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Security Nexus Perspectives

MONGOLIAN SAND AND DUST STORMS' IMPACTS ON ASIA-PACIFIC ENVIRONMENTAL SECURITY

By J. Scott Hauger

Abstract

Mongolian sand and dust storms are an age-old phenomenon. Inter-annual variability is great, but March 2021 saw two extreme dust storm events with human security impacts reaching from Mongolia and China to Korea and Japan. The principal challenges to human security posed by Mongolian dust storms are food insecurity, threats to human health, and infrastructure degradation, plus human migration to escape those impacts. In modern times, dust storm events have not exceeded the capabilities of nations to manage their human security impacts. However, they can threaten regional security if they exceed a nation's ability to respond.

Good governance requires activities to mitigate, prepare for, and respond to dust storms. Currently, China and Mongolia have established programs to mitigate desertification. International cooperation has resulted in an East Asia regional warning system for dust storms. Both the U.S. and China have assisted the Mongolian armed forces in preparing for disaster relief.

Recent analyses identify a need for further knowledge of the region's vulnerability to dust storms. It is in the mutual interests of Asia-Pacific nations to collaborate in joint programs to improve mitigation, preparation, and response to the uncertain and compound future impacts of Mongolian dust storms on regional security.

1. Introduction and approach

This cross-disciplinary study[1] reviews and assesses current scientific and policy-related reports and studies of Mongolian dust storms to better understand their impacts on Asia-Pacific regional security. Its concern is prospective – understanding and managing the emerging regional security impacts of Mongolian dust storms in years to come.

Interactions between natural phenomena such as dust storms and the social and political environment are part of a complex socio-environmental system. Capra (2017) has elaborated a systemic view of the interconnectedness of global problems that captures the complexity of causes and impacts of socio-environmental phenomena. Capra's diagram (Figure 1) illustrates that dust storms impact security as one interactive phenomenon among many. Any consideration of dust storms and security must take this complexity into account.

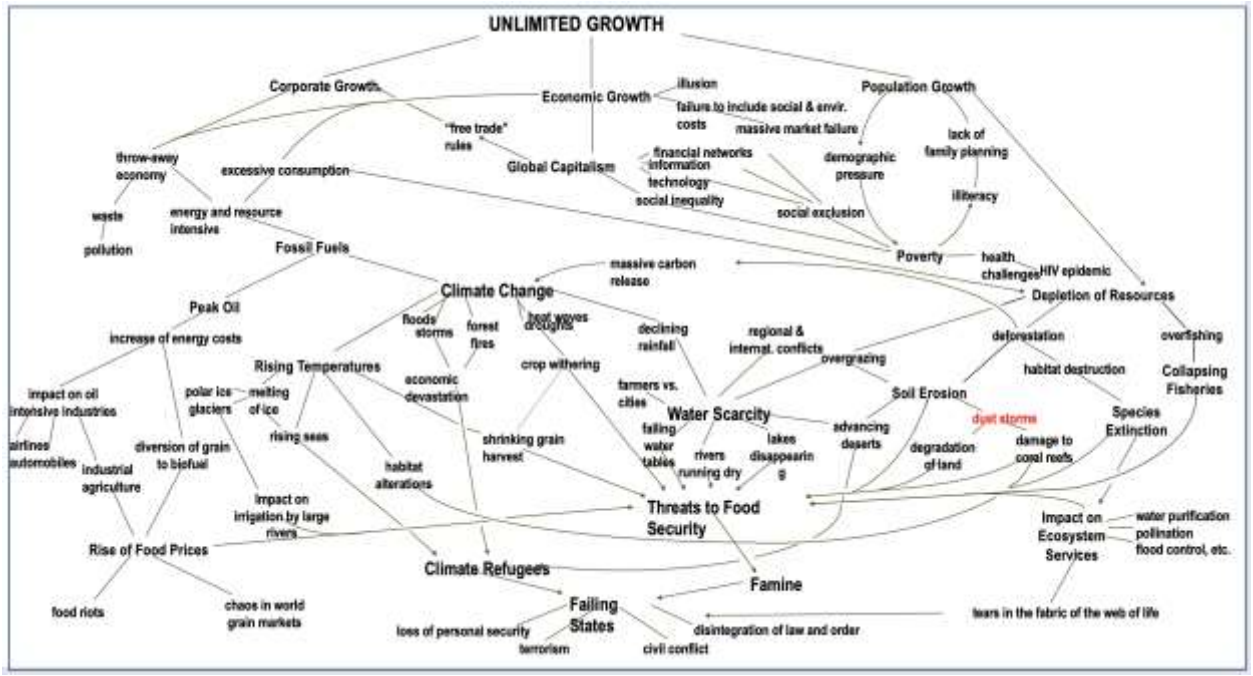

Figure 1. Environmental Security and Complexity (after Capra, 2017)

Therefore, this study approaches the topic of Mongolian dust storms and Asia-Pacific security as interconnected global problems within a complex socio-environmental system. In order to control the number of variables to be explored, it employs the framework of an environmental security domain, which can be understood to be a subset of the socio-environmental system presented by Capra.

[1] This research was supported by a grant from the Chinese Academy of Sciences' Northwest Institute of Eco-Environment and Resources (NIEER) as part of its project, "Sandstorm Risk and Environmental Safety Assessment in Desertification Areas on the Mongolian Plateau," funded by the Chinese Ministry of Science and Technology

Figure 2 presents a portrayal of categoric elements of the environmental security domain. It incorporates selected elements from the complex eco-environmental system that includes dust storms and their impacts. It links environmental phenomena to national and regional security through their human security impacts. The model simplifies by excluding some less-related variables and omitting feedback loops among its categoric variables. In so doing, it provides a focus -- a useful framework for linking eco-environmental phenomena to regional security.

