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Weather Variation and Child Health Outcomes in Nepal

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Abstract

This study examines the relationship between weather variability and child health outcomes in Nepal. The results indicate that temperature deviations significantly impact malnutrition, not stunting and wasting in children under five. Rainfall deviations, on the other hand, do not show a significant association with malnutrition. However, rainfall variability caters to mortality rates, while temperature deviations do not. The study suggests considering climatic variability in child health policy crafting in Nepal. Further studies that consider the climate and socioeconomic heterogeneity might serve better.

Keywords: Temperature variation, Rainfall variation, Malnutrition, Child mortality

1. Introduction

Understanding the complex relationship between climate change and human health is crucial, as climatic conditions, directly and indirectly, impact people's well-being. Direct effects include heat waves, cold spells, flooding, and drought, while indirect consequences involve spreading disease vectors, food shortages, malnutrition, and disruption of economic activities. The data and information constraints on climate and health variables (WHO, 2003) and compromised awareness of public health outcomes of climate change (Patz et al., 2005), limited studies are available in this area of research. Measuring year-to-year variations in temperature, rainfall, and prevalence of extreme events are considered effective indicators of climate change. Previous studies like Deschenes and Moretti (2009); Skoufias et al. (2011); and Kudamatsu, Persson, and Strömberg (2012) have utilized weather variability calculated from historical data to examine its effects on household human health. This study aims to investigate the impact of weather variability on the potential risks of climate change on household health in Nepal, combining weather data with nationally representative household surveys.

Weather variability corroborates food production, prices, agricultural wages, and infectious diseases that hinder children's nutritional intake and cater to malnutrition, responsible for one-third of child deaths worldwide. Unfavorable climatic conditions can lead to crop failures, food price rises, and increased hunger and mortality. Climate variability also affects Nepal's natural resources, such as water supply, soil quality, and biodiversity, which further impacts agricultural productivity and food security. Malnutrition is prevalent in Nepal, with high rates of anemia, underweight, stunting, and wasting among children. Severely malnourished individuals, especially children, are at greater risk of death, and malnutrition can potentiate the effects of infectious diseases (MOHP, 2006; MOHP, New-ERA, & Macro International, 2007). Climate and weather variability might have played a role in malnutrition through their impact on agriculture and disease environments. Identifying the impacts of climate change on health, including malnutrition and mortality, is challenging due to the multi-factorial causes of most diseases and the changing socioeconomic, demographic, and environmental contexts over time. Little effort has been made to understand the geographical variations in likely impacts, and few studies have focused on Nepal specifically.

Some studies like Deaton (2007); Skoufias et al. (2011); and Navaneetham, Dharmalingam, and Caselli (2008) have explored the effects of climate variability on welfare indicators in other regions, such as income, consumption, mortality, and health status. Additionally, while studies have examined the effects of vector-borne diseases in some regions of the country, it is crucial to investigate whether climate influences health through other indirect channels, such as malnutrition (Kafle, 2012). Understanding the complex interactions between climate change and human health is crucial for developing effective strategies to mitigate and adapt to the impacts (Kafle, 2012; Timsina, 2015).

Factors like topography, the vulnerability of the population, and coping strategies influence the geographical variability in the health impacts of environmental changes in Nepal. The country's diverse agro-climatic zones and

Himalayan geography lead to varying climates and affect food production, health, and well-being. Differences in health services, infrastructure, socioeconomic factors, and baseline climate-sensitive diseases contribute to varying vulnerability. This study assesses the effects of weather variability on malnutrition and child mortality in Nepal.

2. Research design and methodology

We developed the conceptual framework for this research based on the literature and available information. It is presented in Figure 1. As indicated schematically, the variability in weather might impact the income and consumption level of the individual at the household level. Heat and cold stresses cause new diseases and amplify the spread of it in the community. It causes both malnutrition and mortality. Likewise, it hampers income and consumption, which ultimately dampens the child's health status, as shown in the diagram. As the capacity curve approach elaborated by Banerjee and Duflo (2011), children's health might reduce the individual's or household's expected future income, and direct toward a low-level equilibrium trap. Thus, it can be hypothesized that climate variability causes poverty, as explained by Banerjee and Duflo (2011) in their seminal work Poor Economics and adapted by Kafle (2012) and Timsina (2015).

The concept presented is translated into a doable research design in the following section of this chapter. Though the transmission channels presented are equally important to analyze empirically, the availability of information, time, and resources forced us to concentrate this research on the impact of weather variability on malnutrition and mortality, followed by capacity curve interpretation of the probable consequences of the impact.

The schematic framework for the research methodology is summarized in Figure 2. It indicates the source of the information and descriptive statistics in the first layer. It also indicates how we derive the dependent and independent variables with a set of control variables. A brief measurement of the variables is also indicated, followed by an anticipated regression equation to be estimated.

