Title: Climate Change Impacts and Response Strategies in the China-Mongolia Border Region: A Comparative Analysis of Environmental Challenges and Policy Approaches

Name: Yuan Cao

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Abstract

This paper analyzes the relationship between the impacts of climate change and policy in the China-Mongolia border region. This temperature increase is alarmingly higher than the global average. Through comprehensive literature review and policy comparison of the two countries, the paper investigates the role of governance and socio-economic factors on climate change policy in the border region. It concludes that whilst Mongolia and China have made impressive strides in climate change policy, inequality in resource and policy divergence results in ineffectiveness. The study tracks an accelerating desertification process that impacts 78% of Mongolia's territory and large areas of Inner Mongolia, together with dramatic changes in water resources and biodiversity. The cooperation section investigates the current cooperation models and the main barriers to effective transboundary climate action and identifies opportunities for future cooperation through financing, technology transfer, and capacity building. This research contributes to understanding transboundary climate issues and makes practical recommendations for improving cooperation on climate change adaptation and mitigation.

Key words: climate change adaptation, China-Mongolia relations, transboundary environmental governance, ecological restoration, pastoral systems, environmental policy, cross-border cooperation, desertification, climate resilience, grassland ecosystems

1. Introduction

The China-Mongolia border region serves as a critical ecological corridor characterized by diverse landscapes or ecosystems (Wang et al., 2023), including Gobi deserts, grassland steppes, and wetlands, making it particularly vulnerable to climate change impacts (Li et al., 2018). This transboundary area is home to unique biodiversity and provides essential ecosystem services, such as water regulation and carbon sequestration. However, the region faces escalating environmental challenges driven by climate change, unsustainable land use practices, and socio-economic pressures.

Climate change represents one of the most pressing challenges facing this region, a vast area characterized by fragile ecosystems and complex socio-ecological interactions (Zhang et al., 2020). This transboundary region, spanning thousands of kilometers, serves as a critical ecological corridor where environmental challenges transcend national borders. As both countries grapple with increasing climate variability and extreme weather events, understanding the differentiated impacts and response strategies becomes crucial for effective environmental management and sustainable development. For instance, China is pursuing large-scale ecological restoration projects while Mongolia balances environmental protection with economic development (Zhang et al., 2020). The transboundary nature of environmental challenges in this region necessitates coordinated responses, yet differences in policy approaches and institutional capacities create barriers to effective collaboration (Wang et al., 2013).

This study aims to critically analyze the impacts of climate change on the China-Mongolia border region, explore the effectiveness of adaptation and mitigation strategies, and assess the role of cross-border cooperation in addressing shared challenges.

Key research questions include:

1. How does climate change manifest differently across the China-Mongolia border region?
2. What are the key differences in climate change response strategies between China and Mongolia?
3. How do cross-border environmental challenges affect both countries' development?

4. What potential exists for enhanced cooperation in climate change adaptation and mitigation between China and Mongolia?

The methodology employed in this study combines comprehensive literature review with comparative analysis of climate policies and response strategies. The research draws on peer-reviewed scientific literature, government reports, and international organization assessments to provide a thorough examination of climate change impacts and policy responses in the region.

Recent studies have documented significant changes in the region's climate patterns. Yu et al. (2020) observed shifts in forest phenology across the China-Mongolia-Russia corridor, while Dong et al. (2013) documented changes in temperature and aridity zones in Eastern Inner Mongolia. These changes have profound implications for both ecosystems and human communities in the region (Batima et al., 2013).