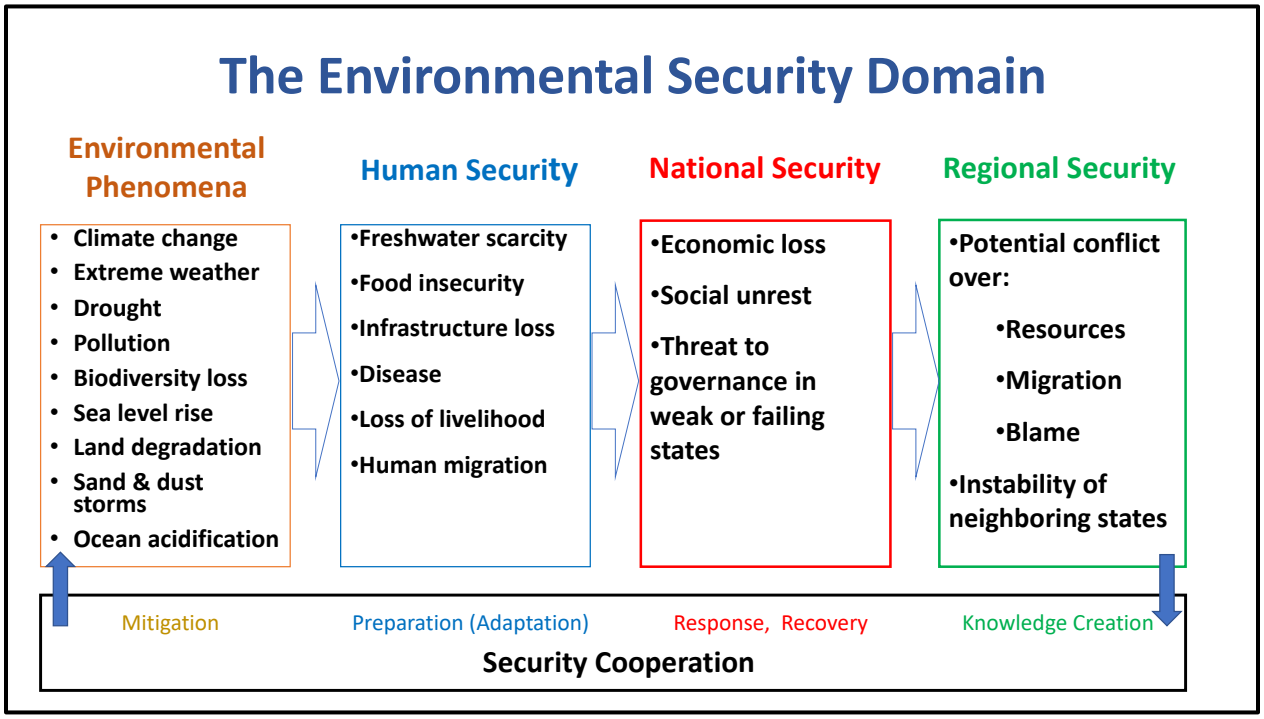

Figure 2. Analytical Framework for Assessing Security Impacts of Environmental Phenomena[2]

Security is not a passive endeavor, but an active one. Thus, our analytic framework includes categories for policy, plans, and action to address the security impacts of environmental phenomena. The disaster response community categorizes governments' tools for managing environmental security as mitigation, preparation, response, and recovery.[3] In the case at hand, mitigation means reduction of the frequency or intensity of Mongolian dust storms. Preparation or adaptation means actions to reduce the impacts of dust storms on people and communities. Response means security sector intervention to ameliorate or heal dust storms' real or perceived impacts. Recovery means restoration of the *status quo ante*.[4]

[2] An early version of this diagram may be found at Hauger. (2012, slide. 6).
[3] Some depictions of the disaster management cycle include prevention as a fifth category. Since dust storms cannot be prevented, we subsume this category as mitigation.
[4] This analysis of tools for environmental security management is a version of the well-known Disaster or Emergency Management Cycle. It merges response and recovery because restoration is generally a mitigation technique for desertification and land degradation-related phenomena.

A focus on the Asia-Pacific region provides geographic boundaries to the research. This study considers the immediate impacts of Mongolian dust on the Mongolian Plateau. It considers the human security threat to downwind nations that experience the direct (though diluted) impacts of dust storms. It considers secondary or indirect impacts on all nations in the Asia-Pacific region and beyond. Finally, it considers security threats from compound socio-environmental events, most notably multiple catastrophes that might threaten regional food security.

As illustrated by Figure 2, environmental phenomena pose a threat to national security and regional stability because they decrease aspects of human security. National and regional security impacts follow because governments must deal with the disruptions to human security, both domestically and with consequent instability in other nations. The following analysis will utilize the model of the environmental security domain to organize its discussion of the historical threat (section 2) and emerging threat (section 3) of Mongolian dust storms to Asia-Pacific security.

2. Mongolian dust storms: The historical case

a. The phenomenon

The World Meteorological Organization (WMO) (Sand and dust storms, n.d.) describes dust storms as a common meteorological hazard that arise when thunderstorms or strong pressure gradients increase wind speeds over a large area. The wind lifts sand and dust from dry soils and can transport them for thousands of kilometers. In the Asia-Pacific region, wind-borne dust particles originating on the Mongolian Plateau are carried eastward. They can affect not only Mongolia and China but also the Korean Peninsula, Japan, and beyond to the North American continent and the Pacific Ocean.

Sand and dust storms are generally discussed as a single phenomenon. The distinction rests on the size of the mineral particles being transported. Because larger sand particles are deposited nearer to the source, the term Mongolian *dust* storms describes the phenomena that directly impact the broader Asia-Pacific region.

