
2	−0.143***	(−0.182, −0.105)
3	−0.256***	(−0.317, −0.194)
4	−0.491***	(−0.570, −0.412)
Random effects		
District	0.039	(0.024, 0.064)
District > Cluster	0.120	(0.097, 0.149)
District > Cluster > Household	0.257	(0.228, 0.290)
Wald chi square	1500.94	
Prob > chi2	0.0000	
Log pseudolikelihood	−41,645.372	
N (district/cluster/household)	64/2,229/18,567	

Total sample: 19,519. Weights not applied

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table 9 Multilevel linear probability regression results for maternal health indicators according no floods or one or more floods 0–9, 10–24, 25–36, 37–60 months prior to childbirth. Only for women from survey 2007 (with pregnancies/births from 2004 or later) and 2017–18 who have been living eight years or more in the same area

Variables	Maternal Healthcare Outcomes							
	At least 1 ANC visit		4 or more ANC visits		Birth with SBA		Birth in health facility	
	Coeff	(95% CI)	Coeff	(95% CI)	Coeff	(95% CI)	Coeff	(95% CI)
Flood exposure (=0)	Ref.	(–)	Ref.	(–)	Ref.	(–)	Ref.	(–)
Flood exposure 0–9 mths (≥1)	0.018	(−0.011, 0.047)	0.016	(−0.019, 0.051)	−0.007	(−0.041, 0.026)	−0.014	(−0.045, 0.017)
Flood exposure 10 – 24 mths (≥1)	−0.057**	(−0.096, −0.018)	−0.040*	(−0.073, −0.008)	0.011	(−0.019, 0.041)	0.014	(−0.016, 0.044)
Flood exposure 25–36 mths (≥1)	−0.045*	(−0.084, −0.005)	−0.039*	(−0.076, −0.001)	−0.041*	(−0.074, −0.008)	−0.041*	(−0.074, −0.008)
Flood exposure 37–60 mths (≥1)	0.026	(−0.004, 0.057)	0.010	(−0.021, 0.041)	−0.026	(−0.070, 0.017)	−0.019	(−0.066, 0.028)
Birth year	0.022***	(0.019, 0.026)	0.016***	(0.012, 0.019)	0.017***	(0.013, 0.021)	0.017***	(0.013, 0.021)
Mother age at birth	0.003	(−0.000, 0.006)	0.006***	(0.003, 0.009)	0.010***	(0.007, 0.013)	0.010***	(0.007, 0.013)
Education (None)	Ref.	(–)	Ref.	(–)	Ref.	(–)	Ref.	(–)
Primary	0.152***	(0.110, 0.194)	0.065***	(0.031, 0.098)	0.023	(−0.012, 0.058)	0.028	(−0.008, 0.065)
Secondary	0.237***	(0.196, 0.279)	0.199***	(0.158, 0.239)	0.158***	(0.104, 0.212)	0.178***	(0.122, 0.234)
Higher	0.281***	(0.232, 0.329)	0.384***	(0.322, 0.446)	0.331***	(0.266, 0.396)	0.340***	(0.269, 0.412)
Occupation (Other/ unknown)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Farmer/ Agriculture	−0.021	(−0.052, 0.009)	−0.051***	(−0.078, −0.023)	−0.051**	(−0.083, −0.018)	−0.053**	(−0.085, −0.020)
Place of residence (Rural)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Urban	0.093***	(0.061, 0.124)	0.111***	(0.073, 0.150)	0.137***	(0.099, 0.175)	0.147***	(0.110, 0.185)
Birth order (1)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
2	−0.040**	(−0.069, −0.011)	−0.044	(−0.108, 0.020)	−0.077**	(−0.133, −0.022)	−0.081**	(−0.133, −0.028)
3	−0.083***	(−0.118, −0.047)	−0.085**	(−0.135, −0.035)	−0.161***	(−0.212, −0.109)	−0.182***	(−0.232, −0.133)

Table 9 (continued)