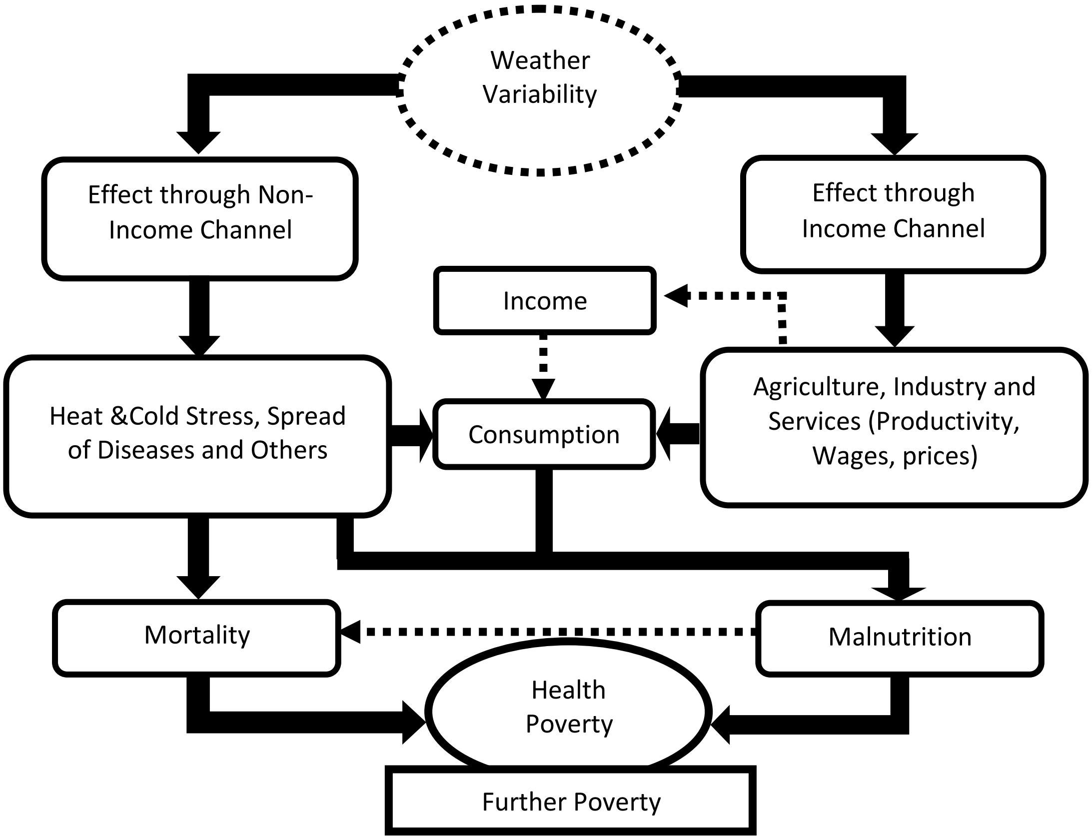

Figure 1: Conceptual framework

We collected the average temperature data from the National Climate Data Center (NCDC), available for 17 nationwide stations from 1973-2013 (Summary in Annex A). The NCDC dataset records the information multiple times during the same day. Thus, its average is considered the representation for that day. This information for six more locations (Dipayal, Dhangadi, Nepalgunj, Dang, Jiri, and Syangboche) is from Department of Hydrology and Meteorology (DHM) stations since the NCDC data set does not maintain information for these locations. The rainfall data (1973-2011) for all the stations under consideration are from the DHM. In the case of Dipayal, the rainfall records start from 1982 onwards only. Climate Variables are the mean deviations from the long-term location-specific mean for rainfall and temperature while the child is alive. For each child, the climate variable is calculated by taking the difference between the observed[1] and a long-term average of respective locations.

