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Environmental variability and child growth in Nepal☆

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ABSTRACT

Data from the 2011 Nepal Demographic Health Survey are combined with satellite remotely sensed Normalized Difference Vegetation Index (NDVI) data to evaluate whether interannual variability in weather is associated with child health. For stunting, we focus on children older than 24 months of age. NDVI anomaly averages during cropping months are evaluated during the year before birth, the year of birth, and the second year after birth. For wasting, we assess children under 59 months of age and relate growth to NDVI averages for the current and most recent growing periods. Correlations between short-run indicators of child growth and intensity of green vegetation are generally positive. Regressions that control for a range of child-, mother- and household-specific characteristics produce mixed evidence regarding the role of NDVI anomalies during critical periods in a child's early life and the subsequent probability of stunting and wasting. Overall findings suggest that the relationship between environmental conditions and child growth are heterogeneous across the landscape in Nepal and, in many cases, highly non-linear and sensitive to departures from normality.

1. Introduction

Despite economic growth and a general decline in poverty rates over the past decade, child undernutrition and mortality rates in Nepal are among the highest in the world. In 2011, 41 percent of Nepalese children were stunted and 11 percent were wasted (Ministry of Health and Population [MOHP], New ERA, and ICF International Inc., 2012). These nutritional outcomes reflect a number of short- and long-term factors that affect a child during gestation and after birth, including food intake. Location also matters (Shively and Celeste Sununtnasuk, 2015), and households in Nepal tend to pursue a wide range of geographically-distinct livelihood strategies that are specific to location (Rahut et al., 2014; Upreti et al., 2012). Although some districts are less reliant on agriculture than others, in most locations food intake is closely tied to on-farm agricultural production, either because households eat what they grow, or because they must rely on agricultural sales or wages to support food purchases. Most of these agriculture-based livelihood strategies are climate-sensitive (Karki and Gurung, 2012). Furthermore, harsh terrain, high transportation costs and poor infrastructure create areas of isolation, and increase the difficulty of moving food from surplus to deficit areas. Severe flooding and landslides often accompany annual monsoonal rains. These factors create a range of short-term and longer-term stresses on household nutrition, including seasonal fluctuations in food availability and intake (Krishnamurthy et al., 2013). The earthquakes of April and May 2015 have exacerbated the already enormous challenges Nepal faces, in terms of food production and weak health and transport infrastructure. Much of the landscape renders large-scale irrigation systems impractical, and only 54 percent of total agricultural land is irrigated (Central Bureau of Statistics [CBS], 2011). Of this proportion, less than a third is irrigated year-round (Government of Nepal [GON] and Department of Irrigation, 2015). This leaves agriculture and those who depend on it vulnerable to either the vagaries of weather or the rudimentary irrigation schemes under farmer- and agency-managed systems (Bastakoti et al., 2010; Bhatta et al., 2005). Poor seed quality, low rates of fertilizer use, and high rates of land degradation all contribute to Nepal's poor agricultural performance, further compromising food security, with potentially important implications for child growth.

The primary research goal in this paper is to measure the relationship between child nutrition outcomes and environmental variability. We do this by linking satellite remotely sensed data on

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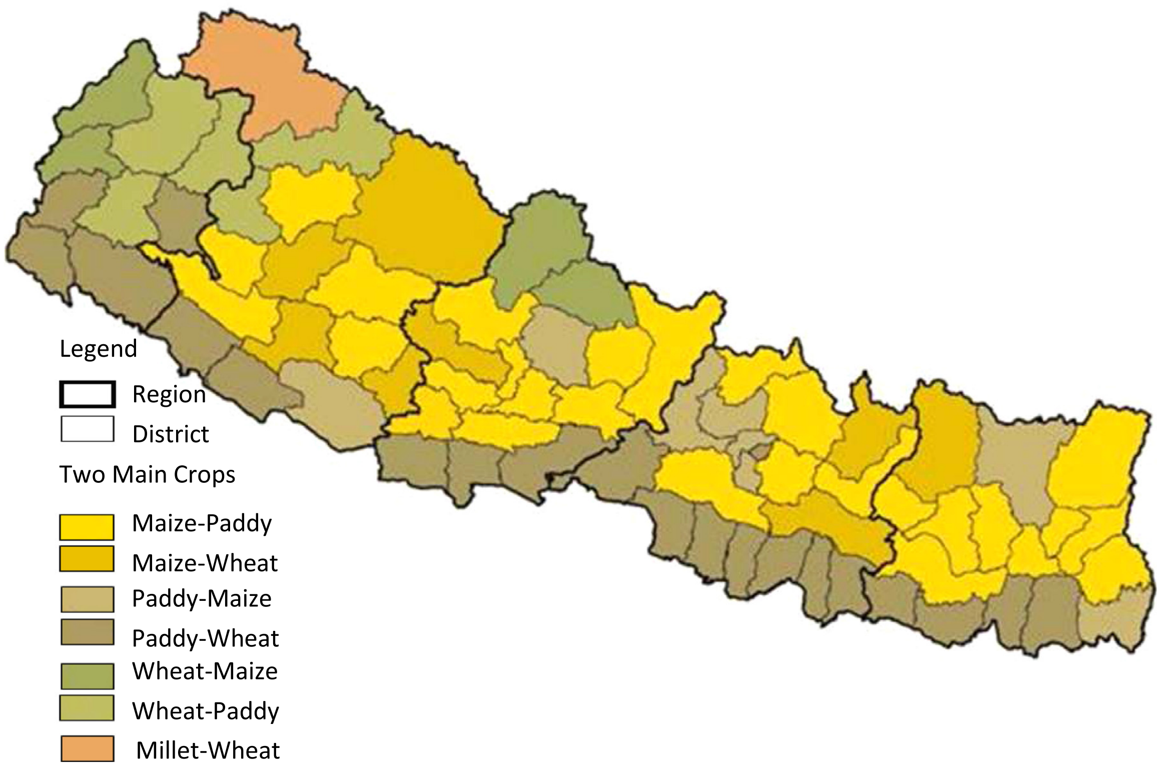

