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Impact of flood-triggering rainfall on adverse pregnancy outcomes in Pakistan: A quantitative analysis

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Declaration

I, Kayanat ILTAF, affirm that this research, titled "Impact of flood-triggering rainfall on adverse pregnancy outcomes in Pakistan: A quantitative analysis," is conducted as a master's thesis. Moreover, the research is conducted to fulfill the requirements of the Erasmus Mundus Joint Master Degree in Global Development Policy (2022-2024). As an author of this thesis, I declare that I have carried out and finished this research under the guidance of Professor Maria Anna Leone from the University of Pavia and Professor Dr. Sebastian Vollmer from the University of Göttingen. Lastly, I assert that the content presented in this document is solely my own unless specifically indicated differently through proper acknowledgments, citations, footnotes, and references.

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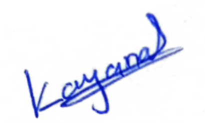

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Zásady pro vypracování

According to the UN, one of the biggest current global challenges is climate change, with a major impact on natural disasters, agriculture, and weather patterns. Pakistan pays a disproportionate amount of the cost despite producing less than 1% of global emissions as the country experiences more frequent climatic shocks that cause huge losses in terms of both human and economic life as well as damage to infrastructure and livestock. This study will examine the often overlooked consequences of weather shocks brought on by climate change on female employment and reproductive health in Pakistan, a nation with over half of its population being female and ranked 18th in terms of disaster risk with high climate vulnerability.
Heatwaves, excessive rainfall, floods and droughts, disproportionately afflict vulnerable groups, especially pregnant women (Kim et al.(2019), Ochani et al.(2022), Koo (2022), Saulnier & Brolin (2015), Sifton & Ijaz (2022), Wheeler (2023), Baharav et al.(2023), one evidence being the 2022 catastrophic floods in Pakistan that struck over 1.6 million women of reproductive age (UNFPA, 2022). Pakistan's agriculture industry, which is vital to the country's economy, is facing challenges due to climate-related disaster and this has a negative impact on rural labour markets, particularly for women workers, who account for approximately 68% of the agricultural workforce compared to 28% for men (Labour Force Survey, 2020-21). Due to limited land ownership, access to migration after disaster and rain dependent crops women face increased gender inequities and employment losses. This additionally exposes them to hazards and makes it more difficult for them to receive relief measures (Tunde, 2011; Chowdhury et al., 2022; Afridi et al., 2022).
This study will highlight the necessity for focused approaches to address Pakistan's growing climate change challenge. The link between dependent and independent variables is likely to be evaluated by a combination of both quantitative and qualitative investigations in this research.

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Addendum: topic specification

The final thesis topic is a more specific version of the original idea, which was broader encompassing “agricultural livelihoods” and “reproductive health” of Pakistani women. The decision to restrict the focus to the "adverse pregnancy outcomes of Pakistani women" was made in consideration of the timeline, word limit of the study, and data access constraints for the other variable. During the initial stages of the research, the researcher observed that the data on crop productivity, number of hours worked, and gender-specific agricultural indicators were not readily accessible and adequate. Additionally, certain data information was exclusively accessible through primary collection and paid products/services. However, it was challenging to accommodate the word limit while addressing a broad subject matter that included "agri-livelihoods" and "reproductive health." The researcher acknowledged the limitations of data, time, and materials and that she might be unable to provide the necessary quantitative analysis to tackle the initial topic effectively. Consequently, the student opted to specify the final topic, “**Impact of flood-triggering rainfall on adverse pregnancy outcomes in Pakistan: A quantitative analysis,”** after consulting with her supervisor(s). The student's supervisor(s) were informed, consulted, and agreed to these modifications.

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I dedicate this thesis to my father, Late Iltaf Hussain, who instilled invincible passion and a can-do spirit in me. I cannot conclude my acknowledgment without thanking Allah Almighty for being my constant source of strength and for providing me with the ability to complete this research.

Foreword

I undertook my thesis research at the Center of Modern Indian Studies (CeMIS), University of Goettingen. CeMIS is dedicated to teaching and researching economic and political growth in South Asia, particularly India. As a research intern under the supervision of Professor Dr. Sebastian Vollmer, my research activities were concentrated on my academic thesis. I actively collected, refined, analyzed, and reviewed relevant data and research literature for my thesis. Furthermore, I participated actively in research-related critical discussions with colleagues and researchers affiliated with the institute. The institute's specific emphasis on South Asia and associated development challenges aided my comprehension of the study's context and intricacy. Professor Vollmer's extensive expertise in health economics and economic growth in the global south provided me with essential insights and research knowledge, considerably enhancing the quality of my thesis. This research internship significantly improved my comprehension of the thesis and my capacity to analyze empirical data.

Abstract

Climate change poses substantial and alarming global health concerns. Multiple studies highlight the disproportionately adverse impact of climate shocks on maternal and infant health outcomes. However, there is a lack of research regarding the effects of specific disasters, such as floods, on perinatal health. The purpose of this study is to investigate the impact of flood-triggering rainfall shocks on the risk of pregnancy loss (stillbirth, miscarriage, and spontaneous abortion) in Pakistan. Moreover, the study explores the potential impact of age, education, and wealth status on the vulnerability and likelihood of adverse pregnancy outcomes. This study uses microdata from three Pakistan Demographic and Health Survey waves (2006-2007, 2012-2013, and 2017-2018) and precipitation data from 29 meteorological stations in Pakistan for 2003-2018. We utilized a linear probability model to perform a cross-sectional analysis and conducted various robustness checks to ensure the model's reliability. We found a positive and statistically significant link between exposure to floods and the likelihood of losing a pregnancy. The study also indicates that younger women, individuals with lesser educational achievements, and those from less wealthy households are more likely to report a pregnancy loss.

Keywords: *Floods, precipitation, pregnancy loss, socioeconomic factors, vulnerability, Pakistan*

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List of Abbreviations

CCKP	Climate Change Knowledge Portal
CRED	Center for Research on the Epidemiology of Disasters
IPCC	Intergovernmental Panel on Climate Change
DHS	Demographic and Health Survey
GADM	Global Administrative Areas
NCEI	National Centers for Environmental Information
IFRC	International Federation of Red Cross and Red Crescent Societies
WHO	World Health Organization
GHG	Greenhouse gases
GIS	Geographic Information System
GPS	Geo Positioning System
PMD	Pakistan Meteorological Department,
LPM	Linear Probability Regression Model
NOAA	National Oceanic and Atmospheric Administration
OCHA	Office for the Coordination of Humanitarian Affairs
PDHS	Pakistan Demographic and Health Survey
UNFPA	United Nations Population Fund
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Emergency Fund
WMO	World Meteorological Organization

Introduction

Globally, temperatures are rising, storms are recurring, floods are becoming more frequent, and so are the concerns regarding climate change. Disasters are significant disruptions that surpass the available resources of communities and impair their normal functioning (IFRC, 2020). The increasing number of extreme climatic and weather events globally indicates significant fluctuations in the global climate. According to a report by the National Oceanic and Atmospheric Administration (NOAA), "the temperature of the earth has risen about 2° F in total since 1850" (2024). Furthermore, the report also emphasized that since 1982, the rate of global warming has increased by nearly three times per decade. Since the inception of worldwide records in 1850, 2023 has been identified as the hottest year (Lindsey & Dahlman, 2024).

In addition to rising temperatures, floods have emerged as a catastrophic phenomenon, causing immense devastation to millions worldwide. Floods have killed over 200,000 people and affected 2.8 billion in the past 30 years (Mallett & Etzel, 2018). Based on the data from a 2021 disaster report by the Center for Research on the Epidemiology of Disasters (CRED), there were a total of 432 catastrophic occurrences documented in 2021. The report further highlights that "in total, these events resulted in 10,492 fatalities, affecting 101.8 million individuals, and economic damages of about 252.1 billion US dollars." These catastrophes were primarily characterized by floods, with 223 instances (CRED, 2022).

Severe weather events can cause significant harm to the health and overall well-being of people, in addition to causing damage to infrastructure (Ebi et al., 2021). People may experience numerous health repercussions such as respiratory illnesses, injuries, dehydration, and long-term impacts on mental health. While climate shocks do not possess inherent discriminatory capabilities, specific segments of the population, such as children, older people, and women, are more susceptible to the effects of climate change. For instance, during the phase of "pregnancy," women experience heightened vulnerability and reduced resilience to shocks, making them more susceptible to external hazards. In addition, infants and individuals with limited socioeconomic resources (such as low income and education) are more likely to experience the adverse effects of disasters.

Several scientific investigations have found that sudden changes in rainfall and temperatures significantly impact young children's initial development and growth. In a study conducted by Kumar et al. (2014), the researchers found that droughts occurring during pregnancy had a substantial adverse effect on the nutrition of babies. Hence, it is imperative to develop resilience against climatic disasters, mainly focusing on the requirements of individuals who are highly vulnerable and lack sufficient resources.

Climate change and injustice have recently gained significant attention in global research and development forums. Climate injustice refers to the disproportionate effects of climate change on different groups or regions. UNDP defines climate injustice as a situation where those least responsible for greenhouse gas emissions bear significant consequences of the climate crisis (2023). Repercussions of climate injustice are primarily apparent in underdeveloped countries and regions. Climate catastrophes disproportionately affect the least developed and small island developing states, exacerbating their vulnerability (Eckstein et al., 2021). In 2023, the Intergovernmental Panel on Climate Change (IPCC) report emphasized that about 3.5 billion individuals reside in regions highly susceptible to climate crises. This climate synthesis report further reveals that countries with higher vulnerability to floods, storms, and droughts have seen a 15-fold increase in human casualties (IPCC, 2023).

Pakistan is often in the spotlight when discussing climate injustice. The frequency of floods in Pakistan has been steadily rising for over a decade, primarily due to frequent fluctuations in rainfall and the melting of glaciers caused by increasing temperatures. Around one-third of the country was submerged in water due to the recent floods in 2022, preceded by a severe heatwave in the region. The flooding in 2022 impacted almost 33 million individuals, with children being half the impacted population (UNICEF, 2023). Adverse impact on pregnant women was reported during the horrific floods of 2010 in Pakistan. In Sindh province, the proportion of women among the 1.5 million displaced persons was 49%. Moreover, in the areas of Sindh that were hardest hit by the 2010 flooding, the maternal death rate rose to 381 per 100,000 live births (Bukhari & Rizvi, 2015).

The phenomenon of El Nino[1] is crucial in influencing precipitation variability that can lead to floods and droughts in the South Asian region. Pakistan features a varied landscape, encompassing towering mountains in the northern region, arid deserts in the southern part, and an extensive coastline stretching between the borders of Iran and India. The climate pattern exhibits aridity and warmth in proximity to the sea, transitioning to a cooler temperature as elevation increases towards the uplands and the Himalayas (CCKP, 2021). Pakistan experiences seasonal variations characterized by dry and chilly winters (December to

[1] An anomalous climate phenomenon characterised by a significant increase in temperature of the surface waters in the eastern equatorial Pacific Ocean.

February), sweltering summers accompanied by the southwestern monsoon rains (June to September), a second period of receding monsoon (October to November), and a spring season (March and May).

Figure 1: Physical Map of Pakistan

Source: GEOATLAS, (2018). Physical map of Pakistan. Worldometer. https://www.worldometers.info/maps/pakistan-physical-map-full/

Flooding is a widespread problem, especially during the monsoon season when scorching summers cause glaciers to melt faster. Pakistan is subjected to annual flooding of varied intensities. The devastating floods of 2022 caused the internal displacement of nearly 7.9 million people in Pakistan (OCHA, 2023). Pakistan struggles to upgrade its water storage infrastructure, as political agendas and regional disparities have slowed dam development, causing present water storage facilities to overflow following excess rainfall. If there had been a sufficient water storage system, this surplus water could have been utilized for electricity generation and enhanced agricultural output, especially during droughts or heat waves. The country's deteriorating political and economic structure has failed to provide the resources to respond to climate-related calamities effectively and adequately. There is a need for global support in terms of technical expertise and financial aid to enhance the ability to withstand and recover from climate disasters.

