

Supplementary Material

Challenges to Viticulture in Montenegro under Climate Change

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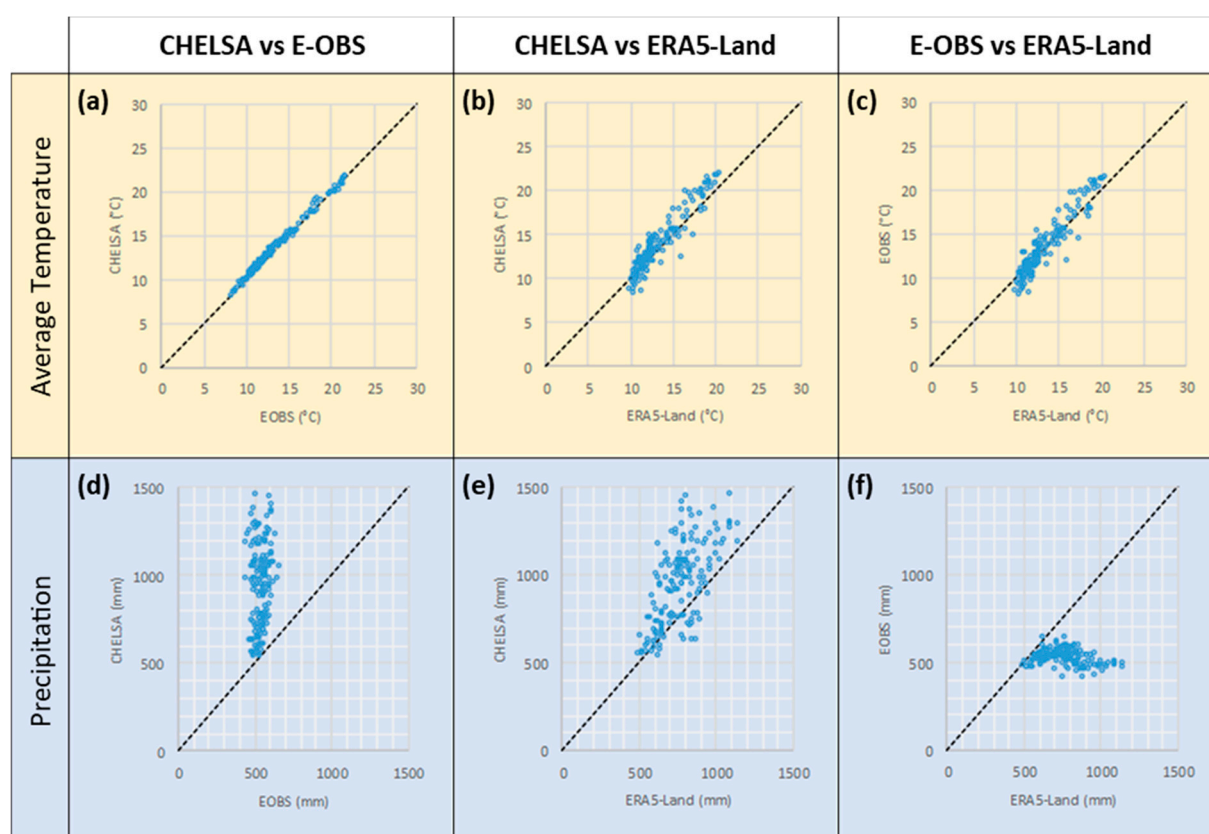


Figure S1. Comparison between data sources, from 1981 to 2010 CHELSA, EOBS and ERA5-Land data. The plotted data correspond to the vineyard's growing season, from April to October. In the first row, is compared the climate average of daily average temperature during the growing season, between CHELSA and EOBS (a), CHELSA and ERA5-Land (b), EOBS and ERA5-Land (c). In the second row, the climate mean precipitation during the growing season, between CHELSA and EOBS (e), CHELSA and ERA5-Land (f), E-OBS and ERA5-Land (g). Note: as the resolution among data sources is different, the datasets were resampled for the resolution of 1° per 1° and grid distribution of EOBS.

