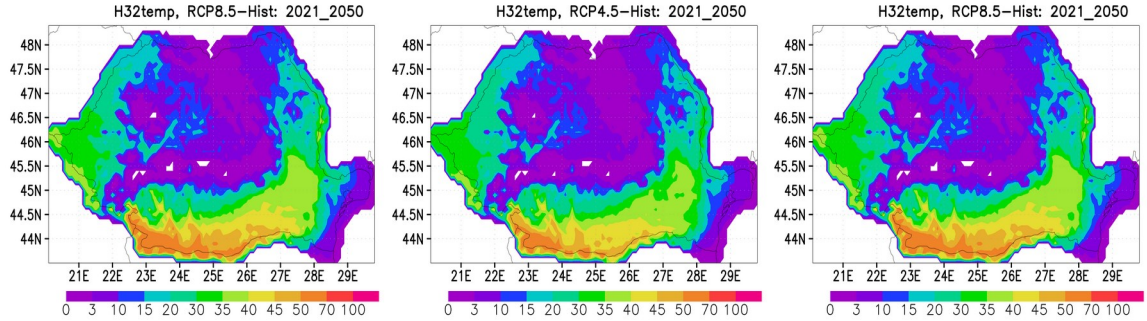
Supplementary material:

Section 1: Projected changes in agro-climate indicators over the SE Romania

a)



b)

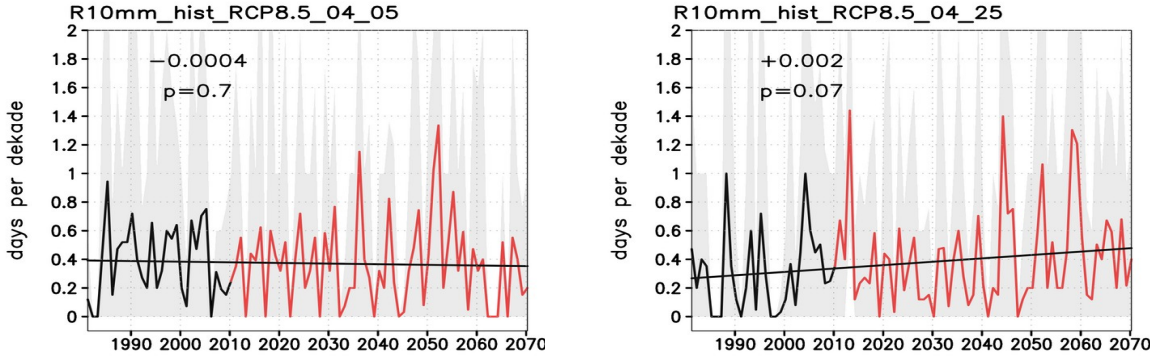


Fig.S1 a) The scorching index H32temp (degrees above 32C sum in summer JJA) for: Hist (1971-2000, left) and changes (2021-2050) relative to it, under RCP4.5 (middle) and RCP8.5 (right). The scorching index classes are: reduced intensity drought for H32temp ϵ[0,10], moderate intensity drought for H32tempϵ(10,30], high intensity for H32tempϵ(30,50] and severe drought conditions for H32temp > 50. Note the difference RCP4.5-Hist is already comparable to the index in Hist in Southern regions.

b) Extreme precipitation R10mm (the number of days with heavy precipitation (>10 mm per day) in a 10-day period), for the Southern Romania target area along historical simulations and RCP8.5 scenarios; the 10-day period shown are centred on April 5$^{th;}$ (right) and on April 25th (left). Note the time shift of extreme precipitation towards late April-May (the trend switches from negative to positive statistically significant at p=0.07 Pearson level). Grey shading shows the range between the minimum and maximum members.

