Quest Journals
Journal of Research in Environmental and Earth Sciences
Volume 11 ~ Issue 12 (December 2025) pp: 123-132
ISSN(Online) :2348-2532
www.questjournals.org

Research Paper

Climate Change, Ethnicity, and Inequality: Understanding the Ethno-spatial Distribution of Climate Vulnerability in China

Hengkun Chen

Abstract
While regional studies have repeatedly revealed the unequal distribution of climate impact across countries, regions, and social groups, exploration in the Chinese context remains inadequate. In particular, the understanding of climate impact's spatial distribution is missing at the national level. To address the current gap, this study applies the IPCC climate vulnerability assessment framework using data available in the 2022 Chinese Statistical Yearbook, computes numerical indices of climate vulnerability at the provincial level, and compares the indexes to understand the distribution of climate risks across provinces. The results were interpreted in relation to the geographical distribution of Chinese ethnic minorities and suggested a disproportionate concentration of climate vulnerability in ethnic minority regions. The paper also qualitatively explores factors motivating the disproportionality and concludes with a discussion on directions for future research that can better our shared understanding of the interaction between ethnic minorities and climate vulnerability. Through the research, the author hopes to highlight the interplay between socioeconomic and climate inequality.

*Received 15 Dec., 2025; **R**evised 28 Dec., 2025; **A**ccepted 31 Dec., 2025 © The author(s) 2025.*
P**ublished with open access at **www.questjournas.org

I. Introduction

Growing up as a Manchu, my bedtime stories revolved around horseback riding, archery, hunting, and the Manchurian steppe, from which every aspect of Manchurian life stems. The steppe, however, is losing its verdure and degrading into barren land (Hilker et al. 2014; Schlag 2021). Due to global climate change, regional precipitation has declined considerably, leading to grassland degradation (Schlag 2021). In the meantime, unsustainable grazing practices, monocultural farming, land clearance, and other anthropogenic arrangements also exert further pressure on the ecological system and contribute to the observed decline (Schlag 2021). For the local economy, the decline is particularly problematic as many regional economic productions depend on the natural environment and translates to direct economic loss in the social system.

As the case of Manchuria suggests, the implications of climate change are often the joint results of human and natural factors. While the initial perturbation is ecological, a system's anthropogenic arrangements, such as the level of economic diversification, social infrastructure, and economic development, also play a role in moderating the effects (Turner et al. 2003; Bohle, Downing, and Watts 1994; White and Haas, 1975). As a result, climate impacts are disproportionately concentrated in countries, regions, and social groups where the moderating structures are less effective (Mileti 1999; Rechkemmer and Falkenhayn 2009). Findings by Mendelsohn et al. (2006) suggested that under-developed countries are facing higher levels of climate change-induced economic loss while Peacock et al. (1997) concluded that, even when faced with the same climate impact, minoritized social groups are systematically worse off.

Together, these findings reveal patterns of climate inequality conditioned by socioeconomic inequality within and without societies.

Despite the growing understanding of climate impact and its unequal distribution, research exploring the distribution in the Chinese context continues to be sparse. The lack of understanding is not only a scholarly concern, but also a practical one, as it undercuts public policy efficacy and denies particularly vulnerable groups the support they need (Mileti 1999). To address this issue, this paper quantitatively models the distribution of climate change across the Chinese provinces and identifies particularly vulnerable provinces. The paper also takes into consideration that China is an ethnically pluralistic country with minority groups divided by geography and discusses the implications of provincial climate change distribution in the context of ethnic minority livelihood. The overall purpose of the paper is twofold: to identify highly vulnerable regions and groups in the context of climate change and to analyze the human-environment factors motivating the disparities in vulnerability. Through the paper, the author aims to highlight not only the inequalities of climate risks but also the entrenched socioeconomic inequalities that shape it.

II. Literature Review

2.1 Climate Vulnerability

To conceptualize the joint influence of human and environmental factors in realizing climate change's impact, scholars in the field have developed a new framework—climate vulnerability assessment—to systematically review, assess, and compare system-wide damage resulting from climate change (Hahn, Riederer, and Foster 2009). The framework provides a basis for comparing and understanding the distribution of climate risks across collections of systems.

However, current scholarship lacks a consensual agreement on the exact definition of climate vulnerability (Schröter, Polsky, and Patt 2005). On the one side, literature on poverty and human development defines climate vulnerability as a function of social arrangements and attributes the vulnerability to socioeconomic factors (Bohle, Downing, and Watts 1994). On the other side, ecological works focus on studying the biophysical sphere and the influence of the natural state on climate vulnerability (Bohle, Downing, and Watts 1994; Closset et al. 2017). As seen, subject-specific definitions often focus exclusively on variables and factors relevant to their field and exclude wider considerations that are beyond the scope of the discipline, resulting in limited frameworks that neglect parts of the collective human-environment system under question. For example, the human development approach fails to consider the socioeconomic effects of natural degradation in the aftermath of a climate event, leading to an incomplete assessment of the risks involved.

In 2007, the Intergovernmental Panel on Climate Change (IPCC) formulated a more comprehensive climate vulnerability framework, defining vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. It is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (Solomon 2007, 17). The IPCC framework considers both the initial ecological perturbation and the social processes through which it is transformed into a tangible impact. The framework has been widely used in application-based studies, and this study adopts it as the basis for inter-provincial climate vulnerability comparison.