2. Background: Regional Context and Climate Change Trends

2.1 Geographic and Ecological Overview

The China-Mongolia border region's geography spans approximately 4,677 kilometers, encompassing diverse ecosystems, including the Gobi Desert (28%), grassland steppes (47%), and wetlands (10%) (Soni, 2018), representing one of the world's most extensive transboundary ecological zones. This varied terrain creates a complex ecosystem mosaic that plays crucial roles in regional climate regulation and biodiversity conservation. The ecological significance of this area extends beyond national boundaries; shared resources such as transboundary rivers (watersheds), grazing lands, and wildlife migration corridors form the vital links between Chinese and Mongolian ecosystems, highlighting the need for coordinated management (Wang et al., 2023). For instance, the Gobi Desert supports unique species like the critically endangered Gobi bear (Ursus arctos gobies), whose survival depends on cross-border conservation efforts.
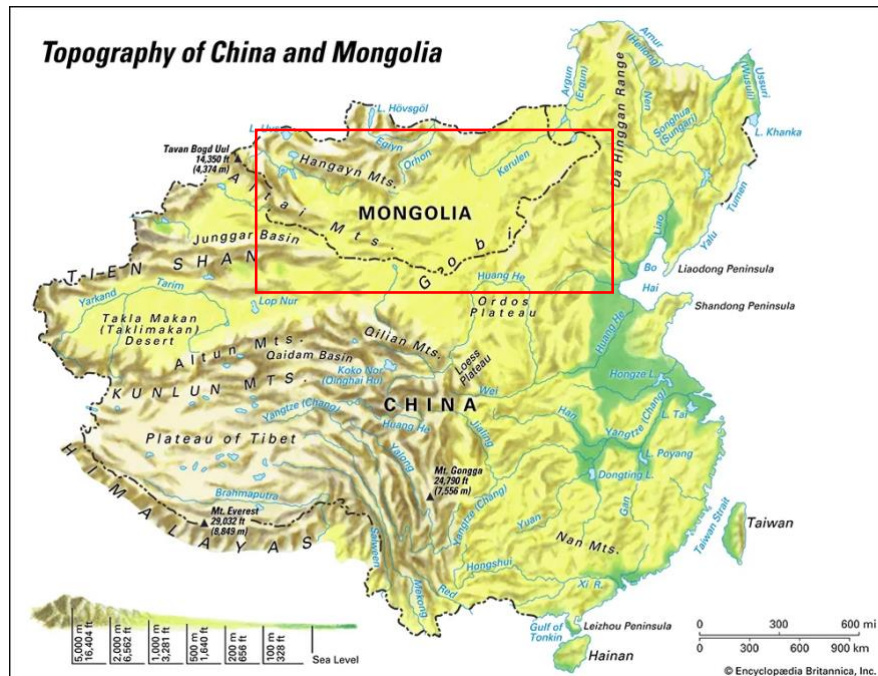
Figure 1. Topography of China-Mongolia Border Region

2.2 Climate Change Trends

The past few decades have dramatically shifted the region's climate. Long-term meteorological records show a 2.1°C rise in average temperature over the last 50 years, a change that is significantly greater than the global average (Zhang et al., 2020). Warming has occurred especially strongly in winter and at high altitudes, with some areas experiencing a rise of up to 3°C (Dong et al., 2013). There have also been significant alterations in precipitation, which is now much more variable, with frequent extreme events. This has particularly affected the transition zones between ecological regions, where small climate changes can disproportionately affect ecosystem health (Li et al., 2018).

Another reason is that the environmental systems in the border region are highly interlinked, which presents a unique challenge in terms of adaptation and mitigation of climate change impacts. Atmospheric circulation allows dust and pollution to be transported across borders, whilst water resources are in growing demand from climate change impacts and human development. For

instance, research has shown that dust storms from the Gobi desert have become more frequent and severe, impacting air quality and human health in both countries (Li et al., 2022). In the same vein, changing precipitation patterns and glacier melt are affecting water resource management across the whole region (Wang et al., 2023).

| Region	Temperature Change (°C)	Precipitation Change (%)	Extreme Weather Events (frequency change)
Northern China Border Areas	+2.3	-15%	+45%
Southern Mongolia Border Areas	+1.9	-12%	+38%
Central Border Region	+2.1	-18%	+52%

Source: Zhang et al., 2020

**Table 1: Comparative Climate Change Trends (1970-2020)
Temperature and Precipitation Changes Across Border Regions**
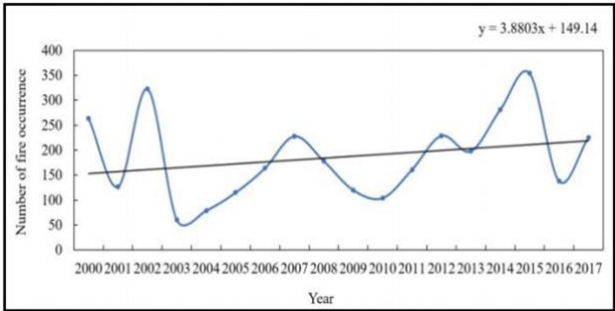
Source: Nasanbat, et al, 2018

Figure 2: Number of wildfires Trends in Mongolia (2000-2017)
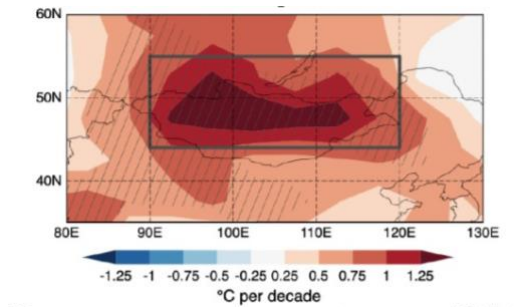
Source: Chen et al., 2024

Figure 3: SAT Trends in China-Mongolia Border Region (1986-2024)

3. Climate Change Impacts in the Region

The appearance of climate change in the China-Mongolia border region shows how it affects the environmental and socio-economic systems and how they interact. This part analyzes the impact through an environmental and socio-economic lens and shows how climate change is an interacting problem.

