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Abstract

Background

Morbidity and mortality related impacts of climate change are increasingly becoming a public health challenge especially among vulnerable groups. India has made significant progress in reducing its child mortality however there exists huge regional variations. This study focuses on Bundelkhand region, and analyses the association between climatic variables and morbidity in children.

Methods

Cases reported to district health office from routine surveillance system between 2009 and 2015, and climate data are used. Fixed effects panel data regression model is employed to find association of temperature and rainfall with incidence of diarrhea, respiratory illnesses and vector-borne diseases in children (0-5 years) controlling for development indicators - percentage households with piped drinking water, improved sanitation, and electricity connection.

Results

The panel data regression finds that incidence of morbidity in children is significantly associated with temperature and rainfall. With 1ºC increase in monthly average Tmax., the incidence of diarrhea increases by 0.11 cases per 1000 child population. Similarly, with 1 mm increase in rainfall the diarrhea cases increase by 0.10 and vector-bourne diseases increases by 0.08 cases with increase in 1 mm of average monthly rainfall. With 1ºC decrease in average monthly minimum temperature, the incidence of respiratory diseases increases by 0.018 units.

Conclusion

The climatic variables are significantly associated with the incidence of morbidity in children in Bundelkhand. The public health system must plan resource deployment for managing such morbidities. The significance of development indicators in reducing morbidity incidence is suggestive of the critical role of inter-sectoral coordination in achieving desired health outcomes.

Keywords: Climate change, Morbidity, Bundelkhand, India, Child health, Rainfall, Temperature

Introduction

Increased frequency and intensity of heat waves, changing pattern of vector-borne diseases, increasing floods, droughts incidences leading to water-borne diseases, and risk of disasters and malnutrition due to climate change affect health outcomes (1,2). The marginalized populations, especially living in low-income countries are more vulnerable to effects of climate change (3–5). Adverse climatic events like droughts and floods disrupt food-chain cycle and may increase malnutrition. Malnourished people are more likely to fall sick; this results in a vicious cycle of poverty and poor health for poor people. The United Nation's Intergovernmental Panel on Climate Change (IPCC) has reported an upward trend of 1.5 – 5.8 °C in the average surface temperature in the 21st century (6,7). Thus, there is need to focus on strategies to reduce health effects of climate change. In light of the above, it is essential to focus on less developed areas as they are most vulnerable to such adverse events. Understanding the health effects of climatic variations may help government to gauge the resource requirement and plan and prepare accordingly. The objective of this study is to investigate the effects of climactic variations on the incidence of child morbidity including diarrhea, respiratory illnesses and vector-borne diseases in Bundelkhand, India.

Climate change and morbidity

Climate change is well recognized as a serious public health concern (8–10) and has direct effect on productivity (11). Literature suggests strong relationship between climatic variations and morbidity and mortality risks. The change in climatic factors are expected to affect the morbidity and mortality patterns by varying the degree of physical exposure to temperature levels (9). Human beings are stressed by unusually high or low temperatures which adversely affects body temperature and metabolism process reducing physical and mental capacity (8).

A systematic review by Bunker et al. (2016) (12) found that increased temperature is associated with cardiovascular, cerebrovascular morbidity while lower temperatures are associated with respiratory illness, especially pneumonia in elderly population (12). The mortality risks of heat waves vary by age groups, making children and elderly more susceptible to climatic variations (13,14).

Recent studies from India report positive association between temperature and incidence of diarrhea (1,15). Mertens et al (2019) (2), examined the associations between high temperature and heavy rainfall with increased all-cause diarrhea and water contamination for children in rural Tamil Nadu, India. They conclude that higher temperatures and diarrhea were positively associated with a lag of 1-3 weeks. Recent studies from other countries also report similar observations, especially in children upto 5years (15,16).