Historical accounts record that Asian dust storms have regularly reached the Korean peninsula over the last 500 years. (Chun et al., 2008). Figure 3 shows the frequency of dust storms reported in Seoul over 90 years from 1915-2005. Although Mongolian sand and dust storms are a recurring phenomenon, inter-annual variability is great. In some years, Korea experienced no dust days; in others, more than 20. Most recently, scientists have reported a 20-year decline in atmospheric dust over the northwest Pacific (Volland, 2020). Despite this trend, March 2021 saw two extreme sand and dust storm events, with significant human security impacts reaching from Mongolia and China to Korea and Japan (Gui et al., 2021).

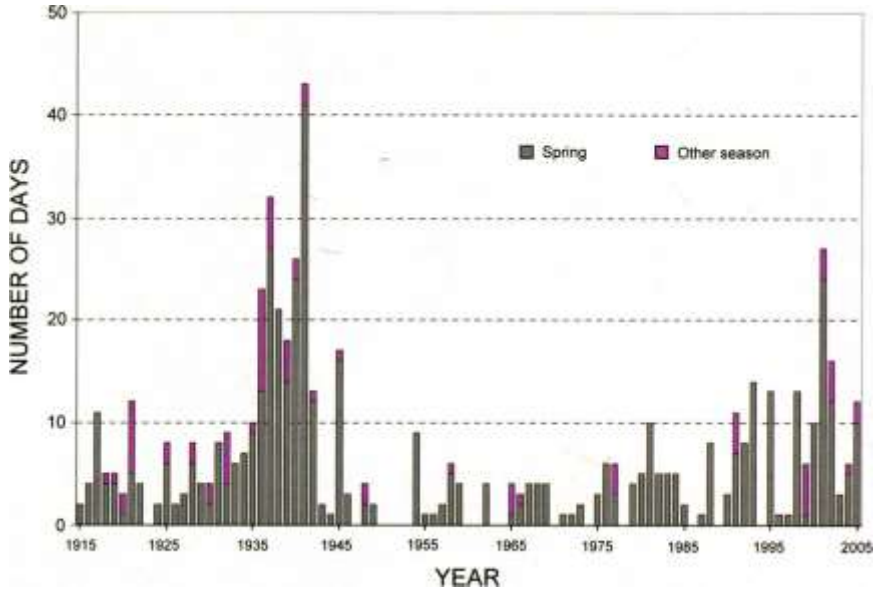

Figure 3. Dust Days in Seoul, Korea (Chun et al. 2008, 827)

Dust storms vary in intensity. There is no standard definition or measure of dust storm intensity. Indices include frequency, wind speed, and dust load (Can et al., 2018, 2). Dust loads are an important measure because they can directly impact human health

Dust loads are expressed as concentrations of coarse particulate matter, 10 micrometers and smaller (PM_{10}), and of fine particulate matter, less than 2.5 micrometers ($PM_{2.5}$). Coarse particulate matter can be inhaled and affect the upper respiratory system. Fine particulate matter can penetrate beyond the upper respiratory system and thus pose a risk to cardiovascular health. WHO guidelines (2021) state that annual average concentrations of $PM_{2.5}$ should not exceed 5 $\mu g/m^3$, while 24-hour average exposures should not exceed 15 $\mu g/m^3$ more than 3 - 4 days per year. PM_{10} concentrations should not exceed 15 $\mu g/m^3$ annual mean, and 45 $\mu g/m^3$ 24-hour mean. Measures of the dust load from Mongolian dust storms, whose particulate matter may be mixed with and augmented by industrial pollution, typically exceed the WHO standards. For example, during the 2021 spring storms, the mean PM_{10} concentration in north China reached 182 $\mu g/m^3$ throughout March (Yin et al., 2022). Beijing saw a 24-hour average $PM_{2.5}$ of 200 $\mu g/m^3$and a peak of 600 $\mu g/m^3$ (Muñoz, 2021). On March 29, Daegu, South Korea, recorded a peak hourly average PM_{10} of 1,115 $\mu g/m^3$ and a peak hourly average $PM_{2.5}$ of 169 $\mu g/m^3$ (Yonhap, 2021).

Horizontal visibility is a good proxy measure for dust load (Y. Wang et al., 2008) and is measured in many locations. WMO classifies dust events as dust storms when they reduce horizontal visibility to less than 1 km (Gewin, 2022).

Dust deposition, atmospheric dust loads, and reduced visibility are the characteristics of Mongolian dust storms that most affect human security through their impacts on infrastructure, agriculture, economic activity, and human health. Aeolian desertification further impacts human security in dust storms' areas of origin. A study of these broader drylands phenomena and their impacts on human

security in Mongolia and China are well-studied and beyond the range of this paper's concern with regional security impacts.

b. Human security impacts

The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) reports that dust storms impact human security by damaging buildings and interrupting infrastructure operations such as transportation hubs, communication networks, power distribution, and water supply systems. They cause crop damage, kill livestock and cause air and road traffic accidents. Longer-term costs include chronic health problems, the deposition of pollutants, and the disruption of global climate regulation services (2018, p. 34).

Dust storms' impact on human health is a major human security concern. Their impact on food security is another. The Intergovernmental Panel on Climate Change (IPCC) (2019) summarized scientific findings that dust storms can transport particulate matter, pollutants, and allergens over long distances (3.4.2.3). IPCC also observed that dust storms threaten food security by impacting crop yields, injuring livestock, and reducing the quantity of water available for irrigation (3.4.1.1).

In a 2021 review of research, Aghababaeian et al. confirmed that Mongolian dust storms have had significant public health impacts. Most studies found that dust storms increase the risk of cardiovascular problems and death or hospitalization due to respiratory illness. Moreover, dust storms can carry and spread pathogenic microorganisms and fungi over a large area. In a 2022 review of 51 scientific articles, Vergadi et al. concluded, "…limited data point towards a significant association of dust storms to infectious disease outbreaks. The most common infectious diseases associated with dust storms were respiratory tract infections, such as pneumonia, COVID-19, pulmonary tuberculosis, coccidioidomycosis, and others" (p. 7).