Section 2: Fertilization: levels of N fertilization in Romania; b) Harvest as a function of precipitation

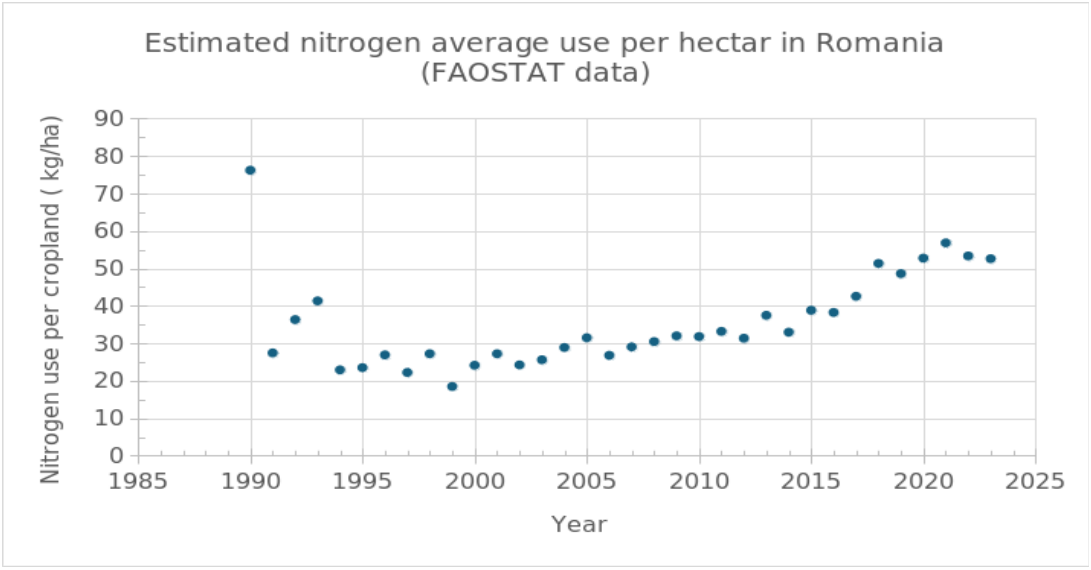


Fig.S2 Evolution of the fertilization levels in Romania (FAOSTAT register data) showing a string decay after 1991, and an increase starting after 2003

Section 3: The grain filling length duration: low sensitivity to model instability

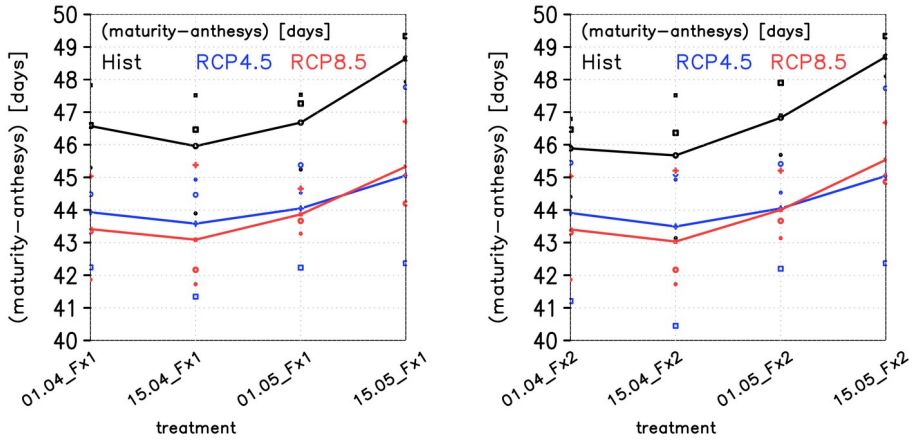


Fig.S3 Difference (days) in the simulated Maturity minus anthesis dates, due to climate conditions leading a too slow grain filling for some models and scenarios. These are small differences (~ 1 day, as discussed in 3.2.1) in ensemble mean time mean, for all sowing dates, shown for Hist (black), RCP4.5 (blue) and RCP8.5 (red), Fx1(left) and Fx2 (right).