However, the current IPCC conceptualization is not without flaws. While the flexibility in the current vulnerability definition allows researchers to operationalize it in a way that is particular to their circumstances, it also produces a largely heterogeneous research landscape where every operation differs. Take Pandey and Bradsley's (2015) and He's (2021) research as examples. Although both used the IPCC framework to construct their operational models, they selected vastly different indicators to assess and derive the final climate vulnerability index.

Hence, while both are informative in presenting the specifics of the region studied, we cannot compare the vulnerability of the two regions through the studies since their respective vulnerability indexes represent incongruent information.

2.2 China

Incomparable findings are particularly problematic in the Chinese context. As mentioned, climate vulnerability remains an underexplored scholarly field in China, and only regional studies are available (Wang et al. 2014; Xia et al. 2021; Yang et al. 2014; Liu et al. 2020). Although regional investigations reveal the distribution of climate vulnerability within the scope of their investigation, the differences in the indicator matrices render a national-level comparison across the studies unattainable. As a result, an understanding of the spatial vulnerability distribution at the national level remains missing.

Another gap in the Chinese climate discussion is the distribution of climate vulnerability across different ethnicities. While many foreign studies illustrate the unequal distribution of climate vulnerability across the ethnic dimension, similar studies are missing in the Chinese context (Phuong et al. 2023; Berkes and Jolly 2001; Brotton and Wall 1997). Current Chinese scholarship exploring the interaction between climate change and ethnicity only uses qualitative case studies and involves selected regions, and the investigation focuses on the impacts of a specific climate factor, such as regional precipitation (Lun et al. 2020). Hence, the studies cannot comprehensively understand system-wide climate risks. Furthermore, the current literature only covers a few ethnic minority communities and leaves the vast majority unaddressed.

To bridge the gap in understanding the distribution of climate vulnerability in China across the ethnic and spatial dimensions, this study strived to answer the following questions:

1. How is climate vulnerability distributed across China at the provincial level?

2. What accounts for the observed distribution of climate vulnerability at the provincial level?
3. How does the spatial distribution of climate vulnerability correlate with the geographical distribution of ethnic minorities?

III. Framework and Methodology

3.1 Research Context:

The focus of this study, China, is one of the world's most populous and expansive countries. China is home to over 1.4 billion people and occupies over 3 million square miles of land. The vast land stretches over many different topographies. The western Chinese region, the Tibetan Plateau, is the highest plateau on Earth. The Himalayas, Karakoram, and Kunlun mountains tower over its border. Moving eastward from the highlands is the Central Plain, where the Yangtze, Yellow, and Pearl rivers flow. The river valley is also China's most agriculturally productive region. To its east is the coastal region, where most of the country's commercial centers are located (Veeck 2021).

The country is also home to 55 ethnic minority groups that comprise 8% of the population. Most ethnic minority groups are concentrated in borderlands (Shen et al. 2011). The Tibetans, Uyghurs, and Mongolians live primarily in the country's western highlands. In the river basins, near the southern borders, are the homes of the Yao, Zhuang, Miao, and many others – the southern border province of Yunnan is home to over 25 ethnic minority groups by itself.

Some other groups, like the Manchus, Sibe, and Oroqens, are in the northern Central Plain while others are dispersed throughout the country after centuries of dispersion (Shen et al. 2011).

3.2 Research Framework

This study adopted the IPCC definition of climate vulnerability: a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (Solomon 2007). Using the definition and established practices in other applications, this study selected 28 socioeconomic and natural indicators to quantitatively assess climate vulnerability across the three aspects of exposure, sensitivity, and adaptive capacity and compare them provincially (see Figure 1).

Exposure measures the frequency, magnitude, and spatial distribution of external climatic perturbations experienced by a system (Cardona et al. 2012; Ford and Smit 2004). This study chose six provincial-level indicators to quantify exposure. The standard deviation of annual temperature and precipitation provides a representative proxy for the level of climate variability, while the areas of land impacted and devastated by climate events (in hectares) and the resulting human and economic loss provide a comparable measure of the magnitude and frequency of climate change.

Sensitivity refers to the human-environment conditions that influence response and coping mechanisms to a given climatic event (Turner et al. 2003). In particular, this study adopted Turner's (2003) definition of social-ecological sensitivity, which attributes a system's sensitivity to entitlement, the legal and customary right of access to life necessities, and endowments, the biophysical and socio-economic capital available to the system. To measure sensitivity, this study selected ten socioeconomic and natural indicators. Water supply coverage, gas supply coverage, medical staff per thousand, hospital bed per thousand, unemployment rate, and social belief rate represent the level of entitlement and endowment available in the social subsystem. The forest coverage rate and air excellence rate are included to indicate the natural endowment available. Also, the study selected rural population proportion and agricultural economic output proportion to indicate the interdependence between the social and natural subsystems and identify additional pathways that can impact the coupled human-environment system and contribute to the system's sensitivity to climate change (Turner et al. 2003).