Studies have also highlighted the role of climate change on respiratory health, primarily due to interaction of climate variables with air pollution. Warmer weather facilitates higher ground level ozone formation, while colder weather influences the atmospheric boundary layer and traps particulate pollutants thereby resulting in higher ground level concentrations of PM2.5. Both these have an impact on respiratory health. Malaria remains a large public health challenge in tropical areas across the world. Such vector-bourne diseases are sensitive to climate- raising concerns on future disease transmission under climate change. Rising temperatures and precipitation are expected to broaden the transmission windows as survival of mosquitoes as well as parasites are enhanced in warmer, humid climates.

Seasonal variations in hospitalizations have been documented in literature. Hypertension, respiratory, cardiovascular and influenza related hospitalizations in the winter season are a known phenomenon. Pneumonia incidences increase in winter and decrease in summer. Therefore, it is reasonable to suggest that climate change will likely influence these disease outcomes.

Methodology

Study Setting

Bundelkhand, a mountainous and dry region located in central India and divided between the states of Madhya Pradesh (MP) and Uttar Pradesh (UP) is the study region. 12 districts out of 14 in Bundelkhand region, including, Chattarpur, Damoh, Datia, Panna, Sagar, Tikamgarh, and Vidisha from MP and Banda, Hamirpur, Jalaun, Jhansi and Chitrakoot from UP have been included while Mahoba and Lalitpur from UP, were dropped due to high missing values of study covariates.

As per the human development report[1], the Bundelkhand lags behind in development indicators as compared to other parts of UP and MP. The districts lying in UP perform better in comparison to districts lying in MP. Bundelkhand region has higher percentage of marginalized social groups, including scheduled castes and scheduled tribes with prevalent upper class domination. The region mainly exhibits agrarian economy and thus highly vulnerable to climatic shocks like droughts and floods.

The average Infant Mortality Rate (IMR) and Child mortality rate (CMR) for Chattarpur, Damoh, Datia, Panna, Sagar and Trikamgarh districts from MP are 70 and 97 while the MP state average are 62 and 83 respectively. Similarly for the districts falling in UP – Banda, Hamirpur, jalaun, Jhansi, Lalitpur, Mahoba, and Chitrakoot, the average IMR and CMR are 56 and 89 with UP state average at 68 and 90 respectively. All India IMR and CMR stand at 41 and 56 respectively. The IMR and CMR clearly indicate poor health

[1] Human Development Report Bundelkhand Region (2018) United Nations Development Programme (UNDP) https://www.undp.org/content/dam/india/docs/human-development/District%20HDRs/Bundelkhand%20Report_23Jan2018.pdf

status of these districts in comparison to all-India figures. Damoh and Panna districts in MP and Lalitpur and Chitrakoot in UP are among the worst performers as per Annual Health Survey (AHS)[2] statistics.

The region is under-developed and under-represented in political debates. It is worst hit by climatic variations related to frequent droughts and scanty rainfall. Thus, it is important to understand the health effects of climatic variations in Bundelkhand and assess the preparedness of public health system to deal with the associated morbidity. We focus on children (upto 5 years of age) as they are considered to be the most vulnerable population (17).

Data

Monthly cases of diarrhea, respiratory illnesses and vector-borne diseases in children upto 5 years of age reported to each district health office from the routine surveillance were used here. The data was accessed online[3] from Health Management Information System (HMIS), Ministry of Health and Family Welfare, India. The data from January 2009 to December 2015 was collected and cleaned using Microsoft Excel and then analyzed using STATA 15.1 version. Monthly historic rainfall and temperature data for the study period were extracted and cleaned from Indian Meteorological Department (IMD) data as prepared by (Ali, Mishra, & Pai, 2014).