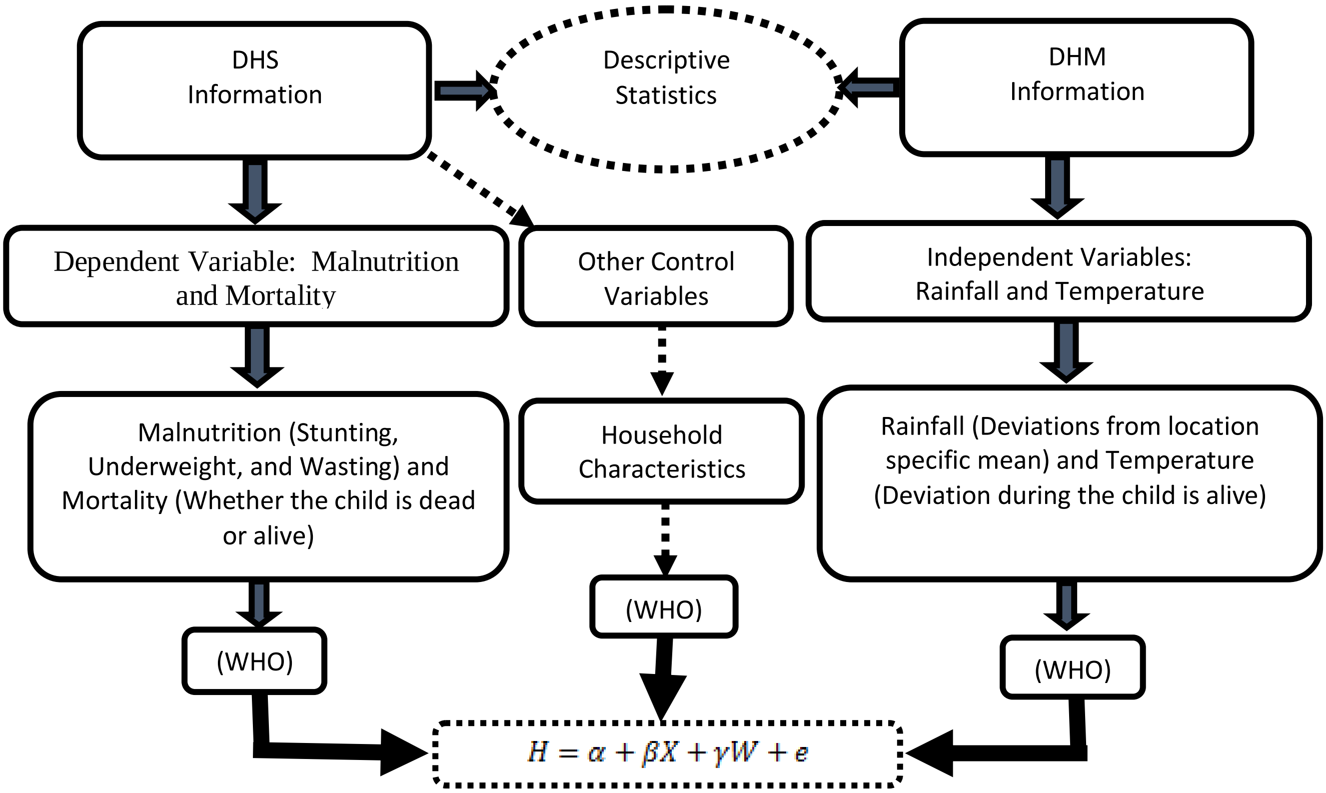

Figure 2: Scematic for the research design

The household characteristics, including malnutrition and mortality, are from the Demographic Health Surveys (DHS-2006). It is a nationally representative survey of 10,793 women aged 15-49 and 4,397 men aged 15-59 (MOHP, New-ERA, & Macro International, 2007). Since major explanatory variables and anthropometric measures are only available for births in the five years preceding the survey, the analysis of malnutrition and mortality is possible for those new births recorded during this period. We matched the weather data from above mentioned 17 climate stations to the Primary Sampling Unit (PSU) of the DHS survey. The 256 PSUs of the DHS data set are matched with climate variables based on their elevation and proximity to the weather stations under consideration.

The health variables are z-scores[2] of (i) height to age (stunting); (ii) weight to age (underweight); and (iii) weight to Height (wasting). They measure a child's deviation in Height or weight in terms of standard deviation units relative to a reference population, according to WHO standards. Following WHO guidelines, children with z-scores below minus two (-2) are identified as chronically malnourished, while those with z-scores below minus three (-3) are considered severely malnourished. For the analysis of mortality, we take the mean deviations from long-term means, using observations from the year of the child's birth. We use this measure instead of all the observations from the duration of the child's life so that mortality may be analyzed using the same measure for all children regardless of whether they are dead or alive. Mortality is measured directly in the birth record of the DHS as to whether each child born to the mother is dead or alive.

This study focuses on child malnutrition, as children are most vulnerable to its consequences. The indicators to measure malnutrition are stunting, wasting, and being underweight. The underweight index reflects chronic and acute undernutrition, while the height-for-age index identifies past growth failure or chronic malnutrition. The weight-for-height index helps identify acute undernutrition or wasting. Wasting is associated with short-term factors such as seasonal changes in food supply or illness. Causes of malnutrition include inadequate food intake, incorrect feeding practices, disease, and infection. Malnutrition can change rapidly, showing seasonal patterns and sensitivity to food availability and disease prevalence (Cogill, 2003; Prosperi et al., 2016).

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1 The rainfall and temperature in the duration of the child's lifetime

2 Median height is considered while calculating the z-scores.

In Annex A of the study, descriptive statistics are provided for the variables used, including dependent, independent, and explanatory variables. The weather variability measure shows positive and negative values at the mean level. The mean temperature deviation is negative for malnutrition and positive for mortality, while the rainfall deviation is negative for both. This indicates that rainfall is mainly below the mean, and temperatures fluctuate above and below the mean during the analysis period. Annex B contains additional information on variable classifications and descriptive statistics. The study employed four regression equations, controlling for other variables, to examine the relationship between climate variables and malnutrition and mortality. Clustered adjusted standard errors were estimated at the PSU[3] level to ensure robust results.

We estimate the following Weather Deviation[4] (W_σ) to malnutrition equations.

$$Z_i^{height} = \propto_a + \beta_a W_\sigma + \sum \gamma_a X_i + \epsilon_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (i)$$

$$Z_i^{weight} = \propto_b + \beta_b W_\sigma + \sum \gamma_b X_i + \epsilon_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (ii)$$

$$Z_i^{height*Weight} = \propto_c + \beta_c W_\sigma + \sum \gamma_c X_i + \epsilon_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (iii)$$

The variables Z_i^{height}, Z_i^{weight}, and $Z_i^{height*Weight}$ represent z-scores for 'height for age', 'weight for age', and 'height times weight', respectively, for the i[th] individual. The vector $\sum X_i$ represents a set of confounding factors. W_σ represents mean deviations in temperature and rainfall from the birth year means. Parameters $\propto_s, \beta_s$ and γ_s are associated with respective equations and variables. Finally, ϵ_i represents the error term at the household level, adjusted by cluster for PSU.

