

## Spatiotemporal Dynamic Changes and Future Multi-scenario Projections of Carbon Storage in Jinchang City from 2000 to 2020

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**Date:** 2026-04-29T00:10:09+00:00

### Abstract

As an important high-energy-consuming resource-based industrial and mining city in the arid region of Northwest China, exploring the spatiotemporal evolution characteristics of carbon storage and low-carbon development paths in Jinchang is of great value for implementing the sustainable development of mining cities in arid regions under the “Double Carbon” background. To address the issue that existing studies have less analysis of the composite mechanisms of land transfer, carbon storage spatial differentiation, and scenario prediction at the micro-scale in Northwest China, this study established a natural development scenario, an ecological protection scenario, and an urban development scenario based on the PLUS-InVEST model integration method. Utilizing land use change data of Jinchang from 2000 to 2020 and comprehensively considering 10 key driving factors, the study simulated the dynamic adjustment of land use and the spatial heterogeneity of carbon storage in Jinchang from 2020 to 2030. The results indicate that: (1) From 2000 to 2020, land use in Jinchang was dominated by unused land, grassland, and cropland, with 252.67 km<sup>2</sup> of grassland transferred to unused land and 82.10 km<sup>2</sup> of unused land transferred to construction land. (2) Carbon storage in the study area continued to decline in 2000, 2010, and 2020, reaching  $5.70 \times 10^7 t$ ,  $5.52 \times 10^7 t$ , and  $5.50 \times 10^7 t$ , respectively, forming a spatial carbon storage difference between the scenarios. Prediction results show that compared to the carbon storage in 2020, the natural development scenario, ecological protection scenario, and urban development scenario reached  $5.70 \times 10^7 t$ ,  $5.52 \times 10^7 t$ , and  $5.50 \times 10^7 t$ , respectively. The research results provide a reference for balancing resource development and ecological protection, adjusting land use structures, preventing soil erosion and water loss, and achieving low-carbon industrial transformation in Jinchang and similar cities in the arid regions of Northwest China.

## Full Text

## Preamble

Vol. 49, No. 4, April 2026

GEOGRAPHY

# Spatiotemporal Dynamic Changes and Future Multi-scenario Projections of Carbon Storage in Jinchang City from 2000 to 2020

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## Abstract

Jinchang City serves as a critical high-energy-consuming, resource-based industrial and mining center in the arid region of Northwest China. Exploring the spatiotemporal evolution of its carbon storage and its potential for low-carbon development is of significant importance for regional ecological security and sustainable economic growth. As a typical city dependent on mineral extraction and heavy industry, Jinchang faces the dual challenges of fragile ecological environments and high carbon emission intensity.

Based on the integrated PLUS-InVEST model approach, this study utilizes land use change data for Jinchang City from 2000 to 2020. By comprehensively considering 10 driving factors—including natural geography, socio-economics, and accessibility—we simulated and predicted the spatial patterns of land use and carbon storage in Jinchang City for the year 2030 under three distinct scenarios: Natural Development (ND), Ecological Protection (EP), and Urban Development (UD).

The results indicate that from 2000 to 2020, the land use structure in Jinchang City was dominated by unutilized land and grassland. During this period, the area of construction land and forest land increased significantly, while the area of unutilized land and grassland decreased. Correspondingly, the total carbon storage in the study area exhibited a fluctuating upward trend, increasing from  $5.70 \times 10^7$  t in 2000 to  $5.50 \times 10^7$  t in 2020. Spatial analysis reveals that carbon storage in Jinchang City exhibits a distribution pattern characterized by being “high in the south and low in the north.” High-value areas are primarily concentrated in the Qilian Mountains in the south, where forest and grassland coverage is high. Conversely, low-value areas are mainly distributed in the northern Gobi and desert regions.

[Figure 1: see original paper]

Simulation results for 2030 suggest that under the Ecological Protection (EP) scenario, the expansion of forest and grassland is effectively maintained, leading to the highest carbon storage levels among the three scenarios. Under the Urban Development (UD) scenario, although the expansion of construction land is rapid, it results in a certain degree of loss in carbon sequestration capacity. Specifically:

- (1) Between 2000 and 2020, land use in Jinchang City was dominated by unused land, grassland, and cropland. During this period,  $252.67 \text{ km}^2$  of grassland was converted to unused land, while  $82.10 \text{ km}^2$  of unused land was transitioned into construction land.
- (2) Carbon storage in the study area exhibited a continuous decline across the years 2000, 2010, and 2020, with recorded values of  $5.70 \times 10^7 \text{ t}$ ,  $5.52 \times 10^7 \text{ t}$ , and  $5.50 \times 10^7 \text{ t}$ , respectively.
- (3) The conversion of grassland to unutilized land resulted in a carbon loss of  $3.01 \times 10^6 \text{ t}$ , while the conversion of land use to grassland resulted in an overall increase in carbon storage of  $1.25 \times 10^6 \text{ t}$ .
- (4) Compared to 2020, the projected carbon storage for 2030 under the Natural Development, Ecological Protection, and Urban Development scenarios decreased by  $1.34 \times 10^5 \text{ t}$ ,  $3.13 \times 10^4 \text{ t}$ , and  $8.35 \times 10^5 \text{ t}$ , respectively. These findings provide a scientific basis for optimizing land spatial layout and achieving “carbon peak and carbon neutrality” goals in arid regional industrial cities.

Keywords: PLUS-InVEST model; Land use change; Carbon storage; Multi-scenario prediction; Jinchang City

## 1. Introduction

Terrestrial ecosystems play a critical role in the global carbon cycle, serving as significant carbon sinks that mitigate the effects of climate change. Land use and land cover change (LUCC) is one of the most direct drivers of fluctuations in terrestrial carbon storage. Human activities, such as urban expansion, deforestation, and agricultural intensification, alter the structure and function of ecosystems, leading to substantial shifts in carbon sequestration capacity. Therefore, accurately simulating historical land use patterns and predicting future trends is essential for regional ecological security and the achievement of “carbon peak” and “carbon neutrality” goals.

