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Assessing Mongolian snow disaster risk using livestock and satellite data

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ABSTRACT

In Mongolia, several record-breaking disastrous dzuds (mass livestock loss directly induced by harsh winter conditions but often influenced by drought in the previous summer) occurred from 1999 to 2003. To understand the mechanism of this climatic disaster, we conducted a tree regression analysis. The predictor variables included two indices developed from remote sensing data—the Normalized Difference Vegetation Index (NDVI) and the Snow Water Equivalent (SWE)—as well as the previous year's livestock numbers and mortality rates. According to the model, serious livestock mortality was associated with low NDVI values (i.e., poor vegetation) in August of the previous year, high SWE values (i.e., significant snow accumulation) in December of the previous year, a high previous year's mortality, and high previous year's livestock population. This result suggests that for dzud risk assessment, we need to monitor snowfall in winter, the vegetation condition in the previous summer, and the density and health condition of the livestock. The tree-based model developed in this study is effective only for a white dzud (deep snow), the most common type of dzud. The large cross-validation error indicates that more data are needed before using the model in order to make predictions.

1. Introduction

The most widely felt climatic disaster in arid regions is drought; it has been identified as the world's most hazardous natural disaster (e.g., Bryant, 1991; Obasi, 1994; Wilhite, 2000). In particular, rural populations dependent on agriculture or livestock farming are significantly impacted by droughts, and since droughts inevitably occur, rural populations are always exposed to the risk of this type of disaster. However, in dry and cold (and in many cases, high latitude and inland) regions, such as Mongolia, people living in rural areas are subjected not only to drought in the summer but also to another natural disaster in the winter. Harsh winter conditions can prevent livestock from accessing pastures and can result in a large number of livestock deaths. Even when winter conditions are comparatively moderate, if the pasture conditions are inadequate due to poor conditions (e.g., drought) in the previous growing season, livestock may not survive the winter.

In Mongolia, this type of disaster—a mass livestock loss directly induced by a harsh winter climate but often influenced by drought in the previous summer—is called a *dzud* (sometimes spelled zud). Dzud is experienced throughout central

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Asia. For example, winter conditions, not drought, have historically controlled livestock numbers in Kazakhstan and winter disasters, including heavy snow and the refreezing of melted snow, are collectively called dzhuut there (Robinson and Milner-Gulland, 2003). The United Nations and Government of Mongolia (2001) described a dzud as a winter disaster that involves the mass debilitation, starvation, and death of livestock that seriously damages the livelihoods of the herder households who depend upon them.

Previous studies of this climatic disaster have been limited to simple analyses of the historic data and classification of the conditions. Begzsuren et al. (2004), in their study in southern Mongolia, concluded that dzud (noting that they use the term dzud to mean severe winter weather in general) resulted in higher livestock mortality than drought. They also found that the average livestock mortality resulting from drought combined with dzud is 18.8%, the mortality rate associated with dzud by itself is 13.3%, drought only is 11%, and the mortality rate attributable to neither drought nor dzud is 8.8%. Thus, a disastrous situation for the livestock sector in Mongolia is likely to occur when a summer drought is followed by severe winter conditions. In the United Nations Development Programme's (UNDP) report on natural disasters in Mongolia, dzud was found to dominate in terms of the severity of damage (as measured by livestock loss), although wildfire was the most commonly occurring natural disaster in Mongolia (UNDPa). According to Templer et al. (1993), there were 24 dzuds in Mongolia between 1944 and 1993, with the most disastrous one occurring in 1944 (a nationwide dzud that caused 37% livestock mortality).

Begzsuren et al. (2004) reported that Mongolian researchers classified dzuds into five types: white dzud (caused by deep snow), black dzud (no accumulated snow), combined dzud (deep snow and sudden temperature drop), storm dzud (increased wind speed and heavy snow), and iron dzud (impenetrable ice cover over pastureland). Begzsuren et al. (2004) concluded that, among all types of dzud, white dzud combined with drought (unfortunately, the timing of the drought is not clearly stated in their paper) resulted in the highest rates of livestock mortality (32% and 24.1%, including natural mortality, in 1962 and 1983, respectively). Morinaga and Shinoda (2005) refined the concept of the combined dzud, calling it a cold dzud (sudden temperature drop), and they added a sixth category, hoof dzud (overgrazing). Morinaga and Shinoda (2005) observed that all six dzud types can be explained using three factors: snow or ice cover, stormy weather, and lack of pasture.

The recent historic dzud in 1999–2003, however, was beyond our conventional understanding of this type of climatic disaster. Severinghaus (2001) identified the 1999–2000 dzud as the most severe one in the past 50 years. The International Federation of Red Cross and Red Crescent Societies (2004) determined that about 8.5 million or 25% of Mongolia's herd perished from 1999 to 2003. The International Monetary Fund (2003) reported that droughts and dzuds between 1999 and 2002 killed 8.2 million livestock and that 3.0 million female livestock miscarried. It estimated that, if there were no droughts or dzuds during this period, Mongolia's annual economic growth rate would have reached about 8%, which is about 4–7% higher than the actual economic growth rate of 1–4%. Additionally, Natsuagdorj (2003) observed that, in the 3 years from 2000 to 2002, more than 100 counties (*soums*) were affected by drought for the first time since 1989, and for the first time in the same period, more than 100 counties were also affected by dzud. The dzuds that occurred in 1999–2002 were described as "multiple dzuds" by the United Nations and Government of Mongolia (2001), a combination of multiple types of dzuds over the years; we classified the dzuds as a combined dzud using the classification of Begzsuren et al. (2004).

Lotsch et al. (2005), using a vegetation index derived from remote sensing data, observed that between 1999 and 2002 a large and geographically extensive decrease in vegetation activity that coincided with below normal rainfall in the Northern Hemisphere, and they associated that decrease with synchronous patterns of ocean circulation anomalies in the Pacific, Atlantic, and Indo-Pacific oceans. The possibility exists that the abnormal climate in Mongolia during this period was part of this larger scale phenomenon.

The significant impact of the dzuds of 1999–2003 prompted a need to better understand this type of climatic disaster, knowledge that would assist in the development of an early warning system (EWS) for Mongolia. In addition to summarizing historical records and classifying the nature of the dzud, a major objective of this study was to further our understanding of dzud, particularly when it starts and how it temporally progresses, and how drought and/or other effects contribute to this process.

The results of this study were considered in a drought/dzud EWS developed as part of an international co-operation project that was launched to strengthen the systems used to track droughts and dzuds in Mongolia (Shinoda and Morinaga, 2005).

In the following sections as this study focuses on the social impact of this climatic disaster, the term dzud refers to abnormally large livestock mortality in winter–spring that occurs as a result of drought and a harsh winter–spring climate (e.g., significant snowfall). Our primary focus was on the white dzud, the most serious type.

2. Study area and data used

2.1. Study area

The study area encompasses all of Mongolia, which has 21 provinces (*aimags*), three of which are significantly smaller than the others, and the capital (Ulaanbaatar), which forms an independent jurisdiction (Fig. 1a). Templer et al. (1993)