Variables	Maternal Healthcare Outcomes							
	At least 1 ANC visit		4 or more ANC visits		Birth with SBA		Birth in health facility	
	Coeff	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**
4	−0.146***	(−0.185, −0.106)	−0.169***	(−0.229, −0.109)	−0.247***	(−0.306, −0.188)	−0.259***	(−0.314, −0.204)
Random Effects								
District (dis)	0.000	(0.000, 0.026)	0.008	(0.004, 0.017)	0.004	(0.002, 0.008)	0.005	(0.002, 0.009)
Cluster (cl)	0.016	(0.011, 0.021)	0.021	(0.015, 0.031)	0.019	(0.013, 0.026)	0.017	(0.012, 0.003)
Household (hh)	0.000	(0.000, 0.000)	0.001	(0.000,1.39 $\times 10^{16}$)	0.014	(0.000, 2.275)	0.000	(0.000, 5.50 $\times 10^{77}$)
Residual	0.121	(0.111, 0.131)	0.146	(0.101, 0.211)	0.124	(0.070, 0.219)	0.140	(0.129, 0.152)
Wald chi square	884.88		1011.19		773.43		1358.38	
Prob > chi2	0.0000		0.0000		0.0000		0.0000	
Log pseudolikelihood	−1472.8272		−1871.6951		−1735.5949		−1755.5976	
N (dis/cl/hh)	64/976/3,547		64/976/3,547		64/976/3,547		64/976/3,547	

Total sample: 3574. Weights not applied

Table 10 Multilevel linear probability regression results for maternal health indicators according no floods or one or more floods 0–9, 10–24, 25–36, 37–60 months prior to childbirth. Only for women from survey 2007 (with pregnancies/births from 2004 or later) and 2017–18

Variables	Maternal healthcare outcomes							
	At least 1 ANC visit		4 or more ANC visits		Birth with SBA		Birth in health facility	
	Coeff	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**
Flood exposure (=0)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Flood exposure 0–9 mths (≥1)	−0.003	(−0.021, 0.014)	0.003	(−0.028, 0.034)	−0.001	(−0.024, 0.021)	−0.004	(−0.025, 0.016)
Flood exposure 10–24 mths (≥1)	−0.036**	(−0.062, −0.009)	−0.022	(−0.047, 0.003)	0.012	(−0.011, 0.035)	0.008	(−0.015, 0.031)
Flood exposure 25–36 mths (≥1)	−0.034*	(−0.065, −0.003)	−0.024	(−0.056, 0.008)	−0.026*	(−0.051, −0.001)	−0.032*	(−0.059, −0.006)
Flood exposure 37–60 mths (≥1)	0.010	(−0.014, 0.034)	0.018	(−0.013, 0.049)	−0.024	(−0.051, 0.004)	−0.024	(−0.053, 0.004)
Birth year	0.017***	(0.015, 0.020)	0.012***	(0.009, 0.015)	0.014***	(0.011, 0.016)	0.013***	(0.011, 0.016)
Mother age at birth	0.004***	(0.003, 0.006)	0.008***	(0.005, 0.011)	0.012***	(0.010, 0.014)	0.012***	(0.010, 0.014)
Education (None)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Primary	0.168***	(0.128, 0.208)	0.077***	(0.045, 0.110)	0.045***	(0.020, 0.070)	0.060***	(0.030, 0.089)
Secondary	0.264***	(0.227, 0.302)	0.225***	(0.185, 0.265)	0.220***	(0.178, 0.261)	0.230***	(0.185, 0.275)
Higher	0.290***	(0.249, 0.332)	0.372***	(0.335, 0.409)	0.401***	(0.356, 0.447)	0.407***	(0.356, 0.458)
Occupation (Other/ unknown)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Farmer/ Agriculture	−0.039***	(−0.059, −0.019)	−0.058***	(−0.080, −0.035)	−0.056***	(−0.085, −0.027)	−0.061***	(−0.089, −0.034)
Place of residence (Rural)	Ref.	(-)	Ref.	(-)	Ref.	(-)	Ref.	(-)
Urban	0.057***	(0.039, 0.075)	0.097***	(0.070, 0.125)	0.107***	(0.080, 0.133)	0.115***	(0.088, 0.142)
Birth order (1)	Ref.	(−)	Ref.	(−)	Ref.	(−)	Ref.	(−)
2	−0.044***	(−0.063, −0.025)	−0.063***	(−0.092, −0.034)	−0.138***	(−0.173, −0.103)	−0.133***	(−0.165, −0.101)
3	−0.085***	(−0.114, −0.057)	−0.099***	(−0.132, −0.067)	−0.202***	(−0.243, −0.161)	−0.216***	(−0.260, −0.171)

Table 10 (continued)