Access to safe drinking water, sanitation, healthcare, and financial resources fosters resilience against climate shocks. However, due to the availability and access issues of these essential utilities, individuals from marginalized groups are more exposed to external climate shocks. According to UNICEF (2023), the 2022 floods in Pakistan damaged most of the drinking water systems in the affected districts, leaving roughly 5.4 million people consuming contaminated water from wells and ponds. Pregnant women exhibit heightened susceptibility to external disturbances, underscoring the need for targeted attention and remedies. Floods can exert detrimental psychological and physiological impacts on women's reproductive well-being (Ochani et al., 2022). Natural calamities such as floods, droughts, earthquakes, and storms intensify psychological distress, potentially resulting in depression, hypertension, and trauma. These detrimental consequences can be particularly harmful during the gestational phase for pregnant women and the growth of the child. Insufficient access to hygiene and sanitation facilities, water contamination, and disrupted healthcare services may significantly increase pregnancy complications. Such circumstances can endanger the lives of both the mother and the developing baby.

The perinatal health effects of climatic shocks may be more apparent in low-income countries that already experience significant maternal health issues and have inadequate resources. World Health Organization (WHO) reports that 95% of maternal deaths in 2020 occurred in lower and lower-middle economies, with 87% in Sub-Saharan Africa and South Asia (2024). Amid climate emergencies, the demand for medical care and services for pregnant women increases remarkably. During the 2022 floods in Pakistan, more than 650,000 pregnant women required maternal health care, highlighting their significant vulnerability to such disasters (UNFPA, 2022). Climate shocks other than floods also threaten mother and newborn health. Other meteorological phenomena, such as droughts and heatwaves, pose a danger to the reproductive cycle and raise the probability of adverse pregnancy outcomes. A study found that rising ambient temperatures increase heat stress in pregnant women, resulting in unfavorable pregnancy outcomes such as preterm birth, miscarriages, and stillbirth (Yüzen et al., 2023).

On top of that, increased temperatures and heat stress have been linked to complications during pregnancy, such as hypertension and gestational diabetes (Kim et al., 2019). Multiple studies have emphasized that excessive heat has a negative impact on the perinatal period, leading to an increased likelihood of stillbirth and premature births. Auger et al. (2014), found that heatwaves lasting four to seven days with a maximum temperature of at least 32°C were associated with a 27% increased risk of early-term birth compared to regular days. Likewise, climate change can also indirectly affect maternal health through several processes, the most significant being the disruption of healthcare infrastructure. Factors such as the distance to aid camps, overcrowding, damaged infrastructure, water contamination, and inadequate sanitation and hygiene contribute significantly to the problem.

Despite the substantially detrimental impacts of climate shocks on reproductive health, this topic does not receive adequate attention and priority in climate change mitigation efforts. According to a UNFPA and Queen Mary University of London report, only one-third of countries' crisis response strategies incorporate sexual and maternal health care (2023). The report further emphasized that out of the 119 countries that have published climate response plans, only 38 have included subjects related to newborn and maternal health services. Due to the significant impact of climate change on pregnant women, countries must prioritize the safety and resilience of these individuals. Hence, immediate global collaboration is crucial in addressing climate injustices and promoting a fair transition towards a sustainable future. Countries with the highest levels of carbon emissions should cooperate with countries with few resources to enhance their capacity to withstand the impacts of climate change. There is an undeniable need for equitable global funding and investment programs to effectively decrease greenhouse gas emissions and transition the world toward a low-carbon future (UNDP, 2023). Developing climate resilience and adaptation capacities requires local governments and industrialized nations' commitment, cooperation, and sincere efforts. Therefore, national and international governments must collaborate to address climate challenges more effectively.

This paper serves as an appeal for climate justice, explicitly focusing on the marginalized and overlooked group of individuals in the population: pregnant women. The **paper's motivation** is to advocate incorporating pregnant women's unique needs into climate change relief efforts and adaptation programs. This inclusion will facilitate the implementation of precise and efficient regulations in this domain.

The study utilizes microdata from three waves of DHS (2006-2007, 2012-2013, and 2017-2018), consisting of a sample of 11,581 women, to analyze the impact of flood shocks on the risk of adverse pregnancy outcomes in Pakistan. Furthermore, a quantitative linear probability regression methodology has been utilized to assess the influence of rainfall that triggers floods on adverse pregnancy outcomes (stillbirths, miscarriages, and abortions). The **primary goal** is to emphasize the often overlooked consequences of climate disasters on pregnant women and to advocate for their specific needs.

The study **hypothesizes** that flood shocks may have a significantly adverse effect on pregnancy losses, and the characteristics of mothers, like age, educational level, and wealth position, are correlated with the likelihood of experiencing a negative pregnancy outcome. The

identifying assumption of the study implies that the rainfall shocks are mostly exogenous and random and that all the clusters in the study are expected to experience the same randomized total number of shocks across the studied period. Nevertheless, the retroactive nature of our research makes it difficult to control for all relevant factors because of the presence of several unobservables. Although we have made an effort to consider possible variables that could affect the outcome, there is still a possibility that unobserved factors could pose endogeneity concerns. Thus, our identification approach asserts that rainfall shocks are primarily external and unpredictable, but we also acknowledge the potential for remaining endogeneity that cannot be addressed entirely. Hence, the effects of rainfall shocks should not be solely regarded as causal in our analysis, as there may still be some causes of variation that are not completely exogenous.

Primary question

- How do flood-triggering precipitation levels affect the risk of adverse pregnancy outcomes in Pakistan?

Sub questions

- Is there an elevated risk of pregnancy outcomes such as miscarriages, stillbirths, and abortions during floods?
- Is there an association between socioeconomic characteristics (such as age, education, and wealth) and pregnancy loss among women?

The study finds an overall positive and significant effect of flood shocks on the risk of losing a pregnancy. Moreover, the study highlights that women from younger age groups with less educational attainment and from socioeconomically disadvantaged families are more susceptible to the hazards of miscarriage, spontaneous abortion, and stillbirth. Our research also shows that when the intensity of the flood shock rises, the probability of experiencing stillbirth, spontaneous abortion, or miscarriage also increases. Overall, the findings are in line with previous research on this topic. This study expands the current knowledge and research of the health consequences of climate change by explicitly examining the impact of flood disruptions on maternal health outcomes in Pakistan.

The main text of the paper is structured as follows. **Section 1** focuses on the literature review and highlights the research gap our study aims to address. **Section 2** introduces a theory of change that presents the potential mechanisms that can link the outcome and independent variable. **Section 3** outlines the data sources, sample design, empirical approach, and model employed in this paper. **Section 4** provides the principal result analysis and discussion of the findings, including a subsection that will specifically examine the robustness of the results.

Section 5 discusses the policy implications of the study, and **section 6** presents the conclusion that highlights the study's shortcomings and suggests future research ideas for further investigation.

SECTION 1

Literature review

Climate change has exacerbated various preexisting maternal health complications and given rise to new health challenges. Consequently, there has been increasing research and literature examining the connection between maternal health and climatic disasters. A study by Costello et al. (2009) identified multiple health issues that can affect the health of both mothers and newborns as a result of climate change. These complications include low birth weight, spontaneous abortions, premature deliveries, dehydration, and vector-borne infections. Another study highlighted the significant association between preterm delivery and rising temperatures (Basu et al., 2010). The researchers of the study also discovered a strong correlation between high temperature and the likelihood of giving premature birth in younger women. Climate disasters have the potential to profoundly affect pregnant women and fetal development through multiple direct and indirect mechanisms. Fluctuations in rainfall can exacerbate psychological distress in pregnant women, leading to an increase in the synthesis of the corticotropin-releasing hormone (Black et al., 2016). This hormone can negatively impact fetal development, posing risks to both the mother and the child.

Furthermore, a study by Kim et al. (2019) revealed that exposure to severe temperatures heightens the likelihood of maternal hospitalization during pregnancy. According to Wheeler et al. (2022), as climate disasters worsen, the hazards to newborns' and mothers' health are also projected to increase. Likewise, another study found that with an increase in global heat stress, there is also a growing likelihood of stillbirth, premature birth, shorter gestational periods, and low birth weights of infants (Kuehn & McCormick, 2017). There are multiple direct and indirect consequences of climate crises on reproductive health. A research article by Giudice et al. (2021) highlights some channels such as the heightened levels of pollutants, water toxins, and the proliferation of vector-borne diseases that can significantly affect the reporductive health of women.

There has been growing research on the relationship between increasing temperatures and pregnancy outcomes. However, there is a significant amount of untapped research potential that can be used to explore the impact of other hydrological climatic shocks on maternal health. Flood-related disasters can have harmful consequences on perinatal health outcomes, negatively affecting the growth of children and threatening the well-being of expecting women. Studies have established a correlation between the incidence of floods and an increase in anxiousness, depression, and post-traumatic stress disorder (Munro et al., 2017; Waite et al., 2017). During a nine-month pregnancy, specific trimesters are more vulnerable to external disturbances than others. Pregnant women in the initial trimester who encounter a significant flood close to their residences are susceptible to giving birth to neonates with reduced birth weight as a result of diminished fetal growth (Hilmert et al., 2016).

Similarly, a study by Tong et al. (2011) indicates that when a flood occurs, there is an increase in adverse health outcomes, such as low birth weight and premature delivery, among women who give birth in the affected regions. Pregnant women typically have elevated levels of depression and anxiety and are often vulnerable to various stressors throughout their pregnancy. Therefore, in the event of climatic emergencies such as floods, droughts, storms, or heatwaves, their vulnerability is also expected to escalate. According to Auger et al.(2014), if the maximum temperatures experienced one week before birth reach or exceed 32°C, the adverse risks connected with delivery are amplified by 4% compared to a relatively high temperature of 20°C.

The magnitude and direction of floods' effect on pregnancy outcomes also depend on individual and country-specific factors, such as the availability of coping and resilience mechanisms (Du et al., 2010). A study by Sanguanklin et al.(2014) found that pregnant women who were displaced during the 2011 flood in Thailand encountered detrimental impacts on the growth of their unborn babies. On the other hand, Hetherington et al. (2021) identified a weak effect of the 2013 Calgary floods on pregnancy outcomes and postpartum mental health. A study by Hamilton et al.(2009) found that the overall birth rate in the counties affected by Hurricane Katrina reduced by 19% twelve months after the disaster compared to the year before. The adverse effects of floods on pregnant women and children necessitate increased awareness, education, and practical interventions, especially in low-income and developing nations (Mallett & Etzel, 2018).

The existence of sufficient research that can establish a definitive connection between flood shocks and adverse maternal outcomes is lacking. Therefore, the shortage of research in this area and the growing risk of flood shocks present a favorable opportunity for aspiring researchers to investigate this topic. In addition, existing studies and publications primarily focus on the impacts of rising temperatures or droughts, but the understanding and conclusiveness regarding the effects of floods remain insufficient. This research gap necessitates comprehensive research on the topic, considering the significance of floods in the

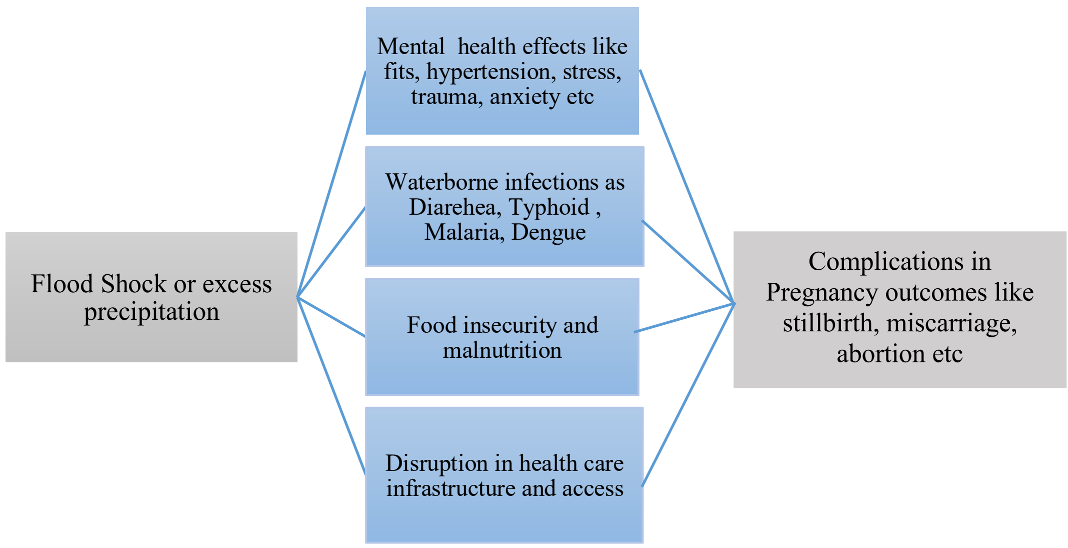
South Asian region. Therefore, our study enhances the current body of knowledge by examining flood shocks in the specific context of Pakistan, broadening the understanding of this significant phenomenon.