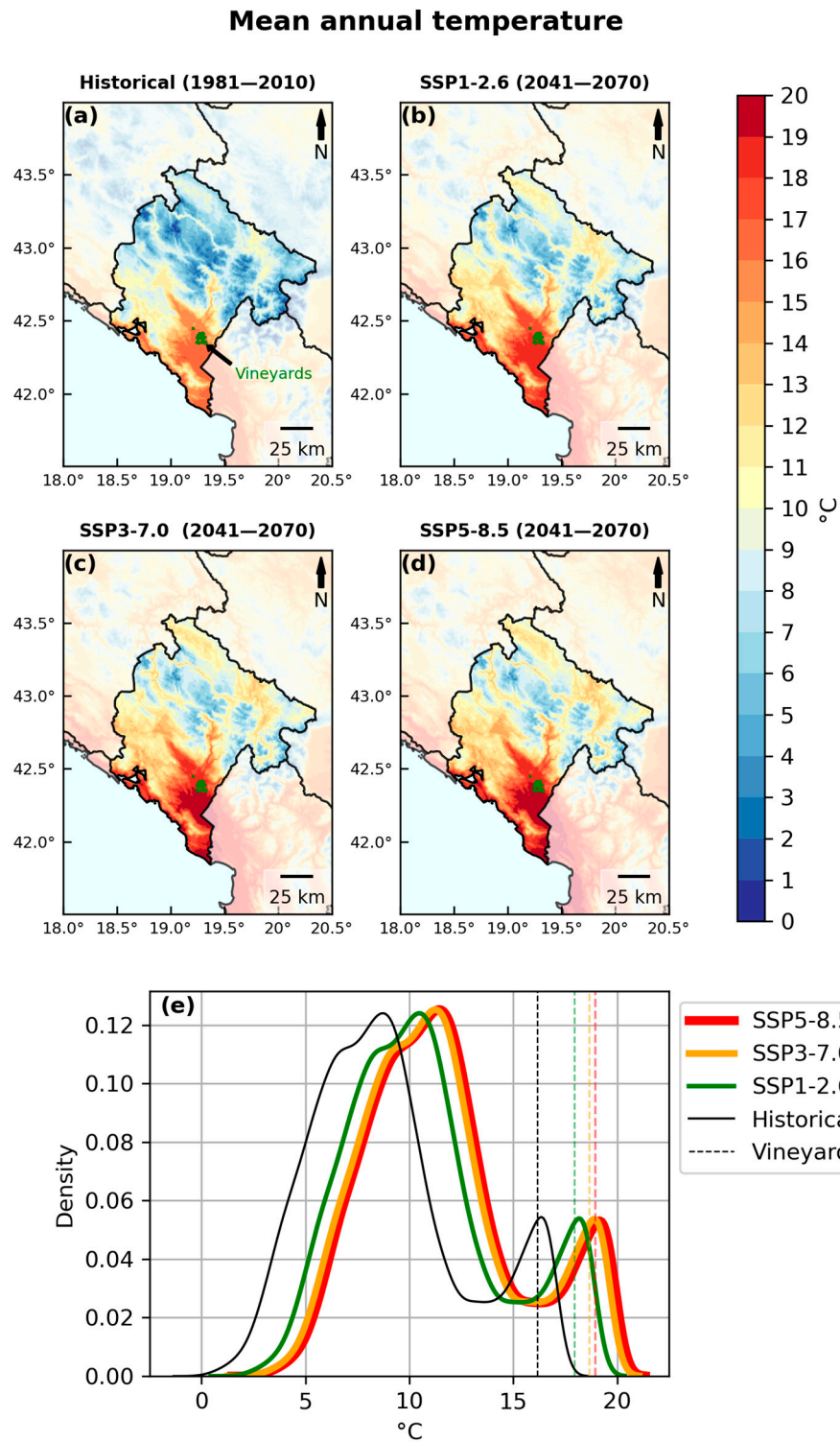


Figure S2. Climate annual mean daily average temperature, for Montenegro according to the CHELSA dataset: (a) over the Historical period (1981–2010), and the future period (2041–2070) under (b) SSP1-2.6, (c) SSP3-7.0 and (d) SSP5-8.5. (e) Corresponding Kernel Density plot of the spatial variability in (a), (b), (c) and (d). The median value in the vineyard area is shown as a vertical dashed line. Projections were estimated by the ensemble median from 5 climate models.