Section 4: Relation between models precipitation and Harvest

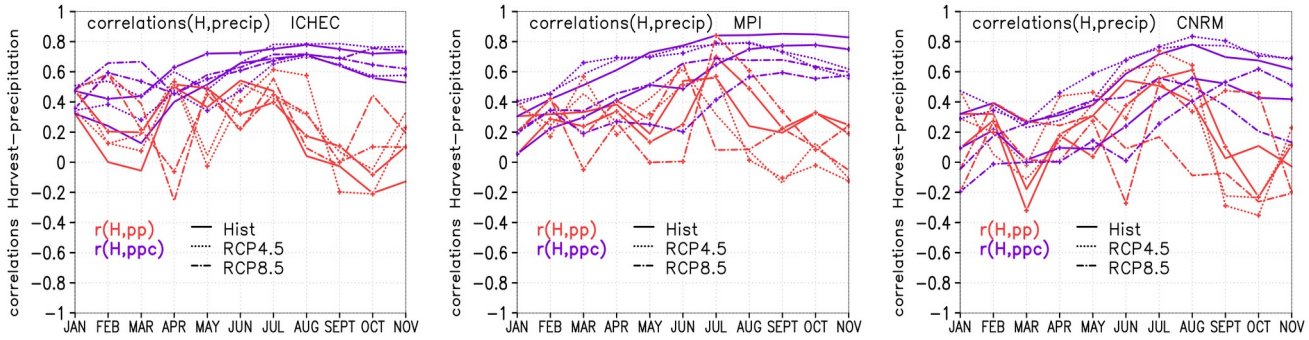
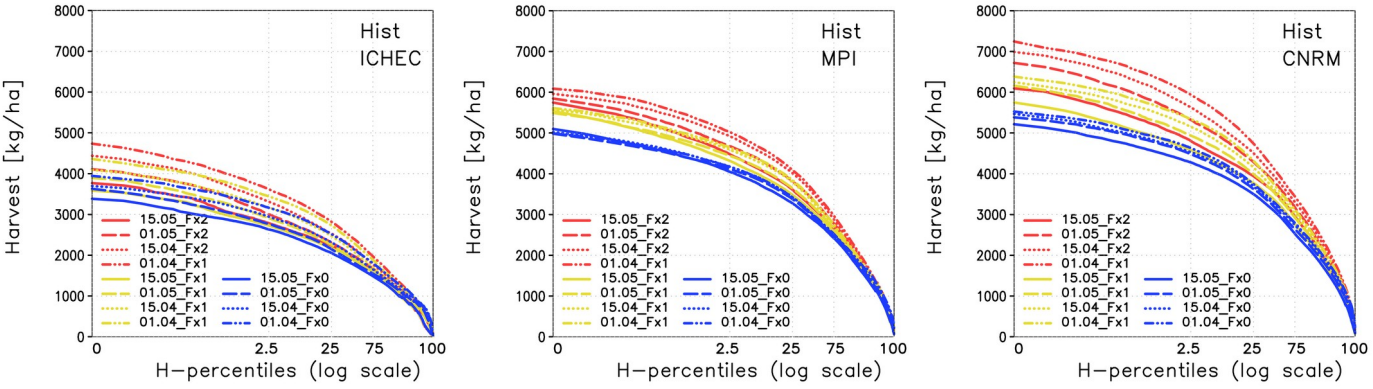


Fig.S4 Correlations between model precipitation (accumulated since January- plum) and monthly (pink) and Harvest for the models: ECEARTH-ICHEC (left); MPI (middle) and CNRM (right); full line is for Hist, dot-line is for RCP4.5 and dot is for RCP8.5; shown are two treatments: 01.04_Fx0 (no mark) and 15.05_Fx2 (marked lines) for each there are twelve curves corresponding to the treatment in Table 1. Note all models show high correlation with accumulated precipitation (to a max ~ 0.8 to 0.9 by spring-summer, discussed in 3.2.2).