SECTION 2

Theory of change

This research aims to investigate the possible impacts of excess rainfall shocks that might trigger floods on the risk of pregnancy loss in Pakistan. The specific type of excess precipitation shock examined in this study is flood. Additionally, our study also analyzes the correlation between adverse pregnancy outcomes and socioeconomic characteristics of women, like age, wealth, and education. Severe climate events such as floods can have several direct or indirect effects on the well-being of pregnant women. Thus understanding specific processes through which an effect is anticipated in pregnancy outcomes when flood shocks occur is crucial. The following theory of change will outline a few indirect and direct mechanisms that can negatively impact pregnancy outcomes in the event of a flood shock. The empirical testing of the following mentioned mechanisms is out of our current study's scope. However, their conceptual inclusion offers a theoretical explanation of the crucial processes that could connect flood shocks to adverse pregnancy outcomes.

Figure 2: Theory of change



Source: Author

Women are disproportionately and highly susceptible to the effects of climate change and face more significant adaptation challenges due to societal constraints and limited access to resources (FAO, 2023). The first potential mechanism at work is psychological stress and trauma associated with disaster onset. Women have been highlighted in many studies as the part of the population that is generally at higher risk of experiencing heightened levels of stress during climatic emergencies. A study examining the impact of Iowa floods on pregnant women found that those who were exposed to the floods experienced elevated levels of trauma and depression during the perinatal period (Brock et al., 2015). Elevated stress levels in pregnant women who experience disasters can be transmitted to their fetuses, resulting in detrimental effects on their cognitive and physical growth, ultimately leading to adverse pregnancy outcomes. Numerous studies have established a link between maternal depression and adverse impacts on children's growth and birth outcomes (Goodman et al., 2011; Simcock et al., 2017).

Other significant factors are access to health care, transport, and communications infrastructure. Evacuating pregnant women after a disaster is a challenging endeavor, especially when the healthcare and transportation systems are devastated, resulting in a lack of timely medical assistance. During the 2022 floods in Pakistan, numerous family healthcare clinics were destroyed, affecting at least 650,000 pregnant women (Sifton & Ijaz, 2022). Furthermore, in countries where a substantial number of births take place at home, the demolition of houses intensifies concerns regarding the availability of appropriate delivery facilities, as well as privacy and safety. Therefore, disruption of transport and communications is an important issue that puts expecting women at risk. Even if people manage to reach health facilities and camps, they have to deal with excessively crowded clinics and a lack of critical medical supplies and drugs in Pakistan. Relief camps, often lacking sufficient resources and accommodating millions of displaced individuals, face the additional challenge of ensuring safety, sanitation, and hygiene.

The risk of contracting vector-borne illnesses and infections is elevated during flood events. Insufficient sewage infrastructure in Pakistan, particularly in small towns and slums, leads to prolonged water stagnation on the streets following floods. The contaminated and polluted water serves as breeding grounds for numerous viruses and bacteria, resulting in rising waterborne illnesses. This scenario highly threatening specially for individuals lacking access to mosquito nets, medications, or water purification systems. After the devastating floods in 2022, health facilities in Pakistan observed a rise in the spread of vector-borne diseases. Within a month of the floods in 2022, more than 660,120 cases of malaria, diarrhea, typhoid, dengue fever, and skin disorders have been recorded due to the consumption of stagnant water tainted with harmful substances (British Red Cross, nd).

Moreover, the likelihood of violence and mistreatment towards women escalates during emergencies. UNICEF recognizes that following natural disasters, social structures' ability to protect women from gender-based violence decreases, making many women more vulnerable to abuse. Disasters cause food insecurity owing to agricultural, infrastructure, and revenue loss. Floods and droughts disrupt the food supply system, putting pregnant women at higher risk for inadequate nutrition.

The above scenarios depict a dismal situation in which vulnerable segments of the population, such as pregnant women and newborns, are exposed to hazardous conditions due to climate shocks.

SECTION 3

3.1. Data sources and sample design

This research uses micro-level data sources to conduct a cross-sectional analysis examining the impact of excessive rainfall shocks on negative pregnancy outcomes. The study analyzes data from the Pakistan Demographic and Health Survey (PDHS) conducted in 2006-2007, 2012-2013, and 2017-2018 to investigate the correlation between pregnancy losses and rainfall that triggers floods. The DHS surveys are extensively utilized for estimating women's and children's health concerns, including reproductive and sexual health-related indicators in lower and middle-income countries. Demographic and Health Surveys (DHS) have been conducted in Pakistan since 1990-1991. The surveys involve the random selection of clusters of households within stratified regions. Substantial attention is given to female respondents, and interviews are carried out with ever-married women between the ages of 15 and 49. Questions are asked regarding their sexual, maternal, and reproductive health history.

Since the survey waves are obtained from different years, our analysis includes fixed effects for survey years. This technique seeks to analyze and account for any temporal variations identified in the surveys and mitigate the influence of any policy initiatives that may have been adopted over these periods. Additional explanatory factors, such as mother-specific fixed effects and residential area information, have also been utilized to evaluate the impact of these predictors on the occurrence of pregnancy loss.

The primary study sample includes 11,581 married women between the age of 15-49 from a total of 495 individual residential and 84 household clusters across Pakistan. All major regions have been covered, and the study area has been expanded to the whole country, excluding the Azad Jammu and Kashmir areas.

Table 1: Regions of Pakistan covered in the analysis

Regions of Pakistan
Punjab
Sindh
KPK/NWFP
Baluchistan
Fata
ICT (Federal territory Islamabad)
Gilgit Baltistan

Given the data's availability and access, rainfall data from 29 weather stations in Pakistan was used from 2003 to 2018.[2] Rainfall data has been retrieved from the global database of the German Weather Authority "Deutscher Wetterdienst," Pakistan Meteorological Department (PMD), Regional Meteorological Center (RMC) Lahore, and National Centers for Environmental Information (NCEI) - NOAA. Data from DHS 2006-2007 and 2017-2018 DHS was GPS[3] referenced with spatial geographic information of the residential clusters being surveyed. Geographic Information System (GIS) software tool has been used to spatially join the geo-referenced residential clusters with the weather station data. For the sixth wave of DHS conducted in 2012-2013, district codes were utilized to identify and associate each residential cluster and its corresponding district region. A district-level shape file was used from the Database of Global Administrative Areas (GADM) as the base layer to spatially locate the residential cluster and the corresponding weather stations across the country. The GIS software utilized the district layer as the foundation, superimposing georeferenced residential cluster shape files from DHS to identify clusters inside districts precisely.

In addition, the weather station coordinates were used to calculate the distance between the weather grids and the nearest clusters. Furthermore, to determine the most appropriate nearby clusters, a distance threshold criterion is utilized for matching. This study utilizes 20 km as the cut-off distance to match the geo-referenced residential clusters with the respective closest weather stations in its primary analysis. Several studies have used different distance levels to measure the closeness of a weather station to the surrounding residential cluster points or districts. For instance, a study by Currie et al. (2009) utilizes the distance of <10 km as the

[2] The list of weather stations included in the study has been provided in the appendix (See Table A in appendix).
[3] Global Positioning System

cut-off for matching the weather stations with the corresponding districts to study the effects of air pollutants on infant health in New Jersey. The decision of distance is not arbitrary but depends on the precision with which a particular distance level can determine proximity. Our study has uses a distance of 20 km, considering the limited amount of weather station information available, sample size, and following the DHS guidelines about using displaced and buffered GPS data.[4] Afterward, residential clusters are matched with the weather station within a 20 km radius, while any remaining unmatched clusters are disregarded. During the robustness checks of the empirical analysis, the distance cutoff is adjusted to ± 3 km from the original threshold of 20 km to assess the consistency and reliability of the results.

3.2. Empirical framework

3.2.1. Identification of rainfall shock

The first and most crucial component in the empirical framework is identifying the rainfall shock and its definition in the study. To accurately capture significant rainfall fluctuations, it is essential to determine the years in which precipitation was abnormally high compared to the typical rainfall patterns in a given location. A commonly employed approach is to calculate the deviation of precipitation levels from the long-run average rainfall in a specific area. This study used a percentile criterion to classify a particular amount of rainfall as one that could potentially trigger a flood. The percentile technique has been employed previously in several research studies to establish and classify external weather and rainfall disturbances as flood or drought-triggering (Burke et al., 2015; Cools et al., 2020; Corno et al., 2020; Currie et al., 2009). In addition, several other methods, such as percentages or levels, have also been utilized in multiple earlier research works (Fafchamps et al., 1998; Paxson, 1992; Tiwari et al., 2017). However, when aggregating rainfall shocks over numerous years, continuous approaches such as levels, percentages, and log levels face difficulties due to the possibility of low rainfall periods being balanced out by high rainfall periods (Burke et al., 2015). Therefore, in this study, a binary indicator variable was used to determine whether or not a rainfall shock occurred in a year.

There is no single and universally accepted approach to precisely identify the quantity or level of rainfall that can be categorized as flood-inducing. The current economic research

[4] One of the analysis approaches used by DHS to generate GPS referenced datasets is "Maximum Likelihood Estimation (MLE)" using a projected covariate. Covariates are generated by applying four rural (r= 20km, 10km, 5km and 1 km) and three urban (u= 5km, 2km, and 1 km) buffer sizes around the offset DHS site. Therefore, the maximum buffer size for the sample has been used to have an adequate sample size for the study that can accurately determine the effect in question. https://www.dhsprogram.com/pubs/pdf/SAR8/SAR8.pdf

uses diverse methods to create measures of comparative rainfall shocks. Numerous studies have used the gamma distribution to quantify droughts and floods instead of the normal distribution because observed rainfall distribution tends to be right-skewed. In this study, potentially extrinsic timing of rainfall is utilized to create an annual shock gauge that is undisturbed by time-insensitive variables (such as the mother's wealth position, education, and age), which could typically impact pregnancy outcomes. A rainfall shock is defined as precipitation that exceeds a predetermined percentile in the distribution specific to a particular area. Excess rainfall shock (independent variable) has been defined as rainfall level that might trigger flood risk in the corresponding residential cluster.

The yearly average rainfall of a residential cluster is categorized as flood-triggering if it is above the 92^{nd} percentile of the local long-run average rainfall of the area (following Burke et al., 2015; Cools et al., 2020; Corno et al., 2020). A local long-run average mean precipitation has been calculated based on 16 years of rainfall data. Unfortunately, the study encountered difficulties in obtaining historical data predating 2003. In addition, a substantial quantity of essential weather station data was missing from the historical records before 2003, rendering it impractical to extend the investigation beyond that year. Thus, considering time and data constraints, a 16-year time frame was more feasible. The study acknowledges that the duration or length of the data for rainfall may not be adequate for generating a more precise long-term average, which is also a primary constraint of this research. The selection of the 2003-2018 (16-year) time frame sufficiently encompasses all the periods covered by this study.

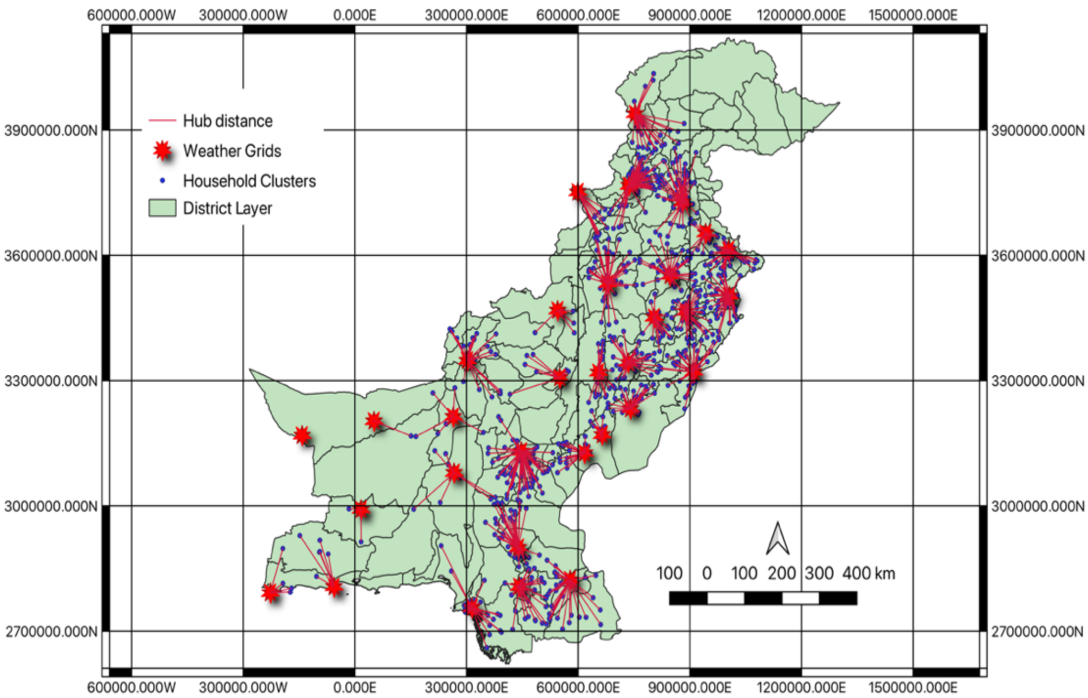
The percentile values have been adjusted by ± 2 to assess the robustness of the outcomes. The primary analysis uses the 92^{nd} percentile, whereas the robustness analysis uses the 90^{th} and 94^{th} percentile levels. As the percentile level increases, it is expected that the intensity of the rain shock will likewise increase. For example, when rainfall exceeds the 94^{th} percentile of the local long-term average, severe flooding is more likely than the lower flood risk associated with rainfall above the 92^{nd} and 90^{th} percentiles.

