**From Food Belt to Migration Belt:  
Assessing the Socio-Spatial Impacts of the 2010 Drought on Agricultural Land Use and Rural Migration in Guizhou, China**

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**Declaration of Authorship**

I confirm that the work presented in this dissertation is my own. Where information has been derived from other sources, I confirm that this has been indicated in the dissertation.

#### Abstract

Provide a concise summary of your research background, aims, methodology, results, and contributions (150–300 words).

#### Acknowledgements

Acknowledge any individuals, institutions, or funding bodies who supported your research.

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# Introduction

## Background

In recent decades, the frequency and severity of extreme weather events have increased, primarily due to human activities (IPCC, 2021). These events, including droughts, floods, and heatwaves, pose an increasingly serious threat to agricultural systems, rural livelihoods, and socio-ecological resilience. Also, mountainous and ecologically fragile regions are particularly vulnerable due to terrain constraints, reliance on rain-fed agriculture, and limited adaptive capacity (Black *et al.*, 2011).

Worldwide, the Intergovernmental Panel on Climate Change (IPCC) reports that the intensity and frequency of compound extreme events are expected to increase under all future warming scenarios. In China, the average temperature has risen by more than 1.6 degrees Celsius over the past 60 years, and extreme drought events have become more frequent in the southwestern region (China Meteorological Administration, 2023). This trend poses a particular risk to agricultural sustainability in areas where more than half of the rural population is directly dependent on agricultural income for their livelihoods (*The State of Food and Agriculture 2021: Making Agrifood Systems More Resilient to Shocks and Stresses*, 2021).

Southwest China, including Guizhou Province, is highly susceptible to such risks. In 2010, the region experienced the most severe drought in decades, classified as an extreme El Niño-La Niña transition event (Luo *et al.*, 2019). Official statistics from Guizhou Province indicate that the drought affected over 1.5 million hectares of farmland, with disaster rates exceeding 70% in core high-risk counties, including Bijie, Dafang, Jinsha River, and Qianxi (Guizhou Provincial Bureau of Statistics, 2011). This drought was one of the most severe in the past 30 years, second only to the 1992 drought, resulting in widespread crop yield reductions, water shortages, increased forest fires, power outages, and long-term ecological stress. Guizhou's karst terrain has constrained the development of irrigation infrastructure, with rain-fed agriculture dominating (Luo *et al.*, 2019), exacerbating the impacts of insufficient rainfall.

Agriculture remains a key component of Guizhou's economy and livelihood, with over 60% of the population engaged in agricultural activities, and rural residents forming the bulk of the province's labour force (Guizhou Provincial Bureau of Statistics, 2011). The province is a major producer of corn, rice, and tuber crops, but its fragmented farmland and low level of mechanisation make it particularly vulnerable to climate change. As a result, climate shocks such as the 2010 drought not only severely impact agricultural production but also have adverse effects on household income security and migration decisions.

## Knowledge Gap and Research Motivation

The relationship between climate shocks, agricultural production, and migration has long been recognised in academic and policy discussions. Existing research indicates that environmental stressors can influence migration through direct channels (when livelihoods become unsustainable) and indirect channels (when agricultural productivity and income decline, prompting labour reallocation) (Black *et al.*, 2011; McLeman, 2018; Cattaneo *et al.*, 2019). However, migration responses are highly context-dependent and influenced by economic opportunities, migration costs, institutional environments, and household capabilities (De Haas, 2021).

In China, evidence suggests that climate change affects rural labour allocation (Wang, Chen and Shen, 2024; Zheng *et al.*, 2024), but most studies have focused on eastern provinces with convenient transportation and high agricultural productivity. For underdeveloped mountainous regions like Guizhou, where migration ability may be constrained, empirical research is scarce. Although the 2010 drought severely reduced agricultural output, it remains unclear whether and to what extent it triggered rural out-migration. Additionally, the spatial heterogeneity of drought impacts (potentially influenced by elevation, agricultural dependency, and infrastructure) has not been systematically evaluated.