Variables	**Maternal healthcare outcomes**							
	At least 1 ANC visit		**4 or more ANC visits**		**Birth with SBA**		**Birth in health facility**	
	Coeff	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**	**Coeff**	**(95% CI)**
4	−0.143***	(−0.172, −0.115)	−0.186***	(−0.230, −0.142)	−0.299***	(−0.337, −0.261)	−0.300***	(−0.337, −0.262)
Random Effects								
District (dis)	0.007	(0.004, 0.013)	0.005	(0.003, 0.009)	0.008	(0.005, 0.013)	0.001	(0.000, 0.002)
Cluster (cl)	0.015	(0.012, 0.020)	0.014	(0.011, 0.018)	0.018	(0.015, 0.023)	0.010	(0.008, 0.013)
Household (hh)	0.017	(0.007, 0.046)	0.019	(0.006, 0.055)	0.019	(0.008, 0.043)	0.010	(0.002, 0.056)
Residual	0.140	(0.123, 0.159)	0.140	(0.121, 0.162)	0.150	(0.134, 0.168)	0.092	(0.074, 0.115)
Wald chi square	1613.61		1213.87		2574.51		2846.37	
Prob > chi2	0.0000		0.0000		0.0000		0.0000	
Log pseudolikelihood	−2473.009		−4474.222		−4166.8343		−4163.0459	
N (dis/cl/hh)	64/1,030/7,459		64/1,030/7,459		64/1,030/7,459		64/1,030/7,459	

Total sample: 3574. Weights not applied

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

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Declarations

Conflict of interest The authors declare no competing interests.

References

Abdullah, A. S., et al. (2019). Effects of climate change and maternal mortality: Perspective from case studies in the rural area of Bangladesh. *International Journal of Environmental Research and Public Health, 16*(23), 4594. https://doi.org/10.3390/ijerph16234594

Adnan, M. S. G., et al. (2019a). The use of watershed geomorphic data in flash flood susceptibility zoning: A case study of the Karnaphuli and Sangu river basins of Bangladesh. *Natural Hazards, 99*(1), 425–448. https://doi.org/10.1007/s11069-019-03749-3

Adnan, M. S. G., Haque, A., & Hall, J. W. (2019b). Have coastal embankments reduced flooding in Bangladesh? *Science of The Total Environment, 682*, 405–416. https://doi.org/10.1016/j.scitotenv.2019.05.048

Ahmed, I., et al. (2019). Climate change, environmental stress and loss of livelihoods can push people towards illegal activities: A case study from coastal Bangladesh. *Climate and Development, 11*(10), 907–917. https://doi.org/10.1080/17565529.2019.1586638

Alderman, K., Turner, L. R., & Tong, S. (2012). Floods and human health: A systematic review. *Environment International, 47*, 37–47. https://doi.org/10.1016/j.envint.2012.06.003

Azad, A. K., Hossain, K. M., & Nasreen, M. (2013). Flood-induced vulnerabilities and problems encountered by women in northern Bangladesh. *International journal of disaster risk science, 4*(4), 190–199. https://doi.org/10.1007/s13753-013-0020-z

Baten, A., et al. (2020). Impact of recurrent floods on the utilization of maternal and newborn healthcare in Bangladesh. *Maternal and Child Health Journal, 24*(6), 748–758. https://doi.org/10.1007/s10995-020-02917-3

Bukhari, S. I. A., & Rizvi, S. H. (2015). Impact of floods on women: With special reference to flooding experience of 2010 Flood in Pakistan. *Journal of Geography & Natural Disasters*, *05*(02). https://doi.org/10.4172/2167-0587.1000140

Burgert, C. R., et al. (2013). *Geographic displacement procedure and georeferenced data release policy for the Demographic and Health Surveys.* DHS Spatial Analysis Reports No. 7. Calverton, Maryland, USA: ICF International.

Chowdhury, H. R., et al. (2010). A comparison of physicians and medical assistants in interpreting verbal autopsy interviews for allocating cause of neonatal death in Matlab, Bangladesh: Can medical assistants be considered an alternative to physicians? *Population Health Metrics, 8*(1), 23. https://doi.org/10.1186/1478-7954-8-23

CRED., & UNDRR. (2020). *Human cost of disasters an overview of the last 20 years 2000–2019*. UN. Retrieved January 26, 2021, from https://www.emdat.be/undrr-press-release-report-%E2%80%9C-human-cost-disasters-2000-2019%E2%80%9D

