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Transboundary hazard risk: the Gobi desert paradigm

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Abstract Transboundary hazard risk reflects how different societies interact with disaster in a shared landscape. In the Gobi desert of northern China and southern Mongolia recurring drought, extreme cold, wind and dust storms are the dominant hazards yet disasters vary significantly in the two countries. Research examined national approaches to environmental engagement and livelihoods in the desert through an assessment of disaster risk in two Gobi communities; farmers in Gansu Province, China, and herders in Dundgov and Omnogov Provinces, Mongolia. Exposure and resilience was evaluated and work examined how risk factors are shaped by policy, economics, culture and social memory. Comparison between two state systems reveals how disaster risk and vulnerability are shaped as much by human action as by the physical climatic event. China stressed government-led disaster management whilst Mongolia emphasised adaptation to hazards. Integrating multiple divisions within a hazard zone is essential to address risk reduction; without this disaster mitigation remains state-specific and lacks applicability to a wider area or global context.

Keywords Gobi · Hazard · Risk · Exposure · Agro-pastoralist · Transboundary

1 Introduction

Climate hazards exemplify how dynamic natural events occur within a geographical context (Yi et al. 2012). Location and landscape frame the hazard; topography, ecology and environment frame physical exposure and impact. Understanding hazard risk requires separating an event, such as drought or flood, from human activity and exposure (Peduzzi et al. 2009). Whilst hazards describe a physical event, disaster risk reflects implications in a social context (Wilhite 2005). This presents a dichotomy where causality is filtered through

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human systems to determine risk and impact. Investigating risk across two societies in a shared landscape highlights how disaster becomes a function of society as well as environment.

1.1 Transboundary issues

Climate hazards are delineated by landscape rather than borders (Zahran et al. 2008; Middleton and Sternberg 2013) whilst countries are often established by physical topography such as mountains (Himalayas, Andes) and rivers (Danube, Amu Darya). Similarly, national boundaries can be artificial creations drawn for political and cultural reasons—for example, many African and Middle Eastern states. Borders often construct hazard environments where risk may be dictated by how a country and community engage with the disaster as much as by a physical event. Potentially transboundary in range, impact is proscribed by human–hazard interaction rather than by national borders. Though physical impacts define a hazard region and risks differ significantly across borders, there are few studies that focus on transboundary risk (Wilhite 2005; Kampragoua et al. 2011). To understand disaster risk, it is important to clarify the physical and social dimensions of hazards and to then evaluate how disaster risk becomes a function of community and location. Thus, a shared landscape provides a setting to evaluate how risk and resilience are affected by people, culture and politics. Investigating hazards in the Gobi desert, Asia stresses the role of environment and society in determining disaster risk in a two countries/one landscape scenario.

The Gobi desert is a vast dryland covering northern China and southern Mongolia (Fig. 1) with recurring drought, extreme cold and dust and wind storms as the dominant hazards. Though exposed to similar risk dynamics across the common landscape, climate disasters vary significantly in the two countries. The desert provides an archetypal situation to assess transboundary disaster risk in a shared environment. China features government-led disaster management whilst Mongolia stresses customary adaptation to hazards (Zou and Yuan 2010; Sternberg et al. 2009; Marin 2010; Fernández-Giménez et al. 2012a; Sternberg and Batbuyan 2013).

This paper looks at the region and hazards and then examines how two states deal with disaster. Physical landscapes, unpredictable climate and the role of livelihoods and governance frame disaster risk and mitigation. Whilst climate hazards occur irrespective of borders, government systems are primary in defining risk and mitigation. Understanding national approaches to environmental engagement and livelihoods in the desert provides insight into disaster risk in two Gobi communities, farmers in Gansu Province, China, and herders in Dundgov and Omnogov Provinces, Mongolia. Evaluation of exposure and resilience in the two communities reflects how disaster can be shaped by policy, economics, culture and mitigation capacity. Comparison between two state systems examines how disaster risk is influenced as much by human actions as by the physical climatic event.