Although existing literature on climate-induced migration in China provides valuable insights, it primarily employs national-scale econometric methods or household survey methods. Few studies have conducted spatially explicit analyses of agricultural and migration outcomes using clearly defined extreme climate events. Furthermore, Guizhou's complex socio-ecological environment—karst topography, high rural poverty rates, and limited non-agricultural employment opportunities—suggests that its migration response may differ significantly from patterns observed in more developed regions. This highlights the necessity of conducting case-specific, data-driven research to better understand the causal pathways linking climate shocks, agricultural viability, and population mobility.

## Research Aim and Questions

This study aims to explore the socio-spatial impacts of the extreme drought in Guizhou Province in 2010, focusing on agricultural productivity, rural population migration, and the moderating effects of local geographical and socio-economic characteristics. Additionally, this study aims to investigate the potential relationship between agricultural decline and population migration, considering the context of spatial heterogeneity.

The core research questions are:

1. Does extreme drought significantly affect agricultural productivity as measured by seasonal crop NDVI?

2. Does drought affect rural migration patterns?

3. How do county-level characteristics (e.g., altitude, urbanisation, and population density) influence these responses?

4. To what extent is the observed decline in agricultural vitality related to drought occurrence and migration trends?

Research contributions include:

1. Data integration — Combining satellite remote sensing (NDVI), climate indices (SPEI) and census data to construct a county-level panel data set.

2. Causal inference — Using difference-in-differences (DiD) estimation and event study designs to determine the causal effects of drought on agricultural productivity and migration.

3. Focus on spatial heterogeneity — Link climate, agriculture and migration within a framework that considers geographical and socio-economic diversity, with a focus on mountainous areas that are often subject to climate stress.

## Significance of the Study

This study contributes to climate-agriculture-migration literature in three ways.

First, it provides event-based empirical evidence from Guizhou, a mountainous and agriculture-dependent region that is largely absent from national and global analyses.

Second, it presents the integration of multi-source datasets (satellite NDVI, drought index (SPEI), and county-level demographic data) to enable spatially explicit assessments of drought impacts.

Third, it employs quasi-experimental methods (Difference-in-Differences and event studies) to strengthen causal inference, revealing spatial heterogeneity shaped by geographical and socio-economic factors.

In addition to academic contributions, the findings are highly aligned with China's rural revitalisation strategy. *The Rural Revitalisation Plan (2024–2027)* emphasises agricultural resilience, food security, improvements to rural infrastructure, and differentiated support for ecologically fragile and underdeveloped regions. By identifying the regions most severely affected by drought and its underlying causes, this study supports the development of targeted adaptation measures, promotes agricultural modernisation, and advances rural livelihood diversification within the framework of the national revitalisation strategy.

# Literature Review



## Climate-Agriculture-Migration Relations: Theoretical Foundations

The link between environmental change, agricultural production, and migration has been widely discussed in the migration literature. Black et al. (2011) propose a "five drivers" framework, identifying environmental change as one of the key drivers of migration, alongside economic, political, social, and demographic factors. Within this framework, environmental change can directly affect migration (e.g., by rendering livelihoods unsustainable) or indirectly influence migration (e.g., by disrupting agricultural productivity and income, prompting families to seek alternative livelihoods elsewhere). McLeman (2018) expanded this discussion by introducing the concept of threshold effects, suggesting that climate shocks only trigger migration when they exceed socio-economic or psychological thresholds.

The ‘desire-ability’ framework (De Haas, 2021) offers another perspective, emphasising that migration decisions depend not only on push factors but also on the ability to realise migration desires. This highlights an important unevenness: even in the face of severe environmental shocks, not all affected households can migrate. Resource-constrained populations, particularly in rural or mountainous areas, may lack the funds, information, or social capital required for migration, leading to what De Haas refers to as ‘involuntary immobility.

This framework helps explain why some vulnerable groups show lower migration rates even when faced with repeated environmental pressures, shifting the analytical focus from ‘why people migrate’ to ‘who can migrate.’ Therefore, when understanding how migrants respond to climate change, it is essential to consider structural and institutional factors.

