Climate change, women, and children: Assessing health vulnerability, impacts, and adaptation in the Kavre district, Nepal

by

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Abstract

Nepal is ranked as one of the countries most vulnerable to climate change. Certain Nepalese subpopulations, including women and children, are at higher risk than others and may experience climate change impacts disproportionately due to socioeconomic disparities, gender roles, limited mobility and access to resources, physiological characteristics, and others. This thesis research qualitatively explored the women's lived experiences concerning climate change and quantitatively investigated the impacts of meteorological factors and air pollution exposure on adverse pregnancy outcomes (APO) and childhood infectious diseases in Kavre, Nepal.

In Chapter II, we conducted a scoping review synthesizing evidence from recent South Asian studies on the relationship of meteorological factors and air pollution with women’s and children’s health. A research librarian executed the search on six databases for the period from January 2010 to May 2020. Two reviewers independently conducted title, abstract, and full-text screening. We extracted data from 42 studies. Most studies were based in India (23) and Bangladesh (14) and focused on meteorological factors (19) as the primary exposure. The impacts of extreme weather events, meteorological factors, and air pollution on children's health were the focus of 34 studies, and only eight focused on women's health. Undernutrition, acute respiratory infection (ARI), diarrheal diseases, low birthweight, and premature mortality were the main health focus in children and women. This study highlighted a gap in the geographic area of studies across regions and suggested opportunities for future work in climate change and women's and children's health.

Chapter III included qualitative research exploring women's perspectives and lived experiences concerning climate change, its adverse impacts on agriculture and health and ongoing adaptation strategies. Eight focus group discussions and eight interviews were conducted using purposive

and snowball recruitment. Interviews in the Nepali language, audio-recorded and transcribed verbatim in Nepali, and content analysis using NVivo 1.7. was conducted. Three primary topical areas appeared. The first topical area, "When the weather changes, it gets very cold," captured participants' perspectives on climate change. The second, ‘the unpredictability of weather,’ captured their lived experience related to climate change. The third, ‘acting locally,’ captured local-level actions to address impacts expected from climate change. These results can guide the development of interventions to address women's and children's needs and concerns.

Chapter IV examined quantitative relationships between environmental exposures and APOs in Kavre, Nepal. Using a historical cohort study design, we conducted a secondary analysis of health facilities-based data. We linked health records to temperature, precipitation, and $PM_{2.5}$ exposures for six months preceding each birth. A random intercept model was used to analyze birthweight. A composite APO outcome was analyzed using multivariable logistic regression. We observed that total precipitation (β: 0.17, 95% CI 0.01 to 0.33) positively affected birthweight in the wetter season. Negative effects for mean maximum (β: -33.37, 95% CI -56.68 to -10.06), mean (β: -32.35, 95% CI -54.44 to -10.27), and mean minimum temperature (β: -29.28, 95% CI -49.58 to -8.98) on birthweight was observed in the wetter season. Future studies should consider larger cohorts to explain these complex relationships in Nepal.

Chapter V included an analysis of health facilities-based data using a historical cohort study design examining the association of meteorological and air pollution exposures with diarrhea and ARI. Daily temperature and precipitation were linked to health records for the two weeks preceding each recorded health outcome. For $PM_{2.5}$, we linked health records to the month preceding each recorded health outcome. Multivariable logistic regression was used to analyze environmental exposures, diarrhea and ARI. We observed a positive effect of mean $PM_{2.5}$

exposure on diarrhea [Adjusted Odds Ratio (AOR) 1.02, 95% CI 1.003 – 1.03]. The mean minimum temperature was positively associated with ARI (AOR 1.04; 95% CI 1.001 – 1.08). The findings from a stratified analysis showed that mean $PM_{2.5}$ exposure positively affected diarrhea among urban residents (AOR 1.03, 95% CI 1.001 – 1.07) and in the wetter season (AOR 1.05, 95% CI 1.02 – 1.07).

This thesis research emphasizes the need for collaborative efforts across local-level government and non-government stakeholders to address the impacts of climate change, including strengthening systems and protecting women's and children's health. Furthermore, the Government of Nepal must improve its climate infrastructure to enable the regular recording and capturing of environmental data.

Preface

This thesis is a compilation of an original work by Ishwar Tiwari under the supervision of Drs. Shelby S. Yamamoto, Stephen Hodgins, Denise Spitzer, and Sherilee Harper. Some of the research conducted for this thesis forms part of a research collaboration led by Associate Professor S.S. Yamamoto at the University of Alberta. The research project, of which Chapter II of this thesis is a part, received ethics approval from the University of Alberta Research Ethics Board, Project Name "Mind The Gap: Assessing Climate Change Vulnerability Across Population," Pro00100033, June 9, 2020.

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Dedication

I dedicated this thesis to my late father, beloved mother, wife, and daughter, who have been my inspiration and strength and continuously providing their moral, spiritual, emotional, mental, and financial support.

To my brothers, sisters, relatives, mentors, friends, and classmates who shared their words of advice and encouragement to help me complete this project.

Lastly, I dedicated this thesis to the Almighty God, thanking you for the guidance, strength, power of mind, protection, and skills and for granting me a healthy life. I offer all of these to you.

The Voice of Earth

In the world facing the looming climate crisis
Lives on earth on the verge of paying the hefty prices
People! We must act before any apocalypse

The ice caps are dying rapidly and vigorously
But oh! Humans are terrestrial not aquatic
It's high time we comply with the global promises rigorously

Dare not! We ignore the fury of floods in the coastal region
And the rage of landslides in the hills and mountains
Sadly, none to blame, but our decisions and actions

Activists and researchers - shouting at the top of their lungs
Reduce! Reduce!! Reduce!!! The harmful gaseous emissions
When lives are taunted by heatwaves, wildfires, and air pollution

The earth consists of $2/3^{rd}$ water, yet dehydrated!
So fragile that billions mouth, but it cannot satiate
We must correct the course or else all beings will be eliminated

Rich or poor, climate change does not differentiate
Neither does it differentiate regions, ethnicity, and race

But, women, children, elderly, immigrants, and poor are more impacted

Yet, within and across the regions, exist the dearth of sense
Poorly gauged health impacts, risk, and resilience
We embark on fathoming and informing the same quest

Dig! Dig! And dig! For days, weeks, and months
Buried under the earth, but excavating for once
Unrelenting efforts and stacked all pertinent inquiries
With only two pairs of eyes and handful of tool kits

Oh! Look here! What we have found
So factual, although unfair, it sounds

Men and women, both exposed
Sadly, mostly women facing storms

On the other side,

Seeing the children's vulnerability saddens me
Their health wracked with undernutrition and diarrheal disease

Older adults and immigrants are also not spared

Smoky, polluted air clogging their lungs and hearts

Hey, wait! Can we adapt? Mitigate?

That's where we need to further excavate

In our work, we identify the remarkable gaps

The weight of mental health and

Diseases borne by vectors need to unwrap

And we conclude:

Ample work opportunities in some populations and regions

One of the many ways to light our path and vision

Acknowledgement

I acknowledge that I am situated within and worked towards this Ph.D. on Treaty 6 Territory, a traditional gathering place for diverse Indigenous Peoples, including the Cree, Blackfoot, Métis, Nakota Sioux, Iroquois, Dené, Ojibway/Saulteaux/Anishinaabe, and Inuit.

Undertaking this Ph.D. has been a truly life-changing experience for me. I want to acknowledge everyone who supported and guided me throughout this adventurous journey.

A huge thank you to my wonderful supervisor, Dr. Shelby Yamamoto, for all the relentless support and encouragement you gave me throughout the program. Thank you, Shelby, for taking on multiple roles besides academic supervisor, including lifeguard, mental health counsellor, career advisor, and guide. Without you, Shelby, this journey would not have been achieved. Thank you for being a wonderful human being and a role model.

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Chapter I: Introduction

1 Background

1.1 Global and Regional Climate and Air Pollution Crises

Climate change is a critical global issue.[1] Human activities, mainly through greenhouse gas emissions, have explicitly caused enhanced global warming, with the global surface temperature reaching 1.1°C in 2011-2020 compared to 1850-1900.[2] The temperature increase over land (1.59°C [1.34 to 1.83]°C) has been observed to be larger than the temperature increase over the ocean (0.88°C [0.68 to 1.01]°C).[2] Regionally, warming has also occurred across most South Asian countries (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka) over the 20th century and into the 2000s.[3] This warming has increased the risk of flooding in the coastal plains of Bangladesh, India, Maldives, and Sri Lanka due to rapid glacier melting and rising sea levels.[4,5] A trend in decreasing South Asian summer monsoon precipitation during the second half of the 20th century has also been observed.[6] Furthermore, South Asia's complex topography, including high mountains, long coastlines, plains, and low-lying islands, heightens its exposure to extreme weather events.[4] Over the last century, the region has observed an increase in the intensity and frequency of other extreme weather events, including heat waves, cold waves, drought, storms, and heavy rainfall.[7] For example, during the last 40 years (1965-2004), 784 disaster events, including hydrological, climatological, and meteorological, were reported in the region.[8] Between 2005 and 2015, the region recorded 481 disaster events, which is nearly 62% of total number of disaster events between 1965 and 2004.[9]

Another significant global environmental risk affecting human health is air pollution. It is a particularly important environmental issue in low- and middle-income countries (LMICs), including South Asia. The Environmental Performance Agency (EPA) 2016 reported that 17 of the 30 cities worldwide with the poorest air quality were from South Asia.[10] Global Burden of Disease (GBD) 2015 estimates of air pollution concentrations for population-weighted mean annual ambient fine particulate matter ($PM_{2.5}$) were 73 μg/m^3 in South Asia (Bangladesh – 89 μg/m^3; Bhutan – 56 μg/m^3, India – 74 μg/m^3; - Nepal – 75 μg/m^3; Pakistan – 65 μg/m^3; Sri Lanka – 28 μg/m^3).[10] In 2015, approximately 91% of the population in the region (Bangladesh 99.9%; India – 89.9%) were living in areas exceeding the World Health Organization (WHO) recommended annual air quality standard (Interim Target-1) of 35 μg/m^3 for $PM_{2.5}$.[10]

Climate change and air pollution are interrelated. Meteorological variables such as temperature, wind characteristics, and humidity can affect pollutant emission, transport, dispersion, chemical transformation, and deposition.[11] Warmer conditions also generally favour the production and release of airborne allergens such as pollen and fungal spores.[12] The greater use of air conditioners, which leads to increased electricity demand and associated emissions of health-deteriorating air pollutants, is also expected to be exacerbated by rising temperatures and more severe heat events.[13] Climate change-associated wildfires that burn more intensely and cover more area could significantly reduce air quality.[14] Studies have indicated that air quality is already affected by climate change.[14–16] For example, Fang et al. estimated that global population-weighted $PM_{2.5}$ increased by 5% and near-surface ozone concentration by 2% due to climate change between 1860 (i.e., preindustrial) and 2000.[16] Equally, some health-deteriorating air pollutants, especially ozone, warm the atmosphere by absorbing radiation. $PM_{2.5}$ components can also affect the climate as heat can be absorbed by black carbon aerosols and transported over some distance, increasing local temperatures where they are deposited.[14] In the Indo-Gangetic Plain of South Asia, the seasonal crop residue burning is a major contributor by up to 70% in

$PM_{2.5}$ and over 40% increase in black carbon concentration in peak period[17] which may affect the temperature in the region.

1.2 Climate and Air Pollution Crises in Nepal

Nepal is a country highly vulnerable to climate change due to its mountainous and challenging topography and lower socioeconomic conditions.[18] The country ranked 143rd out of 195 countries on the Human Development Index (HDI) in 2022.[19] Nepal has experienced changes in temperature and mean precipitation due to climate change. The temperature trends from 1975 to 2005 showed an annual increase in temperature of 0.06 ºC, while mean rainfall for the same period has significantly decreased by an average of 3.7 mm (-3.2%) per month per decade.[18] Nepal's temperature is projected to increase between 0.92 and 1.07 ºC in the medium term (2016 - 2045) and 1.3-1.8 ºC in the long term (2036 - 2065) compared to 1980-2010.[20] For the same period, a decrease in annual precipitation is projected to be in the range of 10 – 20% across the country.[20]

All countries are affected by climate change. Developed countries with higher-income levels experience climate change-attributed disasters, which have less impact on life but result in substantial economic losses.[21] LMICs, including Nepal, experience higher mortality and other losses due to limited climate preparedness and capacity.[21] For example, in 2010, the number of people in Nepal annually affected by river flooding attributed to climate change was approximately 157,000, which could increase by twofold, i.e., 350,000, by 2030.[20] The Global Climate Risk Index 2020 ranked Nepal ninth among the countries most affected by climate change between 1999 and 2018.[22] Nepal is also on the list of the world's 20 most disaster-prone countries: and 80% of its total population is at risk of natural hazards such as floods, landslides, wind storms, rain storms, hail storms, and glacial lake outburst flooding.[23]

Nepal also experiences the impacts of poor air quality. The WHO reported a maximum 24-hour mean $PM_{2.5}$ of 140 µg/m^3 in cities of Nepal, which is almost four times higher than the value for the 24-hour mean Interim target-3 of 37.5 µg/m^3.[24] GBD 2015 estimates of population-weighted mean annual ambient $PM_{2.5}$ was 75 µg/m^3 in Nepal compared to the regional (South Asia) average of 73 µg/m^3.[10] Approximately 90% of Nepal's population lived in areas exceeding WHO recommended air quality standards in 2015.[10] In 2016, the EPA 2016 ranked Nepal 177th among 180 countries in terms of air quality.[25] Population increases, unplanned urbanization, and industrial and vehicular emissions have worsened Nepal's air quality, creating situations in which several urban areas are exposed regularly to unhealthy levels of air pollution.[26]

1.3 Higher-Risk Populations

Climate change and air pollution impact everyone. However, some subpopulations are at higher risk than others.[27] For example, people living on floodplains, coastlines, or in areas prone to severe storms; low-income families; minority-led households; households with disabled, pregnant and nursing mothers; people with chronic medical conditions; Indigenous populations; older adults; and children face higher health risks from climate change.[28] Higher-risk populations experience adversities and may encounter discrimination, bias, and stigma, which can compound the effects of exposures and consequent health hazards.[29] This project focuses on women and children as a higher-risk population.

Existing evidence has shown that women disproportionately experience the impacts of climate change due to physiological differences, cultural norms and the distribution of roles, resources, and decision-making power, particularly in LMICs.[30] For example, pregnant women face critical concerns about safe deliveries following a disaster.[31] Kabir et al. reported that young girls and women face a shortage of sanitary pads and appropriate toilet facilities due to a lack of privacy following disasters.[32] Women, particularly in low-income countries like Nepal, are severely affected by climate risk due to their traditional roles. For example, Nepalese women usually spend 30% of their time fetching water to meet household needs.[33] Women can spend 3-4 hours every day trying to meet household water needs when there is reduced water discharge.[33] The reduced availability and contamination of water causes hygiene-and sanitation-related problems such as urinary tract infections and diarrhea.[31,32,34] Disasters put women and girls, particularly those who belong to marginalized sectors, at higher risk of physical and sexual abuse.[30,35] Air pollution, particularly $PM_{2.5}$, has been associated with an increased risk of low birthweight[36] and preterm birth.[37]

Children are biologically and psychosocially vulnerable due to their rapid physical and psychosocial development, immature immune systems, and reliance on adult caretakers.[38] Children are also at higher risk, particularly during disasters, of sexual abuse, assault, and neglect, as they are more likely to be separated from their families and caretakers.[39] A review showed a positive association between extreme events (e.g., drought) and adverse nutrition-related outcomes (e.g., underweight and wasting) in children.[40] $PM_{2.5}$ exposure in children has been associated with an increased risk of viral diarrhea infection[41] and respiratory infections.[42] The WHO estimated that children under five years bear 88% of the current global burden of diseases attributable to climate change.[43] In 2018, the WHO reported 543,000 deaths in children younger than five years of age due to ambient air pollution exposure, which mainly occurred in LMICs.[44]

1.4 Understanding the Health Impacts of Climate Change and Air Pollution on Women and Children

The relationship between climate, air pollution and health impacts are interlinked (Figure 1).[45] Previous studies have associated climatic factors and air pollution with adverse health outcomes in women and children.[14,36,46–57] For example, prolonged exposure to increased temperature during pregnancy is linked to adverse pregnancy outcomes, including stillbirth, low birth weight, and preterm birth.[58–61] Disasters put pregnant women and those giving birth at higher risk during and following events, increasing the risk of maternal and delivery complications such as preeclampsia (high blood pressure during pregnancy) and low birth weight.[62,63] Disasters like cyclones and floods are likely to cause more deaths among women and children than among men.[31,63] The caretaking roles of women limit their mobility and their ability to take appropriate action to safeguard their own lives.[35,63] Pregnant women exposed to polluted air are also more likely to give birth prematurely and have small, low birth weight children [64]. Temperature and precipitation have been linked to increased water-borne disease-associated hospitalization of children.[65,66] For example, a study conducted by Bhandari et al.[67] in Kathmandu, Nepal, found increased counts of childhood diarrhea cases per 1°C increase in maximum temperature above the recorded average for that month. Mourtzoukou & Falagas[68] reported an increased risk of children developing URTI and LRTI as well as mortality with exposure to colder temperatures. A meta-analysis reported an increased risk of respiratory infections in children with increased environmental $PM_{2.5}$ concentrations.[69]

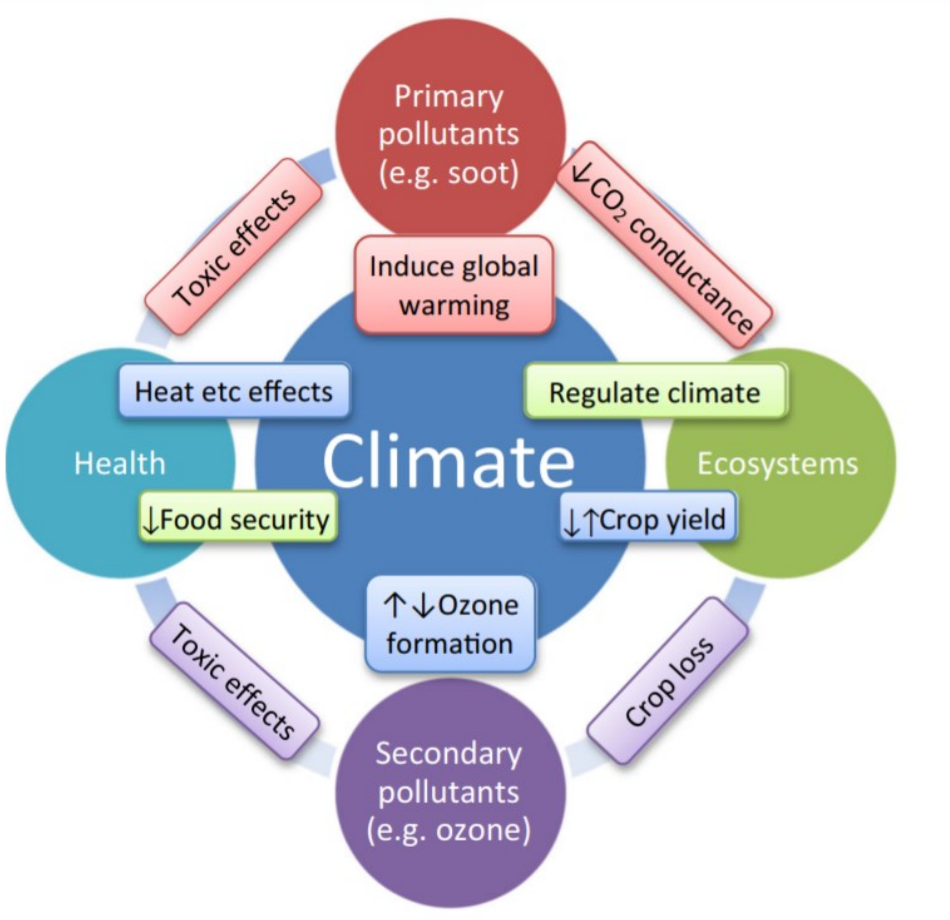

Figure 1: Interaction between climate, air pollution and health from Orru et al.[45]

1.5 Research Objectives

This thesis research has four specific objectives.

Objective 1	To synthesize knowledge about the women and children-focused health impacts of climate change and air pollution in the South Asia region.
Objective 2	To explore women's perspectives and lived experiences concerning climate change, health and agricultural impacts, and adaption in the Kavre district of Nepal.

Objective 3	To examine the potential influences of meteorological factors and particulate matter pollution on adverse pregnancy outcomes in the Kavre district of Nepal.
Objective 4	To examine the link between meteorological factors, particulate matter and childhood infectious diseases in the Kavre district of Nepal.

1.6 Summary of the Chapters

This thesis research has four major chapters, as given below.

Chapter II

This chapter is a scoping review (Objective 1). The review aimed to synthesize evidence from recent studies on the association of climate, meteorological factors, and air pollution with health effects in children and women focused in South Asia. The review also aimed to identify regional research gaps, contribute to knowledge about existing mitigation and adaptation activities in the region, and guide the development of specific research objectives for this doctoral project.

We executed the search of six databases using controlled vocabulary (e.g., MeSH, Emtree, etc.) and keywords representing the concepts "vulnerable populations" and "climate change" and "health impacts" and "South Asia." Databases were searched from January 2010 to May 2020. Papers were screened independently by two researchers. We provided the narrative summary of our study findings in the context of the research question and objectives.

Chapter III

This chapter undertook qualitative research to address the research gap identified in the scoping review (Objective 2). We acknowledge the unique vulnerabilities of women and children due to various factors, including gender roles, culture, age, and physical and physiological characteristics. We also recognize that women's problem-solving and decision-making capacity is vital to developing climate change solutions. Therefore, listening to and learning from women is critical. We employed a qualitative approach to explore women's perspectives and lived experiences regarding climate change, including adverse impacts on health and agriculture, as well as current mitigation and adaptation response to those changes.

We used a descriptive qualitative approach to collect primary data on women's perspectives and lived experiences using focus group discussions (FGDs) and interviews. We conducted eight FGDs (n=40) and eight interviews (n=8) and employed purposive and snowball recruitment. We employed four research assistants with public health backgrounds and climate change training to assist with this work. An interview guide was used to conduct all interviews in the Nepali language. All FGDs and interviews were audio-recorded and transcribed verbatim in Nepali. We used content analysis to analyze data in NVivo 1.7.

Chapter IV

This chapter focuses on the quantitative exploration of relationships between environmental exposures and women's health in the Kavre district. Specifically, our interest lay in examining the association of adverse pregnancy outcomes with meteorological and air pollution exposures (Objective 3). This chapter provides empirical evidence of the impact of meteorological and air pollution exposures on adverse pregnancy outcomes in the Kavre district of Nepal.

Findings were generated from an analysis of secondary data within a health facilities-based retrospective cohort study design. We linked daily temperature (mean maximum, mean, and mean minimum obtained from the CPC Global Unified Temperature dataset from the National

Oceanic and Atmospheric Administration's (NOAA) Physical Sciences Laboratory), total precipitation (obtained from Climate Hazard Group InfraRed Precipitation with Station (CHIRPS)), and mean $PM_{2.5}$ (obtained from the Atmospheric Composition Analysis Group of Washington University in St. Louis) exposures for six months preceding each birth. The Nepal Demographic and Health Survey (NDHS) 2022 dataset was used to spatially link sociodemographic variables [e.g., education, occupation, wealth, smoking status, type of cooking fuel, and Body Mass Index (BMI)] to wards of the Kavre district. We used a random intercept model to analyze birthweight as a continuous outcome. As there were fewer cases of preterm birth and stillbirth, we combined both into one dichotomous outcome (adverse pregnancy outcomes). Multivariable logistic regression was used to examine environmental exposures with adverse pregnancy outcomes.

Chapter V

This chapter extends the investigation of environmental exposure risks to childhood infectious diseases (Objective 4). We analyzed secondary data in a health facilities-based retrospective cohort study to examine the association between meteorological and air pollution exposures and diarrhea and acute respiratory infections. Environmental exposure data and sociodemographic variables were obtained from the sources mentioned above. Health records were linked to daily temperature (mean maximum, mean, mean minimum) and total precipitation for the two weeks preceding each recorded health outcome. For $PM_{2.5}$, health records were linked to the one-month period preceding each recorded health outcome. Area-level variables were linked to the wards of the households. We analyzed environmental exposures, diarrhea and ARI (dichotomous outcomes) using multivariable logistic regression.

In summary, the above four major chapters form the basis of a project focused on climate change and health among women and children in Nepal. This started with a scoping review that synthesized existing knowledge and identified research gaps. It was followed by a qualitative exploration of women's perspectives and lived experiences with climate change and concluded with a quantitative examination of adverse pregnancy outcomes and childhood infectious diseases. These studies were designed to iteratively build on each other and add to our understanding of the role of climate change and air pollution exposures on women's and children's health in Nepal.

Chapter VI

This chapter provides an overall summary of the thesis research. Additionally, the chapter links the sections, triangulates findings obtained from qualitative and quantitative analyses, and outlines the significance of the thesis research.

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Chapter II

Climate change impacts on the health of South Asian children and women subpopulations - A scoping review

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Synopisis

Background and objectives: Climate change impacts are felt unequally worldwide; populations that experience geographical vulnerability, those living in small island states and densely populated coastal areas, and children and women are affected disproportionately. This scoping review aims to synthesize evidence from relevant studies centred on South Asia, identify research gaps specifically focused on children and women's health, and contribute to knowledge about South Asia's existing mitigation and adaptation strategies.

Methods: A research librarian executed the search on six databases using controlled vocabulary (e.g., MeSH, Emtree, etc.) and keywords representing the concepts "vulnerable populations" and "climate change" and "health impacts" and "South Asia." Databases were searched from January 2010 to May 2020. Papers were screened independently by two researchers.

Results: Forty-two studies were included, of which 23 were based in India, 14 in Bangladesh, and five in other South Asian countries. Nineteen studies focused on meteorological factors as the primary exposure. In contrast, thirteen focused on extreme weather events, nine on air pollution, and one on salinity in coastal areas. Thirty-four studies focused on the health impacts on children related to extreme weather events, meteorological factors, and air pollution, while only eight studies looked at health impacts on women. Undernutrition, ARI (acute respiratory infection), diarrheal diseases, low birth weight, and premature mortality were the major health impacts attributed to extreme weather events, meteorological factors, and air pollution exposure in children and women in the region.

Conclusion: Extreme weather events, meteorological factors and air pollution have affected the health of children and women in South Asia. However, the gap in the literature across the South Asian countries concerning relationships between exposure to extreme weather events, meteorological factors, air pollution and health effects, including mental health problems in children and women, are opportunities for future work.

Keywords: climate change, air pollution, South Asia, women, children, health impacts

1. **Introduction**

Climate change is a critical issue worldwide.[1] There has been an average increase of 0.85^0C in the Earth's surface temperature since the 1950s.[2] Globally, the number of cold days and nights has decreased, and the number of warm days and nights has increased.[3] In large parts of Europe, Asia, and Australia, the frequency of heatwaves has also increased.[3] Changes in extreme weather events, such as floods, drought, cyclones and wildfires, have impacted human health across countries.[4]

According to 2019 World Bank data, South Asia - Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka - is home to approximately 1.84 billion people (one-fourth of the world's population) and the most densely populated and most populous geographical region globally.[5] About 65% of South Asia's population lives in rural areas and accounts for 29% of those living in extreme poverty globally.[6] The region has experienced warming over the 20th century and into the 2000s[7] Specifically, Afghanistan experienced the greatest temperature change (0.27°C) between 1990 and 2010, while the Maldives has experienced the smallest temperature change (0.07°C) for the same time period.[8] Other countries in the region have experienced temperature change between 0.09°C and 0.17°C from 1990 to 2010.[8] Consequently, the region is highly vulnerable to catastrophic events such as floods, landslides, drought, wildfires, and cyclones and thus faces severe consequences.[9,10] The Bay of Bengal region, including the coast of Bangladesh and India's eastern coast, has observed a 20% increase in cyclonic events due to increasing sea surface temperature and sea-level rise between 1961 to 1990.[11] The total number of natural disasters in the region increased from 133 in 1990-94 to 166 in 2000-04.[12] In the decade 2005-2016, a total of 481 events (hydrological, climatological, and meteorological) were reported in the region, claiming around 135,000 lives.[13]

The region consistently registers the most significant number of lives and assets lost when disasters occur (e.g., floods, landslides, wildfires) [13] due to its large population and limited capacity to recover.[9]

Food security, water resources protection and public health are strongly related to climate.[14] The increasing temperature, changing precipitation patterns, and higher frequency of extreme events already affect food security.[15] Climate change impacts health in different ways, including leading to death and illness from increasing frequency and intensity of extreme weather events, such as heatwaves, storms and floods, food systems disruption, increases in food, water, and vector-borne diseases, and mental health issues. Between 2030 and 2050, climate change-related effects are expected to result in 250,000 additional deaths per year globally from malnutrition, malaria, diarrhea, and heat stress.[16]

Another environmental issue linked to climate change is air pollution. Air pollution is a significant public health problem in low-and middle-income countries, particularly in South Asia. According to the 2016 Environment Performance Index, 17 of the 30 cities in the world with the poorest air quality were located in South Asia.[17] In addition, the 2015 Global Burden of Disease (GBD) estimated a population-weighted mean annual ambient particulate matter $\leq$ 2.5 μm ($PM_{2.5}$) exposure of 73 $\mu g/m^3$ in the region.[18] Approximately 91% of the population in the region was living in areas routinely exceeding World Health Organization (WHO) recommended air quality standard (Interim Target-1) of $PM_{2.5}$ annual mean concentration - 35 $\mu g/m^3$ (15). In 2016, World Health Organization (WHO) estimated that ambient air pollution caused around 4.2 million premature deaths worldwide, of which 91% occurred in low-and middle-income countries, primarily in South-East Asia.[19] India, Bangladesh, and Pakistan experience higher burdens due to the number of people in these countries, relatively higher exposure levels, and proportion of people affected by chronic diseases.[17] For example, in Pakistan, 135,000 deaths per year are attributed to ambient air pollution, making it the leading underlying contributor to illness and death in the country.[20] Poor air quality in Pakistan has reduced life expectancy by approximately five years.[20] Similarly, the annual number of premature deaths attributed to outdoor air pollution in Nepal had been estimated to be 24,000 in 2020.[21]

Everyone is susceptible to climate change and air pollution-related health impacts.[22] However, some population subgroups are at greater risk[23] due to their socioeconomic status, culture, caste/ethnicity, race, gender, age, physical, physiological, and psychosocial status.[10] Population subgroups such as pregnant women, older adults, children, those with co-existing chronic morbidities, and people with lower socioeconomic status are particularly at risk of climate change and air pollution-related health impacts.[24] Effects can be compounded or magnified in higher-risk groups.

Evidence has shown that women also disproportionately bear the greater climate change impacts than men due to cultural norms and the distribution of roles, resources, and decision-making power, particularly in low-and middle-income countries.[25] Women and girls often eat last and eat the least in certain parts of the world.[26] Extreme weather events affect crop yields and the average essential nutrients supply, such as folate, calcium, thiamine, and pyridoxine, which are critical during pregnancy.[26] Climate change also heavily affects children as their physical, physiologic, and cognitive systems are still developing.[22,27] The critical health effects include increased respiratory and cardiovascular disease, injuries and premature deaths related to extreme weather events, variations in the prevalence and geographical distribution of food- and water-borne illnesses and other infectious diseases, and threats to mental health.[28] The World

Health Organization (WHO) estimated that 88% of the global burden of climate change-related diseases occurs in children younger than five years of age.[29]

This scoping review aims to synthesize evidence from recent studies on associations of climatic and meteorological factors and air pollution with the health effects in children and women in South Asia, identify research gaps specifically focused on children and women, and contribute to knowledge about the region's existing mitigation and adaptation strategies.

2. Methods

We conducted a scoping review following the Briggs Institute Reviewer's Manual guidelines[30], which include the following steps: identifying the research questions, finding relevant studies, selecting studies, charting the data, collating, summarizing, and reporting the results.

2.1 Search strategy

A health research librarian (S.C.) executed a search on the following health databases: PROSPERO, OVID Medline, OVID EMBASE, OVID Global Health, Cochrane Library (CDSR and Central), EBSCO CINAHL, Proquest Dissertations and Theses Global and SCOPUS using controlled vocabulary (e.g., MeSH, Emtree, etc.) and keywords representing the concepts "vulnerable populations" or "women" or "children" and "climate change" and "air pollution" and "health impacts" and "South Asia." The publication date limits from January 2010 to May 2020 aimed to capture recent data on the topic.

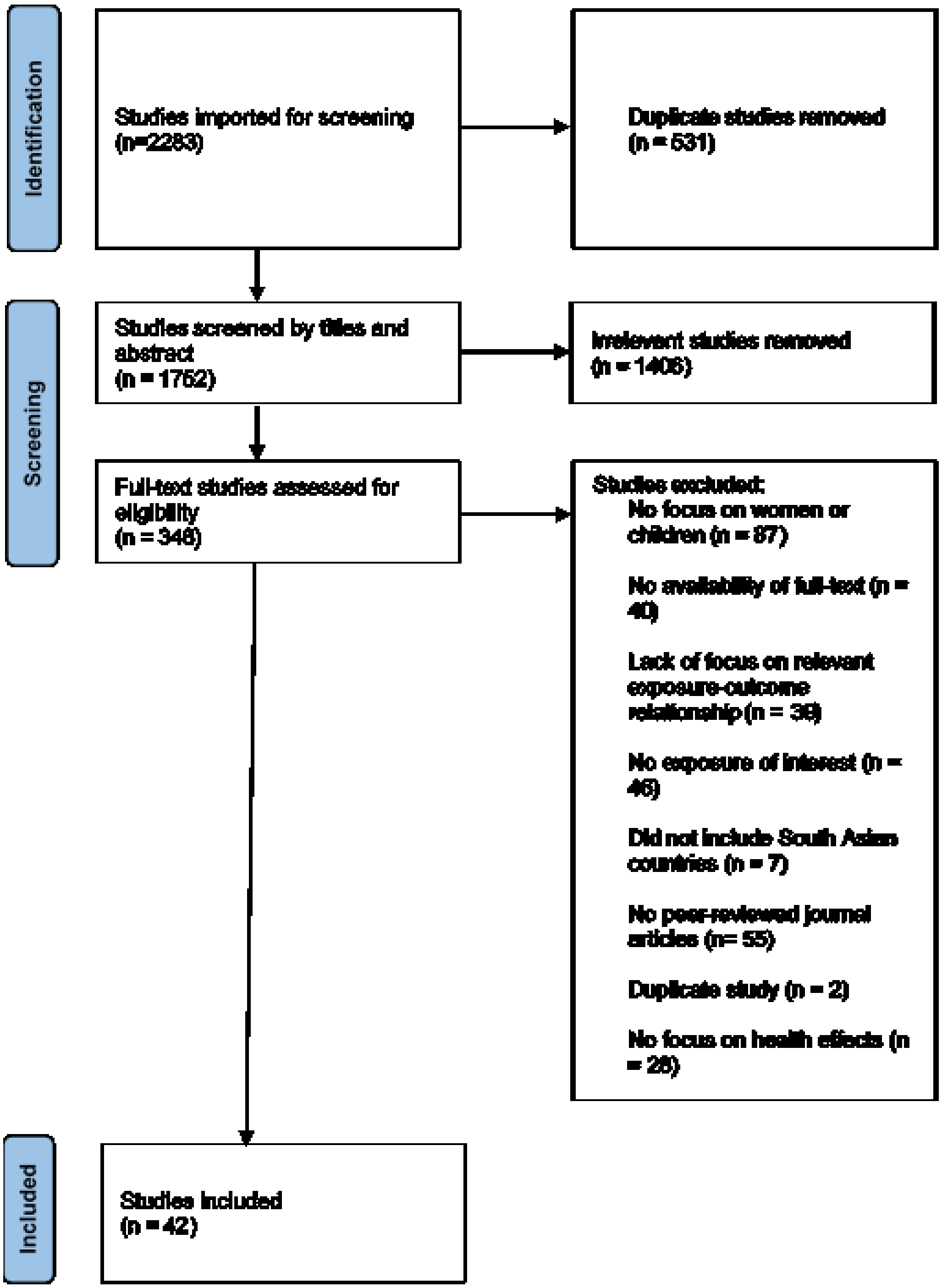
2.2 Screening criteria

We included only peer-reviewed articles (primary research and review articles) focusing on South Asia and those involving human cases of communicable and non-communicable diseases, deaths and hospital admission as outcomes of interest. Only studies that referred to climatic factors or climate and weather-related extreme events such as floods, wildfires, cyclones, drought, and air pollution as the principal exposure were included. The review consists of studies that reported results related to children younger than five years old and women. We included all open access papers and those obtainable through our university library databases. All available ways were explored to obtain the missing full-text articles. Studies focusing on animals, vectors, or vaccines were excluded during the screening. We also excluded editorials, opinion and commentary articles.

2.3 Data management

A total of 2283 identified papers were exported to COVIDENCE review management software[31], and 531 duplicates were removed (Fig 1). Search details are available in Appendix 2s. The study protocol has been registered on Open Science Framework (OSF).[32] Two reviewers (I.T. and M.T.) independently screened the titles and abstracts, following the abovementioned inclusion and exclusion criteria. Abstract and title screening excluded 1406 studies. Full text (346) screening was conducted by the same two reviewers, which yielded 42 relevant studies for data charting (Table 1). Both reviewers discussed and reached a consensus to resolve the conflicts that occurred during both steps of the screening process.

Figure 1: PRISMA flow diagram of the study selection process



2.4 Data charting

For each included study, one reviewer (I.T.) recorded information about study place, time and study population, objectives, study methodologies, exposures, outcomes, statistical methods, and results in an Excel spread sheet.

3. Results

The summary of the studies by geographic location is shown in figure 2. A description of the included studies is listed in Table 1, followed by a narrative synthesis of the data.

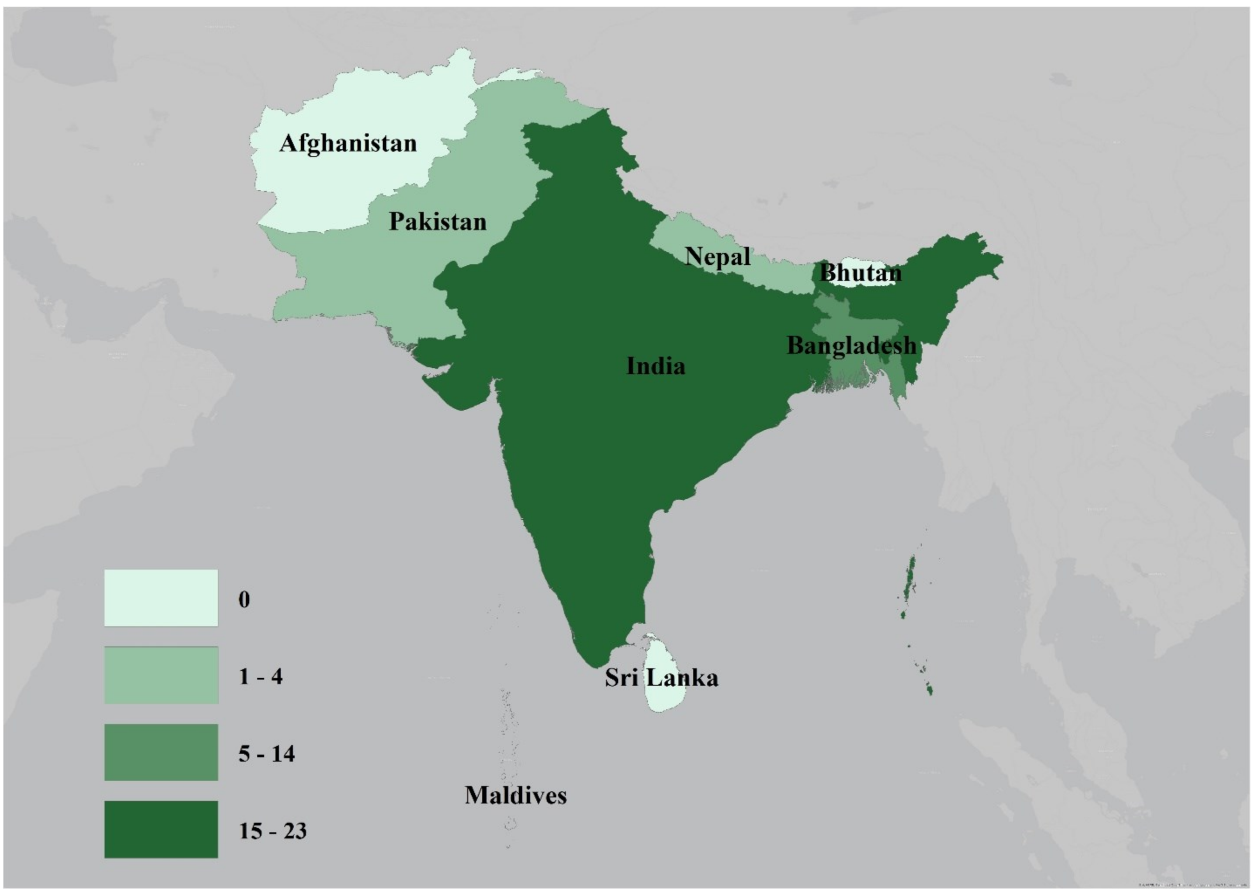


Figure 2: Map of South Asia showing distribution and frequency of included studies

Table 1: Summary table of the included studies

Authors	Location, setting, and period	Population (n, sex, age categories)	Study type	Health impact category	Socioeconomic factors and effect modifiers	Key findings
Extreme events						
Arlappa 2011 [33]	India; rural; 2003	3657 participants; Children (less than five years)	Cross-sectional study	Nutrition deficiency	Female literacy, community backwardness	The prevalence of Vitamin A deficiency was significantly higher among pre-school children of chronic drought-affected areas than non-drought areas.
Beier 2015 [34]	Bangladesh; rural; 2013	977 households; Male: 47.6% and female: 52.4%;	Cross-sectional study	General physical health	Age, education level, employment	Women were at higher risk of severe diseases associated with extreme weather and climate events compared to men.

		Age category: 14-25 (12.7%), 26-35 (32.2%), 36-45 (22.0%), 46-55 (16.6%), and 56+ (16.5%)				
Goudet 2011 [35]	Bangladesh; rural; 1998-99	143 participants; Infants and young children less than three years	Cross-sectional study	Undernutrition	Household expenditure, mother's education	Flooding showed a significant increase in stunting and underweight percentage among children less than three years of age.
Khan 2016 [36]	Bangladesh; 2009-2010	Climate refugee (C.R.) mother: 267 and Non-CR mother: 552	Cross-sectional study	Neurodevelopment	NA	Pregnant mothers who were exposed to natural disasters Sidr cyclones were more likely to have children with

						neurodevelopmental impairments.
Paul 2012 [15]	Bangladesh; rural; 2008	307 women participants (15-49 years); 158 children participants: (6-59 months)	Cross-sectional study	Undernutritio n	Education level, primary occupation, annual income	Cyclone Sidr did not have a discernible negative impact on the nutritional status of reproductive-age women (15-49 years) and children (6-59 months).
Tran 2013 [37]	India; urban; 2012	1650 participants; Children less than five years	Cross-sectional study	Heat-related symptoms	Occupation and work location	Younger children less than five years of age were not at higher risk of heat-related symptoms than all other ages.
Rodriguez-LIanes 2016 [38]	India; rural; 2009	900 participants; Children (6-59 months)	Cross-sectional study	Undernutritio n	Maternal education, land ownership,	Flooding was most significantly associated with wasting indicators. Statistically

					religion, annual income	significant associations with underweight were reported.
Milojevic 2012 [39]	Bangladesh; rural; 2001-07	For ARI: 48794 participants; For diarrhea: 8378 participants; Children (less than five years)	Time series study	Respiratory infections and waterborne disease	Income level	The study found little evidence of elevated risk of diarrhea in a flooded area compared to a non-flooded site. There was no significant difference in the risk of acute respiratory infections in flooded and non-flooded areas.
Shaw 2020 [40]	India; 2015-16	259627 participants; Children (less than five years)	Spatial study	Undernutrition	Mother's education, economic status, media exposure	The study found a positive association between drought and child stunting.

Datar 2013 [41]	India; rural; National Family Health Survey: 1992-93; 1998-99; 2005-06	80000 participants; Children (less than five years)	Ecological study	Childhood morbidity, physical growth	Gender/sex, income, education	Disaster in the past month significantly increased the likelihood of diarrhea, fever, and ARI. Disaster in the past year was significantly associated with underweight and stunting. Significant interactions between disasters and gender and disasters and education were observed for undernutrition.
Kumar 2016 [42]	India; rural; DLHS-2: 2002-04; Monthly rainfall data: 1970-2005	149386 participants; Children (less than five years)	Ecological study	Undernutrition, Infant mortality	Seasonality	Drought exposure in the year before birth or in the year of birth for those born in the second half of the year (June-December) had a positive and

						statistically significant effect on underweight. Infant mortality was significantly higher for children born in the second half of the year in which the drought occurred.
Abdullah 2019 [43]	Bangladesh; rural; 2015	Focus group discussion (FGD): 9-11 participants for each FGD; Age category:18-50 years; In-depth interview: 8 Age category: 25-60 years	Qualitative study	Perception of maternal death; practices and challenges of the community people for emergency maternal care	Marginalized community	Maternal deaths mainly occurred during the rainy season in flood-affected areas. Negligence of maternal healthcare, lack of appropriate healthcare services, communication and transportation problems, unavailability of qualified health workers were important

				with complications		reasons to cause maternal deaths.
Joshi 2011 [44]	India; rural; 2009	807 participants; Children (5-59 months)	Cluster survey	Waterborne disease	Annual income, caste, religion, landholding	There was no significant difference in the prevalence of diarrhea between flood-exposed and flood-unexposed regions.
Meteorological factors						
Kakkad 2014 [45]	India; urban; 2009-12	2025 participants; Infants (less than one year)	Cohort study	Neonatal hospital admission	Seasonality	An increase in temperature was associated with an increase in heat-related admissions of neonates.
Mertens 2019 [46]	India; rural; 2008-09	1284 participants; Male: 50.2%, female: 49.5%;	Cohort study	Waterborne disease	Effect modification by longer-	Diarrhea prevalence was associated with higher quartiles of average temperature during the first, second, and third

		Children less than five years			term (60 days) rainfall trends	weeks before the 7-day diarrhea recall period. The heavy rainfall events (vs. no heavy rainfall events) after a 60-day dry period were associated with higher diarrhea risk in the following 1-3 weeks.
Mullany 2010 [47]	Nepal; rural; 2002-06	23240 participants; Newborns	Cohort study	Neonatal hypothermia	Seasonality	A decrease in ambient temperature is associated with the increased risk of moderate/severe hypothermia. There is a strong association between season and hypothermia, with incidence

						rates peaking in the coldest months of the year.
Rashid 2017 [48]	Bangladesh; rural; 2001-04	Pregnant women: 4436; Infants: 3298	Cohort study	Fetal growth and birth size	Education level	Infants born in colder months were shorter (birth length) than those born in hot, dry and monsoon months. The increased temperature during the last month of pregnancy was significantly related to increased birth length after adjustment. The increased temperature at mid-gestation was significantly associated with increased birth weight.

Babalola 2018 [49]	Bangladesh; rural; 1982-2008	49426 participants; children (less than five years); Female and male mortality (<153 days); Neonate mortality (<30 days); Mortality between 30 and 153 days	Time series study	Mortality	N.A.	There was a protective effect of temperature on child mortality. There is no evidence that child survival is adversely affected by monthly temperature extremes in Bangladesh.
Bhandari 2020 [50]	Nepal; urban; 2003-13	219774 participants; Children (less than five years)	Time series study	Waterborne disease	N.A.	An increase in maximum temperature and rainfall was strongly associated with diarrheal disease among children less than five years of age.

Bush 2014 [51]	India; urban; 2004-07	14723 participants; Children (less than five years)	Time series study	Hospital admission for gastrointestinal-related illness	Age, seasonality	Hospital admissions related to gastrointestinal illness of under-five children were positively and significantly associated with extreme precipitation.
Imai 2014 [52]	Bangladesh; urban; 2005-08	Influenza A: 333, Influenza B: 246; Children (less than five years)	Time series study	Tropical influenza incidence	N.A.	There was a difference in the associations between influenza and weather variability by influenza subtypes. Weather factors were significantly associated with influenza A as compared to influenza B.
Ingole 2012 [53]	India; rural; 2003-10	Total mortality: 1662, Mortality (0-4 years): 46,	Time series study	Mortality	Age and gender/sex	The study indicated that a strong association with temperature and rainfall exists

		Mortality (5-19 years): 62 Mortality (20-59 years): 627 Mortality (60+ years): 927 mortality (men): 954, mortality (female): 708				for all-cause mortality in all age groups, including children (0-4 years). Women are more susceptible to mortality effects following rainfall events compared to men.
Singh 2019 [54]	India; urban; 2009-16	Total all-cause mortality: 64712 Mortality (0-4 years): 4132 Mortality (5-44 years): 10130	Time series study	Mortality	Age, gender/sex, seasonality	The daily mean temperature was strongly associated with child mortality. All-cause mortality varied with the season for both men and women. In summer, daily mean temperature increase was

		Mortality (45-64 years): 17709 Mortality (65+ years): 32741				significantly associated with increased all-cause mortality for both sexes. In winter, daily mean temperature increase was significantly associated with decreased all-cause mortality for both sexes.
Bharti 2019 [55]	India; rural; Undernutrition data:2015-16 Census data: 2011	Children (less than five years)	Spatial study	Undernutritio n	Wealth, literacy	Districts with extreme temperature levels (> 40° C) positively associated with childhood stunting. However, the rainfall levels in districts did not show a strong association with childhood stunting.

Alam 2012 [56]	Bangladesh; rural; 1983-2009	4850 participants; Infants (less than one year) Children (1-4 years); Other age categories: (5-19 years); (20-59 years); (60+ years)	Ecological study	Mortality	Age and gender/sex	The temperature and mortality association was insignificant for infants and children (1-4 years) but was significantly higher for age groups 5-19 years and 20-59 years. Low temperature (below 75th percentile) was associated with increased mortality risk among females but not males. Temperature above the 75th percentile was not associated with mortality risk of any sex and age group. Average rainfall below 14 mm showed a significant reduction in female

						mortality, while average rainfall over 14 mm showed significantly increased mortality risk for both males and females. Average rainfall below 14 mm showed an insignificant reduction of infant mortality but increased mortality of children 1-4 years (insignificant).
WU 2014 [57]	Bangladesh; rural; Health outcome data: 2000-06 Temperature data: 1982-2011	16551 diarrhea cases Children (less than five years)	Ecological study	Waterborne disease	Economic status	Higher temperatures and heavy rainfall were significantly associated with the risk of diarrhea. The average temperature and rainfall showed a weak negative

	Rainfall data: 1998-2008					association with childhood diarrhea.
Banerjee 2020 [58]	India; urban; District Level Household Survey (DLHS)-2: 2002-04; DLHS-3: 2007/08 Temperature and rainfall data: 1900 – 2010	DLHS-2: 507622 (married women); DLHS-3: 643,944 (married women)	Ecological study	Infant mortality	Residence (rural vs urban)	Exposure to high temperatures during pregnancy significantly increases infant death risk.
Mannan 2011 [59]	Bangladesh; urban; 2004-05	12836 participants; Children (0-1 month)	Ecological study	Newborn illness	Seasonality	Higher temperature and heat humidity index values were significantly associated with

						the incidence of very severe disease in newborns.
Tiwari 2016 [60]	Nepal; Demographic Health Survey (DHS) 2005; 2011; 2016;	Wasting: 13682; Male children: 6880; Female children: 6802 Stunting: 13683; Male children: 6884; Female children: 6799; Children (less than five years)	Ecological study	Undernutritio n	Seasonality, sex/gender	An increase above normal monsoon rainfall was strongly associated with an increase in the prevalence of wasting. In contrast, an increase above normal monsoon rainfall was strongly related to reduced wasting. The impact of past monsoon shocks on wasting was similar in both males and females. The study showed that rainfall shocks experienced early in life contribute to faltering child growth.

Shively 2015 [61]	Nepal; Health outcome data: DHS 2006, 2007	7572 participants; Children (less than five years)	Ecological study	Undernutrition	Seasonality	There was a positive association between height-for-age z-score (HAZ), weight-for-height z-score (WHZ), and rainfall.
Murray 2011 [62]	Bangladesh; urban; 2004-05	718 participants; Children (less than five years)	Case-crossover study	Respiratory infections	Household crowding	Rainfall was significantly associated with an increased risk of acute respiratory infections in children less than five years of age.
Ajjampur 2010 [63]	India; urban; 2005-08	2579 participants; Children (less than five years)	Non-randomized experimental study	Waterborne disease	Seasonality, age	The temperature was associated with a higher rate of cryptosporidium positivity during hotter and drier weather in Delhi.
Air pollution						

Maji 2017 [64]	India; urban; 2008-10	Children (0-4 years)	Time-series study	All-cause mortality	Age and gender/sex	The risk of particulate matter pollution attributed mortality was slightly greater in females than males. The mortality attributed to particulate matter pollution in young children (0-4 years) showed a positive but insignificant association.
Akhmat 2014 [65]	Pakistan; 1975-2012	Children (less than one year)	Time-series study	Low birth weight	N.A.	The study showed that air pollution and greenhouse emissions significantly affect low birth weight.
Chakrabarti 2019 [66]	India; rural; Health outcome data: District Level Health	252539 participants; Children (less than five years)	Ecological study	Respiratory infections	Residence, sex/gender	Children (less than five years of age) living in an urban area where crop burning is practiced were at higher risk of acute

	Survey-4, 2012-13					respiratory infections (ARI) than those living in rural areas. The risk of ARI attributed to the burning of agricultural crop residue was significantly higher among women than men.
Goyal 2017 [67]	Bangladesh; urban-rural; 2004-14	23187: stunting and underweight; 23188: wasting; 11870: small birth size; Children (less than five years)	Ecological study	Undernutrition	Wealth and education	Exposure to high levels of PM2.5 in utero was significantly associated with an increased relative risk of stunting, wasting, underweight, and small birth size. Female children were at significantly higher risk of stunting and

						being underweight than male children.
Sinha 2014 [68]	India; 1971-2010	Children (less than one year)	Ecological study	Mortality	Industrialization growth	Bidirectional causal associations were found between changes in infant mortality rate and growth in CO2 emission.
Kurata 2020 [69]	Bangladesh; national Air pollution data: 1998-2016 Child health data: 2011 and 2016	Children (less than five years)	Ecological study	Undernutrition and respiratory infections	Mother's education, father's education, gender/sex, media access, economic status	The prenatal exposure to $PM_{2.5}$ was correlated with stunting only in boys after adjusting for monthly seasonal variation. Postnatal exposure to $PM_{2.5}$ was strongly correlated with stunting in both boys and girls, and its correlation with

						respiratory illness was statistically insignificant.
Maji 2018 [70]	India, Bangladesh, Pakistan; urban; 2016	Children (less than five years)	Air pollution	Premature mortality	Age	$PM_{2.5}$ pollution in India, Bangladesh, and Pakistan megacities contributes to significant premature mortality in children under five years of age due to acute lower respiratory infections.
Ghosh 2015 [71]	India; urban; 2005-06	4665 participants; Children (less than five years)	Non-randomized experimental study	Respiratory ailments	Residence (slum vs non-slum)	Exposure to higher levels of PM_{10} and $PM_{2.5}$ is a significant contributor to childhood respiratory ailments. Thus, children in the slum are at greater risk of adverse health effects from pollution than

						children living outside the slum.
Goswami 2014 [72]	India; urban; Health outcome data: 2011 annual report on registration of births and deaths for acute respiratory disease (ARD) death and ARD case was taken from http://www.india.stat.com	Children (less than five years)	Correlation study	Respiratory diseases (Acute Respiratory Diseases: ARD)	N.A.	Respiratory suspended particulate matter (RSPM) and nitrogen dioxide (NO_2) showed a clear correlation with the observed morbidity rate (ARD). There was no significant correlation between ARD morbidity rate and suspended particulate matter (SPM) and sulphur dioxide (SO_2). The number of cold days (temperature ≤ 20° C) showed a significant correlation with the actual

	Air pollution data: 2000-05 Meteorological data: 2000-05					number of ARD deaths in Delhi.
Drinking water salinity						
Scheelbeek 2020 [73]	Bangladesh; rural; 2009-10	701 participants; Pregnant women	Case-control study	Elevated blood pressure	N.A.	Drinking water with high saline concentrations was associated with higher blood pressure in normotensive pregnant women in Bangladesh's coastal areas.