The independent variable "flood shock" is a binary variable coded as 1 to indicate the presence of flood-triggering rainfall in a residential cluster t years before the survey and 0 to indicate the absence of such rainfall. This study defines the variable "t" as “three years before the survey interview.” This specific period definition encompasses more recent abrupt and substantial precipitation occurrences in a particular geographical area. Hence, the specific choice of "3 years" before the survey interview (in primary analysis) signifies our focus on more recent occurrences of flood shocks. For instance, if a person was interviewed in 2017, the independent variable will be given a value of 1 if rainfall caused a flood in the three years leading up to 2017 (particularly in 2014, 2015, and 2016) and a 0 otherwise.

Our robustness checks consider an alternative time frame (t years) for the shock. By establishing shocks based on a particular location with the historical distribution of rainfall and consistently using the same percentile threshold for all locations to determine a shock (instead of a fixed value), it is expected that every location will likely experience an equal number of shocks over the three-year threshold. Hence, the study assumes that the rainfall shocks are largely exogenous and random; however, the effects should not be interpreted as entirely causal, as there might still be some sources of variation that may not be altogether exogenous. Additionally, we posit that all the clusters in the study possibly encounter a similar and randomized total amount of shocks in rainfall across the 16 years analyzed. We utilize this seemingly random variance of rainfall shocks in our analysis.

Following is the graphical representation of the spatial joining of the residential clusters with the corresponding weather stations conducted in GIS:

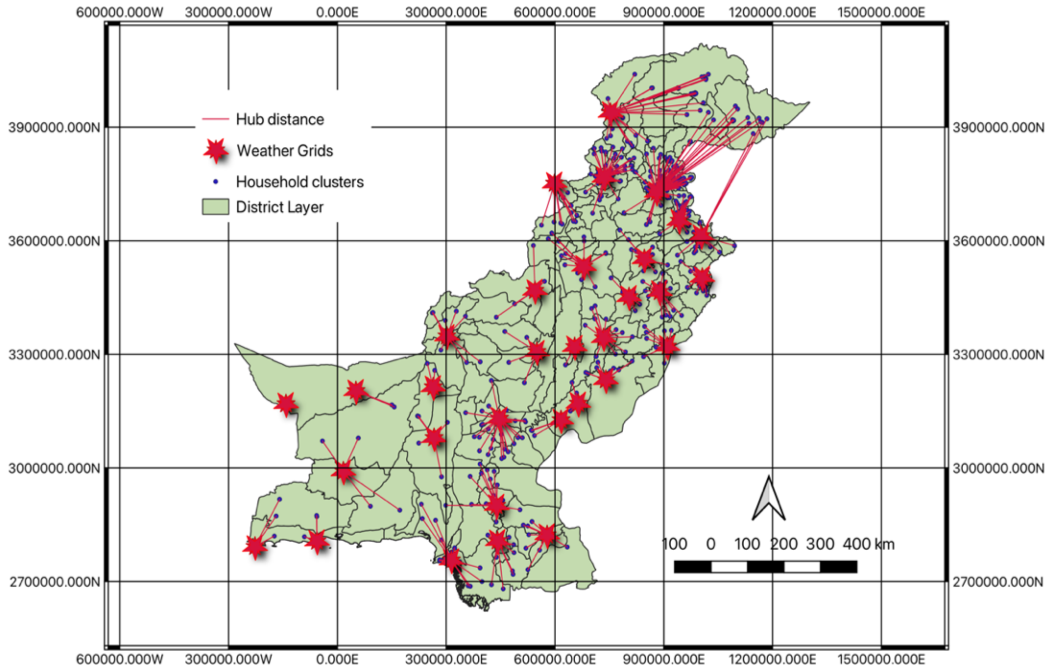
Figure 3: Spatial joining of weather grids with DHS 2006-2007 residential clusters



***Notes**:* Red markers show the weather stations and blue points represent the residential clusters included in DHS 2006-2007. Red lines show the distances between the weather hubs and clusters closest to them. The author created this map using the QGIS. The district base layer is taken from the Database of Global Administrative Areas

(GADM) https://gadm.org/download_country.html#google_vignette. The study covers all of Pakistan's regions except Azad Jammu and Kashmir.

Figure 4: Spatial joining of weather grids with DHS 2017-2018 residential clusters



Notes: All regions of Pakistan are covered except Azad and Jammu Kashmir. Red markers show the weather stations and black dots show the residential cluster surveyed by DHS in 2017-2018. Red lines show the distance between weather hubs and the residential clusters closest to them. The author created this map using QGIS. The district base layer is taken from the Database of Global Administrative Areas (GADM) https://gadm.org/download_country.html#google_vignette . Although DHS 2017-2018 did include the clusters of Azad Jammu and Kashmir, the AJK region is not covered in our study analysis to maintain coherence across all waves.

3.2.2. Identification of pregnancy loss

Three waves of the Pakistan Demographic and Health Survey (PDHS) (2006-2007, 2012-2013, and 2017-2018) have been utilized to gather data on unfavorable pregnancy outcomes. Adverse pregnancy outcomes are characterized by the demise of a baby/fetus before or during childbirth. PDHS describes a pregnancy loss as the event of experiencing a miscarriage, stillbirth, or abortion.

Unfortunately, DHS surveys do not explicitly differentiate between intentional and spontaneous abortions (Sánchez-Páez & Ortega, 2019). This is also a contributing factor to the lack of research in the field of pregnancy terminations and losses. The variable of pregnancy loss within the DHS dataset is highly contextual and influenced by various factors such as attitudes toward family planning, contraception usage, and abortion regulations. Hence, in this regard, Pakistani legal law has been thoroughly studied and analyzed to examine the extent to which the Pakistani penal law addresses women's right to abortion. Although the United Nations acknowledges abortion as a lawful right of women, not all countries share the same legal stance (Shalev, 1998). In Pakistani law, the terms "Isqat-e-Janin" and "Isqat-e-Hamal" are used to refer to abortion. According to articles 338, 338 (A), 338(B), and 338(C)[5], ending a pregnancy is considered a criminal offense "unless it is done in 'good faith' or to protect the woman's life through `necessary treatment`" or the essential medical care.

Furthermore, the definitions of what constitutes "good faith" and "essential treatment" are ambiguous, resulting in a lack of clarity and misinterpretation of the law (Saleem, 2022). The regulations on abortion rights are stringent in Pakistan, and hospitals are reluctant to assist patients unless the mother's life is at risk. Thus, despite women actively seeking abortions, they refrain from openly acknowledging and classifying them as purposeful because of the cultural, societal, and religious stigmas associated with the subject. Furthermore, in numerous cases, abortions are performed in unsafe circumstances, which frequently result in maternal mortality. Given this situation, it is assumed that the abortions recorded in the Pakistan Demographic and Health surveys are primarily spontaneous. Thus, for the scope of this research, abortions categorized as pregnancy losses are presumed and handled as spontaneous abortions. According to the Center for Disease Control and Prevention (2022), a stillbirth refers to the mortality or miscarriage of a baby before or during the process of delivery. Both miscarriage and stillbirth refer to the loss of a pregnancy, but they vary based on the timing of the loss. Pakistan has witnessed an increase in the prevalence of stillbirths from "3.98% to 5.75%" over the duration of 2012 to 2017 (Shakeel et al., 2023). This is concerning, as according to a report by UNICEF (2023), there has been a worldwide decrease of 35% in stillbirths during the past two decades (2000-2021). Moreover, around 13% of pregnancies in the five years leading up to 2019 ended in miscarriage (PDHS, 2019).

The outcome variable for pregnancy loss is a binary variable, with a value of 1 if women reported experiencing a pregnancy loss in the corresponding survey. To precisely assess the

[5] The duration of the punishment can vary, ranging from three years to a longer period of 10 years depending on whether the mother's consent was involved or not. Further information can be found on https://wdd.punjab.gov.pk/system/files/OFFENCES%20AND%20PUNISHMENTS%20AGAINST%20WOMEN_0.pdf

impact of excess rainfall on the occurrence of pregnancy losses in a specific area, we compare the timing of pregnancy loss with the time of the precipitation shock in that particular residential cluster. The same 3-year time frame has been employed in this situation, just as it was utilized to assess rainfall shocks. Therefore, the outcome variable is assigned a value of 1 for pregnancy losses within three years before the respondent's interview year and 0 otherwise. The primary analysis employed a Linear probability technique to examine the impact of exposure to rainfall shocks on the occurrence of pregnancy loss. The LPM model was chosen since the outcome variable is binary, and the findings are easily comprehended. However, during the robustness assessment, the model specification is altered, and a logistic regression model is used to examine the reliability of the principal analysis.

3.3. Model Estimation

$$\boldsymbol{P\ (Y_{irt-3} = 1) = \alpha + \beta F_{r,t-3} + W_{irt} + \gamma_r + \omega_t + \epsilon_{irt-3}}$$

$\boldsymbol{Y_{irt-3}}$**:**

The binary outcome variable of whether a woman (i) in the residential cluster (r) reported having a pregnancy loss in three (t-3) years before the survey interview. This variable is given a value of 0 if no pregnancy loss has been reported and one if a woman did report having a pregnancy loss.

$\boldsymbol{\beta F_{r,t-3}}$**:**

This is the independent variable showing excess rainfall shock (flood-triggering rainfall). It was given a value (0) if a residential cluster/district (r) experienced excess rainfall in three years (t-3) before the survey interview was conducted. A value of 1 will be assigned if an excess rainfall shock has been reported by a residential cluster/district (r) three years before the survey interview and 0 otherwise.

$\boldsymbol{W_{irt}}$**:**

Characteristics of women (i) in the cluster (r) at the time of the survey (t) that are not affected by the excess rainfall shocks like age of mother, education, and wealth status. These are control factors that we incorporate to control for these socioeconomic characteristics of mothers in our model.

$\boldsymbol{\gamma_r}$**:**

Residence type fixed effects to controls of the kind of residential setting of the individual (i). It will be assigned a value of 1 if the residence type is rural and 0 if it is urban.

$\boldsymbol{\omega_t}$**:**

Survey year fixed effects

$\boldsymbol{\epsilon_{irt-3}}$**:**

Error-term.

The standard errors in our analysis are adjusted at the residential cluster level throughout the study. This adjustment is implemented to control for the correlation within clusters and reduce potential biases caused by location-specific factors, thus making the standard errors robust. Moreover, shock specification is later adjusted in the robustness check by altering the definition (percentiles) and time frame of the shock (t level). In the robustness assessment, we also included geographically fixed effects once at the district level and then at the regional level to account for additional location-specific features in the model.

The following summary statistics offer a comprehensive perspective of the distribution and variation of the variables used in the study:

Table 2: Summary/Descriptive Statistics

Variable(s)	Obs	Mean	Std. Dev	Min	Max
Pregnancy loss	11581	.102	.302	0	1
Flood Shock	11581	.475	.499	0	1
Mother Education	11581	.482	.5	0	1
Mother's age (single years)	11581	33.029	8.4	15	49
Mother Age (age group)	11581	4.234	1.696	1	7
Wealth Quintiles	11581	3.474	1.105	1	5
Mother Wealth Index	11581	159.765	367.698	100	19730
Type of residence	11581	.312	.463	0	1

The "Pregnancy loss" variable indicates if pregnancy loss was reported by a woman (i) in the residential cluster (r) three years before the survey interview (t-3). The average value is 0.102, which shows that out of the 11,581 total observations, the average pregnancy loss rate is roughly 10.2%, with a standard deviation of 0.30. The standard deviation indicates a variation in the number of pregnancy loss incidents in the study observations. The primary independent variable of interest is “Flood Shock,” which measures the occurrences of flood-triggering rainfall shocks in the three years preceding the survey interview. The average result indicates that floods were observed in around 47.5% of the cases over the past three years (with a > 92nd percentile threshold and 20 km distance cutoff). The standard deviation of around 49.9% suggests considerable variation in flood occurrences among the observations.

