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Monitoring Glacier Elevation Change in Central Asia Using TanDEM-X DEMs

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INTRODUCTION

Mountain glaciers are sensitive indicators of climate change and play a crucial role in regional hydrology and sea-level regulation (Li et al., 2025). In Central Asia, they provide essential water for irrigation, drinking, and hydropower (Fallah et al., 2024).

Rising temperatures and changing precipitation have accelerated glacier retreat, intensifying water scarcity and glacier-related hazards such as lake outbursts and landslides (Jia et al., 2024).
TanDEM-X DEMs enable precise, high-resolution monitoring of glacier elevation and mass changes, yet detailed analyses remain scarce for Central Asia.

This research aimed to quantify glacier elevation changes across Central Asia using multi-temporal TanDEM-X DEMs to support effective water-resource management and climate adaptation strategies.

METHOD

Central Asia, covering an area of approximately 4,003,451 km², is located in the southern part of the Eurasian continent and includes Kazakhstan, Uzbekistan, Turkmenistan, Kyrgyzstan, and Tajikistan (Figure 1).
To quantify glacier elevation changes within this region, multi-temporal TanDEM-X DEMs were processed. DEMs from different acquisition periods were co-registered, differenced, and overlaid with glacier inventories to identify areas of significant ice thinning.
A frequency-distribution filter was applied to remove extreme outliers and improve the accuracy of the elevation-change estimates. This workflow enables precise assessment of glacier elevation changes across the complex mountain terrains of Central Asia.

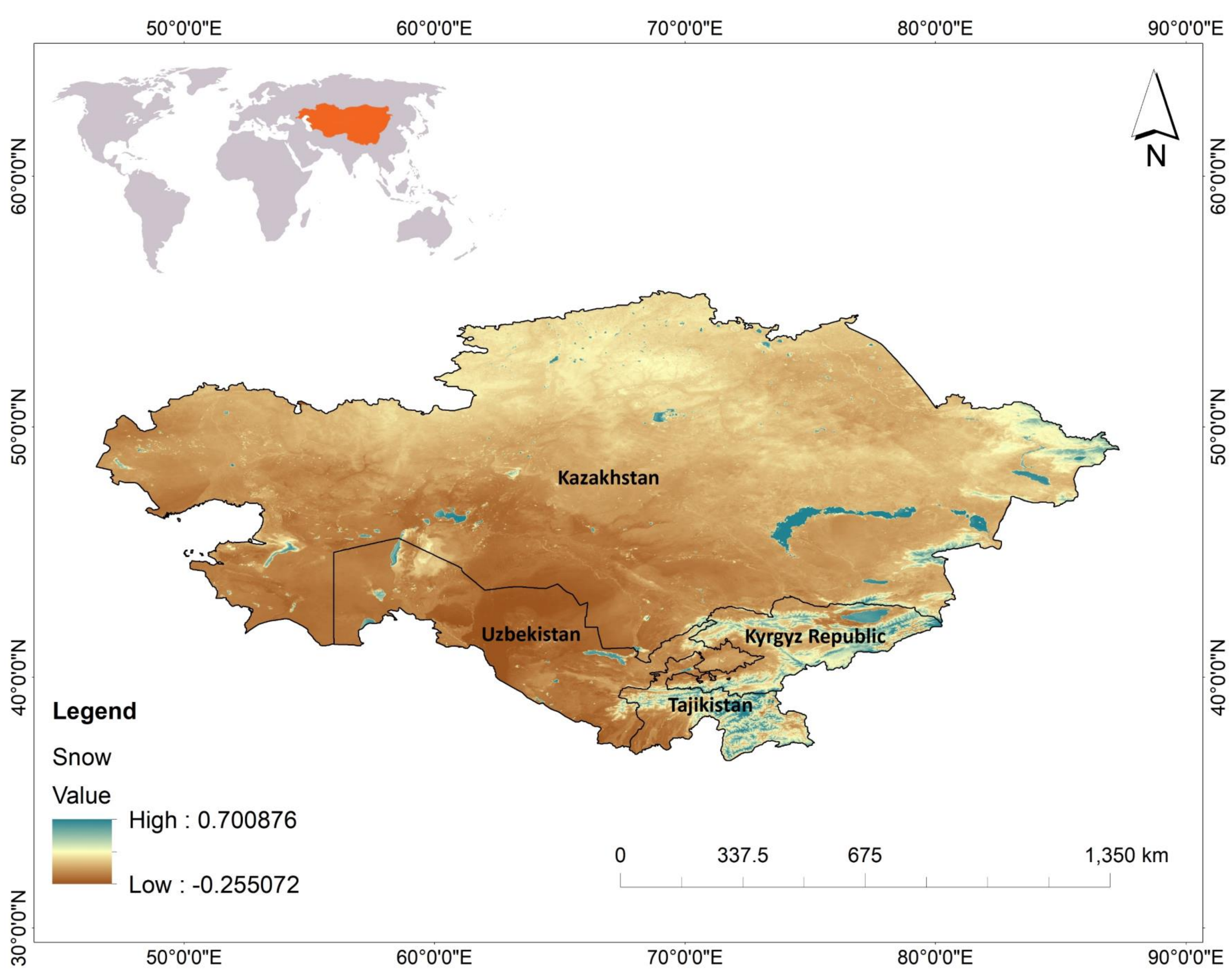

Figure 1. Location of the study area.