Adaptive capacity refers to a system's ability and potential to plan, adapt, and recover in response to climate variability and exposure to harm (Ebi, Kovats, and Menne 2006; Adger et al. 2007). In Pandey and

Bradsley's (2015) case study, the researchers measured a community's adaptive capacity across five types of capital: financial, natural, human, physical, and social. This study synthesized Pandey and Bradsley's (2005) application with that of He et al. (2021), which includes adaptive willingness in its capacity assessment to reflect subjective change willingness. Per capita cultivated land, output value per hectare of land, durable good possession index, agricultural industrial productivity index, illiteracy rate, dependency ratio, secondary school enrollment rate, number of labor unions, number of labor union participants, and per capita disposable income were used to represent the five types of capital holistically. Investment in environmental infrastructures and forest conservancy percentages are selected as indicators for the system-wide adaptive willingness level.

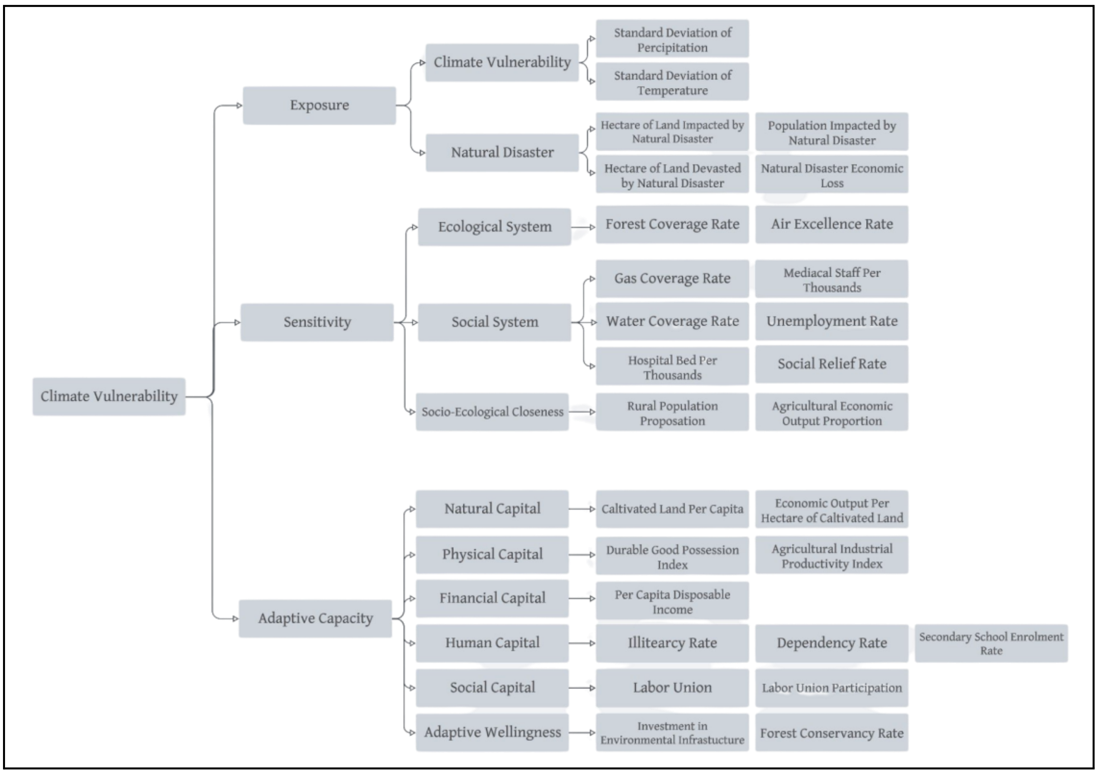


Figure 1. A visualization of the climate vulnerability framework used in the study

3.3 Data Source

Except for the standard deviation of temperature and precipitation, data for all other provincial-level indicators was obtained from the National Bureau of Statistics of China's *2022 Statistical Yearbook.* For the two standard deviations, data was obtained from the China Meteorological Administration's data service center and included annual temperature and precipitation for the past decade (2012 – 2022) at the provincial level.

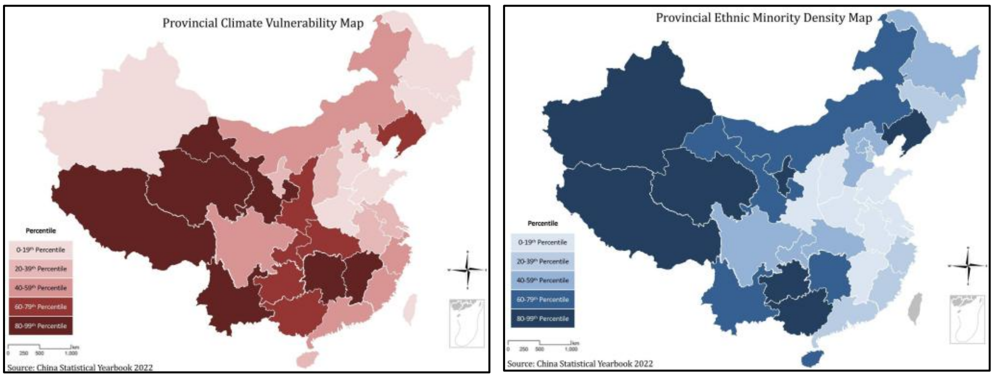
3.4 Research Method

This study adopted a multi-step approach to determine a comparable and impartial climate vulnerability index for each of the 31 Chinese provinces, autonomous territories, and municipalities (excluding the special administrative regions of Hong Kong, Taiwan, and Macau). To account for inherent variability in the population, economic development status, and other confounding factors, the study first relativized all of the indicators, adopting per capita and percentage measurements to ensure horizontal comparability across provinces. Then, the max-min normalization approach was used to standardize the index dimensions. The study also adopted the entropy method, an established approach in vulnerability assessment, to impartially evaluate the weightage of each indicator in the three aspects of exposure, sensitivity, and adaptive capacity. The final vulnerability index was computed using Hahn's (2009) formula. The exact procedure is enclosed in Appendix 1.

