The Impact of Weather Variation on Child Health in Sub-Saharan Africa

Sushenjit Bandyopadhyay, Shireen Kanji, and Limin Wang

It has long been known that children’s health in Africa is vulnerable to changes in weather and in particular to extremes that cause drought or flooding. Until recently it has been hard to quantify precisely the links between weather variation and health due to a paucity of high-quality data (see Patz and others 2005). This study fills that knowledge gap using a unique dataset to analyze the impact of variations in precipitation and maximum and minimum temperatures on children’s health in Sub-Saharan Africa. The dataset has been constructed using the Demographic and Health Surveys (DHSs) from 19 Sub-Saharan African countries between 1992 and 2000, climate data from the Africa Rainfall and Temperature Evaluation System between 1980 and 2000, and the Köppen-Geiger climate map that identifies climate zones. The resulting dataset includes a wide range of childhood disease indicators, measures of undernutrition, access to basic health, education, environmental services, weather variables, and climate zones for 173 subnational regions in Africa.

The investigation of variability in temperature and precipitation is timely. In particular, extreme weather events are predicted to increase as a result
of climate change (McMichael and others 2004, Karl and others 1995, IPCC 2007). Moreover, Africa is likely to be one of the regions most affected by climate change according to the 2007 IPCC report. The human cost of climate change in Africa is likely to be high because of the already higher disease prevalence, faster population growth, and limited adaptive capacity in Africa relative to other regions as shown in Table 1.

This study focuses on the human cost by analyzing the prevalence of diarrhea and acute respiratory infections (ARI), as well as undernutrition, in children under the age of three. Malaria, an important disease that can be affected by changes in precipitation and temperature, is omitted because the DHSs have not collected malaria incidence for all the countries. Respiratory infections and diarrheal disease are ranked as the second and third leading causes of death among children under the age of five in Africa, after malaria (WHO 2002). In recognition of the complex interaction between weather variation and local contexts, a range of socio-environmental factors is controlled for.

The results from this study can also be used to project spatial disease prevalence and disease burden based on local precipitation and extreme temperature information. The integration of the disease indicators with other existing spatial information such as access to safe water and sanitation, infrastructure, poverty measures, and population density can strengthen government’s capacity to better geographically target resources to address the adverse consequences of extreme weather events.

Quantifying the Health Impact of Climate Variability

A reduced form model approach is used to test the statistical relationship between health outcomes and variation in temperature and precipitation, controlling for socio-environmental factors. The availability of panel data helps to reduce the problems associated with omitted confounding factors that limit the interpretation of causality in many studies on the determinants of health outcomes. The model specification and the key variables used in the analysis are presented in Box 1.

**Key findings: Weather effect**

The results from the econometric analysis confirm that variation in maximum and minimum temperatures and precipitation in dry seasons significantly affect the prevalence of diarrhea and ARI, and short-term malnutrition status measured by the WFH z-score, after controlling for socio-environmental conditions, climate zones, and regional effects. As might be expected, there is no significant effect found on the HFA z-score, a measure of

### TABLE 1. Health and Population, Adaptive Capacity and CO2 Emissions by Region

<table>
<thead>
<tr>
<th>Regions</th>
<th>Health and population</th>
<th>Adaptive capacity</th>
<th>CO₂ emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Developing Regions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>146</td>
<td>2.5</td>
<td>58</td>
</tr>
<tr>
<td>South Asia</td>
<td>78</td>
<td>1.8</td>
<td>87</td>
</tr>
<tr>
<td>Middle East and North Africa</td>
<td>38</td>
<td>2.0</td>
<td>89</td>
</tr>
<tr>
<td>East Asia and Pacific</td>
<td>27</td>
<td>2.1</td>
<td>87</td>
</tr>
<tr>
<td>Latin America and Caribbean</td>
<td>26</td>
<td>1.5</td>
<td>91</td>
</tr>
<tr>
<td>Europe and Central Asia</td>
<td>23</td>
<td>0.1</td>
<td>95</td>
</tr>
<tr>
<td><strong>Developed Regions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euro Area</td>
<td>4</td>
<td>0.4</td>
<td>100</td>
</tr>
<tr>
<td>USA</td>
<td>8</td>
<td>1</td>
<td>99</td>
</tr>
</tbody>
</table>