The variable "Mother Education" indicates the mothers' education levels in the survey. It is a binary variable, with 0 indicating uneducated mothers (no education or incomplete primary education) and 1 showing relatively educated mothers (completed primary and more years of education). The descriptive data shows that, on average, 48.2% of the mothers are relatively educated (having completed primary education or more), whereas 51.8% have no education or have not completed primary education. A standard deviation of 0.5 suggests a relatively equal distribution of educational attainment among mothers.

For the age of the mother, we have presented two variables: one that shows age in single years, "Mother age (single years)," and one that converted into age groups, " Mother Age (age group)." "Mother age (single years)" shows that the average age is roughly 33 years, with a standard deviation of 8.4 years. These findings indicate that the mothers in the sample have an average age of approximately 33 years, with some variation in ages among the observations. A similar pattern is observed for the age group of mothers, which encompasses seven age groups (15-19), (20-24), (25-29), (30-34), (35-39), (40-44), and (45-49). The average value of 4.2 suggests that the mean age falls within the third age group, which aligns with the single age year data showing an average age of 33 per individual. In our primary analysis, we use the "Mother Age" variable (showing the mother's age group) and not the age in single years for ease.

We represent the wealth status of individuals using two variables in the data. The first variable, "Wealth Quintiles," indicates the wealth quintile to which an individual belongs. There are five quintiles: the bottom two represent those with lower wealth status, the middle quintile shows middle class, and the top two represent those with higher wealth status. A mean value of 3 for 'Wealth Quintiles' indicates that, on average, the population falls into the middle wealth quintile. The standard deviation shows the variation in wealth status across the studied population.

Similarly, we use another wealth variable, "Mother Wealth (index)," which is an index score reflecting the wealth index of the women in our dataset. The average index score of 160 suggests that most individuals do not belong to the wealthiest quintile but are instead in the middle categories. As with "Wealth Quintiles," the high standard deviation of "Mother Wealth" indicates the variation in wealth index scores among individuals in the study. Given that our research is conducted at the cluster level, we ensure the level of granularity by using the wealth index score of individuals in our primary analysis, which provides more comprehensive and continuous information about wealth distribution. Each individual in the wealth index is assigned a distinct score, which accounts for subtle variations in wealth that may not be captured by quintiles (more broad). Hence, the decision to utilize the wealth index is based on its precision, sensitivity, and adaptability as an indicator.

"Type of residence" indicates the fixed effects associated with type of residence. It is a binary variable indicating 0 for urban and 1 for rural residences. The average value of 0.3 suggests that most women in the sample live in metropolitan regions. The presence of a standard deviation of roughly 0.463 indicates that there is a certain degree of variety in the types of residences observed.

Table 3: Percentage of pregnancy loss and Flood shocks

Pregnancy Outcome	Flood shock in 3 years before the survey	
	No Shock	Shock
Pregnancy loss	9.22%	11.21%
Total	100.00	100.00

The tabulation results of the main independent and dependent variables display an interesting pattern. Table 3 shows the incidence of flood shocks and the corresponding percentage of pregnancy loss. The percentage of pregnancy loss in areas affected by flood shock is high at 11.21%, compared to areas unaffected by flood shock at 9.22%. This suggests a potential association between floods and adverse pregnancy outcomes such as miscarriage, stillbirth, and spontaneous abortion. This will be further examined in the subsequent primary analysis.

SECTION 4

4.1. Main results

The primary analysis employed the linear probability regression model (LPM). Linear probability models are regression models frequently used in research where the dependent variable is binary, and one or more explanatory variables are used to predict the dependent variable. The main advantage of using LPM is its inherent clarity and simplicity in terms of comprehension and interpretation.

Table 4 presents the results of our primary analysis, and the estimates were generated by employing various combinations of control and fixed effects variables. It can be observed that the coefficient of "Flood Shock" is positive and statistically significant in all the versions (columns) of estimations being done. The central column of interest is (4), depicting our analysis's final and most comprehensive estimation, including all controls, fixed effects, and the primary independent variable. All the standard errors throughout the study and in all versions of estimations have been clustered at the residential cluster level, which is the most granular level that can be chosen in DHS data. The primary analysis has been done with a 20 km distance cutoff, above the 92nd percentile level, and a t value of "3 years before survey interview".

Table 4: Effects of flood shocks on Pregnancy loss

	1 Preg loss	2 Preg loss	3 Preg loss	4 Preg loss
Flood Shock	0.0199***	0.0155**	0.0149**	0.0151**
	(0.00700)	(0.00701)	(0.00685)	(0.00683)
Mother Education			-0.0126**	-0.0126**
			(0.00637)	(0.00637)
Mother Age			-0.0256***	-0.0271***
			(0.00162)	(0.00169)
Mother Wealth				-0.0287***
				(0.00669)
Constants	0.0922***	0.0890***	0.205***	0.217***
	(0.00444)	(0.00719)	(0.0118)	(0.0123)
Number of obs	11581	11581	11581	11581
R-squared	0.001	0.004	0.024	0.025
Adj. R-squared	0.001	0.003	0.023	0.024
Type of residence FE		✓	✓	✓
Survey year FE		✓	✓	✓
Standard errors in parentheses				
***** 1% (p<0.01) ** 5% (p<0.05) * 10% (p<0.1**				

Notes: The dependent variable is shown in the column headers by "Preg loss," which indicates pregnancy loss. Standard errors are mentioned in the parenthesis and adjusted at the cluster level. The significance level is shown by the asterisk* signs along with each coefficient estimate (***1% (p<0.01), ** 5% (p<0.05), *10% (p<0.1)). F statistic of the model for the primary column of interest (4) is "F(10, 494) = 32.53" with "Prob > F =0.0000". For an explanation of independent and dependent variables (refer to Table 2 and the corresponding explanation of section 3.3)

Column (1) represents the effect of flood shock on pregnancy loss without any control or fixed variables involved in the model. The “Flood Shock” coefficient of column (1) is 0.019 with a standard error of 0.007 and significance at 1% (highly significant). This indicates that with each unit increase in the risk of flood shock, there is a 1.9% point increase in the probability of pregnancy loss, keeping other variables constant. In column (2), we included the fixed effects (survey year and type of residence fixed effects) and estimated our model 2 analysis. This time, there is a slight change in the standard errors, and the coefficient (0.015) remains positive and statistically significant at a 5% significance level. This indicates that with each unit increase in flood shock, the probability of having an adverse pregnancy outcome increases by 1.5 percent (ceteris paribus).

Column (3) presents our estimations with the inclusion of controls for mother characteristics related to her education level and age along with the fixed effects of residence type and survey year. The coefficient estimate of “Flood Shock” remains positive and significant at a 5% level, indicating that one unit increase in the risk of flood shock increases the likelihood of pregnancy loss to 1.4%, keeping other factors constant. The coefficient estimates associated with the mother`s education level and age show a negative and statistically significant effect in column (3). This indicates that the mother`s level of education and age are negatively related to the incidence of pregnancy loss. Simply put, mothers who are less educated or are younger are more likely to report stillbirths, spontaneous abortions, and miscarriages, keeping other factors constant.

The central column of interest is column (4), which includes all fixed effects and control variables in our analysis. First, the regression coefficient for the dependent variable (Flood Shock) is 0.015, which is positive and significant at a 5% significance level. Assuming all other factors remain constant, a one-unit increase in “Flood Shock” is linked to a 1.5 percentage points increase in the likelihood of experiencing a negative pregnancy outcome at a 5% significance level. Therefore, there is a significantly positive and substantial connection between the occurrence of intense rainfall that can cause floods and the likelihood of experiencing a negative outcome during pregnancy. This demonstrates that women residing in flood-affected regions have a higher probability of encountering negative pregnancy outcomes while keeping all other variables equal. It can be further observed that the influence of a mother's education is statistically significant at a significance level of 5% and negative. There is an inverse relationship between obtaining education and the probability of encountering a pregnancy loss. One unit increase in the level of education is associated with a 1.2% points decrease in the likelihood that a woman will report a pregnancy loss. Thus, assuming all other factors remain constant, it may be deduced that mothers with relatively higher levels of education have less probability of encountering adverse pregnancy outcomes.

Additional factors, such as the socioeconomic situation of the mother and her age, have also been observed to have an inverse and statistically significant effect on the outcome of pregnancy. The regression coefficient for the variable "Mother Age" is -0.027, with a highly significant p-value ($p < 0.01$). This suggests that older women have a lower probability of having pregnancy loss in comparison to younger mothers in our sample. Similarly, the coefficient for mother's wealth is -0.028, with a p-value that is also highly significant ($p < 0.01$). One unit increase in the wealth of women is correlated with a 2.8% points decrease in the likelihood of experiencing a negative pregnancy outcome ceteris paribus. This suggests that the wealth of the mother has a strongly negative and statistically significant impact on adverse pregnancy outcomes. The regression analysis indicates that individuals with higher socioeconomic status have a lower likelihood of experiencing pregnancy loss.

The model includes fixed-effect variables such as "survey year" and "type of residence" to account for time-related effects and those specific to residential settings, therefore reducing potential influences on the dependent variable. Including survey year fixed effects aims to control for any external factors, such as health policies, that may have been implemented during those years and could have impacted the findings. Moreover, the robustness analysis tested additional geographical fixed effects at the district and regional levels.

Generally, a model's statistical significance is determined by the F statistic estimates ($F(10, 494) = 32.53$, $p < 0.001$). The F statistic estimate indicates a statistically significant correlation between the dependent variable and at least one of the independent variables. The standard errors have been adjusted for all 495 clusters in the study sample. Since the DHS data is collected at the cluster level, adjusting the standard errors at this level is crucial. This provides more precise estimations and prevents the possibility of under and overestimating standard errors, improving the results' dependability and precision. The R-squared estimate of the model, commonly used to assess model fit, is very small, indicating that the independent variables explain just 2.53% of the variation in the dependent variable. However, it is not unusual to have a low R-squared value in the social sciences, especially for cross-sectional studies in the case of this study (Wooldridge, 2013). The R-squared values of several high-quality empirical research studies (Burke et al., 2015; Cools et al., 2020; Corno et al., 2020) that conducted comparable cross-sectional analyses are quite low. Therefore, according to Wooldridge (2013), relying solely on R square as the main and only measure of model fit and effectiveness in an economic analysis is not always desirable.

4.2. Discussion

This study examines the impact of excessive deviations in precipitation/rainfall on the likelihood of experiencing an adverse pregnancy outcome in Pakistan. We identified a positive and statistically significant association between flood-triggering rainfall and the risk of losing a pregnancy. Our empirical results (Table 4) indicate that being exposed to severe precipitation, such as floods, raises the likelihood of mothers experiencing miscarriage, spontaneous abortion, and stillbirth. Moreover, the study highlights that women from younger age groups with less educational attainment and from economically disadvantaged backgrounds are more susceptible to the hazards of miscarriage, spontaneous abortion, and stillbirth in Pakistan. Overall, the findings are consistent with previous literature and research studies on this topic. Our research indicates a statistically significant positive relationship between flood shocks and the occurrence of pregnancy loss.

However, the increase in pregnancy loss for each unit increase of flood shock is not very large (1.5% points) which may raise questions about the magnitude of this correlation. Nevertheless, our findings retain their significance and practical implications, keeping numerous factors in consideration. For instance, our research focuses mainly on recent flood shocks that occurred in three years before the survey. We did not consider potential long-term or cumulative effects that could have had a more significant impact. Furthermore, it is imperative to take into account the broader implications on public health, particularly among more vulnerable populations.

Additionally, considering pregnancy loss is not a very common incidence, the significant 1.5% increase in the outcome variable resulting from only a one-unit increase in flood shock highlights a considerable correlation. This emphasizes the need to further examine the extent and consequences of this association. Moreover, discovering a positive and significant connection between flood shocks and pregnancy losses necessitates implementing well-targeted preventive measures. These steps could encompass implementing more advanced early warning systems, awareness campaigns, prenatal care in flood-prone communities, and financial and mental health resources for women.

