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Modelling climate change impacts on early and late harvest grassland systems in Portugal

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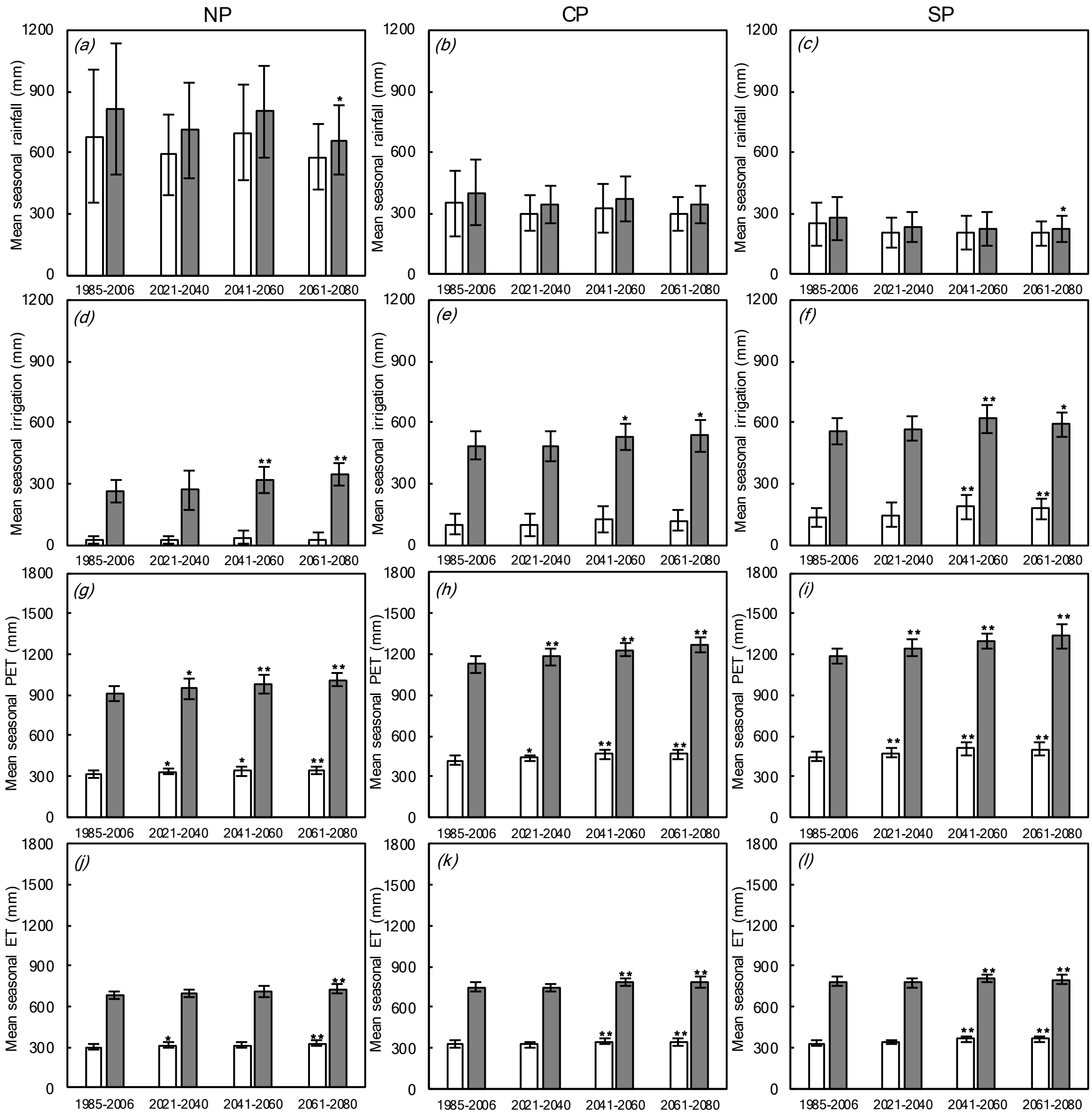

Figure S1. Simulated mean and standard deviation of seasonal quantities (mm) of (*a*–*c*) precipitation, (*d*–*f*) irrigation, (*g*–*i*) potential evapotranspiration (PET) and (*j*–*l*) actual evapotranspiration (ET) over successive periods in study sites. Blank and dark bars were for early spring (ES) and late summer (LS) cut grassland systems, respectively. Independent sample *t*-test was performed in means between baseline and each future period, with significance levels at $p < 0.05$ (*) and $p < 0.01$ (**) respectively.

Table S1. Summary of soil parameters for three study sites, along with respective dataset source and documented literatures for calculation approach