IV. Analysis

4.1 Results

For each province, the study calculated a quantitative vulnerability index. A complete list of the results can be found in Appendix 2. The resulting vulnerability index ranges from 1 to -1, where a higher (more positive) value indicates a higher level of climate vulnerability. Based on the index scores, each province was categorized into one of the five percentile-based categories: Very invulnerable (bottom quintile), Vulnerable (second quintile), Medium (third quintile), Vulnerable (fourth quintile), Very vulnerable (top quintile). The results were visualized in Figure 2 (b). For a categorized list of the provinces, see Appendix 3.



(a) (b)

Figure 2. A visualized distribution of provincial climate vulnerability (a) and ethnic minority density (b).

4.2 Descriptive Overview

As seen in Figure 2, the distribution of climate vulnerability in China is spatially unequal, where the vulnerability is significantly higher in the south and southwest regions. Regional clusters of high climate vulnerability characterize southern and south-western China. The adjacent southern provinces of Yunnan, Guizhou, Hunan, Hubei, Guangxi, Chongqing, and Jiangxi are all relatively high or very high vulnerability regions, as is the Tibet-Qinghai-Gansu cluster. In northern China, however, clusters are of low climate vulnerability. For example, the adjacent northern provinces of Shandong, Henan, and Hebei exhibit very low levels of climate vulnerability. Also, the least vulnerable province, Heilongjiang (-0.47), is at the northern frontier of the country.

More interestingly (but also concerning), the distribution of climate vulnerability largely overlaps with the distribution of ethnic minorities—nine out of the twelve most climate-vulnerable provinces are also the most ethnically diverse (see Figure 2). Hence, the interactions between climate vulnerability and ethnic minority composition deserve further exploration. To investigate, the study categorizes provinces into four distinct categories based on their ethnic minority composition and climate vulnerability (see Table 1). Provinces were categorized as either high (top 50th percentile) or low (bottom 50th percentile) for each of the two variables. The following section analyzes distinct patterns in each category to understand the results of the interaction better.

	High Climate Vulnerability	Low Climate Vulnerability
High Ethnic Minority Composition	Liaoning, Hunan, Guangxi, Chongqing, Guizhou, Yunnan, Tibet, Gansu, Qinghai	Inner Mongolia, Jiling, Hainan, Sichuan, Ningxia, Xinjiang
Low Ethnic Minority Composition	Beijing, Zhejiang, Fujian, Hubei, Jiangxi, Guangdong, Shaanxi	Tianjing, Hebei, Shanxi, Heilongjiang, Shanghai, Anhui, Jiangsu, Shandong, Henan

Table 1. Categorization of the provinces across the ethnic minority composition and climate vulnerability dimensions

4.3 Categorical Analysis:

4.3.1 : High Climate Vulnerability–High Ethnic Minority Composition:

Liaoning, Hunan, Guangxi, Chongqing, Guizhou, Yunnan, Tibet, Gansu, Qinghai

Provinces with high vulnerability and ethnic minority composition have a relatively high exposure (0.38-0.59) to climate change, except Tibet, which will be separately explored. The high levels of exposure to climate change are mainly attributed to natural disasters and their repercussions. For the provinces of Hunan, Gansu, and Yunnan, natural disasters have impacted over 20% of the population, exposing the provincial social system to a great degree of climate damage. For the provinces of Liaoning, Hunan, and Chongqing, the natural disasters impact agricultural land and crops, leading to below-expectation yields in 15%, 30%, and 19% of agricultural land in the provinces, respectively, and leveling damage to the provincial ecological and social

system. Hence, while the exact disaster type and impact pathways differ, the provinces share a high frequency and large magnitude of climate perturbations.
These provinces also share a medium to high level of climate sensitivity (0.34-0.72).
Most provinces (except Chongqing, a developed municipality) have a high level of socio-ecological closeness, where the human and the natural systems are highly intertwined and interdependent. In particular, the provinces have high proportions of rural residents (34 - 62%) who are sensitive to perturbations in their natural surroundings due to physical proximity, economic reliance, and a lack of disaster relief infrastructure.

The provinces also have low levels of adaptive capacity (0.05-0.44), except for Hunan, a highly industrialized province. The provinces have low natural, physical, financial, and social capital levels. Land is scarce in these provinces, and the agricultural yield (measured in output revenue per hectare) is below the national average of 88988 RMB/hectare. The provinces also have low machine inventory levels, disposable income, and labor union participation. When faced with climate perturbations, limited access to physical, financial, and social capital restricts these provinces and their residents' ability to respond productively and prevents households from implementing effective mitigation policies.
Tibet is a special case that deserves particular attention. For Tibet, the main driver behind its climate vulnerability is not exposure to climate change, which is marginal in the region (0.07). Instead, it is the extremely low level of adaptive capacity (0.05) – the lowest in the country – that leads to the observed vulnerability. A historically underdeveloped frontier, Tibet has the lowest level of secondary student enrollment, labor union participation, literacy rate, and land availability across all provinces. Hence, its residents have the country's lowest capacity to respond to any climate event, for they have an extremely limited capital collection.