Analytical Strategy

A monthly panel of districts with longitudinal data on morbidity variables was created since panel data is longitudinal that accounts individual heterogeneity. To analyze the impact of temperature and rainfall, which vary over time, fixed-effects model is used (18). There are two main assumptions here:

i) Individual heterogeneity (district level factors) may affect the predictor or outcome variables. To control for this, we assume that entity's (district) error term and predictor variables are correlated. FE model gives the net effect of the predictors (climatic variations) on the outcome variables (morbidity variables) by removing the effect of time-invariant characteristics (18).

ii) The time-invariant characteristics are unique to the entity (district) and should not be correlated with other entity's characteristics. Each entity is different therefore the entity's error term and the constant (which captures individual characteristics) should not be correlated with others.

Variables

Dependent variables: The dependent variable is monthly average of diarrhea cases, vector-borne diseases, respiratory diseases or rate of inpatient admission reported per 1000 child population in the public health system at district level.

[2] Registrar General of India. Annual Health Survey 2012-13

[3] HMIS. Ministry of Health and Family Welfare. *PUBLISHEDREPORTS\C2. DATA ITEMWISE MONTHLY (UP TO SUB DISTRICT)\3. ALL STATES AND DISTRICTS ACROSS MONTHS*
accessed at: https://nrhm-mis.nic.in/hmisreports/frmstandard_reports.aspx

Predictor variables: Monthly average maximum temperature (Tmax.) and monthly average rainfall.

Control variables: Development indicators at the district level- percentage of households with electricity connections, piped water supply, and sanitation facility.

Empirical model

$Y_{it} = \beta_1 \text{temperature}_{it} + \beta_2 \text{rain}_{it} + \beta_3 x_{2it} + \alpha_i + u_{it}$

Where,

- α_i (i=1, 2, 3, ….12) is the unknown intercept for each district
- Y_{it} is dependent variable in district i at time t
- temperature_{it} represents average monthly maximum temperature in district i at time t
- rain_{it} represents average monthly rainfall in district i at time t
- x_{2it} represents vector of development indicators in district i at time t
- β_1 is the coefficient for average monthly Tmax. and β_2 is the coefficient for average monthly rainfall
- u_{it} is the error term

Results and Discussion

Summary Statistics

Table 1 describes the summary statistics. The Tmax across study districts lie in the range of 18^{o}C to 44^{o}C. The average monthly rainfall varies from 0 mm to 21 mm with a mean value of 2.37 mm. The number of visits to public health centers for diarrhea varies from 0 to 17 per 1000 child population. The average cases for respiratory diseases and vector-borne diseases is 0.52 and 0.59 per 1000 child population respectively. There is not much difference in the inpatient admission rate between male and female child.

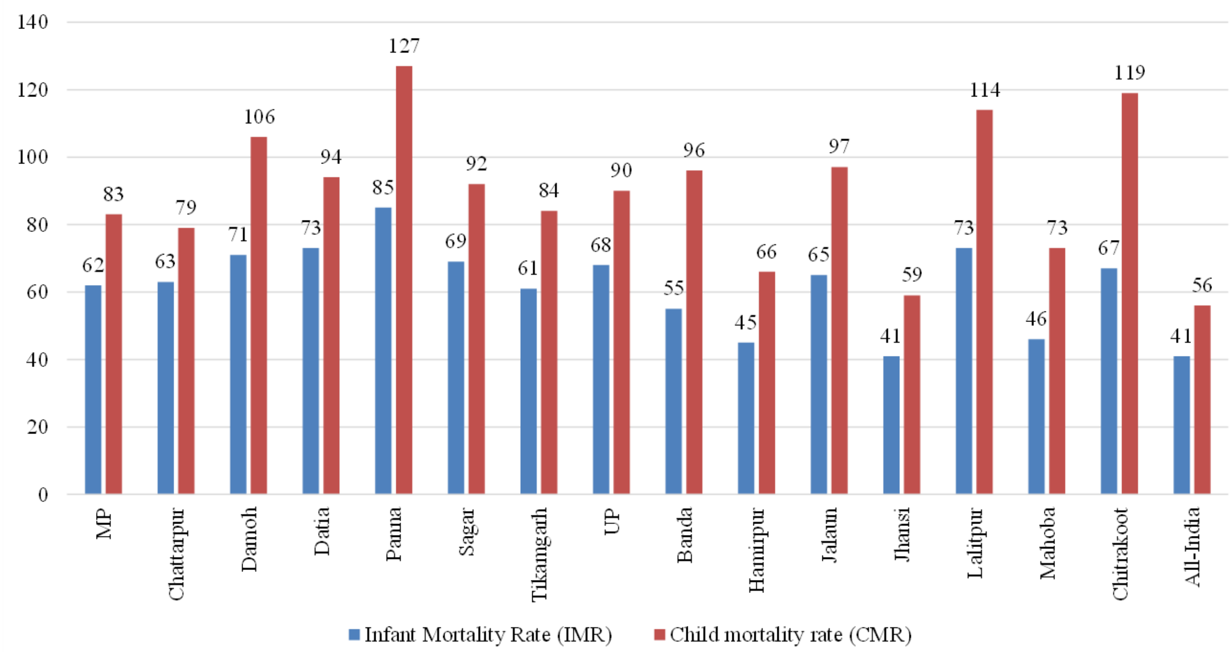
Table 1: Summary Statistics for children morbidity and climatic variables

