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Childbearing in a changing climate: A
quantitative analysis of how extreme weather
events affect access to maternal healthcare in
Bangladesh

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Abstract

Climate change is causing a myriad of new challenges in global health; in Bangladesh, extreme weather events (EWEs) are hypothesised to be creating physical, financial and psychological barriers to maternal healthcare access. This paper contains the first comprehensive, quantitative, population-level study of this relationship; by analysing combined DHS and EM-DAT data from 1989-2017 in a multilevel multivariate logistic regression. It finds that experiencing any, intense or repeated EWEs during pregnancy impacts access to antenatal care, c-sections, institutional delivery, being told about or experiencing pregnancy complications. Therefore, policy is required to mitigate against the differential impacts of climate change on women's health.

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Abbreviations

AL1	Administrative Level 1
ANC	Antenatal care
EM-DAT	Emergency Events Database
EWE	Extreme weather event
CRED	Centre for Research on the Epidemiology of Disasters
DHS	Demographic and Health Survey
GDIS	Geocoded Disasters Dataset
HCP	Healthcare professional
IPCC	Intergovernmental Panel on Climate Change
LMIC	Lower-middle income country
MMR	Maternal mortality ratio
MH	Maternal health
MHC	Maternal healthcare
MOHFW	Ministry of Health and Family Welfare (Bangladesh)
NIPORT	National Institute of Population Research and Training (Bangladesh)
SDG	Sustainable Development Goals
SDH	Social determinants of health
UN	United Nations
UNEP	United Nations Environmental Program
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WHO	World Health Organisation

1. Introduction

Extreme weather events (EWEs), including storms and flooding, are increasing in intensity, frequency and magnitude due to anthropogenic climate change (IPCC 2019). Bangladesh is geographically prone to storms and flooding, as it has low-lying topography, multiple river deltas and heavy monsoon rainfall (Letsch, Dasgupta, and Robinson 2023; Rimi et al. 2019). This means that 60% of the country is exposed to a high flood risk, inducing significant social, economic and environmental costs (Mojid 2020; Ebi et al. 2021). EWEs contribute towards a variety of direct and indirect effects on health, including waterborne diseases, malnutrition and mental stress (Curtis et al. 2017; Stern 2006; Leal Filho et al. 2022). Notably, they can interrupt access to maternal healthcare (MHC), by creating transport difficulties, displacement, damaged healthcare facilities, financial loss, and psychological barriers (Wright et al. 2023). This interrupted access to MHC increases the risk of complications and mortality for both mother and child (Baten et al. 2020). In Bangladesh, this threatens progress in reducing the maternal mortality ratio (MMR), which remains high at 123 deaths per 100,000 live births, and socioeconomically unequal (World Bank Group, n.d.a.; Hossain et al. 2023).

Until now, literature exploring the differential risk of EWEs for women has consisted of scoping reviews or limited short-term studies. There is a notable absence of research with population-level analysis, despite this being essential for policy and planning. To address this gap, this paper assesses whether storms and flooding in Bangladesh between 1989-2017 have affected access to MHC. Emergency Events Database (EM-DAT) data and Demographic and Health Survey (DHS) calendar data are combined to find the exposure of pregnant women to any, intense or repeated EWEs. The correlation between this exposure and access to MHC, along with relevant control variables, are then analysed using a multilevel multivariate logistic regression.

This paper aims to provide quantitative analysis of how climate change differentially impacts women in Bangladesh via their health outcomes. In doing so, it will contribute towards the academic agendas of feminist environmental justice and planetary health, by quantifying the interconnectedness of women's and environmental wellbeing. Furthermore, it can be used to formulate more successful policy responses to mitigate the effect of EWEs on women and children's health.

2. Literature review

2.1 Climate change and EWEs

Climate change refers to long-term shifts in weather and temperature patterns, which since the 1800s have been affected by anthropogenic activities (United Nations, n.d.). The United Nations Environmental Program's (UNEP) current projections suggest that there will be a global increase in average temperatures of 2.5-2.9°C above pre-industrial levels by 2100 (UNEP 2023b). This will generate a range of meteorological effects including more EWEs like flooding, storms, droughts and extreme temperatures. Climate change has increased the intensity, frequency and magnitude of EWEs since the 1800s, with the annual number of EWEs having increased fivefold in the past 50 years (IPCC 2019; World Meteorological Organisation 2021). This has devastating social, economic and environmental impacts; in 2019 alone, 369 EWEs killed 1,755 people, affected 95 million others and cost nearly US\$130 billion globally (Ebi et al. 2021).

Flooding and storms are the most common types of EWEs, accounting for 68% of all people affected by EWEs in 2019 (Mallett and Etzel 2018; Ebi et al. 2021). In the past 30 years, flooding has killed 200,000 people and affected 2.8 billion others (Mallett and Etzel 2018). In particular, flooding and storms generate high numbers of displaced peoples; with predicted climate change of around 3°C by 2050, 200 million people are estimated to be displaced due to flooding (Stern 2006). Climate change directly and indirectly impacts both types of EWEs, by causing rising sea levels, melting glaciers and sudden shifts in regional weather patterns such as the monsoon or El Nino (Stern 2006). Therefore, like all other EWEs, the number of floods and storms globally are expected to increase (Stern 2006).

Climate change and consequent EWEs will challenge the basic elements of human life, such as access to water, food, health, land use and the environment (Stern 2006). Therefore, research on EWEs, and floods and storms in particular, is required to mitigate potentially devastating future impacts.

2.2 Climate change and health

Health is often understood via its physiological manifestations or risk factors, such as diet, exercise or health-seeking behaviours (Link and Phelan 1995). Both operate on the individual scale and so limit analysis of the broader factors which contribute to health outcomes. These broader factors are more effectively accounted for by the social determinants of health theory (SDH), which is mainstream in health research and states that social conditions like housing, income, education, working conditions, conflict and food insecurity influence health outcomes (Link and Phelan 1995; WHO n.d.c). The WHO (n.d.c.) reports that SDH accounts for 30-55% of health outcomes, making them more influential than healthcare or risk factors. Underlying these social determinants are broader structural inequities in power, money and resources; therefore, the WHO Global Commission on the SDH conclude that social injustice is severely inhibiting good health (WHO 2008; Donkin et al. 2018).

Climate change has been posited as the biggest global health threat of the 21st century (Duus and Montag 2022). Climate change is having direct and indirect effects across all of the physical, institutional and social infrastructures which constitute the health system (Curtis et al. 2017). Direct impacts include: malnutrition, heat stress, water contamination, vector-borne diseases and the mental health impact of losing homes, families and communities (Curtis et al. 2017; Stern 2006; Leal Filho et al. 2022). Indirect effects include: damaged infrastructure, food shortages, interruptions of medical supplies, loss of healthcare professionals (HCPs), lack of electricity or safe water for care, loss of social networks and lack of access to healthcare facilities (Orderud 2023; Mroz et al. 2023; Pappas, Kovats, and Ranganathan 2024; Haque, Parr, and Muhidin 2020a; Wright et al. 2023). Lack of access to healthcare can be caused by geographical barriers due to displacement or lack of transport; physical barriers due to the destruction of the facilities; financial barriers due to economic loss experienced in the EWE; or psychological barriers due to the fear of danger in accessing care (Wright et al. 2023).

In order to explore how climate change affects human health, scholars have used the theory of 'planetary health' (S. S. Myers 2017; Horton et al. 2014). This identifies that human-driven changes to the environment, via pollution, altered land use or biodiversity loss, impact human health (S. S. Myers 2017). Therefore, the health of the planet and of humans should be understood as interconnected and interdependent. Planetary health necessitates research into the effect of climate change on health, in order to develop solutions to promote good environmental and human health outcomes (S. Myers and Frumkin 2020). This relationship is already receiving greater research and policy attention, but the United Nations Environmental Program (UNEP 2023a) has still identified a significant gap in global health adaptation.

By combining the SDH and planetary health theories, we can see that the effects of the environment on health often operate through pre-existing social conditions. This supports the argument that the health risks from climate change are not experienced uniformly, but instead mediated by physiological, cultural and socioeconomic vulnerabilities (Lemery, Knowlton, and Sorensen 2021; Orderud et al. 2022).

2.3 Climate change and women's health

Women have physiological differences which cause climate change and EWEs to have augmented and differential impacts on their health, ranging across sexual maturation, fertility, pregnancy outcomes, lactation, breastfeeding and menopause (Chalupka, Latter, and Trombley 2023). For example, pregnant women are more likely to experience heat-induced hypertension and exhaustion because pregnancy affects thermoregulation (Desai and Zhang 2021; Girardi and Bremer 2022). Pregnant women are more susceptible to viruses like Zika and Dengue fever, which can cause

microcephaly, central nervous system malformations and intrauterine growth restrictions in their children (Wright et al. 2023). Furthermore, stress during pregnancy can impact the child through preterm delivery, congenital abnormalities and altered neurodevelopment (Pandipati and Abel 2023; Sun et al. 2020; Harville, Xiong, and Buekens 2010; Iqbal, Iqbal, and Babar 2023; Parayiwa and Behie 2018). These impacts on children extend the immediate effect of climate change on women's health into lifelong effects for future generations (Chalupka, Latter, and Trombley 2023; Ha 2022; Pandipati and Abel 2023).

However, women's vulnerability to poor health is not just physiological; it is also increased by pre-existing SDHs, including lower socioeconomic status, domestic violence, sexual assault, expectations around social roles, less land ownership, lower educational status and greater care responsibilities (Orderud 2023; Sorensen et al. 2018; Desai and Zhang 2021). These reduce women's ability to prepare for, mitigate and react to climate change and its adverse impacts on their health. As a result, EWEs kill three times more women than men on average, and at younger ages (Neumayer and Plümper 2007; Kuehn and McCormick 2017; Carballo et al. 2005).