3.1 Environmental Impacts

Desertification

Environmental impacts have been especially severe in recent decades; desertification, the most obvious impact, has accelerated rapidly since the 1980s. According to recent assessments, approximately 78% of Mongolia's territory now shows some degree of desertification, while Inner Mongolia has experienced significant land degradation across 28% of its territory (Batunacun et al., 2018). This trend is exacerbated by the interaction between climate change and human activities, creating a feedback loop that amplifies environmental degradation. For instance, Mongolia's livestock population has surged from about 25.9 million in 1990 to over 66.5 million in 2018. This overgrazing has rapidly degraded the fragile grasslands into deserts (Sanzheev et al., 2020).

Water Resource Depletion

Water resources in the region have shown marked vulnerability to climate change; long-term studies of surface and groundwater have demonstrated significant trends. River flow volumes have decreased while seasonal variability has increased, creating new challenges for water resource management (Li et al., 2018). Such hydrological changes are significant for agricultural communities and urban areas that need stable water supply; this is now coupled with rising water demand from growing urban populations and industrial expansion.

Biodiversity Loss

Another significant aspect of climate change in the region is its effect on biodiversity. According to Yu et al. (2020), species distributions have been greatly affected, with many species migrating northwards as temperatures rise. This destabilizes ecosystems and pastoral ways of life that rely on certain vegetation types. Furthermore, the loss of habitat connectivity, exacerbated by climate change and human development, stresses wildlife populations, some of which need significant habitats and have seasonal migration needs. The Gobi bear and wild camels are severely threatened with extinction as their habitats gradually reduce and their genetic diversity falls. Initiatives such as the "Gobi Bear Technical Assistance Project" have succeeded in this respect, but ongoing work is required.

3.2 Socio-Economic Impacts

Agricultural and Pastoral Systems

The socio-economic impacts of climate change in the border region have been similarly severe, as it has fundamentally disrupted traditional ways of life and economic activities. Agricultural systems, especially in the transitional zones between pastoral and farming cultures, are increasingly stressed by a shifting climate. According to Wang et al. (2013), crop yields and growing seasons have been significantly affected, with some regions seeing yields drop by as much as 30% during extreme weather events. This has forced farming communities to adapt, often at considerable economic cost.

The pastoralist communities, which have long been the mainstay of much of the region's rural economy, have it worst. The traditional methods of herding that have evolved over the centuries to deal with the variable climate are now under strain as the climate becomes more extreme.

According to Zhang et al. (2020), grassland productivity has been starkly impacted, with pasture available decreasing by 40% in some areas during the drought. This has dramatically impacted the lives of pastoralist communities, preventing them from migrating along traditional routes or abandoning the nomadic way of life.

Urbanization and Migration

Climate change is thought to have hugely accelerated urbanization and population movement in the border region, which has created very mixed socio-economic problems. In Mongolia, urbanization has led to almost half the population living in the capital city Ulaanbaatar, whose population grew from 770,000 in 2000 to 1.6 million in 2023 (Mongolian Statistical Office, 2023). studies show that environmental degradation is the main cause of this urbanization, with around 65% of migrants reporting climate-related livelihood pressures as the main cause for their movement (Batbold et al., 2022). The Inner Mongolia, China has undergone similar demographic changes and make up about 30% of the newly urbanized (Li & Zhang, 2023).

The spatial manifestation of this migration is particularly evident in Ulaanbaatar's ger districts, with population density increasing from 8000 to 12000 persons per square kilometer between 2010 and 2022, the densification putting infrastructural strain to a point that recent surveys show 45% of migrants have no access to basic public services (Wang et al., 2023). Traditional pastoral lifestyles are incompatible with the urban economy, with an unemployment rate of 28% and cultural dislocation.

Public Health

Public health consequences of climate change in the border region have become a major issue, with air pollution the greatest immediate risk to population health. In Ulaanbaatar, winter PM2.5 levels often exceed WHO guidelines by a factor of ten, with the 2022 Air Quality Index averaging 687 (Batbold & Chen, 2023), leading to a huge upsurge in respiratory illnesses, childhood asthma prevalence growing from 3.2% in 2010 to 8.7% in 2022.