The occurrence of monsoon floods has increased considerably, causing a substantial impact on millions of Pakistanis, with the most recent instance of catastrophic flooding being in 2022. Flood shocks, like other climatic disasters, can be life-threatening for expecting mothers and fetuses, as highlighted by the results of our study. A research study by He et al. (2024), found a positive correlation between exposure to floods during pregnancy and an increased probability of pregnancy loss, with an odds ratio of 1.08 points. Moreover, the study unveiled that women with a higher level of schooling and belonging to privileged households exhibit a diminished likelihood of experiencing pregnancy loss. Similarly, a comprehensive review analysis conducted by Partash et al. (2022), emphasized that floods increase the probability of newborns having lower birth weights and pregnant women developing gestational hypertension.

The major obstacles flood victims encounter in Pakistan are the devastation of transport infrastructure, communication networks, and healthcare facilities. The disruption in access to healthcare can pose a significant risk. In many instances, it can even be life-threatening, particularly for women who are forced to give birth in unsafe conditions. Floods worsen healthcare issues in countries with insufficient infrastructure, causing disruptions in accessing essential primary and maternity healthcare services. This argument is substantiated by a study that was carried out in a similar setting as Pakistan, specifically in Bangladesh. The inadequate healthcare resources and services like antenatal checkups and lack of healthcare staff, especially during floods in Bangladesh, lead to a higher incidence of maternal problems and mortality (Abdullah et al., 2019).

As stated in the theory of change, multiple direct and indirect factors establish and influence the association between floods and pregnancy complications. One of the most important mechanisms is the mental health and well-being of pregnant women. Floods increase psychological stress and trauma, especially for those who are in a vulnerable state, such as those who are ill, pregnant, infants, and old. According to Morgan et al. (2022), pregnancy complications that are brought on by stress are a substantial contributor to morbidity and maternal deaths. Between the years 2016 and 2018, obstetric hemorrhage was responsible for 41% of maternal deaths in Pakistan, whereas hypertensive disorders were responsible for 29% of these deaths (DHS, 2019). Similarly, the severity of a climatic disaster is a substantial factor that negatively affects the mental health of pregnant and postpartum women who are exposed to such a disaster (Harville et al., 2010).

Besides restricted healthcare access, another significant aspect contributing to the problem is relief camps' unhygienic and overcrowded circumstances. In addition, due to insufficient water sewage infrastructure and maintenance in flood-prone urban areas, stagnant water remains on roads for long periods, providing an optimal environment for spreading and transmitting diseases. The presence of insufficient healthcare resources, extensive open defecation, and inadequate personal hygiene in flood-affected areas dramatically increases the risk of death and problems during childbirth (Sorensen et al., 2018).

Our study also revealed that the socioeconomic factors of women, such as their wealth and education, significantly influence the likelihood of experiencing adverse maternal health outcomes. Women from more wealthy families typically possess greater financial means. They are more likely to be able to afford and obtain medical care, such as prenatal services and emergency treatment. In addition, attaining higher levels of education decreases obstacles in obtaining information about family planning, contraception, emergency health interventions, and overall health awareness. Therefore, providing financial and educational resources can enable women to adequately plan for health emergencies, increasing their likelihood of accessing essential medical assistance. Hence, our research highlights the significance of allocating resources toward education and socioeconomic empowerment initiatives targeting women, especially those residing in flood-prone areas.

Equipping women with sufficient economic resources and knowledge might enhance their capacity to manage flood-related hazards and mitigate adverse impacts on maternal well-being. Furthermore, by adopting targeted interventions aimed at improving access to reproductive healthcare services and promoting health literacy, it is possible to successfully decrease the discrepancy in vulnerability among women with different educational backgrounds and levels of affluence. Our study results regarding the effect of education and wealth status also align with the prior research and literature. A study by Granés et al. (2023) emphasized that females with a diminished level of schooling exhibited a higher vulnerability to encountering premature birth. Moreover, additional studies have identified a detrimental association between socioeconomic status and the probability of preterm birth (Jenkins et al., 2009; Wood et al., 2014).

Lastly, our study findings demonstrate a statistically significant and inverse relationship between maternal age and the probability of encountering pregnancy loss. This means the younger age of the mother is correlated with an increased likelihood of experiencing negative pregnancy outcomes such as stillbirth, spontaneous abortion, and miscarriage. On the other hand, an increase in the mother's age translates to a lower likelihood of pregnancy loss. Existing research has not yet determined a conclusive and generally accepted pattern regarding the impact of women's age on the outcomes of pregnancy. Multiple research studies have consistently demonstrated that older women have an elevated likelihood of experiencing a miscarriage (He et al., 2024; Magnus et al., 2019; Wang et al., 2021). However, several research studies have indicated that older women are more likely to experience negative pregnancy outcomes. Some other studies have found a higher risk among young mothers. The contradictory results underscore the intricate nature of how maternal age affects pregnancy outcomes and emphasize the necessity for additional research.

Numerous studies have produced similar results to our own, suggesting that younger mothers are more prone to experiencing worse pregnancy outcomes compared to older mothers. According to Mayor (2004), adolescent pregnancy and delivery are major factors that contribute to the high mortality rates among teenagers in low-income countries. A report issued by the World Health Organisation (WHO) cautions that adolescent females aged 10 to 19 are at a higher risk of encountering complications during pregnancy and childbirth. A report issued by the World Health Organisation (WHO) warns that younger females aged 10 to 19 are at a higher risk of encountering complications during pregnancy and childbirth (2024a). Several other studies revealed that teenage and young mothers aged 13 to 17 face a higher probability of encountering preterm deliveries or delivering kids with reduced birth weights (Fraser et al., 1995; Brown et al., 1991; Friede et al., 1987). Teenage and child marriage remains widespread in several regions of Pakistan, resulting in increased rates of adolescent pregnancies. DHS data analysis indicated that 18% of females in the age bracket of 20 to 24 have married before turning 18 in Pakistan (DHS, 2019). Therefore, it is unsurprising to see a greater prevalence of pregnancy losses among younger women in Pakistan.

During floods, numerous pressing issues emerge, encompassing the devastation of infrastructure, increased susceptibility to infectious diseases, unemployment, and forced displacement. These problems significantly influence the well-being of pregnant women and individuals most susceptible to climate-related hazards. Nevertheless, despite the significant impact of climate shocks on maternal health outcomes, pregnant women and newborns are frequently disregarded in national climate plans and strategies. It is crucial to prioritize pregnant women's immediate requirements during catastrophic events and ensure they receive prompt and targeted aid in flood relief operations. Furthermore, it is essential to tackle the societal prejudices associated with matters related to pregnancy, which requires coordinated actions from both the government and society. Through increasing awareness and cultivating conducive circumstances, we may dismantle such obstacles and guarantee that pregnant women promptly receive the necessary treatment and support in times of crisis.

4.3. Robustness Checks

This section thoroughly assesses the robustness of our main findings which demonstrate a positive and statistically significant relationship between pregnancy loss and flood shocks. We perform five robustness checks to check the stability of our primary results. We do this by closely examining the impact of several factors, such as changing shock-defining thresholds (percentiles), using an alternative model, altering the distance thresholds, including geographic fixed effects, and modifying the time “t” threshold.

4.3.1. Changing the shock definition(s)

Firstly, we assessed the impact of variations in the definition of a rainfall shock on our primary findings. We modified the shock definition by selecting alternative percentile thresholds that classify rainfall shock as a trigger for flooding. In our main specification, we establish an excess rainfall shock as a rainfall event that exceeds the 92^{nd} percentile of the mean local rainfall. Here, we adjust the percentile levels by ± 2 points from the original level. By adjusting the upper and lower threshold from the initial level, we could also effectively assess the effect of the severity of flood shock on the risk of experiencing a pregnancy loss. We demonstrated this by analyzing the variations in the point estimates and corresponding significance when the intensity of the shock is altered. The intensity and magnitude of the flood shock are depicted by percentile thresholds (> 94^{th} being the most severe level of shock. In Column (1) of Table 5, we employed a lower percentile level, specifically the 90^{th} percentile, and adjusted the standard errors at the cluster level as in the primary analysis. In this context, a flood-triggering rainfall shock is a precipitation event exceeding the 90^{th} percentile of the long-run average local rainfall.

The result in Table 5 indicates that the point estimates remain consistent, similar to our initial analysis. The impact of flood shock is correlated with the likelihood of experiencing a negative pregnancy outcome, and this association is statistically significant ($p<0.05$), holding all other variables constant. For instance, in Column (1) with (> 90^{th}) percentile shock, one unit increase in flood shock is associated with a 1.3% points increase in the probability of experiencing pregnancy loss (Ceteris Paribus). Furthermore, the regression coefficient for the variable representing the mother's education level is (-0.0125), indicating a negative relationship at 5% significance. This suggests that when other factors are held constant, an increase in maternal education is linked to a 1.2% points decrease in the likelihood of pregnancy loss. The coefficient estimates of “Mother Age” and “Mother Wealth” also show negative and highly significant results at all significance levels ($p<0.01$). One unit increase in the age of a mother is associated with a 2.7 percent points decrease in the risk of pregnancy loss, and one unit increment in a mother`s wealth is associated with a 2.8% points decrease in pregnancy loss chance. This suggests that women who come from impoverished families and are in younger age groups are also more vulnerable to adverse pregnancy outcomes.

Table 5: Robustness to Shock definition

	1		2
	Preg loss		**Preg loss**
Flood Shock (90)	0.0136**	**Flood Shock (94)**	0.0218***
	(0.00655)		(0.00813)
Mother Education	-0.0125**		-0.0115*
	(0.00637)		(0.00633)
Mother Age	-0.0271***		-0.0271***
	(0.00169)		(0.00168)
Mother Wealth	-0.0287***		-0.0287***
	(0.00669)		(0.00664)
Constants	0.216***		0.216***
	(0.0125)		(0.0121)
N (num of obs)	11581		11581
R-squared	0.025		0.026
Adjusted R-squared	0.024		0.025
Residence type FE	✓		✓
Survey Year FE	✓		✓
Standard errors in parentheses			
***** 1% (p<0.01) ** 5% (p<0.05) * 10% (p<0.1)**			

Notes: The dependent variable is shown in the column headers by "Preg loss," which indicates pregnancy loss. Standard errors are mentioned in the parenthesis, and the significance level is shown by the asterisk* signs along with each coefficient estimate (***1% (p<0.01), ** 5% (p<0.05), *10% (p<0.1)). Standard errors have been adjusted at the cluster level. For an explanation of independent and dependent variables (refer to Table 2 and the corresponding explanation of section 3.3)

Similarly, in column (2), the sensitivity analysis is conducted by increasing the shock percentile to show a more severe flood shock (> 94^{th} percentile). This defines a rainfall shock as a rainfall event that exceeds the 94^{th} percentile of the local average rainfall. The results again demonstrate that the point estimate is consistent, as observed in our first analysis. However, the significance level has increased from 5% to 1%. Each additional unit of flood shock is linked to a 2.1 percentage point increase in the likelihood of pregnancy loss while holding all other variables equal. The coefficient for the mother's education is -0.011, showing a negative relationship between the mother`s education and pregnancy loss outcome. However, this effect is significant at a 10% significance level and not at 5%. The results also indicate a strong positive and highly statistically significant ($p < 0.01$) association between the age of a woman, wealth position, and the probability of pregnancy loss. These findings indicate that women who come from affluent families and those who are older are less vulnerable to negative pregnancy outcomes, holding other variables constant.

Overall, we discovered that altering the definition of shock to lower and higher levels did not reverse the significance of the estimates of flood shock and followed the pattern observed in the primary analysis.

Furthermore, regarding the intensity of shock and its effect, we noticed that when the flood shock was more severe (exceeding the 94^{th} percentile), there was a higher and more substantial rise in the risk of pregnancy loss compared to other percentile levels (above 92^{nd} or 90^{th}). The most pronounced impact of flood shock and its significance has been found at levels above the 94^{th} percentile, followed by levels exceeding the 92^{nd} percentile, and finally at levels exceeding the 90^{th} percentile.