Meanwhile, the services required to ensure women's health, including safe sanitation facilities, contraception and termination services, and perinatal care, are frequently interrupted by EWEs (Sharma et al. 2022; Sorensen et al. 2018). Sexual and reproductive health (SRH) is generally deprioritised during and after EWEs, when the government's focus is on infectious diseases, common child illnesses and general patient care (Women Deliver 2021; Purno et al. 2023; Baten et al. 2020). This leads to preventable maternal and newborn morbidity and mortality; increased transmission of STDs including HIV/Aids; and a rise in unplanned pregnancies (Orderud 2023).

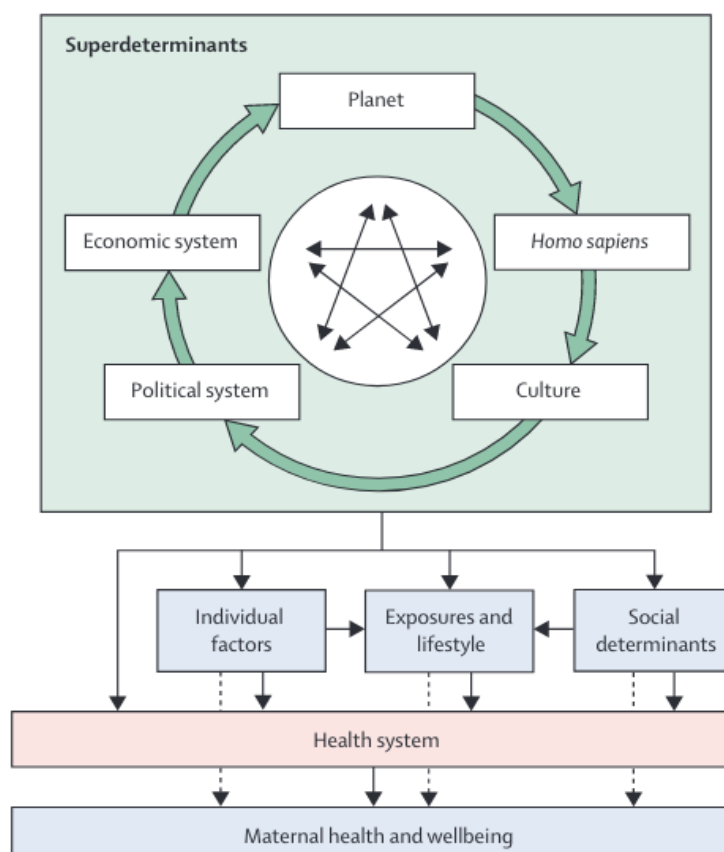
This established relationship between climate change and women's health is evidence for feminist environmental justice theory. Instead of understanding climate change as a human crisis in which gender is irrelevant (MacGregor 2010), constructivist ecofeminists believe that women and nature are being subordinated by the same processes, including capitalism, colonialism or racism (Merchant 1990; Mies and Shiva 1993; Phillips 2018). Feminist environmental justice builds on ecofeminism, by arguing that gender and climate justice must be won together because gender inequalities intensify vulnerability to the impacts of climate change, which in turn undermine women's rights (Gaard 2015; Turquet et al. 2023; Buckingham 2004). Feminist environmental justice responds to Tanyag's (2020) call for planetary health and ecofeminism to be considered together, in order to move beyond viewing health, gender equality and climate change as siloed, but instead as interconnected. To achieve feminist environmental justice, the UN Women's framework calls for redistribution, recognition, reparation and representation (Turquet et al. 2023). Research into this relationship and its effects is a form of recognition and is essential for developing policies for reparation and redistribution.

2.4 Access to maternal healthcare

Maternal health (MH) refers to the ‘health of women during pregnancy, childbirth and the postpartum period’ (WHO n.d.b: n.p.). The determinants of MH can be individual, such as diet or attendance to antenatal care (ANC) appointments, however this is situated within SDHs including poverty, healthcare policies and more (Pappas, Kovats, and Ranganathan 2024). The most common types of poor MH are infection, high blood pressure and obstructed labour (Pappas, Kovats, and Ranganathan 2024).

In their global analysis of the determinants of MH, Souza et al. (2024) extend the SDH theory by introducing ‘super-determinants’ of health: the ‘underlying contexts and forces that broadly influence the health and wellbeing of women before, during and after pregnancy’ (307). Notably, one super-determinant they propose is the ‘planet’, which they specify encompasses the effect of anthropogenic climate change on MHC (308). As seen in Figure 1, these super-determinants influence and interact with individual factors, exposures and lifestyle, and SDH. Their combined impact on MH and wellbeing is mediated by the health system, which can be a protective factor in neutralising or minimising the effects of risk factors (Souza et al. 2024).

Figure 1: Diagram of Souza et al. 's (2024) conceptualisation of the maternal health production process (Source: Souza et al., 2024).



Therefore, Souza et al.'s (2024) theory of super-determinants highlights the importance of access to healthcare in mitigating the potentially negative effects of SDH's, including climate change, on health. Using ideas from Gulliford et al. (2002), Leone et al. (2019: 2) define adequate access to healthcare as an 'uninterrupted supply of services that are affordable, reachable and contextually and culturally acceptable'. Access to MHC is a key indicator of a functioning health system and is used as a target for ensuring 'healthy lives' in Sustainable Development Goal 3 (Travis et al. 2004; UN Department of Economic and Social Affairs, n.d.). This is commonly measured through the maternal mortality ratio (MMR), the coverage of ANC, the place of delivery and rate of caesarean sections. Low utilisation of ANC and institutional births negatively affects the frequency and quality of care, thus increasing the MMR (NIPORT 2016; Begum and Hamid 2023). Greater access to c-sections can reduce maternal and neonatal mortality; however, use without need puts women at greater risk of long-term health problems (NIPORT 2020). Together, these indicators can be used to assess access to and quality of MHC, and of the health system more broadly.

As with other health issues, responses to poor MH have focused on the biomedical causes or risk factors (Souza et al. 2024). Much is still unknown about how MH interventions are affected by socio-demographic, economic, cultural, environmental and epidemiological shifts (Singh et al. 2022). Souza et al.'s (2024) theory of super-determinants begins to address this, by incorporating ideas from planetary health and feminist environmental justice to emphasise the effect of the environment on MHC.

2.5 Study setting: Bangladesh

Bangladesh was ranked the seventh most climate-change-affected country between 2000 and 2019 in the Global Climate Risk Advisory (Eckstein, Künzel, and Schäfer 2021). Since 2000, the number of EWEs in Bangladesh has increased by 46% (Mahmud, Hossain, and Raza 2021). Bangladesh is particularly vulnerable to flooding, as two thirds of the country is under five metres above sea level, and nearly 80% of the land surface is covered by the floodplains of the Ganges, Brahmaputra and Meghna rivers (Letsch, Dasgupta, and Robinson 2023). This means that floods currently submerge 20-25% of Bangladesh's land annually and 60% of the population live in areas with high flood risk (Letsch, Dasgupta, and Robinson 2023). This will be exacerbated by the more intense monsoon rainfall and rising sea levels expected due to climate change (Letsch, Dasgupta, and Robinson 2023; Rimi et al. 2019). The World Bank Group (n.d.b.) estimates that responding to the threat of climate change in the medium-term will cost Bangladesh over US\$12.5 billion (approximately 3% of their annual GDP).

Figure 2: MMR in Bangladesh, South Asia and the World 2000-2020 (Source: World Bank Group, n.d.a.).