The study used OLS regression to estimate equations, considering the continuous nature of z-scores. It accounted for confounding factors, including birth size as a control variable, and incorporated explanatory variables related to child and maternal health. However, potential biases and correlations were acknowledged.

To study the effect of Weather Deviation (W_σ) on mortality, we specify and estimate the following Logit model as:

$$l_i = \log\left(\frac{P_i}{1-P_i}\right) = \mu_0 + \mu_1 W_\sigma + \sum \gamma X_i + \epsilon_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (iv)$$

Where; l_i is an log of odd ration of binary outcomes whether a child is dead or alive, Pi being the probability, W_σ *is* a mean deviations in temperature and rainfall from long term means in the birth year; $\sum X_i$ refers to a vector of confounding factors; μ_0 & μ_1 are constant coefficient and weather variability coefficient; and ϵ_i is an error term at household level and PSU when adjusted by cluster during estimation.

The study used logistic regression to analyze the impact of weather variability on child mortality. Child mortality was treated as a binary variable, and measures were taken to address the potential influence of unobserved child health status. We control birth size and factors related to child and maternal health. However, the study acknowledged the possibility of omitted variables bias and the potential correlation between unobserved child health status and mortality. The timing of birth and corresponding weather observations also posed a concern, as weather deviations were calculated based on observations from the birth year, which could vary for children born at different times.

3. Results and Discussion

Status of malnutrition and mortality

The DHS data set has information for women aged 15-49 in the survey (MOHP, New-ERA, & Macro International, 2007). Since the record is for five years preceding the survey, we analyze the malnutrition and mortality of the same. Malnutrition is measured in three different measures: height to age representing stunting, weight to age representing underweight, and weight to height representing wasting of the child under consideration. The summary of the information is in Table 1.

3 We could also cluster by the weather station since the PSUs are matched to the weather station. Clustering in this way will further inflate the standard errors. However, we do not do this in our paper, and we cluster by PSU so that sample weight is also considered when computing standard errors.

4 It is a proxy for climate variation or climate change in this study.

Table 1: Malnutrition indicators

Variable	Sample Size	Mean[5]	Std. Dev.	Min	Max
All children under 5 years of age					
Height for age	5237	-1.9597	1.3361	-5.96	4.59
Weight for age	5237	-1.7173	1.0606	-5.70	3.06
Weight for height	5237	-0.8441	1.0615	-4.94	4.07
Children under 2 years of age					
Height for age	2088	-1.4864	1.3937	-5.94	4.59
Weight for age	2088	-1.5523	1.1581	-5.70	3.06
Weight for height	2088	-1.0210	1.1567	-4.82	4.07

Source: Author's calculation

To see whether there is a discrepancy among the different cohorts of the child, we also summarized the information separately for less than two-year-old children. Among 7325 surveyed, 2088 births were during the two years of the survey (MOHP, New-ERA, & Macro International, 2007). The standard deviation of malnutrition among the youngest group relative to the full-sample group is higher, whereas the mean values are smaller. It indicates the severity of malnutrition among the youngest group supporting the existing literature on it.

Table 2: Summary of weather variability

Variable	Sample size	Mean[6]	SD	Min	Max
Temperature Deviation	5237	-17.6835	5.9391	-24.6969	4.3652
Rainfall Deviation	5237	-3.8948	2.1449	-10.4725	1.0177

Source: Author's calculation

We merged the child information from DHS with the climate information (Summary in Annex A) from various sources. Table 2 is the summary of the temperature and rainfall variation. This information gives a glimpse of the status of the weather deviation in the sample period, about the child information only. It means the child information from the DHS data set and climate information from NCDC and DHM matched for 5237 children only. Further analysis of these variables' vis-s-vis child information is presented in the following sections. Like malnutrition, while combining the DHS and climate information, 420 children are recorded dead among 7145 births recorded during the past five years of the survey. It is summarized in Table 3.

Table 3: Status of mortality

Variable	Frequency	Percent
Number of children recorded dead at the household level	420	5.88
Number of children recorded alive at the household level	6,725	94.12
Total	7,145	100.00

Source: Author's calculation

Out of 7145 childbirths recorded, only 7022 child information matched with other variables, and the summary prime variables are in Table 4.

Table 4: Descriptive statistics of weather variability for the analysis of mortality

Variable	Sample size	Mean	SD	Min	Max
Temperature deviation	7022	0.4267	1.8737	-3.7782	4.4921
Rainfall deviation	7022	-0.0488	1.2005	-4.2516	1.8664

Source: Author's calculation

Effects of weather variability on malnutrition

Our proxy for weather variability is a mean deviation from the long-term mean for the period the child is alive. We estimated separate regressions for height for age (Stunting), weight for age (Wasting), and weight for height

5 The mean values can be negative in our case because it is the average of the z-score. It indicates that the z-score data for malnutrition in Nepal from 2001 to 2006 is negatively skewed.