Section 5: Model-spread for optimal genotype



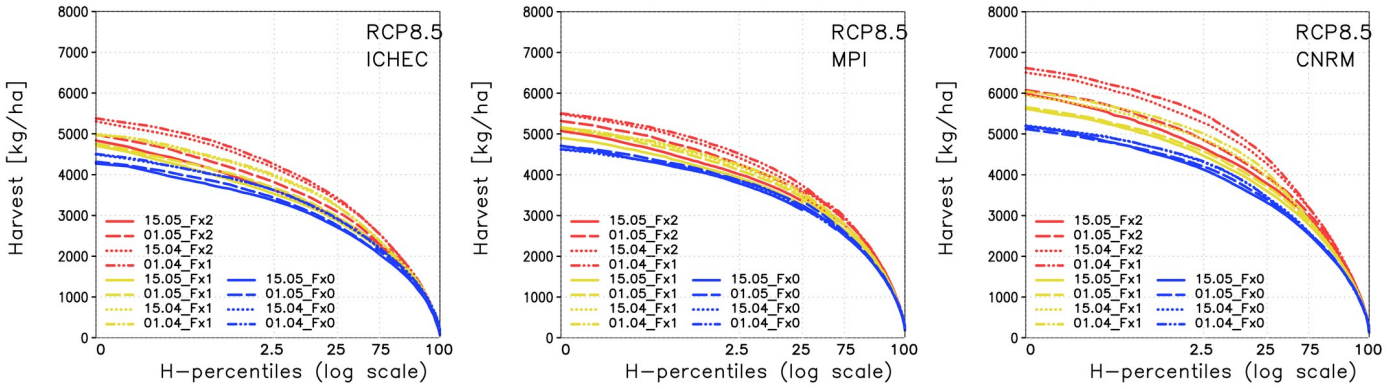


Fig.S5: Harvest time mean simulated by models: ECEARTH-ICHEC (left), MPI (Middle) and CNRM (right). As in Fig.7a, are shown percentiles of the H distribution ordered from maximum H values (left) to minimum H (right), logarithmic scale. Simulations are for Hist (top) and RCP8.5 (bottom). Note: there is a significant inter-model spread, in some models genotypes being found that lead superior highest Harvest in scenarios compared to Hist. This spread is linked to projected precipitation (Fig.S2) for the region.

Section 6: Changes in genotype parameters: percents of change in scenarios relative to Hist for a same H-percentile

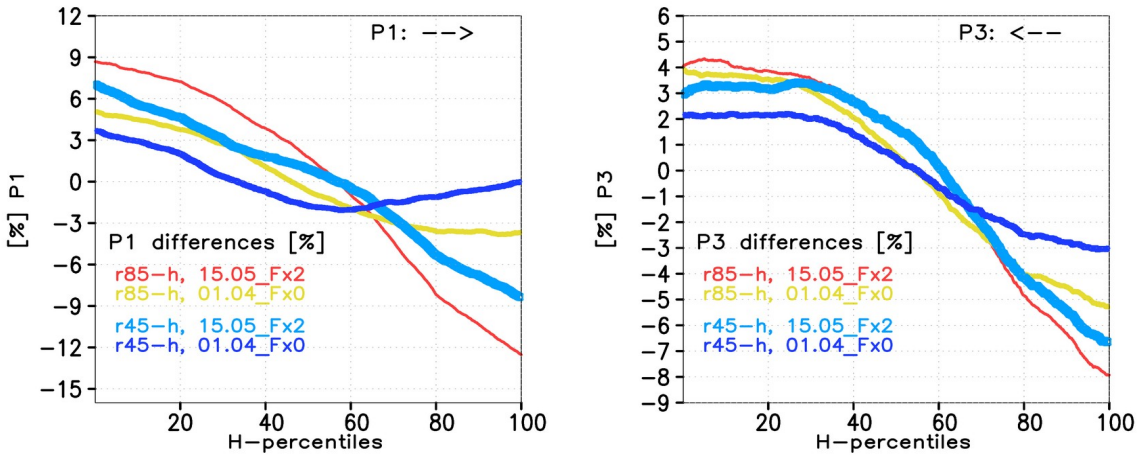


Fig.S6: Percent changes of P1 and P3 genotype parameters (y-axis) as a function of the Harvest percentile (ordered from highest H, left, to the lowest H right, x-axis). Differences (running means over 378=P2xP3xP4xP5 intervals simulated) are shown for treatment 01.04_Fx0 (GTR1 in Table 1b) (yellow for RCP4.5 minus Hist and dark blue for RCP4.5 minus Hist) and for treatment 15.05_Fx2 (GTR12 in Table1b) (red for RCP8.5 minus Hist and light blue for RCP4.5 minus Hist). Percent changes are expressed as differences relative to Hist. Arrows indicate the Harvest monotony as a function of the

genotype parameter (lower H for higher P1 and higher H for higher P3), as seen Fig.8). Computation was done for all parameters, and P1 and P3 show the main percentage of change in scenarios compared to Hist (discussed in 3.3.2 ii).