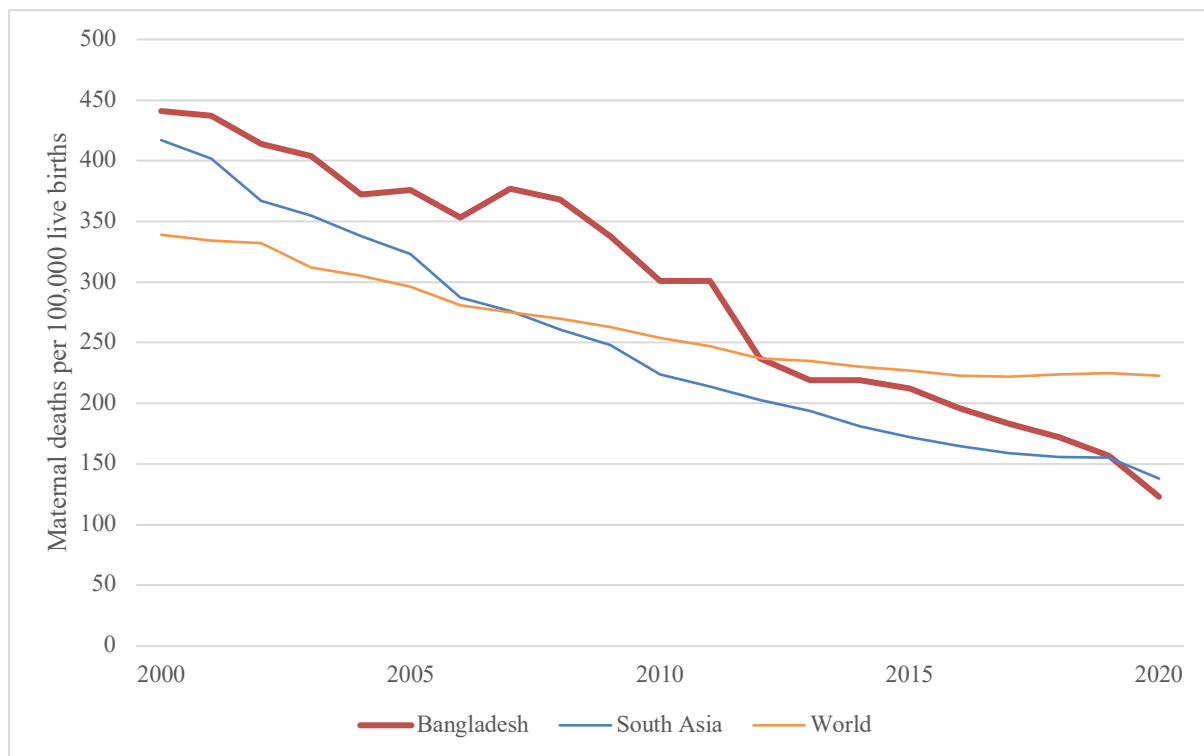
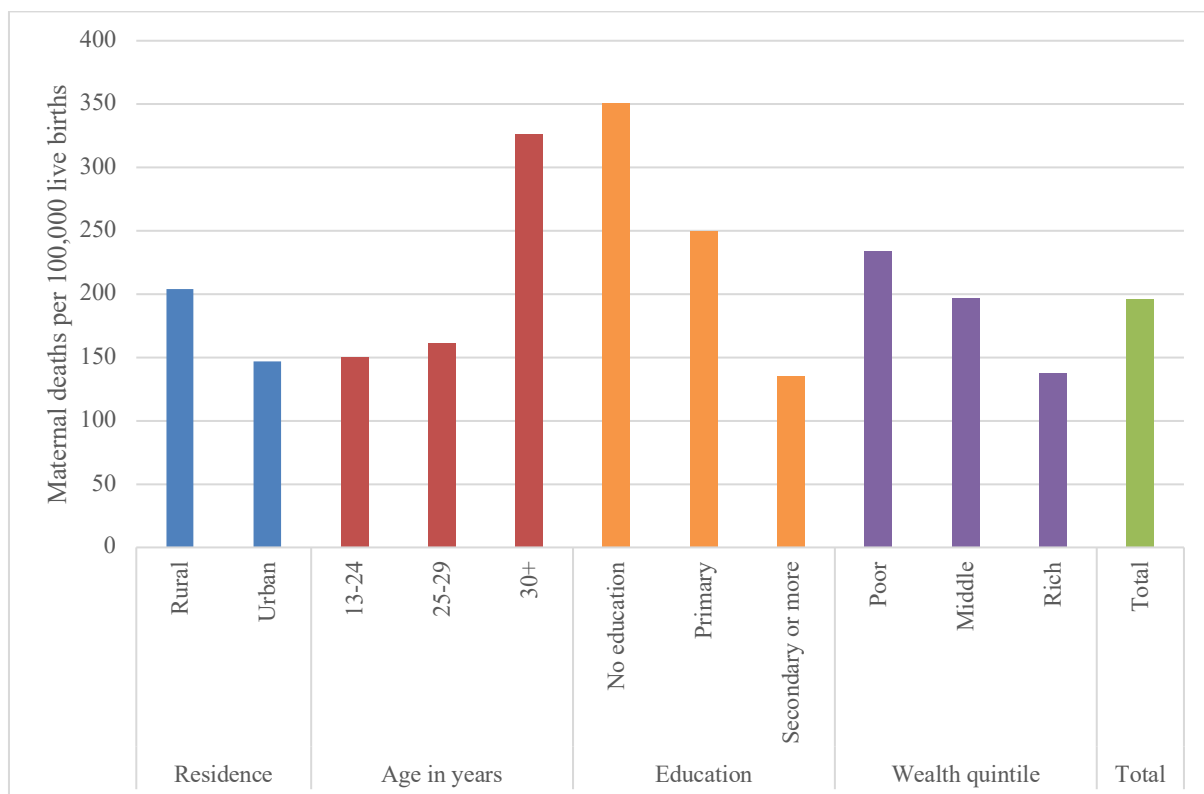


Figure 3: MMR by background characteristics in Bangladesh in 2016 (Adapted from: Hossain et al., 2023).



Bangladesh's maternal mortality ratio (MMR) was higher than the global and South Asian averages until 2012 and 2019 respectively (Figure 2). In 2017, the government pledged to reduce the MMR to 121 deaths per 100,000 live births by 2022 (MOHFW 2017). This was to be achieved through the distribution of family planning methods, supplementary vitamins during pregnancy, vaccinations, the establishment of community clinics, training skilled birth attendants, and increasing the Maternity Allowance Program (Haque, Parr, and Muhidin 2020b). The latest available figures show that the MMR in Bangladesh has reduced to 123 deaths per 100,000 live births, suggesting that they are on track to reach their goal (World Bank Group n.d.a). However, there are significant inequalities in this ratio, as mortality in pregnancy and childbirth is much higher amongst rural, older, less educated and poorer women (Figure 3). Therefore, MHC and outcomes are differentiated by the same pre-existing socioeconomic inequalities that mediate the effect of EWEs.

2.6 Research gap

In Bangladesh, there have been several recent studies beginning to explore the effect of EWEs on MCH. In 2019, Abdullah et al. studied focus groups in the Netrokona district of Bangladesh and found a common perception that maternal mortality increased during flooding events due to poor MHC access. In 2020, two studies found that women displaced multiple times by floods or living in higher-flood prone areas utilised ANC less (Haque, Parr, and Muhidin 2020b; Baten et al. 2020). Then, Begum and Hamid (2023) found that in disaster-prone areas skilled birth attendance and institutional deliveries were lower, perhaps due to lower utilisation of private healthcare facilities. These studies all provide evidence that EWEs have a negative impact on MHC access and usage.

However, similar studies found an inverse relationship: that EWE mitigation efforts by the government, humanitarian agencies and NGOs led to increased access to and usage of ANC amongst EWE-affected women (Orderud et al. 2022; Baten et al. 2020; Begum and Hamid 2023). This additional provision offset any negative effect of EWEs on MHC access, instead increasing the number of women who had at least the WHO-recommended four ANC visits during their pregnancies (WHO n.d.a). Furthermore, Orderud et al. (2022) added that lower MHC usage in flood-prone areas was a result of pre-existing characteristics like rural residences, lower socioeconomic status, and more.

Therefore, the relationship between EWEs and MHC in the literature is not yet fully established (Orderud et al. 2022; Pappas, Kovats, and Ranganathan 2024; Begum and Hamid 2023; Baten et al. 2020). Other existing reviews on the impacts of EWEs tend to focus on birth outcomes rather than the health of the mother, so Pappas et al. (2024) call for more research into MHC itself. Moreover, many

of these studies are carried out in the Global North, despite lower-middle income countries (LMICs) in Asia being highly EWE-prone and often having lower MCH coverage (Ebi et al. 2021). Finally, the number of scoping reviews referenced in this research reveals the reliance on qualitative research in this field, with a marked lack of high-quality quantitative research.

Within Bangladesh, the available studies present a complex relationship between EWEs and MHC, and are limited to specific regions, shorter-time periods or certain criteria like frequency of flooding. This limits their interpretation at the population scale, which is essential to improve national policy and planning for future EWEs (Karacsonyi and Taylor 2021; Orderud 2023).

Therefore, this project will address a gap in the literature for quantitative studies on the effect of EWEs on MHC access in an LMIC, at the national level, across a longer-time period, and incorporating different criteria such as frequency and intensity of flooding. This will contribute towards planetary health scholarship, by quantifying the relationship between the environment and human health. It will also support the feminist environmental justice movement's interest in recognising the differential impact of climate change on women's health, promoting the need for a gendered perspective into climate change adaptation plans (Sorensen et al. 2018; Ebi et al. 2021).

Finally, there was a recurrent theme in the literature that pregnant women felt that their needs were overlooked in the aftermath of EWEs (Pappas, Kovats, and Ranganathan 2024; Abdullah et al. 2019). Therefore, the primary motive of this research is to reprioritise their experiences and contribute towards more attentive policy responses in the future.

2.7 Research questions

The research questions chosen for this paper are:

1. How is access to MHC affected by floods and storms in Bangladesh?
2. How does the frequency of the events affect access?
3. How does the intensity of the events affect access?

3. Methodology

3.1 Feminist methodology

As this paper aims to contribute towards feminist environmental justice by recognising and responding to the differential impacts of climate change on women's health, it is important to extend

this feminist consideration to the methodology. Feminist methodologies are useful for exploring inequalities through intersectionality, positionality and critical assessment of all aspects of the research process which might unintentionally reinforce invisibility and vulnerability. In particular, this paper follows DeVault's (1996) three aims of feminist methodologies: 1) revealing the perspectives of women; 2) minimising harm in the research process; and 3) producing research that is of value to women. It is noted that feminist critics have historically argued that many demographic and quantitative studies lack these three qualities, leading to misrepresentation of women's experiences (Watkins 1993; Sigle 2021). This methodology attempts to reconcile these established oppositions, by considering DeVault's aims throughout the quantitative research process, from the design to the analysis.

Literature on climate change is often focused on science and technology, thus disregarding feminist concerns which are perceived as being less empirical (Echavarren 2023; Gaard 2015). This limits our understanding of how climate change and gender equality are interconnected (Tanyag 2020). Therefore, Turquet et al. (2023) call for the innovative use of existing quantitative data, particularly household survey and geospatial data, to achieve feminist environmental justice. This paper aims to fill this gap, by exploring the existing EM-DAT and DHS datasets to produce new gender-sensitive research outputs.