6 The temperature and rainfall deviation from the long-run deviation take the 2006 value as an assumed mean. Since the variables are monotonically increasing in the case of temperature and have high volatility with an increasing trend in the rainfall variable, the mean mentioned here is not the mean of temperature and rainfall. Instead, they are the mean of the difference of each data point from the 2006 data point. Thus, they are negative. The means are negative; it does not impact our analysis unit in regression because we are considering the variation rather than the scale value. Since the sample size is sufficiently large, the deviation taken from the assumed mean would not significantly differ from the actual deviation.

(Underweight). Each regression has a double estimation first without an adjusted standard error followed by an adjusted one. Each regression is estimated first, having temperature and rainfall variables followed by only one climate variable taking one time. We estimate the logistic regression on child mortality using a similar set of explanatory variables.

We analyze the impact of weather variability on malnutrition using anthropometric indicators from the DHS 2006 dataset. We estimate models both with and without adjusted standard errors by clusters of PSUs. The models include various household, child, and maternal characteristics as explanatory variables, as these factors are related to child malnutrition. The anthropometric indicators used are z-scores for stunting, wasting, and underweight. The analysis results will provide insights into the relationship between weather variability and malnutrition, considering the influence of these explanatory variables.

The regression results in *Table 5* reveal that the deviations in temperature have a significantly positive association with child **stunting** (height for age), even at one percentage level of significance. The coefficient indicates that a one-degree deviation in temperature resulted in a 0.026-point rise in height for age z-scores during our sample period, ceteris paribus. Temperature variation might create uncertainty in the food and nutrition intake resulting in significant damage in growth as per the child's age. However, the rainfall deviation did not significantly affect the child's stunning during the sample period. The simultaneous deviation in rainfall and temperature aggravated the stunning situation of the child quite more. The height coefficient for age with only temperature deviation is only 0.023, which is significantly positive. Thus, weather variability impacts malnutrition in terms of stunning in Nepal.

Besides temperature and rainfall, other variables are also responsible for the variation in stunning outcomes of the child in Nepal. Like, the number of children in the family, the total number of children born within the same household, and whether the mother breastfeeds well, negatively and significantly, matters for the stunning in Nepal during the sample period. Similarly, the family wealth index, height of the mother, education level of the mother, skilled birth attendant, and prenatal care coefficients are positive and significant, signifying their importance in child malnutrition.

Table 5: Weather variation and stunting (*height for age z-scores of child under five)*

Dependent variables	Unadjusted SE			Adjusted SE		
	(1)	(2)	(3)	(4)	(5)	(6)
Temperature deviation	0.026***		0.023***	0.026***		0.023***
	(3.35)		(3.43)	(3.13)		(3.20)
Rainfall deviation	-0.014	0.026*		-0.014	0.026	
	(0.78)	(1.71)		(0.59)	(1.36)	
Breastfed months	-0.024***	-0.026***	-0.024***	-0.024***	-0.026***	-0.024***
	(5.68)	(5.86)	(5.47)	(5.83)	(5.93)	(5.46)
Skilled attendant	0.202**	0.219***	0.215**	0.202***	0.219***	0.215**
	(2.49)	(2.70)	(2.37)	(2.83)	(3.12)	(2.21)
Children related[a]	Y	Y	Y	Y	Y	Y
Mother related[b]	Y	Y	Y	Y	Y	Y
Household related[c]	Y	Y	Y	Y	Y	Y
Constant	-9.666***	-10.087***	-9.094***	-9.666***	-10.087***	-9.094***
	(11.10)	(11.46)	(9.32)	(11.09)	(11.78)	(9.44)
R2	0.26	0.26	0.26	0.26	0.26	0.26
N	2,522	2,522	2,113	2,522	2,522	2,113

****p<0.1; * p<0.05; ** p<0.01 and t-statistics in parenthesis; Y stands for controlled; (a) Children related: The gender of the child, age of the child, the three days nutrition services given or not, prenatal services received or not, and child's birth order is controlled; (b) Mother's characteristics (Age, Age in the first pregnancy, Height, Education, if works at home, and Occupations) controlled; and (c) Household size, gender of the household head, age of the household head, Wealth index of the family, total children born in the household are controlled.*

The summary of the regression results in *Table 6* reveals that the deviations in temperature have a significantly positive association with child **wasting** (weight for age), even at one percentage level of significance. The regression coefficient indicates that one unit deviation in temperature resulted in a 0.023-point rise in weight for age z-scores during our sample period, ceteris paribus. The deviation in temperature might create uncertainty in the food and nutrition availability and intake that hampers healthy weight gain of the child. However, the rainfall deviation reduces the wasting of the child, but the coefficient is insignificant. It can be safe to argue that the simultaneous deviation in rainfall and temperature aggravates the wasting situation of the child quite a lot. The coefficient of weight for age with only temperature deviation is only 0.018, which is significantly positive. Thus, weather variability impacts malnutrition in terms of stunning in Nepal.

Besides temperature and rainfall, other variables are also responsible for the variation in wasting outcomes of the child in Nepal. The number of children in the family, the number of children born there, and whether the mother breastfeeds helped reduce wasting in Nepal during the sample period. Similarly, the family wealth index, height of the mother, education level of the mother, skilled birth attendant, and prenatal care coefficients are positively significant in the model, signifying their importance in child malnutrition.

