

Urban market access shapes social-ecological transformation in mountain oases of Gilgit-Baltistan, Pakistan

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INTRODUCTION

Land-use transformations in mountain regions are increasingly shaped by infrastructure development, market access, and tourism. Yet, the social-ecological consequences of these changes remain little understood in remote high-mountain oasis systems of Gilgit-Baltistan, Pakistan. In this study, we compare two oasis towns, Karimabad and Shimshal, to assess how connectivity is associated with agricultural land-use and livelihood transformations over the past three decades. Karimabad is relatively well connected through the Karakoram Highway (KKH), while Shimshal remains much more isolated and is only accessible by an unpaved road.

METHODS

We applied a mixed methods approach that combines remote sensing, ground truthing, and household surveys in the selected study areas (Fig. 1).

- Remote sensing:** Landsat imagery from 1994, 2014, and 2024 was used for Normalized Difference Vegetation Index (NDVI)-based land cover classification. Images from July and September were selected to cover peak and late-season vegetation status.
- Household surveys:** 200 households were surveyed (100 in each location) addressing questions on agricultural land use change, perceived transformation drivers, and past and present cropping patterns.
- Rainfall variability:** Monthly rainfall for July and September in selected years was assessed in relation to observed NDVI patterns.

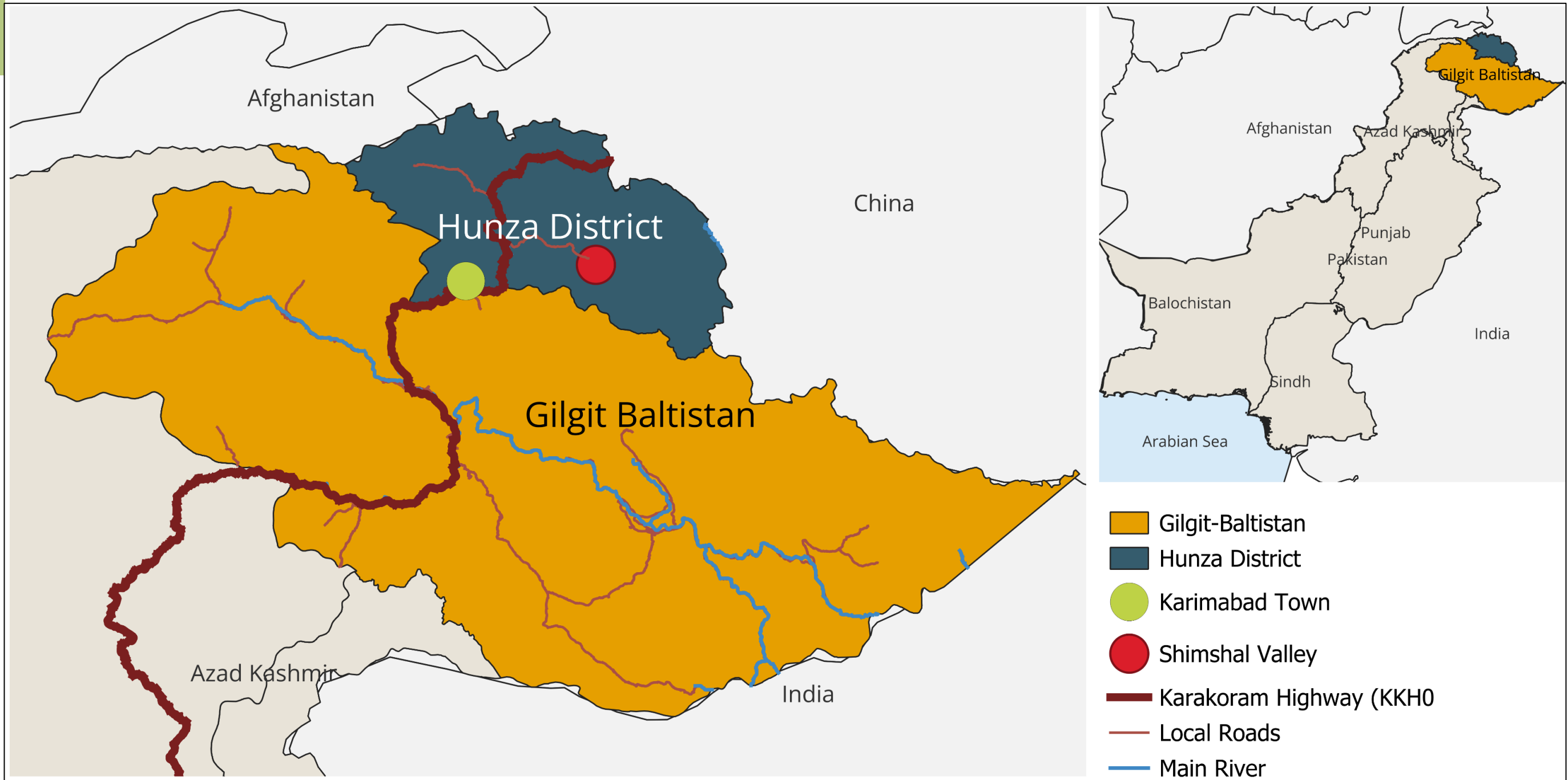


Figure 1. Location of the study areas located in Gilgit-Baltistan, Pakistan.

RESULTS AND DISCUSSION

1. Land use and land cover change (LULCC)

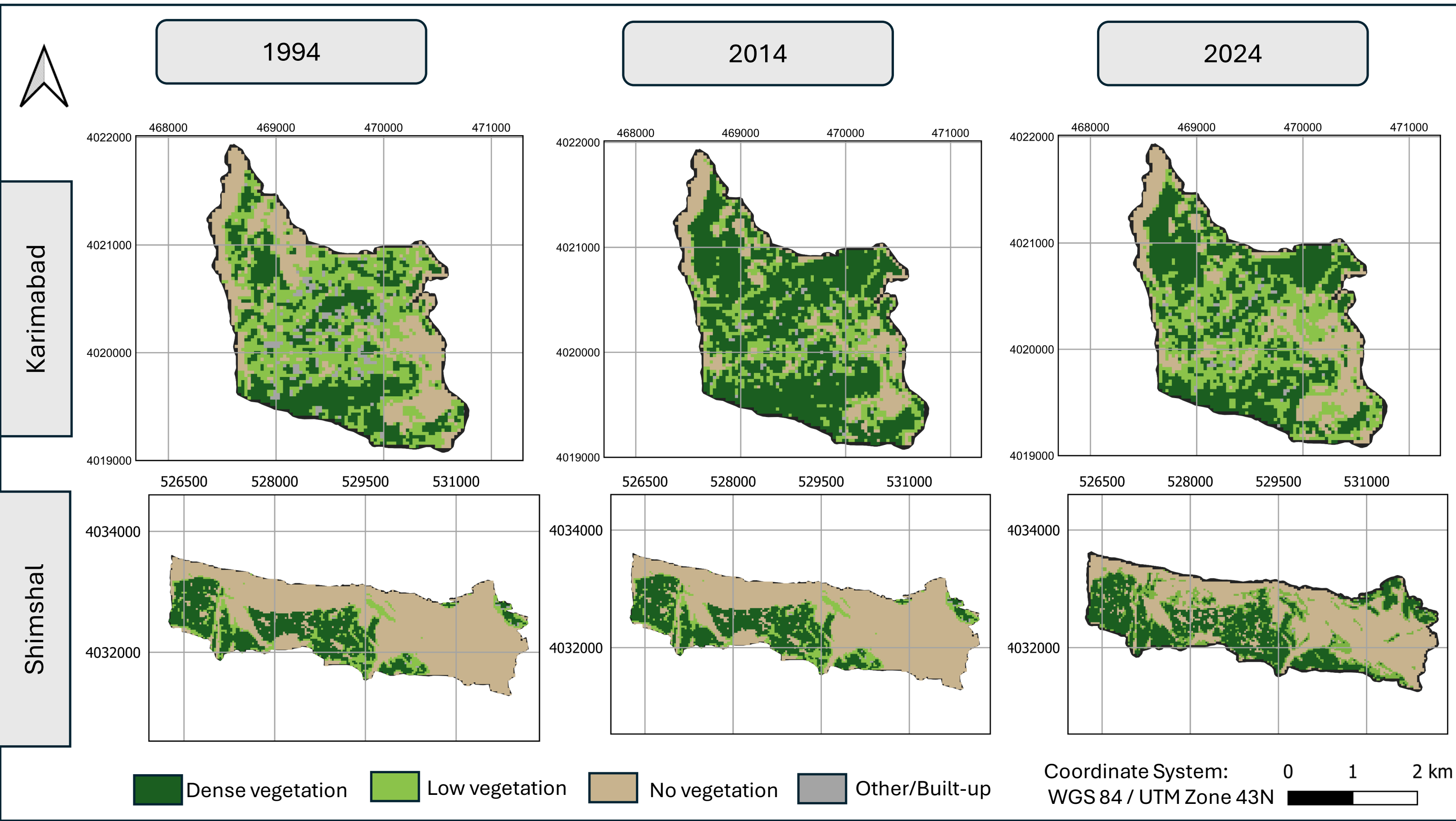


Figure 2. NDVI based vegetation and land cover dynamics in Karimabad and Shimshal, Gilgit-Baltistan, Pakistan, from 1994 to 2024.

