Analysis of the Impact of Climate Change on Grapevines in Turkey Using Heat Unit Accumulation-Based Indices

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Abstract

Temperature is the most important factor influencing grapevine phenology and yield. Various indices have been developed that deal with the temperature sums that grapevines are exposed to during growth and maturation. With the help of these indices, predictions are made about whether the grapes will grow in a certain region and the quality of the grapevines. In this study, the future impacts of climate change on viticultural conditions in Turkey were projected by using Huglin index (HI), Winkler index (WI), and cool night index (CI). Under the RCP8.5 scenario, HI, WI, and CI indices for the future period of 2022–2050 were calculated for Turkey at 10 km spatial resolution with the RegCM4.4 model and compared with the 1972–2000 reference period. As a result of the study, a substantial increase in CI, HI, and WI and at least one level of categorical change were observed in the climatic conditions of the next 30 years in Turkey. These categorical shifts in CI, HI, and WI indicate that there may be changes in the geographical pattern of grapevine species grown in Turkey as well as the aroma and quality.

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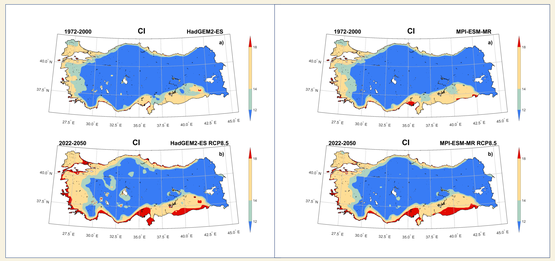

Fig.1. Categorical CI (°C) heatmaps for the baseline period of 1972–2000 (a) and the future period of 2022–2050 (b) under RCP8.5 (RegCM-HG&MPI).

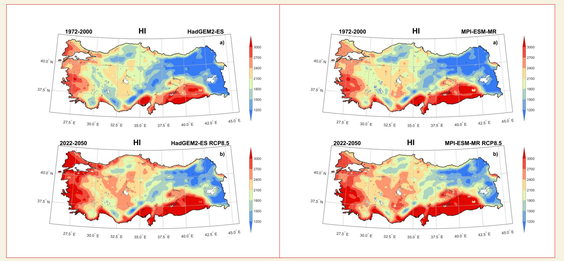

Fig.2. Categorical HI (°C) heatmaps for the baseline period of 1972–2000 (a) and the future period of 2022–2050 (b) under RCP8.5 (RegCM-HG&MPI).

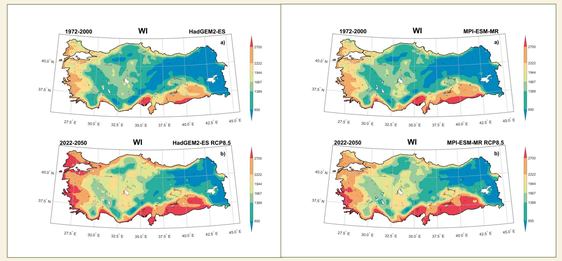

Fig.3. Categorical WI (°C) heatmaps for the baseline period of 1972–2000 (a) and the future period of 2022–2050 (b) under RCP8.5 (RegCM-HG&MPI).

Experimental Design & Data

GCMs	: MPI-ESM-MR & HadGEM2-ES
Domain/Sub-Domains	: Turkey,
RCM	: RegCM4.4.3
Grid resolution	: 50km x 50 km (downscaling) and 10km x 10km (double nested)
Land-Surface Scheme	: BATS
PBL Scheme	: Holtslag
Convection Scheme	: Emanuel over ocean & Tiedtke over land
Baseline time scale	: 1972-2000
Future time scale	: 2022-2050
Projection scenario	: RCP8.5 (BAU) - history and future
Variables	: Huglin index (HI) & Winkler index (WI) & Cool night index (CI)

