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

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## Abstract

Based on data from 53 meteorological stations in the Tianshan Mountains region, 31 CMIP5 global climate models, and integrated annual average climate, socioeconomic, and natural terrain data, the FLUS model was used to project land use changes in the Tianshan Mountains region by 2050 under RCP2.6, RCP4.5, and RCP8.5 emission scenarios. The results show that: The FLUS model can simulate historical land use changes in the study area well, with 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 amplitudes in spring and summer and larger warming amplitudes in autumn and winter. The multi-year average precipitation increased by 22–25 mm. Under the three scenarios, precipitation decreased in some individual years compared with the baseline period, but the overall trend was increasing. Compared with the actual land use results 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 region decreased by 29.2%, 34.6%, and 38.4%, respectively. In the first two scenarios, the urban land area increased slightly, some cropland was converted to urban land and grassland, and forest land area increased slightly. Under the RCP8.5 scenario, however, the urban land area was nearly three times that of 2017, and some forest land was converted to grassland. Under all three scenarios, the total water body area increased slightly, and unused land showed a decreasing trend.

# Full Text

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

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### Abstract

This study integrates 31 global climate models from the Phase 5 of the Coupled Model Intercomparison Project (CMIP5) to investigate comprehensive land use change predictions in the Tianshan Mountains under three Representative Concentration Pathway (RCP) scenarios: RCP 2.6, RCP 4.5, and RCP 8.5. The analysis utilizes observed climate data from 53 meteorological stations, socioeconomic data, and natural geomorphological conditions in the Tianshan region. The results demonstrate: (1) The FLUS model can accurately simulate historical land use changes in the study area; (2) Compared to the baseline period (1970–1999), the average annual temperature during 2021–2050 is projected to increase by 1.67–2.16°C, with lower increases in spring and summer but higher increases in autumn and winter. The average annual precipitation under RCPs 2.6, 4.5, and 8.5 is expected to increase by 22–25 mm. While some years may experience precipitation reduction compared to the baseline period, the overall trend shows an increase; (3) Relative to 2017 land use conditions, glacier and snow-covered areas in the Tianshan Mountains by 2050 are projected to decrease by 29.2%, 34.6%, and 38.4% under RCP 2.6, RCP 4.5, and RCP 8.5 scenarios, respectively. Urban land expansion under RCP 2.6 and RCP 4.5 scenarios will not be significant, with some cultivated land converting to urban land and grassland, while woodland area will slightly increase. Under RCP 8.5, urban land area will be nearly three times that of 2017, with some woodland converting to grassland. Total water body area will slightly increase, while unused land will show a decreasing trend.

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

### 1.3 Study Area

The Tianshan Mountains region was selected as the study area. Climate model data were obtained from 31 CMIP5 global climate models, with meteorological data from 53 stations providing observed temperature and precipitation records. The socioeconomic dataset includes GDP and population data. A 1 km resolution Digital Elevation Model (DEM) was used as the topographic data source. All spatial data were reprojected to the WGS_1984_UTM_zone_43N coordinate system.

### 1.4 Data Sources

Historical climate data from 1970–1999 served as the baseline period. Future climate projections for 2010–2100 were derived from CMIP5 model outputs. The Delta method was applied for climate downscaling:

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

where $T_o$ represents baseline temperature, $T_G$ is GCM-simulated baseline temperature, and $T_{Gf}$ is GCM-projected future temperature. The same method was applied to precipitation data.

### 1.5 Land Use Classification

Land use data were extracted from MODIS MCD12Q1 products using the International Geosphere-Biosphere Programme (IGBP) classification scheme. The classification includes 17 land cover types, which were aggregated into six categories: cultivated land, woodland, grassland, water bodies, urban land, and unused land. The 2010 land use map was validated against 2017 observations, achieving a Kappa coefficient of 0.71 and overall accuracy of 83%.

### 1.6 FLUS Model

The FLUS (Future Land Use Simulation) model couples human and natural effects to simulate multiple land use scenarios. The model structure incorporates: - A neural network module to calculate land use suitability probabilities - A cellular automata module with neighborhood effects and conversion cost matrices - A module for processing restrictive factors and random perturbations

The model operates at 1 km spatial resolution, with simulation parameters including neighborhood size, conversion elasticity coefficients, and iteration settings.

### 1.7 Scenario Settings

Three RCP scenarios were implemented: - **RCP 2.6**: Radiative forcing peaks at 2.6 W/m² by 2100 and then declines - **RCP 4.5**: Radiative forcing stabilizes at 4.5 W/m² after 2100 - **RCP 8.5**: Radiative forcing reaches 8.5 W/m² by 2100

Each scenario incorporates corresponding climate projections, GDP growth rates, and population trends (Table 1).

### 2.1.1 Climate Data Processing

The Delta method was applied to downscale GCM outputs to station-level data. For temperature, the method adds the GCM-projected change to observed baseline values. For precipitation, a multiplicative factor was used. The downscaled data were then interpolated to 1 km resolution using inverse distance weighting.

### 2.1.2 Land Use Data Validation

The 2001-2010 land use change trajectory was used as the basis for model calibration. The 2010 land use map was simulated using the 2001 map as input and validated against the actual 2010 map. The validation showed satisfactory performance with a Kappa coefficient exceeding 0.7. The validated model was then applied to simulate 2017 land use conditions from the 2010 baseline.

### 2.1.3 Simulation Results

Under all three RCP scenarios, significant land use changes are projected by 2050: - **Glacier and snow cover**: Substantial retreat, with losses ranging from 29.2% (RCP 2.6) to 38.4% (RCP 8.5) - **Urban expansion**: Most pronounced under RCP 8.5, where urban area triples compared to 2017 - **Cultivated land**: Partial conversion to urban and grassland, particularly under high-emission scenarios - **Woodland**: Slight expansion under RCP 2.6 and 4.5, but conversion to grassland under RCP 8.5 - **Water bodies**: Marginal increase across all scenarios - **Unused land**: Consistent decreasing trend

The spatial patterns of change show concentration in lower elevation zones and areas with high human accessibility.

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