LULCC in Karimabad: Dense vegetation increased by 87% between 1994 and 2014, reflecting a rapid expansion of cultivated land, before declining by 29% in 2024. Fallow and barren land decreased until 2014 and increased again by 2024 (Fig. 2, Table 1).

LULCC in Shimshal: Dense vegetation increased steadily by 43% between 1994 and 2024. Fallow land also increased, while barren land declined over the observation period (Fig. 2, Table 1).

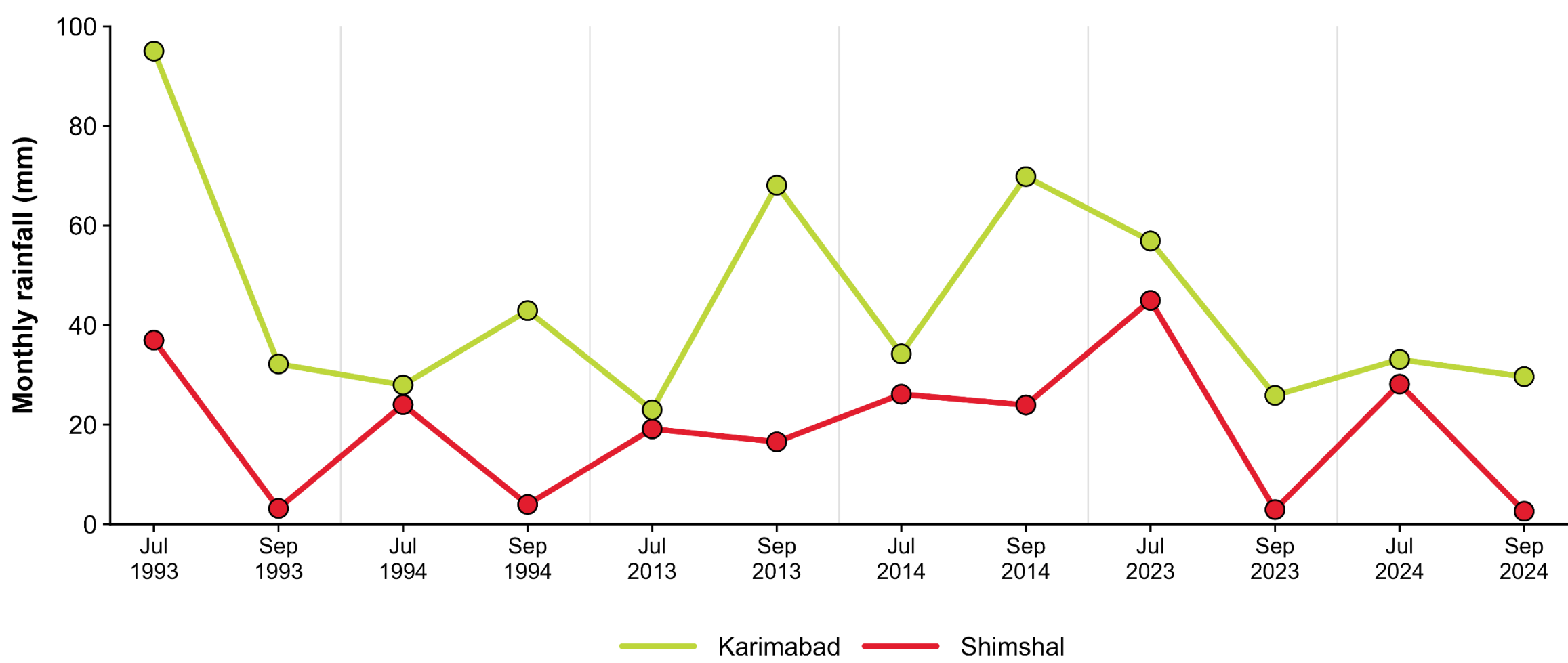


Figure 3. Monthly rainfall (based on CHIRPS rainfall data) in July and September for the years 1994, 2013, 2014, 2023, and 2024.

Table 1. Area of land cover classes in Karimabad and Shimshal in 1994, 2014, and 2024.