The majority of the studies were conducted in India (n=23), followed by Bangladesh (n=14), Nepal (n=4), and Pakistan (n=1). We did not identify relevant studies from Afghanistan, Bhutan, Maldives, or Sri Lanka. The unavailable articles did not focus on these countries. Most of the 42 studies (n=18) focused on meteorological factors (temperature, rainfall, and humidity) and children. Nineteen studies focused on meteorological factors as the primary exposure. In contrast, 13 focused on extreme events (floods, drought, heatwaves, and cyclones), nine focused on air pollution, and the remaining study (one) focused on salinity in coastal areas. A significant proportion of studies (34) focused on health impacts on children related to extreme weather events, meteorological factors, and air pollution. In comparison, only eight studies looked at health impacts on women.

We organized our scoping review results based on exposure (extreme weather events, meteorological factors, and air pollution) grouped by health effects. We discuss six grouped health outcomes: undernutrition, diarrheal diseases, respiratory infections, adverse birth outcomes, mortality, and others.

3.1 Extreme weather events

The adverse health impacts of extreme weather events (floods, drought, and cyclones) were examined in 13 different studies.[15,33,42–44,34–41] Six studies explored the impact of extreme weather events on child undernutrition[15,33,35,38,40,42], and one of which also included women of reproductive age, i.e., 15-49 years.[35] Two studies investigated extreme weather events' impact on diarrheal diseases[39,44] and one each on respiratory infections[39] and mortality.[42] Nine of 13 studies reported a positive association between extreme weather events and different health outcomes.[33–36,38,40,42,43]

3.1.1 Extreme events and undernutrition

All three studies that had drought as the primary exposure found a positive association with adverse nutrition-related outcomes in children.[33,40,42] The adverse impact of severe drought on Vitamin A status was identified in pre-school children, particularly those with illiterate and older-aged mothers.[33] Spatial clusters of districts with a higher prevalence of stunting were seen in drought-prone areas. However, the district-level burden of children underweight and wasting was not significantly predicted by drought.[40] Another study that examined the effect of in-utero drought exposure on children's health outcomes under five years in rural India found that drought exposure in the year before birth or the year of birth was associated with underweight.[42]

Two studies examined the relationship between flooding and child undernutrition.[35,74] Goudet et al.[35] found a significant positive association between flooding and child undernutrition (stunting and underweight) a year after the flood. Rodriguez-Llanes et al.[74] observed a positive relationship between flooding and wasting, a minor association with underweight, but not stunting. However, exposure to cyclone Sidr did not have a noticeable negative impact on children and women's nutritional status.[15]

3.1.2 Extreme weather events and other health impacts

The prevalence of diarrhea was not found to be associated with flooding events. Milojevic et al.[39] did not observe strong evidence of an elevated risk of diarrhea in flooded areas compared to non-flooded areas in children younger than five years. Joshi et al.[44] observed similar findings in their study. Milojevic et al.[39] did not find a significant difference in the risk of acute respiratory infections (ARI) in flooded and non-flooded areas. Kumar et al.[42] observed that infant mortality was increased for children born in the second half of a year in which drought occurs in India.

3.2 Meteorological factors (temperature, rainfall, and humidity)

The adverse impacts of meteorological factors were investigated in 19 studies.[45,46,59,60,75–81,47–49,51,52,55,57,58] Most studies focused on the impacts of meteorological factors on mortality (n=5) and diarrheal diseases (n=4). Few studies focused on examining the relationship of meteorological factors with undernutrition (n=3), other health effects (n=3), respiratory infections (n=2), and adverse birth outcomes (n=1). Almost 95% of the studies (18 of the 19 studies) reported a positive association between meteorological factors and different health outcomes.[45,46,56–63,47,48,50–55]

3.2.1 Meteorological factors and undernutrition

Three studies observed a positive association between extreme temperature and rainfall with childhood undernutrition.[55,60,61] Two studies in Nepal used Demographic and Health Survey (DHS) data linked with meteorological data to investigate the association between rainfall and child undernutrition.[60,61] One study found a positive association between childhood undernutrition (stunting and wasting) and rainfall.[61] The other study observed an increase above current monsoon rainfall levels was strongly associated with reduced wasting.[60] A spatial study in rural India observed that extreme temperatures (>40°C) were positively associated with childhood stunting in districts.[55]

3.2.2 Meteorological factors and diarrheal diseases

All five studies found positive associations between meteorological factors and the risk of diarrheal diseases.[46,50,51,57,63] In a study in rural India, the prevalence of diarrhea was associated with higher quartiles of average temperature (≥ 30.5° C) during the first, second, and third weeks before a seven-day diarrhea recall period.[46] Ajjampur et al.[63] similarly observed a higher rate of cryptosporidium positivity during hotter and drier weather in Delhi. They also observed that heavy rainfall events (vs. no heavy rainfall events) after a 60-day dry period were associated with higher diarrhea risk in the following 1 to 3 weeks. Bhandari et al.[50] estimated an 8.1% (RR.: 1.081; 95% CI: 1.02 - 1.14) increase in the risk of diarrhea cases in children less than five years of age per 1°C increase in maximum temperature above the monthly average recorded within that month. They also estimated a 0.9% (RR.: 1.009; 95% CI: 1.004 – 1.015) increase in the risk of diarrhea cases per 10 mm increase in rainfall above the monthly cumulative values recorded within that month. Overall, the study estimated that 7.5% (95% CI: 2.2% - 12.5%) of the current burden of diarrhea among children less than five years in Kathmandu (urban setting) was attributable to meteorological factors.[50] Likewise, Bush et al.[51] observed a positive association between extreme precipitation and hospital admission due to gastrointestinal illness among children less than five years of age. Wu et al.[57] also observed an association between higher temperature (OR: 1.018; 95% CI: 1.011 – 1.025) and heavy rainfall (OR: 1.013; 95% CI: 1.019 – 1.044) with diarrhea risk.

3.2.3 Meteorological factors and respiratory infections

Temperature and precipitation were found to have a positive association and/or correlation with the risk of respiratory infections. Murray et al.[62] found that rainfall was associated with the increased risk of ARI in children under five years of age. Goswami and Baruah[72] observed that the number of cold days (temperature ≤ 20°C) per month significantly correlated with acute respiratory disease (ARD) morbidity in Delhi. However, ARD morbidity was found even in the absence of cold days, likely indicating the role of other drivers of ARD, such as air pollution.

3.2.4 Meteorological factors and birth outcomes

Rashid et al.[48] found a significant impact of temperature during pregnancy on the birth length and weight. The temperature increase in the last month of pregnancy was associated with the increased birth length. However, the effect varied by the mother's nutritional status. They also found a significant positive association between the increased temperature at mid-gestation and increased birth weight.

3.2.5 Meteorological factors and mortality

Three studies observed a significant association between meteorological factors and mortality.[53,54,56] For example, Alam et al.[56] observed that weekly mean temperatures below the 25th percentile and between the 25th and 75th percentiles were associated with increased mortality risk after adjusting for seasonal patterns and time trends, particularly in females of all ages. Female mortality increased by 4.3% and 3.8% with every 1° C decrease in temperature below the 25th percentile and between the 25th and 75th percentile, respectively. Average rainfall below 14 mm over lag 0-4 weeks significantly reduced female mortality, while average rainfall over 14 mm was associated with significantly increased mortality risk in both males and females.[56] Singh et al.[54] found that all-cause mortality varied with the season for both males and females. During the summer season, the daily mean temperature was positively correlated with all-cause mortality for both sexes. During the winter season, the daily mean temperature was negatively correlated with all-cause mortality for both sexes.[54] Similarly, Ingole et al.[53] observed that mortality was associated with daily ambient temperatures and rainfall for all age groups, including those 0-4 years, after adjusting for seasonality and long-term time trends. Singh et al.[54] also observed the highest relative risk of mortality from heat stress in children in the age group 0-4 years (RR 1.39, 95%CI 1.16 – 1.69).

3.2.6 Meteorological factors and other health impacts

One study examined the association between meteorological factors and heat-related hospital admission. The researchers found a 43% increase in neonatal intensive care unit admission for heat-related illnesses (e.g., dehydration, increased respiratory rate, convulsion).[45] Community-based surveillance in urban Bangladesh also showed that higher temperature and heat humidity index were significantly associated with very severe diseases in newborns.[59] Mullany et al.[47] showed that moderate/severe hypothermia risk increased by 41.3% (95% CI: 40.0% - 42.7%) for every 5° C decrease in average ambient temperature. Furthermore, relative to the highest quintile, the risk was 4.03 (95% CI: 3.77 – 4.30) times higher among infants exposed to the lowest average ambient temperature quintile (3.8°C - 11.7°C).[47]

3.3 Air pollution

The adverse health impacts of air pollution were examined in nine studies.[64–72] Most studies (n=4) focused on respiratory health impacts.[66,69,71,72] Three studies examined impacts on mortality[64,68,70], two on nutrition[67,69] and one on the adverse birth outcomes.[65]

3.3.1 Air pollution and undernutrition

Two studies found that exposure to particulate matter pollution was positively associated with undernutrition in children.[67,69] Masamitsu et al.[69] found gender differences in the association of fine particulate matter ($PM_{2.5}$) exposure with childhood undernutrition. Prenatal exposure to $PM_{2.5}$ showed a strong association with stunting only in boys, while postnatal exposure to $PM_{2.5}$ was strongly associated with stunting in both boys and girls.[69] Goyal and Canning[67] found a significant positive association between $PM_{2.5}$ exposure in utero and child stunting. They also observed that a female child had a significantly higher risk of stunting and being underweight.

3.3.2 Air pollution effect on respiratory infections

Two of the four studies that focused on air pollution observed a significant positive relationship between exposure to air pollution and ARI risk.[66,71] Chakrabarti et al.[66] found that living in a district with intense agricultural crop residue burning (ACRB) - ≥ 100 fires per day - was a leading risk factor for ARI in children (aRR: 2.99; 95% CI: 2.77 – 3.23). Ghosh and Mukherji[71] found that exposure to a higher level of PM_{10} and $PM_{2.5}$ significantly contributes to childhood respiratory ailments. Maji et al.[70] found that long-term exposure to $PM_{2.5}$ is positively associated with increased ARI incidence in children younger than five years. The risk of ARI associated with ACRB was greater in females (aRR: 3.08; 95% CI: 2.75 – 3.45) than in males (aRR: 2.93; 95% CI: 2.64 – 3.25).[66]

3.3.3 Air pollution and other health impacts

Akhmat et al.[65] found an inverse relationship between maternal air pollution exposure and birth weight. A one percent increase in carbon dioxide emissions was associated with a 0.412 percentage point decrease in babies' birth weights.

A positive association between air pollution exposure and mortality was reported in the selected studies.[64,68,70] For example, Maji et al.[70] found that long-term exposure to $PM_{2.5}$ was associated with increased mortality risk due to cerebrovascular disease (e.g., stroke), ischemic heart disease (IHD), chronic obstructive pulmonary disease (COPD) and lung cancer among adults (≥ 25 years). Another study found that pollutants exhibit age and sex-selective effects. A significant effect of particulate matter (PM_{10}) on increased mortality was observed among females (female: RR 1.002 (95% CI 1.001 to 1.004); male: RR 1.001 (95% CI 0.99 to 1.002)). Age group-based analysis revealed that particulate matter affected the age group ≥ 65 years (RR 1.002; 95% CI 1.000 to 1.004) vs the age group below five years (RR 1.000, 95% CI 0.997 to 1.003)).[64]

4. Discussion

Overall, a limited number of studies focused on extreme weather events, meteorological factors, and air pollution-related health impacts, particularly on women in South Asia. Findings indicate the urgent need for study in other South Asian countries beyond India and Bangladesh. Findings showed that undernutrition, diarrheal disease, low birth weight, premature mortality, and temperature-related illnesses (e.g., hypothermia) are critical adverse health impacts attributed to extreme weather events, meteorological factors, and air pollution in children and women in the region. The identification of only one qualitative study in the review reflects the lack of other methodologies in this type of research, thus restricting a complete understanding of the complex relationship between climate change, air pollution and children and women's health.

4.1 Evidence of climate-and air pollution-related health impacts in children and women

This scoping review found evidence of health impacts in children and women attributed to extreme weather events, meteorological factors, and air pollution-related exposure. Undernutrition, diarrheal disease, low birth weight, and premature mortality were critical health risks among children associated with exposure to extreme weather events, meteorological factors and air pollution. Undernutrition in children was positively associated with air pollution exposure. Children were also at greater risk of ARI and premature mortality attributed to meteorological and air pollution exposure. However, few studies linked women's adverse birth outcomes and ARI to air pollution exposure.

The risk of specific types of undernutrition (stunting, underweight, or wasting) varied with exposure from one extreme event to another. For example, exposure to drought was positively associated with chronic undernutrition (e.g., stunting and underweight)[33], while exposure to flooding was positively associated with acute undernutrition, i.e., wasting.[74] The education level and age of mothers were critical sociodemographic factors affecting the association between exposure to extreme events and the risk of undernutrition in children. Arlappa et al.[33] observed a stronger association for older mothers and those with lower level of education or no education. This finding aligns with that of other regions as well. Dimitrova[82] also found that drought-exposed children in Ethiopia born to less educated mothers were at higher risk of undernutrition in Ethiopia than those who were born to more educated mothers.

This review also found evidence of a significant association between exposure to air pollution and the risk of childhood undernutrition.[67,69] A gender difference was evident in the risk of stunting and underweight children, particularly for air pollution exposure, where female children had higher risks than male children.[69] The evidence for the relationship between air pollution exposure and child undernutrition (stunting) is scarce; however, some studies in other regions have supported the positive association between exposure to air pollution and the risk of undernutrition in children.[83,84] One potential pathway through which air pollution might impair the growth of children is through repeated episodes of respiratory illness, which are linked with increased child stunting risk.[85]

No significant associations between flood exposure and the risk of diarrheal diseases were reported in the studies in this review. It may be that previous exposure to flooding in the region might have reduced the vulnerability of the population. In contrast, diarrhea prevalence was significantly associated with meteorological factors. Similar results have been reported from other regions.[86,87] Studies have linked higher temperatures with increased diarrheal disease risk in children. This could be due to the rapid multiplication and survival of pathogens causing diarrhea over a longer period, which mainly occurs in the warmer season. Temporal changes in human behaviour, such as higher water consumption, using unimproved drinking water sources, and compromised hygiene practice due to water scarcity are also potential pathways of exposure.[88–90] Extreme rainfalls are expected to cause a rise in waterborne diseases due to deterioration in water quality.[2,88]

The association between ARI and air pollution exposure varied with the place of residence, i.e., urban vs rural and slum vs outside slum. Odo et al.[91] analyzed demographic and health survey data from 35 low-and middle-income countries. They found a significant association between long-term $PM_{2.5}$ exposure and ARI in children younger than five years. They observed evidence of effect modification by sex, age, and place of residence, suggesting that children, particularly boys, living in rural areas experienced greater ARI effects at the same level of $PM_{2.5}$ exposure compared to girls and those living in urban areas.[91]

There is inconsistent evidence of an association between air pollution and adverse pregnancy outcomes (stillbirth, preterm birth, low birth weight, and macrosomia). Still, several studies have suggested adverse pregnancy outcomes attributed to exposure to air pollution.[92–94] One plausible explanation is that maternal exposure to particulate matter may represent a critical risk factor for intrauterine inflammation, which could then impact the placenta's growth, development, and function.[95] Studies have identified that the effect of air pollutants on adverse pregnancy outcomes varies with specific types of air pollutants. For example, a systematic review showed a consistent association between sulfur dioxide (SO_2) and low birth weight and preterm birth.[92] PM_{10} was also consistently associated with congenital anomalies, particularly cardiovascular defects.[92] In another study, a significant inverse relationship was detected between air pollution exposure, particularly carbon dioxide emissions, and birth weight.[65] The effect of air pollution was also found to vary depending upon maternal comorbidities. For example, the effect of $PM_{2.5}$

and nitrogen dioxide (NO_2) on preterm birth was found to be higher among diabetic mothers, while the effect of ozone on preterm birth was higher among mothers with asthma.[94]

Positive associations between air pollution and meteorological factors with mortality was detected in several studies. We found that more women are impacted by air pollution exposure and disaster-related events to a greater extent than men.[42,64] Other studies globally have also found women are more impacted by climate disasters.[96–98] Neumayer and Plumer[96] observed that the socioeconomic status of women is a critical factor that plays a greater role in women being more impacted by climate disasters than men.

4.2 Research gap: children and women's health risk and geographical coverage

Overall, studies focusing on extreme weather events, meteorological factors and air pollution-related health impacts on women were scarce. Several studies included women or children only as a subpopulation of the main analysis. As such, the evidence of the social, political, and economic determinants of climate change and air pollution impacts on children and women's physical and mental health were limited. In particular, studies that assess mental health in women exposed to extreme weather events (e.g., floods) are lacking in the region. South Asia is one of the most flood-prone regions globally. Floods in the region are often triggered by heavy monsoon precipitation, which can cause considerable damage to lives, crops, assets, and infrastructure.[99] Floods increase the physical injury risk for women and who are more likely to be evicted from their dwellings. In addition, women can face difficulties fetching adequate water for drinking and cooking, securing safe shelter, and maintaining personal hygiene and sanitation. Furthermore, women can be exposed to domestic violence and may be subject to physical and sexual harassment.[100]

Some areas (India, Bangladesh, Sri Lanka, and Maldives) of South Asia are more vulnerable to the effects of climate change and air pollution than others (Nepal, Bhutan, Afghanistan, and Pakistan). For example, coastal area populations in the region face the combined threat of rising sea levels and extreme weather events impacting populations, particularly those who are poor and live in remote areas.[9] However, there were a lack of studies in remote coastal areas. Most of the literature in this scoping review focused only on urban settings in India and Bangladesh. Studies from other South Asian countries and those living in the remote coastal areas were limited, which is a critical knowledge gap.

4.3 Strengths and limitations

The extensive terminology of our search is one of the strengths of the review, but it is possible that we missed studies that additional terms might have retrieved. We also did not consider the pertinent potential papers in the references of the retained papers. The world discourse on climate change has increased significantly in recent years. Our review focuses on post-2010 literature to capture that current discourse; however, it is possible that there is evidence in earlier studies that might have informed our review. Two reviewers independently screened the studies to ensure consistency; however, only one reviewer did the data extraction, and no quality assessment of the evidence included in this review was conducted. We used library databases to retrieve most papers that were not open access, though some papers were not available.

5. Conclusion

The selected literature studied in this scoping review indicates that extreme weather events, meteorological factors and air pollution have affected the health of children and women living in South Asia. The evidence of the relationship between exposures and health impacts on children and women was consistent, except for extreme weather events where evidence was inconsistent across wasting, underweight, and stunting. Most studies have considered children and women only in sub-group analyses, rather than the main population of interest. Therefore, the limited knowledge concerning the relationship between exposure to extreme weather events, meteorological factors, air pollution and the risk of adverse health impacts, particularly in women, are critical knowledge gaps. The lack of literature concerning mental health impacts on both children and women is an area for future research. There is a disparity in the distribution of studies within and across the countries, as most studies focused on urban settings in India and Bangladesh. This highlights the need for more studies within and across all South Asian countries that will provide a comprehensive picture of the effects of climate change and air pollution on children and women.

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Chapter III

"The weather does not support farmers": an exploratory qualitative study in Kavre district, Nepal.

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Synopsis

Kavre district, Nepal, is highly vulnerable to the impacts of climate change, including erratic rainfall, drought, and landslides. Listening to and learning from women is critical to better understand the interacting effects of gender roles, culture, age, physical and physiological characteristics with climate change and air pollution as they affect health risks for women and children in Nepal. Using a descriptive qualitative approach, this study explores women's lived experiences of climate change, including their perspectives regarding adverse impacts on agriculture and health and their ongoing adaptation and mitigation strategies. Eight focus group discussions (FGD) (n = 40) and eight interviews (n = 8) were conducted employing purposive and snowball recruitment. All FGDs and interviews were conducted in the Nepali language, guided by an interview guide, audio-recorded and transcribed verbatim in Nepali. Data were analyzed in NVivo 1.7 using a thematic analysis approach. Forty-two of the 48 participants were women and the rest were men. The largest proportion of participants was aged 50 years or older (18/48), had no formal education (21/48), and were either older women (13/48) or mothers of children under five (11/48). Three main themes emerged. The first theme, "When the weather changes, it gets very cold," captured participants' perspectives on climate change. The second, 'the unpredictability of weather,' captured their lived experience related to climate change. The third, 'acting locally,' captured local-level actions to address impacts expected from climate change. These findings can help inform the development of interventions to better address women's and children's needs and concerns, which are essential to promoting well-being and reducing climate change-exacerbated impacts.

Keywords: climate change, air pollution, health, women, children, Nepal

1. Introduction

Human activities have already caused a mean rise in global surface temperature of approximately 1.1°C between 1850 and 1900.[1] It is projected that if the current trend persists, this will reach 1.5°C between 2030 and 2052[2], resulting in significant threats to human health. Effects will be mediated through social and environmental determinants of health, including air quality and drinking water, and the availability of food and secure shelter, among others.[3] Globally, under mid-range emissions scenarios, climate change is expected to cause additional deaths annually just from malaria, malnutrition, diarrhea and heat stress by 2050.[4] The world must limit global temperature rise to 1.5°C to prevent additional catastrophic human health impacts.

Climate change threatens Nepal's agriculture, food security, water resources, and health. The agriculture sector contributes to over one-third of Nepal's gross domestic product, and two-thirds of its population remains heavily dependent on rain-fed agriculture for subsistence.[5] However, extreme climate conditions, notably persistent increases in mean annual temperature and precipitation, have adversely affected the agricultural production system, exacerbating food insecurity and undernutrition.[4,5] The retreat of glaciers in Nepal's Himalayan region is occurring faster than in other mountain ranges and is one of the most notable impacts of climate change.[6] Such rapid glacier retreat is likely to increase the risk of catastrophic disasters such as glacial lake outburst floods and landslides, with resulting human mortality and morbidity.[6] Thus, the need for climate change adaptive behaviours and actions in this region is urgent.

All countries are at risk of the impacts of climate change. However, those harmed first and worst by the climate crisis have contributed the least to its causes and have the least adaptive capacity, including low-and middle-income countries, such as Nepal.[7] Nepal's contribution to greenhouse gas emissions is 0.027 percent of global emissions[8], but Nepal was ranked ninth among the countries most affected by climate change over the period 1999 through 2018.[9] Approximately 80% of its population is at risk from natural hazards.[10] Nepal's complex topography and comparatively low socioeconomic status further increase its vulnerability to climate change.[8]

Gender roles, decision-making power, culture, age, physical and physiological characteristics disproportionately expose women and children in LMICs, including Nepal, to impacts associated with climate change and air pollution.[7,11–13] Women, particularly in low-income countries, travel long distances to fetch water after natural disasters. The reduced availability and contaminated water cause hygiene-and sanitation-related problems, such as urinary tract infections and diarrhea.[14,15] For example, Kabir et al.[14] reported that women and adolescent girls face difficulties accessing sanitary pads and appropriate toilet facilities due to a lack of privacy following disasters. Pregnant women face the particular challenge of ensuring the safe delivery of a child following a disaster.[15] Disasters put women, girls, and children, particularly those in marginalized segments of society, at higher risk of physical and sexual abuse.[16,17]

Women's problem-solving and decision-making capacity is vital to climate change adaptation. Therefore, eliciting women's perspectives and lived experiences related to climate change, adverse climate change impacts, and adaptation is critical. The Intergovernmental Panel on Climate Change also stipulated that local knowledge is crucial to inform climate adaptation planning.[18] Therefore, we took a bottom-up approach to explore women's perspectives and lived experiences related to climate change, consequent adverse impacts on agriculture and health, and ongoing mitigation and adaptation in response to these changes.

2. Methods

2.1 Study setting

Kavre is one of 77 districts in Nepal and comprises 13 rural and urban municipalities. With Dhulikhel municipality as its headquarters, the district falls within Bagmati Province and covers 1,396 km^2. We conducted this study in two rural municipalities: Bhumlu and Mahabharat (Figure 1).

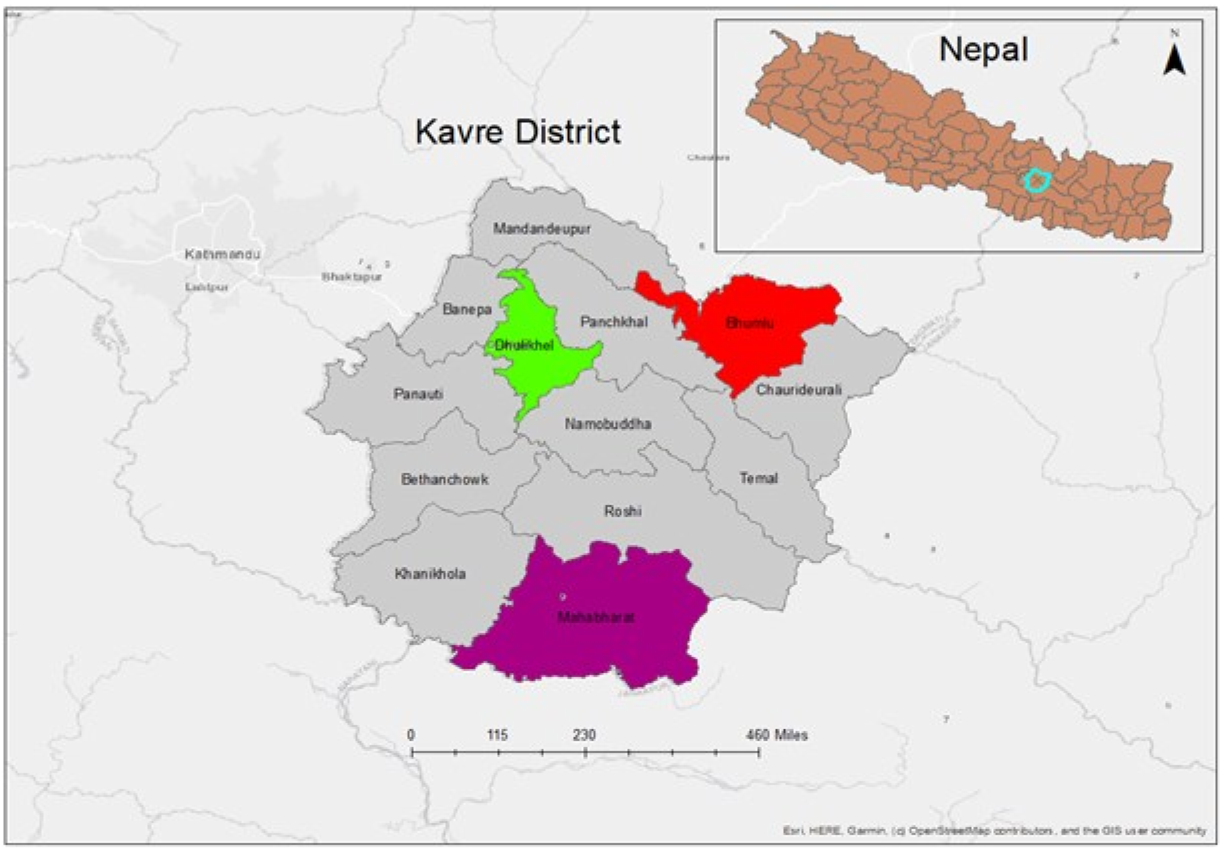

Figure 1: Map of Kavre district showing the study location

Bhumlu rural municipality covers over 91 km^2 and is culturally, linguistically, and ethnically diverse. It has a population of 15,858 people, according to the 2021 Nepal Census.[19] Brahmin, Chhetri, Tamang, Pahari, Dalit, Majhi, Newar, and Dashdani are the major ethnic groups in this municipality.[19] Most of the population is Hindu, followed by Buddhists.[19] Agriculture is the primary source of livelihood, while business and remittances from foreign employment are other important sources of income.[19]

Mahabharat rural municipality covers an area of 186 km^2, divided into eight wards. Its geography includes steep hills and mountains. Nepal's 2021 census reported a total population of 16,148 people.[19] The largest ethnic group is Tamang, followed by Brahmin, Chhetri, Newar, Dalit, and Majhi.[19] The population of this municipality is largely Hindu or Buddhist. The primary source of income is also agriculture. Other sources include livestock farming, tourism, and herb collection.[19]

2.2 Participants and Recruitment

Eligible participants included mainly women, particularly family caregivers of children under five years. Women participants were further grouped into pregnant women, mothers of children under five years, and older women (≥ 55 years). We also included participants representing community health groups, such as health post in-charges and members of health mothers' groups (community groups that bring together women of reproductive age to discuss and promote safe motherhood, maternal and child health, and nutrition, family planning, water, sanitation, and hygiene), Health Facility Operation Management Committee members (HFOMC), and Female Community Health Volunteers. A few participants (n=6) in two FGDs were men and were members of the HFOMCs. HFOMCs did not have sufficient women to conduct women-only FGDs; therefore, we included men. To be eligible, participants needed to:

(i) Be permanent residents of one of the included municipalities and

(ii) Have lived in the municipality for the past 20 years.

Each category of participants was grouped into a separate FGD. The primary reason for this grouping, particularly family caregivers of children under five, was to learn firsthand about their experiences and perspectives concerning weather change, changes in precipitation and agricultural patterns, and consequent health impacts on women and children. The other participants from community-based health-related groups (members of the Health Facility Operation Management Committee, health mother's group members (HFOMC), Female Community Health Volunteers, and chief of health centers)) were included in separate FGDs to elicit broader community perspectives.

A purposive and snowball recruitment was used to invite eligible participants. We received support from community members to identify participants meeting the study inclusion criteria. All potential participants we reached out to agreed to participate in the study.

All eligible participants were considered for FGDs to explore shared experiences and a range of perspectives. Participants selected for the FGDs were enthusiastic and candid, felt comfortable speaking on the topic in the group, and fulfilled the eligibility criteria. However, some participants hesitated to participate in a group setting and expressed feeling more comfortable discussing personal experiences privately, so they chose to do an interview. Additionally, participants selected for interviews were busy or hard-to-reach individuals we could not include in the FGDs. Written informed consent was obtained from each participant.

2.3 Data collection

We employed four local research assistants, two females (ST and BBM) and two males (DD and MN), who were responsible for conducting interviews using an FGD and interview guide in English and Nepali (Table 1). The research assistants had undergraduate degrees in public health and at least one year of community health experience. We oriented the research assistants on the study proposal, including providing a primer on climate change and health. We trained them by conducting repeated mock interviews to enhance familiarity with the discussion topic, build confidence, and troubleshoot potential issues that could arise, such as participants deviating from the discussion topic and unequal participation.

Table 1: Interview guide questions and emergent themes

S.N.	Interview and FGD Questions	Themes emerged
1	What do you think of when you hear "climate change?"	First theme
2	Have you experienced/witnessed or heard of changing rainfall patterns, extreme temperatures, increased intensity and frequency of natural disasters, loss of water sources, or poor air quality? Please explain.	
3	What do you think are the factors that drive climate change/air pollution or the effects mentioned above?	
4	How have you experienced or heard of adverse impacts of climate change/air pollution, changing rainfall patterns, extreme temperatures, increased intensity and frequency of natural disasters, or poor air quality? If so, can you share that with us?	Second theme
5	What are you doing to mitigate or adapt to those adverse impacts? Or what do you think should be done to address those issues?	Third theme

Eight FGDs and eight interviews were conducted, four FGDs (with four to six participants) and four interviews in each rural municipality. Each interview and FGD lasted approximately one and a half hours. Each pair of research assistants consisted of a male and a female research assistant; one pair conducted all the interviews, while the other took reflexive and observational notes during and after the interview and FGDs. We also collected sociodemographic data from the participants. At the end of the interview, each participant was paid an honorarium and provided with refreshments. All research assistants participated in regular debriefing sessions throughout the data collection process to discuss interviews, amend the interview guides, and refine lines of inquiry. All interviews and FGDs were audio-recorded. The research assistants transcribed verbatim all recordings. Another local researcher (NM) fluent in Nepali and English proofread for accuracy.

2.3.1 Positioning the data collection team

Local research assistants and the principal investigator were born and raised in Nepal. The research team members shared the same culture, including the language, food, dress, and way of life as the participants. In this context, the team members were considered insiders. However, the urban upbringing of the research team afforded them certain privileges and access to resources that were not readily available to those residing in rural communities. Therefore, the team approached this research with humility and a commitment to understanding and amplifying the voices of research participants, regardless of their sociodemographic and geographic background.

In conducting FGDs and interviews with rural communities, the team was aware of the intersectionality of various factors, such as gender, caste and ethnicity, education, and socioeconomic status, that are highly likely to influence the dynamic within communities and impact individuals' experiences, perspectives, and contributions to the discussion. Specifically, the male gender and relatively higher socioeconomic status of the research team might have influenced participants' willingness to share their experiences and perspectives, including disclosing sensitive information or providing honest responses. Therefore, we strove to create a safe and inclusive space where participants, particularly women, felt empowered to share their insights and perspectives. To create an inclusive space, we explained the research process, including clear guidelines for respectful communication and behaviour at the beginning of the FGDs. Furthermore, we encouraged active listening among participants by creating opportunities for everyone to speak and be heard without interruption. However, some participants resisted our efforts to promote inclusivity by interrupting when a member of the FGDs shared their perspectives, creating challenges in implementing inclusive practices. Such interruption occurred particularly in two FGDs, which included male participants. We also acknowledge that the note-taking by our research team members, to some extent, created hesitancy among the participants to express their experiences and perspectives. However, the purpose of such a task was clarified at the beginning of the study.

Interacting with rural communities as outsider researchers regarding gender (male), attainment of higher education, urban upbringing, and access to modern technologies, the team recognized the importance of reflexivity in data collection. The team remained mindful of their biases and preconceptions, actively seeking to mitigate their influence on the research process through a research team review meeting after every FGD and interview. By engaging in reflexivity, we aimed to ensure that the data collected accurately reflected the participants' diverse realities and lived experiences.

2.4 Data analysis

Thematic analysis[20] of the Nepali transcripts was completed using NVivo 1.7[21] by the principal investigator, a native Nepali speaker. Only selected references were translated into English for quotes that illustrated key themes, patterns, or findings identified during the data analysis process. The principal investigator familiarized himself with the data and rigorously read transcripts to generate ideas for codes to describe the content. Codes were assigned to data to describe points raised in the interviews and FGDs. Each time the principal investigator noted something different in the data, a new code was generated, a key step in organizing data into meaningful groups. Codes were then sorted into broader themes. The principal investigator and supervisor reviewed and refined the main themes, checked for overlapping sub-themes, and confirmed the relevance of the codes, naming and describing each.

Throughout the data analysis steps, we used an inductive approach to identify, examine and report themes within the data through an iterative analytic process. The process helped achieve deeper insight into participant perspectives and lived experiences.

Furthermore, we approached data analysis with sensitivity to the contextual nuances of the rural setting, recognizing that the findings may be influenced by factors such as gender, sociodemographic status, cultural norms, traditions, and access to resources. We could not involve participants in the data analysis process, but their perspectives remained central to the research. We diligently analyzed the data through a thematic lens to honour and represent the rich diversity of experiences and perspectives shared by participants during the FGDs and interviews. However, the male gender and relatively higher socioeconomic background of the principal investigator might, unconsciously, have led to the interpretation of data through the lens of his own experiences and privileges, potentially overlooking the perspectives of participants.

We obtained ethics approval from the University of Alberta Health Research Ethics Board (Pro00107397) and the Ethical Review Board of Nepal Health Research Council (Protocol Registration # 340/2021) before beginning the study.

3. Results

The study included 48 participants who took part in eight FGDs and eight interviews from two rural municipalities (Table 2). Forty-two of the 48 participants were women. We acknowledge a change in power dynamics to some extent in two FGDs involving the HFOMC members, as men spoke more often than their women counterparts. However, we captured women's perspectives from three-quarters of the FGDs and 100% of the interviews. Therefore, the impact of such changes in power dynamics was minimal on the overall study. The largest proportion of participants was aged greater than or equal to 50 years (18/48), had no formal education (21/48), and were either older women (13/48) or mothers of children younger than five (11/48). Participant sociodemographic data are presented in Table 3.

Table 2: Distribution of FGDs and interviews in two rural municipalities

Participants' group	**Data collection method**	**Mahabharat rural municipality Number of event (number of participants)**	**Bhumlu rural municipality Number of event (number of participants)**
Health Facility Operation	FGD	1 (5)	1(4)

Management Committee			
Mothers of children under five years	FGD	1 (4)	1 (5)
Female Community Health Volunteer	FGD	1 (5)	1 (5)
Older mothers	FGD	1 (6)	1 (6)
Health post in-charge	interview	1 (1)	1 (1)
Lower secondary teacher	interview	1 (1)	1 (1)
Older adult	interview	1 (1)	1 (1)
Pregnant women	interview	1 (1)	1 (1)

Table 3: Sociodemographic characteristics of study participants

Characteristics	**n=48 (%)**
Age in years	
20-29	9 (19)
30-39	7 (15)
40-49	14 (29)
≥ 50	18 (37)
Gender	
Female	42 (88)
Male	6 (12)
Highest completed education	
No formal education	21 (44)
Primary education	5 (10)
Secondary education	16 (33)
Higher secondary education	6 (13)
Stakeholders	
Mothers of children under five years	11 (23)
Older women (≥ 55)	13 (27)
Health Facility Operation Management Committee	9 (19)
Female Community Health Volunteer	10 (21)

Others (farmers, primary school teachers, health mother's group)	5 (10)

Most participants reported never having heard the Nepali phrase for "climate change," so we used a term meaning "a long-term change in the weather." Participants were also asked about the direct impacts of such changes (i.e., loss of previous water resources, increased frequency and intensity of disasters, and poor air quality).

Three central topical areas emerged:

i) "When the weather changes, it gets very cold,"

ii) The unpredictability of weather and

iii) Acting locally.

3.1 "When the weather changes, it gets very cold"

This theme captures participants' perspectives on climate change. An area of discussion across focus groups and interviews was factors they believed drove climate change. Participants of an FGD involving mothers of children younger than five years of age shared that they focused on their livelihoods and were unaware of climate change due to a lack of television and radio access. Most participants who shared their perspectives felt they did not know much and described climate change as seasonal, such changes that occurred from winter to summer. Others reported that extreme weather events, including sudden rain or rapid temperature change, characterized climate change.

> *Participant 5 (P5)- I don't know what to say. When the weather changes, it gets very cold.*

P4- Winter is about to pass, and summer starts. Wind blows.

P3-I don't know.

P2-climate change (The Nepali phrase meaning "a long-term change in the weather") is the start of summer after winter and the rainy season afterward. (U-5 mothers, FGD-7)

A small proportion of participants who reported they had previously heard of climate change reported it as a phenomenon characterized by changing rainfall patterns, extreme temperatures, disasters such as floods, landslides, and wind storms, and the increased duration of foggy weather. Participants described these changes as a shift from previously steady and uniform regional natural patterns to the current state where established patterns have been altered.

Climate change is a change in the climate between now and before. It is getting hotter in Jumla [a district in western Nepal] now. The rainfall is untimely and heavy, but it was not like this before. The heat was tolerable in the summer, but now it is too hot, and winter is colder. The temperature and rainfall patterns have changed. (Health Facility Operation Management Committee, P3, FGD-4)

Participants who reported having heard of climate change were asked about the factors driving climate change. Others were asked about the causes of warming temperatures, changes in precipitation, and changes in the frequency or intensity of extreme weather events (for example, floods, landslides, forest fires, extreme temperatures, etc.). Most participants who reported having heard of climate change identified deforestation as the principal cause. Participants reported that population increases led to more human activity, resulting in deforestation, which led to changes in rainfall, temperatures, loss of water resources, and disaster events. Responses suggested that there was more forest cover in the past and highlighted the impact of human population growth on the environment.

> *There used to be dense forests and fewer people before, but now the population has grown, and people started cutting down trees for different things. The forests are shrinking. So, the rainfall has become unpredictable. The lack of forest area has caused an increase in temperatures. There is no shades, even for the land. (Older mothers, P4, FGD-6)*

Several participants discussed air pollution as another principal cause. They highlighted the increasing use of plastic, particularly for food wrap, and its haphazard disposal and burning as contributing to the deterioration of air quality in the region. They also expressed concern about adverse impacts on the population. Others compared current air quality to past air quality and linked deterioration to road construction and the increasing use of motor vehicles. They also described people's negligence in deliberately setting wildfires to convert wood into fertilizer, contributing to air pollution and climate change.

> *It is not good to burn plastics, but people burn them. Many foods come in plastic packaging, and people throw them in public places and burn them, emitting harmful chemicals into the air. It affects every age group, both males and females. When the summer season starts, people are mobilized, setting fires everywhere. They believe forest fires are essential to convert wood into fertilizer and don't care about the impact on human settlement (Health Facility Operation Management Committee, P2, FGD-2)*

Overall, participants focused on local factors as the causes behind their experiences of climate change with less focus on broader and global scale factors.

3.2 The unpredictability of weather

This theme captures participants' lived experience of adverse impacts that they attributed to climate change. Those who reported not having heard of climate change were asked about their experiences with the effects of unpredictable rainfall, water scarcity, extreme temperature, and natural disasters on agriculture, the environment, and women's and children's health.

3.2.1 "The weather does not support farmers"

Almost all participants across the FGDs and interviews reported that climate change or warming temperatures and changes in precipitation affected agriculture in the region. Participants highlighted four significant impacts in the context of discussion around climate change impacts: crop infestation, increased use of pesticides, soil quality degradation, and decreased productivity. They unanimously recognized crop infestation as a significant problem faced by the community. Some participants reported that crop infestation created a compelling need for the use of pesticides, resulting in increased use. Others expressed distress that pesticide use was not helping to mitigate the problem, but instead, reported that it was contributing to undermining soil quality, resulting in reduced productivity. They mentioned that other factors, such as strong wind, were responsible for destroying crops. They also observed that fruit trees were maturing slower and that the yield and size of the fruits were smaller.

> *P1 ……Pests are damaging crops. Different diseases are emerging, and we are compelled to use pesticides.*
>
> *P5 Pests damaged our crops. We hardly manage to protect crops using pesticides, but a strong wind destroys them. Spinach dies as it begins to grow. There has been a decrease in productivity. I wonder if the soil quality has decreased. Soil has been taken for lab testing, but we do not know the result yet. (Female Community Health Volunteer, FGD-1)*

Participants observed changes with more irregular precipitation than in the past. Most felt this had contributed to reducing agricultural productivity due to this dependence on rainfall.

> *……We rely on rain for farming. During the rainy season, when farmers must plant seeds, it does not rain. The weather does not support farmers. Other times when rain is not necessary, it rains heavily. The rain is unpredictable. (Health Facility Operation Management Committee, P2, FGD-3)*

3.2.2 Uncertainty in rainfall timing and intensity

Participants identified several climate change-attributable environmental impacts in the region. The depletion of water sources was most frequently mentioned and was linked to deforestation. Participants reported wells in their area that dried up over time. They also mentioned a growing shortage of drinking water faced by the community.

> *The water sources have dried compared to what we have seen and used. There were two wells at the base of Swami, but they have dried up. The well near the Baraha tree has also dried up, so the community in that location faces a severe water shortage problem. The intensity of the water flow from the source has decreased. (Female Community Health Volunteer, P5, FGD-1)*

Another environmental impact that most participants mentioned was erratic rainfall. They described challenges resulting from unpredictable and unreliable rainfall. Participants mentioned farmers' reliance on rain for farming. They stated that rain is often untimely, highlighting the importance of rainfall timing and its impact on their crops. They emphasized that the current rainfall pattern differed from the past, which has affected their livelihood through agricultural loss.

….before there used to be timely rainfall. Now, it rains when it is time to harvest rice. It does not rain when we need it. It starts to rain when the rice grain is ready for harvest. Sometimes, it rains frequently; other times, there is no rain. (Older mother, P5, FGD-5)

Participants also mentioned disasters and extreme temperatures. They experienced landslides in their villages and attributed this to deforestation and earthquakes. Participants also highlighted infrastructure construction in the area, such as road transportation, which may have contributed to landslides.

We have faced landslides in our village. Last year, there were massive landslides near the school. (Female Community Health Volunteer, P2, FGD-2)

It is freezing in the winter and sweltering hot in the summer compared to the past. (Health Facility Operation Management Committee, P5, FGD-4)

3.2.3 "Women and children may bear health risks"

Participants were asked about climate change-related health impacts or specific direct impacts of climate change on women and children. However, participants did not explicitly mention the link between climate change and women's and children's health. Participants were then asked to discuss women's and children's health concerns or significant health problems facing communities. Other probes included asking about the health impacts on women, particularly pregnant mothers and children younger than five years, related to changing agricultural patterns, long-term weather patterns, temperature and precipitation changes, and disaster events.

3.2.3.1 "New mothers are becoming weak"

Participants mentioned maternal undernutrition, stillbirth, and low birthweight when prompted to talk about the common health issues of women in the region. They wondered about having observed such health outcomes in the community despite improved health services and awareness compared to the past. One participant (a community health worker) reported that:

> *Due to inadequate crop production and increasing consumption of packaged foods, pregnant women are lean. They come to health centers for an antenatal check as required but complain of weakness and headaches. We used to give birth to babies weighing 3-4 kgs at home, but they can't bear the pain and have to be referred to the Dhulikhel Hospital. (Female Community Health Volunteer, P3, FGD-1)*

Another participant mentioned a stillbirth but did not mention the reason for such an adverse birth outcome.

3.2.3.2 Seasonal variation in pneumonia cases in children

Many FGD and interview participants mentioned respiratory tract infections and diarrheal diseases as critical health problems in young children. Participants believed that respiratory infections were becoming more common and severe, potentially due to changes in weather patterns. Some participants felt diarrhea was becoming less common, possibly due to improved hygiene and sanitation practices:

> *Diarrheal diseases have decreased compared to the past. In the past, there were poor hygiene and sanitation practices; we drink clean water now, every house has a latrine, and there is no more haphazard disposal of waste. That's why the cases of diarrheal diseases have reduced. (Female Community Health Volunteer, P1, FGD-1)*

However, others reported increased diarrhea cases.

3.3 Acting locally

Participants mainly discussed changing patterns of temperatures and precipitation in relation to the local context. They pointed out several climate change-related issues (i.e., agriculture, environmental, and human health) experienced in their region. Participants mentioned several local-level behaviours and actions, including at the household level (use of improved cooking stoves), at the community level (water management, reforestation programs and control of forest fires), and at the local government level (strengthening the health system and planned road construction) to mitigate impacts expected from climate change. Behaviours and actions included proposed solutions and currently practiced actions and behaviours.

3.3.1. Access to drinking water supply close by

Almost all participants across the FGDs and interviews mentioned water shortages in their communities. They reported having implemented various solutions to mitigate water scarcity, including constructing a public water reservoir or water tank. Some participants mentioned water reuse to reduce strains on limited water resources.

> *People used to fetch water from a well. Sometimes they were able to get it, while other times not. Now that there is a water tank, we collect water and keep it full. We don't have to walk long distances. Everyone has the water pipe connected to the water tank. (Health post incharge, Interview-6)*

3.3.2 Collaborate for a greener earth

Most participants mentioned that reforestation could address environmental problems such as poor air quality, water shortages, and disasters. They highlighted the importance of collaborating with local government bodies to protect existing trees and implement reforestation practices.

In our ward, we collaborate with the official from the community forest agency and have initiated a reforestation program. (under 5 mother, P2, FGD-7)

3.3.3 Build hospital at a local level

Most participants spoke of healthcare system-related issues the community faced. They suggested corresponding actions or improvements to increase access to basic health services and meet maternal and child health service needs. Such improvements can address community-level maternal and child health problems caused by diverse factors, including those attributed to climate change. For example, a lack of diagnostic services in the community, such as ultrasound and blood glucose tests, was reported, which compelled them to travel long distances that cost time, energy, and money. They also discussed the lack of qualified health workers, e.g., doctors, as a barrier to receiving quality health services. Overall, participants pointed out a critical gap in providing adequate and accessible healthcare services to the community.

I wish they had constructed a hospital in our municipality. Patients could then commute to the hospital quickly and not have to travel a long distance for treatment. We have to go to the Dhulikhel Hospital to do the video x-ray. It would have been better if we had the provision of video X-rays in our health centers. (Older mothers, P4, FGD-6)

3.3.4 Collective efforts to protect air

Participants reported that monitoring air pollution could protect and promote the health and well-being of the community. They recognized forest fires as a critical problem in their community. Participants suggested mitigation strategies such as checking on forest fires and emphasizing community awareness. They stressed that the community should be sensitized to the importance of forests and the adverse impacts on human health and lives associated with forest fires. They pointed out the critical role of local government in such initiatives along with other local stakeholders and considered formal rules and regulations important.

> *I think if I alone go and tell people to stop setting fires in the forest, it will not work. It needs combined efforts from local government, different organizations, and schools. We must enforce strict rules and regulations, or people will take them lightly. (Health Facility Operation Management Committee, P3, FGD-3)*

Participants pointed to the benefits of replacing traditional cooking stoves with improved cooking stoves or using cleaner fuels (e.g., gas stoves) in the home, including reduced indoor air pollution, less respiratory illness and improved cleanliness. They acknowledged the lack of improved cooking stoves or cleaner fuels in all households in the community and reported that wood stoves are used in most homes.

> *People have been advised to use improved cooking stoves at home. Some households use the improved cooking stove while others don't. If we use the improved cooking stoves, then it will release the smoke outside. We will have less asthma, and the house also looks cleaner. (Under 5 mothers, P2, FGD-7)*

Participants also mentioned the unintended consequences of road expansion, notably ambient air pollution and its consequent effects on respiratory health and vision. They called for a more comprehensive and sustainable approach to infrastructure development.

> *Our neighbourhood has dusty roads. The daily vehicle use makes the area very dusty. It makes it difficult to breathe and open our eyes. It would have been better if they had developed a good road. (Under 5 mother, P4, FGD-7)*

4. Discussion

This study explored climate change perspectives and lived experiences of mostly female participants and family caregivers of children younger than five in two rural Nepali communities. Most participants had not heard of climate change. Among those who had heard of it, their response highlighted that climate change is perceived as seasonal change; however, participants mentioned several climate change-attributed impacts on their daily lives through the disruption of agriculture (e.g., crop infestation, increased pesticide use, soil quality degradation, and decreased productivity) and of their environments (e.g., loss of water resources, erratic rainfall and extreme temperature). Upon probing, they also raised issues of women's and children's health (e.g., maternal and children's undernutrition, low birth weight, stillbirth, respiratory illnesses, and diarrhea) as maternal-child health problems of concern. All participants highlighted local-level climate-relevant behaviours and actions (e.g., water preservation, reforestation programs, strengthening the health system, controlling air pollution, and solid waste management) as critical to adaptation and mitigation in the region.

Many participants expressed unfamiliarity with the concept of climate change, while those aware of it often associated it with changes in weather patterns and seasons. Nevertheless, some attributed changes they had experienced, at least partly, related to climate change. Our findings align with the findings of Nash et al.[18], whose work on community perceptions of local environmental issues and the relevance of climate change in Nepal's Terai region revealed that other Nepali respondents equated climate change with seasonal change. There are implications related to community awareness about climate change because communities experiencing vulnerability need to adapt to increase their resilience.[22] Community climate change awareness can instigate positive change directly by promoting behavioural changes such as more sustainable consumption and lifestyle decisions or indirectly by exerting pressure on the political process.[23] However, community awareness is recognized as a major limitation to climate change adaptation within Nepal.[18]

Study participants mentioned unpredictable changes in climate conditions in their region and concerns about the environment, agriculture, and women's and children's health. They frequently mentioned experiencing and witnessing hotter summers and colder winters, more erratic and lower rainfall volumes, loss of water resources, and deteriorating air quality. Previous studies on community perceptions of environmental and climate-relevant change in Nepal have also reported perceptions of more recurrent foggy days[24], increased drought period[25], more erratic rainfall[26–28], hotter summers[29], and warmer winters[27]. However, there is a lack of consensus on community perceptions on this matter.[18] A few participants also associated disaster events with weather changes, particularly dry landslides in the region. Some participants also pointed to causal factors beyond immediate local risk factors, such as deforestation affecting precipitation and subsequently landslides and forest fires. Such expressions of the lived experiences concerning climate change highlight the urgency that communities face in building their capacity to adapt and improve their resilience.

Most participants mentioned that their agricultural yields had been adversely affected by irregular rainfall, wind, and crop infestation through different pathways, resulting in poor harvests. They expressed helplessness about their dependency on rain-fed agriculture. The reports of a decline in agricultural productivity associated with climatic factors, particularly temperature increases, are found in studies elsewhere.[30–32] Tiwari et al.[29] also reported delayed onset of the monsoon and changes in flowering and fruiting time for certain plant species in the Terai region of Nepal. Such adverse effects on agricultural yield are important, especially for people from rural communities in lower-income countries, due to their dependence on agriculture for subsistence and lack of adaptive capacity compared to high-income countries.[30–32] Furthermore, women are often primary family caregivers in rural households[33] and play crucial agricultural roles.[34] Therefore, agricultural disruption attributed to climate change may disproportionately affect women's roles and food security for their families.[34]

The study investigated participants' experiences of adverse health impacts attributable to climate change. We probed this issue, asking participants what they felt were the most critical health problems for mothers and children in their community. They mentioned stillbirth and low birth weight as critical health problems impacting pregnant women. Previous studies have reported that pregnant women are more likely to experience hypertension, exhaustion, miscarriages and stillbirths with higher temperatures and food insecurity.[35–37] Such health outcomes were more common in women working in the agricultural sector as manual labourers[38,39], a common occupation of the study participants. Diarrhea and respiratory illness were other health effects among young children reported as significant health problems, though these health outcomes were not directly linked to climate change. Children tend to spend more time outdoors than adults, increasing their exposure to heat, cold, rain, and air pollution [40] and consequent risk of illness.

Participants reported undernutrition in women and children as having a significant health impact, as reported in previous studies examining factors such as temperature and rainfall.[41,42] Gender and social inequalities may be crucial in such a health outcome.[43] Studies have shown that climate change exacerbates existing gender and social inequalities and inequities, particularly among women living in remote areas.[44,45] Furthermore, when disasters occur and destroy crops, negatively affecting household income and food consumption, gender discrimination and violence against women increase due to patriarchal gender norms that hold women responsible for these matters.[46,47]

As described by study participants, the environmental, agricultural and health impacts discussed in the context of climate change reveal their socioeconomic vulnerabilities to climate change. For example, most participants had no formal education or only primary education, lived in a rural community, reported using traditional solid-fuel cooking stoves, relied on traditional agricultural practices for livelihoods, and had inadequate access to basic maternal and child health services. This predisposes them to increased experiences of vulnerability to the deleterious effects of climate change. In their call for research, Xu et al.[13] also mention that people with low socioeconomic status are particularly at risk of climate change and air pollution-related health impacts.