2 Gobi desert

For centuries, the Gobi desert has been represented as a geopolitical construct (Sternberg 2014). The Selden Map (ca. 1620) established the vast dryland beyond the Great Wall as an empty territorial void beyond the reaches and interest of the Chinese state, a home to 'barbarians' (Bodleian Library 2012). This conception continued during the Qing dynasty when the region was considered inferior and home to backward, less developed minorities

Fig. 1 Aridity map of the Gobi desert. *Gray area* denotes arid zones, >200 mm annual precipitation, and *black areas* represent semi-arid regions with <500 mm annual precipitation. Raw data are available at the Geospatial database, CGIAR consortium for spatial information (Trabucco and Zomer 2009)

(Lacy 2008). With the collapse of the Qing in 1911 came Russian interest and support for Outer Mongolia, resulting in Mongolia becoming a Soviet satellite state in 1924. This solidified the border and served to draw a line across the Gobi environment that remains today. Remoteness, lack of infrastructure and perceived marginality meant for decades there was limited engagement or study in the greater landscape, entrenching the two societies/one environment context.

At 2.3 million km^2, the Gobi desert covers a vast area of East Asia with the term 'Gobi' or 'Gov' denoting a flat gravel and sand expanse (Sternberg et al. in review; Xuan et al. 2004). The dryland is characterised by significant climate variability, great temperature range and marginal ecological productivity. Average precipitation is <200 mm annually in the arid zone with a yearly temperature range of up to >70 °C (Sternberg et al. 2011). As an inland, high-latitude plateau, the region is subject to extreme weather that affects the dominant agro-pastoral livelihoods (Angerer et al. 2008). In the twentieth century, the cold, dry steppe was contested between China and the Soviet Union with Mongolia as a proxy state (Bulag 2009). Today China's population and economic development predominate; mineral resources give the Gobi the highest GDP growth in the world (Mongolia) (Economist 2012).

In research literature, the dryland is presented as divergent landscapes split between southern Mongolia and northern China rather than as a single environment; studies address conditions by country instead of by geography. The split, focusing on geopolitical boundaries rather than physical characteristics, has social meaning but lacks environmental significance. This process is in part due to the region's division between Soviet and Chinese spheres of influence throughout most of the twentieth century. For scientific inquiry, such as climatic events, the Gobi represents a contiguous environment with similar climate, water and ecological conditions across national boundaries and parallel precipitation regimes—mean annual precipitation is 115 mm in Minqin, Gansu, China, 121 mm Omnogov and 137 mm Dundgov, Mongolia (Stoppato and Bini 2003; CMA 2011;

NAMHEM 2011). Governance and human activities reflect social and cultural factors that are separate from climate and the environment; they become relevant when climate interacts with society.

Improved regional understanding is important because in Asia, hydro-meteorological hazards have increased fivefold since 1950 (Em-Dat 2012). Events occur irrespective of boundaries yet East Asian disaster research fails to cross-borders, reflected in the lack of transboundary scientific inquiry. This is pronounced in the Gobi where no recent academic papers address disaster, risk or resilience at a regional scale though the desert is highly vulnerable to climate hazards (IPCC 2012). The result is limited research relevant to policy and mitigation (Kasperson 2010) across the dryland home to >25 million people. Predominantly farmers and herders, residents face severe climate disasters including drought and extreme winter conditions (locally known as *dzud*) as well as dust, storms, wind and blizzards (Tachiiri et al. 2008). Exposure to climate hazards is heightened because a majority of residents are engaged in environmentally dependent livelihoods.

A conventional view of climate hazards in drylands focuses on drought and moisture limitations (Sternberg et al. 2011), but unusually, in the Gobi, extreme cold events (*dzud*s) are of equal importance and constitute the region's worst climatic hazard (Sternberg 2010; Nandintsetseg and Shinoda 2013; Angerer et al. 2008). Additional concerns are dust, wind and storms that have implications beyond the region, such as severe spring dust storms that originate in the Gobi reaching Beijing and Tokyo and the USA (Akata et al. 2007). Drought and extreme winter conditions are classified as long, slow hazards that contrast with the immediacy and localisation of geophysical disasters (earthquake, volcano). The spatio-temporal scale of long/slow disasters makes event onset, impact and termination difficult to identify. Extreme weather is a case in point—winters in the Gobi are typically cold (to −40 °C); it is not the temperature alone but the extended duration and the impact of snow and ice on animals, forage and infrastructure that creates a disaster (Tachiiri et al. 2008; Sternberg et al. 2009; Fernández-Giménez et al. 2012a). With both physical and socio-economic dimensions, climate disasters are often identified by livestock, crop or financial damage as much as by physical or environmental parameters.