Annual precipitation amount

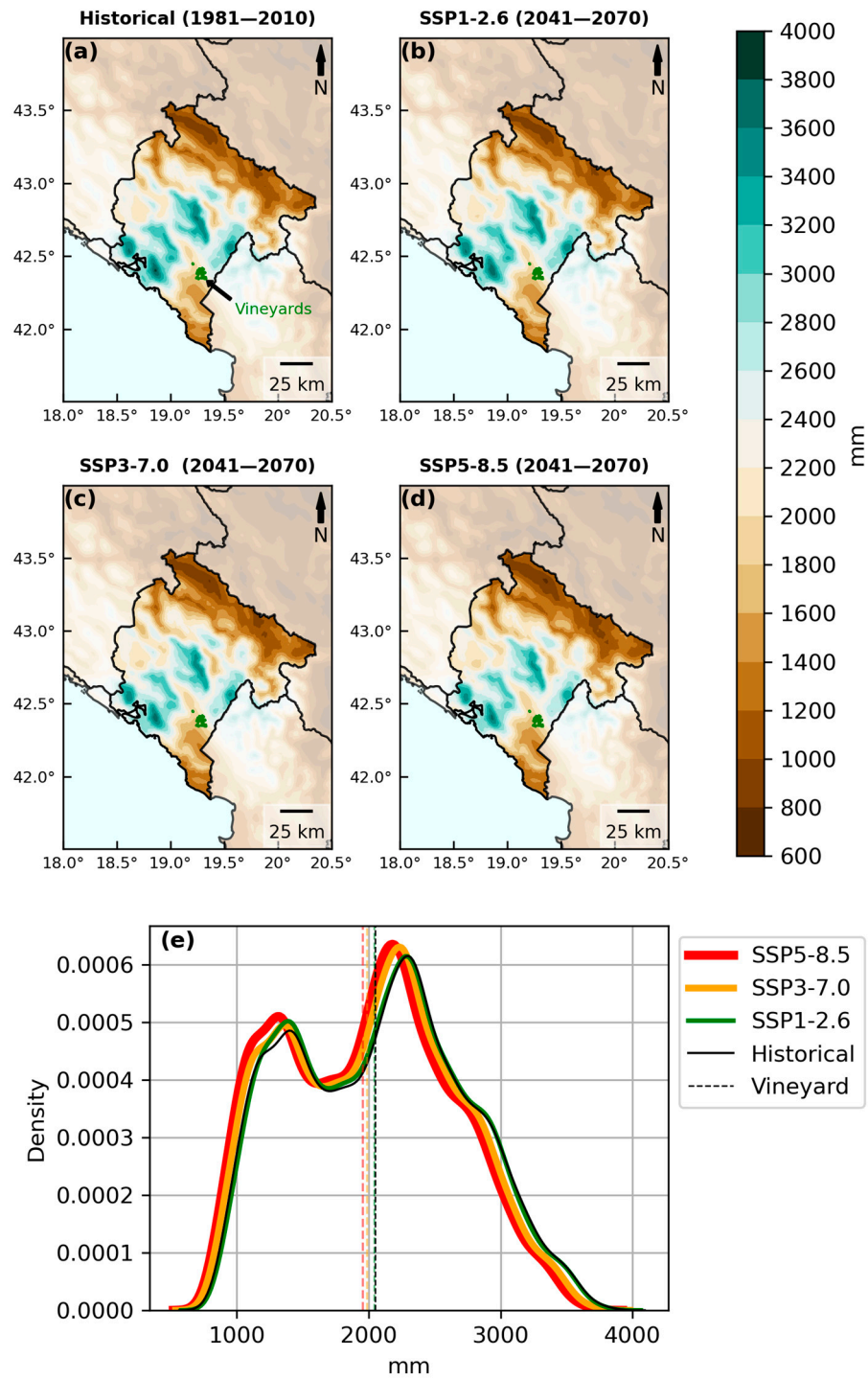


Figure S3. Climate mean of annual precipitation, for Montenegro according to the CHELSA dataset: (a) over the Historical period (1981–2010), and the future period (2041–2070) under (b) SSP1-2.6, (c) SSP3-7.0 and (d) SSP5-8.5. (e) Corresponding Kernel Density plot of the spatial variability in (a), (b), (c) and (d). The median value in the vineyard area is shown as a vertical dashed line. Projections were estimated by the ensemble median from 5 climate models.

