Hello - our analysis has been delayed because the datasets we are using are incomplete. We will present the findings of our test case analyses (see slides included at the bottom of this document) and seek feedback on alternative methodological approaches. Thank you.

IUSSP International Population Conference

Extended Summary Submission by Cara Schulte
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Submission Title
A Global Analysis of Maternal Mortality and Natural Disasters: What Do We Have to Look Forward to?

Background
Over the last fifty years, the world experienced a surge in natural disasters, in part due to climate change.[1] Climate change is increasing both the frequency and intensity of extreme weather events and also altering spatial and temporal patterns of exposure.[2] Heavy precipitation and high temperature extremes have become more common in recent decades; hot seasons are arriving sooner and lasting longer; tropical cyclones are increasing in frequency and are reaching peak intensity at new latitudes; and sea levels are rising across the globe, all of which are driven in part by human-induced climate change.[3–5] Even more concerning is the role climate change has likely played in increasing the frequency of compound events, including concurrent heatwaves and droughts, fire weather, and compound flooding incidents.[3] The cascading impacts of these phenomena heighten the risk of disaster and other emergencies, particularly in already vulnerable communities.[1,2]

Natural disasters can have severe and adverse impacts on health, including sexual and reproductive health (SRH).[4,5] Severe flooding, for example, has been associated with increased rates of gestational hypertension and pregnancy loss.[6,7] Similarly, hurricane exposure has been linked to maternal stress and a range of adverse pregnancy outcomes, including fetal death.[8,9] High temperature extremes have been associated with increased risk of severe maternal morbidity, as well as an array of undesirable birth outcomes, including still birth, preterm birth, and low birth weight.[10] In addition, exposure to wildfire smoke can increase the risk of preterm birth and birth defects.[11,12] Disasters can also interfere with service delivery, contraceptive and other medical devices and supplies' availability, and access to care. Flooding has, for example, in some regions, limited access to maternal healthcare, menstrual regulation, and post-abortion care.[9,13] And there are documented incidents of healthcare providers turning away women in labor or women seeking long-acting reversible contraceptive methods due to clean water shortages resulting from disasters.[14] Disaster-related trauma and/or displacement can also create both physical and psychological burdens that weigh particularly heavily on pregnant people.[15] A significant proportion of maternal deaths occur in humanitarian settings, including those affected by natural disasters.[16] To our knowledge, however, there does not exist any study that has attempted to quantify the association between maternal death and natural disasters at the global scale — only one case study, based in Bangladesh, attempts to quantify this association in a local context.[17]

We propose conducting a study that explores the global impact of natural disasters on maternal mortality. Ultimately, quantifying the impacts of natural disasters on maternal mortality will provide a clearer picture of climate-related threats to health. This data will lay a critical foundation that we hope will influence additional research, appropriate funding, and effective interventions in this field.

Methods

Data sources and definitions

EM-DAT

We use publicly available data from EM-DAT for information on natural disasters. From the database, we pulled information about each type of disaster, the affected districts, and the GPS coordinates of the disaster.[18] To be added to the database, disasters must result in the deaths of ten or more people, affect one hundred or more people, result in a declaration of a state of emergency, or result in a call for international assistance. The database contains information on natural disasters around the world, starting in 1900 to present.

While EM-DAT includes both technological and natural disasters, our focus is on the latter. This category includes hydrological, meteorological, geophysical, biological, extraterrestrial, and climatological events, in line with the Integrated Research on Disaster Risk (IRDR) Peril Classification and Hazard Glossary.[19] We exclude biological events (animal incidents, disease, insect infestation) and extraterrestrial events (impact, space weather). Within the other categories, we include the following events: geophysical (earthquake, mass movement, volcanic activity), hydrological (flood, landslide, wave action), meteorological (convective storm, extratropical storm, extreme temperature, fog, tropical cyclone), climatological (drought, glacial lake outburst, wildfire).

Demographic and Health Surveys

We use publicly available data from the DHS sibling history module to capture maternal deaths. Maternal mortality was added to the DHS in Phase VII. Therefore, we will use all DHS Phase VII and Phase VIII with published data that include a maternal mortality module. We will not use earlier DHS that calculate pregnancy-related deaths because these include deaths due to accidents, which may bias results.[20]

DHS are typically collected every five years in the represented countries and include a Fieldworker, Household, and Woman's Survey.[21] At the start of each DHS cycle, statisticians define geographic clusters within each country. Households are then sampled from each cluster. When fieldworkers collect Household Surveys, they enumerate the women and men living in each household. Any woman of reproductive age (15-49 years —WRA) is then invited to participate in the Woman's Survey; fieldworkers are instructed to make at least three attempts to collect data from the women identified in the Household Survey, at different times of the day or on different days of the week. Women who are not available after three attempts at data collection are excluded from the survey sample. Each female respondent is requested to enumerate each of her living and deceased siblings, provide information about the cause of death, and the census month and year of the death.