3 Two Gobis

There are effectively two Gobi environments framed by policy, development and culture. Different government systems shape livelihoods, communities, landscape interaction and hazard exposure. China has strong state control that regulates land and water access, agriculture and livestock raising through government policy and support. In contrast Mongolia, a maturing democracy has weak government regulation and enforcement and limited presence in the countryside. Political institutions and perceptions are key for both countries' disaster paradigm; this is evidenced by differences in planning, preparedness and response levels. The importance is in the ability of the system to mitigate climate risk and develop societal resilience (Table 1).[1]

[1] The table reflects assessment of data from the China Meteorological Administration and National Agency for Meteorology in Mongolia (IPCC 2012; Sternberg et al. 2011), discussion with officials and experts, research and reading on degradation and desertification (see Yang et al. 2005; Meyer 2006; Sternberg et al. 2010; Wang et al. 2008; Fernandez-Gimenez et al. 2012; Wang et al. 2013) and work on hazards in the region (see Tachiiri et al. 2008; Sternberg et al. 2009; Marin 2010; Nandintsetseg and Shinoda 2013; Huang et al. 2013).

Table 1 Physical and social factors that affect hazard dynamics in Minqin County, China, and Omnogov and Dundgov, Mongolia

Factor	Gobi region	
Topic	Minqin, China	Southern Mongolia
Hazard impact	Low	High
Government	Strong	Weak
Environment degradation	Moderate to high	Low
Climate	Cold/hot try	Cold/hot try
Agriculture	Yes	No
Herding/pastoralism	Low	High
Dzud/winter impact	Low	High
Government support	High	Low
Government policy	Strong	Weak
Infrastructure	Good	Poor
Risk planning	Moderate	Weak
Mining	Yes	Yes
Role of NGOs/International agencies in regards to disaster	Low	High

Until the twentieth century, the Gobi was sparsely populated by pastoralists with cultivators concentrated along the Yellow River corridor. Low population and remoteness isolated the region, referred to in the west first as a 'great sandy desert' (Marco Polo in 1298) and later a 'naked desert' (von Humbolt in 1819) that 'buried cities in the shifting sands' (Forsyth in 1877). For millennia, Mongolian pastoralists engaged in herding across the Gobi. However, since 1950, there has been a significant population increase due to a government policy that encouraged the in-migration of Han Chinese farmers (Zhang et al. 2007; Angerer et al. 2008). Their form of livelihood is important because Han migrants brought agricultural traditions that were poorly suited to the arid region. Thus, cultivation required new water sources, irrigation and inputs to support a growing population with resultant impact on land cover and degradation and increased exposure to hazards events (Meyer 2006).

Today nomadic pastoralism has transitioned to mobile herding in Mongolia and settled livestock-raising in China.[2] In rural Mongolia, transhumance continues to be the key form of adaptation to disaster and is encouraged both culturally and by a studied lack of regulatory policy and enforcement. Though historically similar, herding in northern China has evolved into settled livestock raising that is promoted by government policies including 'ecological resettlement' and 'closing down the grasslands' (Meyer 2006). Strong

[2] Nomadic Pastoralism—livestock production and land use that stresses mobility and is characterised by extensive grazing on rangelands; this differs from nomadism which implies having no fixed base and movements that do not follow a fixed pattern.

Mobile herding—represents herders' ability to migrate in accordance with seasonal or ecological conditions. In Mongolia this identifies flexibility and mobility as integral livelihood strategies.

Transhumance—regular seasonal movements from one pasture to another; in Mongolia mobility may follow a climatic, vegetation or altitudinal rotation throughout the year. Transhumance enables mitigation of harsh environmental conditions (drought, extreme winter, heat), access to better grazing and avoidance of disease or insect infestations.

regulation, fencing, inducements to sedentarise and access to public services (education, health) have seen customary herding shift to intensified ranching, conversion to farming and out-migration to towns and cities for work opportunities (Li and Huntsinger 2011).