All participants tended to focus on variability experienced in local weather patterns. Therefore, local actions and behaviours were discussed in relation to adaptation around this variability. For example, water management through the construction of public water reservoirs was the most common action reported to deal with water shortages. Studies in other lower-middle-income countries like Bangladesh have also reported climate change-induced water shortage problems. Pond sand filters, rainwater harvesting, and bringing in potable water from elsewhere, with support from the government and non-government organizations, were mentioned as possible adaptation strategies.[14]

Although reforestation initiatives have not yet been adopted in the two communities in Kavre, participants across all FGDs and interviews believed that reforestation could help address several problems, including water shortages, poor air quality, and the risk of landslides. Indigenous people in the Dolakha district of Nepal have adopted community-based reforestation and forest management initiatives to mitigate impacts attributed to local climate variability.[48] Community awareness programs can further sensitize people to the importance of preserving forests, desisting from cutting down trees and setting fires for a healthier ecosystem, cleaner ambient air, and improved human health.[48]

A key strength of this study methodology has been its flexibility, which focuses on the participants to generate rich data. The study sampled two rural areas with diverse sociodemographic profiles. The findings provide insights into climate change perspectives and the lived experience of women in a rural setting, which has not previously been well documented. Several areas of concern emerged, notably water shortages, reduced agricultural productivity, crop infestations, and increased pesticide use, which can guide long-term climate change adaptation planning by the local government. This can assist the government of Nepal in fulfilling its climate change commitments while promoting well-being and strengthening the resilience of women in the face of climate change impacts.

A limitation of this study is that it was conducted in only two rural municipalities. Perspectives and the lived experiences of women related to climate change may differ by residence, i.e., rural and urban. Exploring urban residents' perspectives and lived experiences would no doubt yield additional insights.

5. Conclusion

The study provides insight into how rural women in a hill district of Nepal perceive climate change and their related lived experiences. They reported severe impacts, mainly related to the environment and agriculture. These effects are magnified by poverty and poor health service infrastructure. Local interventions, such as promoting climate change education and awareness, improving and increasing access to community health services, managing safe water and sanitation, and supporting community-based climate change adaptation initiatives by local government, are needed to address the needs and concerns of women and children, promote their well-being and boost resilience in the face of climate change impacts.

List of Abbreviations

FCHV	Female Community Health Volunteer
FGD	Focus Group Discussion
HFOMC	Health Facility Operation Management Committee
HMG	Health Mothers Group

Declaration

Ethical approval and consent to participate: We obtained ethics approval from the University of Alberta Health Research Ethics Board (Pro00107397) and the Ethical Review Board of Nepal Health Research Council (Protocol Registration # 340/2021). Signed informed consent was obtained from each before participant before beginning the study.

Consent for publication: Not applicable

Availability of data and materials: The data generated and/or analysed during the current study are not publicly available due to ethical concerns but are available from the corresponding author on reasonable request.

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Chapter IV

Linking climate change and health outcomes: Examining the potential influences of weather factors and particulate matter pollution on adverse pregnancy outcomes in the Kavre district, Nepal.

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Synopsis

Introduction Adverse pregnancy outcomes (APOs) include stillbirth, preterm birth, and low birthweight (LBW). To our knowledge, published peer-reviewed studies exploring the impact of weather factors and air pollution on APOs are unavailable in Nepal and understudied in other South Asian countries. We examined the impacts of prenatal exposure to temperature, precipitation, and air pollution ($PM_{2.5}$) on APOs among women living in the Kavre district of Nepal, which is affected by several environmental challenges, including high-intensity precipitation, water shortages, drought, and poor air quality.

Methods We conducted a hospital and rural health centres-based historical cohort study that included health facility birth records (n=1716), restricted to those whose place of residence was the Kavre district, from the Nepali fiscal year 2017/18 through 2019/20. We linked health

records to temperature, precipitation, and $PM_{2.5}$ data for Kavre district for the six months preceding each birth. Mean daily temperature data were obtained from the CPC Global Unified Temperature dataset from the National Oceanic and Atmospheric Administration's (NOAA) Physical Sciences Laboratory. Climate Hazard Group InfraRed Precipitation with Station (CHIRPS) provided the daily total precipitation data. The mean of monthly surface $PM_{2.5}$ was obtained from the Atmospheric Composition Analysis Group of Washington University in St. Louis. We used the Nepal Demographic and Health Survey (NDHS) 2022 dataset to spatially link sociodemographic variables [e.g., education, occupation, wealth, smoking status, type of cooking fuel, and Body Mass Index (BMI)] to wards in Kavre district. A random intercept model was used to analyze continuous outcome (birthweight), while a composite APO dichotomous outcome variable, was analyzed using multivariable logistic regression in relation to environmental exposures.

Results The mean birthweight of infants in this study was 2943 grams (± 455 grams). The proportion of LBW (<2500 gm), preterm birth (babies born alive before 37 weeks of gestation), and stillbirth was 13%, 4.3%, and 1.5%, respectively, in this study. Overall, around 16% of the study participants had one or more APOs. Temperature (mean maximum, mean, and mean minimum), total precipitation, and mean $PM_{2.5}$ had statistically non-significant effects on birthweight and APOs. However, total precipitation (β: 0.17, 95% CI 0.01 to 0.33, p = 0.03) had a positive effect on birthweight in the wetter season after adjusting for mean temperature, mean $PM_{2.5}$, and individual and area-level confounding variables. Negative effects for mean maximum (β: -33.37, 95% CI -56.68 to -10.06, p = 0.005), mean (β: -32.35, 95% CI -54.44 to -10.27, p = 0.004), and mean minimum temperature (β: -29.28, 95% CI -49.58 to -8.98, p = 0.005) on birthweight was also observed in the wetter season.

Conclusion We did not observe statistically significant associations between temperature (mean maximum, mean, and mean minimum), total precipitation, mean $PM_{2.5}$, and APOs. However, a statistically significant effect of temperature (mean maximum, mean, and mean minimum) and total precipitation on birthweight was found in the wetter season. Given the global evidence of the association between APOs and environmental factors, future research should consider larger cohorts and include additional critical variables to elucidate these complex relationships in Nepal to help guide interventions to optimize birth outcomes. Concurrently, the government of Nepal must improve its climate infrastructure to enable regular recording and capturing of environmental data from a wide geographic area.

Keywords: Temperature, precipitation, fine particulate matter, low birthweight, preterm birth, stillbirth

1. Introduction

Adverse pregnancy outcomes (APOs) include stillbirth, preterm birth, and low birthweight (LBW).[1] They are the crucial predictors of neonatal morbidity and mortality.[2] It is estimated that 10-20% of pregnancies end in miscarriage during the first trimester, but after the fifth to sixth week of gestation.[3] Globally, each year, an estimated 15 million fetuses that do not end in miscarriage are born preterm,[4] three million pregnancies end in stillbirth[5], and 20 million live births are LBW.[3] The APOs are more prevalent in low-and middle-income countries (LMICs) like Nepal than in high-income countries.[6–9] Nine out of ten countries with the highest preterm birth rates are LMICs. Furthermore, LMICs constitute 98% of global stillbirths[10] and carry the highest burden of LBW infants, with three-quarters of the global LBW newborns occurring in South Asia (47%), Eastern and Southern Africa (13%), and West and Central Africa (12%) as of 2015.[11]

The Nepal Demographic and Health Survey (NDHS), 2022[12] reported 0.9% of pregnancies ending in stillbirth. Approximately 11.5% of babies are born LBW, according to the Department of Health Service (DoHS), 2022.[13] There is no NDHS or DoHS-reported data on preterm birth, but based on prior research, it is estimated that approximately 81,000 newborns are born preterm every year in Nepal.[2]

Multiple risk factors, including genetic, behavioural, socioeconomic, and environmental interact to influence pregnancy and birth outcomes.[9,14] Research on how weather factors and air pollution impact fetal development has increased recently, mainly in high-income countries[14–23] and is the focus of this study. Global studies have found that temperature fluctuations or extremes are associated with failed conceptions, miscarriages, or stillbirths[3,24–26] via disruption of the mechanisms needed for proper intrauterine growth during the second and third trimesters.[27]

Temperature is also indirectly linked to pregnancy and fertility outcomes through disease, food security, and nutrition.[3,25,28] Rain can affect fetal health by reducing crop yields in the dry season, which may result in maternal nutritional deficits during pregnancy.[15] Similarly, epidemiologic, clinical, and experimental studies have suggested five significant pathways through which particulate matter pollution ($PM_{2.5}$) can affect APOs: disruption of the physiology and anatomy of the placenta and umbilical cords, through systemic oxidative stress that affects the embryo in its earliest growth stage, pulmonary and placental inflammation, systemic alterations in blood coagulability, and via induced hypertensive disorder.[29,30]

Studies investigating the influence of socioeconomic status and clinical factors on APOs have been conducted in Nepal.[31,32] To our knowledge, published peer-reviewed studies exploring the impact of weather factors and air pollution on APOs are lacking in Nepal and limited in other South Asian countries.[33] The lack of such studies may be likely due to methodological challenges in measuring exposure levels and a general assumption of limited impacts attributed to weather factors and air pollution on pregnancy outcomes.[3,10] It may be problematic to draw inferences from findings in high-income countries and apply them to women in LMICs like Nepal.[10] Nepal has a distinct social, demographic, and weather environment with persistent air pollution problem. High-intensity precipitation, extreme ambient temperature, water shortages, drought, and air pollution are key environmental issues affecting Nepal's agricultural, food security, water resource, and health sectors.[34] Around 80% of the Nepalese population is at risk from natural hazards[35], with infrastructure limitations further increasing its vulnerability to environment-related threats.[36] Therefore, in this study, among the first in Nepal, we examined the impacts of prenatal exposure to weather factors and $PM_{2.5}$ on APOs among women living in Kavre district, Nepal.

2. Methods

2.1 Study Location and Population

The decision to select Kavre district was driven by two critical considerations: ongoing environmental challenges affecting the district[37,38] and the potential availability of health data from the Dhulikhel Hospital, the major source of our health data. Dhulikhel Hospital is a large district-level hospital in the Kavre district that provides tertiary-level healthcare to its urban and rural population, including many patients from other districts.

Kavre is one of 77 districts in Nepal (Figure 1). The district capital is Dhulikhel, and the district is a part of Bagmati province. It covers a total land area of 1,396 square km. It is comprised of 13 municipalities (7 rural and 6 urban) that include 135 wards. Most parts of the district have a subtropical climate. It is situated in a mid-hill area, with an elevation ranging from 280 to 3018 meters above sea level.[39] According to Nepal's 2021 Census, the population of Kavre is 364,039; approximately 51% are female. There are 146,257 ever-married females aged 15-49 years.[40] Skilled agriculture, including forestry and fishery, is the primary source of income for approximately two-thirds (97,516) of the ever-married female population in the district.[40]

We included women in the 15-49 age group who gave birth during the fiscal year 2017/18 through 2019/20 at the Dhulikhel Hospital or one of six community-level birthing centers in Bhumlu (n=3) and Mahabharat (n=3) rural municipalities. The participants were restricted to permanent residents of Kavre district, singleton pregnancies, and those with birth outcome information, including the date of childbirth. Mothers with twin pregnancies were excluded from the study because of a greater likelihood of LBW due to high-risk pregnancies and prematurity.[41]

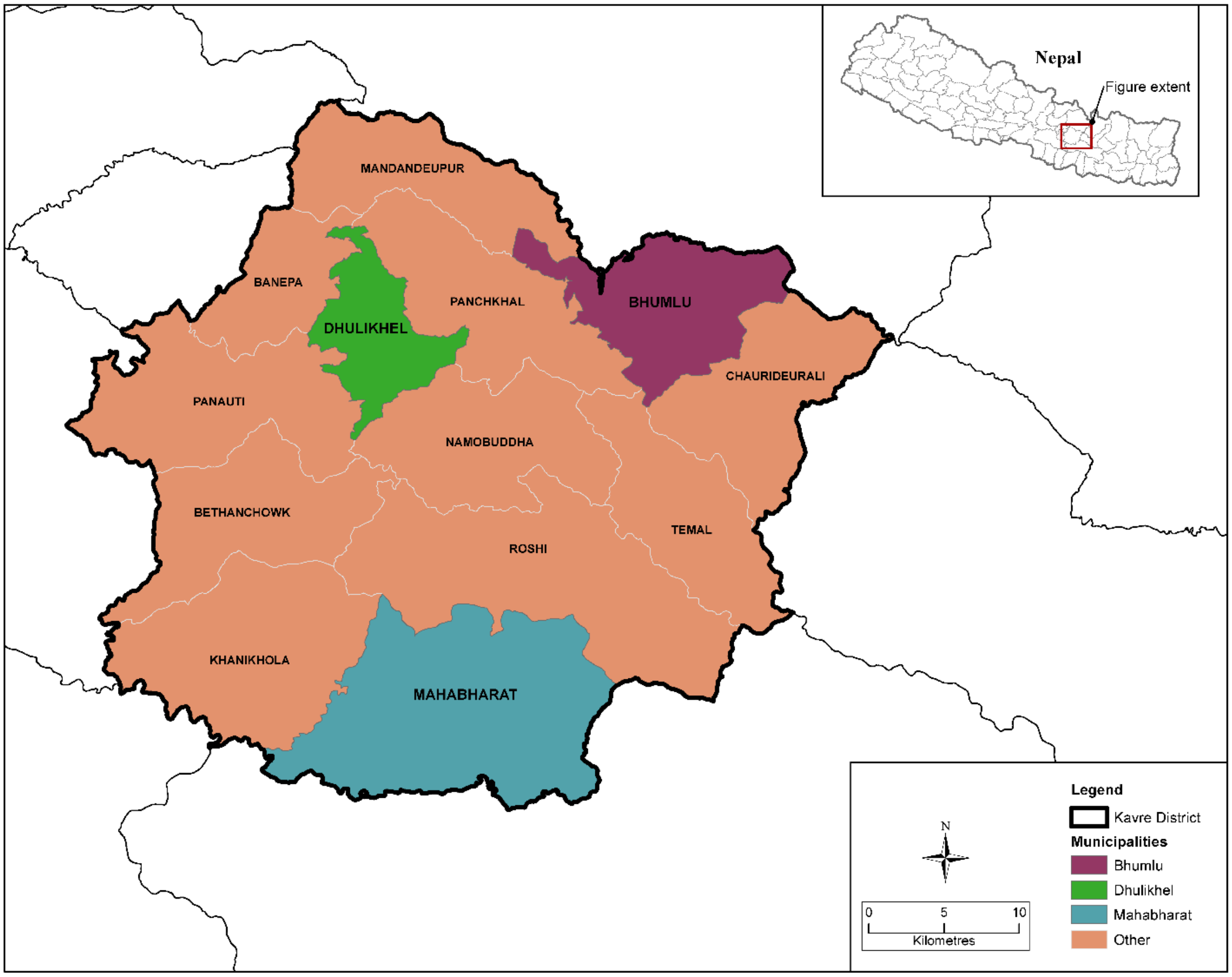


Figure 1: Map of the Kavre district highlighting municipalities in which health centers were selected (Syer, pers. comm.)

2.2 Birth Outcomes

We obtained information on birth outcomes (LBW, preterm birth, and stillbirth) from the maternity and newborn health service register in the rural birthing centers and from the maternity register used in Dhulikhel Hospital. We created a new dichotomous variable, "adverse birth outcome (yes, no)." The variable was coded "yes" if at least one APO (LBW, preterm birth or stillbirth) was reported; otherwise, it was coded "no." We used health records covering the period from July 16, 2017, through July 15, 2020. Over this period, 9769 births were recorded, 9512 at the Dhulikhel Hospital and 257 in the birthing centers. We extracted data from all birth cases from the community birthing centers (257) and a randomly drawn sample of records from the Dhulikhel Hospital (1522), applying proportionate sampling for each year and month. Specifically, we drew participants from the health records from each month and year in the proportions that were recorded in the health records for that month and year. Of the 1522 randomly selected participants, five were multiple pregnancies, 18 had a missing date of childbirth, and 40 birth records did not have a complete residential address to enable linkage to environmental exposures. Therefore, 63 observations were excluded, resulting in a total of 1716 participants retained in the final analysis.

We could not determine the precise gestational age of mothers due to incomplete records in the service register. Data on the date of the last menstrual period and gestational weeks were often missed in the service register. Dhulikhel Hospital and birthing centers follow the World Health Organization's (WHO) definition of stillbirth (a fetus who dies after 20 weeks of pregnancy, but before or during birth[5]), preterm birth (live birth before 37 completed weeks of gestation[42]), and LBW (birthweight of an infant less than 2500 grams, regardless of gestational age[43]).

2.3 Weather and Air Pollution Data

We used remote-sensing technologies to make observations of weather and air pollution at spatial and temporal scales for Kavre, Nepal. Specifically, we obtained the daily precipitation data (mm) from CHIRPS, a publicly available quasi-global precipitation data set, which has a spatial resolution of 0.05° (~5.3 km).[44] Daily temperature (maximum and minimum (°C)) data was obtained from the CPC Global Unified Temperature dataset from the NOAA Physical Sciences Laboratory in netCDF format.[45] We used Python's API for Google Earth Engine[46] to calculate total daily precipitation using the built-in reduce regions function. For temperature, we used Python to identify the grid cell overlapping each ward (based on ward centroids) and then used conventional Python libraries to extract the minimum and maximum daily temperature. We calculated the daily mean temperature, averaging the maximum and minimum temperature. Daily total precipitation and daily temperature (maximum, mean, and minimum) were calculated for every ward (135 wards) in the district beginning January 1, 2016, through December 31, 2020.

Monthly mean surface $PM_{2.5}$ data ($\mu g/m^3$) from 2016 through 2020 was obtained in netCDF format from the Atmospheric Composition Analysis Group of Washington University in St. Louis.[47] The dataset has global spatial coverage with a spatial resolution of approximately 1 km × 1 km. We calculated $PM_{2.5}$ concentrations in every ward using the zonal statistics tool in ArcGIS 10.8.2.[48], taking the mean of cells intersecting the ward. Two wards had inadequate overlap with the raster cells and were buffered by 1 km to ensure $PM_{2.5}$ values were assigned.

2.4 Confounders

We adjusted for several potential confounders known to influence the relationship between weather, air pollution, and birth outcomes based on a priori knowledge. Potential confounders were categorized into individual and area-level confounders pertaining to their resolution.

Data on individual-level confounders were obtained from Dhulikhel Hospital and rural birthing center service registers. They included the age of mothers (continuous measurement), ethnicity (Brahmin/Chhetri, Dalit and others, and Janajati/Indigenous), residence (rural, urban), residential address, visit as per ANC protocol (yes, no), pregnancy frequency (first, second, third, fourth and above), infant's sex (boy, girl), and type of birth (normal, assisted). The other ethnicity category included Terai/Madhesi and other castes. According to the Local Government Operation Act 2017[49], municipalities in Nepal are classified into rural and urban municipalities, sub-metropolitan and metropolitan cities based on several factors, including population, revenue generation, road connectivity, electrification, and drinking water services. Urban municipalities, sub-metropolitan and metropolitan cities were categorized as urban and rural otherwise. The residential address (DDGNWW) refers to a six-digit code for Kavre district. DD is the district code, GN is the municipality (i.e., urban or rural municipality), and WW is the ward number. Wards are the smallest administrative unit in Nepal. Visiting as per ANC protocol refers to visiting a health facility at the fourth, sixth, eighth, and ninth months of pregnancy for an antenatal checkup.[50] Assisted birth type refers to the birth of a child using forceps, a vacuum, or a cesarean section. We also considered season (wetter, drier) as an individual-level confounder, as it was calculated based on the date of childbirth. We defined the wetter season from May through September, and the drier season included months from October through April.

Data on area-level confounders were obtained from the NDHS 2022. NDHS is a nationally representative survey implemented by New ERA under the aegis of the Ministry of Health and Population with the technical support of ICF International.[12] The survey sample is a stratified sample achieved in two stages. Stratification was accomplished by dividing each of the seven provinces into urban and rural areas that formed the sampling stratum for that province, thus creating 14 sampling strata. In the first sampling stage, 476 primary sampling units (PSUs) or clusters were selected using probabilities proportional to PSU sizes and with independent selection in each sampling stratum. PSU is the sampling unit for the first stage of selection in a multi-stage sampling procedure, typically a census enumeration area (EA) or a segment of an EA in DHS. There were 248 urban areas and 228 rural areas out of 476 clusters selected. In the second stage, thirty households were selected from each cluster, a total sample size of 14,280 households. Global Positioning System (GPS) data were collected at the household level during household enumeration and the individual interviews.[12]

We used NDHS GPS datasets and identified seven clusters linked to the Kavre district. Among the seven clusters, Kavre included five clusters (116, 155, 156, 157, 158). Two neighbouring clusters (115 and 147) were also included due to their proximity, assuming they shared similar sociodemographic characteristics as Kavre residents. The NDHS cluster was assigned to the nearest ward of Kavre district. Thus, each participant's residential address (DDGNWW) was assigned one of the seven clusters. We determined the 'nearest' based on the smallest distance between the edge of the ward polygon and the point of the NDHS cluster. Thus, selected NDHS variables were linked to each ward using the common variable 'DDGNWW.'

The selected NDHS variables come from women of reproductive age, 15-49 years, and included maternal educational attainment (higher or secondary or primary or no education), type of cooking fuel (solid or clean fuels), wealth quintile (richest or richer or middle or poorer or poorest), smoking (no smoking or smoking some days or smoking daily), occupation (professional or clerical or sales services or skilled manual or unskilled manual or agriculture), and mean BMI. We used all NDHS variables in this study as they were originally grouped, except for the type of cooking fuel used in the household. We considered using wood, straw/shrub/grass, or agricultural crops as solid fuels. Clean fuels include households using electricity, LPG, solar energy, piped natural gas, or biogas. We linked the levels of each selected NDHS variable to wards of the Kavre district. Except for mean BMI, we calculated the weighted proportion of levels of each selected NDHS variable for each ward.[12]

2.6 Linking APO with Weather Factors and Air Pollution

We calculated the monthly average temperature and $PM_{2.5}$ exposure before childbirth. For precipitation, we calculated the monthly total precipitation. Specifically, we estimated exposures separately in the first, second, third, fourth, fifth, and sixth months before childbirth. We also considered the average exposure (temperature and $PM_{2.5}$) and the total precipitation across the six months before childbirth. We did not use the preferred trimester-specific exposure approach due to a lack of precise information on gestational weeks, which could have overestimated exposures.

2.7 Data Analysis

In the present study, we investigated associations between one continuous outcome (birthweight) using a random intercept model, one composite dichotomous outcome (APO) using multivariable logistic regression, and weather and air pollution exposures, adjusting for confounding.

The study samples were clustered by wards of the district. We assumed that sample characteristics within a ward were homogenous and more heterogeneous across the wards. We fit a linear random intercept model (estimated using REML and nloptwrap optimizer) to examine separately associations of birthweight with environmental exposures (mean maximum, mean, and mean minimum temperature or mean $PM_{2.5}$) and the total sum of precipitation in the six months before birth (Model I). The model included geographic ID, i.e., district ward, as the random effect. Second, we added individual-level confounders in the Model II. Third, we included all environmental exposures, variables of clinical or public health importance, plus area-level confounders (Models IIIa-c).

We performed sensitivity analysis by including different levels (scenarios) of area-level variables in Model III. The three different scenarios of Model III are defined as the above-median scenario

(Model IIIa), median scenario (Model IIIb), and below-median scenario (Model IIIc). The above-median scenario model included the highest levels of area-level socioeconomic variables (i.e., higher education, clean fuel used for cooking, richest wealth category, no smoking, and engaged in a professional occupation). The below-median scenario model included the lowest levels of area-level socioeconomic variables (i.e., no education, solid fuels used for cooking, poorest wealth category, daily smoking, and unskilled manual occupation). The median scenario model included the most frequent area-level socioeconomic variables. We identified no education, solid fuel used for cooking, belonging to the poorer wealth category, not smoking, and engaging in agriculture as the median levels of socioeconomic variables in the NDHS clusters.

We used the median scenario model as our final model. We checked for potential effect modification by rural or urban residence and the wetter or the drier season via interactions. However, we observed a singular fit while attempting to run the final model for urban areas for each environmental exposure and thus employed a Bayesian approach. A singular fit was observed only for the mean maximum temperature for the wetter season. We removed the interaction term from Model III if there was no significant relationship with the pregnancy outcomes.

We repeated the same process with the truncated datasets, i.e., excluding wards with less than five counts of participants. Twenty-seven of Kavre's 135 wards were identified to have fewer than five counts of participants and were removed. The truncated dataset included an analysis of data from 1617 of 1716 participants and is presented as the main analysis (Table 4a-e).

Although conceptually appropriate, few cases of preterm birth (n=74) and stillbirth (n=25) were included, resulting in the model's failure to converge using a random intercept model. Therefore, we performed univariable and multivariable logistic regression for APOs following the same steps as applied to the birthweight models.

We applied Principal Component Analysis (PCA) to accommodate multicollinearity and group variables derived from the NDHS in Model III. Data were centred and scaled. Six principal components (PC) were generated corresponding to the number of variables included in PCA. In the above-median scenario (i.e., higher SES), PC1 (70%) and PC2 (29%) cumulatively explained 99% of the variance and were included in Model IIIa. PC1 alone explained 85% of the variance in the below-median scenario (i.e., lower SES) and was included in Model IIIb. In the median scenario (i.e., moderate SES), PC1 (66%) and PC2 (33%) explained 99% of the variance and were included in Model IIIc. We predicted the PCA values of the selected principal components for all of the study participants, which were included in the models. Data were analyzed using R programming language version 3.4.1.[51]

2.8 Ethics

We received ethical approval from the Ethical Review Board of the University of Alberta (Pro00107397), Nepal Health Research Council (NHRC) (340/2021), and Kathmandu University School of Medical Sciences (KUSMS) (257/2021).

3. Results

We analyzed data from 1716 eligible people who gave birth to children during the fiscal year 2017/18 through 2019/20 at Dhulikhel Hospital and six birthing centers in the Bhumlu and Mahabharat rural municipalities. Table 1 shows the study participant's sociodemographic characteristics and health outcomes. The mean birthweight of infants was 2943 grams (± 455). We observed a prevalence of 13% for LBW, 4.3% for preterm birth, and 1.5% for stillbirth, based on health record data. Overall, around 16% of the study participants had an APO. The mean age of mothers was 25 years (± 5). Most mothers who gave birth to children during the study period were Janajati or Indigenous (55%), urban residents (66%), had visited health facilities as per ANC protocol (85%), had a normal delivery (78%), were primiparous (48%), gave birth to male children (56%), and gave birth during the drier season (59.5%). Table 2 includes the characteristics of respondents based on the NDHS 2022. The survey observed that around 65% of participants had no education, 60% used solid fuel for cooking purposes, 83% came from the poorest households, 91% did not smoke, and 62% engaged in agricultural work. The mean BMI of women was 23 kg/m^2 (± 4.2).

Table 1: Sociodemographic characteristics of study participants in Kavre district, Nepal, July 1, 2017, to June 30, 2020, based on medical records.

Characteristics	N = 1716 (%); Mean (Standard Deviation)
Independent variables	
Age	1716 (100%); 24.6 (4.6)
Ethnicity	
Brahmin/Chhetri	576 (34.0%)
Dalit and others	190 (11.0%)
Janajati/Indigenous	950 (55.0%)
Residence	
Rural municipality	586 (34.0%)
Urban municipality	1130 (66.0%)
Visit as per ANC protocol	

Yes	1426 (85.0%)
No	258 (15.0%)
Birth type	
Normal	1344 (78.0%)
Others	371 (22.0%)
Pregnancy count	
First	816 (48.0%)
Second	544 (32.0%)
Third	251 (15.0%)
Fourth and Above	104 (6.0%)
Infant's sex	
Male	963 (56.0%)
Female	753 (44.0%)
Season	
Wetter	712 (41.5%)
Drier	1004 (59.5%)
Dependent variables	
Birthweight (grams)	1716 (100%); 2943 (± 454.97)
Low birthweight (grams)	
Yes	221 (13.0%)
No	1470 (87.0%)
Preterm birth	
Yes	74 (4.3%)

No	1642 (95.7%)
Stillbirth	
Yes	25 (1.5%)
No	1691 (98.5%)
Adverse Birth outcome	
Yes	1449 (84.4%)
No	267 (15.6%)

Table 2: Characteristics of study participants in Kavre district, Nepal, based on NDHS 2022 data

Characteristics	**N = 450 (%); Mean (Standard Deviation)**
Education	
Higher	6 (1.3%)
Secondary	68 (15.2%)
Primary	82(18.2%)
No education	294 (65.3%)
Type of cooking fuel	
Clean fuel	200 (44.4%)
Solid fuel	250 (55.6%)
Wealth	
Richest	68 (15.1%)
Richer	78 (17.3%)

Middle	86 (19.1%)
Poorer	134 (29.7%)
Poorest	81 (18.0%)
Missing	3 (0.8%)
Smoking	
No smoking	392 (87.1%)
Some day	3 (0.7%)
Smoke daily	55 (12.2%)
Occupation	
Professional	32 (7.1%)
Clerical	5 (1%)
Sales services	26 (5.7%)
Skilled manual	10 (2.3%)
Unskilled manual	10 (2.2%)
Agriculture	285 (63.4%)
Did not work	82 (18.2%)
BMI	23.4 (± 4.2)

Table 3 presents the annual environmental exposure measurements for Kavre district from 2016 through 2020. Notably, 2018 recorded the highest total precipitation (1635.07 mm), whereas 2017 experienced the lowest (1171.65 mm). The mean of maximum temperature across the years remained relatively consistent, ranging from 26.4°C to 27.07°C. The mean temperature fluctuated between 21.1°C and 21.59°C, and the mean minimum temperature consistently hovered around 15°C.

Table 3: Environmental exposure record of Kavre district, 2016 – 2020

	Year				
Variables	**2016**	**2017**	**2018**	**2019**	**2020**
Precipitation (mm)					
Total precipitation	1471.14	1171.65	1635.07	1388.63	1429.3
Mean maximum	122.75	87.04	123.48	168.23	95.33
Mean minimum	0	0	0	0	0
Temperature (°C)					
Mean maximum	26.99	27.07	26.4	26.72	26.48
Mean	21.41	21.59	21.17	21.29	21.10
Mean minimum	15.84	16.12	15.94	15.86	15.72
Mean $PM_{2.5}$ (µg/m^3)	37.57	35.59	39.18	34.50	35.30

We fit individual-level confounders, principal components from area-level variables, and all main environmental variables into three distinct models (Models IIIa to c; Table 4). The result of the sensitivity analysis showed consistent findings across the models, i.e., above-median (Model IIIa), below-median (Model IIIb), and median scenario models (Model IIIc). Temperature, precipitation, and $PM_{2.5}$ were statistically non-significant in terms of birthweight. In Models IIIa, IIIb, and IIIc, we observed that variables such as ethnicity (Janajati/Indigenous), pregnancy count (second), and infant sex (boy) had statistically significant positive effects on birthweight.

Conversely, urban residence and visit as per ANC protocol (no) had negative effects on birthweight (Table 4a-e). Similarly, precipitation, temperature, and $PM_{2.5}$ exposure were not associated with APOs. (Figure 2a,b,c - 6a,b,c).

We used the median scenario (Model IIIb) to check for effect modification by urban/rural residence and season in the exposure-outcome relationship. We did not find a statistically significant interaction by residence for both birthweight and APOs. Total precipitation (β: 0.17, 95% CI 0.01 to 0.33, $p < 0.03$) over the last six months of pregnancy had a positive effect on birthweight in the wetter season (Table 5a). In contrast, mean maximum (β: -33.37, 95% CI -56.68 to -10.06, p = 0.005) (Table 5b), mean (β: -32.35, 95% CI -54.44 to -10.27, p = 0.004) (Table 5c), and mean minimum temperature (β: -29.28, 95% CI -49.58 to -8.98, p = 0.005) (Table 5d) had negative effects on birthweight in the wetter season. The interaction term in our third model for each main environmental variable and season was used to test for effect modification by season, but the result was also statistically non-significant and hence not reported. Neither residence nor season modified the effect of the environmental exposures on APOs (Supplementary Table S1a-e, S2a-e, and S3a-e).

Table 4a: Multilevel regression model examining the relationship between precipitation and birthweight based on truncated data.

Above median scenario					**Below median scenario**				**Median scenario**		
Model IIIa:					**Model IIIb:**				**Model IIIc**		
	Birthweight				**Birthweight**				**Birthweight**		
Variables	*Estimates*	*CI*	*p*		*Estimates*	*CI*	*p*		*Estimates*	*CI*	*p*
Total precipitation	0.06	-0.06 to 0.17	0.31		0.06	-0.06 to 0.17	0.34		0.06	-0.06 to 0.17	0.34
Mean Temperature	-12.27	-27.54 to 2.99	0.12		-11.93	-27.19 to 3.32	0.13		-11.92	-27.20 to 3.35	0.13
Mean $PM_{2.5}$	0.31	-3.88 to 4.50	0.88		0.2	-3.98 to 4.39	0.92		0.16	-4.04 to 4.36	0.94
Maternal Age	1.95	-4.21 to 8.10	0.54		1.99	-4.15 to 8.14	0.53		1.97	-4.18 to 8.13	0.53
Ethnicity											
Brahmin/Chhetri	Ref				Ref				Ref		

Dalit and others	-0.45	-77.86 to 76.97	0.99		-1.99	-79.31 to 75.33	0.96		-1.84	-79.30 to 75.63	0.96
Janajati/Indigenous	144.14	95.03 to 193.26	**<0.01**		143.94	94.82 to 193.05	**<0.01**		143.88	94.74 to 193.02	**<0.01**
Residence											
Rural	Ref				Ref				Ref		
Urban	-109.46	- 177.64 to -41.28	**0.01**		-103.36	-165.91 to - 40.80	**0.01**		-105.16	-173.74 to - 36.59	**0.01**
Visit as per ANC protocol											
Yes	Ref				Ref				Ref		
No	-82.77	-145.04 to -20.50	**0.01**		-82.74	-145.00 to -20.49	**0.01**		-82.82	-145.10 to -20.53	**0.01**
Pregnancy count											

First	Ref				Ref				Ref		
Second	70.63	15.06 to 126.20	**0.01**		70.48	14.94 to 126.03	**0.01**		70.62	15.04 to 126.20	**0.01**
Third	50.24	-23.52 to 123.99	0.18		50.37	-23.35 to 124.09	0.18		50.59	-23.19 to 124.37	0.18
Fourth and above	42.43	-66.13 to 150.98	0.44		43.27	-65.26 to 151.80	0.43		43.3	-65.27 to 151.86	0.43
Birth type											
Normal	Ref				Ref				Ref		
Assisted	-15.36	-70.62 to 39.90	0.59		-14.85	-70.05 to 40.34	0.60		-15.16	-70.47 to 40.15	0.59
Sex											
Girl	Ref				Ref				Ref		
Boy	105.7	61.31 to 150.10	**<0.01**		105.45	61.09 to 149.81	**<0.01**		105.56	61.15 to 149.97	**<0.01**
Season											

Wetter	Ref				Ref				Ref		
Drier	22.99	-40.10 to 86.08	0.48		24.32	-38.76 to 87.40	0.45		24.58	-38.60 to 87.76	0.45
PC1	-1.7	-3.40 to 0.01	0.05		1.54	0.53 to 2.56	**0.01**		1.35	0.25 to 2.46	**0.02**
PC2	0.35	-2.53 to 3.22	0.81		-	-	-		0.54	-0.53 to 1.61	0.32

Table 4b: Multilevel regression model examining the relationship between mean of maximum temperature and birthweight based on truncated data.

Above median scenario					**Below median scenario**				**Median scenario**		
Model IIIa					**Model IIIb**				**Model IIIc**		
	Birthweight				**Birthweight**				**Birthweight**		
Variables	*Estimates*	*CI*	*p*		*Estimates*	*CI*	*p*		Estimates	CI	p
Mean Maximum Temperature	-12.15	-28.03 to 3.72	0.13		-11.9	-27.77 to 3.98	0.14		-11.89	-27.78 to 4.00	0.14

Total precipitation	0.04	-0.06 to 0.15	0.40		0.04	-0.06 to 0.15	0.42		0.04	-0.06 to 0.15	0.42
Mean $PM_{2.5}$	0.43	-3.74 to 4.60	0.84		0.32	-3.84 to 4.49	0.88		0.28	-3.89 to 4.46	0.89
Maternal age	1.94	-4.21 to 8.10	0.54		1.99	-4.16 to 8.13	0.53		1.97	-4.19 to 8.12	0.53
Ethnicity											
Brahmin/Chhetri	Ref				Ref				Ref		
Dalit and others	-1.03	-78.45 to 76.39	0.98		-2.51	-79.84 to 74.81	0.95		-2.35	-79.82 to 75.12	0.95
Janajati/Indigenous	143.82	94.72 to 192.92	**<0.01**		143.64	94.53 to 192.74	**<0.01**		143.59	94.46 to 192.72	**<0.01**
Residence											
Rural	Ref				Ref				Ref		

Urban	-106.21	-173.62 to -38.80	**0.002**		-100.45	-162.23 to -38.67	**0.001**		-102.25	-170.14 to -34.37	**0.01**
Visit as per ANC protocol											
Yes	Ref				Ref				Ref		
No	-83.05	-145.31 to -20.78	**0.01**		-82.98	-145.22 to -20.73	**0.01**		-83.06	-145.33 to -20.78	**0.01**
Pregnancy count											
First	Ref				Ref				Ref		
Second	70.53	14.96 to 126.10	**0.01**		70.4	14.85 to 125.95	**0.01**		70.53	14.95 to 126.12	**0.01**
Third	50.2	-23.56 to 123.96	0.18		50.33	-23.39 to 124.05	0.18		50.55	-23.23 to 124.33	0.18
Fourth and above	42.39	-66.17 to 150.96	0.44		43.24	-65.30 to 151.78	0.44		43.26	-65.31 to 151.84	0.44

Birth type											
Normal	Ref				Ref				Ref		
Assisted	-14.64	-69.85 to 40.58	0.60		-14.19	-69.34 to 40.96	0.61		-14.5	-69.76 to 40.77	0.61
Sex											
Girl	Ref				Ref				Ref		
Boy	105.84	61.44 to 150.23	**<0.01**		105.59	61.23 to 149.95	**<0.01**		105.7	61.29 to 150.11	**<0.01**
Season											
Wetter	Ref				Ref				Ref		
Drier	26.8	-36.99 to 90.59	0.41		28.03	-35.76 to 91.81	0.39		28.27	-35.62 to 92.16	0.39
PC1	-1.65	-3.34 to 0.05	0.06		1.5	0.50 to 2.50	**0.01**		1.31	0.22 to 2.41	0.02
PC2	0.33	-2.54 to 3.20	0.82		-	-	-		0.53	-0.54 to 1.59	0.33

Table 4c: Multilevel regression model examining the relationship between mean temperature and birthweight based on truncated data.

Above median scenario					Below median scenario				Median scenario		
Model IIIa					Model IIIb				Model IIIc		
	Birthweight				Birthweight				Birthweight		
Variables	*Estimates*	*CI*	*p*		*Estimates*	*CI*	*p*		*Estimates*	*CI*	*p*
Mean Temperature	-12.27	-27.54 to 2.99	0.12		-11.93	-27.19 to 3.32	0.13		-11.92	-27.20 to 3.35	0.13
Total precipitation	0.06	-0.06 to 0.17	0.31		0.06	-0.06 to 0.17	0.34		0.06	-0.06 to 0.17	0.34
Mean $PM_{2.5}$	0.31	-3.88 to 4.50	0.88		0.2	-3.98 to 4.39	0.92		0.16	-4.04 to 4.36	0.94
Maternal age	1.95	-4.21 to 8.10	0.54		1.99	-4.15 to 8.14	0.53		1.97	-4.18 to 8.13	0.53
Ethnicity											
Brahmin/Chhetri	Ref				Ref				Ref		

Dalit and others	-0.45	-77.86 to 76.97	0.99		-1.99	-79.31 to 75.33	0.96		-1.84	-79.30 to 75.63	0.96
Janajati/Indigenous	144.14	95.03 to 193.26	**<0.01**		143.94	94.82 to 193.05	**<0.01**		143.88	94.74 to 193.02	**<0.01**
Residence											
Rural	Ref				Ref				Ref		
Urban	-109.46	-177.64 to -41.28	**0.01**		-103.36	-165.91 to -40.80	**0.01**		-105.16	-173.74 to -36.59	**0.01**
Visit as per ANC protocol											
Yes	Ref				Ref				Ref		
No	-82.77	-145.04 to -20.50	**0.01**		-82.74	-145.00 to -20.49	**0.01**		-82.82	-145.10 to -20.53	**0.01**
Pregnancy count											

First	Ref				Ref				Ref		
Second	70.63	15.06 to 126.20	**0.01**		70.48	14.94 to 126.03	**0.03**		70.62	15.04 to 126.20	**0.01**
Third	50.24	-23.52 to 123.99	0.18		50.37	-23.35 to 124.09	0.18		50.59	-23.19 to 124.37	0.18
Fourth and above	42.43	-66.13 to 150.98	0.44		43.27	-65.26 to 151.80	0.43		43.3	-65.27 to 151.86	0.43
Birth type											
Normal	Ref				Ref				Ref		
Assisted	-15.36	-70.62 to 39.90	0.59		-14.85	-70.05 to 40.34	0.60		-15.16	-70.47 to 40.15	0.59
Sex											
Girl	Ref				Ref				Ref		
Boy	105.7	61.31 to 150.10	**<0.01**		105.45	61.09 to 149.81	**<0.01**		105.56	61.15 to 149.97	**<0.01**
Season											

Wetter	Ref				Ref				Ref		
Drier	22.99	-40.10 to 86.08	0.48		24.32	-38.76 to 87.40	0.45		24.58	-38.60 to 87.76	0.45
PC1	-1.7	-3.40 to 0.01	0.05		1.54	0.53 to 2.56	**0.01**		1.35	0.25 to 2.46	**0.02**
PC2	0.35	-2.53 to 3.22	0.81		-	-	-		0.54	-0.53 to 1.61	0.32

Table 4d: Multilevel regression model examining the relationship between mean of minimum temperature and birthweight based on truncated data.

Above median scenario					**Below median scenario**				**Median scenario**		
Model IIIa					**Model IIIb**				**Model IIIc**		
	Birthweight				**Birthweight**				**Birthweight**		
Variables	*Estimates*	*CI*	*p*		Estimates	CI	p		Estimates	CI	p
Mean Minimum Temperature	-11.28	-25.38 to 2.82	0.12		-10.9	-24.99 to 3.19	0.13		-10.89	-25.00 to 3.22	0.13

Total precipitation	0.07	-0.06 to 0.19	0.29		0.06	-0.06 to 0.18	0.32		0.06	-0.06 to 0.18	0.33
Mean $PM_{2.5}$	0.25	-3.95 to 4.46	0.91		0.15	-4.06 to 4.35	0.95		0.11	-4.11 to 4.32	0.96
Maternal age	1.97	-4.19 to 8.12	0.53		2.02	-4.13 to 8.16	0.52		1.99	-4.16 to 8.15	0.53
Ethnicity											
Brahmin/Chhetri	Ref				Ref				Ref		
Dalit and others	0.1	-77.32 to 77.52	0.99		-1.5	-78.82 to 75.83	0.97		-1.34	-78.81 to 76.13	0.97
Janajati/Indigenous	144.32	95.20 to 193.45	**<0.01**		144.1	94.98 to 193.23	**<0.01**		144.04	94.89 to 193.19	**<0.01**
Residence											
Rural	Ref				Ref				Ref		
Urban	-111.42	-180.20	**0.01**		-104.99	-168.13 to	**0.01**		-106.87	-175.99 to	**0.01**

		to -42.64				-41.84				-37.76	
Visit as per ANC protocol											
Yes	Ref				Ref				Ref		
No	-82.92	-145.17 to -20.67	**0.01**		-82.92	-145.16 to -20.69	0.01		-83	-145.27 to -20.73	0.01
Pregnancy count											
First	Ref				Ref				Ref		
Second	70.6	15.03 to 126.17	**0.01**		70.45	14.90 to 126.00	0.01		70.59	15.01 to 126.17	0.01
Third	50.26	-23.50 to 124.01	0.18		50.38	-23.33 to 124.10	0.18		50.61	-23.17 to 124.39	0.18

Fourth and above	42.26	-66.29 to 150.81	0.45		43.1	-65.43 to 151.62	0.44		43.12	-65.44 to 151.68	0.44
Birth type											
Normal	Ref				Ref				Ref		
Assisted	-15.72	-71.02 to 39.58	0.58		-15.17	-70.40 to 40.06	0.59		-15.49	-70.83 to 39.86	0.58
Sex											
Girl	Ref				Ref				Ref		
Boy	105.67	61.28 to 150.07	**<0.01**		105.42	61.06 to 149.78	**<0.01**		105.53	61.12 to 149.95	**<0.01**
Season											
Wetter	Ref				Ref				Ref		
Drier	19.01	-43.81 to 81.83	0.55		20.48	-42.32 to 83.28	0.52		20.75	-42.13 to 83.64	0.52

PC1	-1.72	-3.43 to -0.00	**0.05**		1.56	0.54 to 2.59	**0.01**		1.37	0.26 to 2.49	**0.02**
PC2	0.36	-2.51 to 3.23	0.80		-	-	-		0.55	-0.52 to 1.62	0.31

Table 4e: Multilevel regression model examining the relationship between mean $PM_{2.5}$ and birthweight based on truncated data.

Above median scenario					**Below median scenario**				**Median scenario**		
Model IIIa					**Model IIIb**				**Model IIIc**		
	Birthweight				**Birthweight**				**Birthweight**		
Variables	**Estimates**	**CI**	**p**		**Estimates**	**CI**	**p**		**Estimates**	**CI**	**p**
Mean $PM_{2.5}$	0.31	-3.88 to 4.50	0.88		0.2	-3.98 to 4.39	0.92		0.16	-4.04 to 4.36	0.94
Total precipitation	0.06	-0.06 to 0.17	0.31		0.06	-0.06 to 0.17	0.34		0.06	-0.06 to 0.17	0.34

Mean temperature	-12.27	-27.54 to 2.99	0.12		-11.93	-27.19 to 3.32	0.13		-11.92	-27.20 to 3.35	0.13
Maternal age	1.95	-4.21 to 8.10	0.54		1.99	-4.15 to 8.14	0.53		1.97	-4.18 to 8.13	0.52
Ethnicity											
Brahmin/ Chhetri	Ref				Ref				Ref		
Dalit and others	-0.45	-77.86 to 76.97	0.99		-1.99	-79.31 to 75.33	0.96		-1.84	-79.30 to 75.63	0.96
Janajati/ Indigenous	144.14	95.03 to 193.26	**<0.01**		143.94	94.82 to 193.05	**<0.01**		143.88	94.74 to 193.02	**<0.01**
Residence											
Rural	Ref				Ref				Ref		
Urban	-109.46	-177.64 to -41.28	**0.01**		-103.36	-165.91 to -40.80	**0.01**		-105.16	-173.74 to -36.59	**0.01**
Visit as per											

ANC protocol											
Yes	Ref				Ref				Ref		
No	-82.77	-145.04 to -20.50	**0.01**		-82.74	-145.00 to -20.49	**0.01**		-82.82	-145.10 to -20.53	**0.01**
Pregnancy count											
First	Ref				Ref				Ref		
Second	70.63	15.06 to 126.20	**0.01**		70.48	14.94 to 126.03	**0.01**		70.62	15.04 to 126.20	**0.01**
Third	50.24	-23.52 to 123.99	0.18		50.37	-23.35 to 124.09	0.18		50.59	-23.19 to 124.37	0.18
Fourth and above	42.43	-66.13 to 150.98	0.44		43.27	-65.26 to 151.80	0.43		43.3	-65.27 to 151.86	0.43
Birth type											
Normal	Ref				Ref				Ref		

Assisted	-15.36	-70.62 to 39.90	0.59		-14.85	-70.05 to 40.34	0.60		-15.16	-70.47 to 40.15	0.59
Sex											
Girl	Ref				Ref				Ref		
Boy	105.7	61.31 to 150.10	**<0.01**		105.45	61.09 to 149.81	**<0.01**		105.56	61.15 to 149.97	**<0.01**
Season											
Wetter	Ref				Ref				Ref		
Drier	22.99	-40.10 to 86.08	0.48		24.32	-38.76 to 87.40	0.45		24.58	-38.60 to 87.76	0.45
PC1_	-1.7	-3.40 to 0.01	0.05		1.54	0.53 to 2.56	**0.01**		1.35	0.25 to 2.46	**0.02**
PC2	0.35	-2.53 to 3.22	0.81		-	-	-		0.54	-0.53 to 1.61	0.32

Table 5a: Multilevel regression model examining the relationship between total precipitation and birthweight stratified by season based on truncated data.

Drier					**Wetter**		
	Birthweight				**Birthweight**		
Variables	***Estimates***	***CI***	***p***		***Estimates***	***CI***	***p***
Total Precipitation	-0.05	-0.22 to 0.11	0.52		0.17	0.01 to 0.33	**0.03**
Mean Temperature	4.52	-16.56 to 25.60	0.67		-32.35	-54.44 to -10.27	**0.01**
Mean $PM_{2.5}$	-0.86	-6.63 to 4.90	0.77		1.23	-4.93 to 7.40	0.70

Models adjusted for individual and group-level confounders plus environmental variables

N.B. Models include all variables from the baseline model (Table 4a-e). Coefficients, confidence intervals, and p-values for adjusted variables are not shown.

Table 5b: Multilevel regression model examining the relationship between mean maximum temperature and birthweight stratified by season based on truncated data.

Drier					Wetter		
	Birthweight				Birthweight		
Variables	***Estimates***	***CI***	***p***		***Estimates***	***CI***	***p***
Mean Maximum Temperature	4.59	-17.13 to 26.32	0.68		-33.37	-56.68 to -10.06	**0.01**
Total Precipitation	-0.05	-0.20 to 0.10	0.50		0.15	-0.00 to 0.29	0.05
Mean $PM_{2.5}$	-0.91	-6.66 to 4.83	0.76		1.43	-4.70 to 7.55	0.65

Models adjusted for individual and group-level confounders plus environmental variables

N.B. Models include all variables from the baseline model (Table 4a-e). Coefficients, confidence intervals, and p-values for adjusted variables are not shown.

Table 5c: Multilevel regression model examining the relationship between mean temperature and birthweight stratified by season based on truncated data.

Drier					Wetter		
	Birthweight				**Birthweight**		
Variables	*Estimates*	*CI*	*p*		*Estimates*	*CI*	*p*
Mean Temperature	4.52	-16.56 to 25.60	0.67		-32.35	-54.44 to -10.27	**0.01**
Total Precipitation	-0.05	-0.22 to 0.11	0.51		0.17	0.01 to 0.33	**0.03**
Mean $PM_{2.5}$	-0.86	-6.63 to 4.90	0.77		1.23	-4.93 to 7.40	0.70

Models include all variables from the baseline model (Table 4a-e).

N.B. Models include all variables from the baseline model (Table 4a-e). Coefficients, confidence intervals, and p-values for adjusted variables are not shown.

Table 5d: Multilevel regression model examining the relationship between mean minimum temperature and birthweight stratified by season based on truncated data.

Drier					Wetter		
	Birthweight				Birthweight		
Variables	*Estimates*	*CI*	*p*		*Estimates*	*CI*	*p*
Mean Minimum Temperature	4.1	-15.45 to 23.64	0.68		-29.28	-49.58 to -8.98	**0.01**
Total Precipitation	-0.06	-0.23 to 0.12	0.53		0.19	0.02 to 0.35	**0.03**
Mean $PM_{2.5}$	-0.83	-6.62 to 4.96	0.78		1.2	-4.99 to 7.38	0.70

Models adjusted for individual and group-level confounders plus environmental variables

N.B. Models include all variables from the baseline model (Table 4a-e). Coefficients, confidence intervals, and p-values for adjusted variables are not shown.

Table 5e: Multilevel regression model examining the relationship between mean $PM_{2.5}$ and birthweight stratified by season based on truncated data.

Drier					Wetter		
	Birthweight				Birthweight		
Variables	**Estimates**	**CI**	**p**		***Estimates***	***CI***	***p***
Mean $PM_{2.5}$	-0.86	-6.63 to 4.90	0.77		1.23	-4.93 to 7.40	0.70
Total Precipitation	-0.05	-0.22 to 0.11	0.51		0.17	0.01 to 0.33	**0.03**
Mean temperature	4.52	-16.56 to 25.60	0.67		-32.35	-54.44 to -10.27	**0.01**

Models adjusted for individual and group-level confounders plus environmental variables

N.B. Models include all variables from the baseline model (Table 4a-e). Coefficients, confidence intervals, and p-values for adjusted variables are not shown.