Cattaneo et al. (2019, 2020) synthesised these perspectives and systematically articulated climate-induced migration pathways. They emphasised that agricultural decline (typically manifested as reduced yields, crop failures, or livestock losses) is a key intermediary mechanism between climate events and labour mobility. This pathway is particularly prominent in countries or regions where a significant portion of rural households’ income derives from subsistence or semi-commercial agriculture.

Further literature also demonstrates that the relationship between climate and migration is not universally linear or automatic. For example, Beine and Parsons (2014) point out that when financial or institutional barriers hinder migration, adverse climate conditions may, in some cases, lead to ‘’trapped population". Conversely, favourable environmental shocks may create surplus income, enabling long-delayed migration. This further emphasises the need for contextualised and categorised analysis.

These frameworks are particularly relevant for ecologically fragile and economically marginalised regions such as Guizhou, where livelihoods are heavily dependent on rain-fed agriculture and formal migration opportunities are limited. However, institutional and environmental factors may mitigate these mechanisms, particularly in China, which will be explored in subsequent chapters.

## Climate Shocks and Agricultural Productivity

Empirical studies consistently show that extreme weather events such as droughts, floods and heat waves significantly reduce agricultural productivity, especially in regions that rely on rain-fed agricultural systems. In China, this link is particularly pronounced in inland mountainous areas, where climate stress is compounded by environmental fragility and underdeveloped agricultural infrastructure.

At the national level, Wang, Chen, and Shen (2024) used longitudinal survey data and precipitation indices to examine how extreme rainfall affects crop yields and rural livelihoods. Their findings indicate that households in less affluent regions suffer more severe income losses and are more likely to reallocate labour after experiencing shocks. Although their study focuses on rainfall events rather than drought itself, it provides strong empirical support for the view that climate anomalies have significant impacts on rural production and economic behaviour.

Similarly, Zheng et al. (2024) analysed panel data from rural Chinese households and found that short-term climate variability—particularly changes in precipitation and temperature—affects farmers' labour allocation decisions. Importantly, they observed significant heterogeneity across regions, suggesting that poorer or ecologically fragile areas may be more vulnerable to agricultural disruptions. Their study provides micro-level evidence that climate indirectly affects agricultural labour decisions through income losses and uncertainty.

Focusing on Guizhou, multiple regional studies have confirmed that the province is particularly vulnerable to agricultural pressures caused by drought. Luo et al. (2019) studied the spatiotemporal characteristics of droughts in Guizhou and identified areas prone to persistent droughts, particularly in the northwestern part of the province. Their research highlighted how Guizhou's karst topography—with its thin soil layers and limited water retention capacity—exacerbates the effects of insufficient precipitation. These geographical constraints hinder the development of irrigation, leaving the region heavily reliant on rainfall and highly sensitive to hydrological anomalies.

Wei and Li (2021) used Normalised Difference Vegetation Index (NDVI) data to study vegetation dynamics in the Beipanjiang River Basin, linking topographic gradients and population distribution to vegetation responses. Their findings indicate that high-altitude areas exhibit more pronounced NDVI fluctuations in response to environmental stress. This spatial variability underscores the importance of using remote sensing vegetation indices to assess agricultural viability under climatic stress, particularly in areas where conventional yield statistics are unavailable.

In addition, NDVI has been shown to be of significant value in identifying interannual vegetation trends associated with major drought events. For example, Luo et al. (2019) and Wei and Li (2021) both observed a significant decline in NDVI during the 2010 Guizhou drought, supporting its use as an alternative indicator of crop vitality in drought assessments. Combined with climate indices such as the Standardised Precipitation Evapotranspiration Index (SPEI), these datasets enable researchers to construct time-sensitive, spatially explicit agricultural stress indices.

In summary, these studies support the use of normalised difference vegetation index (NDVI) and specific vegetation index (SPEI) in agricultural impact assessments and highlight the vulnerability of Guizhou's terrain and agricultural systems to climate change. This also lays the foundation for exploring how such environmental pressures trigger or inhibit population migration responses, which will be discussed in the next section.

## Climate Shocks and Migration

The relationship between environmental shocks and population mobility has been widely studied, but its impact remains highly dependent on the specific environment. At the global level, studies by Nawrotzki and DeWaard (2016) and others have shown that drought and aridity are important predictors of internal migration in low- and middle-income countries. These environmental drivers are often amplified in socioeconomically vulnerable environments, where subsistence agriculture dominates and adaptive capacity is limited.