Both herding and farming, as environmentally dependent livelihoods, are sensitive to changes in climate, warming trends, precipitation events (intensity, duration, seasonality) and temperature extremes. Factors that increase risk, such as limited access to water and animal forage, affect coping mechanisms. When encountering potential disaster, the traditional herding response has been migration to better pasture elsewhere, reduced livestock numbers and relocating to hills that offer protection from cold weather and access to a variety of water sources (Marin 2010). Adaptive strategies falter if parameters shift as, for example, where movement is controlled fencing, herd composition is changed for economic or regulatory reasons and when land-use intensification or degradation affect pasture productivity. As herding resilience decreases, vulnerability to disaster increases with risk mitigation a major challenge (Fernandez-Gimenez et al. 2012). Examples include the ability to move, changes in herd composition, reserve pastures and seasonal movements. In China, there is potential government support for emergencies, in part prompted by centralised control that limits livelihood alternatives. In Mongolia, the government, lacking support mechanisms, dispenses *de facto* with rural control. This allows herders the flexibility to move or change herding strategies to adapt to disaster. Both methods can be effective in limiting livestock, personal and economic damage though they represent vastly different approaches. The Chinese approach depends on government support to maintain a cost-intensive human-directed system. By contrast, Mongolia's detached approach, by not burdening or regulating the herder, both decreases the government's ability and implied obligation to respond and places the responsibility for coping with the disaster squarely on the herder.

The role of governance in the disaster paradigm is a combination of history, politics, socio-economic and physical conditions. China's approach is sustained by the centralised control of land and its use.

Settled livestock raising in China—in northern China, the pastures are contracted to individual households and the land is fenced. This is a result of government policies such as the 'Household Production Responsibility System', 'Ecological Resettlement' and 'Retire livestock and restore grassland' programmes. Livestock production has been sedentarised with fodder production and stall-feeding rather than grazing being the dominant food sources.

For additional detail, see Fernandez-Gimenez and Le Febre (2006); Meyer (2006); Marin (2010); Li and Huntsiger (2011), filtered through a lens of economic development and control of border regions (Lacy 2008). The appropriateness of intensive agriculture outside the Yellow River belt was a secondary factor compared with the desire for a Han Chinese majority in the region; Han now comprise >80 % of Inner Mongolia's population (Zhang et al. 2007). Regional desertification occurs in part due to the ongoing struggle to provide adequate agricultural conditions for a sizable population in a dryland (Meyer 2006; Wang et al. 2013). Water is needed, ecological and soil productivity is often poor, and once the ground surface is tilled, subsoils are exposed and are often removed by aeolian processes. With government interest in settled groups, cultivators often have preferential access to better pastures, further marginalising livestock raising. Each step increases the exposure and vulnerability of local populations to disaster. In fact, Inner Mongolia and Ningxia Provinces in the Gobi have China's highest exposure to disaster losses (Huang et al. 2013). Limited water sources reduce harvest potential and restrict livestock movement; degradation affects grassland vegetation and animal weight gain and dust and wind

storms remove soil nutrients. Each process weakens the community's ability to prepare and respond to hazards using traditional (migration, animal off-take) or modern methods (emergency fodder, irrigation, fertiliser, financial support).

A combination of human action, government policy and environmental productivity shapes the disaster risk and resilience debate in the Gobi. Some parameters are fixed—the aridity map delineates a vast dry environment with minimal surface water sources (see Fig. 1) (Trabucco and Zomer 2009). Changing human involvement is reflected through population, land use, livelihoods, animal selection and modification of the environment. Managing risk is a function of mitigating impact on social and community scales. In a cross-border study, shared natural variables enable identification of the livelihood and government role in the disaster equation.

4 Disaster risk in the Gobi: two examples

Risk represents exposure to hazards whilst disaster identifies disruption and damage to human systems (Wilhite 2005). Herein are two examples of human-hazard engagement in the Gobi that focus on land use, livelihoods and exposure to hazards and governance. One case focuses on an agricultural region in Gansu Province, China, and represents hazard risk in a controlled farming system. The environment is organised to minimise natural forces through strong government and human intervention. The principal component is water infrastructure—reservoir and wells—that provides irrigation capacity, reduces dependency on precipitation and mitigates drought impact. The second case examines the herding system in Omnogov and Dundgov, Mongolia, that seeks to adapt to climate factors to reduce disaster risk. The study presents the dominant land-use system in each country, farming in China and herding in Mongolia, to explore the diverse hazard implications and response in the region. The relative difference in the two study areas reflects population levels and human interaction in the desert. The regions highlight the variability in risk and resilience experienced and encapsulate the role of policy and government in hazard exposure and mitigation in the two countries. The former represents efforts to control the landscape; the latter seeks to lessen exposure through customary coping strategies. The different systems reflect government policy and approach to disaster in the two countries.