Section 7: Slopes of P-genotype parameters in Hist and climate scenarios

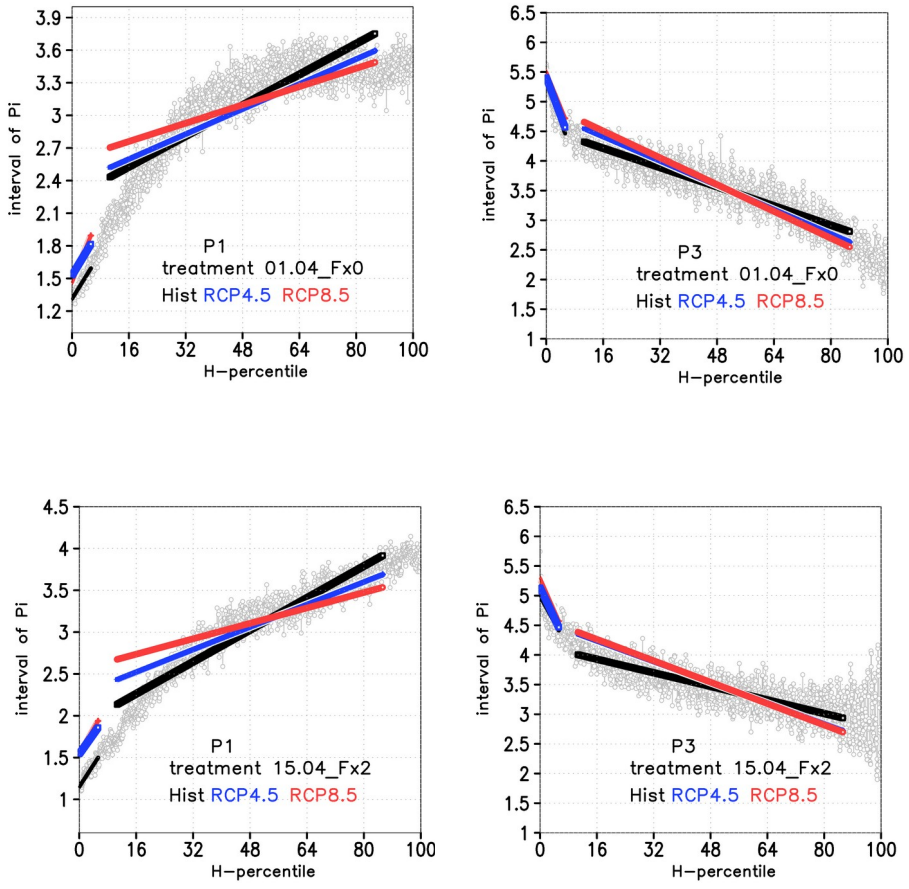


Fig.S7 The linear slopes (thick lines) of P1 and P3 parameters as a function of decreasing harvest H percentiles, x-axis, H ordered from maximum (left) to minimum (right)) are shown for: Hist (black), RCP4.5 (green) and RCP8.5 (red). Grey dot line shows the parameter values for Hist ensemble mean time mean. Slopes are computed over 2 sub-intervals that showed the highest change in the relative difference of slopes in Hist and scenarios (where the difference changes sign), at about 200-300 maximal values or 10-15% of harvest. The values are shown for two treatments: 01.04_Fx0 (top) and 15.05_Fx2 (bottom). Note lower slopes in scenarios, allowing windows of adaptation compared to Hist in scenarios in the intermediate percentile interval as discussed in 3.3.2.iv). The Y-axis represents the fractional change of the parameter relative to its maximal experimental change (here this is 5 for P1 and 6 for P3, for experimental set-up with 5x7x6x3x3 parameter intervals simulated).