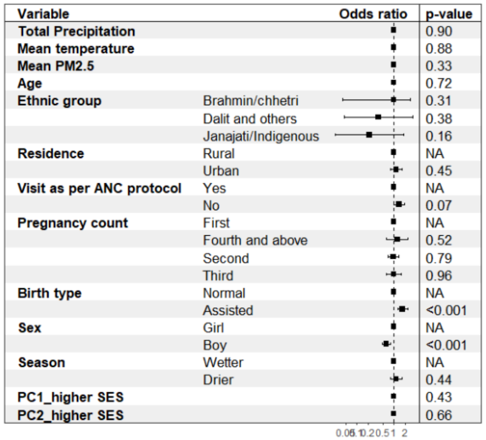


Figure 2a (Above median scenario): Adjusted OR and 95% CI of APO associated with total precipitation

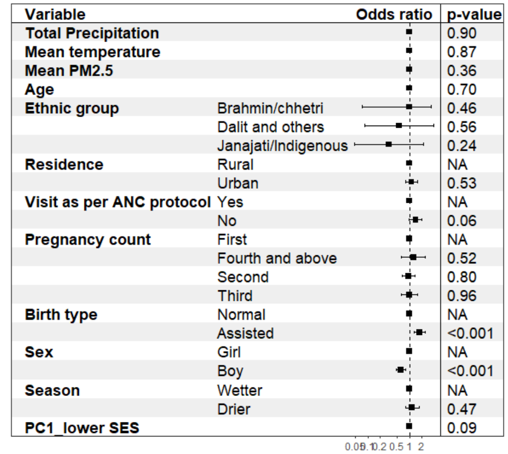


Figure 2c (Below median scenario): Adjusted OR and 95% CI of APO associated with total precipitation

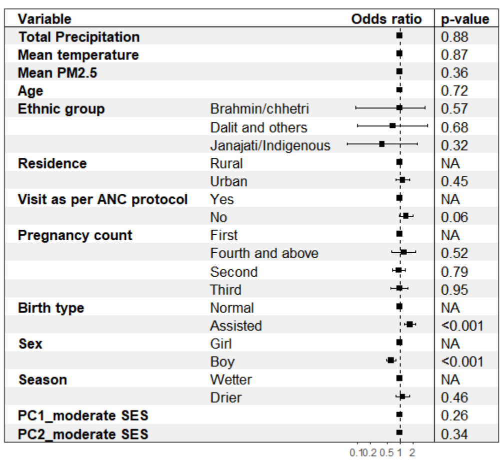


Figure 2b (Median scenario): Adjusted OR and 95% CI of APO associated with total precipitation

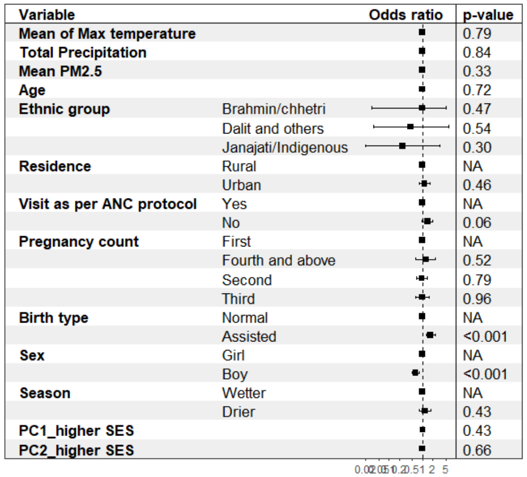


Figure 3a (Above median scenario): Adjusted OR and 95% CI of APO associated with mean maximum temperature

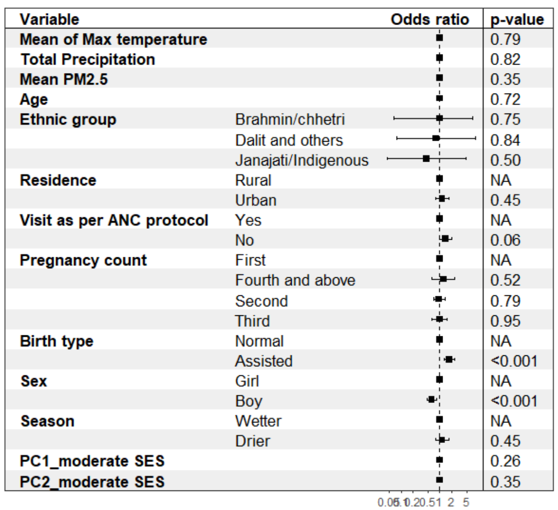


Figure 3b (Median scenario): Adjusted OR and 95% CI of APO associated with mean maximum temperature

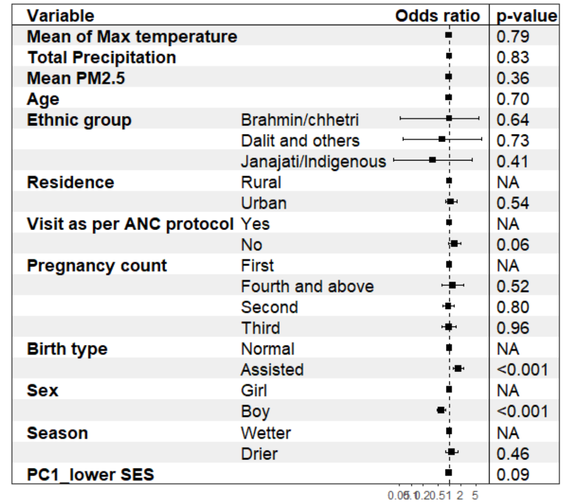
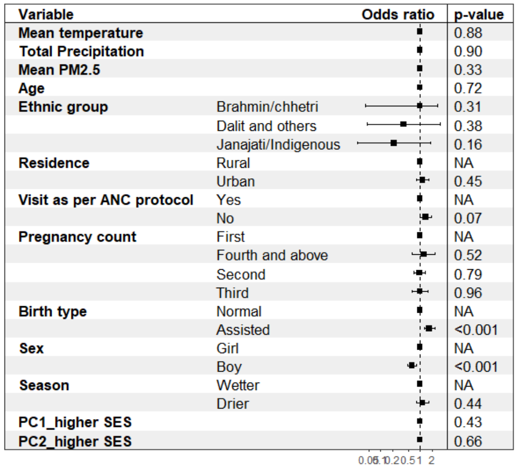
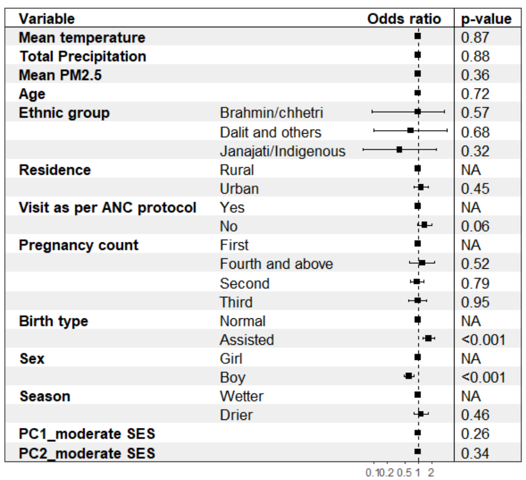


Figure 3c (Below median scenario): Adjusted OR and 95% CI of APO associated with mean maximum temperature



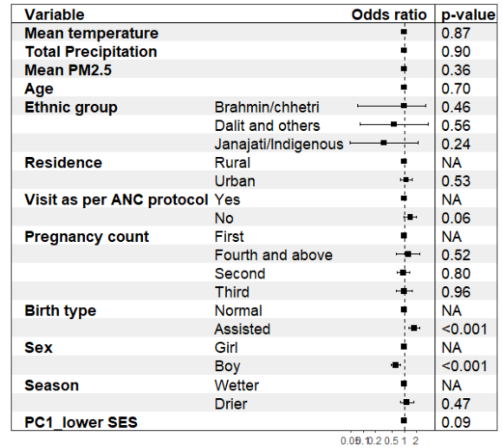
Variable		p-value
Mean temperature		0.88
Total Precipitation		0.90
Mean PM2.5		0.33
Age		0.72
Ethnic group	Brahmin/chhetri	0.31
	Dalit and others	0.38
	Janajati/Indigenous	0.16
Residence	Rural	NA
	Urban	0.45
Visit as per ANC protocol	Yes	NA
	No	0.07
Pregnancy count	First	NA
	Fourth and above	0.52
	Second	0.79
	Third	0.96
Birth type	Normal	NA
	Assisted	<0.001
Sex	Girl	NA
	Boy	<0.001
Season	Wetter	NA
	Drier	0.44
PC1_higher SES		0.43
PC2_higher SES		0.66

Figure 4a (Above median scenario): Adjusted OR and 95% CI of APO associated with mean temperature



Variable		p-value
Mean temperature		0.87
Total Precipitation		0.88
Mean PM2.5		0.36
Age		0.72
Ethnic group	Brahmin/chhetri	0.57
	Dalit and others	0.68
	Janajati/Indigenous	0.32
Residence	Rural	NA
	Urban	0.45
Visit as per ANC protocol	Yes	NA
	No	0.06
Pregnancy count	First	NA
	Fourth and above	0.52
	Second	0.79
	Third	0.95
Birth type	Normal	NA
	Assisted	<0.001
Sex	Girl	NA
	Boy	<0.001
Season	Wetter	NA
	Drier	0.46
PC1_moderate SES		0.26
PC2_moderate SES		0.34

Figure 4b (Median scenario): Adjusted OR and 95% CI of APO associated with mean temperature



Variable		p-value
Mean temperature		0.87
Total Precipitation		0.90
Mean PM2.5		0.36
Age		0.70
Ethnic group	Brahmin/chhetri	0.46
	Dalit and others	0.56
	Janajati/Indigenous	0.24
Residence	Rural	NA
	Urban	0.53
Visit as per ANC protocol	Yes	NA
	No	0.06
Pregnancy count	First	NA
	Fourth and above	0.52
	Second	0.80
	Third	0.96
Birth type	Normal	NA
	Assisted	<0.001
Sex	Girl	NA
	Boy	<0.001
Season	Wetter	NA
	Drier	0.47
PC1_lower SES		0.09

Figure 4c (Below median scenario): Adjusted OR and 95% CI of APO associated with mean temperature

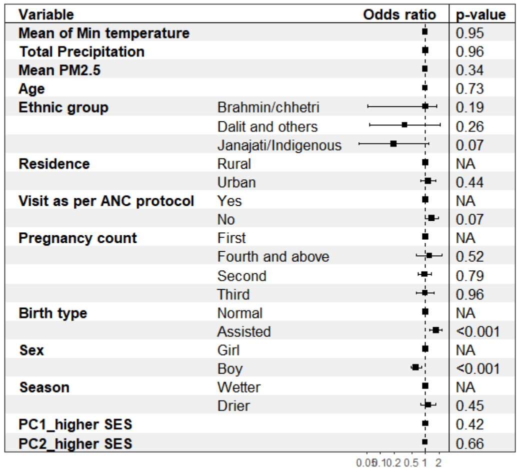


Figure 5a (Above median scenario): Adjusted OR and 95% CI of APO associated with mean minimum temperature

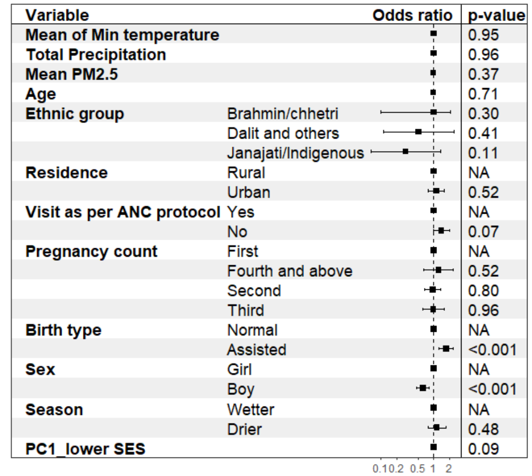


Figure 5c (Below median scenario): Adjusted OR and 95% CI of APO associated with mean minimum temperature

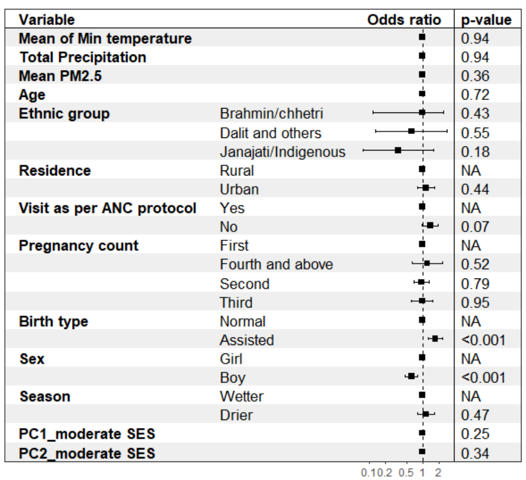
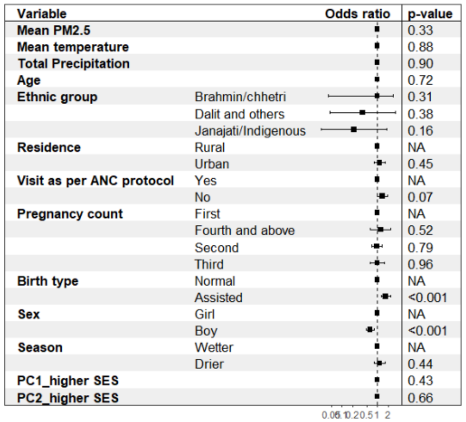
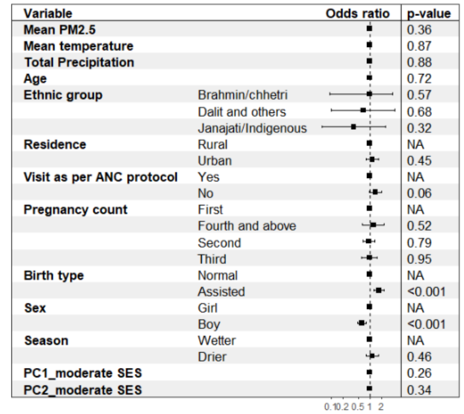


Figure 5b (Median scenario): Adjusted OR and 95% CI of APO associated with mean minimum temperature



Variable		Odds ratio	p-value
Mean PM2.5			0.33
Mean temperature			0.88
Total Precipitation			0.90
Age			0.72
Ethnic group	Brahmin/chhetri		0.31
	Dalit and others		0.38
	Janajati/Indigenous		0.16
Residence	Rural		NA
	Urban		0.45
Visit as per ANC protocol	Yes		NA
	No		0.07
Pregnancy count	First		NA
	Fourth and above		0.52
	Second		0.79
	Third		0.96
Birth type	Normal		NA
	Assisted		<0.001
Sex	Girl		NA
	Boy		<0.001
Season	Wetter		NA
	Drier		0.44
PC1_higher SES			0.43
PC2_higher SES			0.66

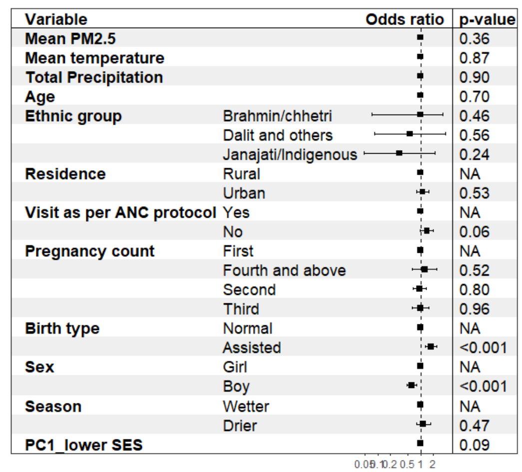
Figure 6a (Above median scenario): Adjusted OR and 95% CI of APO associated with mean $PM_{2.5}$



Variable		Odds ratio	p-value
Mean PM2.5			0.36
Mean temperature			0.87
Total Precipitation			0.88
Age			0.72
Ethnic group	Brahmin/chhetri		0.57
	Dalit and others		0.68
	Janajati/Indigenous		0.32
Residence	Rural		NA
	Urban		0.45
Visit as per ANC protocol	Yes		NA
	No		0.06
Pregnancy count	First		NA
	Fourth and above		0.52
	Second		0.79
	Third		0.95
Birth type	Normal		NA
	Assisted		<0.001
Sex	Girl		NA
	Boy		<0.001
Season	Wetter		NA
	Drier		0.46
PC1_moderate SES			0.26
PC2_moderate SES			0.34

Figure 6b (Median scenario): Adjusted OR and 95% CI of APO

associated with mean PM2.5



Variable		Odds ratio	p-value
Mean PM2.5			0.36
Mean temperature			0.87
Total Precipitation			0.90
Age			0.70
Ethnic group	Brahmin/chhetri		0.46
	Dalit and others		0.56
	Janajati/Indigenous		0.24
Residence	Rural		NA
	Urban		0.53
Visit as per ANC protocol	Yes		NA
	No		0.06
Pregnancy count	First		NA
	Fourth and above		0.52
	Second		0.80
	Third		0.96
Birth type	Normal		NA
	Assisted		<0.001
Sex	Girl		NA
	Boy		<0.001
Season	Wetter		NA
	Drier		0.47
PC1_lower SES			0.09

Figure 6c (Below median scenario): Adjusted OR and 95% CI of APO associated with mean $PM_{2.5}$

4. Discussion

This is one of the first studies to examine a link between environmental exposures and birth outcomes, focusing on a hilly district of Nepal. This study observed LBW as the most frequent APO, followed by preterm birth and stillbirth. We did not observe a statistically significant effect of total precipitation, temperature (mean maximum, mean, and mean minimum), and mean $PM_{2.5}$ on birthweight and APOs in unadjusted and adjusted models in this study. Analyses showed a statistically significant effect of temperature (mean maximum, mean, and mean minimum) and total precipitation on birthweight only in the wetter season, signalling potential effect modification. Janajati/Indigenous ethnic group, urban residence, not visiting as per ANC protocol, second pregnancy count, and male infant sex were statistically significantly associated with pregnancy outcomes.

Environmental Exposures and APOs

We observed a consistent lack of associations between APO and daily temperature (mean maximum, mean, and mean minimum). This result suggests that variations in these environmental parameters within the studied range do not significantly impact pregnancy outcomes, which does not align with prior research.[18,52,53] For example, Bakhtsiyarava et al.[52] observed associations between LBW and exposure to higher temperature (> 19°C) in an investigation of average monthly temperature during gestation and term birthweight, adjusted for child-and-mother-level covariates. The relationship between minimum temperature exposure and pregnancy outcomes is heterogeneous across global studies. For example, a study in Hungary found a small positive but statistically non-significant effect of colder temperatures on birthweight.[53] In contrast, Ha et al.[8] observed cold exposure (< 5th percentile) during the second and third trimesters and across pregnancy was negatively associated with birthweight.

Strand et al.[14] also observed an increased risk of stillbirth with increased mean temperature. They adjusted for socioeconomic variables, preeclampsia and sulfur dioxide in the model, which could not be included in this study due to the unavailability of such data. A qualitative study exploring the perspectives and lived experiences of Nepalese rural women also discussed stillbirth and low birthweight as critical climate change-attributed health problems. (Tiwari, pers.comm.) Pregnancy stages, particularly the second and third trimesters, are crucial times for the growth of the fetus.[54] The uterine blood flow and placental exchange of necessary fetal growth may be affected by extreme hot or cold temperature[54] via disruption to the mechanism required for proper growth during the second and third trimesters[27] leading to LBW and stillbirth.

A study by Weng et al.[55] in Taiwan found a greater risk of preterm birth with exposure to temperature extremes (<19.5°C and >25.4°C) at birth compared to reference temperature 21.5°C - 23.5°C. Guo et al.[17] observed a difference in the effects of temperature in hot areas in China three months before pregnancy up to 21 weeks of gestation. They divided the study area into cold, medium, and hot areas according to the local average temperature and reported a protective effect of exposure to cold temperature in hot areas in terms of preterm birth. Exposure to hot environments in hot areas increased the risk of preterm birth.[17] The precise mechanism by which extreme temperature exposure may influence the preterm birth risk is unclear.[56] One plausible explanation could be a disturbance of hormone homeostasis of the hypothalamic-pituitary-adrenal axis due to heat exposure, increasing the release of cortisol and adrenocorticotropic hormone.[56,57] These hormones may activate myometrial function and increase uterine contractions, potentially leading to preterm birth.[56,57] Furthermore, heat stress-induced dehydration can reduce body fluid in pregnant women's bodies, causing uterine contraction and leading to early labour onset.[58] Although the temperature reported in the compared studies are similar to the temperature in the Kavre district, the observed statistically non-significant relationship between temperature and APO in this study may suggest adaptation to temperature in the Kavre district. From the epidemiological perspective, this statistically non-significant relationship may be attributed to residual confounding.

We found consistent patterns of non-significant effects of precipitation on APOs across models IIIs in this study. These results also do not align with findings from previous studies.[15,23,26] Grace et al.[26] examined the relationship between birthweight and precipitation in 19 African countries and found a positive effect of precipitation on birthweight in all models, with or without temperature. However, the relationship was statistically significant for only the second and third trimesters. On average, a 10 mm increase in precipitation during a particular trimester corresponded to an approximate 0.2 – 0.3 grams increase in birthweight.[26] Another study that examined the association between meteorological factors and birthweight in a rural population in Uganda also found a significant positive effect of precipitation on birthweight during the third trimester.[15] A plausible explanation of the positive effect of precipitation on birthweight may be attributed to harvest cycles and maternal nutritional status, as food may be abundant in the rainy season.[15] Similarly, Chacon-Montalvan et al.[23] examined exposure to different intensities of precipitation and the risk of adverse birth outcomes, including preterm birth in Amazonia. They found exposure to extremely intense precipitation was linked to an increased risk of preterm birth. The mechanism of how precipitation affects preterm birth remains unknown.[59] Many intermediate factors, such as environmental contamination and disease transmission, are associated with precipitation that may affect preterm birth. Precipitation extremes are associated with changes to air moisture content, affecting respiratory systems and increasing asthma risk.[60]

Heavy precipitation also facilitates waterborne disease transmission[59,61,62], which may trigger preterm birth.

This study observed a statistically non-significant effect of $PM_{2.5}$ exposure on APOs, contrasting with findings from other studies.[22,41,63] An analysis of the WHO global survey on maternal and perinatal health by Fleischer et al.[22] found a significant positive effect of $PM_{2.5}$ on LBW. They reported 22% higher odds of LBW among mothers exposed to fourth-quartile concentrations of $PM_{2.5}$ (>20.2 $\mu g/m^3$) compared to those exposed to first-quartile concentrations (<6.32 $\mu g/m^3$). Another population-based retrospective cohort study conducted in the Brazillian Amazon also observed a significant positive effect of $PM_{2.5}$ exposure on LBW, but only for fourth-quartile $PM_{2.5}$ concentrations in the second and third trimesters.[41] In both studies, LBW was associated only with the highest quartile of $PM_{2.5}$, which suggested a possible threshold effect. Similarly, a study conducted by Shezi et al.[63] in Durban, South Africa, reported 1.75 times higher odds of preterm birth per interquartile increase (18 $\mu g/m^3$) in $PM_{2.5}$ exposure. Fleischer et al.[22] also found an association between preterm birth and the highest quartile of $PM_{2.5}$. However, Rudra et al.[64] did not find an association between $PM_{2.5}$ and preterm birth after adjustment for the year of conception, resulting in a smaller effect size. Maternal metabolic or vascular abnormalities, particularly placental defects, are presumed to trigger APO pathogenesis.[65] $PM_{2.5}$ can be transported between maternal and fetal blood through the placenta and negatively affects its physiological function, leading to fluctuations in blood flow, endocrine dysfunction, and oxidative stress[66], which may contribute to APOs.[23]

Season-Stratified Relationship Between Environmental Exposures and Birthweight

We found a statistically significant association between environmental exposures (temperature (mean maximum, mean, and mean minimum) and total precipitation) and birthweight in the wetter season. The effect of total precipitation was positive, while the effect of temperature (mean maximum, mean, and mean minimum) was negative on birthweight. The association between precipitation and birthweight may be connected to agricultural production and household food security.[67] Nepal depends primarily on rain-fed agriculture. Therefore, higher precipitation in the wetter season during the early stages of pregnancy will likely result in more agricultural production and increased agriculture-related incomes and food availability, resulting in improved maternal nutritional status.[63,67] The associations between temperature and birthweight in this study were significant and negative in the wetter season. One potential explanation is the rise in inflammatory, hemostatic, and lipid markers during heat exposure that could result in diabetes and hypertension during pregnancy, leading to reduced birthweight.[68] In addition, pregnant women have a limited ability to thermoregulate due to the increased metabolic demands of pregnancy. The pregnant women's ability to lose heat through sweating may be reduced, leading to increased core body temperature compounded by weight gain, increased fat deposition, and decreased surface area to body mass. This makes them vulnerable to hot temperature, heat shock, and acute fetal distress.[52,68]

Sociodemographic and Health Service-Related Variables and APO

We observed a statistically significant effect of sociodemographic and health service-related variables, including infant sex and visits as per ANC protocol on APOs. Being born as male children was found to be a protective factor for APOs. The finding aligns with prior studies on birthweight, with male children typically having higher birthweights than female children.[20,27] Adherence to ANC protocol provides a platform for critical healthcare functions, including health promotion (e.g., consuming micronutrient supplements), disease prevention, screening, and diagnosis, and timely and appropriate implementation of evidence-based practices which can improve maternal and fetal health.[69]

Strengths and Limitations

The methods used in this study have several strengths. One of the key strengths of this study is the use of remote-sensing technologies, which make it possible to make observations at spatial and temporal scales that Nepal's current environmental monitoring infrastructure cannot. We adopted a multi-pronged approach to explore the relationships between environmental exposures, sociodemographic and health service-related variables, and APOs. We also performed multiple sensitivity analyses, examining different levels of sociodemographic variables in separate models and the effect of environmental exposures on APOs in truncated datasets.

However, this study has limitations, which should be acknowledged. Some of our study results align with the findings from other studies, but we could not directly compare the magnitudes of our estimates with those from previous studies due to substantial differences in environmental exposures, outcomes, and the methods used. The study comparisons were further complicated by variability across countries concerning healthcare systems, recent trends in environmental exposures, and adaptive capacity, including healthcare accessibility and greenspace availability. The environmental exposure variables are ecological and represent an approximation of women's actual exposure as determined by various factors, including, for example, the amount of time they spend outdoors, their activity patterns, and the use of an air cooling system inside the home. The availability of data also restricted our ability to capture the full spectrum of potential confounding variables. For example, we could not include critical variables like maternal anemia, gestational diabetes, and gestational duration. Several critical sociodemographic variables such as education, income, occupation, smoking status, BMI, and type of cooking fuel were not captured by the community-level health centers and Dhulikhel Hospital, which necessitated the creative use of other sources and their application as ward-level variables. Therefore, ecological fallacy may have been introduced in assessing the relationship between environmental exposure and APOs when using a multivariable logistic regression model, as the model did not account for individual-level differences. The potential effect of non-facility births must also be mentioned. The observed relationship in this study may have been exaggerated, assuming fewer non-facility births or underestimated, with higher non-facility births compared to health facility-recorded births. There may also be the potential relative contribution of household air pollution on the APOs, which this study could not directly measure. However, we adjusted for the type of household fuel used for cooking or heating purposes as a proxy of household air pollution. The DHS also deliberately introduces random errors in the GPS coordinates for the centroid of the survey clusters to protect anonymity, causing erroneous linkage of all NDHS variables to wards of the district, which was not accounted for in this study. Health service registers were not complete, resulting in missing LBW, preterm births or stillbirth cases, introducing potential bias. Several factors, including accessibility, affordability, and health awareness, may have introduced this selection bias. The preferred use of meteorological and $PM_{2.5}$ data from the ground monitoring stations also could not be applied due to a limited number of such stations lacking geographical coverage and a higher proportion of missing data, particularly $PM_{2.5}$. As such, we used remote sensing data, though such technologies have limitations in terms of resolution and quality as well, which can affect the accuracy and usefulness of the data.

Study Significance

This is one of the first studies to examine and provide evidence of associations between environmental factors and APOs in Nepal. Researchers can take the learning from the strengths and limitations of this study to design and conduct future studies in the area of climate change, air pollution, and APOs. Evidence can also be used to inform future investigations and healthcare strategies related to climate change in the study area.

5. Conclusion

This is one of the first studies to examine a link between temperature, precipitation, $PM_{2.5}$, and APOs, focusing on a hilly district of Nepal. A significant effect of temperature and precipitation on birthweight was found for those born in the wetter season. However, no evidence of an association between temperature, precipitation, $PM_{2.5}$, and APOs was found in the full analysis. Given the existing global evidence of associations between APOs and environmental factors, future research should consider larger cohorts and expand the scope of variables to further explore these complex relationships and guide interventions to reduce the risk of adverse birth outcomes. Simultaneously, the Government of Nepal must improve its climate infrastructure to enable the robust, regular recording and capturing of environmental data over a wide geographic area.

Acknowledgements

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Chapter V

Potential influences of meteorological factors and particulate matter pollution on childhood infectious diseases in Kavre district, Nepal.

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Synopsis

Introduction As our world faces the impacts of climate change and rising air pollution levels, it has become imperative that we investigate the connections between environmental factors and the emergence, re-emergence, worsening and shifting of diseases spatially and temporally. In this era of environmental challenges, one health concern that has garnered significant focus is the widespread occurrence of childhood infectious diseases, particularly diarrhea and acute respiratory infections (ARI). To this end, we investigated the association of acute exposure to weather factors and air pollution with diarrhea and ARI among children younger than five years old living in Kavre district of Nepal.

Methods We conducted a hospital and rural health centres-based historical cohort study that included health facility records (n=1629) from the fiscal year 2017/18 through 2019/20 in the Kavre district of Nepal. Health records were linked to temperature and precipitation for two

weeks preceding each recorded health outcome. For particulate matter pollution ($PM_{2.5}$), health records were linked to the one-month period preceding each recorded health outcome. We obtained the daily temperature data from the CPC Global Unified Temperature dataset from the National Oceanic and Atmospheric Administration's (NOAA) Physical Sciences Laboratory. Daily precipitation data were obtained from the Climate Hazard Group InfraRed Precipitation with Station (CHIRPS). We obtained the monthly surface $PM_{2.5}$ data from the Atmospheric Composition Analysis Group of Washington University in St. Louis. Sociodemographic variables such as education, occupation, wealth quintile, smoking status, and type of cooking fuel were obtained from the Nepal Demographic and Health Survey (NDHS) 2022 dataset. Area-level variables were linked to the wards of the households. The dichotomous outcomes (diarrhea: yes, no; ARI: yes, no) were analyzed using multivariable logistic regression in relation to environmental exposures.

Results We analyzed data from 1629 eligible children recorded in the service register during the fiscal year 2017/18 through 2019/20 at Dhulikhel Hospital and community health centres in the Bhumlu and Mahabharat rural municipalities. A prevalence of 11% diarrhea and 27% ARI in the study participants was observed. A positive effect of mean $PM_{2.5}$ exposure on diarrhea [Adjusted Odds Ratio (AOR) 1.02, 95% CI 1.003 – 1.03] was found. There was no association between total precipitation exposure and diarrhea, while temperature (mean maximum, mean, and mean minimum) showed a weak association (AOR 1.04, and 95% CI 0.98 - 1.10). Minimum temperature was positively associated with ARI (AOR 1.04; 95% CI 1.001 – 1.08). We did not observe a statistically significant association between total precipitation, mean $PM_{2.5}$ and ARI. The findings from a stratified analysis showed that exposure to mean $PM_{2.5}$ had positive effect on

diarrhea among urban residents (AOR 1.03, 95% CI 1.001 – 1.07) and in the wetter season (AOR 1.05, 95% CI 1.02 – 1.07).

Conclusion This study is among the few studies in Nepal and one of the first to investigate an association between acute exposure to temperature, precipitation, $PM_{2.5}$ and childhood infectious diseases in Kavre district. We found a positive association between mean $PM_{2.5}$ exposure and diarrhea. A statistically significant association between minimum temperature exposure and ARI was also observed in this study. Collaborative efforts across local-level government and non-government stakeholders, including health centres, hospitals, and municipal governments, are needed to develop and implement strategies to minimize air pollution in the region, strengthen systems, and protect and promote children's health. Furthermore, the Government of Nepal must improve its climate infrastructure to enable regular recording and capturing of environmental data.

Keywords: Temperature, precipitation, $PM_{2.5}$, diarrhea, acute respiratory infection, children

1. Introduction

As our world faces the impacts of climate change and rising air pollution levels, evidence regarding environmental factors and human well-being is becoming even more critical.[1] In this era of environmental challenges, one health concern that has garnered significant focus is the widespread occurrence of childhood infectious diseases, particularly diarrhea and acute respiratory infections (ARI).[2–4] These illnesses continue to burden public healthcare systems globally, which may worsen with climate change.[1,5–7]

Diarrhea is among the leading causes of mortality and morbidity, particularly in low- and middle-income countries (LMICs), where access to clean water and sanitation facilities remains limited.[8] In 2019, the Global Burden of Diseases (GBD) reported approximately 6.58 billion incident cases and 99 million prevalent cases of diarrhea, contributing to roughly 1.53 million deaths and 80.9 million Disability Adjusted Life Years (DALYs).[9] Approximately 45.5 million DALYs due to diarrhea occurred in children under five years, the third leading cause of burden in this age group globally.[9,10] In Nepal, diarrhea remains a critical cause of mortality and morbidity among young children, with a 2-week period prevalence of 10% in children younger than five years of age in 2022.[11] The prevalence of diarrhea in Nepal was reported to be higher among children aged 6-23 months, undernourished children, and those belonging to low sociodemographic households, including households with poor water and sanitation facilities, poorer households, and children of lower-educated mothers.[12]

Respiratory infections are another leading cause of mortality and morbidity in children younger than five years globally.[10,13] In 2019, lower respiratory infections were ranked as the second leading cause of the global burden of disease in children under five years.[10] The GBD 2019 reported 489 million incident cases and 11 million prevalent cases of lower respiratory tract infection (LRTI) worldwide, contributing to 2.49 million deaths and 97.2 million DALYs.[14] Similarly, the GBD 2019 reported 237 million prevalent cases of upper respiratory tract infections (URTI), contributing to 9460 deaths and 6.39 million DALYs.[15] A 1% 2-week period prevalence of ARI in children under five years was reported in the most recent NDHS (2022) for Nepal, of whom 75% sought treatment.[11]

Previous studies have shown the influence of weather factors and air pollution on the development of diseases, including diarrhea and respiratory infections.[1,3,15–23] For example, increased ambient temperature is associated with the rapid replication of diarrhea-associated common bacterial pathogens (e.g., diarrheagenic Escherichia coli), and also extends the survival of these pathogens in the external environment.[5,25–27] Some studies have reported excess cases of diarrhea after heavy precipitation and related hydrologic conditions like floods and drought.[5,28] A potential pathway could be flooding and surface runoff, which increase rates of contamination of drinking water sources, particularly at the beginning of the rainy season.[5,28,29] Drought also leads to diarrhea via water scarcity and the high burden of malnutrition.[5,30] $PM_{2.5}$ has been suggested as a vehicle that may transport diarrhea-causing pathogens, contaminating the children's living environment and increasing the risk of diarrhea infection.[31] Children usually spend more time playing outdoors during the warm season and are at higher risk of hazardous exposure to high temperatures and air pollution, increasing the risk of respiratory infections.[20,32] While the effects of weather factors and air pollution on digestive and respiratory systems are felt by children and adults alike, the effects are exacerbated in children due to their developing immune and respiratory systems, smaller lung capacity, and relatively higher proportion of lung surface to inhaled air volume.[21,33]

In previous studies, weather factors such as temperature and precipitation and $PM_{2.5}$ have been associated with diarrheal and respiratory illnesses.[1,3,15–23] However, the association is under-explored in Nepal. Furthermore, the study area, Kavre, is a hilly district in Nepal that experiences several environmental challenges, including high-intensity precipitation, extreme temperatures, water shortages, drought, and air pollution. The relatively low socioeconomic status of people in this district[34] further exposes them, including children, to higher risks from environmental exposures.[35] Published literature exploring the relationship between acute exposure to these environmental factors and childhood infectious diseases in Nepal are scarce. This study investigated the association of acute exposure to weather factors and $PM_{2.5}$ with diarrhea and ARI among children younger than five years living in the Kavre district.

2. Methods

2.1 Study Location and Population

We conducted this study in Kavre, one of Nepal's 77 districts (Figure 1). We chose Kavre because the southern part (Milche-Saldhara) of the district has a history of high-intensity precipitation[36] and is affected by other environmental issues such as water shortages, drought, and air pollution.[37,38] Dhulikhel Hospital is a large district-level hospital in Kavre that provides primary, secondary, and tertiary healthcare to urban and rural populations, including many patients from neighbouring districts.

The district is within Bagmati province. It occupies a land area of 1,396 square km. Kavre has 13 municipalities (7 rural and 6 urban), each with 11 to 14 wards, with 135 wards altogether in the district. The district is in a mid-hilly area, with an elevation ranging from 280 to 3018 meters above sea level, and has primarily a subtropical climate.[39] The district's primary income source is skilled agriculture, including forestry and fishery.[34] Nepal's Census 2021 reported a total population of 366,879, with 24,560 (males: 53% and females: 47%) aged under five years.[34]

We included study participants from July 16, 2017, to July 15, 2020, visiting the Dhulikhel Hospital or six health posts in Bhumlu and Mahabharat rural municipalities. We included children younger than five years of age and those with available health outcomes (diarrhea and ARI) information, recording the date of the visit. The participants were restricted to permanent residents of Kavre, and those with health outcome information, including the visit date.

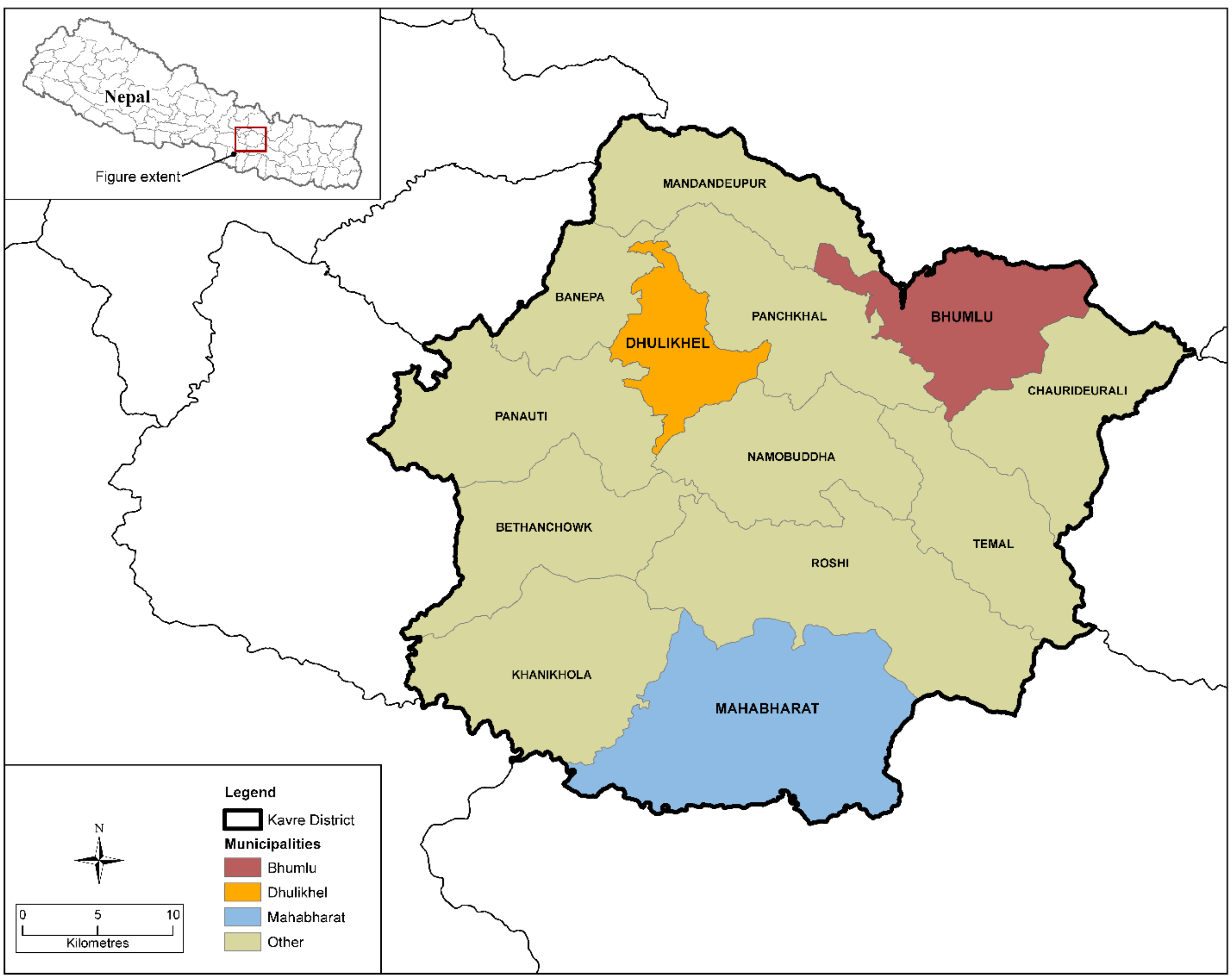

Figure 1: Map of the Kavre district highlighting municipalities in which hospital/health posts were selected (Syer, pers. comm.)

2.2 Outcomes Assessment

We obtained health outcomes information (diarrhea (yes, no), ARI (yes, no)) from the integrated management of neonatal and childhood illness (IMNCI) health service register used in health posts and Dhulikhel Hospital. We captured service records from 2017/18 through 2019/20. We randomly selected 1784 children from the Dhulikhel Hospital (n = 1233) and six health posts (n = 551). Of 1233 randomly selected children, 59 records were excluded due to incomplete residential addresses failing linkage to environmental exposure, 47 were from outside Kavre, 27 had missing dates of visit, and 22 had no health outcome information. Therefore, we excluded 155 observations, resulting in a total of 1629 participants retained in the final analysis. The details of the sample size calculation are provided in Appendix 6.

The health post and the hospital use the World Health Organization (WHO) case definition of diarrhea and ARI. The WHO defines diarrhea as the passage of three or more loose or liquid stools per day or more frequently than is normal for the individual.[40] ARI is the sudden onset of respiratory symptoms such as cough and/or difficulty breathing for at least three consecutive days.[41]

2.3 Weather and Air Pollution Data

The observations of weather and air pollution at spatial and temporal scales for Kavre, Nepal, were captured using remote-sensing technologies. CHIRPS data, a publicly available quasi-global precipitation data set, for daily precipitation was obtained in millimetres (mm), with a spatial resolution of 0.05° (~5.3 km).[42] We obtained the daily temperature (maximum and minimum (°C)) data in netCDF format from the CPC Global Unified Temperature dataset from NOAA Physical Sciences Laboratory.[43] Python's API for Google Earth Engine[44] was used to calculate total daily precipitation using the built-in reduce regions function. For temperature, we used Python to identify the grid cell overlapping each ward (based on ward centroids) and then used conventional Python libraries to extract the minimum and maximum daily temperature. We calculated daily mean precipitation and temperature (mean maximum, mean, and mean minimum) for every ward (135 wards) of the Kavre district beginning January 1, 2016, through December 31, 2020.

We obtained the monthly surface $PM_{2.5}$ ($\mu g/m^3$) concentration data from 2016 through 2020 in netCDF format from the Atmospheric Composition Analysis Group of Washington University in St. Louis.[45] The dataset has global spatial coverage with a spatial resolution of approximately 1 km × 1 km. $PM_{2.5}$ in every ward was calculated using the zonal statistics tool in ArcGIS 10.8.2.[46], taking the mean of cells intersecting the ward. We found two wards with inadequate overlap with the raster cells, which were buffered by 1 km to ensure $PM_{2.5}$ values were assigned.

2.4 Confounders

Based on a priori knowledge, we adjusted for several potential confounders that influence the relationship between weather, air pollution, and childhood infectious diseases. Potential confounders were grouped into individual and area-level confounders based on the data sources.

Individual-level confounders included the age of children (continuous measurement), ethnicity (Brahmin/Chhetri, Dalit and others, and Janajati/Indigenous), residence (rural, urban), and sex (male, female), which were obtained from Dhulikhel Hospital and health post records. We also considered season (wetter, drier) as an individual-level confounder, as it was calculated based on the visit date. May through September visits were categorized as wetter and October through April as drier seasons. The "Dalit and other categories" included Dalit, Terai/Madhesi and other castes. According to the Local Government Operation Act 2017[47], municipalities in Nepal are classified into rural and urban municipalities, sub-metropolitan and metropolitan cities based on several factors, including population, revenue generation, road connectivity, the availability of electricity and drinking water services. Urban municipalities, sub-metropolitan and metropolitan cities were categorized as urban and rural otherwise.

Data on area-level confounders were obtained from the Nepal NDHS 2022.[11] NDHS is a nationally representative survey implemented by New ERA under the aegis of the Ministry of Health and Population with the technical support of ICF International.[11] The survey sample is a stratified sample achieved in two stages. Each of the seven provinces is divided into urban and rural areas that form the sampling stratum for that province, thus creating 14 sampling strata. In the first sampling stage, 476 primary sampling units (PSUs) or clusters were selected with probability proportional to PSU size and with independent selection in each sampling stratum within the sample allocation. Out of the 476 clusters, 248 were urban and 228 were rural. Thirty households were selected from each cluster in the second stage (total number of selected households: 14,28). The survey also collected Global Positioning System (GPS) data for the household.[11]

We used NDHS GPS datasets and identified seven clusters connected to Kavre. Among the seven, five clusters (116, 155, 156, 157, 158) were located within Kavre. Two clusters (115 and 147) outside Kavre were also selected for their proximity. The NDHS cluster was assigned to each nearest ward in Kavre. Thus, each participant's residential address (DDGNWW) was assigned one of the seven clusters. DD represents the district code, GN municipality, and WW ward. We considered the smallest distance between the edge of the ward polygon and the point of the randomly dislocated NDHS cluster to determine the 'nearest' ward. Thus, using a common variable, 'DDGNWW,' relevant NDHS variables were linked to each ward.

The NDHS variables included drinking water sources [piped water, others (protected spring, tube well, unprotected well, bottled water), toilet facility [flush with a septic tank, others (no toilet, flush at sewer system, flush somewhere else), maternal education (higher, secondary, primary, or no education), paternal education (higher, secondary, primary, or no education), type of cooking fuel (solid or clean fuels), wealth quintile (richest, richer, middle, poorer or poorest), smoking (no smoking, smoke someday, or smoke daily), and occupation (professional, household, or agriculture). Variables and their levels were used as is in this study, except for the cooking fuel. We regrouped wood, straw/shrub/grass, or agricultural crops as solid fuels. Clean fuels included households using electricity, LPG, solar energy, piped natural gas, or biogas. We calculated the weighted proportion of levels of each selected NDHS variable and assigned them to wards.[11]

2.5 Linking Health Outcomes with Weather Factors and Air Pollution

We calculated the two-week average of temperature (mean minimum, mean, and mean maximum temperature) (°C)) exposure before the date of visit to a health facility. For precipitation, we calculated the two-week total precipitation (mm). Since we had only monthly data for $PM_{2.5}$, we assessed a $PM_{2.5}$ exposure of one month before the date of the visit.

2.6 Data Analysis

We attempted multilevel models, but the models failed to converge. Therefore, we analyzed dichotomous outcomes (diarrhea and ARI) using multivariable logistic regression models with environmental exposures, adjusting for potential confounding.

We fit a generalized linear model to examine associations of diarrhea and ARI with mean measures of temperature, $PM_{2.5}$ and total precipitation two weeks before the visit date (Model I). Second, we added individual-level confounders in Model II. Third, we added variables of clinical or public health importance plus area-level confounders (Model III). The main rationale for fitting these three models was to examine associations of diarrhea and ARI with environmental variables in the unadjusted and adjusted models (individual and area-level variables). We included different levels of area-level variables (scenarios) in Model III as part of sensitivity analyses. We defined these three models as the above-median scenario (Model IIIa), below median scenario (Model IIIb), and median scenario (Model IIIc). The above-median scenario model included the highest levels of area-level socioeconomic variables (i.e., piped water, flush septic tank, maternal secondary education, paternal higher education, clean fuel for cooking, richest wealth quintile, no maternal smoking, and engaged in professional occupation). The below-median scenario model included the lowest levels of area-level socioeconomic variables (i.e., no maternal education, no paternal education, use of solid fuels for cooking, poorest wealth quintile, daily maternal smoking, and engaged in agricultural occupation). The median scenario model included area-level socioeconomic variables with the highest reported proportions. We identified using piped water, flush septic tank, no maternal education, no paternal education, use of solid fuel for cooking, belonging to the poorer wealth category, no maternal smoking, and engaging in household chores as the most frequently reported socioeconomic variables in the NDHS cluster for the Kavre district.

We considered the median scenario model (Model IIIc) for our final model. To check for potential effect modification, we examined rural or urban residences and by wetter or drier season, using interaction terms in Model III. We did not include interaction terms in the final models if no significant relationships existed with childhood infectious diseases, i.e., p-value < 0.05 for the interaction term.

To accommodate multicollinearity in data obtained from the NDHS, we applied Principal Component Analysis (PCA). We centred and scaled the data. Eight principal components were generated corresponding to the number of variables included in PCA. In the above-median scenario (i.e., higher SES), PC1 explained around 88% of the variance and was included in Model IIIa. PC1 alone explained 87% of the variance in the below-median scenario (i.e., lower SES) and was included in Model IIIb. In the median scenario (i.e., highest frequency SES), PC1 explained 87% of the variance and was included in Model IIIc. PCA values for the selected principal components were generated for all the study participants.

Data were analyzed using R programming language version 3.4.1.[48]

2.7 Ethics

We received ethical approval from the Ethical Review Board of the University of Alberta (Pro00107397), Nepal Health Research Council (NHRC) (340/2021), and Kathmandu University School of Medical Sciences (KUSMS) (257/2021).

3. Results

We analyzed data from 1629 eligible children recorded in the service register during the study period: July 16, 2017, through July 15, 2020, at Dhulikhel Hospital and the health posts in Bhumlu and Mahabharat rural municipalities. The sociodemographic characteristics of the participants and the proportion of diarrhea and ARI are presented in Table 1. We observed a prevalence of 11% for diarrhea and 27% for ARI. The mean age of children included in the study was 21 months (± 16). Most of the children were boys (59%), rural residents (70%), belonged to the Janjati/Indigenous ethnic group (66%), and health facilities visits for diarrhea and ARI were more often in the drier season (57%).

Table 1: Sociodemographic characteristics of study participants in Kavre district, Nepal, July 16, 2017, to July 15, 2020, based on health records.

Characteristics	n = 1629 (%); Mean (Standard Deviation)
Independent variables	
Age in months	1629; 20.8 (± 15.7)
Ethnicity	
Brahmin/Chhetri	408 (25%)
Dalit and others	151 (9%)
Janajati/Indigenous	1070 (66%)
Residence	
Rural	1140 (70%)
Urban	489 (30%)
Sex	
Boy	967 (59%)
Girl	662 (41%)
Diarrhea	
Yes	175 (11%)
No	1454 (89%)
ARI	
Yes	433 (27%)
No	1196 (73%)
Danger Signs	

Yes	66 (4%)
No	1563 (96%)
Fever	
Yes	553 (34%)
No	1076 (66%)
Season	
Drier	932 (57%)
Wetter	697 (43%)

Table 2 represents the households' characteristics based on the NDHS 2022. Approximately 65% of participants used piped water for drinking purposes, 80% had flush toilets with septic tanks, 63% reported no maternal education, 35% reported no paternal education, 25% were poorer households, 95% reported no maternal smoking, 56% used solid fuels for cooking, and 81% of children's mothers were engaged in household work.

Table 2: Characteristics of study samples in Kavre district, Nepal, based on NDHS 2022

Characteristics	**N = 450 (%)**
Drinking water source	
Piped water	292 (64.9%)
Others (protected spring, tube well, unprotected well, bottled water)	158 (35.2%)
Toilet type	
Flush with septic tank	361 (80.2%)

Others (no toilet, flush at sewer system, flush somewhere else)	89 (19.8%)
Mother's education	
No education	284 (63.0%)
Primary education	79 (17.6%)
Secondary education	79 (17.6%)
Higher education	8 (1.7%)
Father's education	
No education	160 (35.5%)
Primary education	146 (32.6%)
Secondary education	96 (21.4%)
Higher education	26 (5.9%)
Unknown	22 (4.7%)
Wealth quintile	
Poorest	83 (18.5%)
Poorer	113 (25.2%)
Middle	88 (19.5%)
Richer	69 (15.3%)
Richest	97 (21.5%)
Smoking	
Do not smoke	429 (95.4%)
Smoke daily	21 (4.6%)
Occupation	

Agriculture	25 (5.6%)
Household	367 (81.5%)
Professional	14 (3.2%)
Others (clerical, sales)	44 (9.7%)
Fuel type	
Clean fuel	196 (43.5%)
Solid fuel	254 (56.5%)

The annual environmental exposure measurements for the Kavre district from 2016 to 2020 are shown in Table 3. Notably, 2018 had the highest total precipitation (1635.07 mm), while 2017 had the lowest (1171.65 mm). The mean maximum temperature over the period ranged from 26.4°C to 27.07°C. The mean temperature varied between 21.1°C and 21.59°C, while the mean minimum temperature remained relatively constant at 15°C.

Table 3: Environmental exposure record of Kavre district, 2016 – 2020

	Year				
Variables	**2016**	**2017**	**2018**	**2019**	**2020**
Precipitation (mm)					
Total precipitation	1471.14	1171.65	1635.07	1388.63	1429.3
Mean maximum	122.75	87.04	123.48	168.23	95.33
Mean minimum	0	0	0	0	0
Temperature (°C)					
Mean maximum	26.99	27.07	26.4	26.72	26.48

Mean	21.41	21.59	21.17	21.29	21.10
Mean minimum	15.84	16.12	15.94	15.86	15.72
Mean $PM_{2.5}$ (µg/m3)	37.57	35.59	39.18	34.50	35.30

We consistently observed a positive effect of $PM_{2.5}$ exposure on diarrhea across the three models (Table 4e). The AOR and 95% CI were the same across the three models (AOR 1.02, 95% CI 1.003 – 1.03). We found no association between precipitation exposure and diarrhea (Table 4a). Although statistically non-significant, temperature (mean minimum, mean, and mean maximum) (Table 4b-d) indicated a potential association with diarrhea (AOR 1.04, 95% CI 0.98 to 1.10 across the three models).

Precipitation and $PM_{2.5}$ exposures were not associated with ARI (Table 5a and 5e). Mean minimum temperature showed a positive association with ARI (Table 5d). The relationship was consistent across the models, with an estimated AOR of 1.04 (95% CI 1.001 – 1.09). Mean maximum and mean temperatures showed statistically non-significant and weaker associations with ARI (Table 5b and 5c). Fever in children was a statistically significant risk factor for diarrhea (AOR 1.45, 95% CI 1.03 – 2.03) and ARI (AOR 2.65, 95% CI 2.08 – 3.38). Urban residence (AOR 0.53, 95% CI 0.38 – 0.74) was a statistically significant protective factor for ARI.

We tested for effect modification by residence and season using the median-scenario model (Model IIIc). Exposure to $PM_{2.5}$ showed a statistically significant association with diarrhea among urban residents (AOR 1.03, 95% CI 1.001 – 1.07) (Table 6e). Similarly, analysis of the relationship between $PM_{2.5}$ exposure and diarrhea by season exhibited a statistically significant association in the wetter season only (AOR 1.05, 95% CI 1.02 – 1.07) (Table 7e). We did not observe effect modification of the relationship between environmental exposures and both diarrhea and ARI with residence or season (Appendix 7: Supplementary Table SIa-e, S2a-e, S3a-e and S4a-e). Therefore, we did not report Model III (a-c) results with interaction terms.