4.1 Methods

Assessment of transboundary hazard risk was done through extensive fieldwork in 2011 and 2012 in Minqin County, Gansu Province, China, and Dundgov and Omnogov Provinces, Mongolia. The study included discussion with local residents and officials that focused on climate and hazard impact on communities, livelihood strategies, physical parameters, coping mechanisms and change over time in rural communities. Research was undertaken with colleagues at the Chinese Academy of Social Science and Lanzhou University in China (May–June 2011; May 2012) and the Mongolian Institute of Geography (October 2011; May–June 2012). Surveys with farmers and livestock raisers and meetings with local officials and bureaucrats (e.g. district governors, environmental managers, agricultural agents, meteorologists, NGO representatives) and the Gansu Anti-Desertification Research Center provided a local perspective on climate hazards, exposure

and disaster risk in both countries and the context for evaluating cross-border risk in the two Gobi regions. Semi-structured interviews were conducted in the agricultural rural areas of Minqin County; a stepping-stone method was employed to locate dwellings in the Omnogov and Dundgov countryside. Analysis evaluated findings with results reflecting respondents' perceptions and engagement with hazards.

4.2 Minqin County, Gansu Province

Minqin County, an area of 300,000 people, illustrates the importance of water in desert agriculture. Situated between the local Tengger and Baidan Jaran shamos (deserts), Minqin receives 115 mm of precipitation annually (CMA 2011). Cultivation is possible because of numerous wells and the Shiyang River that supplies a regional reservoir and local distribution network. Though considered a marginal area, farming is promoted and organised by the government with significant investment and financial support. Water access is regulated by an allotment and pricing system where farmers have certain defined rights to purchase water. Cropping decisions are a balance between cost and perceived income, water access and government direction.

In the Gobi, disaster risk is centred on water availability/drought, with cold and hot extremes also impacting livelihoods. Interestingly, this was not the case in Minqin as intensified management systems existed to supply water, limiting reliance on rainfall. In the regulated system, adequate mechanisms existed to control drought, the significant disaster. Rather than precipitation or temperature, farmers identified wind as the main risk (Table 2). Encouraged by government support and loans, plastic-covered greenhouses with dirt foundations were built to protect seedlings in spring and enable plants to survive cold winters. These greenhouses were costly, consuming up to half of a farmer's annual income. This created the condition where modest greenhouses were vulnerable to windstorms, particularly in winter. High winds tore off the plastic covers, damaged plants, reduced income and required significant investment to repair.

The result was that successful remedies to reduce initial vulnerability displaced risk in two ways. First, it enabled more intensive farming and the building of winter greenhouses that included motorised retractable roofs and blanket covers for protection from cold temperatures. However, this created a new risk of damage to greenhouses. Previously drought had been significant and winter windstorms an inconvenience. Now wind was the major natural disaster in the modified farming system whilst drought had been minimised. Options to reduce this risk, such as through more solid greenhouse construction that could withstand wind, were not considered worth the expense involved.

A second risk was the perception of ongoing steady water supply. Official government comments state that the water supply is constant. This contradicts recent local history, when Wuwei City, located upstream, had taken a greater share of river water. Fluctuations in rainfall and glacial melt were not acknowledged as the officials were concerned with present conditions, not longer-term sustainability. The process suggests that whilst intensified management mitigated risk today, future scenarios were uncertain. Challenges include a declining water table due to the large number of wells and groundwater withdrawals in the area, changes at the source and in the flow of the Shiyang River and the impact of aeolian processes on soil and greenhouses. Minqin represented a high input, high cost approach to disaster management based on strong government intervention. The system evolved as a successful disaster remedy to control drought through irrigated cultivation; it has displaced risk to wind damage on property (Table 2).

Table 2 Hazard dynamics for farmers and herders in Minqin, Gansu, China, and Omnogov and Dundgov, Mongolia

Hazards		China Farmer	China Herder	Mongolia Herder
Extreme winter	Exposure	Moderate	Moderate	High
	Reason	Windstorms demolish greenhouses	Animals in barns	Livestock mortality
	Issue	Cost of replacement	Lack of fodder, expense	Lack of fodder, expense
		Loss of plants/food	Outmigration	Loss of livelihood
Drought	Exposure	Low	Moderate	High
	Reason	Irrigation	Lack of vegetation	Lack of vegetation
	Issue	Water sustainability, shortages—reservoir, groundwater	Lack of fodder, expense	Lack of fodder, expense
			Grassland access	Winter vulnerability
Wind	Exposure	High	Low	Low
	Reason	Can damage greenhouses, crops	Limited pasture damage	Limited pasture damage
	Issue	Cost of replacement, plants die	Barns for shelter	Move to hills, corrals