In China, Cai, Feng, and Oppenheimer (2016) provide one of the few national-level quantitative studies linking climate change to population migration. Using a difference-in-differences (DiD) design and meteorological panel data, they find that adverse climate conditions, particularly drought, reduce crop yields, thereby increasing out-migration from affected rural counties. However, they also noted that the strength of this relationship is moderated by local economic development and labour demand in urban receiving areas. This highlights a dual mechanism: agricultural crop failures ‘push’ migrants away, while economic pull factors and institutional screening determine whether migration is feasible.

Yun, Yin, and Shen (2012) focused more on the drought in Guizhou Province from 2009 to 2010 and provided valuable background insights. Based on field investigations and institutional analyses in Qianxinan Prefecture, they found that households were often the first to feel the impact of drought, while government responses lagged behind. However, they observed that most households did not opt for large-scale migration but instead chose local adaptation strategies, including water rationing, changing cropping patterns, and temporary relocation of some household members. Their research emphasised the importance of distinguishing between permanent and short-term mobility, as well as individual and household coping strategies.

When interpreting Guizhou's population migration statistics, this distinction is crucial. As Huang (2020) demonstrated in her spatial analysis of population changes in the province, rural out-migration is often constrained by structural economic factors. Unlike the more developed provinces in the east, Guizhou still has limited non-agricultural employment opportunities, and the region's economy lacks strong urban labour attraction. Therefore, even if environmental conditions deteriorate, out-migration may be relatively moderate or delayed.

Moreover, institutional factors also play an important role. Ch**a**n (2010) argues that the household registration system creates structural barriers for rural migrant populations, particularly in terms of access to education, healthcare, and urban housing. These restrictions limit long-term or permanent migration and encourage temporary or cyclical migration patterns. Liang and Ma (2004) support this view with census-based evidence showing that the number of China's ‘migrant population’—individuals living and working outside their household registration area but not formally changing their place of residence—increased at the beginning of the 21st century. This mobility is typically excluded from official population migration statistics, which are based on permanent household registration changes.

This statistical blind spot is particularly relevant to research on population migration induced by environmental factors in China. Migration datasets derived from census records or statistical yearbooks may fail to capture drought-induced temporary labour mobility, especially when households retain formal residency rights in their place of origin while engaging in short-term work elsewhere. In such cases, declines in the Normalised Difference Vegetation Index (NDVI) may signal agricultural distress, but translating this into statistically observable migration may be challenging.

In conclusion, although climate stress may reasonably trigger population migration by reducing agricultural viability, actual population movement depends on a range of economic, social, and institutional constraints. Taking Guizhou as an example, the interaction between climate vulnerability, local development constraints, and restrictive institutional frameworks may collectively suppress or delay population migration responses, particularly those reflected in net permanent migration data. These dynamic factors make empirical research complex and necessitate careful consideration of short-term, informal, or unregistered migration as potential adaptation mechanisms.

## Methodological Approaches and Data Integration

Quantitative assessments of climate-induced migration increasingly rely on high-resolution data and quasi-experimental methods to establish causal inferences. An important advance in this field has been the combination of remote sensing data with population and climate indicators to assess how extreme weather events affect land use and population movements in space and time.

In the agricultural field, the Normalised Difference Vegetation Index (NDVI) has become a widely used proxy of crop health and productivity, particularly in studies lacking direct yield or income data. Studies by Liang et al. (2021) and Sun et al. (2023) have shown that NDVI can be used to monitor climate-induced land changes in China, including responses to drought, high temperatures, and changes in growing conditions. Similarly, the Standardised Precipitation Evapotranspiration Index (SPEI) has been widely used to monitor meteorological droughts of varying intensity and duration (Zhao et al., 2020), enabling consistent spatial and temporal comparisons.

To identify the causal effects of climate shocks, difference-in-differences (DiD) and event study designs have been effectively applied. For example, Cattaneo et al. (2019) used these techniques to assess the migration effects of rainfall sudden-change bias. In China, Cai et al. (2016) employed a DiD framework to evaluate how adverse climate trends affect agricultural productivity and indirectly influence labour allocation decisions.