3.2 Data

DHS Data

The DHS survey was established by the United States Agency for International Development (USAID) in 1984, with the objective of improving the 'collection, analysis and dissemination of population, health and nutrition data' (DHS Program n.d.: n.p.). The survey uses a stratified two-stage cluster design, whereby a sample of households is surveyed in each enumeration area in the census (DHS Program n.d.a). Therefore, the survey is representative at the national and regional levels, as well as by urban or rural residence.

The Women's Survey is based on women of reproductive age (15-49 years), and includes questions on reproduction, pregnancy, postnatal care, marriage, sexual activity, and health issues. The calendar data is supplementary to the Women's Survey and records a month-by-month history of reproductive events for five years preceding the date of the interview. It includes births, pregnancies, terminations, contraceptive use and reasons for discontinuation of contraceptive use (DHS Program 2018). The calendar can be linked to background characteristics in the Women's Survey or to other contextual data like climate variables to study their influence (Boyle, Rotem, and King 2023).

EM-DAT and GDIS

The EM-DAT is created by the Centre for Research on the Epidemiology of Disasters (CRED). It contains over 26,000 natural and technological disasters since the 1900s, which meet the criteria of having a) at least 10 fatalities; b) 100 affected people; c) a declaration of a state of emergency; or d) a call for international assistance (CRED n.d.). EM-DAT includes the start date, location, disaster classification and number of people affected by each event. Locations are recorded at the Administrative Levels (AL) 1, 2 and 3 depending on the event.

The Geocoded Disasters Dataset (GDIS) is an extension to EM-DAT with 39,953 locations for 9,924 unique disasters between 1960 and 2018 (Rosvold and Buhaug 2021). The locations are recorded as GIS polygons with centroid latitude and longitude coordinates for each administrative area. This allows for more accurate calculation of exposure to EWEs, which is essential in analysing the impact of these events.

3.3 Study sample

Bangladesh was chosen as the study site because it has the best available data from the DHS, with 8 rounds of the survey in 1994, 1997, 1999, 2004, 2007, 2011, 2014 and 2017. This enables analysis of the effect of EWEs on MHC access over a period of 28 years. Lastly, as detailed in the literature review, Bangladesh needs research to address their high MMR and the increasing risk of EWEs.

3.4 Variables

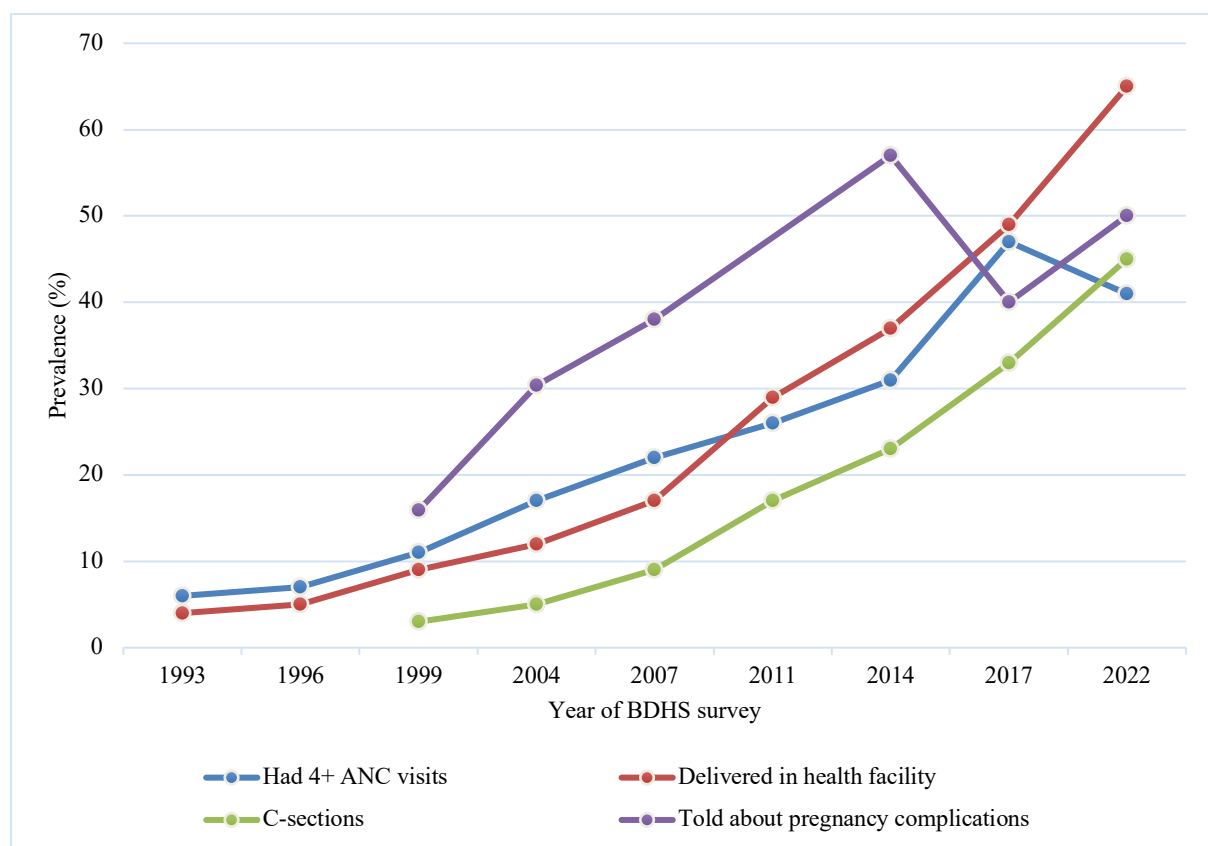
The independent variables chosen are whether the woman experienced an EWE during her pregnancy; the intensity of that EWE; and experiencing repeated EWEs (Table 1). These were coded as binary variables using 0 as no and 1 as yes. The magnitude of the event in wind speed (kph) or flood level (km²) were not available for all disasters in EM-DAT, so as per Orderud et al.'s (2022) method this paper uses the threshold of 1 million people being affected as a proxy for intensity. This information was taken from EM-DAT, by combining the variables containing the number of people killed and affected to create a new variable.

Five dependent variables were chosen to represent access to healthcare, and each coded as a binary variable to prepare them for analysis via logistic regression (UCLA 2024). These variables are: having at least four ANC visits; a c-section; an institutional delivery; being told about pregnancy complications; or experiencing them (Table 1).

ANC visits were coded as 0 if the individual had less than four visits, or 1 if they had four or more. The threshold of four ANC visits is recommended by the WHO because it increases the likelihood

that the mother will receive effective MHC interventions (WHO n.d.a). This was updated to eight visits in 2016, however four is still used in this paper because it is the standard for most of the study period and continues to be used as a WHO indicator (UNICEF 2024). In 2017, Bangladesh pledged to increase their coverage of women having at least four ANC visits to over 50% by 2022 (NIPORT 2020), but instead it fell from 47% in 2020 to 41% in 2022 (DHS Program 2023). This coverage is geographically and socioeconomically differentiated, as women aged below 20, having first order births, living in urban areas, and with greater education and wealth are more likely to have adequate coverage (NIPORT 2016; 2020).

Figure 4: MHC access in Bangladesh 1993-2002 (Source: NIPORT 2020; DHS Program 2023).



C-sections were coded as 0 if the individual did not have a c-section, and 1 if they did. The number of c-sections in Bangladesh has increased from 23% in 2014 to 45% in 2022 (Figure 4). This measure is more complicated to interpret because the potential for short and long-term complications of non-medically necessitated c-sections outweighs the potential benefits (NIPORT 2020). In Bangladesh, 83% of births in private facilities were via c-section, and 48% of those c-sections were decided before the onset of labour (NIPORT 2020). As the rates are significantly higher in private facilities, they may be driven by financial efficiency for the hospital rather than medical necessity. Therefore, increases in delivery by c-section suggest improved access to MHC, but requires careful interpretation.

Place of delivery was coded as 0 if the birth took place at the respondent's home, or 1 if it was in an institution. The types of institutions varied by survey, but included private medical colleges, healthcare centres and district hospitals. In 2022, 65% of mothers in Bangladesh delivered at a health facility, 45% of which were private and 18% public (DHS Program 2023). The rate of institutional delivery is still far below the average among developing countries, and the reliance on private facilities remains a financial barrier to MHC access for many (Begum and Hamid 2023; Purno et al. 2023). In 2017, women in the highest wealth quintile were three times more likely to deliver at a health facility (NIPORT 2020). Therefore, like ANC coverage, the place of delivery is mediated by community and individual-level factors including: residential area, wealth, education, parity and knowledge of available services (Begum and Hamid 2023).

Being told about pregnancy complications was coded as 0 if the respondent was not told, and 1 if they were. This variable is one of three indicators of quality ANC defined by the DHS, along with measurement of weight and blood pressure, and testing of blood and urine (DHS Program 2023). In 2022, 90% of pregnant women in Bangladesh had their blood pressure and weight measured and 80% had their blood and urine measured; however, only 50% received information on pregnancy complications (DHS Program 2023). As being told about pregnancy complications is less universal in Bangladesh, it has been chosen to represent the overall quality of ANC provided. This information was only available for certain DHS surveys between 1999 and 2017.

Experiencing pregnancy complications is the only MHC outcome data used in this paper and reflects whether the women had any direct negative health impacts. It was coded as 0 for women who said they did not experience any complications, and 1 if they did. The question and possible answers were different across DHS surveys - some asked a blanket question about any complications whilst others recorded individual complications such as heavy bleeding, convulsions or pre-eclampsia - so were re-coded for continuity. This data was also only available in DHS surveys between 1993 and 1999.