4.3 Omnogov and Dundgov Provinces, Mongolia

In Mongolia's southern Gobi region, herders encounter multiple hazards (Table 2). Indeed, herding is an exercise in managing risk and potential environmental disasters. Unlike China, no system has evolved to manage the landscape for a specific activity such as farming nor has there been strong government direction of livelihoods or community development. This restricts any large-scale ability to engage with disaster, leaving risk reduction to the individual or local level. Herder decision-making becomes the risk moderator; their actions determine levels of risk to drought and extreme winter, both perceived to be endemic hazards. In a system where control of the environment is not feasible, reduced exposure and increased resilience remains the essential risk strategy.

Herding is a process of exploiting environmental opportunities that simultaneously serve as coping actions. Customary pastoral trademarks—migration, seasonal pasture, herd composition, flexible management—are effective risk management strategies. Mongolian pastoralism has altered significantly in the last century from its original subsistence approach that was organised by the Buddhist hierarchy. Throughout much of the twentieth century, the communist state regulated herding, limited animal numbers, organised migration and provided emergency fodder. Since the Soviet collapse, the country has transitioned to a democratic, market-oriented system. Disasters have been common and were previously considered a natural way of controlling herd size. More recently, drought, extreme winters (*dzud*) and severe insect infestations have caused high livestock mortality, economic loss and livelihood dislocation (Tachiiri et al. 2008). Today herders are very aware of disasters, with the *dzud* of 2010 killing >25 % of the national herd and resulting in 3 % of the population losing their livelihood (Sternberg 2010). The continued inability to cope with extreme winter disaster is a severe problem for environment-dependent livelihoods in an endemically cold region. This underlines that it is not cold alone but exposure and response to climate events, that shape winter disaster. In 2010, natural conditions were exacerbated by a lack of preparation (e.g. emergency fodder, response planning), record livestock numbers and costs involved.

The climate regime impacts vegetation, growing season and productivity and shapes grassland productivity. These factors are important in the livestock system as drought and lack of forage affect animal weight gain and thus the ability to withstand severe winter conditions. Secondly, economic factors drive decision-making at individual and local levels when actions are taken to maximise income or reduce expenses. This may be reflected in an increase in goats for cashmere production (for income), changes in mobility patterns (high cost) and livestock numbers (income) and livestock intensification at wells, all factors which can affect vulnerability of animals or grazing land. Additional issues are governance and disaster policy implementation, such as preparedness and response planning, maintaining infrastructure and veterinary services. In the 2010, *dzud* mitigation was a critical problem as the government lacked capacity and was dependent on international aid for *dzud* response (Table 3) (Sternberg and Batbuyan 2013). The result was delayed relief, great livestock mortality and the country's worst natural disaster in number of people affected (data from 1900 to 2012; Em-Dat 2012).

This highlights that although the herding system is premised on environmental coping strategies changing livelihood factors present new hazard risks. Resilience has enabled herding to adapt and survive as a livelihood, yet as socio-economic forces evolve risk has increased without being matched by improved ability to mitigate disaster. The government's limited response capacity leaves organised disaster response to the international community and ultimately the herders themselves.

Table 3 Role of government and international aid for disaster management in Minqin, Gansu, China, and Omnogov and Dundgov, Mongolia

Issue	Government role			International aid	
	China Farmer	China Herder	Mongolia Herder	China	Mongolia
Extreme winter	Support, loans for greenhouses	Barns for livestock Loans for fodder	If disaster organises international relief	n/a	Provide aid, fodder, food, health, livestock replacement,
	Loan for home	Loan for home	Encourages preparation		Funds emergency relief, carcass burial, capacity building
Drought	Provides water access, minimises drought impact Agricultural technology	Loans for fodder		n/a	Emergency relief when high livestock mortality
Wind	If disaster, may provide loan for greenhouse, give small grant	–	–	n/a	n/a
Livelihood measures	May select crops, assigns land, allocates water, loans development/ infrastructure	Assigns pasture, controls livestock number and type, reduces grazing season	Limited organisation development infrastructure		Sustainable livelihoods support, community based management, increase capacity, preparedness

Minqin and Dundgov/Omnogov highlight two different approaches to risk. The contrasting approaches to livelihoods in the shared desert are influenced by culture, history and policy. China presents a government-led, high input system where initial risk to farming of drought or temperature has been deferred but a new risk has developed. In the controlled system, the government is capable of effective drought and extreme winter management and response yet this has created new vulnerability to wind. The Mongolian scenario features livelihoods based on adapting to environmental conditions through customary coping strategies. However, when disaster occurs, the system often breaks down as individuals and government have weak response capability.