Variable	**N***	**Mean**	**Std. Dev.**	**Min**	**Max**
Temperature (^{o}C)	1,006	32.49	5.83	17.99	43.93
Rainfall (mm)	1,006	2.37	3.67	0.00	20.91
Diarrhea cases	983	1.86	2.16	0.00	16.90
Respiratory disease	654	0.52	0.77	0.00	8.52
Vector-borne diseases	1,001	0.59	1.13	0.00	13.88
Male child inpatient cases	913	6.73	5.03	0.02	32.97
Female child inpatient cases	912	6.16	5.02	0.05	80.54
*N varies due to missing values					

Climatic factors across districts

Graph 1 presents the variability in the average monthly temperature and rainfall across study districts. The climatic variations are suggestive of individual level heterogeneity.

Graph 1: Variability in temperature and rainfall across districts



Variability in morbidity across districts

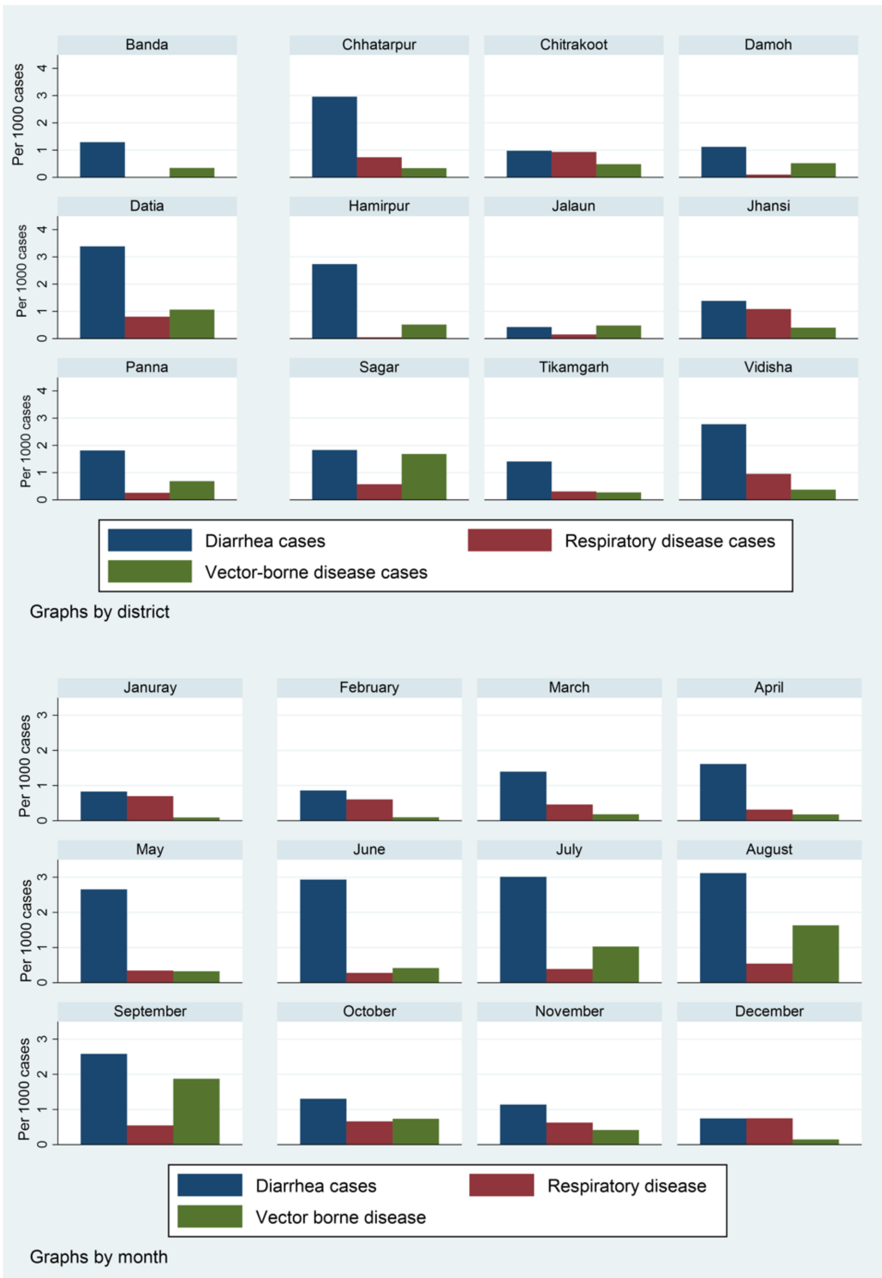
Graph 2 (a) shows per 1000 cases of diarrhea, respiratory disease and vector-borne disease among children reported in public health system at district-level. The variability in morbidity across districts indicates individual level heterogeneity, thus, data is suitable for fixed effects model (19).

Diarrheal cases are higher in Chhatarpur, Datia, Panna, Sagar and Vidisha. Datia and Panna are among the worst performers in terms of development indicators, perhaps that explains the higher morbidity in these districts. However, we cannot rule out the reporting factors, may be use of public health system is higher in these districts and thus reporting of cases is also higher. These variations can be explained by variations in climatic factors, variations in adaptive measures, socio-economic factors or even differential use of public health system.

Variability in morbidity across months

Graph 2 (b) suggests the prevalence of diarrhea all through the year. However, there is an observed increase during summer season (April to June) that remains high till monsoon. The cases of diarrhea show peak in May-June and August. The cases of respiratory illness are higher during winter while vector-borne disease cases peak in August-September.

Graph 2: Per 1000 Cases of Diarrhea, Respiratory Diseases and Vector-borne Diseases (VBD), (a) by district, (b) Monthly average



Panel Data Regression

The results suggest significant role of climatic factors on all-cause morbidity in children. Table 2 presents the results for diarrhea, cases of respiratory illnesses, cases of VBD and inpatient admissions.

Diarrhea

Results indicate that with 1ºC increase in monthly average Tmax, the incidence of diarrhea increase by 0.11 units. After controlling for development indicators at the district-level, we assume that the effect on diarrhea incidences observed is due to climatic variations. We assume that time-invariant socio-economic factors, like literacy level of district, are controlled for by using fixed-effect panel data regression. It should be noted that this increase is only in the cases reported by public health system, which is just 14% of the total diarhea case load within Bundelkhand. Diarrhea cases also show a significant increase with increasing rain, while it decreases significantly after a lag period of about two months from monsoon.