The control variables used are: parity, mother's age, marital status, residence (urban or rural), highest education level and wealth index. These were chosen based on similar studies of MHC access in Bangladesh (Baten et al. 2020; Haque, Parr, and Muhidin 2020b; Orderud et al. 2022; Begum and Hamid 2023). Parity is coded as no prior children or at least one prior child. Age of the mother at birth is coded into categories of >19 years, 19-23 years, 23-28 years and over 28 years (Haque, Parr, and Muhidin 2020b). All other control variables were left as recorded in the DHS dataset.

Table 1: Descriptive statistics of variables used in analysis (Source: Own calculations).

Type of variable	Variable	Category	Number	Percent (%)	Total
Control	Age	<19	5261.3	9.0	58459
		19-23	14848.6	25.4	
		24-28	18239.6	31.2	
		28+	20109.9	34.4	
	Residence	Urban	15900.8	27.2	58459
		Rural	42558.2	72.8	
	Education	None	18413.6	31.5	58456
		Primary	17186.1	29.4	
		Secondary	18472.1	31.6	
		Higher	4384.2	7.5	
	Wealth index	Poorest	2765.3	21.8	12685
		Poorer	2524.3	19.9	
		Middle	2397.5	18.9	
		Richer	2283.3	18.0	
		Richest	2714.6	21.4	
	Marital status	Married	57348.3	98.1	58459
		Widowed	409.2	0.7	
		Divorced	292.3	0.5	
		Separated	409.2	0.7	
	Parity	0	14790.1	25.3	58459
		1 or more	43668.9	74.7	
Independent	EWE	No	22682.1	38.8	58459
		Yes	35718.4	61.1	
	Frequency	0	22682.1	38.8	58459
		1	20694.5	35.4	
		2	10230.3	17.5	
		3	3390.6	5.8	
		4	1110.7	1.9	
		5	292.3	0.5	
		6	5.8	0.0	
	Intense events	None	43201.2	73.9	58459
		1 or more	15257.8	26.1	
Dependent	No. of ANC visits	>4	32840.1	78.2	41995
		4 or more	9154.9	21.8	
	C-section	No	32500.6	86.5	37573
		Yes	5072.4	13.5	
	Institutional delivery	No	31462.6	65.9	44743
		Yes	16280.4	34.1	
	Told about pregnancy complications	No	21507.2	63.2	34052
		Yes	12531.1	36.8	
	Experienced pregnancy complications	No	15458.5	42.0	36,806
		Yes	21347.5	58.0	

3.5 Data analysis

The DHS calendar data for Bangladesh from all eight surveys, on 107,689 women, were combined into one dataset. This was re-coded into an event file format with one entry per pregnancy, totalling 58,459 pregnancies of 43,712 women. Women interviewed in multiple surveys were not removed because there were no duplicates of pregnancies. The start, end and duration of each pregnancy was calculated. EM-DAT data and GDIS data were merged together to add the geospatial information for 187 EWEs. This combined data was then merged with the DHS data by exposure to an EWE during pregnancy and AL1.

A multivariate logistic regression was run in Stata (using the melogit command) to find whether there is a correlation between exposure to an EWE during pregnancy and MHC access. A multilevel effects model was used with cluster and region to account for the hierarchical structure of the data. This

incorporates random effects which account for correlations within groups and variability between groups (Steele 2008).

3.6 Ethical considerations

The procedures and questionnaires for the DHS surveys have already undergone ethical clearance. The DHS Program uses informed and voluntary participation, and the data analysis maintains the privacy and confidentiality of all respondents (DHS Program, n.d.c).

3.7 Positionality

It is important to state my positionality as the researcher, in order to identify how this might affect my research design and interpretation of results (Sigle 2021). I am a white, British female studying at the London School of Economics and Political Science (LSE). My interpretation of the results of this paper is therefore limited by my outsider perspective to the lived experience of the women surveyed in the Bangladesh DHS. To mitigate the effect of my positionality, I have intentionally prioritised Bangladesh-based research when interpreting my results and actively questioned my immediate assumptions. This research is also driven by my identity as a woman, which leads me to pursue research for the benefit of other women. I hope that this research will honour the voices of those involved in the survey, whilst contributing to a base of research and policy development that will mitigate the effect of climate change on women's health globally.

3.8 Data limitations

This paper has several limitations, both due to the data available and the method of analysis.

Quantitative analysis

Overall, this paper employs quantitative analysis to explore the effect of EWEs on MHC, despite feminist methodologies highlighting the limitations of quantitative data in representing women's lived experiences (Turquet et al. 2023). Ideally, a mixed-method research design would have been used to overcome these limitations, however there was no relevant secondary qualitative data available and the scope of study prevented collection of primary qualitative data. Instead, this survey hopes to use quantitative data innovatively, by exploring an existing dataset to produce new gender-sensitive research outputs.

DHS data

This paper uses DHS calendar data, despite the DHS Women's Survey also having birth histories available. Initially, the calendar data was chosen because it contains more accurate birth outcomes data and includes pregnancies that end in termination, stillbirth or abortion (Riese and Zachary 2023;

Becker and Sosa 1992). However, preterm birth data in the calendar are limited by underreporting and the month-by-month style, which restricts more granular analysis of pregnancy length. Therefore, the preterm birth rate across the calendar is 30% lower than in other population sources (Lawn et al. 2010; Stanton et al. 2006), and when tested did not produce a statistically significant output. Stillbirths are also poorly recorded because they are conflated with miscarriages and terminations, which prevents analysis of the effect of EWEs on spontaneous birth outcomes. Therefore, the focus of this paper shifted from birth outcomes to MHC access, on which the DHS contains higher quality data. The DHS calendar data is underutilised in similar research because it is complex and requires advanced data analysis (Boyle, Rotem, and King 2023). Therefore, this paper chooses to use the birth histories from the DHS calendar data to explore possible future applications.

As the DHS calendar data is produced retrospectively, there is a risk that recall bias affects the accuracy of the recorded lengths of pregnancies. The consistency of calendar data is disputed; some researchers found that recall bias had more impact on calendar data than DHS birth histories (Bradley, Winfrey, and Croft 2015; Tumlinson and Curtis 2021) whereas others found it had less (Riese and Zachary 2023). Therefore, the calendar data is not considered to be of lower quality than other retrospective data sources.

There are also other factors which might influence healthcare access during an EWE, like distance to the nearest health facility or quality of local healthcare services. However, these are not in the DHS dataset so could not be included (Baten et al. 2020).

Feminist methodologies call on us to critically assess the survey construction and whom it may exclude (Fledderjohann and Barnes 2018). The DHS survey is sampled from ‘women’ aged 15-49, based on a question asking for the interviewee’s sex with the options ‘male’ or ‘female’. This could misrepresent or exclude transgender or gender-diverse people who also have reproductive capacity and require MHC. For example, the hijra community, who do not identify as male or female, were officially recognised by the Bangladeshi government in 2013 yet remain socially, economically and politically marginalised (Al-Mamun et al. 2022). No question in the DHS identifies hijra people, and so their experiences of maternal and other health access is invisibilised. Therefore, this paper refers to ‘women’ throughout, due to the data sampling and other research publications used, however it acknowledges other experiences which the methodology fails to adequately encompass.

Furthermore, previous literature recommends an intersectional approach to MHC research (Sharma et al. 2022). This paper has included some intersectionalities in the control variables, including wealth and urban or rural residence. However, it has not included ethnicity or race despite these being the focus of much intersectional analysis (Crenshaw 1991), because the Bangladeshi DHS does not

collect this data. This omission is somewhat justifiable in that 98% of Bangladesh is Bengali (Minority Rights Group 2023). However, the remaining 2%, made up of ethnic minority groups, may have distinct experiences of MHC and EWEs which could not be explored in this paper.

EM-DAT data

The EM-DAT also has limitations; the GDIS extension only has GIS polygons for 89.5% of storms and 92% of floods recorded in EM-DAT (Rosvold and Buhaug 2021). Although this coverage is still high, it means that around 1 in 10 events in EM-DAT were not included in this analysis. Furthermore, there is temporal bias in the EM-DAT data, with a strong increase in the number of events being recorded between 1960 and the present (Rosvold and Buhaug 2021). This increase is in part due to climate change and associated processes, but also due to greater information availability and awareness of recording EWEs. Therefore, it is likely that towards the beginning of the study period, there is relative under-recording of events in EM-DAT.

