Historical and future winter chill for temperate fruit and nut trees in Afghanistan

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Introduction

- Temperate fruit trees undergo a dormancy stage during their seasonal cycle to withstand cold winter temperatures (Fadón et al. 2020).
- The required amount of cold exposure during this period is termed as chilling.
- Climate change directly influences chill accumulation and the timing of phenological events (Luedeling et al. 2015).
- Afghanistan's fruit production constitutes 30 % of the total exports earnings (NSIA 2023).

Problem Statement and Objective

- The expected future temperature increases may be detrimental to the trees' ability to fulfill their chilling requirements (viability of orchards).
- To quantify this risk, we use state-of-the-art procedures to estimate and map historical and future Safe Winter Chill (SWC) for Afghanistan.

Methodology

Study area

- **Afghanistan**: The country experiences an arid and semi-arid continental climate.
- It is characterized by cold winters and hot summers.
- The weather data from 51 stations spans two climatic zones (subtropical and temperate).

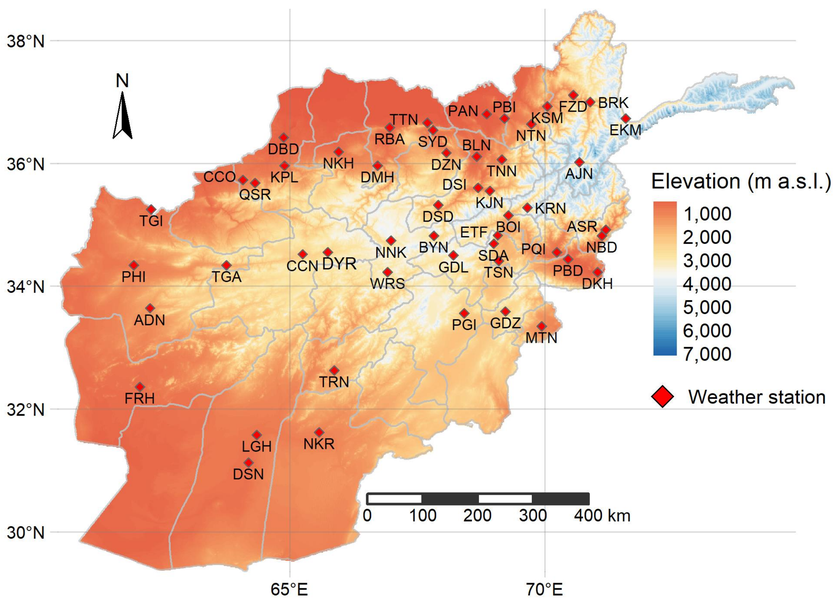
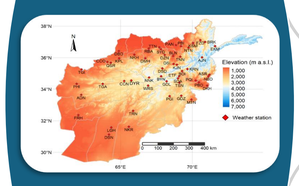


Figure 1. Elevation map of Afghanistan presenting the locations of weather stations used as sources of long-term daily minimum and maximum temperature records.

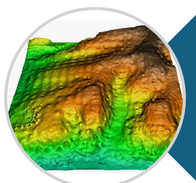
Winter Chill Quantification



- Daily temperature data (1980 to 2020) from 51 weather stations.
- Insufficient observed data → supplement with bias-corrected simulated data from 1980 to 2007.

- Historical scenarios (1980, 1990, 2000, 2010, 2020).
- Future scenarios (SSP126, SSP245, SSP375, SSP585)
- Produced 100 random realizations of synthetic weather records using weather generator.

- Estimated the winter chill and Safe Winter Chill (SWC) for all weather records.
- Used the Dynamic Model in the *chillR* package (Luedeling et al. 2023) in R.



- Kriging as a spatial interpolation technique to estimate chill accumulation across the country.
- Implemented Kriging using the *gstat* package in R (Gräler et al. 2016).

Results and Discussion

Historical scenarios – decrease in SWC accumulation in the eastern and southern lowlands; overall increase northern, northeastern, western, and central regions (Figure 2).