A 1 degree Celsius increase in the average monthly maximum temperature increases the prevalence of diarrheal disease, on average, by about 1 percentage point, representing an approximate 4 percent increase in diarrheal disease prevalence given that the average diarrheal prevalence is 22.7 percent. The analysis finds a statistically significant but smaller impact of changes in minimum temperature on diarrheal prevalence: a 1 degree Celsius increase in the average monthly minimum temperature increases the prevalence of diarrheal disease, on average, by about 0.4 percentage point.
The study finds no significant effect of changes in extreme temperatures on ARI prevalence. The findings from this analysis of the effect of temperature on diarrheal disease are in line with the results from two studies in the developing country context; however, they are not directly comparable because the two studies used data on hospital admissions. For example, using data on the daily number of hospital admissions of children under ten years of age with diarrhea in Lima, Peru, Checkley and others (2000) showed diarrheal admissions increase 8 percent for every 1 degree Celsius increase in temperature (average across all seasons). Singh and others (2001), using monthly data for Fiji, provided an estimate of about 3 percent increase in diarrheal notification for a 1 degree Celsius increase in temperature.

Heavy rainfall in dry seasons is found to have a very large reducing impact on disease prevalence. Relative to the base case of normal rainfall, the event of heavy rainfall reduces the prevalence of diarrhea and ARI by about 3.4 and 7.3 percentage points, respectively. This large rainfall effect on health can be explained by the fact that many regions in Africa are exposed to high water stress. Higher-than-average rainfall during the dry season increases water availability and improves households’ access to safer water sources, such as wells and piped water, as ground water becomes more plentiful.

The analysis finds that better nutritional status plays an important role in protecting against diarrheal prevalence. Better long-term nutritional status (HFA z-score) reduces the prevalence of diarrhea, with a one-unit increase in the HFA z-score being associated with a reduction of diarrheal prevalence of 2 percentage points. (The HFA nutritional status is highly correlated with climate zones, so the health benefit of better nutrition is statistically significant only in the model without climate zones.)

The findings on the impact of variation in extreme temperature and precipitation on childhood diseases from this study suggest that the adverse health consequences associated with climate change must be placed high in the climate change adaptation agenda in Africa.

**FIGURE 1. Estimated Impact of Weather Variability During the Dry Season on Health Status of Children in Sub-Saharan Africa**

Note: The impact of heavy rainfall on the WFH z-score is inconclusive.
Key findings: Socio-environmental effect

The analysis also confirms that long-term investment in access to safe water, electricity, health care, and female education can jointly significantly improve health outcomes among young children. The proportion of the subnational population with access to a toilet and health care are also significant determinants of diarrheal prevalence. The other factors are not found to have a statistically significant impact on disease prevalence. The lack of statistical significance stems mainly from limited variability in these variables, their measurement at the regional rather than individual level, and the small sample size.

The study shows that the country per capita income is associated with large differences in diarrheal prevalence and malnutrition in the subnational regions. A 1 percent increase in country per capita income adjusted for PPP is associated with a reduction in the prevalence of diarrhea of 0.04 percent and an increase of WFH z-score by about 0.23, controlling for access to basic environmental services. It should be noted that the estimated income effect should be interpreted with some caution due to the unavailability of subnational income data.

Projecting Future Cost of Diarrheal Diseases

Africa is projected to be hotter and drier in the coming decades. A range of climate models have projected that the mean surface air temperature for the period 2080-2099 will have increased by between 3 and 4 degrees Celsius compared with the 1980-1999 period in most parts of Africa, with less warming in equatorial and coastal areas (Christensen and others 2007). While precipitation projections are less consistent among different climate models, a general consensus is that climate change and variability are likely to reduce water availability and accessibility, raising the population at risk of increased water stress to between 75 and 250 million by the 2020s and between 350 and 600 million by the 2050s (IPCC 2007).

The estimated impact of above-average rainfall in the dry seasons and temperature changes on disease prevalence provides important statistics that can be used to project the future health burden of these weather events. The cost of diarrheal disease is projected over a 20-year period from 2000 to 2020 as an illustration of the use to which these statistics can be put.

Two assumptions underpin this exercise. First, the frequency of above-average rainfall in the dry seasons and average maximum and minimum temperatures for each locality in the sample countries would change uniformly between 2000 and 2020 as a result of climate change. The probability of higher-than-average rainfall in the dry seasons is assumed to fall to 13 percent from the current level of 25 percent, representing a 50 percent reduction. The maximum and minimum temperatures both are assumed to rise 1 degree Celsius by 2020.
The second assumption is that public investment in the social and environment sectors over the next decade would be sufficient to maintain the current levels of population access to basic services. This is an optimistic scenario as it essentially assumes the rate of investment in access to basic services is the same as the UN projected population growth rate of 2.5 percent per annum in Africa. In reality, progress in improving access to water and sanitation services in Africa has been more limited. Therefore, the projected disease costs should be regarded as a lower bound of the estimate of the disease burden that is associated with changes in temperature and precipitation by 2020.