Table 6: Weather variation and wasting (*weight for age z-scores of child under five*)

Dependent variables	**Unadjusted**			**Adjusted SE**		
	(1)	(2)	(3)	(4)	(5)	(6)
Temperature deviation	0.023***		0.018***	0.023***		0.018***
	(3.82)		(3.54)	(4.08)		(3.63)
Rainfall deviation	-0.025	0.011		-0.025	0.011	
	(1.57)	(0.82)		(1.34)	(0.68)	
Breastfed months	-0.010***	-0.011***	-0.010***	-0.010***	-0.011***	-0.010***
	(2.96)	(3.22)	(2.61)	(2.92)	(3.10)	(2.67)
Skilledattendant	0.169**	0.184***	0.164**	0.169***	0.184***	0.164**
	(2.44)	(2.64)	(1.99)	(2.71)	(2.96)	(2.01)
Children related[a]	Y	Y	Y	Y	Y	Y
Mother related[b]	Y	Y	Y	Y	Y	Y
Household relate[c]	Y	Y	Y	Y	Y	Y
Constant	-6.655***	-7.023***	-5.940***	-6.655***	-7.023***	-5.940***
	(9.94)	(10.46)	(7.85)	(9.60)	(10.39)	(7.57)
R2	0.24	0.24	0.23	0.24	0.24	0.23
N	2,522	2,522	2,113	2,522	2,522	2,113

****p<0.1; * p<0.05; ** p<0.01 and t-statistics in in parenthesis; Y stands for controlled; (a) Children related: The gender of the child, age of the child, the three days nutrition services given or not, prenatal services received or not, and child's birth order are controlled; (b) Mother's characteristics (Age, Age in the first pregnancy, Height, Education, if works at home, and Occupations) controlled; and (c) Household size, gender of the household head, age of the household head, Wealth index of the family, total children born in the household are controlled.*

The regression results in *Table 7* suggest that the deviation in temperature has a positive association with child *underweight* (weight to height), though insignificant. It might be the plausible reasoning that the deviation in temperature has less to do with underweight through the uncertainty in the food and nutrition availability and intake resulting in significant damages to weight gaining process of the child. Similarly, the rainfall deviation and the underweight are negatively associated, though the coefficient is insignificant. It is safe to argue that the simultaneous deviation in rainfall and temperature aggravates the wasting situation of the child quite more. The coefficient of temperature deviation alone is only 0.009, significantly close to 0.011. It signifies that temperature alone is more responsible for the malnutrition status measures in terms of underweight.

Besides temperature and rainfall, we estimated regression coefficients for several other variables with underweight. Among them, the mother's age, education, and child sex significantly and positively caused underweight. Similarly, if the mother works outside the home, there is less immunization intake, the total number of children at home, and the mother's age at birth of the child.

Our results show that weather variability indeed affected child malnutrition status in Nepal. It significantly and positively affected stunting and wasting, though positive, but insignificantly in underweight. This result contrasts with other literature in the case of other countries (Skoufias, 2011; Kudamatsu, 2010), perhaps because when compared to Mexico and Africa, Nepal enjoys a more temperate climate, with mountain regions having a much colder range of temperatures *(Mean for the country as a whole is around 20 degrees, while mean deviation is -17; see table 4.3 and 4.4 with footnote there for details on it)*. Rainfall variability, on the other hand, does not significantly affect malnutrition scores. Children under two are less affected, although they also show the effects of temperature deviations on their malnutrition scores. However, restricting the dataset to only these children produced significant results for temperature and rainfall deviations.

Table 7: Weather variation and underweight (weight to height z-scores of under fives)

Dependent variables	Unadjusted			Adjusted SE		
	(1)	(2)	(3)	(4)	(5)	(6)
Temperature deviation	0.011		0.009	0.011		0.009
	(1.63)		(1.59)	(1.40)		(1.52)
Rainfall deviation	-0.018	-0.002		-0.018	-0.002	
	(1.09)	(0.12)		(0.92)	(0.10)	
Ever immunized	-0.134**	-0.145**	-0.274*	-0.134**	-0.145**	-0.274**
	(2.24)	(2.43)	(1.89)	(2.24)	(2.42)	(2.16)
Family wealth index	0.066*	0.068*	0.071*	0.066**	0.068**	0.071*
	(1.68)	(1.74)	(1.73)	(2.00)	(2.09)	(1.80)
Mother's education	0.203***	0.204***	0.158***	0.203***	0.204***	0.158***
	(2.85)	(2.87)	(2.02)	(2.92)	(2.94)	(1.98)
Children related[a]	Y	Y	Y	Y	Y	Y
Mother related[b]	Y	Y	Y	Y	Y	Y
Household related[c]	Y	Y	Y	Y	Y	Y
Constant	-1.637**	-1.805***	-0.796	-1.637**	-1.805***	-0.796
	(2.45)	(2.71)	(1.07)	(2.48)	(2.68)	(1.09)
R2	0.15	0.15	0.15	0.15	0.15	0.15
N	2,522	2,522	2,113	2,522	2,522	2,113

****p<0.1; * p<0.05; ** p<0.01 and t-statistics in parenthesis; Y stands for controlled; (a) Children related: The gender of the child, age of the child, breastfed months, skilled birth attendant, the three days nutrition services given or not, prenatal services received or not, and child's birth order are controlled; (b) Mother's characteristics (Age, Age in the first pregnancy, Height, if works at home, and Occupations) controlled; and (c) Household size, gender of the household head, age of the household head, total children born in the household are controlled.*

Effects of weather variability on mortality

Similar to the malnutrition study, we examine data from a recent survey to assess child well-being within the past five years. We focus on a binary dependent variable indicating child survival (1=deceased, 0=alive). Employing a Logit model, we analyze climate factors alongside household, maternal, child-related attributes, and child-rearing practices—mirroring the malnutrition investigation. Initially, we conduct regression without cluster-adjusted standard errors. Subsequently, we apply standard error adjustments using 257 PSU-based clusters. Refer to Table 8 for a comprehensive summary of our findings.