Table 6: Severity analysis of Flood Shock on Pregnancy loss

Flood Shock Percentiles	Coefficient Estimates of Flood Shock	A significant level of Flood Shock
90^{th}	0.013	0.039**
92^{nd}	0.015	0.028**
94^{th}	0.021	0.008***

Notes: *** 1% (p<0.01) ** 5% (p<0.05) * 10% (p<0.1)

Table (6) indicates that as the intensity of the flood shock increases, the impact of flood shocks on the risk of losing a pregnancy also gets more pronounced. The coefficient estimates also increase with an increase in the percentile threshold, and a similar pattern is observed for the significance of these effects. This result not only makes intuitive sense but is also complemented by prior research in the area.

4.3.2. Changing the empirical model

To further assess the reliability of our findings, we conducted an additional test by altering the model and employing a logistic probability model instead. We conducted a secondary analysis in Table 7 using a logit regression model at all three levels of the percentile threshold. We want to assess if altering the model for the binary outcome variable would lead to a reversal of the initial analysis findings. The results in Table (7) are in coherence with our primary analysis. It demonstrates a statistically significant and positive correlation between flood shock and the risk of losing a pregnancy. This suggests that the relationship between the two variables is stable across two models (LPM and Logit). Column (1) presents the odds ratio estimates when the percentile threshold of shock is above 90th, column (2) is above 92nd (primary analysis), and column (3) for the highest level of shock (above 94th percentile).

Table 7: Alternative Model Robustness Check (LOGIT)

	1 Preg loss		2 Preg loss		3 Preg loss
Flood Shock (90)	0.154** (0.0741)	**Flood Shock (92)**	0.172** (0.0770)	**Flood Shock (94)**	0.230*** (0.0847)
Mother_Education	-0.133* (0.0721)		-0.134* (0.0720)		-0.120* (0.0717)
Mother_Age	-0.357*** (0.0269)		-0.357*** (0.0269)		-0.356*** (0.0269)
Mother_Wealth	-1.182*** (0.445)		-1.185*** (0.445)		-1.181*** (0.443)
Constants	-0.657*** (0.195)		-0.643*** (0.193)		-0.644*** (0.189)
Num of observations	11581		11581		11581
Pseudo R2	0.0418		0.0419		0.0424
Type of residence FE	✓		✓		✓
Survey Year FE	✓		✓		✓
Standard errors in parentheses ***** 1% (p<0.01) ** 5% (p<0.05) * 10% (p<0.1)**					

Notes: The dependent variable is shown in the column headers by "Preg loss," which indicates pregnancy loss. Standard errors are mentioned in the parenthesis, and the significance levels are shown by the asterisk* signs along with each coefficient estimate (***1% (p<0.01), ** 5% (p<0.05), *10% (p<0.1)). Standard errors have been adjusted at the cluster level. For an explanation of independent and dependent variables (refer to Table 2 and the corresponding explanation of section 3.3)

The coefficient of "Flood Shock" in column (1) indicates that keeping other variables constant, with every one-unit rise in flood shock, the odds of losing a pregnancy increase by approximately ($e^{0.154}$ = 1.166) times, or by 16.6%. Similarly, column (2) shows that with every one-unit increase in flood risk, the odds of adverse pregnancy outcomes increase by 18.7% ($e^{0.172}$ = 1.187) ceteris paribus. These effects are statistically significant at a 5% significance level, keeping all other variables constant. Lastly, in column (3), the odds of stillbirth, miscarriage, and spontaneous abortion increase by 25% ($e^{0.230}$ = 1.258) with a unit increase in the flood-triggering rainfall in that area. Overall, these results imply that the likelihood of losing a pregnancy increases in the presence of flood shocks, keeping other factors constant. It can also be observed again that when the shock level becomes more severe (from above 90^{th}, 92^{nd} to 94^{th}), the odds of pregnancy loss also increase. This confirms our observation and offers valuable insights into the magnitude and severity of the influence, as depicted in Table (6).

The results of other control variables, such as the mother's age, wealth, and education level, also reveal similar results. With every one-unit increase in the mother's education level, the odds of detrimental pregnancy outcomes decrease at all three levels of shock, but the significance is at a 10% level. Moreover, the odds ratio of pregnancy loss decreases with one unit increase in the mother`s age and wealth status across all three levels of shock. Furthermore, these variables have highly significant estimates ($p < 0.01$). The results of the predictors of age and wealth depict that mothers from less educated, younger age groups, and impoverished backgrounds are more likely to experience pregnancy losses, as indicated in the primary analysis.

The robustness of our findings across different model settings underscores the significant association between flood shock and pregnancy loss. There are slight discrepancies in the significance levels of specific predictors, such as education, among different types of models. Nevertheless, the persistent patterns observed suggest that the correlation between flood shock and pregnancy loss remains intact. Similarly, other variables linked to maternal traits (wealth and age) remain mostly consistent regardless of variations in model specifications and different types of disturbances.

4.3.3. Adding geographic fixed effects

In Table (8), we employ the geographic fixed effects in our original model along with the residential type fixed effects and survey year fixed effects. The percentile levels remain at their primary level of above $92^{nd,}$ and standard errors are adjusted at the cluster level. Column (1) shows the estimates when we employ the district-level fixed effects, and column (2) represents estimation results when regional fixed effects are involved in the model. The effects of " Flood Shock" remain consistent with our primary analysis and show a positive and statistically significant link with the risk of pregnancy loss. In case of district fixed effects, one unit increase in flood shock results in 1.5% points increase in pregnancy loss outcome. Moreover, the estimates associated with "Flood Shock" are statistically significant at a 5% significance level ($p < 0.05$). The predictors of "Mother Wealth" and "Age" maintain their highly significant and negative association with pregnancy losses.

Table 8: Geographic fixed effects Robustness Check

	1 Preg loss	2 Preg loss
Flood Shock	0.0156**	0.0141**
	(0.00686)	(0.00670)
Mother Education	-0.00722	-0.0105
	(0.00656)	(0.00647)
Mother Age	-0.0267***	-0.0272***
	(0.00168)	(0.00171)
Mother Wealth	-0.0275***	-0.0285***
	(0.00642)	(0.00651)
Constant	0.216***	0.220***
	(0.0123)	(0.0128)
Num of observations	11581	11581
R-squared	0.033	0.027
Adjusted R-squared	0.029	0.026
Type of residence Fixed Effects	✓	✓
Survey Year FE	✓	✓
District FE	✓	
Region FE		✓
Standard errors in parentheses		
***** 1% (p<0.01) ** 5% (p<0.05) * 10% (p<0.1)**		

Notes: The dependent variable is shown in the column headers by “Preg loss,” which indicates pregnancy loss. Standard errors are mentioned in the parenthesis, and the significance level is shown by the asterisk* signs along with each coefficient estimate (***1% (p<0.01), ** 5% (p<0.05), *10% (p<0.1)). Standard errors have been adjusted at the cluster level. For an explanation of independent and dependent variables (refer to Table 2 and the corresponding explanation of section 3.3)

All of the explanatory factors exhibit the same pattern as the original analysis, except for the "Mother's Education" variable, which remains negative but is no longer statistically significant. Several potential factors could have contributed to this. For instance, introducing geographic fixed effects may have caused multicollinearity (education and geolocation). This could have resulted in inflated standard errors for the education variable and may have decreased its significance. This might raise concerns regarding the over- or under-estimation of standard errors in our primary analysis, which does not include these geographically fixed effects. However, our standard errors have been adjusted at the most granular level of residential clusters, which controls for the fluctuation of standard errors within each cluster. This provides more precise estimations and prevents the possibility of under and overestimating standard errors, improving the results' dependability and precision. It indicates that the likelihood of bias in standard errors due to excluding geographic fixed effects is negligible, as we have already considered fluctuations at the cluster level.

Therefore, although geographically fixed effects offer extra control, their exclusion in the initial framework is not a crucial concern. The consistent patterns seen in most variables and the substantial validity of our main findings (Flood Shock) emphasize the dependability of our initial investigation.

4.3.4. Changing shock time window

We have conducted another robustness check in Table (9) using a different shock window. For our initial research, we used a "three-year before survey interview" or "t-3" timeframe to evaluate the frequency of flood shocks in a specific location. For this check, we are utilizing a time frame called "t-2," which refers to two years before the survey interview in a residential cluster. The percentile levels remain at their primary level of above $92^{nd,}$ and standard errors are adjusted at the cluster level.

Column (1) presents the coefficient estimates of the model with a 2-year time frame, and column (2) presents our original analysis with a 3-year time frame for comparison. The “Flood Shock” point estimate remains consistent across both time frames. Column (1) shows that with one unit increase in flood shock (2 years before the survey interview), the probability of losing a pregnancy increases by 1.7 percent points (ceteris paribus). This shows a positive and statistically significant effect of flood shock on the risk of pregnancy loss at a 5% significance level. Similarly, other predictors also show stable patterns across the two models with some variance in the significance level of the education predictor. The variable of mother education shows that with one unit increase in the education level of mothers, the risk of losing pregnancy decreases by 1.2 percent points, and this effect is statistically significant at a 10% significance level.

Furthermore, the point estimate of “Mother Age” shows that older women have less risk of pregnancy loss, and this effect is highly significant. Similarly, the “Mother Wealth” indicator is inversely linked with the risk of pregnancy loss, showing that a one-unit increase in the wealth of mothers is associated with a 2.8% decrease in pregnancy loss risk in those mothers. Overall, the control predictors show that mothers who are wealthy, more educated, and older are less likely to experience pregnancy loss, keeping other factors constant. Thus, the results align with primary analysis, which uses a three-year shock time frame to assess the occurrence of shocks.

Table 9: Robustness check with different time ranges (t-2)

	1		2
	Preg loss		**Preg loss**
Flood Shock (2Y)	0.0171**	**Flood Shock (3Y)**	0.0151**
	(0.00854)		(0.00683)
Mother Education	-0.0124*		-0.0126**
	(0.00637)		(0.00637)
Mother Age	-0.0271***		-0.0271***
	(0.00169)		(0.00169)
Mother Wealth	-0.0286***		-0.0287***
	(0.00667)		(0.00669)
Constant	0.219***		0.217***
	(0.0122)		(0.0123)
Num of obs	11581		11581
R-squared	0.025		0.025
Adjusted. R-squared	0.024		0.024
Type of residence FE	✓		✓
Survey year FE	✓		✓
Standard errors in parentheses			
***** 1% (p<0.01) ** 5% (p<0.05) * 10% (p<0.1)**			

Notes: The dependent variable is shown in the column headers by "Preg loss," which indicates pregnancy loss. Standard errors are mentioned in the parenthesis, and the significance level is shown by the asterisk* signs along with each coefficient estimate (***1% (p<0.01), ** 5% (p<0.05), *10% (p<0.1)). Standard errors have been adjusted at the cluster level. For an explanation of independent and dependent variables (refer Tableble 2 and the corresponding explanation of section 3.3)

Changing the time frame above and below the primary (t-3) period would have been ideal. Nevertheless, the primary constraint of doing so resides in the concise duration of rainfall data (2003-2018). The accessible data in our study starts from 2003, limiting the maximum time window to 3 years. This three-year timeframe adequately includes most potential flood shocks in our research data. Furthermore, when employing a (t-1) time frame, the data indicates barely any rainfall shocks, with only 2% of flood shocks aggregated across all three waves. Therefore, we cannot examine shocks at the (t-1) level because there are insufficient shocks to conduct a meaningful analysis. As a result, we did not use this approach in our study.

4.3.5. Changing distance levels

Another sensitivity concern was that our results might be influenced by the distance at which we align weather grids with the individual clusters. As another measure of robustness, we adjusted the sample size by altering the distance criterion to match the weather stations with the residential clusters. This is a test to determine if changing the distance, which may affect the sample size, impacts the stability of the primary results. We adjusted the initial distance threshold utilized in the primary study (20 km) by ± 3 kilometers, opting for 17 and 23 km instead. The percentile levels remain at their primary level of above $92^{nd,}$ and standard errors are adjusted at the cluster level.

In column (1) of table (10), we extended the distance to 23 km, resulting in an increased sample size of 12,171 individuals and 514 clusters. The coefficient for “Flood Shock” shows that one unit increase in floods is associated with a 1.5% points increase in pregnancy loss at a 5% significance level (ceteris paribus). Thus, we may assert that as the level of exposure to floods increases, the likelihood of experiencing stillbirth, spontaneous abortion, or miscarriage also increases in that specific residential cluster. Similarly, the coefficient and significance of other control variables like education, age, and wealth of the mother remain stable as in the primary analysis with a 20 km distance cutoff. Column (1) estimates show that more educated, wealthy, and older mothers are less likely to experience a pregnancy loss, keeping other variables constant.