Table 4a: Association of total precipitation with diarrhea

Model IIIa (Above median scenario)					**Model IIIb (Below Median scenario)**				**Model IIIc (Median scenario)**		
	Diarrhea				**Diarrhea**				**Diarrhea**		
Variables	*Odds Ratios*	*CI*	*p*		Odds Ratios	CI	p		*Odds Ratios*	*CI*	*p*
Total precipitation	1.00	0.99 to 1.00	0.07		1.00	0.99 to 1.00	0.07		1.00	0.99 to 1.00	0.07
Mean temperature	1.04	0.98 to 1.10	0.19		1.04	0.98 to 1.10	0.19		1.04	0.98 to 1.10	0.17
Mean $PM_{2.5}$	1.02	1.003 to 1.03	**0.01**		1.02	1.003 to 1.03	**0.01**		1.02	1.003 to 1.03	**0.01**
Ethnicity											
Brahmin/Chhetri	Ref				Ref				Ref		
Dalit and others	0.94	0.48 to 1.77	0.86		0.94	0.48 to 1.77	0.85		0.94	0.48 to 1.77	0.85
Janajati/	1.08	0.72 to	0.71		1.08	0.72 to 1.65	0.72		1.08	0.72 to	0.71

Indigenous		1.66								1.66	
Residence											
Rural	Ref				Ref				Ref		
Urban	0.79	0.50 to 1.22	0.29		0.79	0.50 to 1.22	0.30		0.8	0.51 to 1.24	0.33
Sex											
Boy	Ref				Ref				Ref		
Girl	0.99	0.71 to 1.36	0.93		0.99	0.71 to 1.36	0.93		0.99	0.71 to 1.36	0.93
Age	1.00	0.99 to 1.01	0.58		1.00	0.99 to 1.01	0.58		1.00	0.99 to 1.01	0.57
Fever											
No	Ref				Ref				Ref		
Yes	1.45	1.03 to 2.03	**0.03**		1.45	1.03 to 2.02	0.03		1.45	1.03 to 2.02	**0.03**
Season											

Drier	Ref				Ref				Ref		
Wetter	1.43	0.81 to 2.58	0.22		1.44	0.81 to 2.59	0.22		1.42	0.80 to 2.55	0.24
PC1	1.00	1.00 to 1.01	0.25		1.00	1.00 to 1.01	0.26		1.00	1.00 to 1.01	0.21

Table 4b: Association of mean maximum temperature with diarrhea

Model IIIa (Above median scenario)					**Model IIIb (Below median scenario)**				**Model IIIc (Median scenario)**		
	Diarrhea				**Diarrhea**				**Diarrhea**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean maximum temperature	1.04	0.98 to 1.09	0.20		1.04	0.98 to 1.09	0.20		1.04	0.98 to 1.09	0.19
Total precipitation	1.00	0.99 to 1.00	0.11		1.00	0.99 to 1.00	0.11		1.00	0.99 to 1.00	0.11

Mean $PM_{2.5}$	1.01	1.003 to 1.03	**0.02**		1.01	1.003 to 1.03	**0.02**		1.01	1.003 to 1.03	**0.01**
Ethnicity											
Brahmin/Chhetri	Ref				Ref				Ref		
Dalit and others	0.94	0.48 to 1.77	0.86		0.94	0.48 to 1.77	0.85		0.94	0.48 to 1.77	0.85
Janajati/Indigenous	1.09	0.72 to 1.66	0.70		1.08	0.72 to 1.66	0.70		1.09	0.72 to 1.66	0.70
Residence											
Rural	Ref				Ref				Ref		
Urban	0.78	0.50 to 1.19	0.26		0.78	0.50 to 1.20	0.26		0.79	0.50 to 1.21	0.29
Sex											
Boy	Ref				Ref				Ref		
Girl	0.99	0.71 to 1.36	0.94		0.99	0.71 to 1.36	0.94		0.99	0.71 to 1.36	0.94
Age	1.00	0.99 to 1.01	0.57		1.00	0.99 to 1.01	0.58		1.00	0.99 to 1.01	0.57
Fever											
No	Ref				Ref				Ref		
Yes	1.46	1.04 to 2.03	**0.03**		1.46	1.04 to 2.03	**0.03**		1.46	1.04 to 2.03	**0.03**
Season											

Drier	Ref				Ref				Ref		
Wetter	1.49	0.86 to 2.60	0.16		1.49	0.87 to 2.60	0.15		1.48	0.86 to 2.58	0.17
PC1	1.00	1.00 to 1.01	0.28		1.00	1.00 to 1.01	0.29		1.00	1.00 to 1.01	0.24

Table 4c: Association of mean temperature with diarrhea

Model IIIa (Above median scenario)					**Model IIIb (Below median scenario)**				**Model IIIc (median scenario)**		
	Diarrhea				**Diarrhea**				**Diarrhea**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean temperature	1.04	0.98 to 1.10	0.17		1.04	0.98 to 1.10	0.19		1.04	0.98 to 1.10	0.17
Total precipitation	1.00	0.99 to 1.00	0.07		1.00	0.99 to 1.00	0.07		1.00	0.99 to 1.00	0.07
Mean $PM_{2.5}$	1.02	1.003 to 1.03	**0.01**		1.02	1.003 to 1.03	**0.01**		1.02	1.003 to 1.03	**0.01**
Ethnicity											
Brahmin/Chhetri	Ref				Ref				Ref		
Dalit and others	0.94	0.48 to 1.77	0.86		0.94	0.48 to 1.77	0.85		0.94	0.48 to 1.77	0.85
Janajati/Indigenous	1.08	0.72 to 1.66	0.71		1.08	0.72 to 1.65	0.72		1.08	0.72 to 1.66	0.71

Residence											
Rural	Ref				Ref				Ref		
Urban	0.79	0.50 to 1.22	0.29		0.79	0.50 to 1.22	0.30		0.8	0.51 to 1.24	0.33
Sex											
Boy	Ref				Ref				Ref		
Girl	0.99	0.71 to 1.36	0.93		0.99	0.71 to 1.36	0.93		0.99	0.71 to 1.36	0.93
Age	1.00	0.99 to 1.01	0.58		1.00	0.99 to 1.01	0.58		1.00	0.99 to 1.01	0.57
Fever											
No	Ref				Ref				Ref		
Yes	1.45	1.03 to 2.03	**0.03**		1.45	1.03 to 2.02	**0.03**		1.45	1.03 to 2.02	**0.03**
Season											
Drier	Ref				Ref				Ref		
Wetter	1.43	0.81 to 2.58	0.22		1.44	0.81 to 2.59	0.22		1.42	0.80 to 2.55	0.24
PC1	1.00	1.00 to 1.01	0.25		1.00	1.00 to 1.01	0.26		1.00	1.00 to 1.01	0.21

Table 4d: Association of mean minimum temperature with diarrhea

Model IIIa (Above median scenario)					Model IIIb (Below median scenario)				Model IIIc (Median scenario)		
	Diarrhea				Diarrhea				Diarrhea		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean minimum temperature	1.04	0.98 to 1.10	0.20		1.04	0.98 to 1.09	0.20		1.04	0.98 to 1.10	0.18
Total precipitation	1.00	0.99 to 1.00	0.06		1.00	0.99 to 1.00	0.06		1.00	0.99 to 1.00	0.06
Mean $PM_{2.5}$	1.02	1.003 to 1.03	**0.01**		1.02	1.003 to 1.03	**0.01**		1.02	1.003 to 1.03	**0.01**
Ethnicity											
Brahmin/Chhetri	Ref				Ref				Ref		
Dalit and others	0.94	0.48 to 1.77	0.85		0.94	0.48 to 1.77	0.85		0.94	0.48 to 1.77	0.85
Janajati/Indigenous	1.08	0.72 to 1.65	0.72		1.08	0.72 to 1.65	0.73		1.08	0.72 to 1.65	0.72
Residence											
Rural	Ref				Ref				Ref		
Urban	0.79	0.50 to 1.23	0.31		0.79	0.50 to 1.23	0.31		0.81	0.51 to 1.25	0.35

Sex											
Boy	Ref				Ref				Ref		
Girl	0.99	0.71 to 1.37	0.94		0.99	0.71 to 1.37	0.94		0.99	0.71 to 1.37	0.94
Age	1.00	0.99 to 1.01	0.58		1.00	0.99 to 1.01	0.58		1.00	0.99 to 1.01	0.57
Fever											
No	Ref				Ref				Ref		
Yes	1.44	1.03 to 2.02	**0.03**		1.44	1.03 to 2.02	**0.03**		1.44	1.03 to 2.02	**0.03**
Season											
Drier	Ref				Ref				Ref		
Wetter	1.42	0.78 to 2.60	0.25		1.42	0.78 to 2.61	0.25		1.4	0.77 to 2.56	0.27
PC1	1.00	1.00 to 1.01	0.24		1.00	1.00 to 1.01	0.25		1.00	1.00 to 1.01	0.20

Table 4e: Association of mean $PM_{2.5}$ with diarrhea

Model IIIa (Above median scenario)					Model IIIb (Below median scenario)				Model IIIc (Median scenario)		
	Diarrhea				Diarrhea				Diarrhea		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean $PM_{2.5}$	1.02	1.003 to 1.03	**0.01**		1.02	1.003 to 1.03	**0.01**		1.02	1.003 to 1.03	**0.01**
Total precipitation	1.00	0.99 to 1.00	0.07		1.00	0.99 to 1.00	0.07		1.00	0.99 to 1.00	0.07
Mean temperature	1.04	0.98 to 1.10	0.19		1.04	0.98 to 1.10	0.19		1.04	0.98 to 1.10	0.17
Ethnicity											
Brahmin/Chhetri	Ref				Ref				Ref		
Dalit and others	0.94	0.48 to 1.77	0.86		0.94	0.48 to 1.77	0.85		0.94	0.48 to 1.77	0.85
Janajati/Indigenous	1.08	0.72 to 1.66	0.71		1.08	0.72 to 1.65	0.72		1.08	0.72 to 1.66	0.71
Residence											
Rural	Ref				Ref				Ref		
Urban	0.79	0.50 to 1.22	0.29		0.79	0.50 to 1.22	0.30		0.8	0.51 to 1.24	0.33
Sex											

Boy	Ref				Ref				Ref		
Girl	0.99	0.71 to 1.36	0.93		0.99	0.71 to 1.36	0.93		0.99	0.71 to 1.36	0.93
Age	1.00	0.99 to 1.01	0.58		1.00	0.99 to 1.01	0.58		1.00	0.99 to 1.01	0.57
Fever											
No	Ref				Ref				Ref		
Yes	1.45	1.03 to 2.03	**0.03**		1.45	1.03 to 2.02	**0.03**		1.45	1.03 to 2.02	**0.03**
Season											
Drier	Ref				Ref				Ref		
Wetter	1.43	0.81 to 2.58	0.22		1.44	0.81 to 2.59	0.22		1.42	0.80 to 2.55	0.24
PC1	1.00	1.00 to 1.01	0.25		1.00	1.00 to 1.01	0.26		1.00	1.00 to 1.01	0.21

Table 5a: Association of total precipitation with ARI

Model IIIa (Above median scenario)					Model IIIb (Below median scenario)				Model IIIc (Median scenario)		
	ARI				ARI				ARI		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Total precipitation	1.00	1.00 to 1.00	0.98		1.00	1.00 to 1.00	0.98		1.00	1.00 to 1.00	0.98
Mean temperature	1.03	0.99 to 1.08	0.11		1.03	0.99 to 1.08	0.11		1.03	0.99 to 1.08	0.09
Mean $PM_{2.5}$	1.00	0.99 to 1.01	0.91		1.00	0.99 to 1.01	0.91		1.00	0.99 to 1.01	0.89
Ethnicity											
Brahmin/Chhetri	Ref				Ref				Ref		
Dalit and others	1.31	0.83 to 2.07	0.24		1.31	0.83 to 2.07	0.24		1.31	0.83 to 2.06	0.25
Janajati/ Indigenous	1.18	0.87 to 1.60	0.30		1.18	0.87 to 1.60	0.30		1.18	0.87 to 1.60	0.30
Residence											

Rural	Ref				Ref				Ref		
Urban	0.53	0.38 to 0.74	**<0.01**		0.53	0.38 to 0.74	**<0.01**		0.54	0.38 to 0.75	**<0.01**
Sex											
Boy	Ref				Ref				Ref		
Girl	1.11	0.87 to 1.40	0.40		1.11	0.87 to 1.40	0.40		1.11	0.87 to 1.40	0.40
Age	1.00	0.99 to 1.01	0.57		1.00	0.99 to 1.01	0.56		1.00	0.99 to 1.01	0.58
Danger sign											
No	Ref				Ref				Ref		
Yes	6.57	3.80 to 11.49	**<0.01**		6.58	3.81 to 11.51	**<0.01**		6.58	3.80 to 11.51	**<0.01**
Fever											
No	Ref				Ref				Ref		
Yes	2.65	2.08 to 3.38	**<0.01**		2.65	2.08 to 3.38	**<0.01**		2.65	2.08 to 3.38	**<0.01**
Season											
Drier	Ref				Ref				Ref		
Wetter	0.91	0.59 to 1.41	0.68		0.91	0.59 to 1.41	0.68		0.9	0.59 to 1.39	0.64
PC1	1.00	1.00 to 1.01	0.09		1.00	1.00 to 1.00	0.09		1.00	1.00 to 1.00	0.06

Table 5b: Association of mean maximum temperature with ARI

Model IIIa (Above median scenario)					Model IIIb (Below median scenario)				Model IIIc (Median scenario)		
	ARI				ARI				ARI		
Variables	***Odds Ratios***	***CI***	***p***		**Odds Ratios**	**CI**	**p**		***Odds Ratios***	***CI***	***p***
Mean maximum temperature	1.02	0.98 to 1.06	0.26		1.02	0.98 to 1.06	0.26		1.02	0.98 to 1.06	0.24
Total precipitation	1.00	1.00 to 1.00	0.84		1.00	1.00 to 1.00	0.84		1.00	1.00 to 1.00	0.84
Mean $PM_{2.5}$	1.00	0.99 to 1.01	0.93		1.00	0.99 to 1.01	0.93		1.00	0.99 to 1.01	0.93
Ethnicity											
Brahmin/Chhetri	Ref				Ref				Ref		
Dalit and others	1.32	0.83 to 2.08	0.24		1.32	0.83 to 2.07	0.24		1.32	0.83 to 2.07	0.24
Janajati/ Indigenous	1.19	0.88 to 1.62	0.27		1.18	0.88 to 1.61	0.28		1.19	0.88 to 1.62	0.27

Residence											
Rural	Ref				Ref				Ref		
Urban	0.51	0.37 to 0.71	**<0.01**		0.51	0.37 to 0.71	**<0.01**		0.52	0.37 to 0.72	**<0.01**
Sex											
Boy	Ref				Ref				Ref		
Girl	1.11	0.88 to 1.41	0.38		1.11	0.88 to 1.41	0.38		1.11	0.88 to 1.41	0.38
Age	1.00	0.99 to 1.01	0.57		1.00	0.99 to 1.01	0.56		1.00	0.99 to 1.01	0.57
Danger sign											
No	Ref				Ref				Ref		
Yes	6.63	3.83 to 11.58	**<0.01**		6.64	3.84 to 11.60	**<0.01**		6.64	3.84 to 11.60	**<0.01**
Fever											
No	Ref				Ref				Ref		
Yes	2.67	2.09 to 3.40	**<0.01**		2.67	2.09 to 3.40	**<0.01**		2.67	2.09 to 3.40	**<0.01**
Season											
Drier	Ref				Ref				Ref		
Wetter	1.00	0.67 to 1.51	0.99		1.00	0.67 to 1.51	0.99		0.99	0.66 to 1.50	0.97

PC1	1.00	1.00 to 1.00	0.15		1.00	1.00 to 1.00	0.15		1.00	1.00 to 1.00	0.11

Table 5c: Association of mean temperature with ARI

Model IIIa (Above median scenario)					**Model IIIb (Below median scenario)**				**Model IIIc (Median scenario)**		
	ARI				**ARI**				**ARI**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean temperature	1.03	0.99 to 1.08	0.11		1.03	0.99 to 1.08	0.11		1.03	0.99 to 1.08	0.09
Total precipitation	1.00	1.00 to 1.00	0.98		1.00	1.00 to 1.00	0.98		1.00	1.00 to 1.00	0.98
Mean $PM_{2.5}$	1.00	0.99 to 1.01	0.91		1.00	0.99 to 1.01	0.91		1.00	0.99 to 1.01	0.89
Ethnicity											
Brahmin/Chhetri	Ref				Ref				Ref		
Dalit and others	1.31	0.83 to 2.07	0.24		1.31	0.83 to 2.07	0.24		1.31	0.83 to 2.06	0.25
Janajati/	1.18	0.87 to 1.60	0.30		1.18	0.87 to 1.60	0.30		1.18	0.87 to 1.60	0.30

Indigenous											
Residence											
Rural	Ref				Ref				Ref		
Urban	0.53	0.38 to 0.74	**<0.01**		0.53	0.38 to 0.74	**<0.01**		0.54	0.38 to 0.75	**<0.01**
Sex											
Boy	Ref				Ref				Ref		
Girl	1.11	0.87 to 1.40	0.40		1.11	0.87 to 1.40	0.40		1.11	0.87 to 1.40	0.40
Age	1.00	0.99 to 1.01	0.60		1.00	0.99 to 1.01	0.56		1.00	0.99 to 1.01	0.58
Danger sign											
No	Ref				Ref				Ref		
Yes	6.57	3.80 to 11.49	**<0.01**		6.58	3.81 to 11.51	**<0.01**		6.58	3.80 to 11.51	**<0.01**
Fever											
No	Ref				Ref				Ref		
Yes	2.65	2.08 to 3.38	**<0.01**		2.65	2.08 to 3.38	**<0.01**		2.65	2.08 to 3.38	**<0.01**
Season											
Drier	Ref				Ref				Ref		

Wetter	0.91	0.59 to 1.41	0.68		0.91	0.59 to 1.41	0.68		0.9	0.59 to 1.39	0.64
PC1	1.00	1.00 to 1.01	0.09		1.00	1.00 to 1.00	0.09		1.00	1.00 to 1.00	0.06

Table 5d: Association of mean minimum temperature with ARI

Model IIIa (Above median scenario)					**Model IIIb (Below median scenario)**				**Model IIIc (Median scenario)**		
	ARI				**ARI**				**ARI**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean minimum temperature	1.04	1.001 to 1.08	**0.04**		1.04	1.001 to 1.08	**0.04**		1.04	1.001 to 1.09	**0.04**
Total precipitation	1.00	1.00 to 1.00	0.73		1.00	1.00 to 1.00	0.73		1.00	1.00 to 1.00	0.72
Mean $PM_{2.5}$	1.00	0.99 to 1.01	0.72		1.00	0.99 to 1.01	0.71		1.00	0.99 to 1.01	0.70
Ethnicity											
Brahmin/Chhetri	Ref				Ref				Ref		
Dalit and others	1.31	0.83 to 2.06	0.25		1.31	0.82 to 2.06	0.25		1.31	0.82 to 2.06	0.25

Janajati/ Indigenous	1.17	0.86 to 1.59	0.33		1.16	0.86 to 1.59	0.33		1.17	0.86 to 1.59	0.33
Residence											
Rural	Ref				Ref				Ref		
Urban	0.55	0.39 to 0.76	**<0.01**		0.55	0.39 to 0.77	**<0.01**		0.56	0.40 to 0.78	**0.01**
Sex											
Boy	Ref				Ref				Ref		
Girl	1.1	0.87 to 1.40	0.41		1.1	0.87 to 1.40	0.42		1.1	0.87 to 1.40	0.41
Age	1.00	0.99 to 1.01	0.57		1.00	0.99 to 1.01	0.56		1.00	0.99 to 1.01	0.58
Danger sign											
No	Ref				Ref				Ref		
Yes	6.5	3.76 to 11.37	**<0.01**		6.52	3.76 to 11.40	**<0.01**		6.51	3.76 to 11.39	**<0.01**
Fever											
No	Ref				Ref				Ref		
Yes	2.63	2.06 to 3.35	**<0.01**		2.62	2.06 to 3.35	**<0.01**		2.62	2.06 to 3.35	**<0.01**
Season											

Drier	Ref				Ref				Ref		
Wetter	0.84	0.53 to 1.31	0.43		0.84	0.53 to 1.31	0.43		0.82	0.53 to 1.29	0.40
PC1	1.00	1.00 to 1.01	0.05		1.00	1.00 to 1.01	0.05		1.00	1.00 to 1.00	**0.04**

Table 5e: Association of mean $PM_{2.5}$ with ARI

Model IIIa (Above median scenario)					**Model IIIb (Below median scenario)**				**Model IIIc (Median scenario)**		
	ARI				**ARI**				**ARI**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean $PM_{2.5}$	1.00	0.99 to 1.01	0.91		1.00	0.99 to 1.01	0.91		1.00	0.99 to 1.01	0.89
Total precipitation	1.00	1.00 to 1.00	0.98		1.00	1.00 to 1.00	0.98		1.00	1.00 to 1.00	0.98
Mean temperature	1.03	0.99 to 1.08	0.11		1.03	0.99 to 1.08	0.11		1.03	0.99 to 1.08	0.09
Ethnicity	Ref				Ref				Ref		
Brahmin/Chhetri											
Dalit and others	1.31	0.83 to 2.07	0.24		1.31	0.83 to 2.07	0.24		1.31	0.83 to 2.06	0.25

Janajati/ Indigenous	1.18	0.87 to 1.60	0.30		1.18	0.87 to 1.60	0.30		1.18	0.87 to 1.60	0.30
Residence											
Rural	Ref				Ref				Ref		
Urban	0.53	0.38 to 0.74	**<0.01**		0.53	0.38 to 0.74	**<0.01**		0.54	0.38 to 0.75	**<0.01**
Sex											
Boy	Ref				Ref				Ref		
Girl	1.11	0.87 to 1.40	0.40		1.11	0.87 to 1.40	0.40		1.11	0.87 to 1.40	0.40
Age	1.00	0.99 to 1.01	0.57		1.00	0.99 to 1.01	0.56		1.00	0.99 to 1.01	0.58
Danger sign											
No	Ref				Ref				Ref		
Yes	6.57	3.80 to 11.49	**<0.01**		6.58	3.81 to 11.51	**<0.01**		6.58	3.80 to 11.51	**<0.01**
Fever											
No	Ref				Ref				Ref		

Yes	2.65	2.08 to 3.38	**<0.01**		2.65	2.08 to 3.38	**<0.01**		2.65	2.08 to 3.38	**<0.01**
Season											
Drier	Ref				Ref				Ref		
Wetter	0.91	0.59 to 1.41	0.68		0.91	0.59 to 1.41	0.68		0.9	0.59 to 1.39	0.64
PC1	1.00	1.00 to 1.01	0.09		1.00	1.00 to 1.00	0.09		1.00	1.00 to 1.00	0.06

Table 6: Association of mean $PM_{2.5}$ and diarrhea in the urban areas

	Diarrhea		
Variables	***Odds Ratios***	***CI***	***p***
Mean $PM_{2.5}$	1.03	1.003 to 1.07	**0.04**
Total precipitation	1.00	0.99 to 1.003	0.62
Mean temperature	1.03	0.86 to 1.22	0.75

N.B. Models include all variables adjusted for in the baseline model (Table 4a-e). Coefficients, confidence intervals, and p-values for adjusted variables are not shown.

Table 7: Association of mean $PM_{2.5}$ and diarrhea in the wetter season

	Diarrhea		
Variables	***Odds Ratios***	***CI***	***p***
Mean $PM_{2.5}$	1.05	1.02 to 1.07	**<0.01**
Total precipitation	1.00	1.00 to 1.00	0.88
Mean temperature	0.94	0.81 to 1.08	0.39

N.B. Models include all variables adjusted for the baseline model (Table 4a-e). Coefficients, confidence intervals, and p-values for adjusted variables are not shown.

4. **Discussion**

This is one of the few studies in Nepal and among the first to investigate the effect of weather factors and $PM_{2.5}$ on childhood infectious diseases in Kavre. The study reported a prevalence of 11% for diarrhea and 27% for ARI. Consistently, we observed a statistically significant effect of mean $PM_{2.5}$ exposure on diarrhea in all unadjusted and adjusted models. The association between environmental variables and ARI was statistically significant only for mean minimum temperature exposure in adjusted models. We did not observe effect modification by residence or season for diarrhea and ARI. However, there was a positive association between the diarrhea and mean $PM_{2.5}$ in urban areas and during the wetter season.

This study found a positive effect of mean $PM_{2.5}$ exposure on diarrhea. Studies that directly examined the association between $PM_{2.5}$ exposure and diarrhea are limited. We found only one study conducted in Jilin province in China that examined the short-term impacts of environmental factors, including the air quality index (AQI), on the risk of viral diarrhea infection.[31] The study observed a complicated relationship between viral diarrhea infection risk among children and the AQI. They reported a lower cumulative infection risk of viral diarrhea with a higher AQI. With a lower AQI, they reported a higher cumulative infection risk of viral diarrhea. However, the relationship was statistically non-significant.[31] A few studies have investigated the association between air pollution and cause-specific under-five children mortality, including diarrhea,[49] and air pollution effects in terms of digestive issues.[50] A study by He et al.[49] in China reported that short-term exposure to $PM_{2.5}$ was significantly associated with mortality from various causes, including diarrhea and digestive diseases. Some direct or indirect pathways concerning diarrhea and air pollutants have been discussed.[31] For example, diarrhea-causing pathogens, including rotavirus and norovirus, can be transmitted through the air, forming aerosols.[31] Such pathogens are carried on the surface of inhalable fine particulate matter (e.g., PM_{10} and $PM_{2.5}$), which can contaminate children's living environment and increase the infection risk from digestive tract diseases.[31] Wei et al.[51] discussed the possibility that $PM_{2.5}$ exposure was linked with fluid and electrolyte disorders, which might explain the underlying relationship between $PM_{2.5}$ and diarrhea and digestive-specific child mortality. Furthermore, ingestion of particulate matter has been shown to alter gut microbiota composition and function, which can have detrimental effects on the digestion process and structure and function of the intestinal mucosa.[50]

We found no association between temperature (mean minimum, mean, and mean maximum) exposure and diarrhea in this study, which do not align with previous studies' findings.[16,23,25,26] For example, a study by Hashizume et al.[25] in Bangladesh reported that hospital visits of patients, including children under 15 years for non-cholera diarrhea, was significantly associated with high temperatures. A systematic review and meta-analysis of ambient temperature and diarrhea in people, including children younger than five years, also reported a positive association between ambient temperature and all-cause diarrhea and bacterial diarrhea.[26] Similarly, Bhandari et al.[23] found a significant association between maximum temperature exposure and monthly counts of diarrhea cases in children younger than five years. Specifically, they observed an 8.1% increase in the counts of diarrheal cases with a 1°C increase in maximum temperature above the average recorded within that month.[23] The relationship between temperature and diarrhea is biologically plausible as higher temperatures promote the growth and survival of diarrheagenic pathogens. Some enteric viruses have been found to survive and cause transmission even under lower temperatures.[23,25] Additionally, Levy et al.[52] linked water scarcity during dry summer months to facilitating diarrheagenic pathogens transmission due to compromised hyigiene.[52]

We also observed no association between total precipitation and diarrhea, which contrasts with the findings of previous studies.[25,53] For example, a study by Dimitrova et al.[53] showed strong evidence of an association between symptoms of diarrhea in children under three years and precipitation. Another study by Hashizume et al.[25] showed an increase in non-cholera diarrhea in patients, including children younger than 15 years, with exposure to high levels of precipitation with lags of 0-8 weeks. They also observed an increase in the number of cases with exposure to both high and low levels of precipitation with lags of 0-16 weeks. The pathway through which temperature and precipitation affect the occurrence of diarrhea in children is mainly focused on water scarcity[52] and fecal contamination of water or food.[54,55] For example, a study suggested that precipitation could intensify the propagation and transmission of diarrheagenic pathogens in reservoirs[56], which could then enter a child's body through inappropriate hygiene and sanitation-related behaviours, including the consumption of contaminated food or water. One of the critical reasons for not observing significant impacts of temperature (mean maximum, mean, and mean minimum) and total precipitation on diarrhea in this study may be linked to the availability of potable water in the district throughout the year. According to the Nepal's 2021 census, approximately 80% of the Kavre residents used tap or piped water[34], which is considered to be more protected from fecal contamination.

We found a positive effect of mean minimum temperature on ARI. The study findings are in line with the findings from previous studies. Mourtzoukou and Falagas[57] reported an increased risk of developing URTI and LRTI and mortality with exposure to low environmental temperatures. Furthermore, they reported that the longer the exposure duration, the higher the infection risk. Mäkinen et al.[58] found a higher susceptibility to lower respiratory tract infections at temperatures between 0 and 10°C. Prel et al.[59] also discussed chilliness as contributing to higher respiratory infection hospitalization rates in colder seasons. A qualitative exploration of the Nepalese rural women's perspectives and lived experiences concerning climate change also highlighted ARI as a critical health problem in children younger than five years. (Tiwari, pers.comm.) Several proposed mechanisms exist for the increased occurrence of RTIs with colder temperatures. For example, indoor crowding, particularly during colder temperatures, promotes the transmission of RTIs[58,60] and likely affects the association between minimum temperature and RTIs. It has been suggested that the inhalation of cold air causes cooling of the nasal epithelium, inhibiting respiratory defences against infection, such as mucociliary clearance and the phagocytic activity of leukocytes, resulting in RTIs.[61]

This study did not observe a statistically significant association between mean $PM_{2.5}$ exposure and ARI, which aligns with some previous studies' findings. For example, a meta-analysis of ten European cohort studies involved in the European Study of Cohorts for Air Pollution Effects (ESCAPE) reported a statistically non-significant association between $PM_{2.5}$ exposure and respiratory infection in children younger than two years (AOR 2.58, 95% CI 0.91 – 7.27)[62]. However, the same meta-analysis reported a significant association between PM_{10} and pneumonia[62]. In contrast, another meta-analysis reported a higher risk of respiratory infections in children younger than five years with increased $PM_{2.5}$ concentrations.[63] They reported a 1.12 increase in acute lower respiratory infection risk per 10 $\mu g/m^2$ increase in $PM_{2.5}$ in children.[63] Air pollution, including $PM_{2.5}$, may impair defence mechanisms[64], thus increasing susceptibility to respiratory infections primarily via an inflammatory response.[65]

We observed a statistically non-significant association between total precipitation and ARI in this study. Previous studies have reported mixed findings. For example, Murray et al.[4] reported that precipitation was significantly associated with ARI (OR 2.97, 95% CI 1.87 – 4.70). In contrast, Uttajug et al.[66] analyzed DHS data of sub-Saharan Africa and reported a non-significant association between extreme precipitation and ARI, except in Nigeria. It is hypothesized that precipitation leads to more time spent indoors, increasing exposure to other people and increasing the risk of ARI.[4]

Stratified Analysis of the Association Between Environmental Exposure and Diarrhea

We observed a statistically significant association between mean $PM_{2.5}$ and diarrhea in urban areas and during the wetter season. In rural Nepal, air pollution is generally linked to solid fuel use. According to Nepal's census in 2021, approximately 50% of Kavre households use wood as cooking fuel, mainly in rural settings.[34] Although data on households using improved cooking stoves are unavailable, we can expect reduced exposure to household smoke due to improved cooking stoves. In urban areas of Nepal, vehicular emissions and brick kilns have been reported to be the largest contributors to air pollution[66], including the Kathmandu Valley and Kavre district. Therefore, more urban children in the study may have diarrhea that can be attributed to $PM_{2.5}$ exposure. On the other hand, in the wetter season, high precipitation causes an increase in relative humidity that enhances the adsorption of water vapour onto particles, causing speedy settling and deposition of $PM_{2.5}$[67], which may contaminate children's living environment, including water and food. For this reason, $PM_{2.5}$ during the wetter season may have significantly affected diarrhea.

Strengths and Limitations

This study has several strengths. We used data from remote-sensing technologies at spatial and temporal scales that Nepal's current climate infrastructure cannot capture. We adopted a multi-pronged approach to explore the relationships between environmental exposures, sociodemographic and health service-related variables, and childhood infectious diseases. We also performed a sensitivity analysis, examining different levels of sociodemographic variables in separate models (Model IIIa-c) to investigate the effect of environmental exposures on childhood infectious diseases.

We acknowledge some important limitations of this study. The environmental exposure variables used in this study are ecological and represent an approximation of children's actual exposure. Several area-level sociodemographic variables obtained from the NDHS were used in this study, which may not be true for individual children of the ward. Therefore, ecological fallacy is a potential issue. This observational study restricts our ability to establish causation or capture the full spectrum of potential confounding variables, including maternal variables. Indoor air pollution, which we could not directly measure, may have a relative contribution to diarrhea and ARI risk. However, the type of fuel used by the household for cooking or heating purposes, a proxy indicator of household air pollution, was included in analyses. The DHS also deliberately introduces random errors in the GPS coordinates for the centroid of the survey clusters to protect anonymity, causing erroneous linkage of all NDHS variables to wards of the district, which was not accounted for in this study. The participants who visited the health posts and/or hospital likely differed from those who did not regarding accessibility, affordability, and health awareness, which introduces the potential for selection bias. Furthermore, comparators for this study, i.e., children without diarrhea or ARI, were also randomly selected from the same health record, many of whom are likely to share these exposures. This could have affected the measure of effect, i.e., bias towards or away from the null hypothesis of no association, also known as Berkson's bias.[68] Health records were incomplete, which were filled using other data sources. Nonetheless bias may still be a concern. Despite the nested nature of the population in wards, we could not use multilevel modelling due to the limited number of participants in most wards. Meteorological and $PM_{2.5}$ data from ground-level monitoring stations could not be applied due to the limited number of such stations, leading to poor geographical coverage and a high proportion of missing data observed at these stations, particularly $PM_{2.5}$. The use of remote sensing data also has limitations with regard to resolution and quality, affecting the accuracy and usefulness of the data.

Significance of this Study

This study differs from previous studies in terms of environmental exposures, outcomes, and the methods used. Therefore, we could not directly compare the magnitude of our estimates with those of earlier studies. We only discussed the consistency of study results with those in other studies. Furthermore, there are complexities in comparing studies due to differences in healthcare systems across countries, environmental exposure trends, and communities. However, this study adds to the few studies conducted in Nepal and is the first in Kavre to investigate a relationship between exposure to environmental factors and childhood infectious diseases. Our study showed that $PM_{2.5}$ was significantly associated with diarrhea, and minimum temperature significantly associated with ARI. Researchers and policymakers can use these findings to inform future investigations and healthcare strategies to protect and promote child health in the region.

5. **Conclusion**

This study is among the few studies in Nepal and one of the first to investigate an association between temperature, precipitation, $PM_{2.5}$, and childhood infectious diseases in the Kavre district. We found a positive association between mean $PM_{2.5}$ exposure and diarrhea. A positive association between mean minimum temperature exposure and ARI was also observed in this study. This study is consistent with previous studies that have reported a relationship between $PM_{2.5}$, minimum temperature exposure, diarrhea and ARI.

Tackling these issues will require collaborative efforts from local-level government and non-government stakeholders, including health posts, hospitals, and municipal governments. Strategies to minimize air pollution in the region and to protect and promote children's health by strengthening the local health system and ensuring effective health service delivery are needed. Furthermore, the government of Nepal needs to invest in its climate and health infrastructure to capture environmental and health data reliably.

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Chapter VI

6. Conclusion

Climate change is a critical global concern, with low- and middle-income countries, including Nepal, bearing more significant impacts due to heightened exposures, hazards, and vulnerability. Climate change hazards such as floods, landslides, storms, water scarcity, extreme hot weather, and air pollution have significantly affected Nepal. Population subgroups such as women and children are disproportionately affected by climate change due to factors such as cultural norms, economic dependence, controlled mobility, decision-making exclusion; and immature immune systems, rapid physiological development, and dependence on adult caretakers, respectively.[1–4] Therefore, in this thesis work, we examined the association of perinatal health indicators of women (adverse pregnancy outcomes (APOs): stillbirth, preterm birth, low birthweight) and children (diarrhea and acute respiratory infections (ARI)) with weather variables and air pollution in the Kavre district of Nepal, addressing a critical knowledge gap in the area. This work also explored women's perspectives and lived experiences concerning longer-term changing weather patterns, consequent changes in agriculture and health, and ongoing climate-related adaptation activities in Kavre. The thesis work intended to generate evidence of the poorly examined association between environmental exposures and perinatal and children's health outcomes in a rural district of Nepal. It also aimed to learn from and amplify the voice of Nepalese rural women around their experiences with longer-term weather patterns, air pollution, and related health, agricultural, and environmental impacts.

As a Nepali citizen born and raised in an urban environment, my perspective and experiences were deeply rooted in urban Nepali life. However, my engagement in conducting Focus Group Discussions (FGDs) and interviews within a rural community setting gave me a unique opportunity to step outside my familiar urban surroundings and delve into the realities of rural Nepali life. I was committed to approaching my research with humility, openness, and a willingness to learn from primarily rural women's diverse perspectives and lived experiences. I recognized the importance of acknowledging my positionality of privilege as a male outsider entering this space and strove to engage in meaningful conversations that respected women's perspectives. Through this process, I aimed to build for others and myself a more comprehensive understanding of rural Nepali women's perspectives and lived experiences, ultimately amplifying their voices for more inclusive and equitable initiatives that address their needs and concerns. This work was supported by a diverse doctoral committee with backgrounds in gender and feminist research, climate change, air pollution, qualitative methods, quantitative methods, health policy, health geography, and global health.

This thesis research started with a scoping review (Chapter II) to synthesize existing evidence regarding the health impacts of climate change and air pollution on women and children in South Asia.[1] The scoping review also aimed to explore regional research gaps in climate change and health. The review identified a range of health impacts, including adverse pregnancy outcomes, diarrheal disease, respiratory infections, and acute and chronic undernutrition, which helped inform the direction of the rest of this research. Furthermore, the scoping review also highlighted geographical and research-related gaps (both quantitative and qualitative) revealing the disparity in climate change, air pollution and health-related research within South Asian countries, particularly Nepal.

Chapters III, IV, and V involved mixed methods using qualitative and quantitative approaches. Building upon the research gap identified by the scoping review in Chapter II, we assessed climate change and air pollution-related exposure, hazards, and experiences of vulnerability in women and children living in the Kavre district of Nepal. In Chapter III, we specifically explored women's and other stakeholder's perspectives and lived experiences concerning longer-term weather change and air pollution, consequent agricultural and human health impacts, and ongoing adaptation strategies. Other stakeholders included members of the Health Facility Operation Management Committee, some of whom were men. We conducted both FGDs and interviews with a convenience sample of participants. Focus groups and interview participants highlighted maternal and child undernutrition and low birthweight as critical health problems in the region, linking them to decreased harvest yields and the increased consumption of ready-made food. Participants expressed concerns about adverse agricultural impacts due to extreme heat and untimely rainfall, such as reduced soil fertility, crop infestations, and increased pesticide use, which resulted in decreased agricultural production. Tiwari et al.[5] also reported the loss of soil fertility and consequent decrease in crop yields and crop damage attributed to erratic rainfall, contributing to soil erosion, landslides in the upstream and flooding and sedimentation in the downstream sites. Participants also discussed the need for improving health infrastructure to address women's and children's health, which is also indicated by our empirical evidence showing a positive association between other factors, such as health facility visits and adverse pregnancy outcomes and childhood infectious diseases. These findings help advance our understanding of perceptions of climate change and air pollution and their diverse impacts,[6] fill knowledge gaps, emphasize the importance of conducting inclusive research, and highlight the importance of co-design in climate change research and policy.

Chapter IV's research quantitatively examined climate change and air pollution-related risks in terms of adverse pregnancy outcomes. Specifically, we examined the impacts of prenatal exposure to temperature, precipitation, and air pollution ($PM_{2.5}$) on adverse pregnancy outcomes

(APOs) among women living in the Kavre district of Nepal. Our study found no associations between environmental exposures and adverse pregnancy outcomes, a concern reported by women from our focus groups. Published literature worldwide has shown evidence of the statistically significant association of climate factors[7–10] and air pollution[11–13] with birth outcomes. A statistically significant association of temperatures and precipitation with birthweight was only found in the wetter season in this study, correlating with the findings from Chapter III regarding the importance of precipitation, agriculture, and nutrition, as emphasized by participants. Tanou et al.[14] also discussed the potential role of agricultural production and household food security in terms of a positive relationship between precipitation and birthweight in the Republic of Benin. The observed adverse impacts of climate factors on birth outcomes underline the need for enhanced health infrastructure to cope with increased climate change-related disease risks, a point raised by the focus group participants as an important adaptation and mitigation measure. Community awareness encourages positive change directly through promoting behavioural changes or indirectly by employing pressure via the political process.[15] In Nepal, broader community awareness is recognized as a current limitation to climate change adaptation.[16]

Health facility visits for timely antenatal checkups plus urban residence, among other factors, were found to be significant protective factors in reducing adverse pregnancy outcomes. These findings were also deliberated in the focus groups within the broader theme of adaptation, specifically in terms of improving overall health infrastructure and accessibility.

Chapter V included the findings of a research that quantitatively examined climate change and air pollution-related risks in terms of childhood infectious diseases. Specifically, the study aimed to investigate the association of acute exposure to weather factors and air pollution with diarrhea and ARI among children younger than five years old living in the Kavre district of Nepal. The study observed a statistically significant association of acute exposure to $PM_{2.5}$ with diarrhea. There are limited studies examining the association between $PM_{2.5}$ exposure and diarrhea: one study that focused on this relationship did not find a statistically significant association.[17] Specifically, our study observed a statistically significant association between diarrheal disease and acute exposure to $PM_{2.5}$ in urban areas and during the wetter season. The higher level of pollution in urban areas[18] and increased contamination of children's living environment[19], particularly during the wetter season, may have significantly affected occurrences of diarrhea. The association between environmental variables and ARI was statistically significant only for mean minimum temperature exposure in adjusted models. These and other findings indicated a need for a strategy to reduce air pollution as well as to build resilient health systems to address anticipated heightened burdens from climate change, a point also raised by participants in the focus groups.

The research on climate change and health impacts in Nepal and other low-income countries is rare, due, in no small part, to methodological challenges.[3] We needed to conceptualize, plan, conduct and complete this thesis work creatively to overcome various administrative and methodological challenges, including finding the appropriate data sources and linking available data. As such, this thesis research is one of the first studies to explore weather factors, air pollution and the health risks of women and children in the Kavre district of Nepal. In this thesis work, we observed adverse human health, agricultural, and environmental impacts attributed to environmental exposures, highlighting the need for further research in the study area on this topic. Similarly, the thesis research findings suggest the importance of considering seasonal variations and area of residence in assessing birth and children's health outcomes.

Moreover, the study provides valuable insights that can help inform potential broader adaptation strategies such as enhanced health infrastructure. This work also emphasizes the significance of incorporating local knowledge and experiences in developing targeted strategies to strengthen resilience and foster sustainable adaptation in the face of climate and air pollution-related challenges, as the Intergovernmental Panel on Climate Change recommends. Additionally, this research highlights the need to invest in monitoring in Nepal to regularly record and capture environmental data across a wider geographic area.

This study can be considered a robust investigation of climate change and adverse human health impacts as it depended on a mix of interviews, focus group discussions, hospital/health facility-based data, survey data, and remote sensing data in Nepal. However, there were limitations, which we explain in detail in each chapter. Future investigator(s) may benefit from considering those limitations when planning and designing their study. We suggest conducting a prospective longitudinal study with larger cohorts, which will mitigate many of the shortcomings of using secondary data sources. This will also allow for the inclusion of additional key variables.

Despite these limitations, this study provides some of the first empirical evidence of the relationship between environmental exposures and human health outcomes (APOs and childhood infectious diseases). It also amplifies women's voices about their observed and lived experiences related to longer-term weather changes, air pollution and, corresponding health, and agricultural and environmental impacts. It is hoped that policymakers will consider these findings for use in climate change policies in Nepal and South Asia.

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Appendix

Appendix 1: Study Protocol

Assessing climate change vulnerability in South Asia- A scoping review

Ishwar Tiwari, Mckenzie Tilstra, Sandra Campbell, Shelby Yamamoto

Objective

The objective of this scoping review is to explore prior research to learn about climate change vulnerability in South Asian countries (Nepal, India, Bangladesh, Pakistan, Afghanistan, Bhutan, Maldives, and Sri Lanka). We will explore vulnerability as a function of exposure, sensitivity, and adaptive capacity.

Research question

1. What is the existing evidence on the health-related impacts due to climate change extremes (flooding/landslides/drought/heatwaves/storms/sea-level rise), extreme weather events (and air pollution on vulnerable populations (pregnant women/older adults/young children) in South Asia (Nepal/India/Bangladesh/Pakistan/Afghanistan/Maldives/Bhutan/ Sri Lanka)?
2. What is the existing evidence on the vulnerabilities and impacts of climate change and air pollution for vulnerable populations in South Asia?
3. What is the existing evidence on the adaptation measures that are building the resilience of vulnerable populations in South Asia?

Methods

The scoping review will follow the framework outlined in the Joanna Briggs Institute Reviewer's Manual.[1] The Joanna Briggs Institute Reviewer's Manual draws upon two frameworks: the framework proposed by Arksey and O'Malley and the framework proposed by Levac, Colquhoun and O'Brien.[1-3] The manual includes identifying the research question, finding relevant studies, selecting studies, charting the data, and collating, summarizing and reporting the results. The present scoping review will follow the reporting guidelines set by Tricco et al. in their scoping review extension of the PRISMA checklist.[4]

1.1 Search methods

A search was executed by an expert searcher/health librarian (SC) on the following databases: PROSPERO, OVID Medline, OVID EMBASE, OVID Global Health, Cochrane Library (CDSR and Central), EBSCO CINAHL, Proquest Dissertations and Theses Global and SCOPUS using a controlled vocabulary (eg, MeSH, Emtree, etc) and keywords representing the concepts "vulnerable populations" and "climate change" and "health impacts" and "South Asia." Databases were searched from inception or 2010 to May 2020. No other limits were applied. Results (2283) were exported to COVIDENCE review management software. Duplicates (531) were removed. A detailed search is available in Appendix 1.

i. Electronic Database Search – We will use a comprehensive search to search the following databases:

   a. OVID Medline covers the world's biomedical and health sciences journal literature.

b. OVID Embase is a medical database that covers a wide range of journals in biomedical science.
c. EBSCO CINAHL plus covers topics including patient care, health promotion, professional issues for health care workers, patient education, rehabilitation, and other related subjects.
d. SCOPUS provides literature related to medicine, technology, science, and social sciences.
e. PROSPERO is an international database of prospectively registered systematic reviews in health and social care.
f. Global health brings together the resources of two databases – the Public Health and Tropical Medicine (PHTM) database and the human health and disease information extracted from CAB abstracts.
g. Cochrane Library is a collection of databases that contain different types of high-quality, independent evidence to inform healthcare decision-making.

ii. Proquest dissertation & thesis Global Database of doctoral and masters theses from European universities and North American graduate schools.

iii. Snowball search - We will conduct a snowball search on the reference lists of all the literature that meet the inclusion criteria to capture any articles missed by the initial electronic database search.

2. Screening

2.1 Restrictions

- The search string will not be limited by language.
- Searches will be limited to 2010 to present.

2.2 Level 1 screening

- We will use the screening questions to screen the titles and abstracts that are captured by two independent reviewers in the initial searches.
- Only those articles that completely or partially (unsure) meet the inclusion criteria will move to level two screening (i.e., screening questions that are answered either 'yes' or 'unsure').
- An article that does not meet the inclusion criteria will not move to the second level of screening; however, a second independent reviewer will confirm the exclusion of this article.
- We will use Google Translate to help screen the non-English titles and abstracts.

2.3 Level 2 screening

- This level involves reviewing the full article following the inclusion and exclusion criteria by two independent reviewers.
- The only article that meets all the inclusion criteria will be included in the final review (i.e., any article with 'Unsure' answer will be rejected).

2.4 Inclusion criteria

- We will examine all the published articles irrespective of their original language of publication.
- Only articles that are published in 2010 and onward will be examined.
- We will include any books, book chapters, theses, dissertations, and conference papers and abstract relevant to the topic of interest.

- We will only include researches that focus on the situation for Nepal, Bangladesh, India, Pakistan, Bhutan, Maldives, Afganistan, and Sri Lanka.
- We will include research that examines climate change vulnerability and health effects on vulnerable population:
  - ✓ Must include both climate change vulnerability and health impacts as primary points of interest.
  - ✓ Climate Change: change in climate that persists for a long period of time (decades or longer). Change in climate could be due to natural causes or anthropogenic. Climatic variables (extreme events, extreme temperature, erratic rainfall) in the context of climate change will also be included under this limiter to capture relevant articles that do not directly correlate climatic variables to climate change.
  - ✓ Vulnerability: Health-related vulnerability of different population groups to climate change is defined from three perspectives:
    - ❖ Several exposures to extreme events – e.g., wildfires, floods, heatwaves; air pollution – e.g., particulate matter, ozone
    - ❖ Sensitivity due to the characteristics that increase individuals' exposure-related adverse health risks
    - ❖ The adaptive capacity of systems, institutions, and humans
  - ✓ South Asia refers to countries: Nepal, Bangladesh, Pakistan, India, Bhutan, Maldives, Sri Lanka, and Afghanistan.

2.5 Exclusion criteria

- Articles that are published before 2010 will not be included.

- We will exculde research that describes the situation outside the geographic area of interest (i.e., outside Nepal, Bangladesh, India, Pakistan, Afganistan, Maldives, and Sri Lanka).
- We will exclude the research article that does not examine health-related impacts in vulnerable populations.
- We will exculde the research article that does not focus on the health impacts of climate change and/or air pollution in vulnerable populations.
    - ❖ Research on health-related effects on vulnerable populations, but in the absence of climatic or pollution variables.
    - ❖ Research on the impacts of climatic variables and pollution variables, but not related to the health.
    - ❖ Research on the impacts of climatic variables and pollutants on health but not related to the health of vulnerable populations.

2.6 screening questions

level 1: We will answer the following structured questions after screening each title and/or abstract:

- Does the research focus on exposure to climatic variables (extreme events, extreme temperature, erratic rainfall) and air pollutants?
    - ❖ Yes
    - ❖ No
    - ❖ Unsure
- Does the research include health-related impacts of climate change and air pollution?

- Yes
- No
- Unsure

- Does the research focus on vulnerable populations (elderly, infants, children, and pregnant women)?
  - Yes
  - No
  - Unsure

- Does the research focus on South Asian countries (i.e., Nepal, Bangladesh, India, Pakistan, Afganistan, Bhutan, Maldives, and Sri Lanka)?
  - Yes
  - No
  - Unsure

We will include any articles if the response to the structured questionnaire is 'unsure' or 'yes.'

Level 2: Following the level 1 screening, we will do the second level screening by answering the following questions:

- Does the research focus on exposure to climatic (extreme events) variable and air pollutants?
  - Yes
  - No

- Does the research include health-related impacts of climate change and air pollution?
    - ❖ Yes
    - ❖ No
- Does the research focus on vulnerable populations (elderly, infants, children, and pregnant women)?
    - ❖ Yes
    - ❖ No
- Does the research focus on South Asian countries (i.e., Nepal, Bangladesh, India, Pakistan, Afganistan, Bhutan, Maldives, and Sri Lanka))?
    - ❖ Yes
    - ❖ No

We will include an article if the response to the questions is ‘yes.’

3. Data collection and analysis

3.1 Software

We will use the Covidence © to manage the scoping review. All eligible articles will be exported to Covidence ©. The duplicate records will be removed by the software.

Reference

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9. Campbell, Sandy. A Hedge to Retrieve Studies Related to Bangladesh from the Ovid MEDLINE Database.

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Appendix 2: Search Strategies

Ovid Medline May 12, 2020

#	Search Statement	Results
1	weather/ or Climate/ or climatic processes/ or ((exp climate change/ or cyclonic storms/ or droughts/ or floods/ or greenhouse effect/ or temperature/) and (annual* or daily or month* or ambient or season* or climate or climatic or weather or summer or winter).mp.) or extreme heat/ or hot temperature/ or (((climat* not (political-climate or organizational-climate or economic-climate or financial-climate)) or weather) adj3 (chang* or disrupt* or volati* or instabilit* or unstable or variable or variability or vulnerab*)).mp. or ((chang* or decline* or decrease* or increase*) adj3 humidity).mp. or ((global* or climate) adj2 warm*).mp. or ((climat* or weather) adj (conditions or factors or driven)).mp. or (greenhouse gas* or greenhouse effect* or carbon emission* or carbon dioxide emission* or CO2 emission*).mp. or (((extreme or severe) adj (weather or heat or temperature*)) or hot-weather or heat-wave* or heatwave or high temperatures or ((higher or warm* or hot*) adj3 temperature*)).mp. or ((annual* or daily or month* or ambient or environmental or season* or climate or climatic or weather or summer or winter) adj4 temperature*).mp. or (warm-season* or warm*-month* or (unseasonabl* adj3 (warm or hot or heat or humid* or cold or high or	345030

	low))).mp. or (El Nino or la nina).mp. or (rain or rains or rainstorm* or raining or rainfall or ((high or heavy or extreme or severe or daily or levels) adj2 precipitation) or UV-index or flooding or floods or waterlogging or (drought* not drought-resistan*) or desertifcation or hurricane* or cyclone* or tornado* or superstorm* or dust storm or storm surge* or ice storm* or ((storm or storms) and disaster*) or monsoon*).mp. or (forest fire* or wildfire* or wild fire* or fire disaster* or (uncontrolled adj3 fire*)).mp. or ((sea level* adj3 (rise or rises or rising or increase or increasing or increases)) or ((polar or permafrost or ice-cap or glacier*) adj3 (melt* or retreat* or reced* or thaw*))).mp. or famine*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	

2	exp Air Pollution/ or Traffic-Related Pollution/ or greenhouse gases/ or stratospheric ozone/ or ((gases/ or ammonia/ or carbon dioxide/ or carbon monoxide/ or chlorine/ or greenhouse gases/ or hydrogen sulfide/ or nitrogen/ or nitrogen oxides/ or nitrogen dioxide/ or nitrous oxide/ or ozone/ or sulfur dioxide/ or carbon monoxide*.mp. or hydrogen sulfide*.mp. or hydrogen sulphide*.mp. or H2S.mp. or nitrogen oxide*.mp. or volatile organic*.mp. or voc.mp. or nox.mp. or sulfur dioxide*.mp. or SO2.mp. or sulfur oxide*.mp. or sulphur dioxide*.mp. or sulphur oxide*.mp.) and (exp Pollution/ or pollut*.mp. or emit*.mp. or emission*.mp. or contaminat*.mp. or decontaminat*.mp.)) or ((air or atmospher*) adj3 (pollut* or quality or wast* or contamin* or emission* or immission* or effluent*or acidification or contaminat* or degrad* or decontaminat* or purif* or restor*)).mp. or ((gas or gases) adj3 (toxic* or noxious or releas* or purifi* or scrub* or emit* or waste* or vapo?r)).mp. or (acid* adj3 (deposition* or rain* or snow or fog or mist or precipitation or hail or sleet)).mp. or afterburning.mp. or biogas.mp. or (burning adj3 fossil fuel*).mp. or ((chimney or stack) adj3 height).mp. or dust.mp. or fallout.mp. or fall out.mp. or flaring.mp. or fly ash.mp. or electrosmog.mp. or (greenhouse adj3 (gas or effect or effects or gases or emission*)).mp. or incineration.mp. or odor.mp. or odour.mp. or olfactory pollution.mp. or particulate*.mp. or smog.mp. or smoke.mp. or soot.mp. or sick building syndrome.mp. or vapo?r recovery system*.mp. or ((industrial or automobile* or traffic or freeway or highway or roadway	313380

	or motorway or diesel or vehicle*) adj3 (exhaust* or emission* or emit* or fume or fumes or vapo?r*)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	
3	1 or 2	623906

4	(health* or disease* or outbreak* or infectio* or illness* or virus* or injur* or disorder* or epidemic* or pandemic* or fever* or symptoms).mp. or exp pregnancy complications/ or exp infant, Low Birth Weight/ or stillbirth/ or (deformit* or malformation* or cleft-palate* or cleft-lip* or birth-defect* or congenital heart defect* or spina-bifida or birth-outcome* or pregnancy-outcome* or still-birth or still-born* or stillborn or stillbirth* or low-birth-weight or (fetal-growth adj (restric* or retard*)) or preterm labo* or preterm birth or (hypertension and pregnan*) or preeclampsia).mp. or (((developmental* or intellectual* or learning or mental or cognitive or physical*) adj3 (disab* or impair* or delay* or disorder*)) or mental retard* or handicap* or special needs or down* syndrome or "fragile x" or autis* or asperger* or pervasive developmental disorder* or cerebral palsy or tourette* or tic-disorder* or attention-deficit* or adhd or epilep* or language-disorder* or neurodevelopment* or ((neuro or cognitive or physical*) adj5 development*)).mp. or stress, psychological/ or occupational stress/ or (stress-level* or high*-stress* or psychological-stress* or mental-stress* or burnout or psychiatric or depress* or anxiety or psychos* or stress-disorder* or PTSD or posttrauma* or trauma* or emotional-health).mp. or exp occupational diseases/ or (food-security or food-insecurity or nutrition or undernutrition or malnutrition or malnourish* or undernourish* or overnutrition or famine or food-availability or food-supply or ((nutrition* or vitamin) adj4 deficien*)).mp. or (underweight or	14739699

	thinness or overweight or obes*).mp. or exp diseases/ or exp food safety/ or dietary exposure/ or (food-safety or (food adj4 (contaminat* or poison*))).mp. or ((safe or clean or unsafe or contamina*) adj6 (drink* or potable) adj6 water).mp. or exp mortality/ or exp morbidity/ or pregnancy outcome/ or (mortalit* or death* or fatalit*).mp. or (respiratory or asthma* or allerg* or aeroallerg* or ((breathing or breathe) adj3 (issue* or problem* or difficult* or struggl* or trouble))).mp. or exp heat stress disorders/ or (heat-stress* or heat-exhaustion or heat-stroke* or heatstroke* or sun stroke* or sunstroke*).mp. or (cholera* or diarrhea* or diarrhoea* or dysentery or salmonella or pneumonia* or plasmodium* or babesi* or hantavirus* or giardia* or cryptosporidi* or leptospiros*).mp. or exp parasitic diseases/ or (Trichinos* or trichinellosis or Chikungunya or Dengue or Lymphatic-filariasis or Rift-Valley-fever or Yellow-fever or Zika or Malaria or japanese-encephalitis or tick-borne or West-Nile-fever or Leishmaniasis or Sandfly-fever or phelebotomus-fever or haemorrhagic-fever or Lyme-disease or Relapsing-fever or borreliosis or Rickettsial-diseases or spotted-fever or Q-fever or Tularaemia or Chagas or trypanosomiasis or Sleeping-sickness or Plague or Rickettsiosis or Onchocerciasis or river-blindness or Schistosomiasis or bilharziasis or Typhus or louse-borne-relapsing-fever).mp.	