4.3.2 : High Climate Vulnerability–Low Ethnic Minority Composition:
Beijing, Zhejiang, Fujian, Hubei, Jiangxi, Guangdong, Shaanxi
Provinces in this category have medium to high exposure to climate change (0.16-0.86), except for Beijing, which has a low level of exposure (0.10). The main driver behind the exposure is climate variability. For instance, the standard deviations of precipitation in these provinces are all above 200 ml, far above the 138 ml national average. As for the level of exposure to climate disasters, there is a wider degree of inter-provincial variation. While one of the provinces, Jingxi, has the nation's highest level of exposure to natural disasters, many other provinces in the same category have significantly lower levels, at around the national average of 0.27. Hence, while the level of exposure is high overall, considerable inter-provincial variations still exist.
For climate sensitivity, the provinces consistently have low levels of sensitivity (0.09-0.37). Two main factors account for this observation – the well-placed infrastructures and the separation of social and ecological systems. In all the provinces, there is a high, near-perfect coverage percentage of water and gas supply and a relatively low unemployment rate, suggesting a functioning social system that is resilient to climate perturbations. Additionally, agricultural output composition is low in the provincial economic output (0.3 - 10%), and the rural population is small as a percentage of the population (12 - 38%). The provincial economies are largely separated and independent from their ecological surroundings, so they are not sensitive to environmental changes.

These provinces also have a medium to high adaptive capacity (0.44 - 0.63). The adaptive willingness, in particular, is consistently high across the provinces. The forestry conservancy rate is mostly above 80% across the provinces, suggesting high levels of provincial involvement in restoring and protecting the ecological surroundings. As for the adaptive capitals (social, natural, human, physical, and financial), there exists a larger inter-provincial variation. Overall, the level of capital is medium to high for the provinces, suggesting adequate adaptive ability in the face of climate shocks.

4.3.3 : Low Climate Vulnerability–High Ethnic Minority Composition:
Inner Mongolia, Jiling, Hainan, Sichuan, Ningxia, Xinjiang
These provinces have a medium to low exposure level (0.07-0.35). Most provinces – Jiling, Hainan, Ningxia, Xinjiang – have low incidents of natural disasters, and less than 5% of land and population are impacted by climate events. The social system and its ecological surroundings are largely stable, unaffected by climate events. A few provinces – Inner Mongolia and Sichuan – have higher incidences of climate perturbation, but the proportion of land and population impacted is still below 15%. Overall, exposure remains moderately low in these provinces.

However, sensitivity to climate change is unanimously high across provinces in this category (0.43-0.64). The interdependence between the anthropogenic and ecological systems is the main driver behind the elevated sensitivity level. The rural population comprises 31% to 42% of the provincial population, and agricultural output is 9% to 22% of the provincial output (measured in RMB). The socio-ecological interconnectedness and interdependence render these provinces sensitive to changes in climate, ecology, and the natural environment surrounding them, for they heavily influence the livelihoods of many of their residents.

The provinces' adaptive capacity is medium (0.33 - 0.55). Disposable income, labor union participation, and agricultural machinery inventory are particularly low, impacting provincial financial, social, and physical capital and limiting the provinces' residents' capability to respond, adapt, and mitigate climate perturbations, which heavily involve the use of capital.

4.3.4 : Low Climate Vulnerability–Low Ethnic Minority Composition:

Tianjing, Hebei, Shanxi, Heilongjiang, Shanghai, Anhui, Jiangsu, Shandong, Henan

Provinces in this category face a low level of climate exposure (0.04 - 0.20). The level of natural disaster incidence is low in the nine provinces, where natural disasters or climate perturbations impact less than 10% of land and 8% of the population.

These provinces also have low levels of climate sensitivity (0.15-0.39), except for Heilongjiang, which produces the most agricultural output in China. In these provinces, the social systems are non-fragile, and infrastructures are well-placed, suggesting a high level of societal resilience to climatic changes and shocks. The gas and water coverage rates are near perfect across the provinces, and there is minimal need for social support (government transfer payment). Besides Heilongjiang, agriculture comprises between 0.2% and 11% of total provincial output, indicating a low level of dependence on the ecological surroundings for residents in these provinces.

The level of adaptive capacity is medium to high in these provinces (0.41 - 0.68). Within the category, there are two clusters of provinces, one with medium-level capacities and the other with high levels. High levels of adaptive willingness and physical capital characterize provinces with high levels of adaptive capacity (0.59-0.64). Both the forest conservancy rate and the level of agricultural machinery inventory are high in this cluster of provinces. As for the less adaptive ones (0.41-0.52), the amount of machinery, land endowment, and levels of labor union participation are noticeably lower, reflecting lower levels of provincial physical, natural, and social capital.

4.4 Conclusive Pathways

In the analysis, it is noted that ethnically diverse provinces, regardless of their climate vulnerability level, share a few structural, anthropogenic disadvantages:

1. *High levels of sensitivity* to climate change resulting from the provinces' dependence on agricultural output and their large share of rural residents.
2. *Medium to low adaptive capacity* to climate change because of low levels of disposable income, agricultural machine inventory, and labor union participation that limit the ways in which people can respond to climate stressors.

The only factor differentiating the two groups – high climate vulnerability and low climate vulnerability – is the level of climatic exposure, as determined by regional geography and meteorology. To understand possible factors contributing to the shared structural disadvantage, the following section hypothesizes and explains several possible reasons.