These methodological advances are particularly important in data-scarce environments, such as inland China, where reliable long-term household survey data are often unavailable. In such cases, combining satellite data with official statistics can fill in gaps in microdata, enabling impact analysis that is specific to particular events and spatially explicit.

Building on recent methodological developments, this study adopts a county-level, event-based spatial framework to assess the socio-environmental impacts of the 2010 extreme drought in southwestern China. By integrating MODIS NDVI, SPEI climate indices, and population panel data, it enables a fine-grained, temporally consistent analysis of drought-induced changes in agricultural productivity and population dynamics. This multi-source approach contributes to emerging research efforts that move beyond national-level aggregation, allowing for spatially explicit and policy-relevant interpretations in ecologically fragile and topographically complex regions.

## Research Gaps

Although climate-induced population migration is receiving increasing attention, there are still some important research gaps, especially in China's inland regions. First, existing literature mostly focuses on long-term climate trends (e.g., average temperature or precipitation anomalies) rather than clearly defined extreme weather events. This limits the ability to isolate the causal effects of acute shocks such as droughts and assess specific time responses. Although some global and national-level studies have adopted event-based methods, these methods are rarely used at the sub-provincial level in China, as geographical and institutional heterogeneity may significantly influence research outcomes.

Secondly, there is a lack of spatially disaggregated analysis integrating county-level environmental and population data. Most empirical studies either rely on cross-sectional household surveys or provincial-level aggregated data, which obscures local differences and spatial spillover effects. In ecologically fragile regions such as Guizhou, where terrain is complex, infrastructure is unevenly distributed, and differences between counties are significant, more granular spatial analysis methods are crucial for revealing the unevenness of drought impacts.

Thirdly, although the relationship between agricultural decline and population migration has been thoroughly theorised, empirical evidence from underdeveloped mountainous regions in China remains scarce. Few studies have examined whether a decline in agricultural vitality (measured by vegetation indices such as the Normalised Difference Vegetation Index (NDVI)) translates into observable population migration outcomes. This is partly due to data limitations, as China's population migration statistics typically only reflect changes in permanent residence and fail to capture short-term or seasonal movements that may be driven by environmental pressures.

Finally, the moderating role of policy and institutional contexts is often overlooked. As mentioned earlier, China's household registration system, unequal access to urban services, and the structure of the rural labour market may inhibit or delay migrants' response to climate shocks. However, few quantitative studies systematically incorporate these constraints when assessing the link between climate and migration.

This study addresses these shortcomings by conducting a quasi-experimental, spatially explicit analysis of the 2010 drought in Guizhou, combining normalised difference vegetation index (NDVI), spatial index (SPEI), and census-based migration indicators. By applying county-level panel data and a difference-in-differences estimation, this study contributes to the emerging literature on the complexity and environmental dependence of climate-induced population mobility in developing regions, particularly in institutional contexts such as China.

# Data % Research Area



## Study Area and Overview

Guizhou Province is located in the karst plateau region of southwestern China (24°37′–29°13′N, 103°36′–109°35′E), bordering Sichuan to the north, Yunnan to the west, Guangxi to the south, and Hunan to the east. The province's terrain is predominantly mountainous and hilly, with an average elevation of approximately 1,100 metres (Guizhou Provincial Bureau of Statistics, 2011). The terrain slopes gradually from the high mountains in the west and north to the low hills and basins in the southeast. Due to the widespread distribution of karst topography, soils are generally shallow and nutrient-poor, and surface water resources are unevenly distributed in both space and time (Luo, 2019). This natural environment results in agriculture being highly dependent on rainfall, with limited capacity to construct large-scale irrigation infrastructure.

The province has a subtropical humid monsoon climate, with rainfall concentrated between May and September. Annual precipitation varies significantly, and the region is greatly affected by anomalies in the East Asian summer monsoon (Wei, 2021). Extreme events such as prolonged droughts or excessive rainfall can cause severe damage to agricultural production and rural livelihoods. Agriculture remains the main economic sector in Guizhou Province, contributing more to the province's GDP than in coastal provinces, and the outflow of rural labour has long been a typical socio-economic phenomenon in the region (Huang, 2018). The main crops include rice, corn, potatoes and rapeseed, a large proportion of which are grown on sloping cropland, especially in high-altitude areas (Luo, 2019).