In our study, we use the World Health Organization definition of maternal mortality.[22] Maternal deaths are deaths to women aged 15-49 years old who are pregnant, died during miscarriage, delivery, or abortion procedure, or in the 42 days following pregnancy. This category does not include deaths due to accidents or violence. This is the definition used by the DHS program. We use maternal deaths per 100,000 living women as our measure of maternal mortality.

Statistical analysis
We will match the DHS and EM-DAT data based on GPS coordinates. For most surveys, the DHS identify sampling clusters by GPS coordinates. These locations are randomly displaced by 0-2km (urban clusters) and 0-5km (99% of rural clusters — 1% are displaced up to 10km).[23] First, we will create buffer zones around each DHS cluster of 50km and of each natural disaster of 50km. We then run a fixed effects model for year and location, to control for unobserved heterogeneity.

We will present the natural disaster coefficient, standard error, t-statistic, and p-value. We will run both crude and multivariate models controlling for armed conflict, disaster categories that we are excluding from our (i.e., biological and extraterrestrial events), and sociodemographic characteristics of the DHS respondent as a proxy for their sibling. The model will be produced for countries, regions, and globally.

To assess model robustness, we plan to run three main sensitivity analyses:

1. We will re-run the analysis three times, each time removing a different class of natural disaster (i.e., hydrological, meteorological, geophysical, climatological) to determine whether this significantly affects our final model.

2. We will re-run the analysis three times using differently sized buffer zones (25km, 75km, 100km) to assess the effect of the buffer zone on the relationship between natural disasters and maternal mortality.

3. We will re-run the analysis for different time periods of disaster impact (3 months, 6 months, 9 months) to assess the effect of the assumed effect time on the model.

Results
We will present results at the global, regional, and country level, as well as by the class of natural disaster (i.e., hydrological, meteorological, geophysical, climatological). In the results section, we will produce the following figures and tables:

Table 1. Countries included in the study, sample year, sample size
Figure 1. Natural disaster frequency in countries included in the sample (heat map)
Figure 2. Maternal mortality ratio in countries included in the sample (heat map)
Table 1. The effect of natural disasters on maternal mortality at the global level
Table 2. The effect of natural disasters on maternal mortality at the regional level
Table 3. The effect of natural disasters on maternal mortality at the country level
Table 4. The effect of natural disasters on maternal mortality by natural disaster type Additional tables and figures will provide information on results from the sensitivity analyses.

References

1. Organization (WMO) WM. WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019). Accessed May 4, 2024. https://library.wmo.int/records/item/57564-wmo-atlas-of-mortality-and-economic-losses-from-weather-climate-and-water-extremes-1970-2019
2. Intergovernmental Panel on Climate Change (IPCC), ed. Weather and Climate Extreme Events in a Changing Climate. In: *Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press; 2023:1513-1766. doi:10.1017/9781009157896.013
3. AR6 Synthesis Report: Climate Change 2023. Accessed May 4, 2024. https://www.ipcc.ch/report/ar6/syr/
4. Changing Lengths of the Four Seasons by Global Warming - Wang - 2021 - Geophysical Research Letters - Wiley Online Library. Accessed May 4, 2024. https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020gl091753
5. Mansoor S, Farooq I, Kachroo MM, et al. Elevation in wildfire frequencies with respect to the climate change. *J Environ Manage*. 2022;301:113769. doi:10.1016/j.jenvman.2021.113769
6. He C, Zhu Y, Zhou L, et al. Flood exposure and pregnancy loss in 33 developing countries. *Nat Commun*. 2024;15(1):20. doi:10.1038/s41467-023-44508-0
7. Partash N, Naghipour B, Rahmani SH, et al. The impact of flood on pregnancy outcomes: A review article. *Taiwan J Obstet Gynecol*. 2022;61(1):10-14. doi:10.1016/j.tjog.2021.11.005
8. Silva-Suarez G, Rabionet SE, Zorrilla CD, Perez-Menendez H, Rivera-Leon S. Pregnant Women's Experiences during Hurricane Maria: Impact, Personal Meaning, and Health Care Needs. *Int J Environ Res Public Health*. 2021;18(16):8541. doi:10.3390/ijerph18168541
9. Loewen S, Pinchoff J, Ngo TD, Hindin MJ. 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*. 2022;157(1):11-18. doi:10.1002/ijgo.13768
10. Chersich MF, Pham MD, Areal A, et al. Associations between high temperatures in pregnancy and risk of preterm birth, low birth weight, and stillbirths: systematic review and meta-analysis. *BMJ*. 2020;371:m3811. doi:10.1136/bmj.m3811
11. Requia WJ, Papatheodorou S, Koutrakis P, Mukherjee R, Roig HL. Increased preterm birth following maternal wildfire smoke exposure in Brazil. *International Journal of Hygiene and Environmental Health*. 2022;240:113901. doi:10.1016/j.ijheh.2021.113901
12. Birth Outcomes, Health, and Health Care Needs of Childbearing Women following Wildfire Disasters: An Integrative, State-of-the-Science Review | Environmental Health Perspectives | Vol. 130, No. 8. Accessed May 5, 2024. https://ehp.niehs.nih.gov/doi/full/10.1289/EHP10544
13. Impacts of seasonal flooding on geographical access to maternal healthcare in the Barotse Floodplain, Zambia | International Journal of Health Geographics | Full Text. Accessed May 5, 2024. https://ij-healthgeographics.biomedcentral.com/articles/10.1186/s12942-023-00338- 3