5	((exp Geriatrics/ or Aged/ or (elders or elderly or geriatric* or old age or (seniors not "high school") or older adult* or centenarian* or nonagenarian* or octogenarian* or septuagenarian* or sexagenarian* or dottering or decrepit or tottering or overaged or "oldest old").mp. or exp child/ or exp "congenital, hereditary, and neonatal diseases and abnormalities"/ or exp infant/ or adolescent/ or exp pediatrics/ or child, abandoned/ or exp child, exceptional/ or child, orphaned/ or child, unwanted/ or minors/ or (pediatric* or paediatric* or child* or newborn* or congenital* or infan* or baby or babies or neonat* or pre-term or preterm* or premature birth* or NICU or preschool* or pre-school* or kindergarten* or kindergarden* or elementary school* or nursery school* or (day care* not adult*) or schoolchild* or toddler* or boy or boys or girl* or middle school* or pubescen* or juvenile* or teen* or youth* or high school* or adolesc* or pre-pubesc* or prepubesc*).mp. or (child* or adolesc* or pediat* or paediat*).jn. or Refugees/ or exp emigrants/) and immigrants/) or (immigrant* or immigration or emmigrant* or emmigration or refugee* or asylum seeker* or asylee* or displaced person* or "incomer*" or "in comer*" or "new comer*" or newcomer* or childbearing or childbirth or pregnan* or fertile or fecund or womanish or womanly or maternal).mp. or Pregnancy/	1181111
6	3 and 4 and 5	12924

7	exp Nepal/ or (Nepal or Nepali or Nepalese or Bharatpur or Bhimdatta or Birganj or Biratnagar or Budhanilkantha or Butwal or Dhangadhi or Dharan or Gokarneshwar or Hetauda or Itahari or Janakpur or Kathmandu or Mount Everest or Nepalganj or Pokhara or Tilottama).mp. or ((Bhojpur or Dhankuta or Ilam or Jhapa or Khotang or Morang or Okhaldhunga or Panchthar or Sankhuwasabha or Solukhumbu or Sunsari or Taplejung or Terhathum or Udayapur or Saptari or Siraha or Dhanusa or Mahottari or Sarlahi or Bara or Parsa or Rautahat or Sindhuli or Ramechhap or Dolakha or Bhaktapur or Dhading or Kavrepalanchok or Lalitpur or Nuwakot or Rasuwa or Sindhupalchok or Chitwan or Makwanpur or Baglung or Gorkha or Kaski or Lamjung or Maqnang or Mustang or Myagdi or Nawalpur or Parbat or Syangja or Tanahun or Kapilvastu or Parasi or Rupandehi or Arghakhanchi or Gulmi or Palpa or Dang or Pyuthan or Rolpa or Rukum or Ganke or Bardiya or Salyan or Dolpa or Humla or Jumla or Kalikot or Mugu or Surkhet or Dailekh or Jajarkot or Kailali or Achham or Doti or Bajhang or Bajura or Kanchanpur or Dadeldhura or Baitadi or Darchula) adj2 District).mp.	11990
8	exp BANGLADESH/ or (bangladesh or Bogra or Kushita or Jessore or Cox 's Bazar or Brahamanbaria or Dinajpur or Nawabganj or Tangail or Sirajganj or Feni or Jamalpur or Pabna or Noakhali or Faridpur or Dhaka Division or Chittagong Division or Rajshahi Division or Mymensingh Division or Rangpur Division or Khulna division).mp.	15458

9	exp India/ or (India or Indian Subcontinent or south* Indian or Arunachal Pradesh or Itanagar or Assam or Dhuburi or Dibrugarh or Dispur or Guwahati or Jorhat or Nagaon or Sibsagar or Silchar or Tezpur or Tinsukia or Bihar or Ara or Baruni or Begusarai or Bettiah or Bhagalpur or Bihar Sharif or Bodh Gaya or Buxar or Chapra or Darbhanga or Dehri or Dinapur Nizamat or Gaya or Hajipur or Jamalpur or Katihar or Madhubani or Motihari or Munger or Muzaffarpur or Patna or Purnia or Pusa or Saharsa or Samastipur or Sasaram or Sitamarhi or Siwan or Chandigarh or Chandigarh or Chhattisgarh or Ambikapur or Bhilai or Bilaspur or Dhamtari Durg or Jagdalpur or Raipur or Rajnandgaon or Dadra or Nagar Haveli or Silvassa or Diu or Daman or Delhi or Madgaon or Panaji or Gujarat or Ahmadabad or Amreli or Bharuch or Bhavnagar or Bhuj or Dwarka or Gandhinagar or Godhra or Jamnagar or Junagadh or Kandla or Khambhat or Kheda or Mahesana or Morvi or Nadiad or Navsari or Okha or Palanpur or Patan or Porbandar or Rajkot or Surat or Surendranagar or Valsad or Veraval or Haryana or Ambala or Bhiwani or Chandigarh or Faridabad or Firozpur Jhirka or Gurgaon or Hansi or Hisar or Jind or Kaithal or Karnal or Kurukshetra or Panipat or Pehowa or Rewari or Rohtak or Sirsa or Sonipat or Himachal Pradesh or Bilaspur or Chamba or (Dalhousie not (Halifax or Canada or England)) or Dharmshala or Hamirpur or Kangra or Kullu or Mandi or Nahan or Shimla or Jammu or Kashmir or Anantnag or Baramula or Doda or Gulmarg or Jammu or Kathua or Punch or Rajauri or Srinagar or	179849

	Udhampur or Jharkhand or Bokaro or Chaibasa or Deoghar or Dhanbad or Dumka or Giridih or Hazaribag or Jamshedpur or Jharia or Rajmahal or Ranchi or Saraikela or Karnataka or Badami or Ballari or Bangalore or Belgavi or Bhadravati or Bidar or Chikkamagaluru or Chitradurga or Davangere or Halebid or Hubballi Dharwad or Kalaburagi or Kolar or Madikeri or Mandya or Mangaluru or Mysuru or Raichur or Shivamogga or Shravanabelagola or Shrirangapattana or Tumkuru or Kerala or Alappuzha or Badagara or Idukki or Kannur or Kochi or Kollam or Kottayam or Kozhikode or Mattancheri or Palakkad or Thalassery or hiruvananthapuram or Thrissur or Madhya Pradesh or Balaghat or Barwani or Betul or Bharhut or Bhind or Bhojpur or Bhopal or Burhanpur or Chhatarpur or Chhindwara or Damoh or Datia or Dewas or Dhar or Guna or Gwalior or Hoshangabad or Indore or Itarsi or Jabalpur or Jhabua or Khajuraho or Khandwa or Khargon or Maheshwar or Mandla or Mandsaur or Mhow or Morena or Murwara or Narsimhapur or Narsinghgarh or Narwar or Neemuch or Nowgong or Orchha or Panna or Raisen or Rajgarh or Ratlam or Rewa or Sagar or Sarangpu or Satna or Sehore or Seoni or Shahdol or Shajapur or Sheopur or Shivpuri or Ujjain or Vidisha or Maharashtra or Ahmadnagar or Akola or Amravati or Aurangabad or Bhandara or Bhusawal or Buldana or Chandrapur or Daulatabad or Dhule or Jalgaon or Kalyan or Karli or Kolhapur or Mahabaleshwar or Malegaon or Matheran or Mumbai or Nagpur or Nanded or Nashik or Osmanabad or Pandharpur or Parbhani or Pune or	

	Ratnagiri or Sangli or Satara or Sevagram or Solapur or Ulhasnagar or Vasai Virar or Wardha or Yavatmal or Manipur or Imphal or Meghalaya or Cherrapunji or Shillong or Mizoram or Aizawl or Lunglei or Nagaland or Kohima or Phek or Wokha or Zunheboto or Odisha or Balangir or Baleshwar or Baripada or Bhubaneshwar or Brahmapur or Cuttack or Dhenkanal or Keonjhar or Konark or Koraput or Paradip or Phulabani or Puri or Sambalpur or Udayagiri or Puducherry or Karaikal or Mahe or Puducherry or Yanam or Punjab or Amritsar or Batala or Chandigarh or Faridkot or Firozpur or Gurdaspur or Hoshiarpur or Jalandhar or Kapurthala or Ludhiana or Nabha or Patiala or Rupnagar or Sangrur or Rajasthan or Ajmer or Alwar or Amer or Barmer or Beawar or Bharatpur or Bhilwara or Bikaner or Bundi or Chittaurgarh or Churu or Dhaulpur or Dungarpur or Ganganagar or Hanumangarh or Jaipur or Jaisalmer or Jalor or Jhalawar or Jhunjhunu or Jodhpur or Kishangarh or Kota or Merta or Nagaur or Nathdwara or Pali or Phalodi or Pushkar or Sawai Madhopur or Shahpura or Sikar or Sirohi or Tonk or Udaipur or Sikkim or Gangtok or Gyalsing or Lachung or Mangan or Tamil Nadu or Arcot or Chengalpattu or Chennai or Chidambaram or Coimbatore or Cuddalore or Dharmapuri or Dindigul or Kanchipuram or Kanniyakumari or Kodaikanal or Kumbakonam or Madurai or Mamallapuram or Nagappattinam or Nagercoil or Palayankottai or Pudukkottai or Rajapalaiyam or Ramanathapuram or Thanjavur or Tiruchchirappalli or Tirunelveli or Tiruppur or Tuticorin or Udhagamandalam or Vellore or	

	Telangana or Hyderabad or Karimnagar or Khammam or Mahbubnagar or Nizamabad or Sangareddi or Warangal or Tripura or Agartala or Uttar Pradesh or Agra or Aligarh or Allahabad or Amroha or Ayodhya or Azamgarh or Bahraich or Ballia or Banda or Bara Banki or Bareilly or Basti or Bijnor or Bithur or Budaun or Bulandshahr or Deoria or Etah or Etawah or Faizabad or "Farrukhabad cum Fatehgarh " or Fatehpur or Fatehpur Sikri or Ghaziabad or Ghazipur or Gonda or Gorakhpur or Hamirpur or Hardoi or Hathras or Jalaun or Jaunpur or Jhansi or Kannauj or Kanpur or Lakhimpur or Lalitpur or Lucknow ORMainpuri or Mathura or Meerut or Mirzapur Vindhyachal or Moradabad or Muzaffarnagar or Partapgarh or Pilibhit or Rae Bareli or Rampur or Saharanpur or Sambhal or Shahjahanpur or Sitapur or Sultanpur or Tehri or Varanasi or Uttarakhand or Almora or Dehra Dun or Haridwar or Mussoorie or Nainital or Pithoragarh or West Bengal or Alipore or Alipur Duar or Asansol or Baharampur or Bally or Balurghat or Bankura or Baranagar or Barasat or Barrackpore or Basirhat or Bhatpara or Bishnupur ORBudge Budge or Burdwan or Chandernagore or Darjiling or Diamond Harbour or Dum Dum or Durgapur or Halisahar or Haora or Hugli or Ingraj Bazar or Jalpaiguri or Kalimpong or Kamarhati or Kanchrapara or Kharagpur or Koch Bihar or Kolkata or Krishnanagar or Malda or Midnapore or Murshidabad or Navadwip or Palashi or Panihati or Purulia or Raiganj or Santipur or Shantiniketan or Shrirampur or Siliguri or Siuri or Tamluk or	

	Titagarh).mp.	

10	exp Pakistan/ or (Pakistan* or Abbottabad or Alizai or Bahawalpur or Bannu or Bara Tehsil or Battagram or Bhimbar or Burewala or Charsadda or Chiniot or Dadu or Darra Adam Khel or Dera Ghazi Khan or Dera Ismail Khan or Faisalabad or Gojra or Gujrat or Gujranwala or Ghulam Khana or Hafizabad or Haveli or Islamabad or Jacobabad or Jamrud or Jhelum or Jhang Sadr or Kamoke or Karachi or Kasur or Khar Bajaur or Khairpur or Khanpur or Kohat or Kotli or Khuzdar or Khyber Pass or Kurram or Lahore or Landi Kotal or Larkana or Laskathan or Makeen or Multan or Muzaffarabad or Mardan Malir Cantonment or Mehrabpur or Mingora or Mir Ali or Miranshah or Mirpur Khas or Muzaffargarh or Muridke or Mandi Bahauddin or Nawabshah or Neelum Valley or Nowshera or Okara or Pallindri or Parachinar or Peshawar or Quetta or Rahim Yar Khan or Razmak or Rawalakot or Rawalpindi or Sahiwal or Sadda or Saddiqabad or Sargodha or Shahkot or Sialkot or Shikarpur or Sukkur or Shekhupura or Swabi or Tando Allahyar or Wana Tehsil).mp.	29314

11	(Afghanistan/ or afghan*.mp. or ((Andkhoy or Aqcha or Asadabad or Baghlan or Bagramor Balkh or Bamyan or Baraki Barak or Bharak or Chaki Wardak or Chaghcharan or Chaharikar or Charikar or Day Mirdad or Dihdadi or Farah Province or Farah City or Faryab or Ghazni or Fayzabad or Gardez or (Ghor not (Jordan or Israel or Dead Sea)) or Guzara or Helmand or (Herat not "herat failure") or Jaghori or Jalalabad or Jowzjan or Kandahar or Khost or Khulm or Kohistan or Kunduz or Laghman or Lashkargah or Logar or Mahmud Raqi or Maidan Shar or Maymana or "Mazar i Sharif" or Mihtarlam or Nangarhar or Nijrab or Panjshir or Parwan or Puli Alam or Puli Khumri or "Qala i Naw" or "Sar e Pol" or Sharana or Sheberghan or Shinwar or Taloqan Takhar or Taluqan or Tsamkani or Yakawlang or Yangi Qala or Zaranj).mp. or (Andar.mp. not Portuguese.lg.) or (kabul.mp. not Turkish.sl.))) not ((Iran not (Iran and afghan*)) or (Pakistan not (Pakistan and afghan*))).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	8520
12	BANGLADESH/ or (Bangladesh* or Bogra or Kushita or Jessore or Cox's Bazar or Brahamanbaria or Dinajpur or Nawabganj or Tangail or Sirajganj or Feni or Jamalpur or Pabna or Noakhali or Faridpur or "Dhaka Division" or "Chittagong Division" or "Rajshahi Division" or	16189

	"Mymensingh Division" or "Rangpur Division" or "Khulna division").mp.	
13	Bhutan/ or bhutan*.mp.	908
14	Sri Lanka/ or ("sri lanka*" or srilanka or ceylon).mp. or "sri lanka".cp. or ("Colombo City or Colombo District" or "Dehiwala-Mount Lavinia" or Galle or Jaffna or Kalamunai or Kandy or Moratuwa or Negomgo or "Pita Kotte" or ("Point Pedro" not "10-point") or "Sri Jayewardenepura Kotte" or Trincomalee).mp.	10749
15	Maldives/ or (Maldive* or Maldivian or Addu Atoll or alif alif atoll or Ari Atoll or "Baa Atholhu" or Dhidhdhoo or Eydhafushi or "Faafu Atoll" or Feridhoo or Funadhoo or Fuvahmulah or "Gaafu Alif Atoll" or "Gaafu Dhaalu Atoll" or "Gnyaviyani Atoll" or "Haa Alifu Atholhu" or "Haa Dhaalu Atholhu" or Haddummati Atoll or "Hithadhoo oenu" or Hulhumale or "Ihavandippolu Atoll" or Kulhudhuffushi or "Lhaviyani Atholhu" or "Kaafu Atoll" or "Male Atoll" or Maafushi or Magoodhoo or "Meemu Atoll" or Naifaru or "Rasdhoo Atoll" or Seenu or "Shaviyani Atholhu" or Thinadhoo or Viligili).mp.	997
16	7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15	245946
17	6 and 16	371

18	limit 17 to yr="2010 -Current"	195

Embase <1974 to 2020 May 08>

#	Search Statement	Results
1	weather/ or Climate/ or climatic processes/ or ((exp climate change/ or cyclonic storms/ or droughts/ or floods/ or greenhouse effect/ or temperature/) and (ambient or season* or climate or climatic or weather or summer or winter).mp.) or extreme heat/ or hot temperature/ or (((climat* not (political-climate or organizational-climate or economic-climate or financial-climate)) or weather) adj3 (chang* or disrupt* or volati* or instabilit* or unstable or variable or variability or vulnerab*)).mp. or ((chang* or decline* or decrease* or increase*) adj3 humidity).mp. or ((global* or climate) adj2 warm*).mp. or ((climat* or weather) adj (conditions or factors or driven)).mp. or (greenhouse gas* or greenhouse effect* or carbon emission* or carbon dioxide emission* or CO2 emission*).mp. or (((extreme or severe) adj (weather or heat or temperature*)) or hot-weather or heat-wave* or heatwave or high temperatures or ((higher or warm* or hot*) adj3 temperature*)).mp. or ((annual* or daily or month* or ambient or environmental or season* or climate or climatic or weather or summer or winter) adj4 temperature*).mp. or (warm-season* or warm*-month* or (unseasonabl*	355855

	adj3 (warm or hot or heat or humid* or cold or high or low))).mp. or (El Nino or la nina).mp. or (rain or rains or rainstorm* or raining or rainfall or ((high or heavy or extreme or severe or daily or levels) adj2 precipitation) or UV-index or flooding or floods or waterlogging or (drought* not drought-resistan*) or desertifcation or hurricane* or cyclone* or tornado* or superstorm* or dust storm or storm surge* or ice storm* or ((storm or storms) and disaster*) or monsoon*).mp. or (forest fire* or wildfire* or wild fire* or fire disaster* or (uncontrolled adj3 fire*)).mp. or ((sea level* adj3 (rise or rises or rising or increase or increasing or increases)) or ((polar or permafrost or ice-cap or glacier*) adj3 (melt* or retreat* or reced* or thaw*))).mp. or famine*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	

2	exp Air Pollution/ or Traffic-Related Pollution/ or greenhouse gases/ or stratospheric ozone/ or ((gases/ or ammonia/ or carbon dioxide/ or carbon monoxide/ or chlorine/ or greenhouse gases/ or hydrogen sulfide/ or nitrogen/ or nitrogen oxides/ or nitrogen dioxide/ or nitrous oxide/ or ozone/ or sulfur dioxide/ or carbon monoxide*.mp. or hydrogen sulfide*.mp. or hydrogen sulphide*.mp. or H2S.mp. or nitrogen oxide*.mp. or volatile organic*.mp. or voc.mp. or nox.mp. or sulfur dioxide*.mp. or SO2.mp. or sulfur oxide*.mp. or sulphur dioxide*.mp. or sulphur oxide*.mp.) and (exp Pollution/ or pollut*.mp. or emit*.mp. or emission*.mp. or contaminat*.mp. or decontaminat*.mp.)) or ((air or atmospher*) adj3 (pollut* or quality or wast* or contamin* or emission* or immission* or effluent*or acidification or contaminat* or degrad* or decontaminat* or purif* or restor*)).mp. or ((gas or gases) adj3 (toxic* or noxious or releas* or purifi* or scrub* or emit* or waste* or vapo?r)).mp. or (acid* adj3 (deposition* or rain* or snow or fog or mist or precipitation or hail or sleet)).mp. or afterburning.mp. or biogas.mp. or (burning adj3 fossil fuel*).mp. or ((chimney or stack) adj3 height).mp. or dust.mp. or fallout.mp. or fall out.mp. or flaring.mp. or fly ash.mp. or electrosmog.mp. or (greenhouse adj3 (gas or effect or effects or gases or emission*)).mp. or incineration.mp. or odor.mp. or odour.mp. or olfactory pollution.mp. or particulate*.mp. or smog.mp. or smoke.mp. or soot.mp. or sick building syndrome.mp. or vapo?r recovery system*.mp. or ((industrial or automobile* or traffic or freeway or highway or	459419

	roadway or motorway or diesel or vehicle*) adj3 (exhaust* or emission* or emit* or fume or fumes or vapo?r*)).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	
3	1 or 2	754855

4	(health* or disease* or outbreak* or infectio* or illness* or virus* or injur* or disorder* or epidemic* or pandemic* or fever* or symptoms).mp. or exp pregnancy complications/ or exp infant, Low Birth Weight/ or stillbirth/ or (deformit* or malformation* or cleft-palate* or cleft-lip* or birth-defect* or congenital heart defect* or spina-bifida or birth-outcome* or pregnancy-outcome* or still-birth or still-born* or stillborn or stillbirth* or low-birth-weight or (fetal-growth adj (restric* or retard*)) or preterm labo* or preterm birth or (hypertension and pregnan*) or preeclampsia).mp. or (((developmental* or intellectual* or learning or mental or cognitive or physical*) adj3 (disab* or impair* or delay* or disorder*)) or mental retard* or handicap* or special needs or down* syndrome or "fragile x" or autis* or asperger* or pervasive developmental disorder* or cerebral palsy or tourette* or tic-disorder* or attention-deficit* or adhd or epilep* or language-disorder* or neurodevelopment* or ((neuro or cognitive or physical*) adj5 development*)).mp. or stress, psychological/ or occupational stress/ or (stress-level* or high*-stress* or psychological-stress* or mental-stress* or burnout or psychiatric or depress* or anxiety or psychos* or stress-disorder* or PTSD or posttrauma* or trauma* or emotional-health).mp. or exp occupational diseases/ or (food-security or food-insecurity or nutrition or undernutrition or malnutrition or malnourish* or undernourish* or overnutrition or famine or food-availability or food-supply or ((nutrition* or vitamin) adj4 deficien*)).mp. or (underweight or	24312819

	thinness or overweight or obes*).mp. or exp diseases/ or exp food safety/ or dietary exposure/ or (food-safety or (food adj4 (contaminat* or poison*))).mp. or ((safe or clean or unsafe or contamina*) adj6 (drink* or potable) adj6 water).mp. or exp mortality/ or exp morbidity/ or pregnancy outcome/ or (mortalit* or death* or fatalit*).mp. or (respiratory or asthma* or allerg* or aeroallerg* or ((breathing or breathe) adj3 (issue* or problem* or difficult* or struggl* or trouble))).mp. or exp heat stress disorders/ or (heat-stress* or heat-exhaustion or heat-stroke* or heatstroke* or sun stroke* or sunstroke*).mp. or (cholera* or diarrhea* or diarrhoea* or dysentery or salmonella or pneumonia* or plasmodium* or babesi* or hantavirus* or giardia* or cryptosporidi* or leptospiros*).mp. or exp parasitic diseases/ or (Trichinos* or trichinellosis or Chikungunya or Dengue or Lymphatic-filariasis or Rift-Valley-fever or Yellow-fever or Zika or Malaria or japanese-encephalitis or tick-borne or West-Nile-fever or Leishmaniasis or Sandfly-fever or phelebotomus-fever or haemorrhagic-fever or Lyme-disease or Relapsing-fever or borreliosis or Rickettsial-diseases or spotted-fever or Q-fever or Tularaemia or Chagas or trypanosomiasis or Sleeping-sickness or Plague or Rickettsiosis or Onchocerciasis or river-blindness or Schistosomiasis or bilharziasis or Typhus or louse-borne-relapsing-fever).mp.	

5	((exp Geriatrics/ or Aged/ or (elders or elderly or geriatric* or old age or (seniors not "high school") or older adult* or centenarian* or nonagenarian* or octogenarian* or septuagenarian* or sexagenarian* or dottering or decrepit or tottering or overaged or "oldest old").mp. or exp child/ or exp "congenital, hereditary, and neonatal diseases and abnormalities"/ or exp infant/ or adolescent/ or exp pediatrics/ or child, abandoned/ or exp child, exceptional/ or child, orphaned/ or child, unwanted/ or minors/ or (pediatric* or paediatric* or child* or newborn* or congenital* or infan* or baby or babies or neonat* or pre-term or preterm* or premature birth* or NICU or preschool* or pre-school* or kindergarten* or kindergarden* or elementary school* or nursery school* or (day care* not adult*) or schoolchild* or toddler* or boy or boys or girl* or middle school* or pubescen* or juvenile* or teen* or youth* or high school* or adolesc* or pre-pubesc* or prepubesc*).mp. or (child* or adolesc* or pediat* or paediat*).jn. or Refugees/ or exp emigrants/) and immigrants/) or (immigrant* or immigration or emmigrant* or emmigration or refugee* or asylum seeker* or asylee* or displaced person* or "incomer*" or "in comer*" or "new comer*" or newcomer* or childbearing or childbirth or pregnan* or fertile or fecund or womanish or womanly or maternal).mp. or Pregnancy/	1167126
6	3 and 4 and 5	17375

7	exp Nepal/ or (Nepal or Nepali or Nepalese or Bharatpur or Bhimdatta or Birganj or Biratnagar or Budhanilkantha or Butwal or Dhangadhi or Dharan or Gokarneshwar or Hetauda or Itahari or Janakpur or Kathmandu or Mount Everest or Nepalganj or Pokhara or Tilottama).mp. or ((Bhojpur or Dhankuta or Ilam or Jhapa or Khotang or Morang or Okhaldhunga or Panchthar or Sankhuwasabha or Solukhumbu or Sunsari or Taplejung or Terhathum or Udayapur or Saptari or Siraha or Dhanusa or Mahottari or Sarlahi or Bara or Parsa or Rautahat or Sindhuli or Ramechhap or Dolakha or Bhaktapur or Dhading or Kavrepalanchok or Lalitpur or Nuwakot or Rasuwa or Sindhupalchok or Chitwan or Makwanpur or Baglung or Gorkha or Kaski or Lamjung or Maqnang or Mustang or Myagdi or Nawalpur or Parbat or Syangja or Tanahun or Kapilvastu or Parasi or Rupandehi or Arghakhanchi or Gulmi or Palpa or Dang or Pyuthan or Rolpa or Rukum or Ganke or Bardiya or Salyan or Dolpa or Humla or Jumla or Kalikot or Mugu or Surkhet or Dailekh or Jajarkot or Kailali or Achham or Doti or Bajhang or Bajura or Kanchanpur or Dadeldhura or Baitadi or Darchula) adj2 District).mp.	14614
8	exp BANGLADESH/ or (bangladesh or Bogra or Kushita or Jessore or Cox 's Bazar or Brahamanbaria or Dinajpur or Nawabganj or Tangail or Sirajganj or Feni or Jamalpur or Pabna or Noakhali or Faridpur or Dhaka Division or Chittagong Division or Rajshahi Division or Mymensingh Division or Rangpur Division or Khulna division).mp.	19798

9	exp India/ or (India or Indian Subcontinent or south* Indian or Arunachal Pradesh or Itanagar or Assam or Dhuburi or Dibrugarh or Dispur or Guwahati or Jorhat or Nagaon or Sibsagar or Silchar or Tezpur or Tinsukia or Bihar or Ara or Baruni or Begusarai or Bettiah or Bhagalpur or Bihar Sharif or Bodh Gaya or Buxar or Chapra or Darbhanga or Dehri or Dinapur Nizamat or Gaya or Hajipur or Jamalpur or Katihar or Madhubani or Motihari or Munger or Muzaffarpur or Patna or Purnia or Pusa or Saharsa or Samastipur or Sasaram or Sitamarhi or Siwan or Chandigarh or Chandigarh or Chhattisgarh or Ambikapur or Bhilai or Bilaspur or Dhamtari Durg or Jagdalpur or Raipur or Rajnandgaon or Dadra or Nagar Haveli or Silvassa or Diu or Daman or Delhi or Madgaon or Panaji or Gujarat or Ahmadabad or Amreli or Bharuch or Bhavnagar or Bhuj or Dwarka or Gandhinagar or Godhra or Jamnagar or Junagadh or Kandla or Khambhat or Kheda or Mahesana or Morvi or Nadiad or Navsari or Okha or Palanpur or Patan or Porbandar or Rajkot or Surat or Surendranagar or Valsad or Veraval or Haryana or Ambala or Bhiwani or Chandigarh or Faridabad or Firozpur Jhirka or Gurgaon or Hansi or Hisar or Jind or Kaithal or Karnal or Kurukshetra or Panipat or Pehowa or Rewari or Rohtak or Sirsa or Sonipat or Himachal Pradesh or Bilaspur or Chamba or (Dalhousie not (Halifax or Canada or England)) or Dharmshala or Hamirpur or Kangra or Kullu or Mandi or Nahan or Shimla or Jammu or Kashmir or Anantnag or Baramula or Doda or Gulmarg or Jammu or Kathua or Punch or Rajauri or Srinagar or	271678

	Udhampur or Jharkhand or Bokaro or Chaibasa or Deoghar or Dhanbad or Dumka or Giridih or Hazaribag or Jamshedpur or Jharia or Rajmahal or Ranchi or Saraikela or Karnataka or Badami or Ballari or Bangalore or Belgavi or Bhadravati or Bidar or Chikkamagaluru or Chitradurga or Davangere or Halebid or Hubballi Dharwad or Kalaburagi or Kolar or Madikeri or Mandya or Mangaluru or Mysuru or Raichur or Shivamogga or Shravanabelagola or Shrirangapattana or Tumkuru or Kerala or Alappuzha or Badagara or Idukki or Kannur or Kochi or Kollam or Kottayam or Kozhikode or Mattancheri or Palakkad or Thalassery or hiruvananthapuram or Thrissur or Madhya Pradesh or Balaghat or Barwani or Betul or Bharhut or Bhind or Bhojpur or Bhopal or Burhanpur or Chhatarpur or Chhindwara or Damoh or Datia or Dewas or Dhar or Guna or Gwalior or Hoshangabad or Indore or Itarsi or Jabalpur or Jhabua or Khajuraho or Khandwa or Khargon or Maheshwar or Mandla or Mandsaur or Mhow or Morena or Murwara or Narsimhapur or Narsinghgarh or Narwar or Neemuch or Nowgong or Orchha or Panna or Raisen or Rajgarh or Ratlam or Rewa or Sagar or Sarangpu or Satna or Sehore or Seoni or Shahdol or Shajapur or Sheopur or Shivpuri or Ujjain or Vidisha or Maharashtra or Ahmadnagar or Akola or Amravati or Aurangabad or Bhandara or Bhusawal or Buldana or Chandrapur or Daulatabad or Dhule or Jalgaon or Kalyan or Karli or Kolhapur or Mahabaleshwar or Malegaon or Matheran or Mumbai or Nagpur or Nanded or Nashik or Osmanabad or Pandharpur or Parbhani or Pune or	

	Ratnagiri or Sangli or Satara or Sevagram or Solapur or Ulhasnagar or Vasai Virar or Wardha or Yavatmal or Manipur or Imphal or Meghalaya or Cherrapunji or Shillong or Mizoram or Aizawl or Lunglei or Nagaland or Kohima or Phek or Wokha or Zunheboto or Odisha or Balangir or Baleshwar or Baripada or Bhubaneshwar or Brahmapur or Cuttack or Dhenkanal or Keonjhar or Konark or Koraput or Paradip or Phulabani or Puri or Sambalpur or Udayagiri or Puducherry or Karaikal or Mahe or Puducherry or Yanam or Punjab or Amritsar or Batala or Chandigarh or Faridkot or Firozpur or Gurdaspur or Hoshiarpur or Jalandhar or Kapurthala or Ludhiana or Nabha or Patiala or Rupnagar or Sangrur or Rajasthan or Ajmer or Alwar or Amer or Barmer or Beawar or Bharatpur or Bhilwara or Bikaner or Bundi or Chittaurgarh or Churu or Dhaulpur or Dungarpur or Ganganagar or Hanumangarh or Jaipur or Jaisalmer or Jalor or Jhalawar or Jhunjhunu or Jodhpur or Kishangarh or Kota or Merta or Nagaur or Nathdwara or Pali or Phalodi or Pushkar or Sawai Madhopur or Shahpura or Sikar or Sirohi or Tonk or Udaipur or Sikkim or Gangtok or Gyalsing or Lachung or Mangan or Tamil Nadu or Arcot or Chengalpattu or Chennai or Chidambaram or Coimbatore or Cuddalore or Dharmapuri or Dindigul or Kanchipuram or Kanniyakumari or Kodaikanal or Kumbakonam or Madurai or Mamallapuram or Nagappattinam or Nagercoil or Palayankottai or Pudukkottai or Rajapalaiyam or Ramanathapuram or Thanjavur or Tiruchchirappalli or Tirunelveli or Tiruppur or Tuticorin or Udhagamandalam or Vellore or	

	Telangana or Hyderabad or Karimnagar or Khammam or Mahbubnagar or Nizamabad or Sangareddi or Warangal or Tripura or Agartala or Uttar Pradesh or Agra or Aligarh or Allahabad or Amroha or Ayodhya or Azamgarh or Bahraich or Ballia or Banda or Bara Banki or Bareilly or Basti or Bijnor or Bithur or Budaun or Bulandshahr or Deoria or Etah or Etawah or Faizabad or "Farrukhabad cum Fatehgarh " or Fatehpur or Fatehpur Sikri or Ghaziabad or Ghazipur or Gonda or Gorakhpur or Hamirpur or Hardoi or Hathras or Jalaun or Jaunpur or Jhansi or Kannauj or Kanpur or Lakhimpur or Lalitpur or Lucknow ORMainpuri or Mathura or Meerut or Mirzapur Vindhyachal or Moradabad or Muzaffarnagar or Partapgarh or Pilibhit or Rae Bareli or Rampur or Saharanpur or Sambhal or Shahjahanpur or Sitapur or Sultanpur or Tehri or Varanasi or Uttarakhand or Almora or Dehra Dun or Haridwar or Mussoorie or Nainital or Pithoragarh or West Bengal or Alipore or Alipur Duar or Asansol or Baharampur or Bally or Balurghat or Bankura or Baranagar or Barasat or Barrackpore or Basirhat or Bhatpara or Bishnupur ORBudge Budge or Burdwan or Chandernagore or Darjiling or Diamond Harbour or Dum Dum or Durgapur or Halisahar or Haora or Hugli or Ingraj Bazar or Jalpaiguri or Kalimpong or Kamarhati or Kanchrapara or Kharagpur or Koch Bihar or Kolkata or Krishnanagar or Malda or Midnapore or Murshidabad or Navadwip or Palashi or Panihati or Purulia or Raiganj or Santipur or Shantiniketan or Shrirampur or Siliguri or Siuri or Tamluk or	

	Titagarh).mp.	

10	exp Pakistan/ or (Pakistan* or Abbottabad or Alizai or Bahawalpur or Bannu or Bara Tehsil or Battagram or Bhimbar or Burewala or Charsadda or Chiniot or Dadu or Darra Adam Khel or Dera Ghazi Khan or Dera Ismail Khan or Faisalabad or Gojra or Gujrat or Gujranwala or Ghulam Khana or Hafizabad or Haveli or Islamabad or Jacobabad or Jamrud or Jhelum or Jhang Sadr or Kamoke or Karachi or Kasur or Khar Bajaur or Khairpur or Khanpur or Kohat or Kotli or Khuzdar or Khyber Pass or Kurram or Lahore or Landi Kotal or Larkana or Laskathan or Makeen or Multan or Muzaffarabad or Mardan Malir Cantonment or Mehrabpur or Mingora or Mir Ali or Miranshah or Mirpur Khas or Muzaffargarh or Muridke or Mandi Bahauddin or Nawabshah or Neelum Valley or Nowshera or Okara or Pallindri or Parachinar or Peshawar or Quetta or Rahim Yar Khan or Razmak or Rawalakot or Rawalpindi or Sahiwal or Sadda or Saddiqabad or Sargodha or Shahkot or Sialkot or Shikarpur or Sukkur or Shekhupura or Swabi or Tando Allahyar or Wana Tehsil).mp.	45052
11	Sri Lanka/ or ("sri lanka*" or srilanka or ceylon).mp. or "sri lanka".cp. or ("Colombo City or Colombo District" or "Dehiwala-Mount Lavinia" or Galle or Jaffna or Kalamunai or Kandy or Moratuwa or Negomgo or "Pita Kotte" or ("Point Pedro" not "10-point") or "Sri Jayewardenepura Kotte" or Trincomalee).mp.	12271
12	exp Bhutan/ or butan*.mp.	45934

13	Maldives/ or (Maldive* or Maldivian or Addu Atoll or alif alif atoll or Ari Atoll or "Baa Atholhu" or Dhidhdhoo or Eydhafushi or "Faafu Atoll" or Feridhoo or Funadhoo or Fuvahmulah or "Gaafu Alif Atoll" or "Gaafu Dhaalu Atoll" or "Gnyaviyani Atoll" or "Haa Alifu Atholhu" or "Haa Dhaalu Atholhu" or Haddummati Atoll or "Hithadhoo oenu" or Hulhumale or "Ihavandippolu Atoll" or Kulhudhuffushi or "Lhaviyani Atholhu" or "Kaafu Atoll" or "Male Atoll" or Maafushi or Magoodhoo or "Meemu Atoll" or Naifaru or "Rasdhoo Atoll" or Seenu or "Shaviyani Atholhu" or Thinadhoo or Viligili).mp.	482
14	(Afghanistan/ or afghan*.mp. or ((Andkhoy or Aqcha or Asadabad or Baghlan or Bagramor Balkh or Bamyan or Baraki Barak or Bharak or Chaki Wardak or Chaghcharan or Chaharikar or Charikar or Day Mirdad or Dihdadi or Farah Province or Farah City or Faryab or Ghazni or Fayzabad or Gardez or (Ghor not (Jordan or Israel or Dead Sea)) or Guzara or Helmand or (Herat not "herat failure") or Jaghori or Jalalabad or Jowzjan or Kandahar or Khost or Khulm or Kohistan or Kunduz or Laghman or Lashkargah or Logar or Mahmud Raqi or Maidan Shar or Maymana or "Mazar i Sharif" or Mihtarlam or Nangarhar or Nijrab or Panjshir or Parwan or Puli Alam or Puli Khumri or "Qala i Naw" or "Sar e Pol" or Sharana or Sheberghan or Shinwar or Taloqan Takhar or Taluqan or Tsamkani or Yakawlang or Yangi Qala or Zaranj).mp. or (Andar.mp. not Portuguese.lg.) or (kabul.mp. not Turkish.sl.))) not ((Iran	9291

	not (Iran and afghan*)) or (Pakistan not (Pakistan and afghan*))).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	
15	bhutan.mp. or exp Bhutan/	970
16	or/7-15	402113
17	6 and 16	526
18	limit 17 to yr="2010 -Current"	373

Global Health <1910 to 2020 Week 18>

#	Search Statement	Results

1	weather/ or Climate/ or climatic processes/ or ((exp climate change/ or cyclonic storms/ or droughts/ or floods/ or greenhouse effect/ or temperature/) and (ambient or season* or climate or climatic or weather or summer or winter).mp.) or extreme heat/ or hot temperature/ or (((climat* not (political-climate or organizational-climate or economic-climate or financial-climate)) or weather) adj3 (chang* or disrupt* or volati* or instabilit* or unstable or variable or variability or vulnerab*)).mp. or ((chang* or decline* or decrease* or increase*) adj3 humidity).mp. or ((global* or climate) adj2 warm*).mp. or ((climat* or weather) adj (conditions or factors or driven)).mp. or (greenhouse gas* or greenhouse effect* or carbon emission* or carbon dioxide emission* or CO2 emission*).mp. or (((extreme or severe) adj (weather or heat or temperature*)) or hot-weather or heat-wave* or heatwave or high temperatures or ((higher or warm* or hot*) adj3 temperature*)).mp. or ((annual* or daily or month* or ambient or environmental or season* or climate or climatic or weather or summer or winter) adj4 temperature*).mp. or (warm-season* or warm*-month* or (unseasonabl* adj3 (warm or hot or heat or humid* or cold or high or low))).mp. or (El Nino or la nina).mp. or (rain or rains or rainstorm* or raining or rainfall or ((high or heavy or extreme or severe or daily or levels) adj2 precipitation) or UV-index or flooding or floods or waterlogging or (drought* not drought-resistan*) or desertifcation or hurricane* or cyclone* or tornado* or superstorm* or dust storm or storm surge* or ice	76789

	storm* or ((storm or storms) and disaster*) or monsoon*).mp. or (forest fire* or wildfire* or wild fire* or fire disaster* or (uncontrolled adj3 fire*)).mp. or ((sea level* adj3 (rise or rises or rising or increase or increasing or increases)) or ((polar or permafrost or ice-cap or glacier*) adj3 (melt* or retreat* or reced* or thaw*))).mp.	
2	(((carbon monoxide* or hydrogen sulfide* or hydrogen sulphide* or H2S or nitrogen oxide* or volatile organic* or voc or nox or sulfur dioxide* or SO2 or sulfur oxide* or sulphur dioxide* or sulphur oxide*) and (pollut* or emit* or emission* or contaminat* or decontaminat*)) or ((air or atmospher*) adj3 (pollut* or quality or wast* or contamin* or emission* or immission* or effluent*or acidification or contaminat* or degrad* or decontaminat* or purif* or restor*)) or ((gas or gases) adj3 (toxic* or noxious or releas* or purifi* or scrub* or emit* or waste* or vapo?r)) or (acid* adj3 (deposition* or rain* or snow or fog or mist or precipitation or hail or sleet)) or afterburning or biogas or (burning adj3 fossil fuel*) or ((chimney or stack) adj3 height) or dust or fallout or fall	92079

	out or flaring or fly ash or electrosmog or (greenhouse adj3 (gas or effect or effects or gases or emission*)) or incineration or odor or odour or olfactory pollution or particulate* or smog or smoke or soot or sick building syndrome or vapo?r recovery system* or ((industrial or automobile* or traffic or freeway or highway or roadway or motorway or diesel or vehicle*) adj3 (exhaust* or emission* or emit* or fume or fumes or vapo?r*))).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes]	
3	1 or 2	159019

4	(health* or disease* or outbreak* or infectio* or illness* or virus* or injur* or disorder* or epidemic* or pandemic* or fever* or symptoms or (deformit* or malformation* or cleft-palate* or cleft-lip* or birth-defect* or congenital heart defect* or spina-bifida or birth-outcome* or pregnancy-outcome* or still-birth or still-born* or stillborn or stillbirth* or low-birth-weight or (fetal-growth adj (restric* or retard*)) or preterm labo* or preterm birth or (hypertension and pregnan*) or preeclampsia) or (((developmental* or intellectual* or learning or mental or cognitive or physical*) adj3 (disab* or impair* or delay* or disorder*)) or mental retard* or handicap* or special needs or down* syndrome or "fragile x" or autis* or asperger* or pervasive developmental disorder* or cerebral palsy or tourette* or tic-disorder* or attention-deficit* or adhd or epilep* or language-disorder* or neurodevelopment* or ((neuro or cognitive or physical*) adj5 development*)) or (stress-level* or high*-stress* or psychological-stress* or mental-stress* or burnout or psychiatric or depress* or anxiety or psychos* or stress-disorder* or PTSD or posttrauma* or trauma* or emotional-health) or (food-security or food-insecurity or nutrition or undernutrition or malnutrition or malnourish* or undernourish* or overnutrition or famine or food-availability or food-supply or ((nutrition* or vitamin) adj4 deficien*)) or (underweight or thinness or overweight or obes*)).mp. or exp diseases/ or exp food safety/ or dietary exposure/ or (food-safety or (food adj4 (contaminat* or poison*))).mp. or ((safe or clean or unsafe or contamina*) adj6 (drink*	3220450

	or potable) adj6 water).mp. or exp mortality/ or exp morbidity/ or pregnancy outcome/ or (mortalit* or death* or fatalit*).mp. or (respiratory or asthma* or allerg* or aeroallerg* or ((breathing or breathe) adj3 (issue* or problem* or difficult* or struggl* or trouble))).mp. or exp heat stress disorders/ or (heat-stress* or heat-exhaustion or heat-stroke* or heatstroke* or sun stroke* or sunstroke*).mp. or (cholera* or diarrhea* or diarrhoea* or dysentery or salmonella or pneumonia* or plasmodium* or babesi* or hantavirus* or giardia* or cryptosporidi* or leptospiros*).mp. or exp parasitic diseases/ or (Trichinos* or trichinellosis or Chikungunya or Dengue or Lymphatic-filariasis or Rift-Valley-fever or Yellow-fever or Zika or Malaria or japanese-encephalitis or tick-borne or West-Nile-fever or Leishmaniasis or Sandfly-fever or phelebotomus-fever or haemorrhagic-fever or Lyme-disease or Relapsing-fever or borreliosis or Rickettsial-diseases or spotted-fever or Q-fever or Tularaemia or Chagas or trypanosomiasis or Sleeping-sickness or Plague or Rickettsiosis or Onchocerciasis or river-blindness or Schistosomiasis or bilharziasis or Typhus or louse-borne-relapsing-fever).mp.	

5	(elders or elderly or geriatric* or old age or (seniors not "high school") or older adult* or centenarian* or nonagenarian* or octogenarian* or septuagenarian* or sexagenarian* or dottering or decrepit or tottering or overaged or "oldest old" or (pediatric* or paediatric* or child* or newborn* or congenital* or infan* or baby or babies or neonat* or pre-term or preterm* or premature birth* or NICU or preschool* or pre-school* or kindergarten* or kindergarden* or elementary school* or nursery school* or (day care* not adult*) or schoolchild* or toddler* or boy or boys or girl* or middle school* or pubescen* or juvenile* or teen* or youth* or high school* or adolesc* or pre-pubesc* or prepubesc*)).mp. or (child* or adolesc* or pediat* or paediat*).jn. or (immigrant* or immigration or emmigrant* or emmigration or refugee* or asylum seeker* or asylee* or displaced person* or "incomer*" or "in comer*" or "new comer*" or newcomer* or childbearing or childbirth or pregnan* or fertile or fecund or womanish or womanly or maternal).mp.	757940
6	3 and 4 and 5	22622

7	exp Nepal/ or (Nepal or Nepali or Nepalese or Bharatpur or Bhimdatta or Birganj or Biratnagar or Budhanilkantha or Butwal or Dhangadhi or Dharan or Gokarneshwar or Hetauda or Itahari or Janakpur or Kathmandu or Mount Everest or Nepalganj or Pokhara or Tilottama).mp. or ((Bhojpur or Dhankuta or Ilam or Jhapa or Khotang or Morang or Okhaldhunga or Panchthar or Sankhuwasabha or Solukhumbu or Sunsari or Taplejung or Terhathum or Udayapur or Saptari or Siraha or Dhanusa or Mahottari or Sarlahi or Bara or Parsa or Rautahat or Sindhuli or Ramechhap or Dolakha or Bhaktapur or Dhading or Kavrepalanchok or Lalitpur or Nuwakot or Rasuwa or Sindhupalchok or Chitwan or Makwanpur or Baglung or Gorkha or Kaski or Lamjung or Maqnang or Mustang or Myagdi or Nawalpur or Parbat or Syangja or Tanahun or Kapilvastu or Parasi or Rupandehi or Arghakhanchi or Gulmi or Palpa or Dang or Pyuthan or Rolpa or Rukum or Ganke or Bardiya or Salyan or Dolpa or Humla or Jumla or Kalikot or Mugu or Surkhet or Dailekh or Jajarkot or Kailali or Achham or Doti or Bajhang or Bajura or Kanchanpur or Dadeldhura or Baitadi or Darchula) adj2 District).mp.	7417
8	exp BANGLADESH/ or (bangladesh or Bogra or Kushita or Jessore or Cox 's Bazar or Brahamanbaria or Dinajpur or Nawabganj or Tangail or Sirajganj or Feni or Jamalpur or Pabna or Noakhali or Faridpur or Dhaka Division or Chittagong Division or Rajshahi Division or Mymensingh Division or Rangpur Division or Khulna division).mp.	12802

9	exp India/ or (India or Indian Subcontinent or south* Indian or Arunachal Pradesh or Itanagar or Assam or Dhuburi or Dibrugarh or Dispur or Guwahati or Jorhat or Nagaon or Sibsagar or Silchar or Tezpur or Tinsukia or Bihar or Ara or Baruni or Begusarai or Bettiah or Bhagalpur or Bihar Sharif or Bodh Gaya or Buxar or Chapra or Darbhanga or Dehri or Dinapur Nizamat or Gaya or Hajipur or Jamalpur or Katihar or Madhubani or Motihari or Munger or Muzaffarpur or Patna or Purnia or Pusa or Saharsa or Samastipur or Sasaram or Sitamarhi or Siwan or Chandigarh or Chandigarh or Chhattisgarh or Ambikapur or Bhilai or Bilaspur or Dhamtari Durg or Jagdalpur or Raipur or Rajnandgaon or Dadra or Nagar Haveli or Silvassa or Diu or Daman or Delhi or Madgaon or Panaji or Gujarat or Ahmadabad or Amreli or Bharuch or Bhavnagar or Bhuj or Dwarka or Gandhinagar or Godhra or Jamnagar or Junagadh or Kandla or Khambhat or Kheda or Mahesana or Morvi or Nadiad or Navsari or Okha or Palanpur or Patan or Porbandar or Rajkot or Surat or Surendranagar or Valsad or Veraval or Haryana or Ambala or Bhiwani or Chandigarh or Faridabad or Firozpur Jhirka or Gurgaon or Hansi or Hisar or Jind or Kaithal or Karnal or Kurukshetra or Panipat or Pehowa or Rewari or Rohtak or Sirsa or Sonipat or Himachal Pradesh or Bilaspur or Chamba or (Dalhousie not (Halifax or Canada or England)) or Dharmshala or Hamirpur or Kangra or Kullu or Mandi or Nahan or Shimla or Jammu or Kashmir or Anantnag or Baramula or Doda or Gulmarg or Jammu or Kathua or Punch or Rajauri or Srinagar or	140504

	Udhampur or Jharkhand or Bokaro or Chaibasa or Deoghar or Dhanbad or Dumka or Giridih or Hazaribag or Jamshedpur or Jharia or Rajmahal or Ranchi or Saraikela or Karnataka or Badami or Ballari or Bangalore or Belgavi or Bhadravati or Bidar or Chikkamagaluru or Chitradurga or Davangere or Halebid or Hubballi Dharwad or Kalaburagi or Kolar or Madikeri or Mandya or Mangaluru or Mysuru or Raichur or Shivamogga or Shravanabelagola or Shrirangapattana or Tumkuru or Kerala or Alappuzha or Badagara or Idukki or Kannur or Kochi or Kollam or Kottayam or Kozhikode or Mattancheri or Palakkad or Thalassery or hiruvananthapuram or Thrissur or Madhya Pradesh or Balaghat or Barwani or Betul or Bharhut or Bhind or Bhojpur or Bhopal or Burhanpur or Chhatarpur or Chhindwara or Damoh or Datia or Dewas or Dhar or Guna or Gwalior or Hoshangabad or Indore or Itarsi or Jabalpur or Jhabua or Khajuraho or Khandwa or Khargon or Maheshwar or Mandla or Mandsaur or Mhow or Morena or Murwara or Narsimhapur or Narsinghgarh or Narwar or Neemuch or Nowgong or Orchha or Panna or Raisen or Rajgarh or Ratlam or Rewa or Sagar or Sarangpu or Satna or Sehore or Seoni or Shahdol or Shajapur or Sheopur or Shivpuri or Ujjain or Vidisha or Maharashtra or Ahmadnagar or Akola or Amravati or Aurangabad or Bhandara or Bhusawal or Buldana or Chandrapur or Daulatabad or Dhule or Jalgaon or Kalyan or Karli or Kolhapur or Mahabaleshwar or Malegaon or Matheran or Mumbai or Nagpur or Nanded or Nashik or Osmanabad or Pandharpur or Parbhani or Pune or	

	Ratnagiri or Sangli or Satara or Sevagram or Solapur or Ulhasnagar or Vasai Virar or Wardha or Yavatmal or Manipur or Imphal or Meghalaya or Cherrapunji or Shillong or Mizoram or Aizawl or Lunglei or Nagaland or Kohima or Phek or Wokha or Zunheboto or Odisha or Balangir or Baleshwar or Baripada or Bhubaneshwar or Brahmapur or Cuttack or Dhenkanal or Keonjhar or Konark or Koraput or Paradip or Phulabani or Puri or Sambalpur or Udayagiri or Puducherry or Karaikal or Mahe or Puducherry or Yanam or Punjab or Amritsar or Batala or Chandigarh or Faridkot or Firozpur or Gurdaspur or Hoshiarpur or Jalandhar or Kapurthala or Ludhiana or Nabha or Patiala or Rupnagar or Sangrur or Rajasthan or Ajmer or Alwar or Amer or Barmer or Beawar or Bharatpur or Bhilwara or Bikaner or Bundi or Chittaurgarh or Churu or Dhaulpur or Dungarpur or Ganganagar or Hanumangarh or Jaipur or Jaisalmer or Jalor or Jhalawar or Jhunjhunu or Jodhpur or Kishangarh or Kota or Merta or Nagaur or Nathdwara or Pali or Phalodi or Pushkar or Sawai Madhopur or Shahpura or Sikar or Sirohi or Tonk or Udaipur or Sikkim or Gangtok or Gyalsing or Lachung or Mangan or Tamil Nadu or Arcot or Chengalpattu or Chennai or Chidambaram or Coimbatore or Cuddalore or Dharmapuri or Dindigul or Kanchipuram or Kanniyakumari or Kodaikanal or Kumbakonam or Madurai or Mamallapuram or Nagappattinam or Nagercoil or Palayankottai or Pudukkottai or Rajapalaiyam or Ramanathapuram or Thanjavur or Tiruchchirappalli or Tirunelveli or Tiruppur or Tuticorin or	

	Udhagamandalam or Vellore or Telangana or Hyderabad or Karimnagar or Khammam or Mahbubnagar or Nizamabad or Sangareddi or Warangal or Tripura or Agartala or Uttar Pradesh or Agra or Aligarh or Allahabad or Amroha or Ayodhya or Azamgarh or Bahraich or Ballia or Banda or Bara Banki or Bareilly or Basti or Bijnor or Bithur or Budaun or Bulandshahr or Deoria or Etah or Etawah or Faizabad or "Farrukhabad cum Fatehgarh " or Fatehpur or Fatehpur Sikri or Ghaziabad or Ghazipur or Gonda or Gorakhpur or Hamirpur or Hardoi or Hathras or Jalaun or Jaunpur or Jhansi or Kannauj or Kanpur or Lakhimpur or Lalitpur or Lucknow ORMainpuri or Mathura or Meerut or Mirzapur Vindhyachal or Moradabad or Muzaffarnagar or Partapgarh or Pilibhit or Rae Bareli or Rampur or Saharanpur or Sambhal or Shahjahanpur or Sitapur or Sultanpur or Tehri or Varanasi or Uttarakhand or Almora or Dehra Dun or Haridwar or Mussoorie or Nainital or Pithoragarh or West Bengal or Alipore or Alipur Duar or Asansol or Baharampur or Bally or Balurghat or Bankura or Baranagar or Barasat or Barrackpore or Basirhat or Bhatpara or Bishnupur ORBudge Budge or Burdwan or Chandernagore or Darjiling or Diamond Harbour or Dum Dum or Durgapur or Halisahar or Haora or Hugli or Ingraj Bazar or Jalpaiguri or Kalimpong or Kamarhati or Kanchrapara or Kharagpur or Koch Bihar or Kolkata or Krishnanagar or Malda or Midnapore or Murshidabad or Navadwip or Palashi or Panihati or Purulia or Raiganj or Santipur or Shantiniketan or	

	Shrirampur or Siliguri or Siuri or Tamluk or Titagarh).ti,ab,gl.	