Precipitation amount from April to October

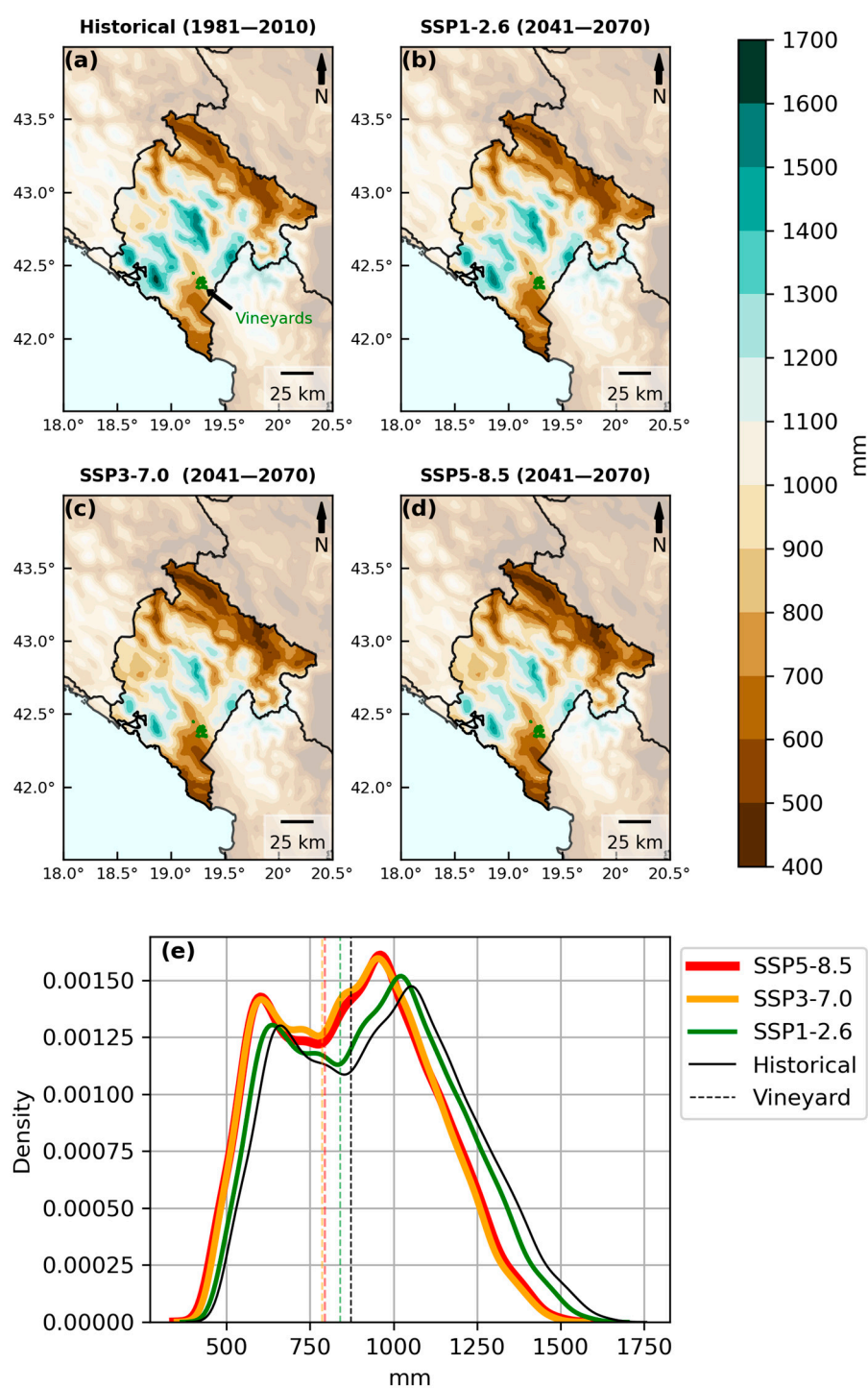


Figure S4. Climate mean of precipitation during the vineyard growing season, from April to October, for Montenegro according to the CHELSA dataset: (a) over the Historical period (1981–2010), and the future period (2041–2070) under (b) SSP1-2.6, (c) SSP3-7.0 and (d) SSP5-8.5. (e) Corresponding Kernel Density plot of the spatial variability in (a), (b), (c) and (d). The median