

## Postprint: Future Land Use Change Projection in the Tianshan Mountains Based on the FLUS Model

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### Abstract

Based on data from 53 meteorological stations in the Tianshan Mountains, 31 CMIP5 global climate models, and integrated annual average climate data, socioeconomic and natural terrain data, the FLUS model was employed to project land use changes in the Tianshan Mountains in 2050 under RCP2.6, RCP4.5, and RCP8.5 emission scenarios. The results indicate that: The FLUS model can effectively simulate historical land use changes in the study area, demonstrating high simulation accuracy. Compared with the baseline period (1970-1999), the multi-year average temperature increased by 1.67-2.16 °C under the three scenarios, with smaller warming magnitudes in spring and summer and larger warming magnitudes in autumn and winter. The multi-year average precipitation increased by 22-25 mm; although individual years under the three scenarios exhibited precipitation decreases relative to the baseline period, the overall trend was increasing. Compared with the observed land use data in 2017, the projected results for 2050 under RCP2.6, RCP4.5, and RCP8.5 show that the ice and snow area in the Tianshan Mountains decreased by 29.2%, 34.6%, and 38.4%, respectively. Under the first two scenarios, the urban land area increased modestly, with some cropland converted to urban land and grassland, and forest area increased slightly. Under the RCP8.5 scenario, the urban land area was nearly three times that of 2017, with some forest converted to grassland. Under the three scenarios, the total water body area increased slightly, while unused land exhibited a decreasing trend.

### Full Text

## Estimation of Future Land Use Change in the Tianshan Mountains Based on FLUS Model

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## Abstract

In this paper, the 31 global climate models were integrated from the Phase 5 of Coupled Model Intercomparison Project (CMIP5) to study the overall prediction of land use change in the Tianshan Mountains under three emission scenarios, i.e., the Representative Concentration Pathways (RCPs) 2.6, 4.5 and 8.5. In the study, the observed climatic data from 53 meteorological stations, socioeconomic data and natural geomorphological conditions in the Tianshan Mountains were used. The results showed that: (1) FLUS model could be used to simulate the historical land use change in the study area with high accuracy; (2) Compared with the base period from 1970 to 1999, the average annual temperature would be increased by 1.67-2.16°C during 2021-2050, and its increase would be low in spring and summer but high in autumn and winter. It was revealed that the average annual precipitation would be increased by 22-25 mm under RCPs 2.6, 4.5 and 8.5. Under the three scenarios, precipitation reduction would occur in some years compared to the base period, but there would be holistically an increase trend; (3) Compared with the situation of land use change in 2017, it was estimated that, under the RCP 2.6, RCP 4.5 and RCP 8.5 scenarios, the glacier and snow areas in the Tianshan Mountains in 2050 would be reduced by 29.2%, 34.6% and 38.4% respectively. The enlargement of urban land area in 2050 would not be significant under RCP 2.6 and RCP 4.5. Some of the cultivated land would be converted into urban land and grassland, and the area of woodland would be slightly enlarged. The urban land area under the RCP 8.5 scenario would be nearly three times of that in 2017. Part of woodland would be converted into grassland. The total area of waters would be slightly enlarged, and the area of unused land will be in a reduction trend.

**Keywords:** climate change; scenario simulation; land use change; FLUS model; Tianshan Mountains

## 1. Introduction

Land use and land cover change (LUCC) represents one of the most direct manifestations of human-environment interactions and has become a critical component in global change research. Climate change, as a key driving factor of LUCC, significantly influences land use patterns through altering temperature and precipitation regimes. The Tianshan Mountains, a vital ecological barrier in Central Asia, are particularly sensitive to climate variability. Understanding future land use dynamics under different climate scenarios is essential for regional sustainable development and ecological conservation planning.

## 2. Data and Methods

### 2.1 Data Collection and Processing

The study integrated 31 global climate models from CMIP5 to project land use change in the Tianshan Mountains under three RCP scenarios (2.6, 4.5, and 8.5). Observed climate data from 53 meteorological stations, socioeconomic data, and natural geomorphological conditions served as primary inputs. The meteorological data included temperature and precipitation records, while socioeconomic data comprised GDP and population statistics. A 30-meter resolution Digital Elevation Model (DEM) was used to represent topographic conditions. All spatial data were resampled to a 1 km resolution grid for model consistency.

### 2.2 Climate Scenario Downscaling

The Delta method was employed for downscaling GCM outputs to local scales. The correction formulas applied were:

$$P_f = P_o + (P_{Gf} - P_G)$$

$$T_f = T_o + (T_{Gf} - T_G)$$

where  $P_o$  and  $T_o$  represent observed precipitation and temperature,  $P_G$  and  $T_G$  denote GCM-simulated baseline values,  $P_{Gf}$  and  $T_{Gf}$  indicate future GCM projections, and  $P_f$  and  $T_f$  are the corrected future climate estimates.

### 2.3 FLUS Model Configuration

The Future Land Use Simulation (FLUS) model was utilized to project spatial land use patterns. Model validation was performed through hindcast simulations. Using 2001 land use data as the initial state, the model simulated 2010 land use patterns, achieving a Kappa coefficient of 0.71 and overall accuracy of 0.83. Subsequently, 2010 data were used to simulate 2017 conditions for further verification. The model demonstrated robust performance in capturing land use dynamics in the study region.

### 2.4 Simulation Scenarios

Three RCP scenarios were implemented: RCP 2.6 (low emission, radiative forcing of  $2.6 \text{ W} \cdot \text{m}^{-2}$  by 2100), RCP 4.5 (medium emission,  $4.5 \text{ W} \cdot \text{m}^{-2}$ ), and RCP 8.5 (high emission,  $8.5 \text{ W} \cdot \text{m}^{-2}$ ). Socioeconomic projections for GDP and population growth under each scenario were derived from established global databases. The simulation targeted the year 2050 as the primary future projection horizon.

### 3. Results

The simulation results revealed distinct land use transformation patterns across scenarios. Under RCP 2.6 and RCP 4.5, urban expansion remained relatively constrained, with modest conversions from cultivated land to urban and grassland uses. Woodland areas exhibited slight expansion trends. In contrast, RCP 8.5 projected substantial urban growth, nearly tripling the 2017 urban area, accompanied by woodland conversion to grassland. Water bodies showed marginal increases across all scenarios, while unused land consistently decreased. Glacier and snow cover exhibited dramatic retreat, with area reductions of 29.2%, 34.6%, and 38.4% under RCP 2.6, 4.5, and 8.5 respectively.

### 4. Discussion

The projected temperature increases of 1.67-2.16°C by 2050 align with regional climate model ensembles, though seasonal variations suggest amplified autumn and winter warming. Precipitation projections indicate an overall increase of 22-25 mm, despite interannual variability showing potential dry years. The asymmetric response of land use classes highlights the complex interplay between climate forcing and socioeconomic factors. The pronounced glacier loss under RCP 8.5 underscores the vulnerability of cryospheric resources to high-emission pathways.

### 5. Conclusion

The FLUS model successfully simulated land use change in the Tianshan Mountains with high accuracy. Climate projections indicate significant warming and moderate precipitation increases by 2050. Land use transformations will be scenario-dependent, with RCP 8.5 driving the most extensive changes, particularly in urban expansion and cryospheric decline. These findings provide critical insights for adaptive land management strategies in mountainous regions under climate change.

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