This study covers all 88 county-level administrative units in Guizhou Province from 2008 to 2012, including counties, county-level cities, and urban districts. The time window includes the severe drought that struck most of southwestern China from late 2009 to mid-2010, widely regarded as the most severe drought in over a century (Yun, Jun and Hong, 2012). The drought was characterised by precipitation levels far below average, temperatures above average, crop yields in the hardest-hit counties declining by over 30%, and severe shortages of drinking water in both urban and rural areas (Wei, 2021).

According to the Standardised Precipitation Evapotranspiration Index (SPEI), in the double difference and event study analyses, the county’s most severely affected by drought in 2010 were designated as the treatment group, while the remaining counties served as the control group. As shown in Figure 3.1.1, the treatment group counties are mainly located in the northwestern and central high-altitude areas, where sloping cropland, shallow soil layers, and limited irrigation facilities are common, exacerbating vulnerability to water shortages (Luo, 2019). In contrast, counties in the southeastern lowland areas have relatively more favourable agricultural conditions, including deeper soil layers, more reliable precipitation, and relatively better water resource management systems, thereby mitigating losses to agriculture and livelihoods during the 2010 drought. The combination of these geographical, climatic, and socio-economic differences forms the basis for the heterogeneity analysis in subsequent chapters.

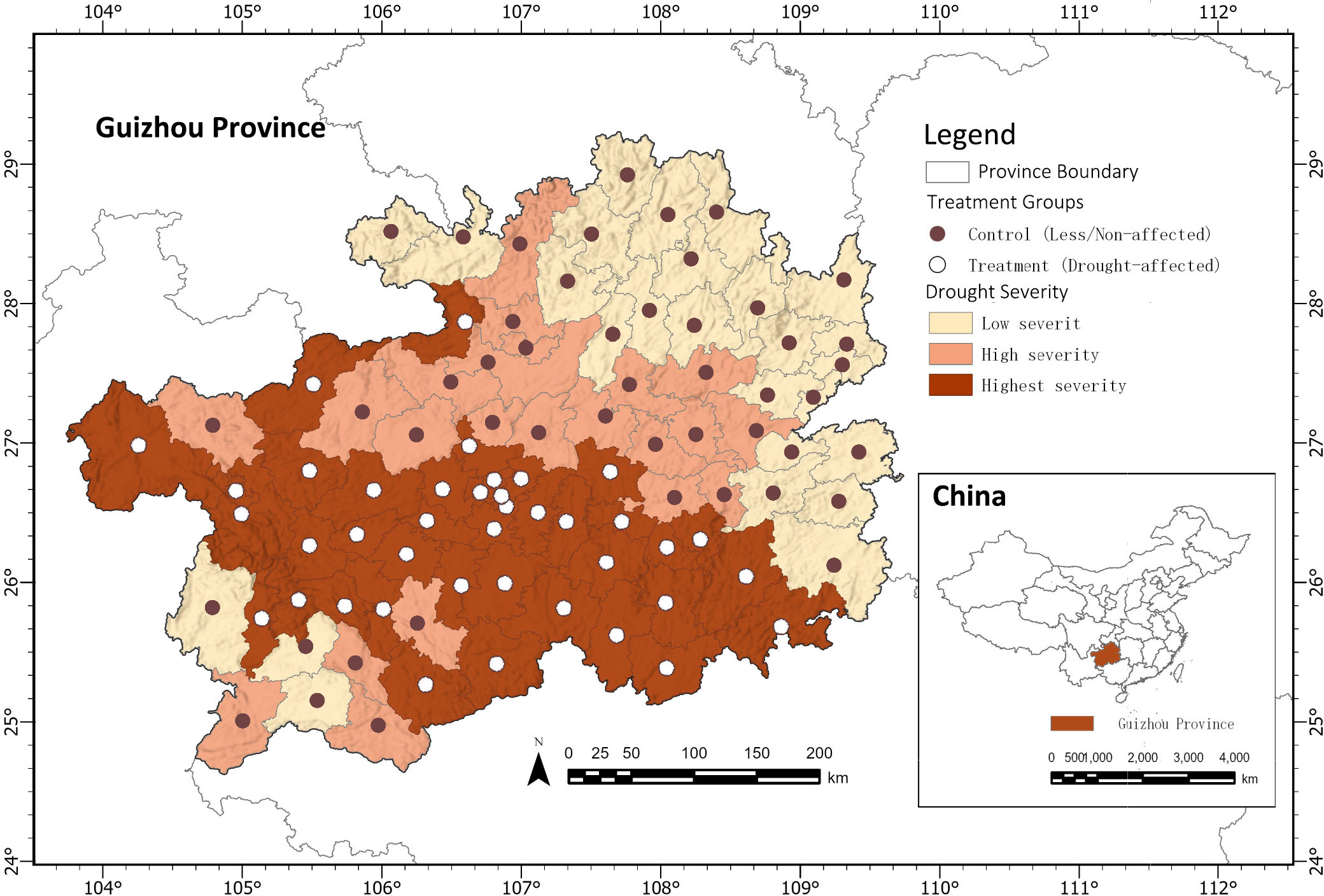


Figure . Location of the study area in Guizhou Province, China, showing county-level boundaries, mean elevation, and drought treatment status in 2010. Treatment counties are defined as those in the top quartile of median drought frequency (SPEI < –1.5, February–June 2010). Data sources: SRTM DEM, SPEIbase v2.10, Guizhou county boundaries.

## Data Sources and Processing

This study's empirical analysis combines climate, remote sensing, statistical, and topographical datasets to construct a balanced county-level annual panel dataset for Guizhou Province from 2008 to 2012. All geospatial processing was conducted using Google Earth Engine (GEE), while subsequent data integration, cleaning, and variable construction were performed using the Python programming language. Figure 3.2 provides a brief overview of the data integration workflow, with the complete methodological workflow detailed in Chapter 4.