Table 2 summarizes the health impact projection in 2020. The projections show that the prevalence of diarrheal disease would increase from 22.5 percent in 2000 to about 23.6 percent by 2020. Consequently, the total number of diarrheal cases among children under the age of five would increase by about 11 million, from 26 million cases in 2000 to 37 million cases in 2020, representing about a 40 percent increase. (The UN population growth projection is not available for the under-three age group; the prevalence of diarrhea disease for the two age groups is assumed to be the same.) The total cost of increased diarrheal cases by 2020 account for about 3 percent of GDP in Africa in 2020.

How much of the increased diarrheal cases is attributable to projected increases in extreme temperature and reduction in precipitation in the dry seasons? The decomposition analysis (for details see Box 2) shows that of the 40 percent increase in diarrheal cases between 2000 and 2020, population growth contributes about 36 percentage points and the effect of the reduced high rainfall events and rise in minimum and maximum temperature about 4 percentage points.

The projected health cost of diarrheal disease alone that is attributable to changes in temperature and precipitation is about 0.24 percent of GDP by 2020. Several studies have shown that a range of other diseases are also affected by weather variation, including malaria (Marten and others 1999 and Bouma and Kaay 1996, on India and Sri Lanka; Zhou and others 2004, on East Africa; and Tanser and others 2003, on Africa), dengue fever (Hales and others 2002, on Africa), and ARI and malnutrition as documented in this analysis. When these diseases and malnutrition are included, the projected health cost could be much larger.

**Policy Messages**

The results of this study highlight that good rainfall and improved water availability in dry seasons can have a large and significant effect on reducing the prevalence of childhood diseases, in particular diarrhea and ARI. These findings suggest that adaptation measures should focus on water management as well as on devising specific disease prevention measures to cope with the high level of water stress that already exists in Africa, and which is likely to get worse with climate change. These measures need to be an integral part of adaptation policies devised to safeguard against further climate change.

**TABLE 2. Projection of Health Impact in 2020: Diarrheal Disease**

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2020</th>
<th>Impact due to increased weather variation in 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diarrheal cases (1000)</td>
<td>26,451</td>
<td>36,970</td>
<td>1,723</td>
</tr>
<tr>
<td>DALY (1000)</td>
<td>25,072</td>
<td>35,042</td>
<td>1,633</td>
</tr>
<tr>
<td>Health cost as % of GDP</td>
<td>3.7</td>
<td>3.2</td>
<td>0.24</td>
</tr>
<tr>
<td>Diarrheal incidence (%)</td>
<td>22.5</td>
<td>23.6</td>
<td>23.6</td>
</tr>
<tr>
<td>Population (1,000)</td>
<td>115,822</td>
<td>156,652</td>
<td>156,652</td>
</tr>
</tbody>
</table>

*Note:* (1) population for 2020 is from UN population projection; (2) DALY per child death is assumed to be 34 (WHO 2000), (3) health cost is calculated as DALY times GDP per capita, and (4) the climate change scenario is defined as the probability of heavy precipitation of 13 percent during dry seasons and a rise in maximum and minimum temperature of 1 degree Celsius.
Improving the effectiveness in public resource use requires resources to be targeted to localities where the projected health consequences are particularly severe and the local adaptive capacity particularly limited. In the absence of country-specific estimates of the health impact of weather variation, the estimates from this study can be used to develop maps showing scenarios of future health risks if the country-level climate projection models are available. The spatial disease prevalence can be linked with poverty and infrastructure maps to support the targeting of resources to the neediest localities.

Policies that focus on improving nutritional status among young children should be strengthened as a matter of priority. This study confirms what is widely known—that better nutritional status has a preventive effect on the prevalence of diarrhea, in addition to benefits to child survival, long-term health, and cognitive functioning.

The impact of population growth in increasing the disease burden highlights the importance of increasing investment in access to basic environmental and health services, access to electricity, and female education in the coming decades.

The findings from this study provide important empirical evidence on the links between weather variation and health outcomes in Africa. However, future analytical studies on individual countries are needed in order to provide country-specific policy recommendations to support the development of adaptation strategies to cope with weather variation and climate change.

References