Climate change has also modified transmission patterns of many diseases across the region. Vector-borne diseases have moved northward, with the incidence of brucellosis rising 40% in the last decade (Zhang et al., 2023). Such changes in disease ecology have been linked to rising temperatures and changing patterns of rainfall, and pose new threats to public health systems in both countries.

The health effects of such extreme weather events are becoming ever more evident, as heat-related morbidity has sharply increased, with the typical number of heat wave days rising from 3 in 1990 to 15 in 2022, disproportionately affecting the vulnerable, as elderly mortality during heat waves

has risen by 28% (Li et al., 2023), with economic costs also being significant, as heat-related labour productivity losses are estimated at 2.3% of regional GDP.

4. Policy Analysis and Cross-Border Cooperation

4.1 Comparative Policy Analysis

The policy responses to climate change in China and Mongolia reflect distinct approaches shaped by different governance systems, economic capacities, and national priorities.

China's Approach

China's strategy has involved large-scale ecological restoration projects and huge state investment; the "Three-North" Shelter Forest Program is an example, as it aims to prevent desertification through tree planting and grassland restoration on a large scale, one of the most significant ecological engineering projects in the world, with enormous impacts for climate change adaptation in the border area (Tian et al., 2015).

Mongolia's Approach

Despite the similar emphasis on environmental protection, Mongolia's comparative policy response is limited by economic and institutional constraints. The country has reliable climate change adaptation policies, but these are primarily concerned with pastoral resilience. However, implementation is sometimes inhibited by resource limitations and competing priorities for development (Batima et al., 2013), with initiatives like the "One Billion Trees" project having only 50% survival rates of planted trees.

Comparative analysis

First, China's policies are usually centered on technology and large-scale measures, with the aid of large state investment; for instance, the installation of high-tech irrigation in Inner Mongolia's agriculture has been common, with a lot of research and development invested (Li et al., 2018).

In contrast, Mongolia's approach often focuses on community-based adaptation strategies and traditional knowledge systems. This is particularly evident in pastoral sector policies, where efforts have concentrated on enhancing the resilience of traditional herding practices rather than fundamentally transforming them (Wang et al., 2013) (Table 2).

Policy Aspect	China's Approach	Mongolia's Approach	Implementation Challenges
Institutional Framework	Centralized, top-down	Decentralized, community-based	Coordination difficulties
Resource Allocation	Substantial state investment	Limited resources	Resource disparity
Technical Approach	Technology-focused	Traditional knowledge integration	Technology transfer barriers
Implementation Scale	Large-scale projects	Local initiatives	Scale mismatch

Table 2: Policy Response Comparison Framework

4.2   Cross-border Cooperation

Notwithstanding the varying approaches each country has taken, the transboundary nature of climate change has compelled China and Mongolia to enhance their cooperation, with current cooperation frameworks mainly relying on bilateral environmental agreements and multilateral platforms, e.g., the China-Mongolia Memorandum on Desertification Control (supported by UNDP-GEF) and the China-Mongolia desertification prevention and control cooperation center (Boykova, 2021). According to Boykova (2021), the effectiveness of the arrangements has been constrained by structural constraints and resource disparities.

Economic and technical asymmetry between the two nations has also posed a challenge in terms of undertaking joint projects. While China has ample technology and finance, Mongolia lacks the same level of resourcefulness in joint projects, which has the potential to complicate project planning and execution (Soni, 2018).

However, many more successful cooperative projects, even in private sectors, show potential for greater cooperation, such as dust storm monitoring and shared early warning systems, which have enhanced response in both nations and coordinated biodiversity conservation in border regions (Li et al., 2022).

5. Future Opportunities

The review of the present situation and current cooperation models shows there are strong prospects for more and better cooperation between China and Mongolia on climate change along a number of lines, and through a variety of modes, which could significantly strengthen the border area cooperation on climate change (Table 3).

Opportunity Area	Potential Impact	Implementation Complexity	Resource Requirements
Joint Monitoring	High	Medium	Moderate
Policy Harmonization	Very High	High	Low
Technology Transfer	High	Medium	High
Capacity Building	Very High	Medium	Moderate

Table 3: Future Cooperation Opportunity Matrix

In relation to policy cooperation, there is a strong mutual interest in adapting to climate change at the border region. In the words of Wang et al. (2023), "climate change adaptation policies could be more aligned between the two countries". For example, grassland management could be coordinated to ensure ecological continuity whilst allowing for traditional pastoral lifestyles. This would need institutional mechanisms able to cross governance divides, bearing in mind national sovereignty and developmental concerns.