V. Discussion:

The observed disadvantages might have resulted from many economic, social, and cultural factors. However, the lack of relevant data and research prevents quantitative corroboration and identifying specific drivers. The following section uses qualitative, ethnographic studies of the interested regions to explore potential pathways leading to the structural disadvantage. The exploration focuses primarily on ethnic minority relevant factors because high levels of ethnic minority composition are a shared feature in the provinces.

V.1 : Reliance on Agriculture

Many ethnic minority communities rely on agriculture as a primary means of income. In Yunnan, Jingpo, Bulang, Jinuo, Dulong, and other ethnic minority communities primarily
practice shifting agriculture (Zhong and Liu 2013). Many ethnic minorities in southwestern

China also use terraced agriculture, which is more apt for elevated and varied geography. Miao, Yao, Zhuang, She, and Dong are among many ethnic minorities that adopt terraced agriculture as their main form of agricultural production (Lun et al. 2020). In central China, ethnic minority such as Dong and Dai uses paddy field farming, sometimes developing sophisticated agricultural chains – like the "rice-fish-duck" system of the Dong people that compound numerous economic production within the space of the paddy fields (Nursey-Bray et al. 2022). The development and continuation of such culturally unique and geographically situated means of agricultural production often form an integral part of social arrangements in ethnic minority communities and inform their sense of ethnic self.

However, such traditional practices often cannot adapt to climate change and expose the communities that practice them to great risk and loss. In southwest China, climate change has strained the local water supply necessary to irrigate terraced fields and increased the frequency of crop disease and insect pests, leading to lowered levels of economic production and income (Lun et al. 2020). For the Dai Paddy farm, the recent rise in temperature and drought frequency has led to a decline in rice yield, as many cultivated species are not resilient to heat and drought (Lun et al. 2020). In many such instances, ethnically traditional farming practices, developed in a climate-stable context, struggle to respond to changes in the ecological system effectively, and reliance on such practices has led to degrees of economic loss.

V.2 Lack of Access to Capitals

Lack of access to capital is also a possible contributor to the ethnic minorities' structural disadvantage. Bhalla and Qiu's (2006) investigation revealed significant income gaps between ethnic minority and Han communities in different regions of the country in the twentieth century. Although newer data is no longer available, economic and financial gaps likely persist in contemporary times. Also, ethnographic studies indicate that ethnic minorities, such as the Uyghur, use traditional machinery to practice agriculture production, suggesting a lack of inventory for capital that can improve efficiency and climate resilience in the production process (Nursey-Bray et al. 2022).

The lack of financial and physical capital limits these communities' ability to adapt in response to climate change. For example, heavy rain and flooding can easily overflow the Wa people's shifting agriculture fields at the hillside, for they lack efficient irrigation systems (Lun et al. 2020). Similarly, the Tibetan Alpines, an important ecological link in the local agro-pastoralist economic arrangements, are exposed to high levels of precipitation variability and experiencing rapid degradation in the absence of preventative or recovery mitigation measures (Wang et al. 2014). The lack of physical capital and financial resources reduces ethnic minority communities' ability to actively respond in the face of climate pattern changes and perturbation, exposing them to a higher degree of risk.

VI. Limitations and Future Research Directions:

Still, it should be noted that the pathways proposed are only a few of the many potential factors, and in no way is the study trying to suggest exclusive, casual ethnic minority ownership for the observed disadvantage. The purpose behind the tentative exploration is to suggest possible future research directions that can be further explored when and if data becomes available:

1. What are the main socioeconomic (ethnic-related or non-ethnic-related) drivers behind the observed structural disadvantage?
2. What is the distribution pattern of structural disadvantage across different ethnic minority-rich provinces?
3. What are some possible policies that can account for the structural disadvantage while maintaining ethnic minority heritage, community, and identity?
4. What are the implications of the observed structural disadvantage on ethnic minority cultural, community, and identity preservation?

Besides the lack of data, there are also a few other limitations worth highlighting. First, the study mainly uses cross-sectional data from one sampling year, 2022, which might expose the study and its findings to random errors and impact its level of representation. One way this can be improved is by using the average of a longer sampling period (i.e., a decade). Second, the selection of indicators might have introduced biases in the research, especially when a few indicators are close substitutes for one another (i.e., the proportion of the population on social relief and the proportion of the population on government transfer payments). This could have been improved if and when more standardized operational procedures became available. Lastly, the study could have adopted more sophisticated statistical techniques, such as Pearson's Chi-Square Test, ANOVA (ANCOVA), or MANOVA (MANCOVA), to explore the interactions of ethnic minority composition and climate vulnerability and conclude statistically sound findings with regard to the hypothesized correlation.

VII.Conclusion:

Overall, this paper analyzed the spatial distribution of climate vulnerability in China.
Findings from the vulnerability assessment indicate a highly unequal distribution concentrated primarily in the south, subjecting southern provinces to greater degrees of climate risks. The findings also suggest that the vulnerability distribution concentrates disproportionately on ethnic minority-rich provinces, where 9 out of the 12 provinces with the most ethnic minorities are also the most climate-vulnerable. Through corroboration with ethnographic studies, this study proposed a few possible impact pathways that might have led to the observed phenomenon, but without comprehensive data, no conclusive findings on ethnic inequality in climate vulnerability distribution were identified. Through the study, the author highlighted the joint influence of socioeconomic and geographical forces in shaping a region's, in this case, a province's, level of climate vulnerability, and how climate vulnerability inequality can build on top of existing inequality within and across societies. To move forward in this under-explored area, future researchers should consider exploring the implications of climate vulnerability in the context of historically minoritized and marginalized communities and how public policy can best support those of particular vulnerability.