Exposure to EWEs

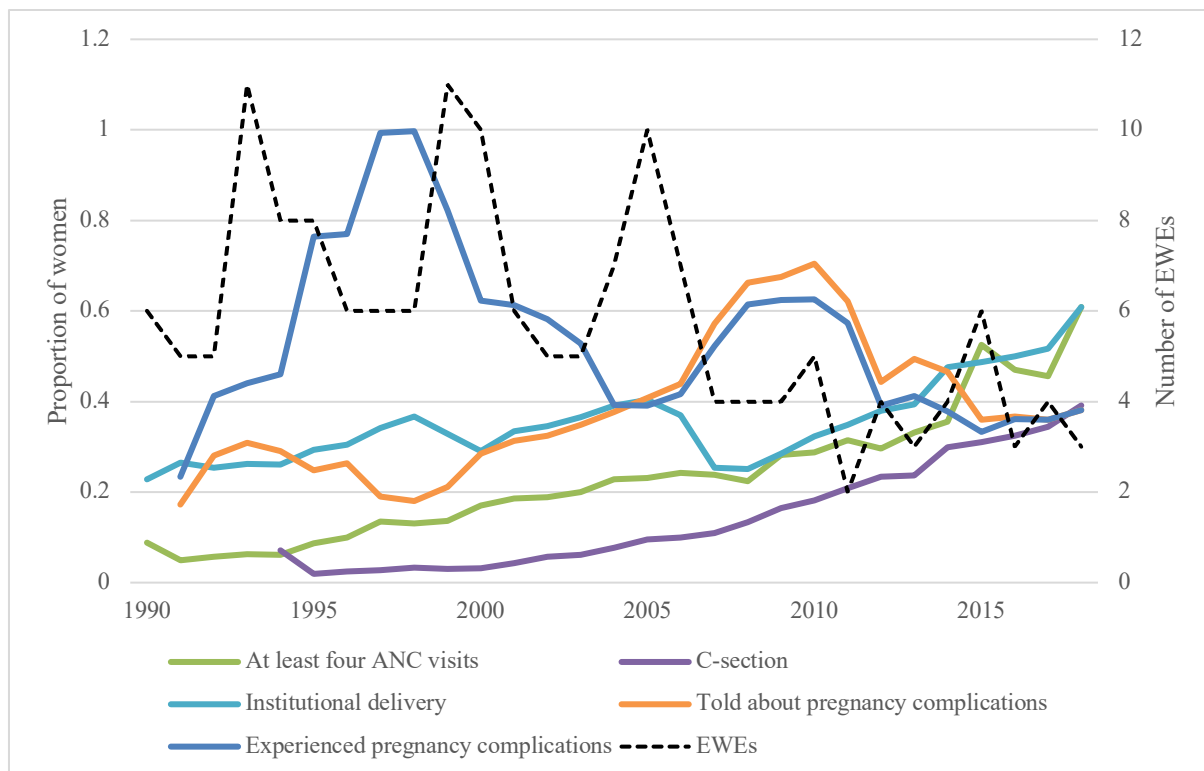
Exposure to the EWE may be overestimated because it is calculated at the AL1, however some disasters may not have affected this whole area. Nonetheless, the AL1 was used because this is the region (v024) used in the DHS and because the EM-DAT does not always include AL2 or AL3. Orderud et al.'s (2022) paper, which explores DHS and EM-DAT data, uses AL1 too.

Finally, the AL1 location recorded for each interviewee in the DHS survey is where they currently live at the time of interview. However, exposure to EWEs could lead to short or long-term migration due to immediate displacement or choosing to move somewhere with lesser risk. It is very possible therefore that people who experienced a disaster may have changed location since, and so their exposure to that disaster would not be included in this paper. Those experiencing short-term displacement must have moved back before taking part in the DHS survey or they would be unable to participate, so this effect is negligible (Orderud et al. 2022). However, the calendar data was chosen because it is restricted to births in the past five years, which lessens the likelihood of the interviewee having moved permanently between the birth and interview. This follows other papers which were restricted to births in the three years prior to the interview (Orderud et al. 2022; Haque, Parr, and Muhidin 2020b; Baten et al. 2020). Therefore, using the calendar data means calculation of exposure to the EWE is more accurate.

4. Results

4.1 MHC over time

Figure 5: Access to MHC and number of EWEs in Bangladesh 1990-2018 (Source: Own calculations using DHS and EM-DAT data).



The proportion of women receiving at least four ANC visits, having a c-section and having an institutional delivery all increased over the period 1990 to 2018. The proportion of women receiving at least four ANC visits increased the most, from 0.09 in 1990 to 0.6 in 2018. There was a particularly large increase from 0.36 to 0.53 between 2014 and 2015, and from 0.46 and 0.61 between 2017 and 2018. The largest proportion of women having at least four ANC visits and institutional deliveries in the period was recorded in 2018.

The proportion of women who reported experiencing pregnancy complications between 1991 and 2018 showed more variation. In 1996-1997, the data showed that all women reported some pregnancy complications. Since 2004, the proportion of women being told about and reporting pregnancy complications followed a similar trajectory.

Meanwhile, the number of EWEs between 1990-2015 has fluctuated greatly. In 1993, 2000 and 2005 there were at least 10 EWEs in Bangladesh. Since 2005, the number of EWEs has remained lower,

however there have still been frequent fluctuations of a lesser magnitude. The pattern of each MHC variable does not neatly match the pattern of EWEs experienced over time.

4.2 Experiencing any EWE

Table 2: Multilevel logistic regression results between experiencing an EWE during pregnancy and MHC access (Source: Own calculations using DHS and EM-DAT data in Stata).

	<4 ANC visits		C-sections		Institutional delivery		Told about complications		Experienced complications	
Variables	C	SE	C	SE	C	SE	C	SE	C	SE
EWE	-0.174*	0.067	-0.153	0.094	-0.141**	0.051	-0.182***	0.057	-0.010	0.052
Residence										
Urban					Reference					
Rural	-0.850***	0.097	-0.597***	0.115	-0.288***	0.085	-0.173**	0.080	-0.024	0.099
Maternal age										
<19					Reference					
19-23	0.273**	0.112	0.114	0.170	-0.112	0.081	0.073	0.094	0.209**	0.087
24-28	0.511***	0.123	0.609**	0.179	-0.437***	0.087	0.108	0.103	0.210**	0.093
28+	0.418**	0.132	1.022***	0.192	-1.007***	0.093	0.143	0.109	0.387***	0.097
Education										
None					Reference					
Primary	0.441***	0.100	0.804***	0.214	0.551***	0.063	0.299***	0.075	0.071	0.062
Secondary	1.284***	0.110	1.878***	0.203	1.090***	0.069	0.811***	0.080	0.434***	0.071
Higher	2.406***	0.134	2.722***	0.216	2.216***	0.116	1.204***	0.114	0.816***	0.114
Wealth index										
Poorest					Reference					
Poorer	0.208	0.133	0.010	0.289	0.022	0.075	0.036	0.094	0.004	0.075
Middle	0.444***	0.130	0.367	0.266	0.093	0.077	0.278**	0.093	0.115	0.077
Richer	0.836***	0.133	0.892***	0.248	0.224**	0.081	0.456***	0.094	0.316***	0.082
Richest	1.458***	0.133	1.810***	0.246	0.719***	0.092	0.635***	0.103	0.501***	0.095
Marital status										
Married					Reference					
Widowed	-0.655	0.404	0.279	0.526	-0.086	0.267	-0.468	0.315	-0.224	0.259
Divorced	-0.875	0.698			0.445	0.381	-1.127**	0.568	-0.657	0.437
Separated	-0.920**	0.381	0.016	0.510	0.889***	0.207	-0.601**	0.294	-0.219	0.223
Parity										
0					Reference					
1 or more	-0.439***	0.082	-1.131***	0.110	-0.818***	0.061	-0.059***	0.057	-0.603***	0.132

*** p<0.001 ** p<0.05 *p<0.1

Women who experienced an EWE during their pregnancy were significantly less likely to have at least four ANC visits (-0.174 p<0.1), to have an institutional delivery (-0.141 p<0.05) and to be told about pregnancy complications (-0.182 p<0.001). The greatest impact was the decrease in the number of women being told about pregnancy complications, with a coefficient of -0.182 (p<0.001). They were also less likely to report pregnancy complications (-0.010) and less likely to have a c-section (-0.153), however these were not statistically significant.

Women who experienced an EWE during pregnancy were also significantly more likely to have at least four ANC visits and an institutional delivery if they were more educated, wealthier and having their first child. Both having at least four ANC visits and having an institutional delivery were more common amongst women living in urban areas; however, older women were likely to have more ANC visits, and less likely to have an institutional delivery.

Women were significantly more likely to be told about pregnancy complications if they lived in an urban area, were more educated, wealthier, married and having their first child. However, there was not a significant correlation with age.

Having higher education had the greatest impact of all control variables; it increased women's likelihood of having more than four ANC visits (2.406 $p < 0.001$), a c-section (2.722 $p < 0.001$), an institutional delivery (2.216 $p < 0.001$), being told about pregnancy complications (1.204 $p < 0.001$) and experiencing them (0.816 $p < 0.001$).

4.3 Intense EWEs

Table 3: Multilevel logistic regression results between experiencing an intense EWE during pregnancy and MHC access indicators (Source: Own calculations using DHS and EM-DAT data in Stata).