Valley/class	1994	2014	2024
Karimabad (Total area: 366 ha)			
Dense vegetation (forest + agricultural land)	112	209	149
Low vegetation (fallow land)	140	89	126
No vegetation (barren land)	96	63	85
Shimshal (Total area: 876 ha)			
Dense vegetation (forest + agricultural land)	189	261	270
Low vegetation (fallow land)	81	126	135
No vegetation (barren land)	606	490	471

Rainfall variability in Karimabad and Shimshal: Rainfall varied among the selected years but showed no trend and consistency with the observed LULCC (Fig. 3).

2. Social-ecological reasons and implications of LULCC

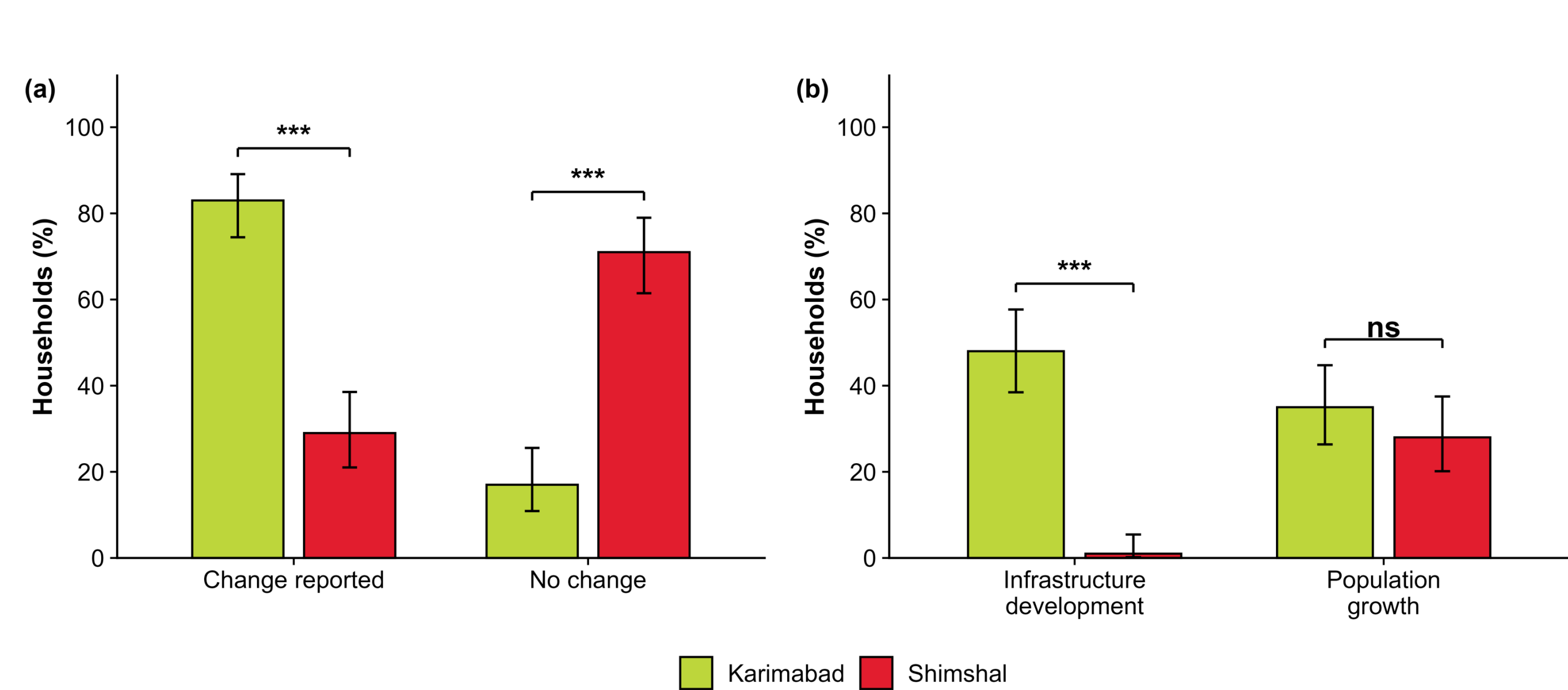


Figure 4. Perception (a) and reasons (b) of agricultural land use change in Karimabad and Shimshal. 95% CI; proportion test: *** p < 0.001, ** p < 0.01, * p < 0.05; not significant (ns).

Agricultural land-use change was reported by 83% of households in Karimabad, compared with 29% in Shimshal (Fig. 4). Infrastructure development was the main reported reason in Karimabad (48%), but was rarely reported in Shimshal (1%). Population growth as a driver for LULCC was reported at similar levels in Karimabad (35%) and Shimshal (28%).