The regression coefficients indicate that temperature deviation and mortality are negatively associated. However, rainfall deviation and child mortality are positively associated in Nepal during the sample period. As the deviation in temperature increases by one unit, a child born during 2001-2006 is less likely to die, other things remain the same. It may be the case that infants have no direct exposure to extreme events that result in death. However, the unit increase in rainfall variability results in a positively significant level of chances of mortality. It may result from the direct association of the child to rainfall deviation, resulting in life-threatening diseases than temperature-born ones in Nepal. Temperature and rainfall deviation coefficients have opposing effects, perhaps because the rise in temperature affects areas where crops can be grown and reduces the effects of cold stress in Nepal.

In contrast, rainfall deviations could alter the disease environment negatively, spreading infectious and vector-borne diseases. Besides temperature and rainfall, other variables are also responsible for child mortality in Nepal. However, child-rearing quality, like the number of months for breastfed and prenatal services used held, reduces the likelihood of child death at the household level. Other control variables are also supportive of the theory for size and sign, like household size, whether three days of nutrition are not appropriately taken, the total number of children born in the family, and the mother's age at the first birth causes more mortality. Likewise, the number of live siblings, the mother's education, the height of the mother, months of breastfeeding, prenatal care, and skilled birth attendants reduce the chances of mortality in Nepal.

Climate change and weather variability have a significant impact on the Nepalese economy through various channels. Firstly, climate change has likely led to a reduction in crop production, particularly in the case of wheat production in Nepal, as indicated by Thapa-Parajuli and Devkota (2016). Additionally, climate change has profound implications for livelihoods, even in highland areas, as KC and Thapa Parajuli (2014). It is worth noting that there have been instances, such as in the Manaslu region of Gorkha, Nepal, where climate change has positively influenced tourism, as reported by KC and Thapa Parajuli (2015). However, it is crucial to recognize that this phenomenon cannot be generalized to the entire country or region. As established in our study, another significant concern for the Nepalese economy is the potential deterioration of child health at the family or household level due to climate change. This is particularly worrisome because Nepal's economic growth process is already unbalanced and heavily reliant on the primary sector, as Khanal, Thapa, and Belbase (2012) highlighted in 2012. One potential solution to address this issue is to internalize the negative externalities associated with climate change into development interventions. This can be achieved by adopting a climate change-adapted green economy framework, as Bhuju, Thapa-Parajuli, Sharma, and Aryal (2015) proposed. Consequently, understanding the link between climate change and household poverty, transmitted through child health in Nepal, is crucial for effectively integrating climate change facts into development interventions.

Table 8: Effect of weather variation on child mortality

Dependent Variable takes 1 if child is dead and 0 otherwise: logistic estimates						
Independent variables	**Unadjusted SE**			**Adjusted SE at PSU Level**		
	(1)	(2)	(3)	(4)	(5)	(6)
Temperature deviation	-0.239*		-0.201	-0.239		-0.201
	(1.69)		(1.44)	(1.54)		(1.31)
Rainfall deviation		0.569**	0.501*		0.569**	0.501*
		(2.10)	(1.79)		(2.14)	(1.81)
Breastfed months	-0.209***	-0.208***	-0.219***	-0.209***	-0.208***	-0.219***
	(5.29)	(5.92)	(5.63)	(6.01)	(7.16)	(6.48)
Prenatal service taken	-1.086***	-1.117***	-1.101***	-1.086***	-1.117***	-1.101***
	(3.06)	(3.05)	(2.98)	(2.66)	(2.74)	(2.61)
Children related[a]	Y	Y	Y	Y	Y	Y
Mother related[b]	Y	Y	Y	Y	Y	Y
Household related[c]	Y	Y	Y	Y	Y	Y
Geo-spatial dummies[d]	N	N	N	Y	Y	Y
Constant	4.809	4.467	4.539	4.809	4.467	4.539
	(0.85)	(0.77)	(0.78)	(0.81)	(0.74)	(0.75)
R2	0.35	0.35	0.32	0.35	0.35	0.32
N	2,934	2,934	2,934	2,934	2,934	2,934

****p<0.1; * p<0.05; ** p<0.01 and t-statistics in parenthesis; Y stands for controlled; (a) Children related: The gender of the child, age of the child, skilled birth attendant, Birth size[7], the three days nutrition services given or not, and child's birth order are controlled; (b) Mother's characteristics (Age, Age in the first pregnancy, Height, if works at home, and Occupations) controlled; and (c) Household size, gender of the household head, age of the household head, total children born in the household, and (d) The Geo Region Controlled[8], Rural-urban Dummy, High altitude Dummy, and Ecological Belt are controlled[9]*

Conclusion and Recommendation

Our results demonstrate a significant association between temperature variability and child malnutrition. Temperature changes have a slightly positive effect on stunting and wasting in children under five. However, we did not observe any significant impact of rainfall deviations on the malnutrition status of children under five. On the other hand, a one-unit change in rainfall deviations decreases underweight scores, indicating an increase in malnutrition. It is possible that consumption is not negatively affected for all households but only for poor households, which could explain the observed underweight results primarily driven by seasonal changes in nutritional status.