	<4 ANC visits		C-sections		Institutional delivery		Told about complications		Experienced complications	
Variables	C	SE	C	SE	C	SE	C	SE	C	SE
EWE	0.183**	0.082	0.117	0.111	-0.013	0.058	0.081	0.066	-0.158**	0.059
Residence										
Urban					Reference					
Rural	-0.930***	0.116	-0.570***	0.135	-0.278***	0.091	-0.188**	0.088	-0.056	0.104
Maternal age										
<19					Reference					
19-23	0.234	0.143	0.306	0.215	-0.123	0.097	0.065	0.116	0.248**	0.104
24-28	0.365**	0.156	0.607**	0.227	-0.510***	0.104	0.178	0.126	0.307**	0.111
28+	0.374**	0.167	1.066***	0.242	-1.020***	0.111	0.179	0.132	0.447***	0.115
Education										
None					Reference					
Primary	0.383**	0.122	0.856***	0.247	0.548***	0.073	0.199**	0.112	0.014	0.071
Secondary	1.274***	0.122	1.757***	0.235	1.057***	0.081	0.758***	0.093	0.439***	0.083
Higher	2.435***	0.165	2.721***	0.251	2.169***	0.135	1.120***	0.134	0.721***	0.134
Wealth index										
Poorest					Reference					
Poorer	0.386**	0.171	0.539	0.360	0.075	0.089	0.200*	0.112	0.074	0.087
Middle	0.598***	0.167	0.797**	0.342	0.118	0.092	0.443***	0.110	0.188**	0.089
Richer	0.979***	0.163	1.094***	0.329	0.259**	0.095	0.628***	0.112	0.383***	0.095
Richest	1.729***	0.169	2.120***	0.324	0.797***	0.107	0.776***	0.112	0.527***	0.109
Marital status										
Married					Reference					
Widowed	-0.627	0.485	0.020	0.681	-0.278	0.329	0.077	0.342	0.015	0.311
Divorced	-0.514	0.787			0.095	0.463	-0.662	0.588	-0.310	0.497
Separated	-1.373**	0.525	0.350	0.525	0.754**	0.136	-0.515	0.329	-0.318	0.259
Parity										
0					Reference					
1 or more	-0.428***	0.102	-1.115***	0.131	-0.798***	0.072	-0.085	0.084	-0.005	0.076

*** $p < 0.001$ ** $p < 0.05$ * $p < 0.1$

Experiencing an intense EWE, one which affected over one million people, only had a significant relationship with the number of ANC visits (0.183 $p < 0.05$) and experiencing pregnancy complications (-0.158 $p < 0.05$). It was not significantly correlated with c-sections, institutional deliveries, or being told about pregnancy complications.

Women who experienced an intense EWE were significantly more likely to have at least four ANC visits (0.183 $p<0.05$). The likelihood was further increased if they were older, wealthier, more educated, living in an urban area, having their first child and not separated.

These women were also significantly less likely to report having pregnancy complications (-0.158 $p<0.05$). This was even lower amongst women who were younger, less educated and less wealthy, however there was no significant relationship with rural or urban residence, marriage status or parity.

Again, having higher education had the greatest impact on MHC access, increasing the likelihood of having at least four ANC visits (2.435 $p<0.001$) and reporting pregnancy complications (0.721 $p<0.001$).

4.4 Repeated EWEs

Table 4: Multilevel logistic regression results between experiencing repeated EWEs during pregnancy and MHC access indicators (Source: Own calculations using DHS and EM-DAT data in Stata).

	<4 ANC visits		C-sections		Institutional delivery		Told about complications		Experienced complications	
Variables	C	SE	C	SE	C	SE	C	SE	C	SE
EWE	0.101	0.080	0.115	0.107	0.088	0.056	-0.064	0.063	-0.067	0.056
Residence										
Urban					Reference					
Rural	-0.927***	0.116	-0.569***	0.135	-0.275**	0.091	-0.193**	0.088	-0.056	0.104
Maternal age										
<19					Reference					
19-23	0.234	0.143	0.308	0.216	-0.122	0.097	0.065	0.116	0.251**	0.104
24-28	0.369**	0.156	0.614**	0.227	-0.507***	0.104	0.177	0.126	0.311**	0.111
28+	0.380**	0.167	1.073***	0.242	-1.012***	0.111	0.175	0.132	0.449***	0.115
Education										
None					Reference					
Primary	0.384**	0.122	0.856***	0.247	0.547***	0.073	0.201**	0.087	0.012	0.071
Secondary	1.267***	0.122	1.752***	0.235	1.054***	0.081	0.761***	0.093	0.439***	0.083
Higher	2.426***	0.165	2.767***	0.251	2.168***	0.135	1.120***	0.134	0.725***	0.134
Wealth index										
Poorest					Reference					
Poorer	0.370**	0.171	0.534	0.360	0.076	0.089	0.197*	0.112	0.078	0.087
Middle	0.592***	0.167	0.797**	0.342	0.119	0.092	0.442***	0.110	0.186**	0.089
Richer	0.971***	0.163	1.091***	0.329	0.265**	0.095	0.621***	0.112	0.382***	0.095
Richest	1.717***	0.169	2.115***	0.324	0.798***	0.107	0.774***	0.122	0.528***	0.109
Marital status										
Married					Reference					
Widowed	-0.628	0.483	0.028	0.677	-0.283	0.329	0.074	0.341	0.025	0.311
Divorced	-0.554	0.787			0.101	0.464	-0.681	0.588	-0.113	0.496
Separated	-1.387**	0.526	0.341	0.526	0.753***	0.237	-0.522	0.330	-0.312	0.259
Parity										
0					Reference					
1 or more	-0.437***	0.101	-1.119***	0.131	-0.799***	0.072	-0.087	0.084	-0.005	0.076

*** $p<0.001$ ** $p<0.05$ * $p<0.1$

Experiencing repeated events had a positive relationship with having at least 4 ANC visits (0.101), a c-section (0.115) and an institutional delivery (0.088) and a negative relationship with being told

about (-0.064) or reporting pregnancy complications (-0.067). However, none of these were statistically significant.

Nonetheless, being in the highest wealth index and having higher education increased the likelihood of women accessing all the outcome variables. Wealth particularly increased the likelihood of having a c-section (2.115 $p<0.001$), whilst education had a large impact on having at least four ANC visits (2.426 $p<0.001$), having a c-section (2.767 $p<0.001$) and institutional deliveries (2.168 $p<0.001$).

All variables of MHC access were significantly lower in rural areas. ANC usage (0.380 $p<0.05$), c-sections (1.073 $p<0.001$) and reporting pregnancy complications (0.449 $p<0.001$) were significantly more likely amongst older women, whereas having an institutional delivery was significantly less likely (-1.012 $p<0.001$) and there was no significant relationship with being told about pregnancy complications. Women who already had a child were less likely to have at least 4 ANC visits (-0.437 $p<0.001$), a c-section (-1.119 $p<0.001$) and an institutional delivery (-0.799 $p<0.001$).

5. Discussion

This paper offers the first analysis of the effect of EWEs on access to MHC at the population level and on this timescale in Bangladesh. It builds on previous studies by including all storms and floods, differentiating the effect of intense and repeated EWEs, and using a wide range of MHC access outcome variables. Together, this produces a valuable contribution to wider literature on the effect of environmental change on women's health, which tends to be sparse, fragmented and qualitative. Furthermore, it represents the innovative data analysis requested by Turquet et al. (2023) to explore differential effects of environmental change on women, in order to drive feminist environmental justice.

The data from EM-DAT displayed in Figure 5 shows a decline in the number of EWEs experienced in Bangladesh between 1990-2018. This may be an underestimation of the true extent of the decline, because there is temporal bias in the EM-DAT data whereby more EWEs are reported recently due to greater awareness and monitoring technologies (Rosvold and Buhaug 2021). However, this data is not reliable enough to comment on the validity of the hypothesis that the number of EWEs in Bangladesh will increase with climate change, made in other studies (Mahmud, Hossain, and Raza 2021; Letsch, Dasgupta, and Robinson 2023; Rimi et al. 2019). Instead, this tension suggests the need for more rigorous measurement of these events and warns that the full impacts of climate change have not yet been experienced. Ultimately, since any EWE can have the detrimental impact on MHC access outlined in the literature, they must be investigated regardless of frequency (Orderud et al. 2022; Baten et al. 2020; Begum and Hamid 2023; Haque, Parr, and Muhidin 2020b; Abdullah et al. 2019).

The analysis shows that there is a significant negative correlation between experiencing an EWE whilst pregnant and MHC access. The likelihood of having at least four ANC visits, an institutional delivery and being told about pregnancy complications were all lower for women who had experienced an EWE. This finding is supported by wider literature, which hypothesised that EWEs produce physical, economic and social barriers to accessing MHC (Sorensen et al. 2018; Sharma et al. 2022). For example, storms and flooding can destroy local healthcare facilities, reduce the number of HCPs available, and lessen people's financial capacity to pay for private care (Abdullah et al. 2019). Although this affects access to all forms of healthcare, MHC is deprioritised after EWEs relative to infectious diseases, child illnesses and general patient care (Women Deliver 2021; Purno et al. 2023; Baten et al. 2020). Therefore, EWE response policies need to include provision for MHC to mitigate their negative impact on access.

The likelihood of women who experienced an EWE having a c-section was also lower, although not significantly. This suggests that access to c-sections is not determined by the same barriers as other aspects of MHC and so remains unaffected by EWEs. In Bangladesh, 83% of births in private facilities were c-sections (NIPORT 2020) and most people who can afford it use private healthcare (Purno et al. 2023), suggesting that access to c-sections is pre-determined by wealth. Wealth is a protective factor against the negative impacts of EWEs on MHC, as the wealthiest are able to pay for access to limited healthcare staff or to travel further for private care (Abdullah et al. 2019). This could explain why EWEs do not have a significant impact on access to c-sections, despite disrupting access to all other variables of MHC.

Neither the intensity nor frequency of EWEs were found to affect all variables of MHC access. For women who experienced an intense EWE (which affected over 1 million people) during their pregnancy, the only significant change from experiencing any EWE was increased likelihood of receiving at least four ANC visits and decreased likelihood of experiencing complications. This is supported by Begum and Hamid's (2023) and Baten et al.'s (2020) findings that in disaster-affected areas in Bangladesh, NGO provision of MHC increases ANC usage. In particular, the latter identified that NGOs had focused on expanding community-based provision of MHC and introducing mobile health centres. This suggests that these interventions had successfully increased ANC usage. However, the number of institutional deliveries, c-sections or being told about pregnancy complications did not significantly increase after severe flooding; therefore, NGOs and the government should increase their focus on these aspects of MHC to fill this gap.