Croft, T. N., Marshall, A. M. J., & Allen, C. K. (2018). *Guide to DHS Statistics DHS-7*. Rockville, Maryland: USA: ICF. https://dhsprogram.com/data/Guide-to-DHS-Statistics/Age_at_First_Birth.htm
Cutter, S. L. (2017). The forgotten casualties redux: Women, children, and disaster risk. *Global Environmental Change, 42*, 117–121. https://doi.org/10.1016/j.gloenvcha.2016.12.010
DaVanzo, J., et al. (2013). Influences on pregnancy-termination decisions in Matlab. *Bangladesh. Demography, 50*(5), 1739–1764. https://doi.org/10.1007/s13524-013-0202-8
Dewan, T. H. (2015). Societal impacts and vulnerability to floods in Bangladesh and Nepal. *Weather and Climate Extremes, 7*, 36–42. https://doi.org/10.1016/j.wace.2014.11.001
Guha-Sapir, D., Santos, I., & Borde, A. (Eds.). (2013). *The economic impacts of natural disasters*. Oxford University Press.
Hallegatte, S., et al. (2020). From poverty to disaster and back: A review of the literature. *Economics of Disasters and Climate Change, 4*(1), 223–247. https://doi.org/10.1007/s41885-020-00060-5
Hallegatte, S., Fay, M., & Barbier, E. B. (2018). Poverty and climate change: Introduction. *Environment and Development Economics, 23*(3), 217–233. https://doi.org/10.1017/S1355770X18000141
Haque, M. R., Parr, N., & Muhidin, S. (2019). Parents healthcare-seeking behavior for their children among the climate-related displaced population of rural Bangladesh. *Social Science & Medicine, 226*, 9–20. https://doi.org/10.1016/j.socscimed.2019.02.032
Haque, R., Parr, N., & Muhidin, S. (2020). Climate-related displacement and antenatal care service utilization in rural Bangladesh. *International Perspectives on Sexual and Reproductive Health, 46*, 175. https://doi.org/10.1363/46e9620
Hoq, M. S., Raha, S. K., & Hossain, M. I. (2021). Livelihood vulnerability to flood hazard: understanding from the flood-prone haor ecosystem of Bangladesh. *Environmental Management, 67*(3), 532–552. https://doi.org/10.1007/s00267-021-01441-6
Huq, S., et al. (Eds.) (2019). *Confronting climate change in Bangladesh*. New York, NY: Springer Berlin Heidelberg.
ICF International. (2012). *Demographic and Health Survey Sampling and Household Listing Manual.* MEASURE DHS. Calverton, Maryland, USA: ICF International.
Islam, M. R. (2020). Water access in changing climate in Bangladesh: A study of social impacts on women who manage household water. *Bandung, 7*(1), 107–129. https://doi.org/10.1163/21983534-00701006
Islam, N. K. M. (2013). Urban and nonagricultural impacts of flooding and their assessments - The case of Bangladesh. In *The Economic Impacts of Natural Disasters*. Oxford; New York: Oxford University Press.
Juran, L., & Trivedi, J. (2015). Women, gender norms, and natural disasters in Bangladesh. *Geographical Review, 105*(4), 601–611. https://doi.org/10.1111/j.1931-0846.2015.12089.x
Khan, A. N. S. et al. (2018). A cross-sectional study of partograph utilization as a decision making tool for referral of abnormal labour in primary health care facilities of Bangladesh. In M. Mathai (Ed.), *PLOS ONE* (vol. 13, no. 9, p. e0203617). https://doi.org/10.1371/journal.pone.0203617
Loewen, S., et al. (2021). The impact of natural disasters and epidemics on sexual and reproductive health in low‐ and middle‐income countries: A narrative synthesis. *International Journal of Gynecology & Obstetrics*, ijgo.13768. https://doi.org/10.1002/ijgo.13768
Mahmood, S. S., et al. (2019). Does healthcare voucher provision improve utilisation in the continuum of maternal care for poor pregnant women? *Experience from Bangladesh. Global Health Action, 12*(1), 1701324. https://doi.org/10.1080/16549716.2019.1701324
Mallett, L. H., & Etzel, R. A. (2018). Flooding: What is the impact on pregnancy and child health? *Disasters, 42*(3), 432–458. https://doi.org/10.1111/disa.12256
Mani, M. S. & Wang, L. (2014) *Climate change and health impacts: how vulnerable is bangladesh and what needs to be done?* Washington D.C.: World Bank (88665). Retrieved August 12, 2021, from https://openknowledge.worldbank.org/handle/10986/21820
Ministry of Health and Family Welfare (MOHFW). (2018). *Bangladesh Health Bulletin 2018*. Bangladesh: Managment Information System: Directorate General of Health Services. Retrieved August 4, 2022, from https://old.dghs.gov.bd/images/docs/Publicaations/HB%202018%20final.pdf
Mirza, M. M. Q. (2011). Climate change, flooding in South Asia and implications. *Regional Environmental Change, 11*(S1), 95–107. https://doi.org/10.1007/s10113-010-0184-7
NAWG Bangladesh. (2020). *Monsoon Floods 2020 Coordinated Preliminary Impact and Needs Assessment*. Humanitarian Needs Overview. Dhaka, Bangladesh: Needs Assessment Working Group (NAWG), Care International - Care Bangladesh. Retrieved March 2, 2021, from https://