14. In northern Kenya, women-led climate justice is taking shape - Ipas. Accessed May 5, 2024. https://www.ipas.org/news/in-northern-kenya-women-led-climate-justice-is-taking-shape/
15. Carballo M, Hernandez M, Schneider K, Welle E. Impact of the Tsunami on reproductive health. *J R Soc Med*. 2005;98(9):400-403. doi:10.1177/014107680509800904
16. Nordenstedt H, Rosling H. Chasing 60% of maternal deaths in the post-fact era. *The Lancet*. 2016;388(10054):1864-1865. doi:10.1016/S0140-6736(16)31793-7
17. Abdullah ASM, Dalal K, Halim A, Rahman AF, Biswas A. Effects of Climate Change and Maternal Morality: Perspective from Case Studies in the Rural Area of Bangladesh. *Int J Environ Res Public Health*. 2019;16(23):4594. doi:10.3390/ijerph16234594
18. CRED. EM-DAT - The international disaster database. Accessed May 19, 2024. https://www.emdat.be/
19. IRDR - Addressing the challenges of natural & human-induced environmental hazards. Accessed May 19, 2024. https://irdrinternational.org/knowledge_pool/publications/13
20. Rutstein SO, Guillermo Rojas MCS. *Guide to DHS Statistics*. ORC Macro, Calverton, MD; 2006.
21. Croft TN, Allen CK, Zachary BW, et al. Guide to DHS Statistics (DHS-8) - The Demographic and Health Surveys Program. DHS Program. Published 2023. Accessed September 27, 2023. https://dhsprogram.com/data/Guide-to-DHS-Statistics/index.cfm
22. WHO. Maternal mortality. Published February 22, 2023. Accessed April 10, 2024. https://www.who.int/news-room/fact-sheets/detail/maternal-mortality
23. The DHS Program - GPS Data. Accessed May 19, 2024. https://dhsprogram.com/Methodology/GPS-Data.cfm

Do Natural Disasters Increase the Risk of Maternal Mortality?

A Global Analysis Using Publicly Available Data

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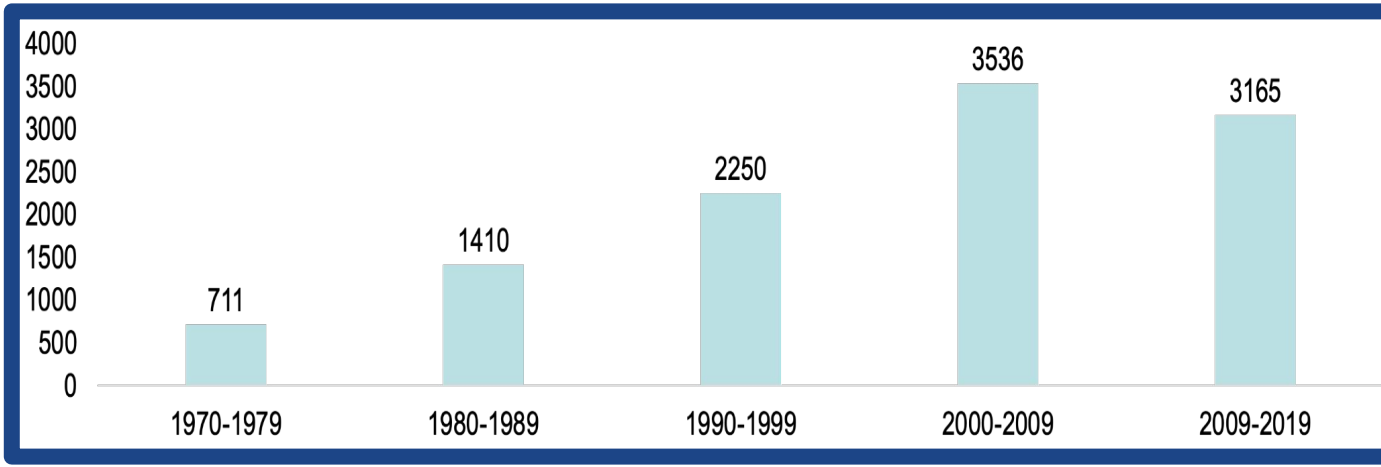
AGENDA