10	exp Pakistan/ or (Pakistan* or Abbottabad or Alizai or Bahawalpur or Bannu or Bara Tehsil or Battagram or Bhimbar or Burewala or Charsadda or Chiniot or Dadu or Darra Adam Khel or Dera Ghazi Khan or Dera Ismail Khan or Faisalabad or Gojra or Gujrat or Gujranwala or Ghulam Khana or Hafizabad or Haveli or Islamabad or Jacobabad or Jamrud or Jhelum or Jhang Sadr or Kamoke or Karachi or Kasur or Khar Bajaur or Khairpur or Khanpur or Kohat or Kotli or Khuzdar or Khyber Pass or Kurram or Lahore or Landi Kotal or Larkana or Laskathan or Makeen or Multan or Muzaffarabad or Mardan Malir Cantonment or Mehrabpur or Mingora or Mir Ali or Miranshah or Mirpur Khas or Muzaffargarh or Muridke or Mandi Bahauddin or Nawabshah or Neelum Valley or Nowshera or Okara or Pallindri or Parachinar or Peshawar or Quetta or Rahim Yar Khan or Razmak or Rawalakot or Rawalpindi or Sahiwal or Sadda or Saddiqabad or Sargodha or Shahkot or Sialkot or Shikarpur or Sukkur or Shekhupura or Swabi or Tando Allahyar or Wana Tehsil).ti,ab,gl.	19793

11	(Afghanistan/ or afghan*.mp. or ((Andkhoy or Aqcha or Asadabad or Baghlan or Bagramor Balkh or Bamyan or Baraki Barak or Bharak or Chaki Wardak or Chaghcharan or Chaharikar or Charikar or Day Mirdad or Dihdadi or Farah Province or Farah City or Faryab or Ghazni or Fayzabad or Gardez or (Ghor not (Jordan or Israel or Dead Sea)) or Guzara or Helmand or (Herat not "herat failure") or Jaghori or Jalalabad or Jowzjan or Kandahar or Khost or Khulm or Kohistan or Kunduz or Laghman or Lashkargah or Logar or Mahmud Raqi or Maidan Shar or Maymana or "Mazar i Sharif" or Mihtarlam or Nangarhar or Nijrab or Panjshir or Parwan or Puli Alam or Puli Khumri or "Qala i Naw" or "Sar e Pol" or Sharana or Sheberghan or Shinwar or Taloqan Takhar or Taluqan or Tsamkani or Yakawlang or Yangi Qala or Zaranj).mp. or (Andar.mp. not Portuguese.lg.) or (kabul.mp. not Turkish.sl.))) not ((Iran not (Iran and afghan*)) or (Pakistan not (Pakistan and afghan*))).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes]	2612
12	Bhutan/ or bhutan*.mp.	633
13	Sri Lanka/ or ("sri lanka*" or srilanka or ceylon).mp. or "sri lanka".cp. or ("Colombo City or Colombo District" or "Dehiwala-Mount Lavinia" or Galle or Jaffna or Kalamunai or Kandy or Moratuwa or Negomgo or "Pita Kotte" or ("Point Pedro" not "10-point") or "Sri Jayewardenepura	7951

	Kotte" or Trincomalee).mp.	
14	Maldives/ or (Maldive* or Maldivian or Addu Atoll or alif alif atoll or Ari Atoll or "Baa Atholhu" or Dhidhdhoo or Eydhafushi or "Faafu Atoll" or Feridhoo or Funadhoo or Fuvahmulah or "Gaafu Alif Atoll" or "Gaafu Dhaalu Atoll" or "Gnyaviyani Atoll" or "Haa Alifu Atholhu" or "Haa Dhaalu Atholhu" or Haddummati Atoll or "Hithadhoo oenu" or Hulhumale or "Ihavandippolu Atoll" or Kulhudhuffushi or "Lhaviyani Atholhu" or "Kaafu Atoll" or "Male Atoll" or Maafushi or Magoodhoo or "Meemu Atoll" or Naifaru or "Rasdhoo Atoll" or Seenu or "Shaviyani Atholhu" or Thinadhoo or Viligili).mp.	243
15	7 or 8 or 9 or 10 or 11 or 12 or 13 or 14	180617
16	6 and 15	1548
17	limit 16 to yr="2010 -Current"	733

CINAHL Plus with Full Text Searched May 12, 2020 Results =160

#	Query	Limiters/ Expanders	Results
S1	(health* or disease* or outbreak* or infectio* or illness* or virus* or injur* or disorder* or epidemic* or pandemic* or fever* or symptoms or (deformit* or malformation* or cleft-palate* or cleft-lip* or birth-defect* or congenital heart defect* or spina-bifida or birth-outcome* or pregnancy-outcome* or still-birth or still-born* or stillborn or stillbirth* or low-birth-weight or (fetal-growth Near (restric* or retard*)) or preterm labo* or preterm birth or (hypertension and pregnan*) or preeclampsia) or (((developmental* or intellectual* or learning or mental or cognitive or physical*) Near/3 (disab* or impair* or delay* or disorder*)) or mental retard* or handicap* or special needs or down* syndrome or "fragile x" or autis* or asperger* or pervasive developmental disorder* or cerebral palsy or tourette* or tic-disorder* or attention-deficit* or adhd or epilep* or language-disorder* or neurodevelopment* or ((neuro or cognitive or physical*) Near/5 development*)) Near/ 6 water) or (mortalit* or death* or fatalit*) or	Expanders - Apply equivalent subjects Search modes - Find all my search terms	Display

(respiratory or asthma* or allerg* or aeroallerg* or ((breathing or breathe) Near/3 (issue* or problem* or difficult* or struggl* or trouble))) or (heat-stress* or heat-exhaustion or heat-stroke* or heatstroke* or sun stroke* or sunstroke*) or (cholera* or diarrhea* or diarrhoea* or dysentery or salmonella or pneumonia* or plasmodium* or babesi* or hantavirus* or giardia* or cryptosporidi* or leptospiros*) or (Trichinos* or trichinellosis or Chikungunya or Dengue or Lymphatic-filariasis or Rift-Valley-fever or Yellow-fever or Zika or Malaria or japanese-encephalitis or tick-borne or West-Nile-fever or Leishmaniasis or Sandfly-fever or phelebotomus-fever or haemorrhagic-fever or Lyme-disease or Relapsing-fever or borreliosis or Rickettsial-diseases or spotted-fever or Q-fever or Tularaemia or Chagas or trypanosomiasis or Sleeping-sickness or Plague or Rickettsiosis or Onchocerciasis or river-blindness or Schistosomiasis or bilharziasis or Typhus or louse-borne-relapsing-fever)

S2	ti ((ambient OR season* OR seasonal* OR climate OR climatic OR weather OR summer OR winter OR (((climat* AND NOT (political-climate OR "organizational climate*" OR economic-climate OR financial-climate)) OR weather) N/3 (chang* OR disrupt* OR volati* OR instabilit* OR unstable OR variable OR variability OR vulnerab*)) OR ((chang* OR decline* OR decrease* OR increase*) N/3 humidity) OR ((global* OR climate) N/2 warm*) OR ((climat* OR weather) N/1 (conditions OR factors OR driven)) OR ("greenhouse gas*" OR "greenhouse effect*" OR "carbon emission*" OR "carbon dioxide emission*" OR "CO2 emission*"))) OR (((extreme OR severe) N/1 (weather OR heat OR hot* OR temperature*)) OR ((annual* OR daily OR month* OR ambient OR environmental OR season* OR climate OR climatic OR weather OR summer OR winter) N/4 temperature*) OR (warm-season* OR warm*-month* OR ((unseasonabl* OR unusual*) N/3 (warm OR hot OR heat OR humid* OR cold OR high OR low)))) OR ((("El Nino" OR "La Nina") OR (rain OR rains OR rainstorm* OR raining OR	Search modes - Find all my search terms	Display

rainfall OR ((high OR heavy OR extreme OR severe OR daily OR levels) N/2 precipitation) OR uv-index OR flooding OR floods OR waterlogging OR (drought* AND NOT drought-resistan*) OR desertifcation OR hurricane* OR cyclone* OR tornado* OR superstorm* OR "dust storm*" OR "storm surge*" OR "ice storm*" OR ((storm OR storms) AND disaster*) OR monsoon*) OR ("forest fire*" OR wildfire* OR "wild fire*" OR "fire disaster*" OR (uncontrolled N/2 fire*)) OR (("sea level*" N/3 (rise OR rises OR rising OR increase OR increasing OR increases)) OR ((polar OR permafrost OR ice-cap OR glacier*) N/3 (melt* OR retreat* OR reced* OR thaw*))) OR famine*))

S3	ti (((carbon monoxide* or hydrogen sulfide* or hydrogen sulphide* or H2S or nitrogen oxide* or volatile organic* or voc or nox or sulfur dioxide* or sulfur oxide* or sulphur dioxide* or sulphur oxide*) and (pollut* or emit* or emission* or contaminat* or decontaminat*)) or ((air or atmospher*) N/3 (pollut* or quality or wast* or contamin* or emission* or immission* or effluent*or acidification or contaminat* or degrad* or decontaminat* or purif* or restor*)) or ((gas or gases) N/3 (toxic* or noxious or releas* or purifi* or scrub* or emit* or waste* or vapo?r)) or (acid* N/3 (deposition* or rain* or snow or fog or mist or precipitation or hail or sleet)) or afterburning or biogas or (burning adj3 fossil fuel*) or ((chimney or stack) N/3 height) or dust or fallout or fall out or flaring or fly ash or electrosmog or (greenhouse N/3 (gas or effect or effects or gases or emission*)) or incineration or odor or odour or olfactory pollution or particulate* or smog or smoke or soot or sick building syndrome or vapo?r recovery system* or ((industrial or automobile* or traffic or freeway or highway or roadway or motorway or	Search modes - Find all my search terms	Display

	diesel or vehicle*) N/3 (exhaust* or emission* or emit* or fume or fumes or vapo?r*)))		
S4	(pediatric* or paediatric* or child* or newborn* or congenital* or infan* or baby or babies or neonat* or “pre-term” or preterm or “premature birth*” or NICU or preschool* or “pre-school*” or kindergarten* or “elementary school*” or “nursery school*” or schoolchild* or toddler* or boy or boys or girl* or “middle school*” or pubescen* or juvenile* or teen* or youth* or “high school*” or adolesc*or prepubesc* or “pre-pubesc*” or "(MH "Child+") OR (MH "Adolescence+") OR (MH "Minors (Legal)") or "(MH "Child Abuse, Sexual") OR (MH "Child Behavior Disorders+") OR (MH "Child, Medically Fragile") OR (MH "Child Day Care") OR (MH	Expanders - Apply equivalent subjects Search modes - Find all my search terms	Display

	"Child Behavior+") OR (MH "Child Mortality") OR (MH "Child Passenger Safety") OR (MH "Child Development Disorders, Pervasive+") OR (MH "Child Custody") OR (MH "Child Abuse+") OR (MH "Child Nutritional Physiology+") OR (MH "Child Behavior Checklist")) OR SO (child* or pediatric* or paediatric* or adolescent)		
S5	(MH "Pakistan") OR (MH "Nepal") OR (MH "India") OR (MH "Bangladesh") or (MH "Afghanistan") or (MH "Bhutan") or (MH "Maldives") or (MH "Sri Lanka")	Expanders - Apply equivalent subjects Search modes - Find all my search terms	56,499
S6	S2 OR S3	Expanders - Apply equivalent subjects Search modes - Find all my search terms	Display

S7	TI India or indian subcontinent" or nepal* or bangladesh* or pakistan* or bhutan* or maldiv* or "sri lanka*" or afghani or afghanistan	Expanders - Apply equivalent subjects Search modes - Find all my search terms	20,339
S8	AB India or indian subcontinent" or nepal* or bangladesh* or pakistan* or bhutan* or maldiv* or "sri lanka*" or afghani or afghanistan	Expanders - Apply equivalent subjects Search modes - Find all my search terms	23,379
S9	S5 OR S7 OR S8	Expanders - Apply equivalent subjects	65,619

		Search modes - Find all my search terms	
S10	S1 AND S4 AND S6 AND S9	Expanders - Apply equivalent subjects Search modes - Find all my search terms	230
S11	AB (((carbon monoxide* or hydrogen sulfide* or hydrogen sulphide* or H2S or nitrogen oxide* or volatile organic* or voc or nox or sulfur dioxide* or sulfur oxide* or sulphur dioxide* or sulphur oxide*) and (pollut* or emit* or emission* or contaminat* or decontaminat*)) or ((air or atmospher*) N/3 (pollut* or quality or wast* or contamin* or emission* or immission* or effluent*or acidification or contaminat* or degrad* or decontaminat* or purif* or restor*)) or ((gas or gases) N/3 (toxic* or noxious or releas* or purifi* or scrub* or emit* or waste* or	Expanders - Apply equivalent subjects Search modes - Find all my search terms	Display

vapo?r)) or (acid* N/3 (deposition* or rain* or snow or fog or mist or precipitation or hail or sleet)) or afterburning or biogas or (burning adj3 fossil fuel*) or ((chimney or stack) N/3 height) or dust or fallout or fall out or flaring or fly ash or electrosmog or (greenhouse N/3 (gas or effect or effects or gases or emission*)) or incineration or odor or odour or olfactory pollution or particulate* or smog or smoke or soot or sick building syndrome or vapo?r recovery system* or ((industrial or automobile* or traffic or freeway or highway or roadway or motorway or diesel or vehicle*) N/3 (exhaust* or emission* or emit* or fume or fumes or vapo?r*)))

S12	AB ((ambient OR season* OR seasonal* OR climate OR climatic OR weather OR summer OR winter OR (((climat* AND NOT (political-climate OR "organizational climate*" OR economic-climate OR financial-climate)) OR weather) N/3 (chang* OR disrupt* OR volati* OR instabilit* OR unstable OR variable OR variability OR vulnerab*)) OR ((chang* OR decline* OR decrease* OR increase*) N/3 humidity) OR ((global* OR climate) N/2 warm*) OR ((climat* OR weather) N/1 (conditions OR factors OR driven)) OR ("greenhouse gas*" OR "greenhouse effect*" OR "carbon emission*" OR "carbon dioxide emission*" OR "CO2 emission*"))) OR (((extreme OR severe) N/1 (weather OR heat OR hot* OR temperature*)) OR ((annual* OR daily OR month* OR ambient OR environmental OR season* OR climate OR climatic OR weather OR summer OR winter) N/4 temperature*) OR (warm-season* OR warm*-month* OR ((unseasonabl* OR unusual*) N/3 (warm OR hot OR heat OR humid* OR cold OR high OR low)))) OR ((("El Nino" OR "La Nina") OR (rain OR rains OR rainstorm* OR raining OR	Expanders - Apply equivalent subjects Search modes - Find all my search terms	Display

	rainfall OR ((high OR heavy OR extreme OR severe OR daily OR levels) N/2 precipitation) OR uv-index OR flooding OR floods OR waterlogging OR (drought* AND NOT drought-resistan*) OR desertifcation OR hurricane* OR cyclone* OR tornado* OR superstorm* OR "dust storm*" OR "storm surge*" OR "ice storm*" OR ((storm OR storms) AND disaster*) OR monsoon*) OR ("forest fire*" OR wildfire* OR "wild fire*" OR "fire disaster*" OR (uncontrolled N/2 fire*)) OR (("sea level*" N/3 (rise OR rises OR rising OR increase OR increasing OR increases)) OR ((polar OR permafrost OR ice-cap OR glacier*) N/3 (melt* OR retreat* OR reced* OR thaw*))) OR famine*))		
S13	S2 OR S3 OR S11 OR S12	Expanders - Apply equivalent subjects Search modes - Find all my search terms	Display

S14	(S2 OR S3 OR S11 OR S12) AND (S1 AND S4 AND S9 AND S13)	Expanders - Apply equivalent subjects Search modes - Find all my search terms	533
S15	(S1 AND S4 AND S9 AND S13)	Expanders - Apply equivalent subjects Search modes - Find all my search terms	533
S16	((S1 AND S4 AND S9 AND S13)) AND (S2 OR S3)	Expanders - Apply equivalent subjects	230

		Search modes - Find all my search terms	
S17	((S1 AND S4 AND S9 AND S13)) AND (S2 OR S3)	Limiters - Published Date: 20100101-20201231 Expanders - Apply equivalent subjects Search modes - Find all my search terms	160

Proquest Dissertations and Theses Searched April 15, 2020 Results =81

noft("climate change" OR "severe weather" OR "violent weather" OR superstorm* OR "environmental change" OR "sea level rise" OR "greenhouse gas*" OR "greenhouse effect" OR "carbon emission" OR "global warm*" OR "El Nino" OR "La Nina" OR flooding OR waterlogging OR desertification OR "dust storm*" OR "storm surge*") OR (noft("climate change" OR "severe weather" OR "violent weather" OR superstorm* OR "environmental change" OR "sea level rise" OR "greenhouse gas*" OR "greenhouse effect" OR "carbon emission" OR "global warm*" OR "El Nino" OR "La Nina" OR flooding OR waterlogging OR desertification OR "dust storm*" OR "storm surge*") OR noft((extreme OR violent OR unseasonabl* OR unusual) NEAR/3 (heat OR hot OR cold OR storm* OR wind OR winds OR flood* OR humidity OR high OR low))) OR noft((air OR atmospher*) NEAR/3 (pollut* OR emit* OR emission* OR contaminat* OR decontaminat*)) OR noft(((gas OR gases) NEAR/3 (toxic* OR noxious OR releas* OR purifi* OR scrub* OR emit* OR waste* OR vapo?r))) OR noft(((("carbon monoxide") OR ("hydrogen sulfide") OR ("hydrogen sulphide") OR H2S OR ("nitrogen oxides") OR ("volatile organic") OR voc OR nox OR ("sulphur dioxide") OR "sulphur oxide*") NEAR/3 (pollut* OR emit* OR emission* OR contaminat* OR decontaminat*))) OR noft(afterburning OR biogas OR (burning NEAR/3 fossil fuel*) OR ((chimney OR stack) NEAR/3 height) OR dust OR fallout OR "fall out" OR flaring OR fly ash OR electrosmog OR incineration OR odor OR odour OR "olfactory pollution" OR particulate* OR smog OR smoke OR soot OR "sick building syndrome" OR "vapor recovery system*") OR noft(((industrial OR automobile* OR traffic OR freeway OR highway OR roadway OR motorway OR diesel OR vehicle*) NEAR/3 (exhaust* OR emission* OR emit* OR fume OR fumes OR vapo?r*)))) AND (noft(elders) or noft(elderly) or noft(geriatric*) or noft("old age") or noft("senior citizens") or (noft("older adult") OR noft("older adults")) or noft(centenarian*) or noft(nonagenarian*) or noft(octogenarian*) or noft(septuagenarian*) or noft(sexagenarian*) or noft(dottering) or noft(decrepit) or noft(tottering) or noft(overaged) or noft("oldest old") or noft(pediatric*) or noft(paediatric*) or noft(child*) or noft(newborn*) or noft(congenital*) or noft(infan*) or noft(baby) or noft(babies) or noft(neonat*) or noft(pre-term) or noft(preterm*) or (noft("premature birth") OR noft("premature births")) or noft(NICU) or noft(preschool*) or noft(pre-school*) or noft(kindergarten*) or noft(kindergarden*) or (noft("elementary school") OR noft("elementary schoolchildren") OR noft("elementary schoolhome") OR noft("elementary schooling") OR noft("elementary schoolk") OR noft("elementary schools") OR noft("elementary schoolteacher")) or (noft("nursery school") OR noft("nursery schools")) or (noft(day care*) not noft(adult*)) or noft(schoolchild*) or noft(toddler*) or noft(boy) or noft(boys) or noft(girl*) or (noft("middle school") OR noft("middle schooler") OR noft("middle schoolers") OR noft("middle schooling") OR noft("middle schools")) or noft(pubescen*) or noft(juvenile*) or noft(teen*) or noft(youth*) or noft(high school*) or noft(adolesc*) or noft(pre-pubesc*) or noft(prepubesc*) or noft(immigrant*) or noft(immigration) or noft(emmigrant*) or noft(emmigration) or noft(refugee*) or noft(asylum seeker*) or noft(asylee*) or (noft("displaced person") OR noft("displaced persons")) or noft("incomer*") or noft("in comer*") or (noft("new comer") OR noft("new comers")) or noft(newcomer*) or noft(childbearing) or noft(childbirth) or noft(pregnan*) or noft(fertile) or noft(fecund) or noft(womanish) or noft(womanly) or noft(maternal) or noft(vulnerable)) AND (noft(India or afghanistan*) or noft(Indian subcontinent) or noft(nepal* or bhutan*) or noft(pakistan* or maldives or maldive or maldivian) or noft(bangladesh* or “sri lanka*”))

SCOPUS Searched May 12, 2020 Result =545

(((TITLE-ABS-KEY (afterburning OR smog OR electrosmog OR flaring OR ordor OR odour OR "fly ash" OR "fall out" OR "acid rain" OR "acid precipitation" OR "airborne particulate")) OR (TITLE-ABS-KEY ((air OR atmosphere OR gas*) W/3 (emission* OR immission* OR quality OR pollut* OR vapor* OR vapour* OR purifi* OR fume*))) OR (TITLE-ABS-KEY (dust OR ((industrial OR traffic OR automobile OR diesel

AND of AND vehicle OR roadway OR motorway OR highway) AND (emit* OR emiss* OR vapor* OR vapour* OR fume*)))) OR (TITLE-ABS-KEY ("workplace air" OR "factory air" OR "airborne pesticide*" OR "airborne herbicide*" OR "airborne insecticide*" OR "insecticide mist*" OR "pesticide mist*" OR "herbicide mist*")) OR (TITLE-ABS-KEY ("climat* change" OR global-climate* OR "climate event" OR "disaster storm*" OR "global warming" OR "evironmental change" OR "greenhouse gas*" OR "greenhouse effect*" OR "carbon emission*" OR "carbon dioxide emission*" OR "CO2 emission*" OR desertifcation OR hurricane* OR cyclone* OR tornado* OR superstorm* OR "dust storm*" OR "storm surge*" OR "ice storm*" OR monsoon* OR "extreme heat" OR "extreme temperature*" OR "extreme cold" OR wildfire* OR "fire disaster*" OR "uncontrolled fire*" OR "sea level rise" OR "permafrost melt" OR "sea level ris*" OR "glacial retreat" OR "ice cap melt*" OR "thermohaline conveyor" OR "extreme precipitation" OR waterlogging OR flood* OR "El Nino" OR "La Nina" OR uv-index OR uv-rays OR ozone AND hole))) AND (TITLE-ABS-KEY ((elders OR elderly OR geriatric* OR "old age" OR "senior citizens" OR "older adult*" OR centenarian* OR nonagenarian* OR octogenarian* OR septuagenarian* OR sexagenarian* OR dottering OR decrepit OR tottering OR overaged OR "oldest old" OR pediatric* OR paediatric* OR child* OR newborn* OR congenital* OR infan* OR baby OR babies OR neonat* OR pre-term OR preterm* OR "premature birth*" OR nicu OR preschool* OR pre-school* OR kindergarten* OR kindergarden* OR "elementary school*" OR "nursery school*" OR "day care*" OR schoolchild* OR toddler* OR boy OR boys OR girl* OR "middle school*" OR pubescen* OR juvenile* OR teen* OR youth* OR "high school*" OR adolesc* OR pre-pubesc* OR prepubesc* OR immigrant* OR immigration OR emmigrant* OR emmigration OR refugee* OR "asylum seeker*" OR asylee* OR "displaced person*" OR "incomer*" OR "in comer*" OR "new comer*" OR newcomer* OR childbearing OR childbirth OR pregnan* OR fertile OR fecund OR womanish OR womanly OR maternal OR vulnerable))) AND (TITLE-ABS-KEY ((india OR "indian subcontinent" OR nepal* OR pakistan* OR bangladesh* OR afghanistan* OR maldives OR maldivian OR "sri lanka*" OR bhutan)))) AND ((TITLE-ABS-KEY (health* OR disease* OR outbreak* OR infectio* OR illness* OR virus* OR injur* OR disorder* OR epidemic* OR pandemic* OR fever* OR symptoms OR (deformit* OR malformation* OR cleft-palate* OR cleft-lip* OR birth-defect* OR congenital AND heart AND defect* OR spina-bifida OR birth-outcome* OR pregnancy-outcome* OR still-birth OR still-born* OR stillborn OR stillbirth* OR low-birth-weight OR (fetal-growth W/3 (restric* OR retard*)) OR preterm AND labo* OR preterm AND birth OR (hypertension AND pregnan*) OR preeclampsia) OR (((developmental* OR intellectual* OR learning OR mental OR cognitive OR physical*) W/3 (disab* OR impair* OR delay* OR disorder*)) OR mental AND retard* OR handicap* OR special AND needs OR down* AND syndrome OR "fragile x" OR autis* OR asperger* OR pervasive AND developmental AND disorder* OR cerebral AND palsy OR tourette* OR tic-disorder* OR attention-deficit* OR adhd OR epilep* OR language-disorder* OR neurodevelopment* OR ((neuro OR cognitive OR physical*) W/5 development*)) W/ 6 water) OR (mortalit* OR death* OR fatalit*) OR (respiratory OR asthma* OR allerg* OR aeroallerg* OR ((breathing OR breathe) W/3 (issue* OR problem* OR difficult* OR struggl* OR trouble))) OR (heat-stress* OR heat-exhaustion OR heat-stroke* OR heatstroke* OR "sun stroke*" OR sunstroke*) OR (cholera* OR diarrhea* OR diarrhoea* OR dysentery OR salmonella OR pneumonia* OR plasmodium* OR babesi* OR hantavirus* OR giardia* OR cryptosporidi* OR leptospiros*) OR (trichinos* OR trichinellosis OR chikungunya OR dengue OR lymphatic-filariasis OR rift-valley-fever OR yellow-fever OR zika OR malaria OR japanese-encephali))) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010))

Proquest Dissertations and These Global May 12, 2020 Result =81

noft((health* OR disease* OR outbreak* OR infectio* OR illness* OR virus* OR injur* OR disorder* OR epidemic* OR pandemic* OR fever* OR symptoms OR (deformit* OR malformation* OR cleft-palate* OR cleft-lip* OR birth-defect* OR congenital AND heart AND defect* OR spina-bifida OR birth-outcome* OR pregnancy-outcome* OR still-birth OR still-born* OR stillborn OR stillbirth* OR low-birth-weight OR (fetal-growth NEAR/3 (restric* OR retard*)) OR preterm AND labo* OR preterm AND birth OR (hypertension AND pregnan*) OR preeclampsia) OR (((developmental* OR intellectual* OR learning OR mental OR cognitive OR physical*) NEAR/3 (disab* OR impair* OR delay* OR disorder*)) OR mental AND retard* OR handicap* OR special AND needs OR down* AND syndrome OR "fragile x" OR autis* OR asperger* OR pervasive AND developmental AND disorder* OR cerebral AND palsy OR tourette* OR tic-disorder* OR attention-deficit* OR adhd OR epilep* OR language-disorder* OR neurodevelopment* OR ((neuro OR cognitive OR physical*) W/5 development*)) W/ 6 water) OR (mortalit* OR death* OR fatalit*) OR (respiratory OR asthma* OR allerg* OR aeroallerg* OR ((breathing OR breathe) W/3 (issue* OR problem* OR difficult* OR struggl* OR trouble))) OR (heat-stress* OR heat-exhaustion OR heat-stroke* OR heatstroke* OR ("sun stroke") OR sunstroke*) OR (cholera* OR diarrhea* OR diarrhoea* OR dysentery OR salmonella OR pneumonia* OR plasmodium* OR babesi* OR hantavirus* OR giardia* OR cryptosporidi* OR leptospiros*) OR (trichinos* OR trichinellosis OR chikungunya OR dengue OR lymphatic-filariasis OR rift-valley-fever OR yellow-fever OR zika OR malaria OR japanese-encephal)) and (noft("climate change" OR "severe weather" OR "violent weather" OR superstorm* OR "environmental change" OR "sea level rise" OR ("greenhouse gas" OR "greenhouse gases") OR "greenhouse effect" OR "carbon emission" OR ("global warming") OR "El Nino" OR "La Nina" OR flooding OR waterlogging OR desertification OR ("dust storm" OR "dust storms") OR ("storm surge" OR "storm surges")) OR (noft("climate change" OR "severe weather" OR "violent weather" OR superstorm* OR "environmental change" OR "sea level rise" OR ("greenhouse gas" OR "greenhouse gases") OR "greenhouse effect" OR "carbon emission" OR ("global warming") OR "El Nino" OR "La Nina" OR flooding OR waterlogging OR desertification OR ("dust storm" OR "dust storms") OR ("storm surge" OR "storm surges")) OR noft((extreme OR violent OR unseasonabl* OR unusual) NEAR/3 (heat OR hot OR cold OR storm* OR wind OR winds OR flood* OR humidity OR high OR low))) OR noft((air OR atmospher*) NEAR/3 (pollut* OR emit* OR emission* OR contaminat* OR decontaminat*)) OR noft(((gas OR gases) NEAR/3 (toxic* OR noxious OR releas* OR purifi* OR scrub* OR emit* OR waste* OR vapo?r))) OR noft(((("carbon monoxide") OR ("hydrogen sulfide") OR ("hydrogen sulphide") OR H2S OR ("nitrogen oxides") OR ("volatile organic") OR voc OR nox OR ("sulphur dioxide") OR "sulphur oxide*") NEAR/3 (pollut* OR emit* OR emission* OR contaminat* OR decontaminat*))) OR noft(afterburning OR biogas OR (burning NEAR/3 fossil fuel*) OR ((chimney OR stack) NEAR/3 height) OR dust OR fallout OR "fall out" OR flaring OR fly ash OR electrosmog OR incineration OR odor OR odour OR "olfactory pollution" OR particulate* OR smog OR smoke OR soot OR "sick building syndrome" OR "vapor recovery system*") OR noft(((industrial OR automobile* OR traffic OR freeway OR highway OR roadway OR motorway OR diesel OR vehicle*) NEAR/3 (exhaust* OR emission* OR emit* OR fume OR fumes OR vapo?r*)))) AND (noft(elders) or noft(elderly) or noft(geriatric*) or noft(“old age”) or noft(“senior citizens”) or (noft("older adult") OR noft("older adults")) or noft(centenarian*) or noft(nonagenarian*) or noft(octogenarian*) or noft(septuagenarian*) or noft(sexagenarian*) or noft(dottering) or noft(decrepit) or noft(tottering) or noft(overaged) or noft("oldest old") or noft(pediatric*) or noft(paediatric*) or noft(child*) or noft(newborn*) or noft(congenital*) or noft(infan*) or noft(baby) or noft(babies) or noft(neonat*) or noft(pre-term) or noft(preterm*) or (noft("premature birth") OR noft("premature births")) or noft(NICU) or noft(preschool*) or noft(pre-school*) or noft(kindergarten*) or noft(kindergarden*) or (noft("elementary school") OR noft("elementary schoolchildren") OR noft("elementary schoolhome") OR noft("elementary schooling") OR noft("elementary schoolk") OR noft("elementary schools") OR noft("elementary schoolteacher")) or (noft("nursery school") OR noft("nursery schools")) or (noft(day care*) not noft(adult*)) or noft(schoolchild*) or noft(toddler*) or noft(boy) or noft(boys) or noft(girl*) or (noft("middle school") OR noft("middle schooler") OR noft("middle schoolers") OR noft("middle schooling") OR noft("middle schools")) or noft(pubescen*) or noft(juvenile*) or noft(teen*) or noft(youth*) or noft(high school*) or noft(adolesc*) or noft(pre-pubesc*) or noft(prepubesc*) or noft(immigrant*) or noft(immigration) or noft(emmigrant*) or noft(emmigration) or noft(refugee*) or noft(asylum seeker*) or noft(asylee*) or (noft("displaced person") OR noft("displaced persons")) or noft("incomer*") or noft("in comer*") or (noft("new comer") OR noft("new comers")) or noft(newcomer*) or noft(childbearing) or noft(childbirth) or noft(pregnan*) or noft(fertile) or noft(fecund) or noft(womanish) or noft(womanly) or noft(maternal) or noft(vulnerable)) AND (noft(India or afghanistan*) or noft(Indian subcontinent) or noft(nepal* or bhutan*) or noft(pakistan* or maldives or maldive or maldivian) or noft(bangladesh* or ("sri lanka" OR "sri lankabhimanya" OR "sri lankan" OR "sri lankans" OR "sri lankathe")))

Cochrane Library (Wiley) Searched May 12, 2020 Result =105

ID Search Hits

#1 ((elders OR elderly OR geriatric* OR "old age" OR "senior citizens"

OR "older adult*" OR centenarian* OR nonagenarian* OR octogenarian*

OR septuagenarian* OR sexagenarian* OR dottering OR decrepit OR tottering

OR overaged OR "oldest old" OR pediatric* OR paediatric* OR child*

]OR newborn* OR congenital* OR infan* OR baby OR babies OR neonat*

OR pre-term OR preterm* OR "premature birth*" OR nicu OR preschool*

OR pre-school* OR kindergarten* OR kindergarden* OR "elementary scho

" OR "nursery school*" OR "day care*" OR schoolchild* OR toddler* OR boy O

R boys OR girl* OR "middle school*" OR pubescen* OR juvenile* OR teen*

OR youth* OR "high school*" OR adolesc* pre-pubesc* OR prepubesc*

OR immigrant* OR immigration OR emmigrant* OR emmigration OR refugee* OR "asylum seeker*" OR asylee* OR "displaced person*" OR "incomer*" OR "in comer*" OR "new comer*" OR newcomer* OR childbearing OR childbirth OR pregnan* OR fertile OR fecund OR womanish OR womanly OR maternal OR vulnerable)):ti,ab,kw 373525

#2 ("climat* change" or global-climate* OR "climate event" or "disaster storm*" or "global warming" or "evironmental change" or "greenhouse gas*" OR "greenhouse effect*" OR "carbon emission*" OR "carbon dioxide emission*" OR "CO2 emission*" or desertifcation OR hurricane* OR cyclone* OR tornado* OR superstorm* OR "dust storm*" OR "storm surge*" OR "ice storm*" OR monsoon* or "extreme heat" or "extreme temperature*" or "extreme cold" or wildfire* or "fire disaster*" or "uncontrolled fire*" or "sea level rise" or "permafrost melt" or "sea level ris*" or "glacial retreat" or "ice cap melt*" or "thermohaline conveyor" or "extreme precipitation" or waterlogging or flood* or "El Nino" or "La Nina" or uv-index or uv-rays or ozone hole):ti,ab,kw 548

#3 ((air or atmosphere or gas*) AND (emission* or immission* or quality or pollut* or vapor* or vapour* or purifi* or fume*)):ti,ab,kw 14361

#4	(afterburning or smog or electrosmog or flaring or ordor or odour or "fly ash" or "fall out" or "acid rain" or "acid precipitation" or ‘ "airborne particulate"):ti,ab,kw	1513
#5	(dust or ((industrial or traffic or automobile or diesel of vehicle or roadway or motorway or highway) and (emit* or emiss* or vapor* or vapour* or fume*))):ti,ab,kw	2095
#6	("workplace air" or "factory air" or "airborne pesticide*" or "airborne herbicide*" or "airborne insecticide*" or "insecticide mist*" or "pesticide mist*" or "herbicide mist*"):ti,ab,kw	6
#7	#2 or #3 or #4 or #5 or #6	18128
#8	((india OR "indian subcontinent" OR nepal* OR pakistan* OR bangladesh* or afghanistan* or maldives or maldivian or "sri lanka*" or bhutan)):ab	8908
#9	((india OR "indian subcontinent" OR nepal* OR pakistan* OR bangladesh* or afghanistan* or maldives or maldivian or "sri lanka*" or bhutan)):ti	3881
#10	#8 or #9	10116
#11	#1 and #7 and #10	106

PROSPERO Searched May 12, 2020 Results =91

LineSearch forHits

#1 ((elders OR elderly OR geriatric* OR "old age" OR "senior citizens" OR "older adult*" OR centenarian* OR nonagenarian* OR octogenarian* OR septuagenarian* OR sexagenarian* OR dottering OR decrepit OR tottering OR overaged OR "oldest old" OR pediatric* OR paediatric* OR child* OR newborn* OR congenital* OR infan* OR baby OR babies OR neonat* OR pre-term OR preterm* OR "premature birth*" OR nicu OR preschool* OR pre-school* OR kindergarten* OR kindergarden* OR "elementary school*" OR "nursery school*" OR "day care*" OR schoolchild* OR toddler* OR boy OR boys OR girl* OR "middle school*" OR pubescen* OR juvenile* OR teen* OR youth* OR "high school*" OR adolesc* OR pre-pubesc* OR prepubesc* OR immigrant* OR immigration OR emmigrant* OR emmigration OR refugee* OR "asylum seeker*" OR asylee* OR "displaced person*" OR "incomer*" OR "in comer*" OR "new comer*" OR newcomer* OR childbearing OR childbirth OR pregnan* OR fertile OR fecund OR womanish OR womanly OR maternal OR vulnerable)) 33079

#2 ("climat* change" or global-climate* OR "climate event" or "disaster storm*" or "global warming" or "evironmental change" or "greenhouse gas*" OR "greenhouse effect*" OR "carbon emission*" OR "carbon dioxide emission*" OR "CO2 emission*" or desertifcation OR hurricane* OR cyclone* OR tornado* OR superstorm* OR "dust storm*" OR "storm surge*" OR "ice storm*" OR monsoon* or "extreme heat" or "extreme temperature*" or "extreme cold" or wildfire* or "fire disaster*" or "uncontrolled fire*" or "sea level rise" or "permafrost melt" or "sea level ris*" or "glacial retreat" or "ice cap melt*" or "thermohaline conveyor" or "extreme precipitation" or waterlogging or flood* or "El Nino" or "La Nina" or or uv-rays or ozone hole) 187

#3 ((air or atmosphere or gas*) AND (emission* or immission* or quality or pollut* or vapor* or vapour* or purifi* or fume*)) 4333

#4 (afterburning or smog or electrosmog or flaring or ordor or odour or "fly ash" or "fall out" or "acid rain" or "acid precipitation" or "airborne particulate") 54

#5 (dust or ((industrial or traffic or automobile or diesel of vehicle or roadway or motorway or highway) and (emit* or emiss* or vapor* or vapour* or fume*))) 101

#6 ("workplace air" or "factory air" or "airborne pesticide*" or "airborne herbicide*" or "airborne insecticide*" or "insecticide mist*" or "pesticide mist*" or "herbicide mist*")

0

#7 ((india OR "indian subcontinent" OR nepal* OR pakistan* OR bangladesh* or afghanistan* or maldives or maldivian or "sri lanka*" or bhutan))

2330

#8 6 OR #5 OR #4 OR #3

4424

#9 #8 OR #2 4569

#10 #1 AND #7 AND #9 91

Appendix 3: Research Positionality Statement

I was born and raised in a low-income family in Kathmandu, Nepal. I am a male, age 35, who speaks Nepali and comes from a Hindu family. I am a Ph.D. candidate with over four years of experience working in rural community health in Nepal. Most of my works were focused on improving maternal and children's health. Considering my birthplace, religion, and primary language, I may consider myself an insider in this thesis research as this was conducted in similar population groups in Nepal. However, I consider myself to be an outsider researcher in this study from the lens of educational attainment, my work, the natural and built environment that I was brought up in and exposed to (e.g., urban setting, population size, technology, infrastructure development, i.e., schools/colleges/universities, hospitals, telecommunications, roads etc.). For example, the study location is a rural community in Kavre district. The infrastructure in the study area is underdeveloped compared to the Kathmandu district. The study site has only one independent, not-for-profit, non-government district-level hospital, Dhulikhel Hospital. In contrast, Kathmandu district has 47 private and government-run hospitals serving at least 1.7 million people.[1] The study area has only a few Nepali-medium secondary-level government schools that provide education to a few students living in the area. The English language is a critical challenge to almost all government-run school students due to a lack of qualified English teachers. I was fortunate to have access to an English-medium school where education was generally better than the government-run schools. Roads in Kathmandu are wider and pitched in most parts but are not without potholes. In contrast, mostly gravelled roads and hiking trails are common in the study area, often interrupted in the rainy season. Although cell phones have reached every corner of the country, there is still inequality in access to the internet. Cellular data are relatively expensive but are the only significant internet source in Nepal's remote areas, including the study location, while

Kathmandu district has several internet service providers. In summary, being born and brought up in a big urban city has given me much exposure to the technology and development that participants in the rural community have been deprived of, and that justifies my position as an outsider researcher in this study.

My position as an outsider researcher included both advantages and disadvantages. On the positive side, I approached participants as an expert who can encourage and build enthusiasm to share their lived experiences and insights during focus group discussions (FGD) and interviews. On the other hand, the community did not easily open up and faced difficulties in two-way interaction due to a lack of rapport.

As mentioned earlier, I worked for almost four years in community health programs such as SUAAHARA (***Good nutrition***) in the capacity of Essential Nutrition Action (ENA) officer. The primary goal of the SUAAHARA program was to improve the nutritional status of 1000-day mothers, i.e., pregnant women or mothers having children less than two years of age (9*30 + 730 =1000). The program allowed me to work closely with 1000-day mothers and observe their lived experiences. The social inequity and inequality, gender disparity, and men's dominance were more apparent to me than ever before. I witnessed how a woman lives the life of a full-time unpaid homemaker and yet, discounted, be the last one to eat in the family after everyone is complete and needs approval from a man for anything, including seeking a health service and deciding for the family planning. Nepal's national maternal and child health indicators also shout out the suffering of women and children compared to national statistics of developed countries such as Canada. According to the Nepal Demographic and Health Survey (NDHS) 2016, the under-five mortality rate and infant mortality rate are 39/1000 (vs 5.2 in Canada) and 21/1000 (vs 4.2 in Canada) live births, respectively, while the maternal mortality ratio is 239/100,000 live births (Vs 10 in

Canada).[2] The first-hand observation of the critical situation of women and children and the national statistical evidence are my sole motivations for conducting women- and children-focused thesis research for my Ph.D. My thesis research can supplement the voices of unheard and suppressed women and children in Nepal and support their health needs and priorities.

I recognized that working with a different community was critical but challenging for an outsider researcher. However, I used the following principle while working with the community people.

- Transparency: We provided complete, accurate information on the project goals and objectives and a transparent and open procedure for FGDs and interviews to all the study participants.
- Inclusion and demographic diversity: We included people from diverse socioeconomic backgrounds with different voices, ideas, and information to lay the groundwork for quality outcomes and democratic legitimacy.
- Equality: We prioritized treating all participants equally, regardless of age, gender/sex, educational attainment, religion, caste and ethnicity, and economic status.
- Respect and integrity: We paid due respect to all participants for contributing to the study and considered their perspectives. We explained potential risks and benefits to the participants, including incentives, from engaging in the research.
- Power balance: We welcomed suggestions and feedback from the participants to the researcher or study. We did not force participants for any task.

References

1. List of hospitals in Nepal - Wikipedia. https://en.wikipedia.org/wiki/List_of_hospitals_in_Nepal.

2. Ministry of Health Nepal, ICF & New ERA. 2016 Nepal Demographic and Health Survey Key Findings. *Kathmandu, Nepal Minist. Heal. Nepal* 1, 20 (2017).

Appendix 4: Sample Size Calculation for APO paper

A sample size of 1694 was estimated for this study using the sample size calculation formula for the cohort study, which we had inflated by 10% to compensate for data loss due to any reason.

$$n = \frac{\left[z_\alpha \sqrt{(1+1/m)\bar{p}(1-\bar{p})} + z_\beta \sqrt{p_0(1-p_0)/m + p_1(1-p_1)}\right]^2}{(p_0 - p_1)^2}$$

α = 1.96, 0.05 two-sided significance

β = 0.84, 80% power

Prevalence of preterm births in Nepal (P0) = 14%

The global prevalence of $PM_{2.5}$-associated preterm births (P1) = 18%

$$\bar{p} = \frac{p_1 + mp_0}{m+1}$$

$\bar{p}$ = 0.16

Replacing all the values in the equation, n = ~1694

Inflating calculated sample size by 10% gave: (1694 + 10% of 1694) = 1863

Appendix 5: Supplementary table (Advrese Pregnancy Outcomes)

S1a: Multilevel regression model of the relationship between total precipitation and birthweight stratified by residence

Rural					**Urban**	
	Birthweight				**Birthweight**	
Variables	***Estimates***	***CI***	***p***		***Estimates***	***CI (95%)***
Total Precipitation	0.11	-0.09 to 0.31	0.29		0.10	-0.05 to 0.25
Mean Temperature	-23.13	-49.81 to 3.54	0.09		-16.89	-37.14 to 3.58
Mean $PM_{2.5}$	4.85	-3.45 to 13.16	0.25		-1.74	-6.73 to 3.28
Age	11.52	0.03 to 23.01	**0.05**		-1.75	-9.19 to 5.69
Ethnicity						
Brahmin/Chhetri	Ref				Ref	
Dalit and others	74.42	-74.13 to 222.97	0.33		-37.07	-133.21 to 57.01
Janajati/Indigenous	187.59	85.64 to 289.54	**<0.01**		126.67	70.91 to 184.37
Visit as per ANC Protocol						
Yes	Ref				Ref	

No	-109.48	-208.65 to -10.31	**0.03**		-76.48	-156.55 to 0.40
Pregnancy Count						
First	Ref				Ref	
Fourth and above	-119.69	-301.85 to 62.46	0.20		105.28	-37.24 to 246.66
Second	28.97	-74.88 to 132.82	0.58		88.1	20.09 to 157.92
Third	-35.84	-175.22 to 103.54	0.61		75.95	-11.09 to 164.64
Birth Type						
Normal	Ref				Ref	
Assisted	-21.52	-156.37 to 113.33	0.75		-12.11	-74.73 to 47.47
Sex						
Girl	Ref				Ref	
Boy	46.98	-33.55 to 127.51	0.25		128.58	71.76 to 184.74
Season						
Wetter	Ref				Ref	
Drier	-35.88	-145.32 to 73.57	0.52		53.39	-21.42 to 129.16
PC1	2.63	0.15 to 5.10	**0.04**		0.25	-1.10 to 1.59

PC2	0.47	-1.64 to 2.59	0.66		-0.26	-1.57 to 1.07

Table S1b: Multilevel regression model of the relationship between mean maximum temperature and birthweight stratified by residence

Rural					**Urban**	
	Birthweight				**Birthweight**	
Variables	***Estimates***	***CI***	***p***		***Estimates***	***CI (95%)***
Mean Maximum Temperature	-21.42	-48.60 to 5.76	0.12		-15.07	-35.58 to 6.13
Total Precipitation	0.08	-0.11 to 0.26	0.41		0.07	-0.06 to 0.20
Mean $PM_{2.5}$	4.75	-3.56 to 13.07	0.26		-1.44	-6.70 to 3.51
Age	11.70	0.20 to 23.19	**0.05**		-1.80	-9.00 to 5.52
Ethnicity						
Brahmin/Chhetri	Ref				Ref	
Dalit and others	71.90	-76.93 to 220.73	0.34		-38.44	-132.56 to 57.25
Janajati/Indigenous	185.68	83.77 to 287.59	**<0.01**		126.88	68.72 to 183.41
Visit as per ANC Protocol						

Yes	Ref				Ref	
No	-110.35	-209.57 to -11.13	**0.03**		-77.92	-160.16 to 6.28
Fourth and above	-123.05	-305.20 to 59.11	0.19		106.80	-33.53 to 240.75
Second	27.68	-76.18 to 131.55	0.60		88.33	20.08 to 154.67
Third	-36.37	-175.82 to 103.09	0.61		75.80	-13.05 to 167.01
Birth type						
Normal	Ref				Ref	
Assisted	-19.55	-154.36 to 115.26	0.78		-11.80	-73.67 to 50.22
Sex						
Girl	Ref				Ref	
Boy	46.31	-34.26 to 126.89	0.26		129.58	78.02 to 181.31
Season						
Wetter	Ref				Ref	
Drier	-24.72	-134.89 to 85.45	0.66		55.55	-25.43 to 133.94
PC1	2.45	0.01 to 4.90	**0.05**		0.20	-1.04 to 1.44
PC2	0.43	-1.70 to 2.55	0.70		-0.22	-1.57 to 1.09

Table S1c: Multilevel regression model of the relationship between mean temperature and birthweight stratified by residence

Rural					**Urban**	
	Birthweight				**Birthweight**	
Variables	***Estimates***	***CI***	***p***		***Estimates***	***CI (95%)***
Mean Temperature	-23.13	-49.81 to 3.54	0.09		-16.6	-36.94 to 3.71
Total Precipitation	0.11	-0.09 to 0.31	0.29		0.10	-0.05 to 0.25
Mean $PM_{2.5}$	4.85	-3.45 to 13.16	0.25		-1.86	-6.72 to 3.18
Age	11.52	0.03 to 23.01	**0.05**		-1.70	-9.12 to 5.56
Ethnicity						
Brahmin/Chhetri	Ref				Ref	
Dalit and others	74.42	-74.13 to 222.97	0.33		-40.34	-135.33 to 59.20
Janajati/Indigenous	187.59	85.64 to 289.54	**<0.01**		126.17	69.81 to 182.23
Visit as per ANC Protocol						
Yes	Ref				Ref	

No	-109.48	-208.65 to -10.31	**0.03**		-77.36	-159.14 to 5.63
Pregnancy Count						
First	Ref				Ref	
Fourth and above	-119.69	-301.85 to 62.46	0.20		104.80	-36.66 to 247.36
Second	28.97	-74.88 to 132.82	0.58		89.07	22.08 to 152.74
Third	-35.84	-175.22 to 103.54	0.61		77.02	-12.88 to 162.95
Birth Type						
Normal	Ref				Ref	
Assisted	-21.52	-156.37 to 113.33	0.75		-12.44	-77.13 to 48.88
Sex						
Girl	Ref				Ref	
Boy	46.98	-33.55 to 127.51	0.25		128.88	72.99 to 182.81
Season						
Wetter	Ref				Ref	
Drier	-35.88	-145.32 to 73.57	0.52		52.79	-24.34 to 129.53
PC1	2.63	0.15 to 5.10	**0.04**		0.24	-1.12 to 1.52

PC2	0.47	-1.64 to 2.59	0.66		-0.28	-1.63 to 1.05

Table S1d: Multilevel regression model of the relationship between mean minimum temperature and birthweight stratified by residence

Rural					Urban	
	Birthweight				Birthweight	
Variables	***Estimates***	***CI***	***p***		***Estimates***	***CI (95%)***
Mean Minimum Temperature	-22.67	-47.84 to 2.50	0.08		-16.51	-35.74 to 2.43
Total Precipitation	0.13	-0.09 to 0.34	0.24		0.12	-0.04 to 0.28
Mean $PM_{2.5}$	4.91	-3.39 to 13.21	0.25		-2.02	-7.11 to 3.07
Age	11.37	-0.13 to 22.87	0.05		-1.73	-9.08 to 5.54
Ethnicity						
Brahmin/Chhetri	Ref				Ref	
Dalit and others	77.60	-70.81 to 226.00	0.31		-36.92	-128.98 to 55.93
Janajati/Indigenous	188.94	86.92 to 290.96	**<0.01**		126.81	71.46 to 182.36
Visit as per ANC Protocol						

Yes	Ref				Ref	
No	-108.77	-207.92 to -9.62	**0.03**		-77.80	-155.60 to -0.26
Pregnancy Count						
First	Ref				Ref	
Fourth and above	-116.69	-298.95 to 65.56	0.21		104.39	-33.53 to 236.95
Second	30.04	-73.82 to 133.91	0.57		87.89	21.79 to 155.03
Third	-35.62	-174.97 to 103.73	0.62		75.20	-11.03 to 162.56
Birth Type						
Normal	Ref				Ref	
Assisted	-22.48	-157.35 to 112.39	0.74		-12.72	-74.45 to 47.42
Sex						
Girl	Ref				Ref	
Boy	47.71	-32.80 to 128.23	0.25		128.31	70.87 to 183.77
Season						
Wetter	Ref				Ref	
Drier	-47.43	-157.79 to 62.92	0.40		49.66	-26.71 to 127.16

PC1	2.71	0.21 to 5.21	**0.03**		0.27	-1.03 to 1.58
PC2	0.53	-1.58 to 2.64	0.62		-0.31	-1.61 to 1.02

Table S1e: Multilevel regression model of the relationsip between mean $PM_{2.5}$ and birth weight stratified by residence

Rural					**Urban**	
	Birthweight				**Birthweight**	
Variables	***Estimates***	***CI***	***p***		***Estimates***	***CI (95%)***
Mean $PM_{2.5}$	4.85	-3.45 to 13.16	0.25		-1.75	-6.91 to 3.37
Total Precipitation	0.11	-0.09 to 0.31	0.29		0.10	-0.05 to 0.24
Mean Temperature	-23.13	-49.81 to 3.54	0.09		-16.75	-36.74 to 2.98
Age	11.52	0.03 to 23.01	**0.05**		-1.85	-9.36 to 5.78
Ethnicity						
Brahmin/Chhetri	Ref				Ref	
Dalit and others	74.42	-74.13 to 222.97	0.33		-38.13	-130.90 to 58.73
Janajati/Indigenous	187.59	85.64 to 289.54	**<0.01**		126.75	70.08 to 183.45

Visit as per ANC Protocol						
Yes	Ref				Ref	
No	-109.48	-208.65 to -10.31	**0.03**		-77.24	-155.46 to 4.20
Pregnancy Count						
First	Ref				Ref	
Fourth and above	-119.69	-301.85 to 62.46	0.20		104.79	-33.18 to 246.97
Second	28.97	-74.88 to 132.82	0.58		88.22	21.56 to 155.79
Third	-35.84	-175.22 to 103.54	0.61		76.36	-11.89 to 166.07
Birth Type						
Normal	Ref				Ref	
Assisted	-21.52	0	0.75		-12.07	-73.62 to 51.97
Sex						
Girl	Ref				Ref	
Boy	46.98	-33.55 to 127.51	0.25		128.89	74.44 to 182.25
Season						
Wetter	Ref				Ref	

Drier	-35.88	-145.32 to 73.57	0.52		52.52	-26.13 to 132.78
PC1	2.63	0.15 to 5.10	**0.04**		0.26	-1.01 to 1.54
PC2	0.47	-1.64 to 2.59	0.66		-0.28	-1.64 to 1.12

Table S2a: Multivariable logistic regression showing the relationship between total precipitation and APOs stratified by residence

Rural					Urban		
	APO				APO		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Total precipitation	1.00	1.00 to 1.00	0.63		1.00	1.00 to 1.00	0.58
Mean Temperature	0.97	0.84 to 1.12	0.70		1.03	0.91 to 1.17	0.60
Mean $PM_{2.5}$	0.98	0.94 to 1.03	0.44		1.00	0.97 to 1.03	0.88
Age	0.95	0.88 to 1.03	0.21		1.01	0.97 to 1.06	0.65
Ethnicity							
Brahmin/Chhetri	Ref				Ref		

Dalit and others	0.89	0.38 to 1.96	0.77		1.32	0.78 to 2.19	0.29
Janajati/Indigenous	0.69	0.39 to 1.23	0.20		0.65	0.46 to 0.93	**0.02**
Visit as per ANC protocol							
Yes	Ref				Ref		
No	0.90	0.46 to 1.67	0.76		1.73	1.10 to 2.66	**0.02**
Pregnancy count							
First	Ref				Ref		
Fourth and above	1.92	0.59 to 5.84	0.26		1.04	0.44 to 2.31	0.93
Second	0.99	0.51 to 1.88	0.97		0.94	0.62 to 1.41	0.75
Third	1.22	0.50 to 2.85	0.65		0.93	0.54 to 1.58	0.80
Birth type							
Normal	Ref				Ref		
Assisted	2.38	1.23 to 4.48	**0.01**		1.60	1.12 to 2.29	**0.01**
Sex							
Girl	Ref				Ref		

Boy	0.67	0.41 to 1.10	0.11		0.60	0.43 to 0.84	**0.01**
Season							
Wetter	Ref				Ref		
Drier	1.53	0.80 to 2.96	0.20		0.98	0.61 to 1.58	0.94
PC1	1.00	0.98 to 1.01	0.59		1.00	0.99 to 1.01	0.77
PC2	0.99	0.98 to 1.00	0.27		1.00	0.99 to 1.01	0.71

Table S2b: Multivariable logistic regression showing the relationship between mean maximum temperature and APOs stratified by residence

Rural					**Urban**		
	APO				**APO**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean Maximum Temperature	0.96	0.82 to 1.11	0.57		1.02	0.90 to 1.16	0.72
Total Precipitation	1.00	1.00 to 1.00	0.52		1.00	1.00 to 1.00	0.68