www.humanitarianresponse.info/en/operations/bangladesh/document/nawg-monsoon-flood-pliminary-impact-and-kin20200725
Naz, F., & Saqib, S. E. (2021). Gender-based differences in flood vulnerability among men and women in the char farming households of Bangladesh. *Natural Hazards, 106*(1), 655–677. https://doi.org/10.1007/s11069-020-04482-y
Nguyen, H. T. H., et al. (2012). Encouraging maternal health service utilization: An evaluation of the Bangladesh voucher program. *Social Science & Medicine, 74*(7), 989–996. https://doi.org/10.1016/j.socscimed.2011.11.030
NIPORT., & ICF. (2019). *Bangladesh Health Facility Survey 2017*. Dhaka, Bangladesh: National Institute of Population Research and Training (NIPORT), ACPR, and ICF.
NIPORT., & ICF. (2020). *Bangladesh Demographic and Health Survey 2017–18.* Dhaka, Bangladesh and Rockville, Maryland, USA: NIPORT and ICF. Retrieved March 4, 2021, from https://www.measureevaluation.org/resources/publications/tr-17-218
Nove, A., et al. (2021). Potential impact of midwives in preventing and reducing maternal and neonatal mortality and stillbirths: A Lives Saved Tool modelling study. *The Lancet Global Health, 9*(1), e24–e32. https://doi.org/10.1016/S2214-109X(20)30397-1
Nowreen, S., Jalal, M. R., & Shah Alam Khan, M. (2014). Historical analysis of rationalizing South West coastal polders of Bangladesh. *Water Policy, 16*(2), 264–279. https://doi.org/10.2166/wp.2013.172
Partash, N., et al. (2022). The impact of flood on pregnancy outcomes: A review article. *Taiwanese Journal of Obstetrics and Gynecology, 61*(1), 10–14. https://doi.org/10.1016/j.tjog.2021.11.005
Parvin, G., et al. (2016). Flood in a changing climate: The impact on livelihood and how the rural poor cope in Bangladesh. *Climate, 4*(4), 60. https://doi.org/10.3390/cli4040060
Pathak, P. K., Singh, A. & Subramanian, S. V. (2010). Economic inequalities in maternal health care: Prenatal care and skilled birth attendance in India, 1992–2006. In A. M. Noor (Ed.), *PLoS ONE* (vol. 5, no. 10, p. e13593). https://doi.org/10.1371/journal.pone.0013593
Paul, S., & Islam, M. R. (2015). Ultra-poor char people's rights to development and accessibility to public services: A case of Bangladesh. *Habitat International, 48*, 113–121. https://doi.org/10.1016/j.habitatint.2015.03.018
Pinchoff, J., et al. (2019). Spatio-temporal patterns of pre-eclampsia and eclampsia in relation to drinking water salinity at the district level in Bangladesh from 2016 to 2018. *Population and Environment, 41*(2), 235–251. https://doi.org/10.1007/s11111-019-00331-8
Pulok, M. H., et al. (2018). Socioeconomic inequality in maternal healthcare: An analysis of regional variation in Bangladesh. *Health & Place, 52*, 205–214. https://doi.org/10.1016/j.healthplace.2018.06.004
Rabe-Hesketh, S., & Skrondal, A. (2012). *Multilevel and longitudinal modeling using Stata* (3rd ed.). Stata Press Publication.
Rahman, H. M. T., et al. (2018). Livelihood exposure to climatic stresses in the north-eastern floodplains of Bangladesh. *Land Use Policy, 79*, 199–214. https://doi.org/10.1016/j.landusepol.2018.08.015
Rahman, R., & Salehin, M. (2013). Flood risks and reduction approaches in Bangladesh. In R. Shaw, F. Mallick, & A. Islam (Eds.), *Disaster Risk Reduction Approaches in Bangladesh* (pp. 65–90). Tokyo: Springer Japan (Disaster Risk Reduction). https://doi.org/10.1007/978-4-431-54252-0_4
Rawal, L. B., et al. (2016). Training mid-level health cadres to improve health service delivery in rural Bangladesh. *Primary Health Care Research & Development, 17*(05), 503–513. https://doi.org/10.1017/S1463423616000104
Ray-Bennett, N. S., et al. (2019). Understanding reproductive health challenges during a flood: Insights from Belkuchi Upazila, Bangladesh. *Gates Open Research, 3*, 788. https://doi.org/10.12688/gatesopenres.12920.2
Reggers, A. (2019). Climate change is not gender neutral: Gender inequality, rights and vulnerabilities in Bangladesh. In S. Huq, et al. (Eds.), *Confronting Climate Change in Bangladesh* (pp. 103–118). Cham: Springer International Publishing (The Anthropocene: Politik—Economics—Society—Science). https://doi.org/10.1007/978-3-030-05237-9_8
Rentschler, J., & Salhab, M. (2020). *People in harm's way: Flood Exposure and poverty in 189 countries*. World Bank (Background paper for 2020 Poverty and Shared Prosperity Report, 9447).
Rentschler, J. E. (2013). Why resilience matters-the poverty impacts of disasters. *World Bank Policy Research Working Paper.* [Preprint], 6699.
Rosales-Rueda, M. (2018). The impact of early life shocks on human capital formation: evidence from El Niño floods in Ecuador. *Journal of Health Economics, 62*, 13–44. https://doi.org/10.1016/j.jhealeco.2018.07.003