RESULTS & DISCUSSION

The analysis indicates glacier thinning across Central Asia, while non-glacierized areas exhibit minimal elevation changes, confirming the robustness of the methodology.
To improve visualization, the eastern mountainous regions with dense glacier coverage were enlarged for detailed examination (Figure 2).

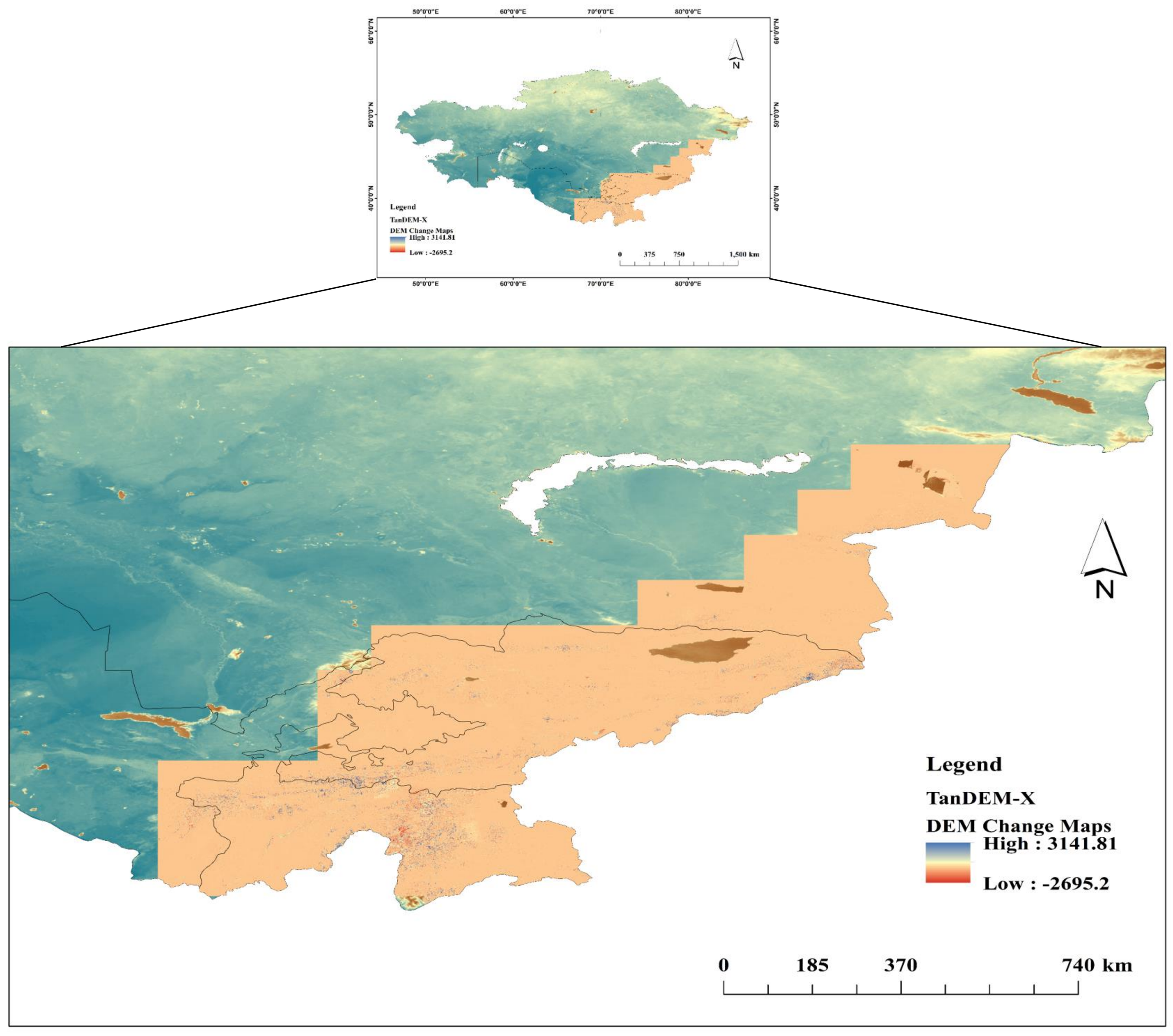

Figure 2. DEM change map

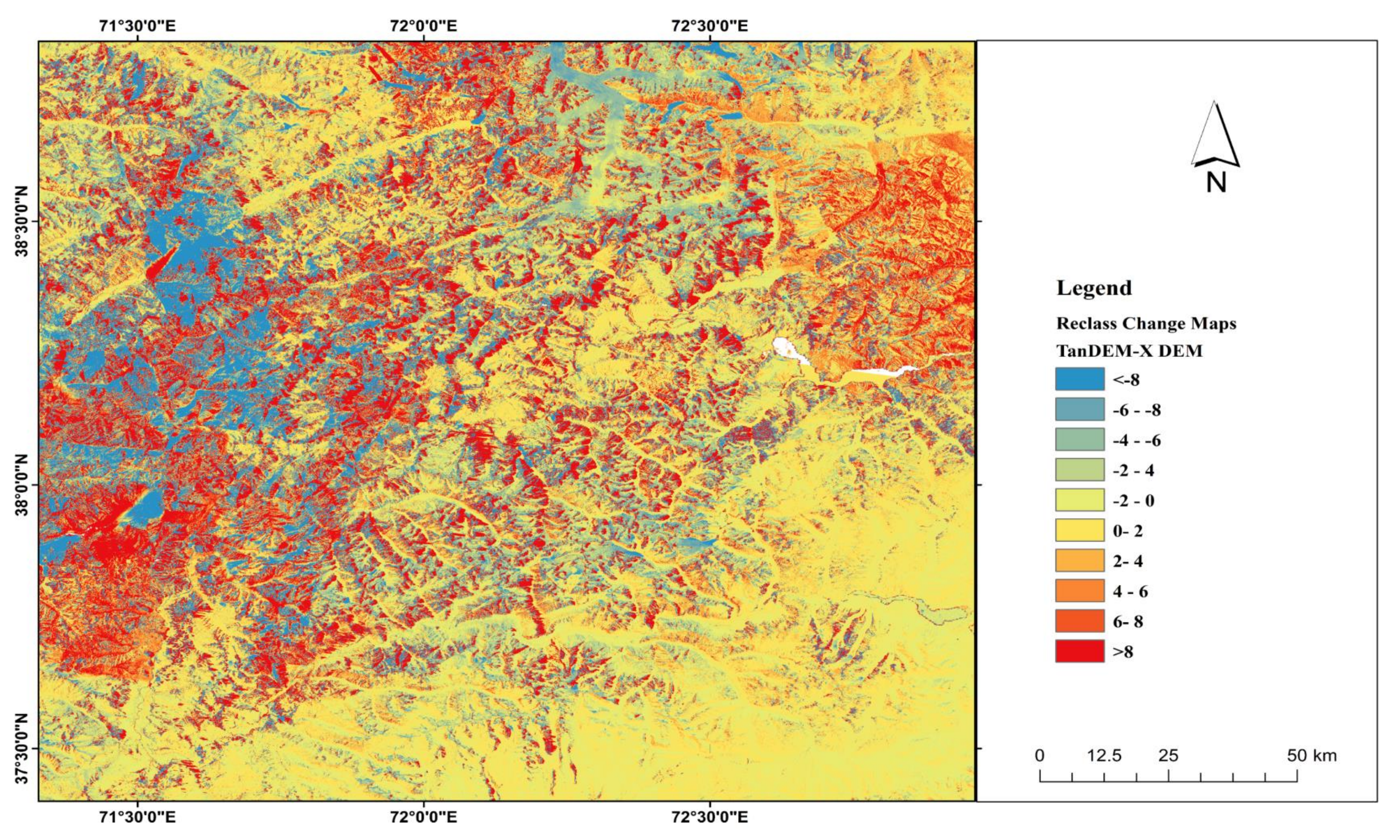

Figure 3. High-resolution DEM change map focusing on the southeastern glacierized region.

A DEM change map with a legend ranging from −10 to +10 meters in 2-meter intervals was generated to capture subtle elevation variations in glacierized zones (Figure 3).
Histogram analysis helped detect and remove extreme outliers caused by noise or co-registration errors, improving the reliability of elevation-change estimates. Spatial patterns show significant heterogeneity, with hotspots of accelerated mass loss influenced by aspect, elevation, and debris cover, alongside stable zones shaped by local climatic and geomorphological factors. These findings demonstrate the effectiveness of TanDEM-X DEM differencing for operational glacier monitoring in remote and data-scarce regions.

CONCLUSION

This study demonstrates that TanDEM-X DEM differencing is a reliable and high-resolution method for monitoring glacier elevation change in Central Asia. The results provide essential information for water-resource management and climate adaptation, and the workflow can be effectively applied in other data-scarce mountain regions.

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