Fig. 1. Main crops grown in Nepal, by district (Source: Food and Agriculture Organization of the United Nations [FAO] and the World Food Programme [WFP], 2007).

green vegetation to child growth. We employ a general strategy outlined in Brown et al. (2014) using the Normalized Difference Vegetation Index (NDVI). The NDVI can provide spatially explicit estimates of photosynthetic activity. In Nepal, where agricultural production and food availability are highly localized in rural areas, NDVI measures may further act as a monitor of food security by helping to predict crop yields.[1] NDVI values have been shown to be directly correlated with precipitation levels (Lotsch et al., 2003) and the start of growing seasons, which can aid in assessing season crop outcomes (Brown and de Beurs, 2008). In addition to observing changes in vegetative growth, detecting droughts, and facilitating comparisons across regions, remotely sensed satellite images have been used as components of famine early warning systems (Hutchinson, 1991; Brown, 2008).

NDVI measures have been less commonly linked to child nutrition indicators, which are most often explained by measuring correlations between a child's anthropometric data and underlying household, maternal, and child characteristics. The primary research question investigated in this paper relates to whether, after controlling for observable differences in the characteristics of children, their mothers, and their household environment, short-term and long-term nutrition indicators are sensitive to environmental signals. We make conceptual, methodological and empirical contributions. From a conceptual point of view, we study patterns in anthropometric indicators, accounting for agricultural growing conditions, as measured by NDVI. We also demonstrate a method by which one can use GPS coordinates and crop calendars to match clusters of households with time- and location-specific NDVI values. Our empirical contribution is to measure the determinants of child growth, as observed in the 2011 Nepal Demographic and Health Survey (NDHS) The spatial and time series dimensions of NDVI data allow us to study vegetative health in specific locations and during periods in the calendar that are agronomically critical and also developmentally important to child growth. By combining child anthropometric data and the vegetation index, we test the hypothesis that interannual variability in weather is correlated with a child's nutritional outcome.

[1] We use NDVI as an indicator of vegetative health rather than the Enhanced Vegetation Index (EVI). Matsushita et al. (2007) demonstrate that the topographic adjustment factor used in calculating the EVI makes it more sensitive to shadows and other terrain effects than the NDVI. This makes it difficult to compare EVI time series across multiple regions in Nepal, since some regions are more affected by terrain than others.

2. Background

2.1. Nepal's agricultural landscape

Nepal is rich in cultural, biological and topographical diversity. The country is divided into three distinct ecological zones: the Mountains, the Hills and the Terai. Varying by climate, terrain and altitude, these zones extend east to west across the country and are further divided along a north-south gradient by five development regions: Eastern, Central, Western, Mid-Western and Far-Western. The Mountain zone accounts for roughly 35 percent of the total land area of Nepal, but of the roughly 17 percent of total land suitable for agriculture, only two percent is located in the Mountains (Food and Agriculture Organization of the United Nations [FAO] and the World Food Programme [WFP], 2007) (Fig. 1). The zone is characterized by short growing seasons and limited agricultural capacity due to high altitude and low temperatures. Major crops grown include millet, barley, potatoes and maize. The Hill zone comprises 42 percent of the total land area of Nepal, but only 10 percent of the area is cultivated. The zone is characterized by steep slopes and numerous valleys. Maize, rice, wheat and millet are the most prominent crops. Of the three ecological zones, the Terai carries the most agricultural potential due to its flat and fertile land and availability of reliable irrigation. Thirty-eight percent of the Terai is cultivated, with rice and wheat as the dominant crops. Though it is the smallest zone in terms of land mass, 49