Reference List

[1]. Adger, W., Shardul Agrawala, M.M.Q. Mirza, Cecilia Conde, Karen O'Brien, Juan Pulhin, R. Pulwarty, B. Smit, and Kiyoshi Takahashi. 2007. "Assessment of Adaptation Practices, Options, Constraints and Capacity. Climate Change 2007: Impacts, Adaptation and Vulnerability." *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, January, 717–43.

[2]. Berkes, Fikret, and Dyanna Jolly. 2001. "Adapting to Climate Change: Social-Ecological Resilience in a Canadian Western Arctic Community." *Conservation Ecology* 5 (2). https://doi.org/10.5751/ES-00342-050218.

[3]. Bhalla, A. S., and Shufang Qiu. 2006. *Poverty and Inequality Among Chinese Minorities.*Routledge.

[4]. Bohle, Hans G., Thomas E. Downing, and Michael J. Watts. 1994. "Climate Change and Social Vulnerability: Toward a Sociology and Geography of Food Insecurity." *Global Environmental Change* 4 (1): 37–48. https://doi.org/10.1016/0959-3780(94)90020-5.

[5]. Brotton, Janet, and Geoffrey Wall. 1997. "CLIMATE CHANGE AND THE BATHURST CARIBOU HERD IN THE NORTHWEST TERRITORIES, CANADA." *Climatic Change* 35 (1): 35–52. https://doi.org/10.1023/A:1005313315265.

[6]. Cardona, Omar-Dario, Maarten K. Van Aalst, Jörn Birkmann, Maureen Fordham, Glenn McGregor, Rosa Perez, Roger S. Pulwarty, et al. 2012. "Determinants of Risk: Exposure and Vulnerability." In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, edited by Christopher B. Field, Vicente Barros, Thomas F. Stocker, and Qin Dahe, 1st ed., 65–108. Cambridge University Press. https://doi.org/10.1017/CBO9781139177245.005.

[7]. Closset, Mathilde, Sosso Feindouno, Patrick Guillaumont, and Catherine Simonet. 2017. "A Physical Vulnerability to Climate Change Index: Which Are the Most Vulnerable Developing Countries?" https://hal.science/hal-01719925.

[8]. Ebi, Kristie L., R. Sari Kovats, and Bettina Menne. 2006. "An Approach for Assessing Human Health Vulnerability and Public Health Interventions to Adapt to Climate Change." *Environmental Health Perspectives* 114 (12): 1930–34. https://doi.org/10.1289/ehp.8430.

[9]. Ford, J. D., and B. Smit. 2004. "A Framework for Assessing the Vulnerability of Communities in the Canadian Arctic to Risks Associated with Climate Change." *ARCTIC* 57 (4): 389–400. https://doi.org/10.14430/arctic516.

[10]. Gilbert F. White and J. Eugene Haas. 1975 "Assessment of Research on Natural Hazards." MIT Press. Accessed June 18, 2024. https://mitpress.mit.edu/9780262080835/assessment-of-research-on-natural-hazards/.

[11]. Hahn, Micah B., Anne M. Riederer, and Stanley O. Foster. 2009. "The Livelihood Vulnerability Index: A Pragmatic Approach to Assessing Risks from Climate Variability and

[12]. Change—A Case Study in Mozambique." *Global Environmental Change* 19 (1): 74–88. https://doi.org/10.1016/j.gloenvcha.2008.11.002.

[13]. He, Yueyue, Zhou, Changchun, and Ahmed, Tanveer. 2021. "Vulnerability Assessment of Rural Social-Ecological System to Climate Change: A Case Study of Yunnan Province, China." *International Journal of Climate Change Strategies and Management* 13 (2): 162–80. https://doi.org/10.1108/IJCCSM-08-2020-0094.

[14]. Hilker, Thomas, Enkhjargal Natsagdorj, Richard H. Waring, Alexei Lyapustin, and Yujie Wang. 2014. "Satellite Observed Widespread Decline in Mongolian Grasslands Largely Due to Overgrazing." *Global Change Biology* 20 (2): 418–28. https://doi.org/10.1111/gcb.12365.

[15]. Liu, Yimeng, Saini Yang, Chuanliang Han, Wei Ni, and Yuyao Zhu. 2020. "Variability in Regional Ecological Vulnerability: A Case Study of Sichuan Province, China." *International Journal of Disaster Risk Science* 11 (6): 696–708. https://doi.org/10.1007/s13753-020-00295-6.

[16]. Lun, Yin, Misiani Zachary, Yanyan Zheng, and Xiaohan Zhang. 2020. "The Impacts of Climate Change on the Traditional Agriculture of Ethnic Minority in China." *Journal of Environmental Science and Engineering A* 9 (2). https://doi.org/10.17265/2162-5298/2020.02.001.

[17]. Mendelsohn, Robert, Ariel Dinar, and Larry Williams. "The Distributional Impact of Climate Change on Rich and Poor Countries." *Environment and Development Economics* 11, no. 2 (2006): 159–78. https://doi.org/10.1017/S1355770X05002755.