value in the vineyard area is shown as a vertical dashed line. Projections were estimated by the ensemble median from 5 climate models.

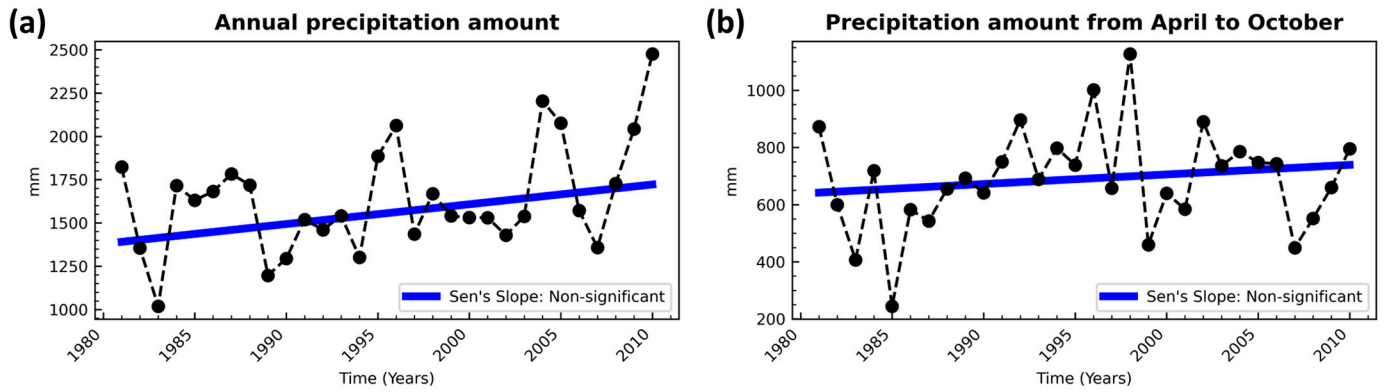


Figure S5. Chronograms of the outlined indices for Podgorica weather station during the Historical period (1981-2010). (a) Annual mean of annual precipitation during the vineyard growing season, from April to October. (b) Annual mean of total precipitation during from April to October.