Soil parameter description	Locations NP	CP	SP	Dataset source/ Reference literature
Soil layer division	30 cm of topsoil and 70 cm of subsoil			HWSD
Soil structure	normal soil compaction and low gravel content			HWSD
Soil salinity level	Extremely low			HWSD
Soil organic matter (% weight)	2.72 topsoil 1.07 subsoil	0.70 topsoil 0.27 subsoil	0.40 topsoil 0.24 subsoil	HWSD
Topsoil pH (H_2O)	5.3	5.1	6.5	HWSD
Topsoil carbonate content (%)	0	0	0	HWSD
Topsoil USDA texture	Loam	Sandy loam	Loamy sand	HWSD
Topsoil fraction (%)	41% sand 36% silt 23% clay	75% sand 15% silt 10% clay	82% sand 8% silt 10% clay	HWSD
Subsoil USDA texture	Loam	Sandy loam	Sandy loam	HWSD
Subsoil fraction (%)	44% sand 32% silt 24% clay	68% sand 17% silt 15% clay	75% sand 8% silt 17% clay	HWSD
Estimation of soil hydraulic parameters	θ_{FC1}= 29% θ_{WP1}= 16% θ_{FC2}= 28% θ_{WP2}= 15% TAW_{soil}= 130 mm	θ_{FC1}= 13% θ_{WP1}= 6% θ_{FC2}= 17% θ_{WP2}= 9% TAW_{soil}= 77 mm	θ_{FC1}= 11% θ_{WP1}= 6% θ_{FC2}= 17% θ_{WP2}= 10% TAW_{soil}= 64 mm	Soil texture and structure, organic matter content, salinity / (Saxton and Rawls 2006)
Estimation of cumulative maximum soil evaporation without energy limit (mm)	q0 = 9.84	q0 = 8.75	q0 = 9.6	Topsoil fraction / (Brisson *et al.* 2009)
Estimation of slope degree (%)	0–4.5%	0–6.1%	0–2.1%	GTOPO30
Estimation of surface runoff coefficient	Ruisolnu = 0.03	Ruisolnu = 0.03	Ruisolnu = 0	Slope degree / (Brisson *et al.* 2009)

Note: θ_{FC1} and θ_{WP1} respectively symbolized soil volumetric moisture content at field capacity and permanent wilting point of topsoil, with θ_{FC2} and θ_{WP2} indicated for subsoil. TAW_{soil} represented total available water amount calculated as moisture difference between field capacity and permanent wilting point over soil profile.

Table S2. Mean atmospheric CO_2 concentration for study periods of historical global record and climate change scenario (RCP8.5)

Study periods	Mean CO_2 concentration (ppm)	Data source
Baseline (1985–2006)	362.6	NOAA
Short term (2021–2040)	451.9	
Medium term (2041–2060)	545.4	RCP8.5
Long term (2061–2080)	682.3	

Table S3. Summary of defined grassland system parameters with supported references

Grassland system parameters	Parameter values				Relevant references
Initial status	Plant initialization (LAI = 1 $m^2\,m^{-2}$, dry matter = 1.5 t ha^{-1}, root depth = 60 cm)				(Ruget *et al.* 2009; Courault *et al.* 2010)
Grass features	*Grass-prairiep* with standard value: *GDD* from emergence to end of juvenile stage = 116ºC, *GDD* from emergence to end of leaf initialization = 1500ºC, *GDD* from emergence to grain filling = 1000ºC				(Ruget *et al.* 2006)
Farming practices	Locations	NP	50 kg/ha mineral N per cut and 216 kg/ha slurry (with 65 kg/ha ammonium nitrogen) applied in winter	Early cut dates (DOY_1=73, DOY_2=143) Late cut dates (DOY_1=143, DOY_2=250)	(Trindade *et al.* 1997; Lopes and Reis 1998)
		CP	25 kg/ha mineral N per cut	Early cut dates (DOY_1=91, DOY_2=152) Late cut dates (DOY_1=155, DOY_2=260)	(Carneiro *et al.* 2005)
		SP	25 kg/ha mineral N per cut	Early cut dates (DOY_1=80, DOY_2=144) Late cut dates (DOY_1=144, DOY_2=250)	(Lourenco and Palma 2001; Aires *et al.* 2008a)
Residue matter	Estimated residue matters after cutting (LAI = 0.2 $m^2\,m^{-2}$, dry matter = 1 t ha^{-1})				(Aires *et al.* 2008b; Ruget *et al.* 2009)

Note: *Grass-prairiep* was the original plant file parameterized for simulation of perennial grassland. *GDD* was growing degree days with base temperature of 0ºC. DOY_1 and DOY_2 were day of year for the first and the second cut, respectively.

Table S4. Summary of variations in mean annual temperature (T_{mean}) and mean annual precipitation sum (P_{rec}) of future periods in relative to baseline. Student's *t*-test was performed for changes in the mean values of each future period compared to baseline (* and ** indicated significance level at $p < 0.05$ and $p < 0.01$, respectively)

Future periods in RCP8.5	Location of NP		Location of CP		Location of SP	
	T_{mean} (ºC)	P_{rec} (%)	T_{mean} (ºC)	P_{rec} (%)	T_{mean} (ºC)	P_{rec} (%)
2021–2040 (short-term)	+0.7**	–12	+0.9**	–15*	+0.9**	–16*
2041–2060 (medium-term)	+1.4**	–4	+1.8**	–8	+1.7**	–15*
2061–2080 (long-term)	+2.3**	–9	+2.8**	–17*	+2.7**	–20*

Table S5. Summary of number of days in summer with frequency above 50% for the occurrence of defined extreme heat stress in each study period (figures in brackets indicate the increased days)

Periods	Extreme heat stress in summer (days)		
	NP	CP	SP
Baseline	0	0	20
short-term	3 (+3)	19 (+19)	68 (+48)
medium-term	14 (+11)	46 (+27)	71 (+3)
long-term	35 (+21)	71 (+25)	83 (+12)

Table S6. Summary of number of days in summer with frequency between 10% and 30% for the occurrence of defined severe water stress in each study period (figures in brackets indicate the variations of days)

Periods	Severe water stress in summer (days)		
	NP	CP	SP
Baseline	22	34	42
short-term	36 (+14)	64 (+30)	51 (+9)
medium-term	44 (+8)	69 (+5)	57 (+6)
long-term	47 (+3)	73 (+4)	48 (–9)