4.4 External risk and mitigation

Evaluating hazard risk in the Gobi is part of a larger discourse that recognises external forces. Two examples reflect how these issues can be physical, such as climate change, or social, such as the region's interaction with the global community. In the future, northern China and southern Mongolia are projected to experience warming temperatures, greater precipitation intensity and volatility and increased drought events with negative impacts on agriculture, water resources and land degradation/desertification (IPCC 2012). These fluctuations will affect environmental sustainability and exposure to hazards. For instance, Minqin County's rapid development over three decades (1972–2000) saw its population increased 80 %, groundwater extraction expanded by 1.43×10^9 m^3 and canal length in kilometres multiplied 43 times (Ma et al. 2005). Continued expansion and livelihood viability may be affected and constrained by climate conditions as resources (water, arable land) are impacted. In Mongolia, a lack of agriculture reduces exposure whilst pastoral mobility provides a coping mechanism for climate variability yet the country will need improved strategies strengthen hazard resilience.

Another factor is national engagement with global disaster risk reduction (DRR) efforts. As participants in the United Nation's 'Hyogo Framework for Action: Building the resilience of nations and communities to disasters' (UNISDR 2007), Mongolia and China are part of the international effort to reduce disaster risk. How the countries' conceive and present themselves in National Action Plans to the Hyogo Framework (HFA) is instructive of how hazard risk is viewed and engaged with in the two countries. Mongolia focuses on using the HFA as a guideline to strengthen governance, capacity and organisation to reduce disaster risk (Mongolia: National Progress Report 2011; Sternberg and Batbuyan 2013). The Chinese report stresses the completeness of the nation's disaster structure and legal framework. It identifies that US $34 billion has been allocated for risk reduction, centred on floods and earthquakes, and notes that the 'one law for one event' approach to disasters is an inefficient use of resources (China National Progress Report 2012, p. 8). The two national documents reflect the different conceptions of hazards. Mongolia presents risk reduction as part of a long process; China rates itself a high 'level of progress' in all DRR categories, whereas China identifies existing integrated management and control of disasters Mongolia aims to improve mitigation through HFA/international guidance and support (see Table 3). However, both documents identify difficulties strengthening support and skills at the local level.

The fluctuating risk levels and pressure points will become evident in China if systemic controls and support can no longer be sustained; in Mongolia, stressors will show when customary strategies fail and government or external response is inadequate. The marked difference in exposure, risk and response reflects how human action has become integral in determining disaster in the Gobi. If landscape alone defined disaster risk, conditions would

be similar across the region in both hazard exposure and event impact. Instead, governance, livelihoods, socio-economic forces and the ability to shape and manipulate the environment determine disaster risk.

5 Discussion

In the transboundary Gobi region, China and Mongolia provide different examples of hazard engagement in the shared environment. This reflects the roles of livelihoods, governance and divergent approaches to risk management and mitigation. China seeks to modify the environment and reduce risk through government action and infrastructure (Zou and Yuan 2010). Across the border, Mongolia follows a less intensive, more customary manner of disaster engagement that stresses adaptation to minimise risk. The two methods highlight variability, strengths and vulnerabilities in the dynamic region and emphasise how human action is central to hazard exposure and mitigation.

Risk is viewed differently in the two Gobi examples. China looks at how the impact of natural events can be moderated through investment and infrastructure, a capital-intensive approach that has reduced exposure to drought and cold weather through water provision, winter sheds and greenhouses. This has been a boon locally as it has delivered economic growth and perceived social stability. However, modifications are temporary measures as the environment is controlled rather than accommodated. In Minqin County, farmers' dependence on irrigation rather than precipitation has reduced drought exposure, affecting crop selection (now grapes, tomatoes) and stressing economic motivation in farming decisions (income vs. expense) rather than environmental considerations. This has led to potential new risks including wind damage to structures, desertification and soil loss. Continued government interest and ability to control the environment will determine future risk levels in the region (Zou and Yuan 2010).