Rosvold, E. L., & Buhaug, H. (2021). GDIS, a global dataset of geocoded disaster locations. *Scientific Data, 8*(1), 61. https://doi.org/10.1038/s41597-021-00846-6

Sadia, H., et al. (2016). Gender-sensitive public health risks and vulnerabilities assessment with reference to floods in Pakistan. *International Journal of Disaster Risk Reduction, 19*, 47–56. https://doi.org/10.1016/j.ijdrr.2016.08.024

Sarker, A. A., & Rashid, A. K. M. M. (2013). Landslide and flashflood in Bangladesh. In R. Shaw, F. Mallick, & A. Islam (Eds.), *Disaster Risk Reduction Approaches in Bangladesh* (pp. 165–189). Tokyo: Springer Japan (Disaster Risk Reduction). https://doi.org/10.1007/978-4-431-54252-0_8

Sarker, A. R., et al. (2021). Households out-of-pocket expenditure for healthcare in Bangladesh: A health financing incidence analysis. *The International Journal of Health Planning and Management, 36*(6), 2106–2117. https://doi.org/10.1002/hpm.3275

Sengupta, S., & Manik, J. A. (2020) A quarter of Bangladesh is flooded. millions have lost everything. *The New York Times*, *30*. Retrieved March 23, 2021, from https://www.nytimes.com/2020/07/30/climate/bangladesh-floods.html

UNFPA Bangladesh. (2020). *Annual Report 2019, Progress and Highlights*. Annual Report. Dhaka, Bangladesh. Retrieved March 4, 2021, from https://bangladesh.unfpa.org/sites/default/files/pub-pdf/UNFPA%20Bangladesh%20-%20Annual%20Report%2020b19%20-%20eVersion%20-%20Low%20Resolution.pdf

WHO. (2016). *WHO recommendations on antenatal care for a positive pregnancy experience*. World Health Organization.

WHO. (2019). *Trends in maternal mortality 2000 to 2017 estimates by WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division*. World Health Organization.

Winsemius, H. C., et al. (2018). Disaster risk, climate change, and poverty: Assessing the global exposure of poor people to floods and droughts. *Environment and Development Economics, 23*(3), 328–348. https://doi.org/10.1017/S1355770X17000444

Zahran, S., et al. (2013). Abnormal labor outcomes as a function of maternal exposure to a catastrophic hurricane event during pregnancy. *Natural Hazards, 66*(1), 61–76. https://doi.org/10.1007/s11069-011-0065-5