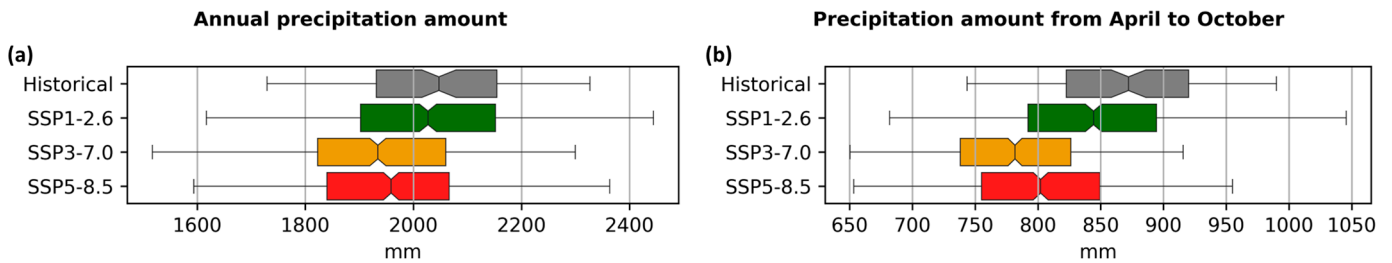


Figure S6. Notch boxplots of precipitation indices from the CHELSA dataset in the vineyard areas of Montenegro, for the Historical period (1971-2010) and the future period (2041-2070) under SSP1-2.6 SSP3-7.0 and SSP5-8.5. (a) Climate mean of annual precipitation. (b) Climate mean of precipitation during the vineyard growing season, from April to October.

Table S1. Median values of the selected bioclimatic indices from Chelsa Dataset. It is represented the median value among MVAs, for the historical period, and for each of Climate Model for each of the SSP scenarios. The median values for each model and scenario are underlined and marked in bold.

		Mean temperature from 04 to 10 (°C)	Mean temperature of the warmest quarter (°C)	Mean annual temperature (°C)	Temperature seasonality (°C)	Growing degree days heat sum above 5°C	Winkler Index (°C)	Growing degree days with average temperature > 5°C	Annual precipitation amount (mm)	Precipitation amount from 04 to 10
Historical Period		21.5	25.4	16.2	7.2	2530	2454	262	2040	869
SSP5—8.5	GFDL-ESM4	24.4	28.9	18.8	7.6	3313	3081	<u>305</u>	1958	838
	IPSL-CM6A-LR	25.4	30.1	19.6	8.0	3545	3290	305	1924	<u>792</u>
	MPI-ESM1-2-HR	24.4	<u>29.2</u>	18.7	7.9	3274	3082	290	1877	783
	MRI-ESM2-0	<u>24.6</u>	29.1	<u>19.0</u>	7.7	<u>3352</u>	<u>3130</u>	295	2072	833
	UKESM1-0-LL	26.7	31.9	21.1	<u>7.8</u>	4068	3572	365	<u>1951</u>	765
SSP3—7.0	GFDL-ESM4	24.2	28.5	<u>18.7</u>	7.5	3252	3051	300	<u>1983</u>	774
	IPSL-CM6A-LR	24.5	29.1	18.9	<u>7.7</u>	3303	3097	<u>297</u>	1908	805
	MPI-ESM1-2-HR	<u>24.3</u>	<u>28.9</u>	18.5	8.0	3239	<u>3057</u>	290	1787	761
	MRI-ESM2-0	24.2	28.5	<u>18.7</u>	7.5	<u>3264</u>	<u>3035</u>	295	1999	<u>783</u>
	UKESM1-0-LL	26.0	30.9	20.5	7.7	3839	3425	333	2015	784
SSP1—2.6	GFDL-ESM4	23.5	27.5	<u>18.0</u>	7.5	<u>3077</u>	2886	291	2143	917
	IPSL-CM6A-LR	<u>23.6</u>	28.0	18.1	7.5	3071	<u>2919</u>	<u>286</u>	1936	<u>837</u>
	MPI-ESM1-2-HR	23.4	27.7	17.9	<u>7.6</u>	3019	2868	285	1906	797
	MRI-ESM2-0	23.7	<u>28.0</u>	<u>18.0</u>	7.7	3079	2931	279	<u>2033</u>	817
	UKESM1-0-LL	24.7	29.3	19.1	7.6	3392	3142	302	2128	858