- **The WI** provides information on heat accumulation during the growing season (Winkler et al. 1974). WI totals below 850 °C-days are considered too cold for viticulture, while over 2700 °C units are too hot.
  $\sum_{01/04}^{31/10}\left[\frac{Tmax+Tmin}{2}-10\right]$, where *Tmax and Tmin* are the daily maximum and minimum temperatures.
- **The HI** is a modified version of WI(Huglin 1978). HI considers the accumulated temperature in daylight rather than the entire 24-h period. The length of day coefficient "*k*," which varies between 1.02 and 1.06 at latitudes of 40 to 50° (Tonietto and Carbonneau 2004). The "*k*" allows to consider the effect of high temperatures, which are more exposed on long days at high latitudes, especially in summer. HI takes values between 1500 and 3000 °C units. $\sum_{01/04}^{30/09}\left[\frac{(Tmean-10)+(Tmax-10)}{2}\right]*k$. where *Tmean* is the daily mean and *Tmax* is the daily maximum temperature.
- **The CI** represents the average of minimum nighttime tempera- tures during the ripening period (September for the Northern Hem- isphere) (Tonietto and Carbonneau, 2004). It takes values between 12–18 °C $\sum_{September}\frac{Tmin}{total\ number\ of\ days}$ where *Tmin* is the daily minimum temperature.

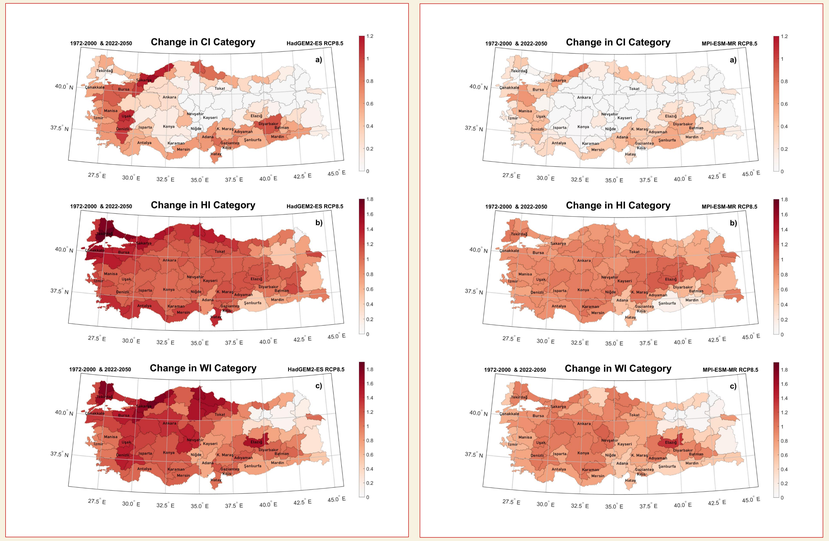

Fig.4. Expected category change (rank) in indices from the reference period (1972– 2000) to the future period (2022–2050) under the RCP8.5 scenario (RegCM-HG&MPI). It shows expected changes in HadGEM2-ES (left side) and in MPI-ESM-MR (right side) in CI (a), HI (b), and WI (c).

Results 1.

- The increased frequency of extremely high summer temperatures in the twenty-first century may be a high-risk factor for grape production.
- The effect of increasing temperatures on grape production and quality of wines.
- Grape varieties that can better withstand high temperatures and water stress may emerge.
- The great impact of climate on the distribution of vineyards

Results 2.

- Categorical increases in CI, HI, and WI in Turkey.
- Striking increase in CI for both the HadGEM-2-ES and MPI-ESM-MR models, in the Mediterranean, Aegean, and Southeastern Anatolia regions, where most of the grape production in the country takes place.
- Remarkable increase in HI in the coastal areas of the Mediterranean and Aegean regions
- Noticeable shifts in at least one upper category in the WI index throughout the country.
- A significant increase in CI, HI and WI
- A trend of a shift to upper categories in future climatic conditions in Turkey.
- In a 30-year period in the future, increasing temperatures and decreasing precipitation in Turkey will change the optimum conditions for grape-producing regions.

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