7 Four dummies for very small (reference), small, average, large and very large were estimated.

8 Four dummies for East, Centre, West, Mid-west, and Far-west (reference) were estimated.

9 Two dummies for High Hill, mountain, and Tarai (reference) were estimated.

The increase in income resulting from temperature deviations may contribute to the improvement in z-scores and the reduction in malnutrition. Additionally, the mean deviation is significantly below the historical average at -17°C, which may explain the positive effects observed, as reducing cold stress in extremely cold climates can lead to health gains. The range of climatic conditions experienced by children in different locations, with minimum temperatures at -24°C and maximum temperatures at 4.4°C, collectively contribute to the positive impact on malnutrition.

In terms of mortality, our findings indicate that rainfall variability increases mortality rates, whereas temperature deviations have the opposite effect. This suggests that interventions, including medical interventions, must address malnutrition among younger cohorts, particularly in regions facing increasing rainfall variability. While temperature deviations decrease the likelihood of mortality, this result loses significance when temperature and rainfall are considered together in the analysis. The opposing effects of rainfall and temperature deviations indicate that these variables operate through different mechanisms. Both temperature and rainfall variability potentially influence health outcomes through income effects, whereas rainfall variability likely has a direct negative impact due to changes in disease environments.

The study highlights the importance of considering temperature-related information when formulating child health policies, as temperature variations are found to impact malnutrition. Stakeholders involved in child health policies should closely examine temperature and rainfall trends to maximize welfare gains from temperature deviations and minimize losses from rainfall deviations. A possible extension of this study could have involved decomposing temperature variability into negative and positive deviations, considering seasonal variations, increasing the number of weather stations, and analyzing heterogeneities of impact based on socio-economic characteristics using comprehensive household datasets. However, the availability of high-quality rainfall and temperature data for Nepal needs to be improved.

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Appendix A

Table A1: List of weather stations used in analysis

Station Name	Zone	Belt	Elevation	Region	Area (KM2)
Dadeldhura	Mahakali	Mountain	1865	Far-West	19,539
Dipayal	Seti	Hill	617	Far- West	
Dhangadhi	Seti	Terai	187	Far-West	
Surkhet	Bheri	Hill	720	Mid-West	42,378
Nepalgunj Airport	Bheri	Terai	165	Mid-West	
Jumla	Karnali	Mountain	2300	Mid-West	
Dang	Rapti	Hill	634	Mid-West	
Pokhara Airport	Gandaki	Hill	827	Western	29,398
Bhairawa Airport	Lumbini	Terai	109	Western	
Simra Airport	Narayani	Terai	137	Central	27,410
Kathmandu Airport	Bagmati	Hill	1337	Central	
Jiri	Janakpur	Mountain	2003	Central	
Syangboche	Sagarmatha	Mountain	3700	Eastern	28,465
Okhaldhunga	Sagarmatha	Mountain	1720	Eastern	
Taplejung	Mechi	Mountain	1732	Eastern	
Dhankuta	Koshi	Hill	1210	Eastern	
Biratnagar Airport	Koshi	Terai	72	Eastern	

Source: Author's calculation

Table A2: Source of temperature data, time covered and missing observations

Location	Temp(Years)	Source	Missing	Observations	Missing (%)
Dadeldhura	1978-2011	NCDC	268	7,312	3.67
Dipyal	1982-2010	Dep of Hydrology	32	10,801	0.30
Dhangadhi	1975-2010	Dep of Hydrology	515	13,519	3.81
Surkhet	1976-2011	NDCC	413	30,289	1.36
Nepalgunj Airport	1973-2010	Dep of Hydrology	534	14,181	3.77
Jumla	1975-2011	NCDC	252	7,210	3.50
Dang	1989-2010	Dep of Hydrology	401	8,160	4.91
Pokhara Airport	1977-2011	NCDC	271	7,157	3.79
Bhairawa Airport	1977-2011	NCDC	414	29,395	1.41
Simra Airport	1974-2011	NCDC	269	7,240	3.72
Kathmandu Airport	1973-2011	NCDC	5,484	91,890	5.97
Jiri	1973-2011	Dep of Hydrology	462	13,880	3.33
Syangboche	1976-1980	NCDC	49	1,430	3.43
Okhaldhunga	1976-2011	NCDC	280	8,463	3.31
Taplejung	1978-2011	NCDC	286	6,234	4.59
Dhankuta	1976-2011	NCDC	522	30,391	1.72
Biratnagar Airport	1977-2011	NCDC	285	7,325	3.89
All Locations		NCDC +Dept of Hid	10737	294,877	3.6

Source: Author's calculation