Jinchang City, located in the Hexi Corridor of Gansu Province, is a typical industrial city characterized by a fragile ecological environment and significant mineral resource extraction. As a vital node in the Silk Road Economic Belt, Jinchang faces the dual challenge of economic development and ecological restoration. Rapid urbanization and mining activities have historically led to complex land use transitions, which in turn affect the regional carbon balance.

In recent years, the integration of land use simulation models with ecosystem service assessment models has become a mainstream approach. The Patch-generating Land Use Simulation (PLUS) model has demonstrated superior performance in capturing the drivers of land expansion compared to traditional models. Simultaneously, the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model is widely utilized for quantifying carbon storage. This study employs the PLUS-InVEST coupled model to simulate land use patterns in Jinchang City under multiple scenarios for 2030, providing a theoretical basis for achieving sustainable development in water-scarce mining cities.

## 2. Materials and Methods

### 2.1 Study Area

Jinchang City is located in the northwestern part of Gansu Province ( $37^{\circ}47'10''$ - $39^{\circ}00'30''$  N,  $101^{\circ}04'35''$ - $102^{\circ}43'40''$  E), situated in the middle of the Hexi Corridor. The region is characterized by a typical continental temperate arid climate, with an annual average temperature of  $9.1^{\circ}\text{C}$  and annual precipitation of approximately 140.5 mm. The topography descends from the southwest (Qilian Mountains) toward the northeast (desert Gobi). Primary soil types include sierozem, irrigation-silting soil, and aeolian sandy soil.

### 2.2 Data Sources and Preprocessing

The primary datasets include land use data for 2000, 2010, and 2020 (30m resolution), meteorological data (temperature and precipitation), and digital elevation models (DEM). Socio-economic drivers such as population density, GDP, and distances to infrastructure (highways, railways, water bodies) were also integrated. All spatial data were standardized to a  $30\text{ m} \times 30\text{ m}$  resolution in ArcGIS.

### 2.3 Research Methods

**2.3.1 InVEST Model for Carbon Storage** The InVEST Carbon Storage and Sequestration model calculates carbon stocks based on four primary pools: aboveground biomass ( $C_{above}$ ), belowground biomass ( $C_{below}$ ), soil organic matter ( $C_{soil}$ ), and dead organic matter ( $C_{dead}$ ). The total carbon storage ( $C_{total}$ ) is calculated as:

$$C_{total} = \sum_{k=1}^n A_k \times (C_{k,above} + C_{k,below} + C_{k,soil} + C_{k,dead})$$

where  $A_k$  represents the area of land-use type  $k$ . Carbon density values were corrected for Jinchang City based on Mean Annual Temperature (MAT) and Mean Annual Precipitation (MAP) using established correction formulas [?, ?].

**2.3.2 PLUS Model** The PLUS model was used to simulate land use changes. It integrates a Land Expansion Analysis Strategy (LEAS) and a CA model based on multi-type random patch seeds (CARS). Accuracy verification using 2010 data to simulate 2020 patterns yielded a Kappa index of 0.85 and an overall accuracy of 91.5%, indicating high reliability for future projections.

## 2.4 Scenario Construction

Three scenarios were established for 2030: 1. **Natural Development (ND)**: Follows historical trends (2010–2020) without additional policy interventions. 2. **Ecological Protection (EP)**: Prioritizes the preservation of forests, grasslands, and water bodies, strictly limiting the conversion of ecological land to construction land. 3. **Urban Development (UD)**: Prioritizes economic growth and infrastructure expansion, allowing for accelerated conversion of cropland and unused land to construction land.

## 3. Results and Analysis

### 3.1 Spatiotemporal Dynamics of Land Use

From 2000 to 2020, Jinchang City was dominated by unused land, grassland, and cropland. The most significant transitions involved the conversion of 252.67 km<sup>2</sup> of grassland to unused land and the expansion of construction land by 82.10 km<sup>2</sup>, primarily sourced from unused land.

### 3.2 Spatiotemporal Evolution of Carbon Storage

Carbon storage exhibited a “high in the south, low in the north” spatial pattern. The total carbon storage decreased from  $5.70 \times 10^7$  t in 2000 to  $5.50 \times 10^7$  t in 2020. The primary driver of carbon loss was the degradation of grassland into unused land, resulting in a loss of  $3.01 \times 10^6$  t.

### 3.3 Multi-scenario Projections for 2030

Simulation results for 2030 indicate that the Ecological Protection scenario is most effective at mitigating carbon stock decline. Compared to 2020: - **ND Scenario**: Carbon storage decreases by  $1.34 \times 10^5$  t. - **EP Scenario**: Carbon storage decreases by only  $3.13 \times 10^4$  t. - **UD Scenario**: Carbon storage decreases by  $8.35 \times 10^5$  t due to rapid urban expansion.

## 4. Conclusion and Discussion

This study demonstrates that land-use transitions in Jinchang City significantly impact regional carbon storage. The integration of PLUS and InVEST models provides a robust framework for simulating these dynamics. To achieve “dual carbon” goals, Jinchang should prioritize ecological restoration and intensive land use, particularly by protecting high-value carbon sinks in the southern

mountainous regions and controlling the expansion of construction land. These findings offer a scientific basis for balancing resource exploitation and ecological conservation in arid, resource-based cities.

*Note: Figure translations are in progress. See original paper for figures.*

*Source: ChinaXiv –Machine translation. Verify with original.*