Dust storms can similarly impact food security through health impacts on agricultural plants and animals. Gonzales-Martin et al. (2014) reviewed studies of the long-range dispersion of dust-borne pathogens that affect plants and livestock. They observed, "…research is just beginning to demonstrate the quantity and diversity of organisms that can survive this type of transport" (p. 1). They reported the detection of many dust-borne pathogens that cause diseases in plants, poultry, and livestock, including many collected in Korea and Japan. At least two of the studies which they reviewed reported pathogens transported from Asian deserts across the Pacific Ocean to Oregon, USA (Table 1.2).

The most significant impacts of dust storms on food security, however, are near the areas of origin where the complex effects of desertification, land degradation, as well as wind-borne sand and dust can degrade food production. Mongolian dust storms' greatest impacts on food security are in China and Mongolia. It is difficult or impossible to isolate the contribution of dust storms to regional or global food insecurity, however, because they are but one element of a complex eco-environment. That complexity was described by Michel Jarraud, WMO Secretary-General, who said, "Under the scenario of climate change, droughts, flash floods, dust storms, famine, migratory movements, forest

fires - all linked to desertification - are likely to increase, and so will their impact on global food security" (WMO, 2006).

Two examples can illustrate the threat of dust storms to food security. The Food and Agriculture Organization of the United Nations (FAO) (2022) reported that the March 2021 dust storms killed 200,000 livestock and destroyed 121 animal shelters in Mongolia. In northern China, a May 1993 sandstorm buried over 2,000 km of irrigation ditches, destroyed more than 370,000 hectares of crops, and led to 120,000 animals being killed or missing (UNEP, WMO, UNCCD, 2016, Box 4.2).

Major infrastructure damage from sand accumulation, blocking roads or structures, occurs on the Mongolian Plateau and nearby locations. Further downwind, sand and dust storms regularly impact transportation systems through reduced visibility. They cause interruptions in ports and railway services, flight delays and cancellations, automobile accidents, and traffic jams (UNESCAP, 2018, Chapter 3).

The World Meteorological Organization (Aviation hazards, n.d.) advises that dust storms pose serious aviation hazards that can reduce visibility close to zero, reduce engine power or cause engine failure, and cause problems with electrical equipment. Again, cumulative impact analyses are few. For the year 2002, Jeong (2008, p. 19) reports that 102 Korean airline flights were canceled due to yellow dust, costing $578,000. Single-event news reports indicate the scope of the problem. For example, On March 15, 2021, Hohhot airport was shut down, while around 20% of flights in and out of Beijing were canceled (Reuters, 2021).

Dust can also degrade energy infrastructure. WMO notes that keeping the solar collectors dust-free requires significant time and labor. (WMO Sand and Dust Storms, n.d.). APDIM's 2021 report estimated that China's loss of energy due to sand and dust impacts on solar power plants exceeds $17 million annually, an amount that will increase as the deployment of solar power increases (p. 36). Dust particles can erode wind power plants and reduce their energy output. (p. 33). Dust storms can also degrade electric grid transmission (Pouran, 2022).

The Asia-Pacific region has seen a rhetorical blame game over the impacts of dust storms. For example, during the major dust storms of spring 2021, *The Asahi Shinbun* reported that South Korean media "…[blames] China as the source of the scourge causing serious degradation of air quality." A Chinese press officer deflected the blame to Mongolia, saying, "'China is not the source. It's only a way station.'" Two years earlier, an article in the KAIST Herald characterized the long-running dispute over air pollution this way: "Korea maintains the accusation that China's yellow dust pollution is the culprit, while China condemns Korea's cowardly refusal to take care of its own affairs." The author concludes, "At the end of the day, everything calls for both China and Korea to stop disputing about their share of blame and instead begin looking for ways to actually overcome their shared air quality problem" (Chrysan, 2019).

In a 2021 review, Opp et al. summarized that sand and dust storms (SDS) have significant impacts on human health, agriculture, industry, transportation, water, and air quality, but in the end, "…our review of SDS publications has confirmed the huge lack of knowledge in the field of the economic evaluation of SDS effects" (p. 14). Nonetheless, it is clear that, as part of a complex eco-environmental system, Mongolian dust storms contribute to human security impacts that national governments must address. The nature of those impacts is understood in general, but empirical data that characterize specific events and their contribution to human security outcomes are often lacking. Better knowledge of this complex socio-eco-environmental system can better support human security governance. Governments' success or failure at individually and collaboratively managing those impacts through mitigation, preparation, response, restoration, and knowledge creation will influence regional stability and security.

c. Asia-Pacific security impacts

An analytic focus on human security draws attention to the complexity of the environmental phenomena that in combination impact human security. Thus, food insecurity on the Mongolian Plateau is not caused by dust storms alone – neither a single event nor their cumulative impact. Kang et al., for example, described the complex interactions of dust storms and *dzud* disasters on Mongolian livestock in this way:

> "Drought, dust, desertification, and winter livestock disasters (called dzuds) are unique natural disasters that affect the region. These disasters are related in that they share major causes, such as dryness and low vegetation cover that combine with other conditions, wind, cold waves, livestock, and land-surface energy, to dramatically impact the ecosystem" (2021, p. 1).).

In short, threats to national and regional security are not caused by environmental phenomena directly but are mediated by their impact on human security. Food insecurity, human health, and infrastructure degradation have been the human security concerns most closely associated with Mongolian dust storms. However, each of these impacts can be the result of multiple and reinforcing environmental phenomena, such as dust storms and dzuds, or dust storms and epidemics. Moreover, environmental phenomena interact with social phenomena, such as overgrazing or carbon released into the atmosphere.