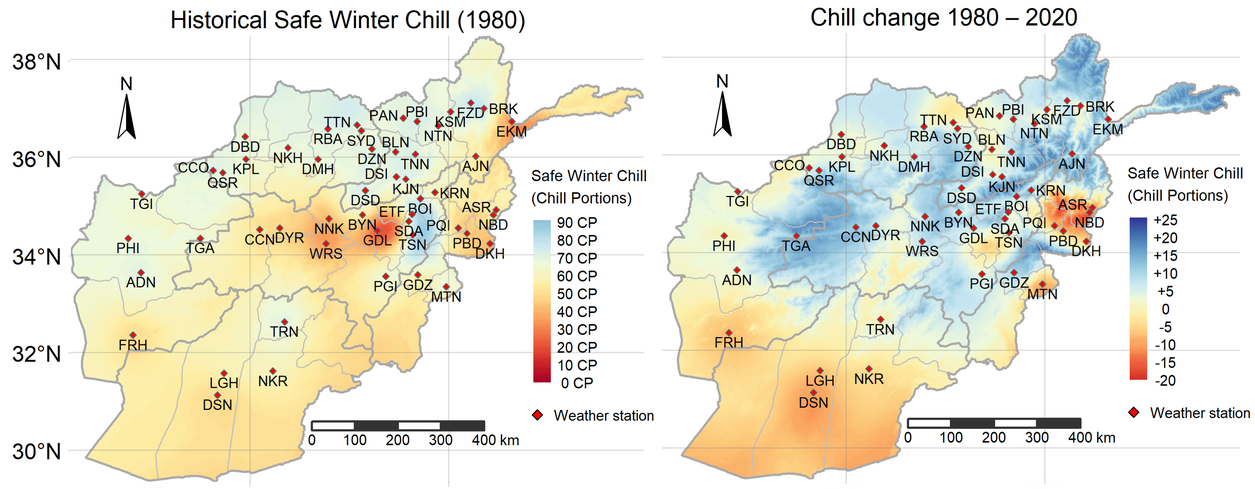


Figure 2. Maps of historical Safe Winter Chill (SWC) and chill change between 1980 and 2020 in Afghanistan.

Future scenarios – Except for the central highlands, many stations in the north, northeast, and western regions experienced chill losses, especially in the low-lying regions (Figure 3).

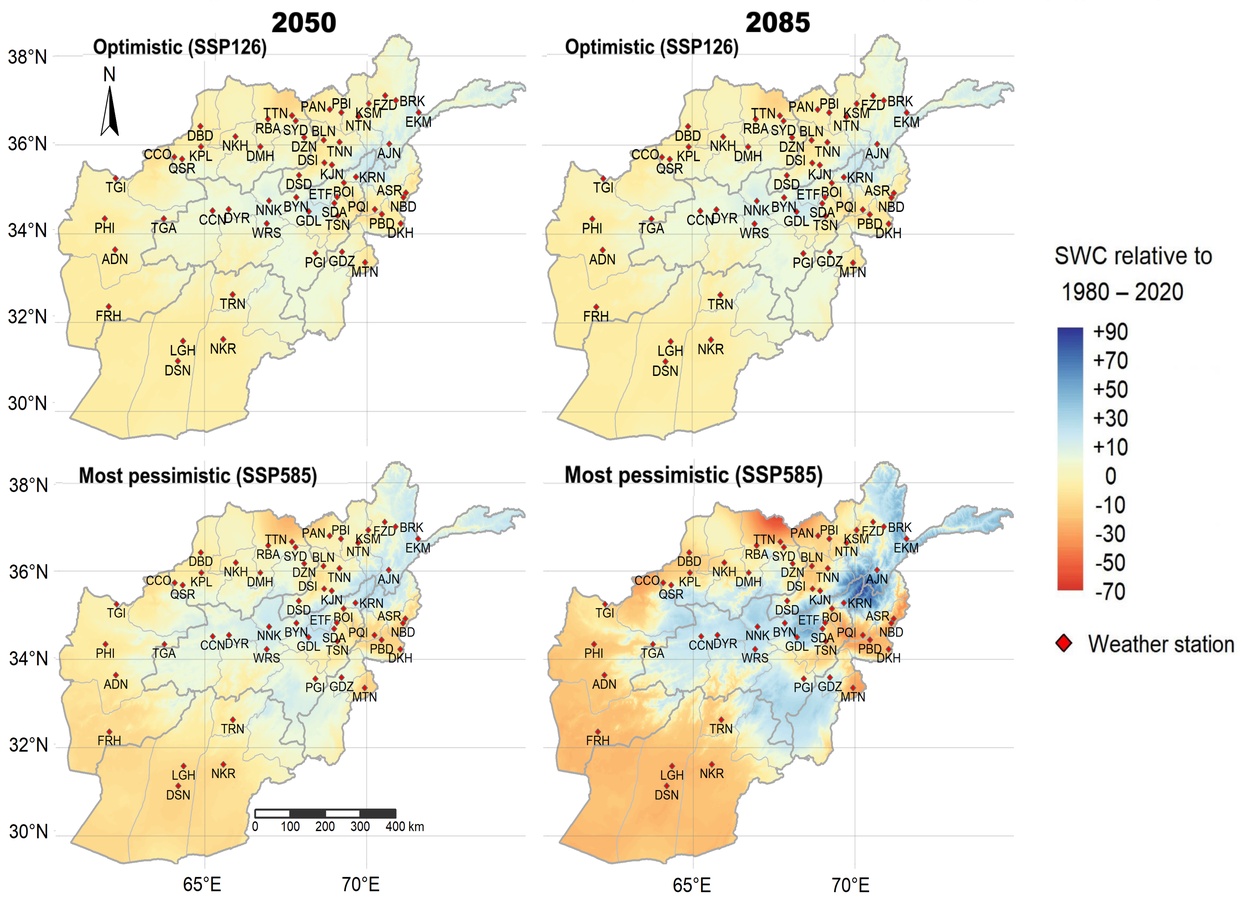


Figure 3. Map of Safe Winter Chill (SWC) for future climate scenarios in Afghanistan.

- Reduction in the degree of chill overlap between historical and future scenarios.
- Chill losses mainly in perennial fruit-producing regions (apricots, peaches, almonds, etc.).
- Chill gains at high altitudes as warming drives temperature closer to the effective range.
- Similar challenges to other subtropical regions (e.g. California, Tunisia, etc.).

Conclusion

- Cultivar-specific chill estimation to facilitate the selection of appropriate germplasm.
- Need to overcome scarcity of long-time phenology data series.
- Consider location-specific chill profiles when selecting tree cultivars.

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