The issue of financial support systems is yet another critical area that needs to be developed going forward. There are significant differences in funding which is an obstacle to executing joint projects. According to Li et al. (2018), new financing models, such as cross-border environmental funds or joint carbon trading platforms, could mitigate this challenge. These models could take

advantage of China's financial strength while ensuring fair allocation of funds for climate change adaptation projects in the border area.

Technology transfer and sharing is where there is great potential. China's technological development in ecological restoration and climate observation could assist Mongolia in its adaptation efforts. For instance, China's successful use of remote sensing and early warning technologies in Inner Mongolia could be applied to Mongolia's similar ecosystems (Zhang et al., 2020). But this would need to be paired with capacity building for proper use and long-term sustainability.

Capacity building programs are particularly important as they not only can remedy present inequalities, but can lay the groundwork for future collaboration, with stronger institutions in both countries able to work together; as Batunacun et al.(2018) point out, building local institutional capacity, especially in implementation and monitoring of climate adaptation, will be key to long-term success, which could be supported by joint research programs, technical training programs, and platforms for sharing knowledge.

6. Discussion

The research of climate-change responses in the border region of China and Mongolia shows the transnational nature of the environmental challenge and the need for integrated responses: the different governance models that China and Mongolia have are interesting in that they show the complementarity that may be harnessed for climate adaptation, from China's resources and technology and Mongolia's community-based heritage and local knowledge, to potentially create more effective hybrid models of governance.

Asymmetry of resources is a key obstacle to transboundary cooperation, which new financing instruments like joint climate funds or cross-border carbon markets could begin to surmount, albeit with equity and local capacity considerations carefully integrated into their design.

The institutional arrangements responsible for trans-boundary climate-change reactions need updating to fit the contemporary profile of the problem; new models of adaptive governance that

are emerging, and which center on flexibility and multi-actor participation, seem promising, but these must not jeopardize the need for concerted action at the cost of local custom and culture.

The experiences of the China-Mongolia border region can be informative to other transboundary areas in a similar situation: the integration of diverse governance approaches, knowledge bases and resource allocation strategies could be of interest to regions such as the Sahel, the Amazon Basin, who are facing similar challenges, and have similar institutional capabilities and resource endowments. These experiences indicate that transboundary climate governance, to be effective, should be: institutional design and local context to be considered, with a balancing act including flexibility to adapt to changing situations.

7. Conclusion

The analysis of climate change's impact and response measures in the China-Mongolia border region reveals not only major challenges but also opportunities for greater cooperation. The data and analysis support the argument that climate change is impacting both China and Mongolia in interrelated ways and that their responses to the threat should be coordinated, as the effects cross national borders.

These researches lead to several conclusions: first, climate change impacts in the border region are more substantial than previously thought, with severe consequences for environmental and socio-economic systems; temperatures in the region have risen by 2.1°C over the last 50 years, a rate significantly higher than the global average, indicating that the region is especially vulnerable to climate change (Zhang et al., 2020).

Second, although both countries have made significant climate change adaptation efforts, the success of these initiatives has been constrained by policy convergence and resource gaps; the difference between significant technological investments in China and Mongolia's regional and community-focused approach underscores this (Wang et al., 2013).

Third, cooperation frameworks to date, despite having potential, have not fully grappled with the scale and complexity of the climate change crisis in the region, with future success dependent on institutional mechanisms, resource sharing, and capacity building (Li et al., 2022).

Based on these findings, several recommendations can be made:

- Develop a joint climate change tracking and response system that uses current cooperation structures but improves on current weaknesses.
- Create new financing models to help fund coordinated adaptation efforts in the border region.
- Build more vigorous capacity-building exercises, especially in fields where current resource inequalities impede good cooperation.
- Build platforms for sharing knowledge and transferring technology that are mindful of both countries' specific circumstances and help drive effective climate change mitigation and adaptation responses.

With more research, there can be more precise ideas on how to implement these ideas, especially considering the changing climate and socio-economic reality. Furthermore, a deeper dive into successful cooperation examples could offer helpful guidance for scaling up effective responses throughout the border region.

The results of this research will help inform transboundary climate change impact and response research and provide useful guidance for policymakers and practitioners on improving climate resilience in the China-Mongolia border area, which is experiencing increasing climate change impacts.

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