Though sometimes severe, the impacts of a single dust storm event have not risen to the level of a major crisis for national governance or regional stability in modern times. Nations in the Asia-Pacific region have generally been able to absorb and manage these impacts. The two nations most severely impacted by Mongolian dust storms, China and Mongolia, have managed to address national security issues and respond to the resulting levels of economic loss, social unrest, and their political consequences – sometimes with international assistance or cooperation. They have developed and implemented policies and plans to combat desertification, including mitigation, preparation, and response elements. They have devoted substantial research and development resources to address problems related to desertification.

For example, beginning in 1978, China began the Three-North Shelterbelt Program (the Great Green Wall). Its National Forestry and Grassland Administration has monitored desertification since 1994. In 1996, China prepared its National Action Plan to implement the UNCCD. From 2001-2022, China undertook the Beijing and Tianjin Sandstorm Source Treatment project. (F. Wang et al., 2012; Petri, 2017; Choo, 2018). Between 1986 and 2020, according to a recent bibliometric survey, the Chinese Academy of Sciences accounted for the largest number of scientific papers reporting research on Chinese deserts (Shi et al., 2021).

Mongolia undertook a national desertification assessment in 1992, adopted the UNCCD in 1996, and developed and updated its National Action Plan to combat desertification under that convention. Mongolia has implemented several cross-sectoral programs to combat desertification and mitigate dust storms, supported by the national budget, donor countries, and international organizations (T. Wang et al., 2022). However, as Han et al. point out, as a developing nation, Mongolia requires international resources and expertise to fully manage its environmental security (Han et al., 2021, 4071).

The direct human security threat of dust storms originating on the Mongolian Plateau to downwind nations is diminished by dilution and distance. The Korean peninsula is the most strongly impacted by potential health and infrastructure issues, Japan less so. North America only occasionally experiences detectable levels of Mongolian dust that degrade viewsheds and could carry hitchhiking microbes. Historically, Mongolian dust storms have not degraded human security in these developed nations to the point of social or political unrest. Economic losses have been manageable within the national context.

Economic assessments can provide a metric for the overall impacts of dust storms and the stresses they may place on national security. Middleton et al. (2019) conducted a broad review of the economic impacts of sand and dust storms, finding,

> "There are few assessments of the economic consequences of SDS and those studies that have been conducted lack consistency in data collection methods and analysis. SDS do not result in the significant damage to infrastructure usually associated with many disasters, but the cumulative effects on society can be significant because SDS occur more commonly than most other types of natural hazard" (p. 390).

One of the few economic assessments is that of Jeong (2008), who estimated that the cumulative cost of dust storms in South Korea in 2002 was approximately $5.6 million, accounting for 0.8 percent of GDP (p. 22). Though manageable, that cost is not insignificant. Thus, the Republic of Korea (RoK) has a national interest in dust storm mitigation and thus in activities conducted in China and Mongolia to reduce dust storm frequency and intensity.

Economic impacts are greater closer to the Mongolian Plateau. In her master's thesis (2003), Ning Ai assessed dust storms' impact on the Beijing region for the year 2000. She calculated direct impacts of $264 million (p. 65), and total impacts of $1.7 - 2.2 billion across fifteen industrial sectors, or 5 – 7

percent of Beijing's GDP (p. 84). Asia-Pacific nations have an interest in mitigating Mongolian dust storms that can impact China's food and economic security because they indirectly impact their own.

Cross-border migration associated with Mongolian dust storms and desertification has not been a significant security problem. Internal migration has been significant in China, with both positive and negative impacts on migrants and their new communities (Igini, 2021). Such internal migration has been managed domestically without a major impact on regional security. China initiated an exploratory program in ecological migration in 1983 (Su, 2017). Yang (2014) details how the provincial government of Inner Mongolia (China) has favored environmental migration to counter land degradation and improve living standards. By 2017, more than 200,000 residents had been moved (Su, 2017).

Raulerson (2022) described the large-scale migration in Mongolia consequent to livestock loss from eco-environmental phenomena in the 21st century and noted the national government's attempt to ban migration to the capital (2017-2020) to deal with overpopulation in Ulaanbaatar. In a 2022 report, the U.N. International Organization for Migration (IOM) reviewed Mongolia's immigration policy and programs, reporting, "In Mongolia, internal migration and displacement are increasingly shaped by a diverse combination of environmental factors often linked to climate change," and noting that the Municipality of Ulaanbaatar has implemented a mobility tracking program to "…collect and utilize accurate and disaggregated data as a basis for evidence-based policies" (p. 4).

In modern times, Asia-Pacific nations have been able to absorb the impacts on human security brought about by Mongolian dust storms and the broader phenomena of desertification and land degradation on the Mongolian Plateau. The region has not experienced cross-border conflict over resources, migration, or blame. National governments have managed the economic losses and social unrest associated with the economic and social impacts of dust storms on the human security of their citizens, sometimes drawing upon international aid. Nor have governments fallen because of eco-environmental events.

3. Climate change: A threat multiplier?

The Mongolian Plateau has undergone significant warming over recent years. The government of Mongolia reports that near-surface air temperature across the nation increased by 2.24 degrees C between 1940 and 2015 (Mongolia, 2018, p. 122). However, the impacts of climate change on Mongolian dust storm events are hard to predict. Different aspects of climate change are expected to have conflicting impacts on the frequency and intensity of Mongolian dust storms.

Wind speed and the availability of exposed sand and dust particles are the driving factors of dust storms (UNESCAP, p. ix). Wind speeds have declined over the last fifty years, which Zhu et al. (2008) attribute to the effects of local warming on the intensity of Mongolian cyclones. They predict a continued decline in the frequency and intensity of spring dust storms as global warming increases (p. 1). S. Wang et al., (2021) concur. However, they report an increase in dust storms at other times of the year (p. 7). IPCC (2021) finds that although surface wind speeds over Easy Asia may have

decreased, there has been an increase in the number of intense tropical cyclones for the last 30 years, with a northwestward shift in tracks, increasing exposure over East China, the Korean Peninsula and Japan (p. 139).