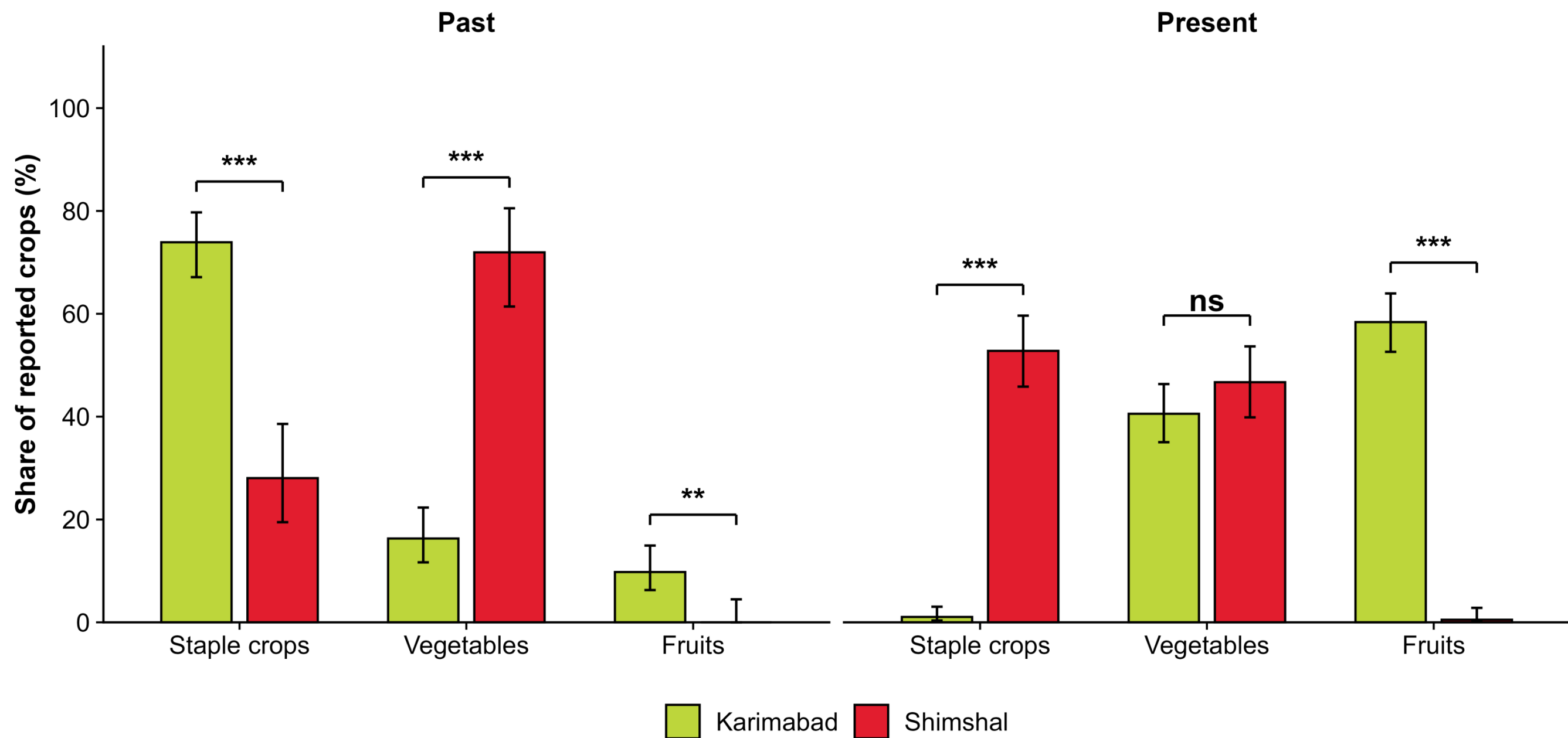


Figure 5. Past and present crop composition in Karimabad and Shimshal. 95% CI; proportion test: *** p < 0.001, ** p < 0.01, * p < 0.05; not significant (ns).

Karimabad showed a pronounced shift from staple crops towards fruits and vegetables (Fig. 5). The share of households cultivating staple crops declined from 74% in the past to 1% at present. In Shimshal, 53% of the households surveyed reported that they currently grow staple crops.

TAKE HOME MESSAGES

1

Infrastructure and market connectivity emerge as key drivers of social-ecological transformations in Gilgit-Baltistan.

2

Karimabad shows greater agricultural land use change and a strong shift from staple crops toward market-oriented fruits and vegetables, while Shimshal shows lower rates of LULCC and cropping systems remain staple-oriented.

3

Connectivity can create new opportunities but may also put pressure on land resources. Future infrastructure development should therefore be supported by agricultural land-use planning.