**Figure 3.2 Simplified workflow for the construction of the county-level panel dataset (2008–2012), integrating climate (SPEI), vegetation (MODIS NDVI), land cover (MODIS MCD12Q1), demographic (Guizhou Statistical Yearbook, Population Census), and topographic (SRTM DEM) datasets. All geospatial processing was conducted in Google Earth Engine (GEE); statistical integration and cleaning were implemented in Python.**

Population and migration data primarily come from the *Guizhou Statistical Yearbook* (2009–2013), supplemented by data from the 2000 and 2010 population censuses (Guizhou Provincial Bureau of Statistics, 2011). The total annual permanent resident population and rural population for each county are recorded at the end of the year. For counties classified as urban core areas (such as Guiyang, the provincial capital of Guizhou), the rural population total is designated as zero to reflect their population structure dominated by non-agricultural residents.

To construct the net migration indicator, the study adjusted the year-on-year change in total population based on natural growth (the difference between births and deaths). In cases where county-level birth and death data were unavailable, the crude birth and death rates from the provincial-level statistical yearbooks were used. The resulting net migration estimates were standardised per thousand people to facilitate comparisons between counties of different population sizes. Additionally, data quality markers were added to the panel data to distinguish between directly reported values and estimated values. Missing data were handled based on the extent of the gap: small gaps (≤1 year) were filled using linear interpolation, while structural gaps (e.g., urban core counties) were left as missing values to avoid introducing bias.

The severity of the 2010 drought was measured using the Standardised Precipitation Evapotranspiration Index (SPEI) from the SPEIbase v2.10 dataset, which integrates precipitation and potential evapotranspiration to provide a standardised drought indicator. The three-month SPEI from February to June 2010 was selected to capture the peak of the prolonged drought affecting southwestern China (Yun, Jun and Hong, 2012). Pixels with SPEI values below -1.5 were classified as drought affected. For each county, the median pixel-level drought frequency during the five-month period was calculated to represent local drought conditions. The counties were then divided into four categories of relative severity based on the quartiles of this median drought frequency, enabling heterogeneity analysis in subsequent sections.