Increasing aridity, drought, and desertification consequent to global warming, on the other hand, are projected to increase the exposure of sand and dust to wind. In 2021, Han et al. revisited the causes of Mongolian sandstorms following the major events of that spring. They concluded, "Climate factors and land degradation have resulted in a positive feedback loop between soil moisture deficits and surface warming in the region, yielding a hotter and drier climate regime with unprecedented drought witnessed in recent years (p. 4070).

As summarized by Kang et al. (2021), "It is difficult to predict DSS [dust and sandstorm] events in both the near and distant future because these depend on complex mechanisms that operate at various spatial and temporal scales" (p. 2). IPCC (2019) reports, "…an understanding of long-term future dust dynamics, inter-annual dust variability and how they will affect future climate still requires substantial work (p. 167). The need for greater knowledge of the interactions between dust storms and climate change was also highlighted by IPCC's Sixth Assessment Report (2021), which stated that for climate impact drivers, including dust storms,

> "The probability of compound events … will likely continue to increase with further global warming, including for concurrent heatwaves and droughts, compound flooding, and the possibility of connected sectors experiencing multiple regional extreme events at the same time (for example, in multiple breadbaskets) (high confidence)" (p. 135).

The term "threat multiplier" has often been applied by the security sector to characterize the impacts of climate change (e.g., Huntjens & Nachbar, 2015; Stricof, 2021). In this case, climate change can multiply dust storms' threats to human security by increasing the probability of compound disasters.

Recent events illustrate how environmental phenomena interact in the global system to degrade food security. A key message of the FAO et al. report on The State of Food Security and Nutrition in the World, for example, states:

> "In the last ten years, the frequency and intensity of conflict, climate variability and extremes, and economic slowdowns and downturns have increased significantly. The increased occurrence of these major drivers, now exacerbated by the COVID-19 pandemic, has led to a rise in hunger and has undermined progress in reducing all forms of malnutrition, particularly in low- and middle-income countries…. Each of these major drivers is unique and, while they are external to food systems, they interact to create multiple, compounding impacts at many different points within food systems, to the detriment of food security and nutrition" (2021, p. 51).

In the Asia-Pacific region, a complex series of such events, some climate-related, can potentially impact future food security. Among these is the conflict in Europe, which is affecting global wheat and cooking oil supplies. The COVID-19 epidemic has continuing effects on supply chains. In the summer of 2022, heat waves and drought in China drove up the cost of fruits and vegetables and threatened the autumn harvest of rice. In August, extreme floods damaged crops in nearby Pakistan, which anticipates needing to import wheat in the coming year (Javaid-ur-Rahman, 2022). At the same time, heat and drought threatened crops in India, causing the government to ban wheat exports, further stressing global wheat supplies (UNEP, 2022).

While dust storms alone have posed a manageable threat to human security, these complex environmental events entangled with climate change pose a significant potential threat to internal security and thus to regional stability, a situation that national governments and international organizations recognize. For example, in a March 6, 2022, address to the National Committee of the Chinese People's Political Consultative Conference (CPPCC), President Xi Jinping highlighted the importance of food security to governance in China. He called food security a fundamental Chinese interest in the face of profound and complex changes in global affairs, saying that security and sufficient annual grain production are essential to feed over 1.4 billion people. (Xu, 2022; CGTN, 2022).

Four months later, at the launching of the U.N.'s report, *State of Food Security and the World 2022*, General Assembly President Abdullah Shahid provided a succinct statement of the threat of compound events to food security:

> "We are now living in the wake of a devastating pandemic, and the strain it has put on our resources, including food resources, has been immense. Similarly, the pandemic's impact on our supply chains has been profoundly detrimental. Added to this, the cumulative effects of climate change, environmental degradation, and economic stagnation have further compromised our supply chains and agricultural output. Millions of people around the world now face more difficulties in accessing adequate food and nutritious diets, even as their savings and earning potential have diminished. And the insecurities have further deepened with the ongoing conflict in Ukraine."

The complexity of the global eco-environmental system, the increasing threat to the human security of compound environmental events, and the need for better knowledge of the phenomena and their interactions in the complex system provide a strong incentive for international cooperation to address the consequent threat to national security and regional stability.

4. Asia-Pacific security cooperation

The level of economic and social disruption posed by dust storms to nations on the Mongolian Plateau has been significant but manageable. Direct impacts on developed nations downwind have been smaller and have not risen to the level of a threat to regional stability. Nonetheless, these nations have organized domestic programs and cooperated internationally to manage the potential security threat.

Most recently, in 2019, the United Nations Environment Program organized a Coalition to Combat Sand and Dust Storms. The coalition includes 15 UN-affiliated agencies and programs whose interests include sand and dust storms. The coalition is establishing five working groups that correspond to the categories of the risk management cycle (UNEMG, 2019; UNEMG, n.d.). There is little additional public information on the coalition's progress.

At the regional level, in 1993, six nations – China, the Democratic Peoples' Republic of Korea (DPRK), Japan, Mongolia, Russia, and RoK established a North-East Asian Subregional Programme for Environmental Cooperation (NEASPEC). Desertification and land degradation comprise one of its five priority areas (NEASPEC, 2022). However, a 2020 review commissioned by UNESCAP reported, "While this thematic area is well-suited to NEASPEC's transboundary agenda, the extent of duplication with other instruments has made it difficult to identify a value-added contribution" (Miller, p. x).

Since 1995, China, Japan, and South Korea have engaged in trilateral scientific cooperation on transboundary air pollution. It is generally concerned with air quality, including particulate matter transported by dust storms (Chang et al., 2011; Joint Research Project, 2019). Since 2007, the three countries have exchanged environmental research outcomes more broadly under a Tripartite Environmental Ministers Meeting (TEMM). The organization supports two working groups – one to improve early warning systems through DSS monitoring and modeling and another for mitigation measures on the Mongolian Plateau (OECC, Japan. 2021).