Mean $PM_{2.5}$	0.98	0.94 to 1.03	0.44		1.00	0.97 to 1.03	0.83
Age	0.95	0.88 to 1.03	0.21		1.01	0.97 to 1.06	0.66
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	0.88	0.38 to 1.95	0.76		1.32	0.78 to 2.19	0.29
Janajati/Indigenous	0.69	0.39 to 1.23	0.20		0.65	0.46 to 0.92	**0.02**
Visit as per ANC protocol							
Yes	Ref				Ref		
No	0.91	0.46 to 1.67	0.76		1.74	1.11 to 2.67	**0.01**
Pregnancy count							
First	Ref				Ref		
Fourth and above	1.93	0.60 to 5.85	0.26		1.04	0.43 to 2.30	0.93
Second	0.99	0.51 to 1.87	0.97		0.94	0.62 to 1.41	0.75
Third	1.23	0.50 to 2.86	0.64		0.93	0.54 to 1.58	0.80

Birth type							
Normal	Ref				Ref		
Assisted	2.38	1.23 to 4.48	**0.01**		1.60	1.11 to 2.28	**0.01**
Sex							
Girl	Ref				Ref		
Boy	0.67	0.41 to 1.10	0.11		0.60	0.43 to 0.84	**0.01**
Season							
Wetter	Ref				Ref		
Drier	1.56	0.81 to 3.01	0.18		0.98	0.61 to 1.58	0.93
PC1	1.00	0.98 to 1.01	0.62		1.00	0.99 to 1.01	0.79
PC2	0.99	0.98 to 1.00	0.26		1.00	0.99 to 1.01	0.73

Table S2c: Multivariable logistic regression showing the relationship between mean temperature and APOs stratified by residence

Rural					**Urban**		
	APO				**APO**		

Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean Temperature	0.97	0.84 to 1.12	0.70		1.03	0.91 to 1.17	0.60
Total Precipitation	1.00	1.00 to 1.00	0.63		1.00	1.00 to 1.00	0.58
Mean $PM_{2.5}$	0.98	0.94 to 1.03	0.44		1.00	0.97 to 1.03	0.88
Age	0.95	0.88 to 1.03	0.21		1.01	0.97 to 1.06	0.65
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	0.89	0.38 to 1.96	0.77		1.32	0.78 to 2.19	0.29
Janajati/Indigenous	0.69	0.39 to 1.23	0.20		0.65	0.46 to 0.93	**0.02**
Visit as per ANC protocol							
Yes	Ref				Ref		
No	0.90	0.46 to 1.67	0.76		1.73	1.10 to 2.66	**0.02**
Pregnancy count							
First	Ref				Ref		

Fourth and above	1.92	0.59 to 5.84	0.26		1.04	0.44 to 2.31	0.93
Second	0.99	0.51 to 1.88	0.97		0.94	0.62 to 1.41	0.75
Third	1.22	0.50 to 2.85	0.65		0.93	0.54 to 1.58	0.80
Birth type							
Normal	Ref				Ref		
Assisted	2.38	1.23 to 4.48	**0.01**		1.60	1.12 to 2.29	**0.01**
Sex							
Girl	Ref				Ref		
Boy	0.67	0.41 to 1.10	0.11		0.60	0.43 to 0.84	**0.01**
Season							
Wetter	Ref				Ref		
Drier	1.53	0.80 to 2.96	0.20		0.98	0.61 to 1.58	0.94
PC1	1.00	0.98 to 1.01	0.59		1.00	0.99 to 1.01	0.77
PC2	0.99	0.98 to 1.00	0.27		1.00	0.99 to 1.01	0.71

Table S2d: Multivariable logistic regression showing the relationship between mean minimum temperature and APOs stratified by residence

Rural					Urban		
	APO				APO		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean of Minimum Temperature	0.98	0.86 to 1.13	0.82		1.04	0.92 to 1.17	0.53
Total Precipitation	1.00	1.00 to 1.00	0.73		1.00	1.00 to 1.00	0.52
Mean $PM_{2.5}$	0.98	0.94 to 1.03	0.43		1.00	0.97 to 1.03	0.92
Age	0.95	0.88 to 1.03	0.22		1.01	0.97 to 1.05	0.66
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	0.89	0.38 to 1.97	0.78		1.32	0.78 to 2.19	0.29
Janajati/Indigenous	0.68	0.39 to 1.23	0.20		0.65	0.46 to 0.93	**0.02**
Visit as per ANC protocol							

Yes	Ref				Ref		
No	0.90	0.46 to 1.66	0.75		1.72	1.10 to 2.65	**0.02**
Pregnancy count							
First	Ref				Ref		
Fourth and above	1.91	0.59 to 5.80	0.27		1.05	0.44 to 2.32	0.92
Second	0.99	0.51 to 1.88	0.97		0.94	0.62 to 1.41	0.76
Third	1.22	0.50 to 2.83	0.66		0.93	0.54 to 1.59	0.80
Birth type							
Normal	Ref				Ref		
Assisted	2.39	1.23 to 4.49	**0.01**		1.61	1.12 to 2.30	**0.01**
Sex							
Girl	Ref				Ref		
Boy	0.67	0.41 to 1.10	0.11		0.60	0.43 to 0.84	**0.01**
Season							
Wetter	Ref				Ref		
Drier	1.52	0.79 to 2.97	0.21		0.99	0.62 to 1.58	0.96

PC1	1.00	0.98 to 1.01	0.55		1.00	0.99 to 1.01	0.76
PC2	0.99	0.98 to 1.00	0.27		1.00	0.99 to 1.01	0.691

Table S2e: Multivariable logistic regression showing the relationship between mean $PM_{2.5}$ and APOs stratified by residence

Rural					**Urban**		
	APO				**APO**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean $PM_{2.5}$	0.98	0.94 to 1.03	0.44		1.00	0.97 to 1.03	0.88
Mean Temperature	0.97	0.84 to 1.12	0.70		1.00	1.00 to 1.00	0.58
Total Precipitation	1.00	1.00 to 1.00	0.63		1.03	0.91 to 1.17	0.60
Age	0.95	0.88 to 1.03	0.21		1.01	0.97 to 1.06	0.65
Ethnicity							
Brahmin/Chhetri	Ref				Ref		

Dalit and others	0.89	0.38 to 1.96	0.77		1.32	0.78 to 2.19	0.29
Janajati/Indigenous	0.69	0.39 to 1.23	0.20		0.65	0.46 to 0.93	**0.02**
Visit as per ANC protocol							
Yes	Ref				Ref		
No	0.90	0.46 to 1.67	0.76		1.73	1.10 to 2.66	**0.02**
Pregnancy count							
First	Ref				Ref		
Fourth and above	1.92	0.59 to 5.84	0.26		1.04	0.44 to 2.31	0.93
Second	0.99	0.51 to 1.88	0.97		0.94	0.62 to 1.41	0.75
Third	1.22	0.50 to 2.85	0.65		0.93	0.54 to 1.58	0.80
Birth type							
Normal	Ref				Ref		
Assisted	2.38	1.23 to 4.48	**0.01**		1.60	1.12 to 2.29	**0.01**
Sex							
Girl	Ref				Ref		

Boy	0.67	0.41 to 1.10	0.11		0.60	0.43 to 0.84	**0.01**
Season							
Wetter	Ref				Ref		
Drier	1.53	0.80 to 2.96	0.20		0.98	0.61 to 1.58	0.94
PC1	1.00	0.98 to 1.01	0.59		1.00	0.99 to 1.01	0.77
PC2	0.99	0.98 to 1.00	0.27		1.00	0.99 to 1.01	0.71

Table S3a: Multivariable logistic regression showing the relationship between total precipitation and APOs stratified by season

Drier					**Wetter**		
	APO				**APO**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Total Precipitation	1.00	1.00 to 1.00	0.99		1.00	1.00 to 1.00	0.59
Mean Temperature	1.00	0.89 to 1.13	0.98		0.98	0.86 to 1.12	0.77

Mean $PM_{2.5}$	1.00	0.97 to 1.04	0.79		0.97	0.93 to 1.01	0.13
Age	0.99	0.94 to 1.04	0.70		1.00	0.94 to 1.05	0.88
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.28	0.73 to 2.21	0.38		0.98	0.48 to 1.91	0.95
Janajati/Indigenous	0.80	0.54 to 1.19	0.26		0.49	0.31 to 0.77	**0.01**
Residence							
Rural	Ref				Ref		
Urban	1.10	0.69 to 1.79	0.69		1.22	0.66 to 2.30	0.54
Visit as per ANC protocol							
Yes	Ref				Ref		
No	1.36	0.83 to 2.16	0.21		1.35	0.77 to 2.30	0.28
Pregnancy count							
First	Ref				Ref		
Fourth and above	1.49	0.61 to 3.44	0.362		0.95	0.33 to 2.54	0.93

Second	0.92	0.58 to 1.45	0.72		1.01	0.60 to 1.69	0.98
Third	1.27	0.71 to 2.22	0.41		0.64	0.28 to 1.36	0.26
Birth type							
Normal	Ref				Ref		
Assisted	2.20	1.46 to 3.30	**<0.01**		1.28	0.77 to 2.09	0.32
Sex							
Girl	Ref				Ref		
Boy	0.63	0.44 to 0.89	**0.01**		0.62	0.40 to 0.94	**0.03**
PC1	1.00	0.99 to 1.00	0.24		1.00	0.99 to 1.01	0.84
PC2	1.00	0.99 to 1.00	0.41		1.00	0.99 to 1.01	0.41

Table S3b: Multivariable logistic regression showing the relationship between mean maximum temperature and APOs stratified by season

Drier					**Wetter**		
	APO				**APO**		

Variables	*Odds Ratios*	*CI*	*p*		*Odds Ratios*	*CI*	*p*
Mean Maximum Temperature	0.99	0.88 to 1.12	0.89		0.98	0.84 to 1.13	0.73
Total Precipitation	1.00	1.00 to 1.00	0.91		1.00	1.00 to 1.00	0.55
Mean $PM_{2.5}$	1.00	0.97 to 1.04	0.80		0.97	0.93 to 1.01	0.13
Age	0.99	0.94 to 1.04	0.69		1.00	0.94 to 1.05	0.88
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.28	0.73 to 2.21	0.38		0.98	0.48 to 1.90	0.95
Janajati/Indigenous	0.80	0.54 to 1.19	0.26		0.49	0.31 to 0.77	**0.01**
Residence							
Rural	Ref				Ref		
Urban	1.09	0.68 to 1.77	0.71		1.22	0.66 to 2.29	0.52
Visit as per ANC protocol							
Yes	Ref				Ref		

No	1.36	0.83 to 2.17	0.21		1.36	0.77 to 2.31	0.27
Pregnancy count							
First	Ref				Ref		
Fourth and above	1.50	0.61 to 3.46	0.36		0.95	0.32 to 2.54	0.92
Second	0.92	0.58 to 1.45	0.72		1.01	0.60 to 1.69	0.98
Third	1.27	0.71 to 2.22	0.41		0.64	0.28 to 1.36	0.26
Birth type							
Normal	Ref				Ref		
Assisted	2.19	1.46 to 3.28	**<0.01**		1.28	0.77 to 2.09	0.32
Sex							
Girl	Ref				Ref		
Boy	0.63	0.44 to 0.89	**0.01**		0.61	0.40 to 0.94	**0.02**
PC1	1.00	0.99 to 1.00	0.25		1.00	0.99 to 1.01	0.83
PC2	1.00	0.99 to 1.00	0.41		1.00	0.99 to 1.01	0.42

Table S3c: Multivariable logistic regression showing the relationship between mean temperature and APOs stratified by season

Drier					Wetter		
	APO				APO		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean Temperature	1.00	0.89 to 1.13	0.98		0.98	0.86 to 1.12	0.77
Total Precipitation	1.00	1.00 to 1.00	0.99		1.00	1.00 to 1.00	0.59
Mean $PM_{2.5}$	1.00	0.97 to 1.04	0.79		0.97	0.93 to 1.01	0.13
Age	0.99	0.94 to 1.04	0.70		1.00	0.94 to 1.05	0.88
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.28	0.73 to 2.21	0.38		0.98	0.48 to 1.91	0.95
Janajati/Indigenous	0.80	0.54 to 1.19	0.26		0.49	0.31 to 0.77	**0.01**
Residence							
Rural	Ref				Ref		

Urban	1.10	0.69 to 1.79	0.69		1.22	0.66 to 2.30	0.52
Visit as per ANC protocol							
Yes	Ref				Ref		
No	1.36	0.83 to 2.16	0.21		1.35	0.77 to 2.30	0.28
Pregnancy count							
First	Ref				Ref		
Fourth and above	1.49	0.61 to 3.44	0.36		0.95	0.33 to 2.54	0.93
Second	0.92	0.58 to 1.45	0.72		1.01	0.60 to 1.69	0.98
Third	1.27	0.71 to 2.22	0.41		0.64	0.28 to 1.36	0.26
Birth type							
Normal	Ref				Ref		
Assisted	2.20	1.46 to 3.30	**<0.01**		1.28	0.77 to 2.09	0.32
Sex							
Girl	Ref				Ref		
Boy	0.63	0.44 to 0.89	**0.01**		0.62	0.40 to 0.94	**0.03**

PC1	1.00	0.99 to 1.00	0.24		1.00	0.99 to 1.01	0.84
PC2	1.00	0.99 to 1.00	0.41		1.00	0.99 to 1.01	0.41

Table S3d: Multivariable logistic regression showing the relationship between mean minimum temperature and APOs stratified by season

Drier					Wetter		
	APO				**APO**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean Minimum Temperature	1.01	0.90 to 1.12	0.88		0.98	0.87 to 1.11	0.81
Total Precipitation	1.00	1.00 to 1.00	0.89		1.00	1.00 to 1.00	0.62
Mean $PM_{2.5}$	1.00	0.97 to 1.04	0.78		0.97	0.93 to 1.01	0.13
Age	0.99	0.94 to 1.04	0.70		1.00	0.94 to 1.05	0.88
Ethnicity							
Brahmin/Chhetri	Ref				Ref		

Dalit and others	1.28	0.73 to 2.21	0.38		0.98	0.48 to 1.91	0.95
Janajati/Indigenous	0.80	0.54 to 1.19	0.26		0.49	0.31 to 0.78	0.01
Residence							
Rural	Ref				Ref		
Urban	1.11	0.69 to 1.82	0.67		1.23	0.66 to 2.31	0.52
Visit as per ANC protocol							
Yes	Ref				Ref		
No	1.35	0.83 to 2.16	0.22		1.35	0.77 to 2.30	0.28
Pregnancy count							
First	Ref				Ref		
Fourth and above	1.49	0.61 to 3.42	0.37		0.95	0.33 to 2.54	0.93
Second	0.92	0.58 to 1.45	0.72		1.01	0.60 to 1.69	0.98
Third	1.27	0.71 to 2.22	0.41		0.64	0.28 to 1.36	0.26
Birth type							
Normal	Ref				Ref		

Assisted	2.21	1.46 to 3.31	<0.01		1.28	0.77 to 2.09	0.33
Sex							
Girl	Ref				Ref		
Boy	0.63	0.44 to 0.89	0.01		0.62	0.40 to 0.94	0.03
PC1	0.99	0.99 to 1.00	0.23		1.00	0.99 to 1.01	0.83
PC2	1.00	0.99 to 1.00	0.40		1.00	0.99 to 1.01	0.41

Table S3e: Multivariable logistic regression showing the relationship between mean $PM_{2.5}$ and APOs stratified by season

Drier					**Wetter**		
	APO				**APO**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean $PM_{2.5}$	1.00	0.97 to 1.04	0.79		0.97	0.93 to 1.01	0.13
Total Precipitation	1.00	1.00 to 1.00	0.99		1.00	1.00 to 1.00	0.59

Mean temperature	1.00	0.89 to 1.13	0.98		0.98	0.86 to 1.12	0.77
Age	0.99	0.94 to 1.04	0.70		1.00	0.94 to 1.05	0.88
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.28	0.73 to 2.21	0.38		0.98	0.48 to 1.91	0.95
Janajati/Indigenous	0.80	0.54 to 1.19	0.26		0.49	0.31 to 0.77	**0.01**
Residence							
Rural	Ref				Ref		
Urban	1.10	0.69 to 1.79	0.69		1.22	0.66 to 2.30	0.52
Visit as per ANC protocol							
Yes	Ref				Ref		
No	1.36	0.83 to 2.16	0.21		1.35	0.77 to 2.30	0.28
Pregnancy count							
First	Ref				Ref		
Fourth and above	1.49	0.61 to 3.44	0.36		0.95	0.33 to 2.54	0.93

Second	0.92	0.58 to 1.45	0.72		1.01	0.60 to 1.69	0.98
Third	1.27	0.71 to 2.22	0.41		0.64	0.28 to 1.36	0.26
Birth type							
Normal	Ref				Ref		
Assisted	2.20	1.46 to 3.30	**<0.01**		1.28	0.77 to 2.09	0.32
Sex							
Girl	Ref				Ref		
Boy	0.63	0.44 to 0.89	**0.01**		0.62	0.40 to 0.94	**0.03**
PC1	1.00	0.99 to 1.00	0.24		1.00	0.99 to 1.01	0.84
PC2	1.00	0.99 to 1.00	0.41		1.00	0.99 to 1.01	0.41

Appendix 6: Sample Size Calculation for Childhood Infectious Disease Paper

We estimated a sample size of 1622 for this study using the sample size calculation formula for the cohort study, which we had inflated by 10% to compensate for data loss due to any reason.

$$n = \frac{\left[z_\alpha \sqrt{(1+1/m)\bar{p}(1-\bar{p})} + z_\beta \sqrt{p_0(1-p_0)/m + p_1(1-p_1)}\right]^2}{(p_0 - p_1)^2}$$

$$\bar{p} = \frac{p_1 + mp_0}{m+1}$$

Where,

P0 = prevalence of diarrhea among children in the general population in Nepal

P1 = prevalence of diarrhea among children attributed to temperature in Kathmandu, Nepal

M = number of unexposed children per exposed children

α = 1.96, 0.05 two-sided significance

β = 0.84, 80% power

What we already knew:

Prevalence of diarrhea in children younger than five years (P0) = 7.6%

Relative risk (RR) = 1.081 - For one unit increase in maximum temperature above the monthly average recorded within that month, the risk of diarrhea among those younger than five years increases by 8.1%.

RR = $\frac{P1}{P0}$1.081 = $\frac{P1}{0.076}$ P1 = 1.081 * 0.076 = 0.08

$$\bar{p} = \frac{p_1 + mp_0}{m+1}$$

After inserting value of P1, m, and P0

$\bar{p}$ = 0.07

Replacing all the values in the equation:

$$n = \frac{\left[z_\alpha \sqrt{(1+1/m)\bar{p}(1-\bar{p})} + z_\beta \sqrt{p_0(1-p_0)/m + p_1(1-p_1)}\right]^2}{(p_0 - p_1)^2}$$

n = ~1622

Inflating the calculated sample size by 10% gives (1622 + 10% of 1622) = 1784

Appendix 7: Supplementary Tables (Childhood Infectious Diseases)

Table S1a: Association of total precipitation and diarrhea stratified by residence

Rural					Urban		
	Diarrhea				Diarrhea		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Total precipitation	1.00	0.99 to 1.004	0.08		1.00	0.99 to 1.005	0.62
Mean temperature	1.04	0.98 to 1.10	0.19		1.03	0.86 to 1.22	0.75
Mean $PM_{2.5}$	1.01	1.00 to 1.02	0.06		1.03	1.003 to 1.07	**0.04**
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.17	0.54 to 2.48	0.69		0.55	0.08 to 2.14	0.45
Janajati/Indigenous	1.33	0.79 to 2.32	0.30		0.79	0.38 to 1.66	0.54
Sex							
Boy	Ref				Ref		
Girl	0.94	0.65 to 1.36	0.75		1.3	0.61 to 2.70	0.48
Age	0.99	0.98 to 1.00	0.10		1.02	0.99 to 1.04	0.15
Fever							
No	Ref				Ref		
Yes	1.20	0.83 to 1.73	0.33		2.82	1.28 to 6.00	**0.01**
Season							
Drier	Ref				Ref		

Wetter	1.04	0.55 to 1.98	0.90		4.8	1.06 to 27.04	0.05
PC1	1.00	1.00 to 1.01	0.14		1.00	0.99 to 1.01	0.89

Table S1b: Association of mean maximum temperature and diarrhea stratified by residence

Rural					Urban		
	Diarrhea				Diarrhea		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean maximum temperature	1.04	0.98 to 1.10	0.20		1.02	0.86 to 1.19	0.84
Total precipitation	1.00	0.99 to 1.00	0.12		1.00	0.99 to 1.00	0.66
Mean $PM_{2.5}$	1.01	1.00 to 1.02	0.08		1.03	1.003 to 1.06	**0.04**
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.17	0.54 to 2.48	0.68		0.55	0.08 to 2.14	0.45
Janajati/Indigenous	1.34	0.80 to 2.34	0.29		0.79	0.38 to 1.66	0.54
Sex							
Boy	Ref				Ref		
Girl	0.94	0.65 to 1.36	0.75		1.3	0.61 to 2.70	0.49
Age	0.99	0.98 to 1.00	0.10		1.02	0.99 to 1.04	0.15
Fever							

No	Ref				Ref		
Yes	1.21	0.84 to 1.74	0.31		2.83	1.28 to 6.02	**0.01**
Season							
Drier	Ref				Ref		
Wetter	1.08	0.59 to 1.99	0.81		5.3	1.33 to 25.42	**0.03**
PC1	1.00	1.00 to 1.01	0.16		1.00	0.99 to 1.01	0.89

Table S1c: Association of mean temperature and diarrhea stratified by residence

Rural					**Urban**		
	Diarrhea				**Diarrhea**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean temperature	1.04	0.98 to 1.10	0.19		1.03	0.86 to 1.22	0.75
Total precipitation	1.00	0.99 to 1.00	0.09		1.00	0.99 to 1.00	0.62
Mean $PM_{2.5}$	1.01	1.00 to 1.02	0.06		1.03	1.003 to 1.07	**0.04**
Ethnicity							
Brahmin/Chhetri	Ref						
Dalit and others	1.17	0.54 to 2.48	0.69		0.55	0.08 to 2.14	0.45
Janajati/Indigenous	1.33	0.79 to 2.32	0.30		0.79	0.38 to 1.66	0.54
Sex							
Boy	Ref						
Girl	0.94	0.65 to 1.36	0.75		1.30	0.61 to 2.70	0.48

Age	0.99	0.98 to 1.00	0.10		1.02	0.99 to 1.04	0.15
Fever							
No	Ref						
Yes	1.20	0.83 to 1.73	0.33		2.82	1.28 to 6.00	**0.01**
Season							
Drier	Ref						
Wetter	1.04	0.55 to 1.98	0.90		4.8	1.06 to 27.04	0.05
PC1	1.00	1.00 to 1.01	0.14		1.00	0.99 to 1.01	0.89

Table S1d: Association of mean minimum temperature and diarrhea stratified by residence

Rural					**Urban**		
	Diarrhea				**Diarrhea**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean minimum temperature	1.04	0.98 to 1.10	0.20		1.04	0.87 to 1.23	0.67
Total precipitation	1.00	0.99 to 1.00	0.07		1.00	0.99 to 1.00	0.58
Mean $PM_{2.5}$	1.01	1.00 to 1.03	0.06		1.03	1.003 to 1.07	**0.05**
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.17	0.54 to 2.47	0.69		0.54	0.08 to 2.13	0.44
Janajati/Indigenous	1.32	0.79 to 2.32	0.31		0.79	0.38 to 1.65	0.53

Sex							
Boy	Ref				Ref		
Girl	0.94	0.65 to 1.36	0.75		1.31	0.61 to 2.71	0.47
Age	0.99	0.98 to 1.00	0.10		1.02	0.99 to 1.04	0.15
Fever							
No	Ref				Ref		
Yes	1.20	0.83 to 1.73	0.34		2.82	1.28 to 6.00	**0.01**
Season							
Drier	Ref				Ref		
Wetter	1.03	0.54 to 2.00	0.92		4.38	0.89 to 26.82	0.09
PC1	1.00	1.00 to 1.01	0.14		1.00	0.99 to 1.01	0.89

Table S1e: Association of mean $PM_{2.5}$ and diarrhea stratified by residence

Rural					Urban		
	Diarrhea				Diarrhea		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean $PM_{2.5}$	1.01	1.00 to 1.02	0.06		1.03	1.003 to 1.07	**0.04**
Total precipitation	1.00	0.99 to 1.00	0.09		1.00	0.99 to 1.00	0.62
Mean temperature	1.04	0.98 to 1.10	0.19		1.03	0.86 to 1.22	0.75
Ethnicity							

Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.17	0.54 to 2.48	0.69		0.55	0.08 to 2.14	0.45
Janajati/Indigenous	1.33	0.79 to 2.32	0.30		0.79	0.38 to 1.66	0.54
Sex							
Boy	Ref				Ref		
Girl	0.94	0.65 to 1.36	0.75		1.3	0.61 to 2.70	0.49
Age	0.99	0.98 to 1.00	0.10		1.02	0.99 to 1.04	0.15
Fever							
No	Ref				Ref		
Yes	1.20	0.83 to 1.73	0.33		2.82	1.28 to 6.00	**0.01**
Season							
Drier	Ref				Ref		
Wetter	1.04	0.55 to 1.98	0.90		4.8	1.06 to 27.04	0.05
PC1	1.00	1.00 to 1.01	0.14		1.00	0.99 to 1.01	0.89

Table S2a: Association of total precipitation and diarrhea stratified by season

Wetter					**Drier**		
	Diarrhea				**Diarrhea**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Total precipitation	1.00	1.00 to 1.00	0.88		0.99	0.98 to 1.01	0.35
Mean temperature	0.94	0.81 to 1.08	0.39		1.05	0.99 to 1.13	0.12

Mean $PM_{2.5}$	1.05	1.02 to 1.07	**<0.01**		1.00	0.99 to 1.02	0.67
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	0.90	0.32 to 2.30	0.83		0.96	0.37 to 2.27	0.92
Janajati/Indigenous	1.06	0.58 to 2.00	0.85		1.15	0.65 to 2.11	0.63
Sex							
Boy	Ref				Ref		
Girl	1.18	0.72 to 1.91	0.50		0.84	0.53 to 1.32	0.46
Age	0.99	0.97 to 1.01	0.22		1.00	0.99 to 1.01	0.97
Fever							
No	Ref				Ref		
Yes	1.65	1.01 to 2.70	**0.05**		1.25	0.78 to 2.00	0.34
Residence							
Rural	Ref				Ref		
Urban	1.41	0.72 to 2.76	0.32		0.39	0.19 to 0.77	**0.01**
PC1	1.00	0.99 to 1.00	0.49		1.00	1.00 to 1.01	0.12

Table S2b: Association of mean maximum temperature and diarrhea stratified by season

Wetter					Drier		
	Diarrhea				Diarrhea		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***

Mean maximum temperature	0.93	0.80 to 1.07	0.28		1.04	0.98 to 1.11	0.19
Total precipitation	1.00	1.00 to 1.00	0.90		1.00	0.98 to 1.01	0.43
Mean $PM_{2.5}$	1.05	1.03 to 1.07	**<0.01**		1.00	0.99 to 1.02	0.77
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	0.90	0.32 to 2.30	0.83		0.96	0.37 to 2.27	0.93
Janajati/Indigenous	1.07	0.59 to 2.01	0.84		1.16	0.66 to 2.13	0.61
Sex							
Boy	Ref				Ref		
Girl	1.18	0.73 to 1.91	0.50		0.85	0.53 to 1.33	0.48
Age	0.99	0.97 to 1.01	0.22		1.00	0.99 to 1.01	0.97
Fever							
No	Ref				Ref		
Yes	1.64	1.00 to 2.68	**0.05**		1.27	0.79 to 2.02	0.32
Residence							
Rural	Ref				Ref		
Urban	1.39	0.72 to 2.66	0.33		0.38	0.18 to 0.73	**0.01**
PC1	1.00	0.99 to 1.00	0.45		1.00	1.00 to 1.01	0.16

Table S2c: Association of mean temperature and diarrhea stratified by season

Wetter					Drier		
	Diarrhea				Diarrhea		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean temperature	0.94	0.81 to 1.08	0.39		1.05	0.99 to 1.13	0.12
Total precipitation	1.00	1.00 to 1.00	0.88		0.99	0.98 to 1.01	0.35
Mean $PM_{2.5}$	1.05	1.02 to 1.07	**<0.01**		1.00	0.99 to 1.02	0.67
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	0.90	0.32 to 2.30	0.83		0.96	0.37 to 2.27	0.92
Janajati/Indigenous	1.06	0.58 to 2.00	0.85		1.15	0.65 to 2.11	0.63
Sex							
Boy	Ref				Ref		
Girl	1.18	0.72 to 1.91	0.50		0.84	0.53 to 1.32	0.47
Age	0.99	0.97 to 1.01	0.22		1.00	0.99 to 1.01	0.97
Fever							
No	Ref				Ref		
Yes	1.65	1.01 to 2.70	**0.05**		1.25	0.78 to 2.00	0.34
Residence							
Rural	Ref				Ref		
Urban	1.41	0.72 to 2.76	0.32		0.39	0.19 to 0.77	**0.01**

PC1	1.00	0.99 to 1.00	0.49		1.00	1.00 to 1.01	0.12

Table S2d: Association of mean minimum temperature and diarrhea stratified by season

Wetter					**Drier**		
	Diarrhea				**Diarrhea**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean minimum temperature	0.96	0.84 to 1.10	0.56		1.06	0.99 to 1.13	0.08
Total temperature	1.00	1.00 to 1.00	0.82		0.99	0.98 to 1.01	0.29
Mean $PM_{2.5}$	1.04	1.02 to 1.07	**<0.01**		1.00	0.99 to 1.02	0.59
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	0.90	0.32 to 2.29	0.82		0.95	0.37 to 2.26	0.92
Janajati/Indigenous	1.05	0.58 to 1.98	0.88		1.14	0.65 to 2.10	0.66
Sex							
Boy	Ref				Ref		
Girl	1.17	0.72 to 1.90	0.52		0.84	0.53 to 1.32	0.46
Age	0.99	0.97 to 1.01	0.22		1.00	0.99 to 1.01	0.97
Fever							
No	Ref				Ref		
Yes	1.65	1.00 to 2.70	**0.05**		1.24	0.77 to 1.98	0.37

Residence							
Rural	Ref				Ref		
Urban	1.48	0.75 to 2.91	0.25		0.41	0.20 to 0.80	**0.01**
PC1	1.00	0.99 to 1.00	0.60		1.00	1.00 to 1.01	0.10

Table S2e: Association of mean $PM_{2.5}$ and diarrhea stratified by season

Wetter					**Drier**		
	Diarrhea				**Diarrhea**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean $PM_{2.5}$	1.05	1.02 to 1.07	**<0.01**		1.00	0.99 to 1.02	0.67
Total precipitation	1.00	1.00 to 1.00	0.88		0.99	0.98 to 1.01	0.35
Mean temperature	0.94	0.81 to 1.08	0.39		1.05	0.99 to 1.13	0.12
Ethnicity							
Brahmin/Chhetri	Ref						
Dalit and others	0.90	0.32 to 2.30	0.83		0.96	0.37 to 2.27	0.92
Janajati/Indigenous	1.06	0.58 to 2.00	0.85		1.15	0.65 to 2.11	0.63
Sex							
Boy	Ref						
Girl	1.18	0.72 to 1.91	0.50		0.84	0.53 to 1.32	0.46
Age	0.99	0.97 to 1.01	0.22		1.00	0.99 to 1.01	0.97
Fever							

No	Ref						
Yes	1.65	1.01 to 2.70	**0.05**		1.25	0.78 to 2.00	0.34
Residence							
Rural	Ref						
Urban	1.41	0.72 to 2.76	0.32		0.39	0.19 to 0.77	**0.01**
PC1	1.00	0.99 to 1.00	0.49		1.00	1.00 to 1.01	0.12

Table S3a: Association of total precipitation and ARI stratified by residence

Rural					**Urban**		
	ARI				**ARI**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Total precipitation	1.00	1.00 to 1.00	0.88		1.00	1.00 to 1.01	0.30
Mean temperature	1.03	0.99 to 1.08	0.16		1.05	0.94 to 1.17	0.41
Mean $PM_{2.5}$	1.00	0.99 to 1.01	0.76		1.00	0.97 to 1.02	0.81
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.39	0.81 to 2.36	0.23		1.14	0.37 to 3.01	0.81
Janajati/Indigenous	1.21	0.83 to 1.79	0.32		0.96	0.56 to 1.67	0.89
Sex							
Boy	Ref				Ref		
Girl	1.20	0.92 to 1.56	0.18		0.75	0.42 to 1.33	0.34

Age	1.00	0.99 to 1.01	0.64		1.01	1.00 to 1.03	0.08
Danger sign							
No	Ref				Ref		
Yes	3.21	1.34 to 7.89	**0.01**		9.61	4.66 to 20.25	**<0.01**
Fever							
No	Ref				Ref		
Yes	3.06	2.34 to 4.01	**<0.01**		1.03	0.49 to 2.04	0.93
Season							
Drier	Ref				Ref		
Wetter	0.84	0.52 to 1.35	0.46		1.01	0.35 to 3.07	0.98
PC1	1.00	1.00 to 1.01	**0.01**		1.00	0.99 to 1.00	0.26

Table S3b: Association of mean maximum temperature and ARI stratified by residence

Rural					**Urban**		
	ARI				**ARI**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean maximum temperature	1.03	0.98 to 1.07	0.25		1.01	0.91 to 1.12	0.89
Total precipitation	1.00	1.00 to 1.00	0.96		1.00	1.00 to 1.01	0.24
Mean $PM_{2.5}$	1.00	0.99 to 1.01	0.86		0.99	0.97 to 1.02	0.54
Ethnicity							

Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.39	0.82 to 2.37	0.22		1.13	0.37 to 2.98	0.82
Janajati/Indigenous	1.22	0.84 to 1.80	0.30		0.96	0.56 to 1.67	0.89
Sex							
Boy	Ref				Ref		
Girl	1.20	0.92 to 1.57	0.18		0.77	0.43 to 1.36	0.38
Age	1.00	0.99 to 1.01	0.64		1.01	1.00 to 1.03	0.07
Danger sign							
No	Ref				Ref		
Yes	3.22	1.35 to 7.91	**0.01**		10.10	4.92 to 21.21	**<0.01**
Fever							
No	Ref				Ref		
Yes	3.08	2.36 to 4.03	**<0.01**		1.06	0.50 to 2.08	0.88
Season							
Drier	Ref				Ref		
Wetter	0.89	0.56 to 1.41	0.61		1.35	0.50 to 3.71	0.56
PC1	1.00	1.00 to 1.01	**0.02**		1.00	0.99 to 1.00	0.22

Table S3c: Association of mean temperature and ARI stratified by residence

Rural					Urban		
	ARI				ARI		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean temperature	1.03	0.99 to 1.08	0.16		1.05	0.94 to 1.17	0.41
Total precipitation	1.00	1.00 to 1.00	0.88		1.00	1.00 to 1.01	0.30
Mean $PM_{2.5}$	1.00	0.99 to 1.01	0.76		1.00	0.97 to 1.02	0.81
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.39	0.81 to 2.36	0.23		1.14	0.37 to 3.01	0.81
Janajati/Indigenous	1.21	0.83 to 1.79	0.32		0.96	0.56 to 1.67	0.89
Sex							
Boy	Ref				Ref		
Girl	1.20	0.92 to 1.56	0.18		0.75	0.42 to 1.33	0.34
Age	1.00	0.99 to 1.01	0.64		1.01	1.00 to 1.03	0.08
Danger sign							
No	Ref				Ref		
Yes	3.21	1.34 to 7.89	**0.01**		9.61	4.66 to 20.25	**<0.01**
Fever							
No	Ref				Ref		
Yes	3.06	2.34 to 4.01	**<0.01**		1.03	0.49 to 2.04	0.93

Season							
Drier	Ref				Ref		
Wetter	0.84	0.52 to 1.35	0.46		1.01	0.35 to 3.07	0.98
PC1	1.00	1.00 to 1.01	**0.01**		1.00	0.99 to 1.00	0.26

Table S3d: Association of mean minimum temperature and ARI stratified by residence

Rural					Urban		
	ARI				ARI		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean minimum temperature	1.04	0.99 to 1.08	0.11		1.09	0.98 to 1.23	0.12
Total precipitation	1.00	1.00 to 1.00	0.70		1.00	1.00 to 1.01	0.49
Mean $PM_{2.5}$	1.00	0.99 to 1.01	0.65		1.00	0.98 to 1.03	0.79
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.38	0.81 to 2.35	0.24		1.15	0.38 to 3.05	0.80
Janajati/Indigenous	1.21	0.83 to 1.78	0.34		0.96	0.55 to 1.67	0.88
Sex							
Boy	Ref				Ref		
Girl	1.20	0.92 to 1.56	0.19		0.74	0.41 to 1.30	0.31
Age	1.00	0.99 to 1.01	0.64		1.01	1.00 to 1.03	0.08

Danger sign							
No	Ref				Ref		
Yes	3.19	1.33 to 7.86	**0.01**		8.98	4.34 to 18.98	**<0.01**
Fever							
No	Ref				Ref		
Yes	3.04	2.33 to 3.98	**<0.01**		1.01	0.48 to 2.00	0.97
Season							
Drier	Ref				Ref		
Wetter	0.79	0.48 to 1.31	0.37		0.69	0.22 to 2.27	0.54
PC1	1.00	1.00 to 1.01	**0.01**		1.00	0.99 to 1.00	0.28

Table S3e: Association of mean $PM_{2.5}$ and ARI stratified by residence

Rural					**Urban**		
	ARI				**ARI**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean $PM_{2.5}$	1.00	0.99 to 1.01	0.76		1.00	0.97 to 1.02	0.81
Total precipitation	1.00	1.00 to 1.00	0.88		1.00	1.00 to 1.01	0.30
Mean temperature	1.03	0.99 to 1.08	0.16		1.05	0.94 to 1.17	0.41
Ethnicity							
Brahmin/Chhetri	Ref						
Dalit and others	1.39	0.81 to 2.36	0.23		1.14	0.37 to 3.01	0.81

Janajati/Indigenous	1.21	0.83 to 1.79	0.32		0.96	0.56 to 1.67	0.89
Sex							
Boy	Ref						
Girl	1.20	0.92 to 1.56	0.18		0.75	0.42 to 1.33	0.34
Age	1.00	0.99 to 1.01	0.64		1.01	1.00 to 1.03	0.08
Danger sign							
No	Ref						
Yes	3.21	1.34 to 7.89	**0.01**		9.61	4.66 to 20.25	**<0.01**
Fever							
No	Ref						
Yes	3.06	2.34 to 4.01	**<0.01**		1.03	0.49 to 2.04	0.93
Season							
Drier	Ref						
Wetter	0.84	0.52 to 1.35	0.46		1.01	0.35 to 3.07	0.98
PC1	1.00	1.00 to 1.01	**0.01**		1.00	0.99 to 1.00	0.26

Table S4a: Association of total precipitation and ARI stratified by season

Wetter					**Drier**		
	ARI				**ARI**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Total precipitation	1.00	1.00 to 1.00	0.97		1.00	0.99 to 1.01	0.92

Mean temperature	1.03	0.92 to 1.15	0.60		1.04	0.99 to 1.09	0.15
Mean $PM_{2.5}$	1.00	0.98 to 1.01	0.73		1.00	0.99 to 1.01	0.70
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.30	0.62 to 2.67	0.48		1.28	0.70 to 2.31	0.41
Janajati/Indigenous	1.57	0.99 to 2.54	0.06		0.90	0.60 to 1.37	0.63
Sex							
Boy	Ref				Ref		
Girl	1.21	0.85 to 1.73	0.29		1.04	0.75 to 1.44	0.81
Age	1.01	0.99 to 1.02	0.35		1.00	0.99 to 1.01	0.91
Danger sign							
No	Ref				Ref		
Yes	5.83	2.05 to 17.38	**0.01**		7.43	3.81 to 14.72	**<0.01**
Fever							
No	Ref				Ref		
Yes	2.62	1.83 to 3.76	**<0.01**		2.72	1.94 to 3.81	**<0.01**
Residence							
Rural	Ref				Ref		
Urban	0.77	0.46 to 1.29	0.32		0.38	0.23 to 0.60	**<0.01**
PC1	1.00	1.00 to 1.01	0.18		1.00	1.00 to 1.00	0.30

Table S4b: Association of mean maximum temperature and ARI stratified by season

Wetter					Drier		
	ARI				ARI		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean maximum temperature	1.00	0.90 to 1.11	0.99		1.03	0.98 to 1.08	0.25
Total precipitation	1.00	1.00 to 1.00	0.88		1.00	0.99 to 1.01	0.94
Mean $PM_{2.5}$	1.00	0.98 to 1.01	0.70		1.00	0.99 to 1.01	0.82
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.31	0.62 to 2.69	0.47		1.29	0.71 to 2.31	0.41
Janajati/Indigenous	1.60	1.01 to 2.57	**0.05**		0.91	0.60 to 1.38	0.65
Sex							
Boy	Ref				Ref		
Girl	1.22	0.86 to 1.74	0.27		1.05	0.76 to 1.45	0.78
Age	1.01	0.99 to 1.02	0.36		1.00	0.99 to 1.01	0.92
Danger sign							
No	Ref				Ref		
Yes	5.75	2.03 to 17.13	**0.01**		7.55	3.88 to 14.96	**<0.01**
Fever							
No	Ref				Ref		

Yes	2.63	1.84 to 3.78	**<0.01**		2.74	1.96 to 3.84	**<0.01**
Residence							
Rural	Ref				Ref		
Urban	0.72	0.43 to 1.19	0.20		0.37	0.23 to 0.58	**<0.01**
PC1	1.00	1.00 to 1.01	0.29		1.00	1.00 to 1.00	0.39

Table S4c: Association of mean temperature and ARI stratified by season

Wetter					**Drier**		
	ARI				**ARI**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean temperature	1.03	0.92 to 1.15	0.60		1.04	0.99 to 1.09	0.15
Total precipitation	1.00	1.00 to 1.00	0.97		1.00	0.99 to 1.01	0.92
Mean $PM_{2.5}$	1.00	0.98 to 1.01	0.73		1.00	0.99 to 1.01	0.70
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.30	0.62 to 2.67	0.48		1.28	0.70 to 2.31	0.41
Janajati/Indigenous	1.57	0.99 to 2.54	0.06		0.90	0.60 to 1.37	0.63
Sex							
Boy	Ref				Ref		
Girl	1.21	0.85 to 1.73	0.29		1.04	0.75 to 1.44	0.80
Age	1.01	0.99 to 1.02	0.35		1.00	0.99 to 1.01	0.914

Danger sign							
No	Ref				Ref		
Yes	5.83	2.05 to 17.38	**0.01**		7.43	3.81 to 14.72	**<0.01**
Fever							
No	Ref				Ref		
Yes	2.62	1.83 to 3.76	**<0.01**		2.72	1.94 to 3.81	**<0.01**
Residence							
Rural	Ref				Ref		
Urban	0.77	0.46 to 1.29	0.32		0.38	0.23 to 0.60	**<0.01**
PC1	1.00	1.00 to 1.01	0.18		1.00	1.00 to 1.00	0.30

Table S4d: Association of mean minimum temperature and ARI stratified by season

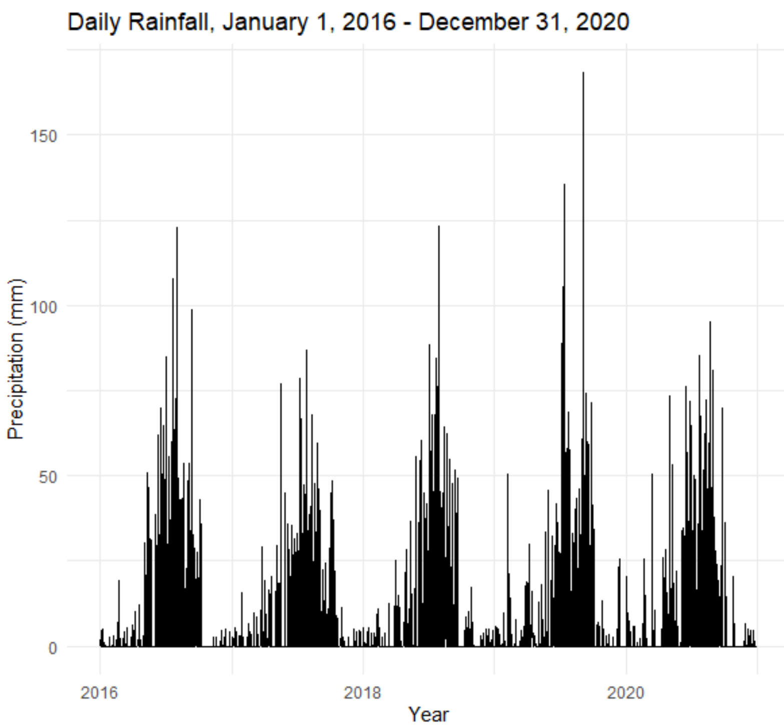
Wetter					**Drier**		
	ARI				**ARI**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***
Mean minimum temperature	1.05	0.95 to 1.16	0.34		1.04	0.99 to 1.09	0.09
Total precipitation	1.00	1.00 to 1.00	0.80		1.00	0.99 to 1.01	0.80
Mean $PM_{2.5}$	1.00	0.98 to 1.02	0.97		1.00	0.99 to 1.01	0.61
Ethnicity							
Brahmin/Chhetri	Ref				Ref		

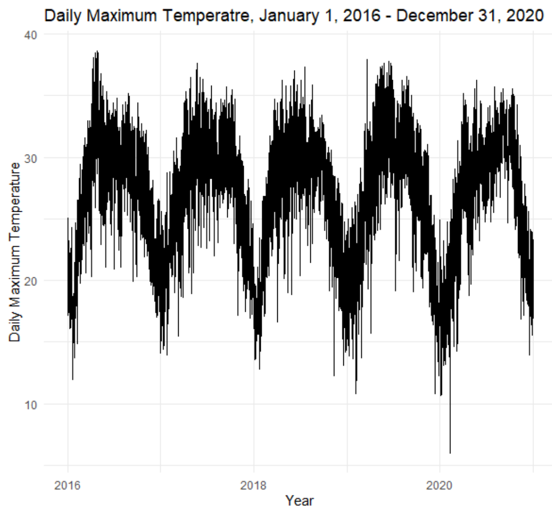
Dalit and others	1.28	0.61 to 2.64	0.51		1.28	0.70 to 2.31	0.41
Janajati/Indigenous	1.55	0.98 to 2.50	0.07		0.90	0.59 to 1.36	0.60
Sex							
Boy	Ref				Ref		
Girl	1.21	0.84 to 1.72	0.30		1.04	0.75 to 1.44	0.82
Age	1.01	0.99 to 1.02	0.35		1.00	0.99 to 1.01	0.91
Danger sign							
No	Ref				Ref		
Yes	5.87	2.07 to 17.56	**0.01**		7.29	3.74 to 14.47	**<0.01**
Fever							
No	Ref				Ref		
Yes	2.59	1.81 to 3.72	**<0.01**		2.69	1.92 to 3.78	**<0.01**
Residence							
Rural	Ref				Ref		
Urban	0.82	0.48 to 1.37	0.44		0.39	0.24 to 0.62	**<0.01**
PC1	1.00	1.00 to 1.01	0.11		1.00	1.00 to 1.01	0.23

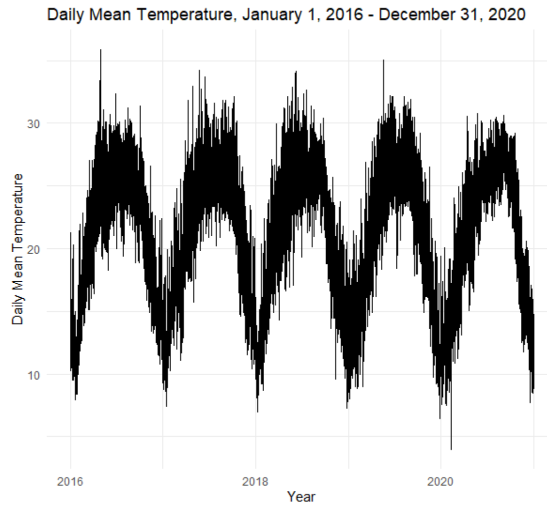
Table S4e: Association of mean $PM_{2.5}$ and ARI stratified by season

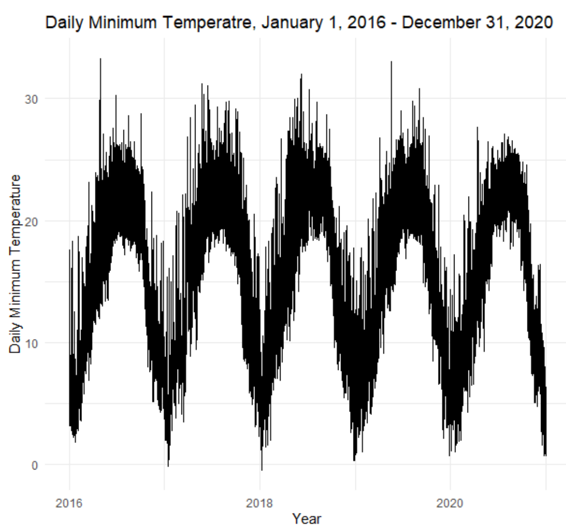
Wetter					**Drier**		
	ARI				**ARI**		
Variables	***Odds Ratios***	***CI***	***p***		***Odds Ratios***	***CI***	***p***

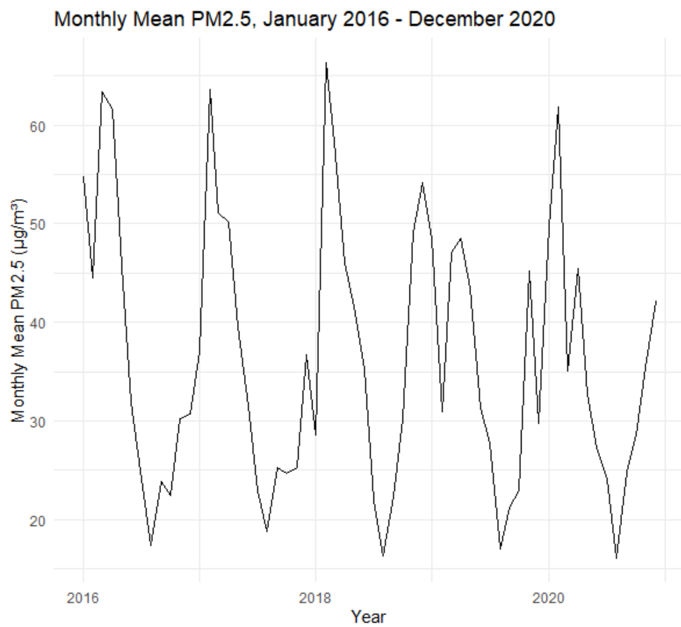
Mean $PM_{2.5}$	1.00	0.98 to 1.01	0.73		1.00	0.99 to 1.01	0.70
Total precipitation	1.00	1.00 to 1.00	0.97		1.00	0.99 to 1.01	0.92
Mean temperature	1.03	0.92 to 1.15	0.60		1.04	0.99 to 1.09	0.15
Ethnicity							
Brahmin/Chhetri	Ref				Ref		
Dalit and others	1.30	0.62 to 2.67	0.48		1.28	0.70 to 2.31	0.41
Janajati/Indigenous	1.57	0.99 to 2.54	0.06		0.90	0.60 to 1.37	0.63
Sex							
Boy	Ref				Ref		
Girl	1.21	0.85 to 1.73	0.29		1.04	0.75 to 1.44	0.80
Age	1.01	0.99 to 1.02	0.35		1.00	0.99 to 1.01	0.91
Danger sign							
No	Ref				Ref		
Yes	5.83	2.05 to 17.38	**0.01**		7.43	3.81 to 14.72	**<0.01**
Fever							
No	Ref				Ref		
Yes	2.62	1.83 to 3.76	**<0.01**		2.72	1.94 to 3.81	**<0.01**
Residence							
Rural	Ref				Ref		
Urban	0.77	0.46 to 1.29	0.32		0.38	0.23 to 0.60	**<0.01**
PC1	1.00	1.00 to 1.01	0.18		1.00	1.00 to 1.00	0.30

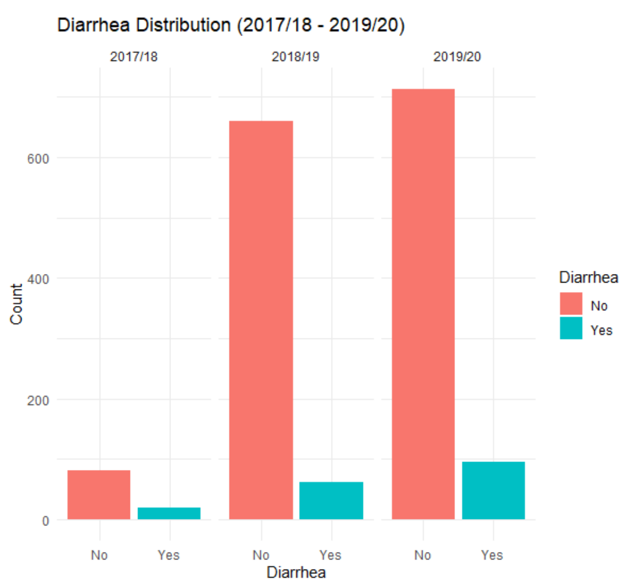

Daily Rainfall, January 1, 2016 - December 31, 2020
Precipitation (mm)
150
100
50
0
2016
2018
2020
Year

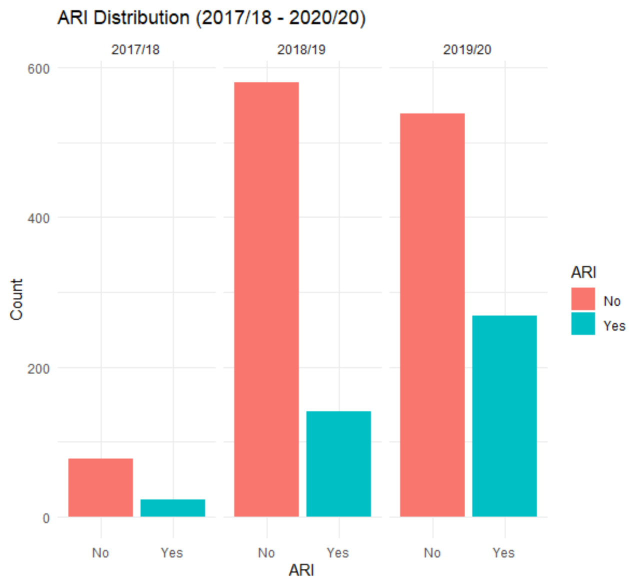

Daily Maximum Temperatre, January 1, 2016 - December 31, 2020
Daily Maximum Temperature
40
30
20
10
2016
2018
2020
Year


Daily Mean Temperature, January 1, 2016 - December 31, 2020
Daily Mean Temperature
30
20
10
2016
2018
2020
Year


Daily Minimum Temperatre, January 1, 2016 - December 31, 2020
Daily Minimum Temperature
30
20
10
0
2016
2018
2020
Year


Monthly Mean PM2.5, January 2016 - December 2020
Monthly Mean PM2.5 (µg/m³)
60
50
40
30
20
2016
2018
2020
Year


Diarrhea Distribution (2017/18 - 2019/20)
2017/18
2018/19
2019/20
Count
600
400
200
0
No
Yes
No
Yes
No
Yes
Diarrhea
Diarrhea
No
Yes



ARI Distribution (2017/18 - 2020/20)
2017/18
2018/19
2019/20
600
400
200
0
Count
No
Yes
No
Yes
No
Yes
ARI
ARI
No
Yes