[18]. Mileti, Dennis. 1999. *Disasters by Design: A Reassessment of Natural Hazards in the United States*. Washington, D.C.: Joseph Henry Press. https://doi.org/10.17226/5782.

[19]. Nursey-Bray, Melissa, Robert Palmer, Ann Marie Chischilly, Phil Rist, and Lun Yin. 2022.

[20]. "Ethnic Minorities, Traditional Livelihoods and Climate Change in China." In *Old Ways for New Days*, by Melissa Nursey-Bray, Robert Palmer, Ann Marie Chischilly, Phil Rist, and Lun Yin, 77–90. SpringerBriefs in Climate Studies. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-97826-6_5.

[21]. Pandey, Rishikesh, and Douglas K. Bardsley. 2015. "Social-Ecological Vulnerability to Climate Change in the Nepali Himalaya." *Applied Geography* 64 (October):74–86. https://doi.org/10.1016/j.apgeog.2015.09.008.

[22]. Peacock, Walter Gillis, Hugh Gladwin, and Betty Hearn Morrow, eds. 1997. *Hurricane Andrew: Ethnicity, Gender and the Sociology of Disasters*. London: Routledge. https://doi.org/10.4324/9780203351628.
[23]. Phuong, Tran Thi, Nguyen Quang Tan, Nguyen Cong Dinh, Huynh Van Chuong, Hoang Dung
[24]. Ha, and Hoang Thanh Hung. 2023. "Livelihood Vulnerability to Climate Change:
[25]. Indexes and Insights from Two Ethnic Minority Communities in Central Vietnam." *Environmental Challenges* 10 (January):100666. https://doi.org/10.1016/j.envc.2022.100666.
[26]. Rechkemmer, A., and L. Von Falkenhayn. 2009. "The Human Dimensions of Global Environmental Change: Ecosystem Services, Resilience, and Governance." *The European Physical Journal Conferences* 1:3–17. https://doi.org/10.1140/epjconf/e2009-00906-y.
[27]. Schlag, Juliane. 2021. "Living in Decline – the Dynamics of Anthropogenic Disturbances in the Recent Landcover History of Manchuria and Its Consequences for Northeast Asia." *Asian Geographer* 38 (2): 179–96. https://doi.org/10.1080/10225706.2021.1952884.
[28]. Schröter, Dagmar, Colin Polsky, and Anthony G. Patt. 2005. "Assessing Vulnerabilities to the Effects of Global Change: An Eight Step Approach." *Mitigation and Adaptation*
[29]. *Strategies for Global Change* 10 (4): 573–95. https://doi.org/10.1007/s11027-005-6135-9.
[30]. Shen, Zehao, Peng Li, Hongkai Sun, and Lihua Pang. 2011. "Geographical Patterns of Chinese Ethnic Minority Population Composition and Ethnic Diversity." *Chinese Geographical Science* 21 (4): 454–64. https://doi.org/10.1007/s11769-011-0487-8.
[31]. Solomon, Susan, Intergovernmental Panel on Climate Change, and Intergovernmental Panel on Climate Change, eds. 2007. *Climate Change 2007: The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge ; New York: Cambridge University Press.
[32]. Turner, B. L., Roger E. Kasperson, Pamela A. Matson, James J. McCarthy, Robert W. Corell, Lindsey Christensen, Noelle Eckley, et al. 2003. "A Framework for Vulnerability
[33]. Analysis in Sustainability Science." *Proceedings of the National Academy of Sciences* 100 (14): 8074–79. https://doi.org/10.1073/pnas.1231335100.
[34]. Veeck, Gregory, Clifton W. Pannell, Xiaoping Shen, and Youqin Huang. 2021. "China's Geography: Globalization and the Dynamics of Political, Economic, and Social Change, Fourth Edition." Rowman & Littlefield. April 2021.
[35]. Wang, Yaping, Shi Benwei, Liang Zhang, Jianjun Jia, Xiaomin Xia, Liang Zhou, Rui Yu, Yang Yang, and Jianhua Gao. 2017. "Assessing the Vulnerability of Changing Coasts, Hainan Island, China." *Acta Oceanologica Sinica* 36 (January). https://doi.org/10.1007/s13131-017-0972-8.
[36]. Wang, Yang, Jun Wang, Shuangcheng Li, and Dahe Qin. 2014. "Vulnerability of the Tibetan Pastoral Systems to Climate and Global Change." *Ecology and Society* 19 (4). https://www.jstor.org/stable/26269655.
[37]. Xia, Mu, Kun Jia, Wenwu Zhao, Shiliang Liu, Xiangqin Wei, and Bing Wang. 2021. "Spatio-Temporal Changes of Ecological Vulnerability across the Qinghai-Tibetan Plateau." *Ecological Indicators* 123 (April):107274. https://doi.org/10.1016/j.ecolind.2020.107274.
[38]. Yang, Saini, Shuai He, Juan Du, and Xiaohua Sun. 2014. "Screening of Social Vulnerability to Natural Hazards in China." *Natural Hazards* 76, no. 1 (May): 1–18. https://doi.org/10.1007/s11069-014-1225-1.
[39]. Zhong, Shuoling, and Wendian Liu. 2013. *Overview of Chinese Regional Cultures*. Vol. Guangxi.
[40]. Beijing Shi: Zhonghua Book Company.