In column (2), the distance is reduced to -3 levels at 17km. As a result, the sample size has decreased to 10,747, with 457 residential clusters. The linear regression model shows that the coefficient for “Flood Shock” is 0.0129, indicating that one unit increase in floods is associated with a 1.2 points increase in pregnancy loss in a cluster. Although the coefficient indicates a positive correlation between dependent and independent variables, this link does not reach statistical significance at 5% as in the primary study. “Flood Shock” is statistically significant at a significance level of 10% ($p = 0.06$), keeping other variables constant. The coefficient for the variable "Mother Education" shows that a one-unit increase in the risk of floods is linked with a 1.2 percent points decrease in the likelihood of miscarriage, stillbirth, and spontaneous abortion.

Other variables of a mother's wealth status and age consistently demonstrate an inverse association with the probability of pregnancy loss. The point estimates of “Mother Wealth” and “Mother Age” in column (2) depict that younger and poorer mothers are more likely to lose pregnancy, and this effect is highly statistically significant.

Table 10: Robustness check with different distance levels

	1		2
	Preg loss		**Preg loss**
Flood Shock (23KM)	0.0150**	**Flood Shock (17KM)**	0.0129*
	(0.00700)		(0.00712)
Mother Education	-0.0142**		-0.0127*
	(0.00675)		(0.00670)
Mother Age	-0.0307***		-0.0275***
	(0.00161)		(0.00177)
Mother Wealth	-0.0268***		-0.0282***
	(0.00622)		(0.00672)
Constants	0.233***		0.221***
	(0.0116)		(0.0130)
Num of observations	12171		10747
R-squared	0.027		0.026
Adjusted. R-squared	0.026		0.025
Type of residence FE	✓		✓
Survey Year FE	✓		✓
Standard errors in parentheses			
***** 1% (p<0.01) ** 5% (p<0.05) * 10% (p<0.1)**			

Notes: The dependent variable is shown in the column headers by "Preg loss," which indicates pregnancy loss. Standard errors are mentioned in the parenthesis, and the significance level is shown by the asterisk* signs along with each coefficient estimate (***1% (p<0.01), ** 5% (p<0.05), *10% (p<0.1)). Standard errors have been adjusted at the cluster level. For an explanation of independent and dependent variables (refer to Table 2 and the corresponding explanation of section 3.3)

Overall, the results align with our initial research that utilized a 20 km distance threshold. It is essential to mention that the variable "Flood Shock" is not statistically significant at the 5% level but at the 10% level when the distance is reduced to 17 km. This could be attributed primarily to the diminished sample size resulting from the shorter distance. Our study has limited weather station data, with just 29 out of 110 stations. This limited dataset does not adequately cover all the significant places in the country that could be prone to flooding. Therefore, it is possible that by reducing the distance requirements in this situation, specific crucial residential clusters were likely removed from the analysis, which could have experienced more flood shocks. As a result, the reduced sample size may have weakened the statistical power, resulting in a decrease in the levels of significance. Hence, witnessing a lower significance of the primary independent variable (Flood Shock) is unsurprising as we decrease the distance cut-off and sample size in our investigation.

SECTION 5

Policy implications

To adequately tackle the intricate aspects of disaster response, it is imperative to consider immediate, practical and sustainable measures to mitigate the impact of climate shocks, particularly for more vulnerable individuals. When dealing with climatic shocks, which are often not preventable, the question of appropriate response techniques becomes crucial. Our study analysis indicates specific areas where intervention is needed through which the government and corresponding agencies can strengthen the resilience of communities by incorporating more targeted actions. Therefore, within the scope of this study, the following are some of the policy recommendations that also highlight the practical significance and implications of the study. These recommendations could potentially enhance the resilience of the Pakistani population, with a particular focus on pregnant women, against the threat of climate-related shocks.

5.1.Making national climate plans more gender inclusive

Despite the recognition that women and infants are particularly susceptible to climate shocks' impacts, most national plans lack strategies to prioritize their specific needs. Hence, it is imperative to incorporate sexual and maternal health into the climate strategies. Especially in countries like Pakistan, where gender inequality is already a significant problem, and discussing reproductive health and pregnancy difficulties publically is associated with social shame. This study advocates incorporating reproductive health into the discussions and developing national strategies to address climate change.

5.2.Promotion of evidence-based and gender-sensitive research

We must enhance our data and research to evaluate gender-related climate risks and vulnerabilities appropriately. Providing financial assistance for evidence-based research on these projects is essential to highlight this issue on national and international platforms. The World Meteorological Organisation also emphasizes the importance of obtaining more gender-sensitive data regarding climate change. Weather and climate have disparate impacts on women and men, necessitating the provision of gender-appropriate services and information (WMO, 2024). Establishing and supporting efforts to collect and distribute data that can be distinguished by gender will make adopting practical, focused, and efficient solutions easier.

This will additionally aid in identifying the most susceptible population groups to the impacts of climate change, facilitating the more accurate and responsive mobilization of climate action.

5.3.Installation of additional weather stations and early warning systems

Climate-related disasters are inherently unpredictable, yet precise weather forecasting can help to mitigate their consequences. People and organizations across different sectors require precise weather predictions to facilitate daily decision-making and overcome challenges and uncertainties with anticipation and adaptability. However, Pakistan has insufficient meteorological stations, which is not in line with its diverse topography, climate vulnerability, large area, and international standards. International regulations suggest that a weather station should be located within a distance of 30 to 50 km, whereas Pakistan only has 110 stations for an area of 770,820 km^2 (Khan, 2023).

This illustrates the scarcity of meteorological stations in the country. This inadequacy impairs the precision and dependability of weather predictions and warning systems, presenting obstacles to efficient disaster response and preparedness. This problem is particularly evident in remote districts, which depend on neighboring districts for meteorological information that might not be accurate given highly diverse geographical and weather patterns.

The government should prioritize expanding the network of weather stations and developing early warning systems, particularly in remote locations. Furthermore, in remote villages and rural regions where digital devices such as mobile phones and televisions are restricted, it is crucial to build alternate communication channels like radio broadcasts and newspapers to ensure timely dissemination of early warnings. Improving weather grids and early warning systems would allow government agencies to evaluate weather conditions, send timely alerts, and empower local people to better prepare for unfavorable weather events.

5.4.Upgrading the health infrastructure

Urgent measures are required to build advanced healthcare facilities (like mobile health clinics) and hubs that guarantee continuous service provision throughout the year. In Pakistan, where monsoon floods occur frequently, local authorities must take proactive measures to establish and upgrade sewage and drainage systems in anticipation of monsoons. In addition, it is essential to maintain sufficient stocks of medications for vector-borne diseases to fulfill the heightened demand during floods, thus preventing any delays in treatment. To combat mosquito-borne illnesses, it is recommended that free or subsidized mosquito nets be distributed according to household size. To adequately prepare for flood situations, it is imperative to increase the number of relief camps, considering the safety and welfare of women, especially pregnant women. These measures can help communities enhance their resilience to climate-related disasters.

5.5.Awareness and support for sexual, reproductive, and mental health

Our study indicates a lack of education and teenage/younger pregnancies as one of the factors that increase the susceptibility of pregnant women. Hence, it is crucial to implement awareness campaigns addressing family planning, contraceptive usage, child marriages, and safe childbirth. Incorporating these subjects within the educational curriculum is fundamental to enable individuals to understand the situation better and respond appropriately when necessary. Furthermore, both social and telecommunications media present an unexplored opportunity for disseminating information and raising awareness about the dangers associated with child marriage and pregnancies occurring outside of the reproductive age. Creating helplines is essential to offer a secure platform for women to report instances of domestic violence or involuntary situations that may lead to teenage pregnancy (such as child marriage or sexual assault) while maintaining their privacy if requested.

The psychological well-being of pregnant women is significantly affected by disasters through depression, stress, and trauma. Establishing support groups, particularly in relief camps, might be helpful. Addressing societal restrictions and promoting the acceptance and services of therapy during pregnancy can strengthen women's ability to cope with difficulties. This can be accomplished by implementing media and non-media campaigns, educational initiatives, and online and physical health services that provide reduced-cost or complimentary individual sessions for expectant mothers.

5.6.Financial subsidies and stability

Our data highlights that women from socioeconomically poor households are more susceptible to experiencing adverse pregnancy outcomes like pregnancy loss. Therefore, it is crucial to enhance the availability of alternative economic possibilities and vocational training to strengthen women's financial resilience. This may help women, especially those living in flood-prone regions, quickly recover from climate emergencies. Furthermore, it is imperative to ensure that women have convenient access to bank accounts, particularly in rural areas. This would enable them to effectively utilize digitally transferred flood compensations or relief money. Another effective strategy could be to encourage the expansion of e-commerce for products such as apparel, handicrafts, and jewelry. Such initiatives are in great demand and tend to be less affected by emergencies.

Section 6

Conclusion

The present study extends the current body of research by conducting a quantitative analysis to determine the influence of rainfall shocks on negative pregnancy outcomes in Pakistan. Additionally, our research investigates the correlation between the risk of pregnancy loss and the education level, age, and financial condition of a mother. The study utilizes data from three waves of Demographic and Health Surveys and weather station data gathered by national and international climate research and data collection organizations. Based on our research findings, pregnant women who are exposed to flood shocks have an increased probability of suffering a miscarriage, stillbirth, or spontaneous abortion. Moreover, as the intensity of the flood increases, the impact becomes increasingly substantial and elevated. The cross-sectional methodology employed in this study highlights that relatively educated, wealthy, and older mothers are less vulnerable to pregnancy losses. Our research identifies the risk climate change poses to pregnant women in Pakistan, a country characterized by poor development, lower economic growth, and high climate sensitivity.

While our study offers valuable micro-level information about the impact of climate change on maternal health outcomes, it is essential to acknowledge that our study has certain limitations. One significant limitation of the study is the insufficient availability of rainfall data that covers a more substantial number of geographical areas in Pakistan. Furthermore, the meteorological station data about rainfall were either inadequate or inaccessible for several essential weather grids after 2003. Due to this constraint, we could not accurately compute a significant enough long-term average rainfall and assess the variations in rainfall over a prolonged duration. As a result, the study's sample size was constrained by the restricted availability of rainfall data, affecting the number of clusters or districts included in the analysis. In addition, our definition of floods does not fully address the endogeneity issue, and there may still be certain factors that are not entirely exogenous. Furthermore, our study could not adjust the shock time frame beyond the primary level (represented by t-3 years) to more options (t-4 or t-5) due to limitations in the available data.

Future research can expand on this study by investigating an expanded dataset comprising a more significant number of weather stations and a more extensive range of clusters for analysis. In addition, subsequent research can enhance these findings by conducting a heterogeneity analysis to investigate the relationship between socioeconomic characteristics and pregnancy outcomes in areas affected by floods. Another potential area of research could be the empirical testing of the direct and indirect mechanisms through which climate shocks affect perinatal health outcomes. Future research can also investigate the specific phase of pregnancy, such as the trimester, that is more vulnerable to the impacts of external climate shocks with a similar or a different case study.

In conclusion, this study emphasizes the importance of including perinatal and maternal health in national and international climate strategies. Additionally, it highlights the urgent need to implement effective measures that prioritize the protection of pregnant women during climate emergencies.

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Appendix

Table A: Weather stations included

Names of available and matched weather stations	Freq.	Percent	Cum.
Bahawalnagar	115	0.99	0.99
Bahawalpur	188	1.62	2.62
Barkhan	27	0.23	2.85
Dalbandin	27	0.23	3.08
Dera Ghazi Khan	171	1.48	4.56
Dera Ismail Khan Airport	249	2.15	6.71
Faisalabad	492	4.25	10.96
Hyderabad	523	4.52	15.47
Islamabad Airport	2248	19.41	34.88
Jacobabad	177	1.53	36.41
Jhang	199	1.72	38.13
Jhelum	93	0.80	38.93
Jiwani Airport	34	0.29	39.23
Kalat	105	0.91	40.13
Karachi Airport	2318	20.02	60.15
Khanpur	113	0.98	61.13
Khuzdar	179	1.55	62.67
Lahore City	835	7.21	69.88
Multan	424	3.66	73.54
NawabShah	105	0.91	74.45
Panjgur	10	0.09	74.54
Parachinar	88	0.76	75.30
Pasni	15	0.13	75.43
Peshawar	1287	11.11	86.54
Quetta Airport	720	6.22	92.76
Rahim Yar Khan	202	1.74	94.50
Sargodha	273	2.36	96.86
Sialkot Airport	284	2.45	99.31
Zhob	80	0.69	100.00
Total	11581	100.00	