Vector-borne diseases (VBD)

The incidence of VBD increases by 0.08 cases per 1000 child population with increase in 1 mm of average monthly rainfall. The incidence of VBD significantly reduces with a lag of 1-2 months in average monthly rainfall. The availability of improved sanitation facilities is significantly negatively associated with VBD.

Respiratory diseases

With 1ºC decrease in average monthly temperature, the incidences of respiratory diseases reported in public health system increase by 0.018 units. Inpatient admission rate in both male and female child is significantly positively associated with extreme heat. With every 1°C rise in average Tmax, the monthly inpatient admission rate increases by 0.09 for male child and 0.08 for female child.

It can be observed that if a district has higher percentage of electricity connection, then incidences of diarrhea and respiratory illnessess reduce. Access to electricity helps mitigate the effects of excess heat or cold through use of modern appliances.

For vector-borne diseases, with improved sanitation, the incidences of malaria, dengue, and chikungunia decrease. It is likely that districts with poor sanitation facilities may have more open pits, tanks, etc. which serve as breeding sites for mosquites. The results highlight the importance of development in reducing burden of disease.

Table 2: Results of Panel data regression for child morbidity

	Incidence rate (per 1000)			Inpatient admission rate (child)	
Variables	Diarrhea	Respiratory	Vector-borne	Male	Female
tmax	0.11*** (0.00985)			0.0894*** (0.0248)	0.0813*** (0.0263)
rain	0.101*** (0.0157)	-0.000412 (0.00742)	0.0876*** (0.00788)	0.102*** (0.0385)	0.119*** (0.0405)
L.rain	-0.0183 (0.0157)	-0.0138** (0.00660)	-0.0388*** (0.00786)	-0.0655* (0.0383)	-0.0424 (0.0403)
L2.rain	-0.0320** (0.0157)		-0.0275*** (0.00783)	-0.0996*** (0.0386)	-0.0825** (0.0406)
water	0.000461 (0.0109)	0.00778 (0.00700)	0.00430 (0.00548)	0.00108 (0.0345)	0.131*** (0.0362)
sanitation	0.0433** (0.0186)	0.0210** (0.00871)	-0.0356*** (0.00936)	0.00756 (0.0491)	-0.137*** (0.0523)
electricity	-0.0399*** (0.00836)	-0.0399*** (0.00567)	0.00680 (0.00418)	0.117 (0.0239)	0.0266 (0.0250)
tmin		-0.0188*** (0.00438)	0.028*** (0.0046)		
Constant	-0.0644 (0.770)	2.821*** (0.390)	0.0637 (0.385)	-5.161** (2.308)	-6.049** (2.436)
Observations	955	651	973	896	895
R-squared	0.177	0.140	0.172	0.082	0.050
Number of id	12	12	12	12	12

Conclusion

This study assesses the impacts of climatic factors (temperature and rainfall) on the incidence of diarrhea, respiratory illnesses and vector-borne diseases using fixed effect panel data regression. There is significant positive association between temperature and the incidence of diarrhea. The lag effect for rainfall also significantly associates with diarrhea case load perhaps due to water-borne diarrhea from contaminated water. The respiratory illness episodes are significantly affected by lower temperatures. The inpatient cases are higher during extreme temperatures indicating vulnerability of children to such events.

The study highlights the role of development indicators, like access to safe drinking water, improved sanitation facilities and electricity connections in reducing child morbidity. Improved sanitation facilities have been found to be significantly negatively associated with vector-borne diseases. This suggests that inter-departmental coordination can help improve health outcomes. Further, electricity access can help mitigate extreme heat or cold related morbidity by enabling use of modern appliances, like air conditioner, coolers or heaters.

The study has implications for policymakers to gauge the need for health system preparedness in response to anticipated climate change impacts like higher temperatures, higher rainfall or extreme weather.

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