Vegetation productivity (used as a proxy indicator for agricultural performance) is measured using the normalised difference vegetation index specific to farmland obtained from MODIS MOD13Q1 images. This product provides 16-day composite images with a spatial resolution of 250 metres, scaled to reflectance values (0–1) and averaged over the growing season (April to September) for each year from 2008 to 2012. Cropland pixels are identified using the 2010 MODIS MCD12Q1 land cover product, applying the International Geosphere-Biosphere Programme (IGBP) classification (Class 12: Farmland). If the primary land cover category remains stable during the study period, this static mask is consistently applied across all years. The resulting variable reflects only the vegetation greenness of agricultural land, excluding forest and built-up areas.

Land use structure is expressed as the proportion of cropland, calculated from the 2010 MODIS MCD12Q1 data as the percentage of valid land pixels classified as cropland. Although this variable is not used as a direct control variable in the main regression model, it supports heterogeneity analysis because it allows for a comparison of counties with high and low proportions of cropland in terms of their response to drought and migration.

Data coordination involves aligning all datasets by county name (transliterated into English) and year to ensure consistency across different sources. Continuous variables are stored in standard units—the normalised vegetation index (NDVI) ranges from 0 to 1, migration rates are calculated per thousand people, and the proportion of cropland is expressed as a percentage—while categorical variables (such as treatment status and high altitude classification) are coded uniformly across the panel. The final balanced dataset covers 88 counties over five years (440 observations), with each record containing adjusted environmental, land use, and demographic indicators for comprehensive analysis.

The panel structure is designed to support double difference and event study analyses, as well as heterogeneity tests based on geographical and land use characteristics. Detailed processing steps, including spatial aggregation, time window selection, and the complete data workflow, are documented in Chapter 4 (see Figure 4.1).

## Descriptive Statistics and Spatial Patterns

To provide an overview of temporal dynamics, Figure 3.3 shows the annual trends in specific vegetation productivity and net flux for treated and control counties from 2008 to 2012. The figure above displays the average normalised difference vegetation index (NDVI) calculated for agricultural pixels during the growing season (April to September). In 2010, the NDVI in the treatment counties showed a significant decline compared to previous years, corresponding to the period of extreme drought, while the control counties maintained a relatively stable trend with minimal interannual variation. Between 2009 and 2010, the average NDVI in the treatment group decreased by approximately X% (value derived from the data), while the control group decreased by only Y%.

**Figure 3.3 Annual trends in cropland-specific Normalised Difference Vegetation Index (NDVI) during the growing season (upper panel) and net migration rates per 1,000 persons (lower panel) for treatment and control counties, 2008–2012. Shaded areas represent ±1 standard error. The vertical dashed line marks the 2010 drought year. Data sources: MODIS MOD13Q1, MODIS MCD12Q1, Guizhou Statistical Yearbook.**

The figure below shows the net migration rate per thousand people, which is adjusted for natural population growth. The change in migration rate over time does not appear to be as pronounced as the change observed in NDVI. The difference between the treatment group and the control group is relatively small, with interannual fluctuations within ±Z per thousand people. The vertical dotted lines in both figures mark the year 2010, providing a visual reference for comparing the trajectories before and after the drought.

These descriptive statistics provide a preliminary overview of how key variables have changed over time. However, it is not yet possible to draw causal inferences; formal statistical analysis will be presented in Chapter 5.

# Methodology

Explain your research design, models, and analytical approach.

Example Figure with Caption:

Figure 1. Example figure caption text

Example Table with Caption:

Table 1. Example table caption text

# Results

Present your main findings with figures and tables. Make sure each figure and table has a caption.

# Discussion

Interpret your results, compare with previous research, and discuss implications.

# Conclusion

Summarise your research contributions, limitations, and future work.

# References

Black, R., Adger, W.N., Arnell, N.W., Dercon, S., Geddes, A. and Thomas, D. (2011) The effect of environmental change on human migration. Global Environmental Change, 21(S1), pp. S3–S11.

# Appendices

Include supplementary material such as extended tables, figures, or code.