Baten et al. (2020) also found an increase in ANC usage in areas with repeated EWEs, which was not sustained by the analysis in this paper. On the contrary, women who experienced repeated EWEs were

not found to have significantly higher ANC usage. This suggests that NGO provision of MHC is concentrated in areas that experience severe EWEs rather than repeated ones. This pattern was not discussed in previous literature; however, it could be that severe EWEs elicit a greater perceived sense of ‘emergency’ or ‘crisis’ and consequently attract more resources (Foley and Hendrixson 2011). Alternatively, those in repeatedly affected areas may be regarded as more ‘adaptive’, which rationalises their deprioritisation in EWE responses (Baten et al. 2020: 757). However, unlike in Baten et al.’s (2020) study, this paper finds no significant increase in ANC usage amongst those ‘adaptive’ individuals affected by repeated EWEs. Regardless, greater efforts to identify those whose ANC usage is more disrupted is necessary to effectively prioritise limited resources for interventions.

The other significant impact of intense EWEs was that they decreased the number of women who reported having experienced pregnancy complications. Extensive literature suggests that EWEs have greater direct and indirect effects on women’s health during pregnancy, due to enhanced physiological and socioeconomic vulnerability (Chalupka, Latter, and Trombley 2023; Curtis et al. 2017; Stern 2006; Leal Filho et al. 2022). These suggest that if a woman experiences a more intense EWE, she would be more likely to report pregnancy complications, making the decrease found in this paper unexpected (Abdullah et al. 2019; Mallett and Etzel 2018; Iqbal, Iqbal, and Babar 2023; Sharma et al. 2022). This could be due to a mediating factor between the direct or indirect effect and health outcome; for example, greater usage of ANC could have increased earlier identification and treatment of health issues, preventing development into full complications (Begum and Hamid 2023). If sustained by further analysis, this emphasises the importance of ANC usage in ensuring women’s health.

The decrease in women experiencing pregnancy complications could also be due to under-reporting. Leone et al. (2019) found that, in conflict settings, less information-sharing by HCPs led fewer women to report pregnancy complications. This theory could be applied to EWEs, which have many similar elements of disrupted MHC in crisis. However, Leone et al.’s (2019) explanation is not supported by this data, which shows no significant reduction in the numbers of women being told about pregnancy complications by a HCP. Alternatively, the crisis could lead to underreporting due to recall bias as a result of stress (Bradley, Winfrey, and Croft 2015; Tumlinson and Curtis 2021), or women deprioritising their own health in relation to other consequences of the EWE such as displacement, financial strain or loss of social networks. Regardless, the decrease in reporting of pregnancy complications should be analysed with care, and further attention given to researching these possible mechanisms in the context of EWEs.

The reliability of the data on reported pregnancy complications could be improved by changing how the data is collected. Questions on experiencing pregnancy complications were not included in all

surveys and varied between them, making long-term analysis of this data more complicated. As discussed in the methodology, other birth outcomes data, like preterm births or size of the child, are poorly reported in the DHS data (Lawn et al. 2010; Stanton et al. 2006). This prevents more advanced analysis of how disruption to MHC access by EWEs or other causes might result in poor birth outcomes. As such, this paper supports wider calls for improved data instruments to study differential impacts on women's health (Turquet et al. 2023).

Despite experiencing difficulties with the MHC access data, by reimagining the project and re-coding it was still possible to successfully analyse the key SDHs of MHC during EWEs. The significant effect of EWEs on MHC supports Souza et al. (2024)'s theory of super-determinants: the overarching factors including the environment which operate through social determinants to produce health outcomes. The accompanying social determinants were also statistically assessed in the logistic regressions; for women who experienced any, intense or repeated EWEs, factors like age, wealth, education, urban or rural residence, marriage status and parity were all found to have significant impact on MHC access. This addresses the lack of insight into how MHC is affected by socio-demographic factors, identified by Singh et al. (2022). It also confirms that the SDH theory (Link and Phelan 1995; WHO n.d.c) and super-determinants (Souza et al. 2024) are useful in conceptualising the relationship between EWEs, sociodemographic factors, and MHC outcomes.

Wealth and level of education both had significant correlations with all indicators of MHC access. EWEs are often considered to affect people indiscriminately, however many of the barriers to MHC during EWEs, such as damaged facilities, interruptions of medical supplies or fewer available HCPs, can be somewhat overcome by the ability to pay for private services (Wright et al. 2023; Orderud 2023; Pappas, Kovats, and Ranganathan 2024). Similarly, education gives women greater knowledge about MHC and ability to advocate for their own care (Abdullah et al. 2019). This creates a cycle of vulnerability; as the poorest and least educated are most likely to be negatively impacted by EWEs and consequently experience greater disruption to their wealth, wages and schooling (Orderud et al. 2022). Therefore, investment into education and MHC amongst the poorest is necessary to reduce the negative impact of EWEs on MHC overall.

EWEs were also shown to cause greater disruption to MHC access in rural areas. Abdullah et al.'s (2019) paper found that this urban/rural divide was because the healthcare facilities in rural areas were less concentrated so women had to travel longer distances. In 2023, the average distance to a sub-district hospital in Bangladesh was 10km, which can take several hours of travel with poor transport links (Purno et al. 2023). During floods and storms, reliance on boat travel made these journeys even more time-consuming and expensive, causing women to delay seeking help (Abdullah et al. 2019).

The findings suggest that this delay leads to lower numbers of ANC visits, fewer institutional deliveries, fewer c-sections and a decreased likelihood of being told about pregnancy complications.

Alternatively, Orderud et al. (2022) argue that it is not the floods themselves that cause poorer MHC access outcomes in rural areas but the pre-existing characteristics of those living there. Residents of flood-prone rural areas are likely to be poorer and less educated, because those who can afford to will move to lower-risk areas. Also, agriculture, the main industry in rural areas in Bangladesh, relies on using flood-prone land near rivers for irrigation or seas for fishing (Huq et al. 2015). As wealth and education level are significant social determinants of MHC access, lower rates of both would constitute lower overall access to MHC in rural areas. To reduce the effect of EWEs on MHC, policy interventions should focus on deploying midwives to rural areas, particularly during EWEs (Purno et al., 2023). Furthermore, they should build on the successful community-based provision and mobile health centres established by NGOs in rural Bangladesh (Baten et al. 2020).

Age was also found to determine access to MHC, with women aged 28 or over more likely to have at least four ANC visits and a c-section, but less likely to have an institutional delivery. This could be due to greater health-seeking behaviour and MHC required by older mothers, as they are biologically more prone to complications during pregnancy (Samandari et al. 2020; NIPOORT 2020). Moreover, Haque, Parr and Muhidin (2020b) found that older women are more likely to have knowledge of SRH, live in urban areas with better MHC access and be having a wanted pregnancy. Also, older women are less likely to be giving birth to their first child, as 66% of women in Bangladesh have their first child before the age of twenty (Samandari et al. 2020). The risks associated with pregnancy at different ages are thus complex and interact with other factors such as parity, wealth, education and residence. Greater MHC access for older women is a combination of demand and supply-related issues, and there is a need to increase the MHC access of younger women to achieve equity.

Overall, this paper contributes to the planetary health and feminist environmental justice frameworks by finding statistically significant correlations between environmental and women's health. Returning to DeVault's (1996) criteria, this paper successfully employs a feminist methodology by shifting the focus of climate change literature towards women's experiences and producing research of value to women. It concludes that climate change is differentially impacting women's health, particularly for young, rural, poor and less educated women. This creates cycles of vulnerability; women with these socioeconomic characteristics are already more vulnerable to EWEs, but the negative impact of the EWE on their MHC furthers their vulnerability. Therefore, policy and interventions to break this cycle, ideally addressing environmental and gendered issues together, is essential in order to ensure equitable access to health and resilience to EWEs for all. To complete the feminist aims of this

research, it should be used to generate social change or action which is beneficial to women (DeVault 1996).

6. Conclusion

Using national data from Bangladesh between 1989 and 2017, this paper finds that experiencing an EWE during pregnancy has a significantly negative impact on access to MHC. Experiencing an intense event, which affects over one million people, significantly increases the likelihood of having at least four ANC visits and decreases the likelihood of reporting pregnancy complications. On the contrary, experiencing multiple EWEs rather than just one had no significant effect on access to MHC. Socioeconomic determinants such as age, wealth, education, parity, rural or urban residence and marriage status had varying significant correlations with access to MHC.

The paper could not examine MH outcomes comprehensively due to limitations with the dataset, however the strong connection outlined in the literature between MHC access and outcomes allows for the assumption that there will be direct MH impacts along the stratifications in MHC access outlined in this discussion. The methodology employed reveals the need for development of better data collection on this topic, particularly regarding MH outcomes. Furthermore, the research invites further development, such as the addition of qualitative or mixed methods study, greater attention racial intersectionality, application to other EWE-prone areas, and projection forward to estimate future changes. These were outside the scope of the paper itself, but would provide further insight into how climate change differentially impacts women's health.

Nonetheless, this paper provides strong evidence that women are differentially and disproportionately impacted by climate change via their health outcomes. This is a result of both physiological differences and socioeconomically determined access to MHC (Lemery, Knowlton, and Sorensen 2021; Orderud 2023). Therefore, this paper calls for social change in the form of greater funding, research and policy focus into ensuring equitable health outcomes for women and children. As MHC access is a core element of a functioning health system (Travis et al. 2004), the lack of resilience of MHC systems to EWEs may reflect wider impacts on the healthcare system and thus health outcomes for all. Therefore, mitigating the disruption to MHC access caused by EWEs, especially for those most socioeconomically vulnerable, is crucially important in order to achieve good health for all.

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