It would be possible to address cooperation for environmental security among Asia-Pacific nations chronologically, treaty by treaty and institution by institution, starting with the Rio Conference on Environment and Development in 1992. Such a systematic historical account is beyond the scope and purpose of this paper. Since our focus is on the security impacts of Mongolian dust storms, it is more useful to approach the topic by considering the modes of security response, as presented in Figure 2, above.

a. Mitigation

Mitigating dust storms and related environmental phenomena is critical to sustaining agricultural productivity on the Mongolian Plateau and thus to food security. Because food insecurity can challenge national security and thus regional stability, remote nations have a vested interest in national mitigation programs in China and Mongolia. Downwind nations, notably on the Korean Peninsula, are also interested in reducing the impacts of dust on infrastructure degradation.

Mitigation activities fall into two broad categories: stabilization and restoration of degraded lands and steps to reduce the weather impacts of climate change, such as drought, aridity, or windstorms. The former are local and may benefit from international support. The latter are global and depend on international cooperation.

Mitigation of Mongolian dust storm events has centered on national activities to decrease land degradation and reclaim desertified land. China has a long history of leadership in addressing these desertification issues (T. Wang, 2014). According to a recent assessment, China contributed more than 18% of the global net restored land area in 2018 (Kong et al., 2021, section 4.1). Mongolia has planned and implemented mitigation projects since 1996, but according to a recent review by Chinese and Mongolian scientists, "Measures taken at the government level (government-led) have been executed to a certain degree. However, due to the limited economic capacity of Mongolia, the investment in desertification control is still insufficient. Therefore, the effect of desertification control is not very satisfactory" (Liang et al. 2021, 11).

International cooperation continues to be important to dust storm mitigation. For example, Korea's contributions to work on the Mongolian Plateau began in the mid-1990s when the Korea Forest Service supported an afforestation project in China's Kubuqi Desert. In 2007, the Korean and Mongolian governments undertook an ongoing greenbelt project planting trees across the country (B. Choi, 2021). In 2009, the Seoul city government also provided funds expressly to reduce yellow dust problems in the city (AFP, 2009).

China has participated in various international research programs to understand dust transport from the Mongolian Plateau. For example, in 2000, Japan and China undertook a research project to understand wind erosion processes with the goal of better understanding dust storms' contribution to climate change (Mikami et al., 2006). Most recently, at the time of the 2021 Mongolian dust storm, according to a report in the *South China Morning Post*, Chinese Premier Li Keqiang told Mongolian Prime Minister Oyun-Erdene, "Environmental problems know no borders, and China is ready to cooperate with Mongolia in environmental protection, desertification prevention and control to jointly address challenges" (Wu and Rui, 2021).

International organizations have also supported mitigation activities in China and Mongolia. Since 1994, UNCCD has been a principal vehicle for international collaboration in these efforts. Between 2012 and 2020, the World Bank supported a major sand-fixing project in China's Ningxia Province (World Bank, 2021). Target 15.3 of the 2015 Sustainable Development Goals (SDGs) has provided an

internationally accepted framework for mitigating land degradation and promoting sustainable dryland management. (Lucatello and Sannwald, 2020).

Global efforts to mitigate greenhouse gas emissions are meant to reduce the rate and extent of desertification. However, we have seen that climate change's impacts on Mongolian dust storm frequency and intensity are unpredictable, given current knowledge. As reported in IPCC 2019, "Climate change impacts on dust and sandstorm activity remain a critical gap" (p. 305). Filling that gap is a key area for international research collaboration.

b. Preparation / Adaptation

Where mitigation fails, nations and communities must adapt to the impacts of environmental security threats. Mitigation efforts may reduce but are unlikely to eliminate Mongolian dust storms. Preparation thus means adaptive actions to reduce the impacts of those unavoidable dust storms.

Developing a regional warning system for Mongolian dust storm events has been a major arena for international cooperation. China has routinely monitored dust storm events since the 1950s (UNESCAP, 2018, p.52). In 2002, the Asian Development Bank sponsored a technical assistance project with the governments of China, Mongolia, South Korea, and Japan to establish a regional mechanism for preventing and controlling dust and sandstorms (ADB, 2005). In 2007, the WMO sponsored a Sand and Dust Storm Warning Advisory and Assessment System. The system's regional center was established in Beijing in 2017 and now provides 5-day forecasts to the region (China National Meteorological Centre, 2019; WMO, 2019).

International aid is often in the form of general economic assistance, so it can be difficult to discern an amount attributable to preparation for dust storms or desertification. In August 2022, for example, The Asian Development Bank approved $100 million in emergency support to Mongolia "…to help it weather the impacts of severe economic shocks." The ADB announcement refers to rising food and fuel process and the need to help poor and vulnerable groups in the face of external shocks, though it does not explicitly mention the major sand and dust storms of March and April and their impact on food security.

Migration is another form of human adaptation. In the face of environmental disasters, migration can threaten national and regional security. Managed migration in anticipation of a threat can lower the human security impacts of environmental phenomena and enhance national security. Both China and Mongolia have developed national programs to manage internal environmental migration. There are no indicators that unregulated climate-related cross-border emigration from the Mongolian Plateau is a foreseeable threat to regional stability. China and Mongolia are member states of the International Organization for Migration (IOM), as are Japan and RoK, though DPRK is not.

Preparation for environmental security threats is not necessarily disaster specific. Adaptation to climate change is a general goal of many international treaties and agreements, often under the heading of sustainable development. Thus UNFCCC, UNCCD, and global and regional financial organizations support resilience to environmental disasters and climate change more generally.