The Mongolian example presents a more nuanced hazard environment where risk and vulnerability is managed at the household level. Rather than disaster being moderated by government action the herder or resident is responsible for risk alleviation. The result is greater exposure to hazards when everyday coping ability is insufficient (Huang et al. 2013) and continues the country's reliance on international aid for disaster response (see Table 3). Improvements include preventative measures (fodder, migration), alternative income sources (work), mining, stronger government support and increased preparation and mitigation ability. The outcome is that livelihoods continue to follow modified customary patterns that attempt to adapt and avoid hazards but have minimal response capacity when events occur.

The region presents different versions of how to engage with risk. One method is not better or preferable; they reflect local strategies and capabilities that are determined by two societies rather than hazard conditions in one landscape. Drought, severe winter and wind are common hazards yet their impact varies significantly depending on management that reflects government strength, policy and funding (see Table 2). Exposure and policy relate not only to livelihoods and income sources but to who resides in an area, where cities and populations are settled and the ability to deliver valuable resources (water, assistance) to residents.

The central theme is that in the Gobi desert climate and hazards maybe transboundary in nature but impact depends on national systems. A Chinese or a Mongolian assessment alone provides a half-picture of the disaster environment. The desert becomes an excellent example of the cross-border implications of climate events in a rapidly changing region; as

societies evolve and develop livelihood choices, land use and perceptions will shift. Policies and practice across the border can be evaluated and assessed for effectiveness; both countries could benefit from knowledge and experience drawn from risk paradigms in the shared environment. Currently Chinese and Mongolian Academies of Science cooperate on the 'Mongolian Plateau Environment' project, a potential model for disaster risk reduction efforts between relevant government ministries and researchers. Further research could explore the Gobi-wide hazard context by incorporating settled livestock raising common in Inner Mongolia.

Several factors such as climate change, geopolitics and natural resources are key components of a serious discussion of disaster in the Gobi. Currently governance and livelihoods are the primary determinants of hazard risk; human well-being is disrupted when imposed or deficient systems breakdown in the face of extreme climate events. The Gobi exhibits how government-led disaster management and traditional coping strategies can both be effective ways to reduce risk. The region also reflects inherent weaknesses when low development levels hinder mitigation efforts or intensive systems stress technical and financial support rather than adaptation or resilience to disaster.

The greater significance of examining hazards at the transboundary scale is the relevance to global conditions as risk continues to increase (Kasperson 2010). This study provides a regional scale assessment and enables comparison and contrast with other dryland zones such as the Middle East and Africa. Cross-border disasters are well-known with recent episodes including the 2011–2012 drought in the Horn of Africa, 2010s extreme heat wave in Russia, Ukraine and Eastern Europe and the great Sahelian drought and famine in the 1980s. Broader understanding of hazard dynamics would inform and improve preparedness and preparation in affected regions. This is especially salient in areas where multiple countries are exposed to related climate hazards. Flooding in Southeast and South Asia, drought in much of Africa and extreme winter and drought in Inner and East Asia typify transborder disasters. The Gobi exemplifies how regional (as opposed to country) assessment and coordination can be particularly beneficial to developing nations' efforts to improve knowledge and capacity. With uncertainty regarding climate change, international cooperation will be a key component of disaster mitigation in the future.

6 Summary

The Gobi region exemplifies how two countries in one environment can show great variability in perception of disaster risk, vulnerability levels and mitigation practices. Minqin County, China, and Dundgov and Omnogov Provinces, Mongolia, present different hazard risks, scenarios and responses to climate events. The countries demonstrate the importance of society and governance in risk engagement. In this work, China used its rapid development and strong state regulation to control hazards through investment, infrastructure and support whilst Mongolia relied on customary coping strategies. Approaches reflect the nations' self-conception, livelihoods, economics and state systems, making the validity or vulnerability of risk response contextual. As a transboundary hazard zone, the two countries epitomise the importance of landscape rather than borders for comprehensive knowledge of risk. The concept is significant to move disaster risk assessment beyond national perspectives to encompass physical parameters. Integrating multiple divisions within a hazard zone is essential to address risk reduction; without this disaster, mitigation remains state-specific and lacks applicability to a wider regional or global context.

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