- **BACKGROUND**
- **METHODOLOGY**
- **CASE STUDY RESULTS**
- **NEXT STEPS**
- **FEEDBACK REQUEST**
  - GENERAL FEEDBACK
  - ALTERNATIVE DATASETS
  - OTHER MODELING APPROACHES

BACKGROUND

Natural disasters around the world, 1979-2019



NATURAL DISASTERS → HEALTH IMPACTS, INCLUDING SRH

GESTATIONAL HYPERTENSION

PREGNANCY LOSS

AFFECT MATERNAL HEALTHCARE DELIVERY

AFFECT MENSTRUAL REGULATION, INDUCED ABORTION, + POST-ABORTION CARE DELIVERY

AFFECT FAMILY PLANNING SERVICE DELIVERY

IMPACTS FERTILITY DESIRES

TO OUR KNOWLEDGE,

ONLY ONE STUDY [IN BANGLADESH] ATTEMPTS TO QUANTIFY THE ASSOCIATION BETWEEN NATURAL DISASTERS AND MATERNAL DEATH.

(ABDULLAH 2019)

DATA SETS

- **International Disaster Database (EM-DAT):** N = 435 events

  We downloaded data for ten years of disasters (from 2014-2024), pulled information on the disaster, the affected districts, and the coordinates of the disaster. We included hydrological, meteorological, geophysical, and climatological events, and excluded biological, extraterrestrial, and technological disasters.

- **Demographic and Health Surveys (DHS):** N = 872,651 siblings

  We retrieved data from DHS Phase VII and Phase VIII that included a maternal mortality module (with sibling histories) and GPS data.

EXPOSURE DEFINITION

- **Women were considered exposed if they lived within *50km* of a natural disaster.**
- **They remained exposed for *a year after the disaster* occurred.**

METHODOLOGY:
CASE STUDY OF THREE COUNTRIES IN THREE REGIONS
HAITI, UGANDA, + MYANMAR

STATISTICAL ANALYSIS

1. **FIXED EFFECTS MODEL**
   for year + location to control for unobserved heterogeneity
2. **CRUDE MODEL**
3. **MULTIVARIATE MODEL**
   controlling for socio-demographic traits of DHS respondent as a proxy for their sibling

RESULTS

DISASTERS IN HAITI, UGANDA, + MYANMAR

Unadjusted models exploring the association between exposure to natural disasters and maternal death

Country	Estimate	Std. Error	p-value
Haiti	-0.0027	0.0001	$p < 0.001$
Uganda	-0.0039	0.0001	$p < 0.001$
Myanmar	-0.0012	0.0001	$p < 0.001$

Adjusted models exploring the association between exposure to natural disasters and maternal death*

Country	Estimate	Std. Error	p-value
Haiti	-0.0027	0.0001	$p < 0.001$
Uganda	-0.0039	0.0001	$p < 0.001$
Myanmar	-0.0012	0.0010	$p < 0.001$

* Adjusted for number of children ever born, education level, community healthcare worker visit in the past 12 months, location.

PRELIMINARY CONCLUSION

Preliminary analyses show that in all three country-wise cases, there are significant negative associations between exposure to natural disasters and maternal death, both in unadjusted and adjusted models.

However, the effect size is extremely small.

NEXT STEPS

- **Continue search for alternative databases**
- **Control for armed conflict + excluded disaster categories**
- **Run model for additional countries, regions, + global data set**
- **Conduct three sensitivity analyses**
  - Remove a different class of natural disaster each time
  - Use differently sized buffer zones (25km, 75km, 100km)
  - Use different time periods of disaster impact (3, 6, 9 months)

SEEKING FEEDBACK

1. ALTERNATIVE MODELING IDEAS
2. ALTERNATIVE DATA SETS