The same has been true for military-to-military assistance for disaster planning in Mongolia. Since 2009, the U.S. Army Pacific (USARPAC) and Mongolia's National Emergency Management Agency (NEMA) have conducted an annual joint exercise for disaster response in Mongolia. Exercise Gobi Wolf is designed to test preparedness plans, coordinate civil-military cooperation, and strengthen Mongolia's ability to receive international humanitarian assistance. Since 2016, the exercise has included multi-national participants, including Japan and the Republic of Korea (Bedard, 2017). In 2013, Chinese and Mongolian armed forces similarly conducted joint training for natural disaster relief (Xinhua, 2013).

c. Response

Where mitigation and preparation are insufficient to prevent an environmental crisis, the international community may be called upon to provide humanitarian assistance and disaster relief (HADR) to re-establish national security and ensure regional stability. National governments routinely provide disaster relief when their resources are adequate to the task. Regional security interests are engaged when international missions respond to a human security crisis that exceeds national capacity to respond.

The Asia-Pacific region has experienced many major disasters where international assistance has contributed to restoring human security. In such events, assistance is provided at the request of the affected nation under protocols coordinated by the United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA, n.d.). As discussed above, individual Mongolian dust storm events have not impacted human security to the extent of such major disasters. Developed nations, including China, have not requested international assistance for dust storm events. Mongolia has received significant international aid for environmental security, though such aid is often associated more closely with dzuds than dust storms. In response to the major dust storms of 2021, a Japanese NGO, Save the Children Japan, distributed gers (shelter), hygiene kits, and cash support to families in Mongolia (Japan Platform, 2021).

The joint U.S. - Mongolia military exercise Gobi Wolf is an activity to improve response to future disasters. Similarly, in March 2022, USAID announced a two-year training program to strengthen Mongolia's capacity to respond to natural disasters, including dust storms and dzuds (USAID, 2022).

5. Discussion: Challenges and opportunities

This study has explored the interconnections between an environmental phenomenon – Mongolian dust storms – and Asia-Pacific security. It has done so through the linking concept of human security. The topic and the choice of analytical framework constrain the variables of that system, thus enabling the analysis and drawing attention to certain challenges and opportunities for the collaborative management of environmental security.

The principal challenges to human security posed by Mongolian dust storms are food security, human health, and infrastructure degradation, plus human migration to escape those impacts. In modern

times, dust storm events have not exceeded the capabilities of nations to manage their human security impacts, sometimes with assistance from other nations. However, these challenges can threaten national security if they exceed a nation's ability to respond.

Food insecurity and risk to agro-pastoral livelihoods are the greatest threats to populations and governments on the Mongolian Plateau, which are subject to dust storm events, land degradation, and desertification. Like downwind nations, they are impacted by dust-borne pathogens and infrastructure degradation from airborne dust and sand. Food insecurity is multiplied by concurrent environmental events, for example, when spring dust storms follow winter dzuds, and socio-political events, such as when global food supply chains are disrupted by epidemic or conflict.

Because of other global trends such as population growth, urbanization, and climate change, the potential exists for dust storms to impact human security to a greater extent than in recent experience. Climate change will impact the frequency and intensity of Mongolian dust storms in uncertain ways, but it will likely increase the frequency of compound events as global warming continues. Compound events need not be geographically coincident. For example, sea level rise may degrade coastal food production; at the same time, dzud, dust storms, or drought may impact food security in drylands. Past experience is an imperfect guide to environmental security management in an era of global change, and new knowledge is needed to inform mitigation, adaptation, and response in the face of compound environmental events in a complex eco-environment.

Despite the successes of recent research and programs to address environmental phenomena and their impacts, much remains unknown or uncertain. The most important review of dust storms and environmental security, UNESCAP's 2018, *Sand and Dust Storms in Asia and the Pacific*, concludes, "Combating sand and dust storms in source and impact areas requires science-based national, regional and international cooperation and partnerships to observe, predict, mitigate and cope with the adverse effects of sand and dust storms" (p. x). It recognizes a need for cross-disciplinary research and dialog between source and impacted countries to generate science-based policy interventions. It advocates for establishing a regional mechanism for science-policy cooperation to address the gaps and to support regular scientific assessments of the multi-hazard and transboundary nature of Asian dust and sandstorms (p. xii).

In other words, managing human, national, and regional security in an environment of global change will require new knowledge at the science and policy interface. It will require deeper levels of collaboration beyond knowledge sharing among nations to true collaboration and active integration of research teams across the boundaries of natural science and social science, the boundaries of disciplines, the geographic boundaries of source and impact, and the boundaries of national pride and sovereignty. Media and governments must transcend the rhetoric of blame for transboundary environmental phenomena and address common interests in mitigation, preparation, and response.

Knowledge creation – research, development, and innovation – is a global enterprise. No single expert, institution, discipline, or nation has a monopoly on the resources and talent needed to anticipate and manage the complex threats of environmental phenomena to human security.

Moreover, singular perspectives and disciplinary approaches, while necessary, are inadequate to master the complexity of eco-environmental problems. Cross-disciplinary and international research collaborations will be essential to develop understandings of environmental, social, and political aspects of security management.

National security among Asia-Pacific states depends on managing environmental impacts on human security. Regional stability depends on the success of nations in managing those impacts. Therefore, Asia-Pacific nations have a vested interest in environmental security on the Mongolian plateau. They have a vested interest in contributing to activities to mitigate, prepare, respond to, and better understand Mongolian dust storms and related environmental phenomena, including desertification, land degradation, and climate change. It is in their mutual interest to collaborate in knowledge creation to improve those activities and to understand the emerging global change phenomena as they impact the eco-environmental system.

The challenge of environmental security is an opportunity for nations, their governments, and their regional organizations to assume a leadership position, to innovate, and collaborate to enhance national and regional security by better managing the security impacts of dust storms, desertification, and land degradation on the Mongolian Plateau.

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