Crop model calibration for assessing climate change impacts on Mediterranean staple crops

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Purpose
In the last century the Mediterranean basin experienced a generalized decrease of precipitation (Sousa et al., 2011; Norrant and Douguédroit, 2006), a significant annual warming trend (+0.75°C) especially during winter and summer (Vautard et al., 2007) and an increase in climate extremes (Kostopoulou and Jones, 2005; Zolina et al., 2008; Kyselý, 2009; Ulbrich et al., 2013) which have negatively affected the whole agricultural sector. Despite uncertainties, the majority of climate models predict a worsening of climate pattern in the future over the Mediterranean basin which is expected to exacerbate its impacts on and vulnerability of staple crops. The use of crop models, can enable evaluating impacts of future climatic scenarios and also assess benefits provided by the adoption of adaptation strategies compared to the current management. This paper describes the models (namely CropSyst, OLIVE.model CNR and UNIFI.GrapeML) calibration procedures used for simulating growth and development of the main staple crops cultivated in the three islands targeted by the LIFE ADAPT2CLIMA project, (namely wheat, barley, olive tree, grapevine) so as to assess climate change impacts and suggest adaptation strategies in the Mediterranean agriculture.

Methods
The simulation models tested are: i) CropSyst for wheat and barley; ii) OLIVEmodel.CNR for olive tree; iii) UNIFI.GrapeML for grapevine. CropSyst model (Stöckle et al., 2003) is a process-based model designed to predict the climate impact on crop performances and the environmental impacts determined by crop rotations and by different cropping (or farming) system management. CropSyst was calibrated to reproduce phenology (anthesis and maturity) and final yield of two barley cultivars (i.e. Mattina and Aliseo) and seven wheat cultivars (i.e. Bronte, Ciccio, Claudio, Duilio, Iride, Platani and Simeto). The reference phenological and biomass data used to calibrate these crops were retrieved from Long Term Experiments (LTE) in Foggia (Apulia, Italy) for barley and tomato; ii) Caltagirone (Sicily, Italy) for several wheat cultivars. The OLIVE.model.CNR (Moriondo et al., 2019) simulates the growth and development of olive agroecosystem at daily time step. OLIVEm was calibrated and validated using experimental data for a generic olive tree variety from Venturina (Tuscany, 43.02 Lat N 10.61; Lon E) in the period 2008-2011 where yield data was recorded for an olive orchard under three irrigation regimes, rain fed, deficit irrigation (50%) and full irrigation. UNIFI.GrapeML (Leolini et al., 2018) is a BioMA (http://www.biomamodelling.org/) software model library jointly developed by UNIFI and CREA-AA and used for simulating vine development and growth considering different canopy management practices. GRAPEm was calibrated for two grape cultivars, namely Chardonnay and Cabernet Sauvignon, with observed data of phenology, soil water and grape yield retrieved in a vineyard located in Spain (41.53 Lat N; 1.7 Lon E, 340 m a.s.l.) and accounting for climate and soil monitored during the period 1998-2012.

Results
The statistics in table 1 indicate that the calibrated models correctly simulated the day of anthesis of both sowing (wheat and barley) and perennial crops (grapevine and olive tree) with good performances considering the inter-annual variability of the occurrence of this stage as indicated by Pearson’s coefficient (r) and relative root mean square error (RRMSE). Though, lower performances resulted in simulating the final yield of wheat varieties by the model (r ranging from -0.1 to 0.6 and RRMSE ranging from 28 to 53.4%). Conversely, the simulations of both grapevine and olive tree provided the best results in detecting the average yield of each variety, highlighting very good performances considering also the simulation of yield inter-annual variability with r ranging from 0.6 to 0.9 with RRMSE from 12 to 27%.

Conclusions
Model calibration procedures were performed within the action 4.2 ('Use of crop models for assessing the vulnerability of agriculture to climate change') of LIFE ADAPT2CLIMA project, focused on assessing the impacts of future climate on agricultural sector over the three Mediterranean islands of Crete, Cyprus and Sicily. While contrasting model performances resulted in simulating yield and anthesis of barley and wheat varieties, model

calibration of tree crops (olive and grapevine) provided good results in simulating both phenology and final yields. Once calibrated, the three models were applied over the study areas so as to determine the impacts of specific adaptation practices able to reduce crop vulnerability under future climatic scenarios.

Table 1. Performances of calibrated model in simulating the average yield and phenology (anthesis) for each crop and variety over the study period. The performances of each model in detecting the inter-annual variability of both yield and anthesis was evaluated using the Pearson's coefficient (r) and the Relative Root Mean Square Errors (RRMSE). DOY, day of the year.

		Anthesis (DOY)				**Yield (Kg dry matter ha^{-1})**			
	Variety	**Obs**	**Sim**	**r**	**RRMSE**	**Obs**	**Sim**	**r**	**RRMSE**
Wheat	**Bronte**	114	114	0.9	4.9	3073	3060	0.5	29.7
	Ciccio	115	117	0.9	4.6	3053	3364	0.1	37.7
	Claudio	121	117	0.9	5.7	3258	3281	0.5	30.5
	Duilio	115	111	0.9	5.9	3224	3196	-0.1	48.1
	Iride	117	116	0.9	4.5	2921	3219	0.4	28
	Platani	113	114	0.9	3.7	3113	3261	0.6	30.5
	Simeto	117	116	0.9	4.1	3316	2295	0.4	53.4
Barley	**Aleiseo**	125	125	0.8	2.4	5820	5300	0.5	25.3
	Mattina	127	126	0.8	2.9	5750	5940	0.6	20.4
Grape	**Chardonnay**	137	137	0.7	2.1	1460	1400	0.6	23
	Cabernet	151	153	0.6	2.5	1326	1270	0.5	27
Olive tree		155	156	0.7	22	4400	4400	0.9	12

Reference

Durao, R.M., Pereira, M.J., Costa, A., Delgado, J., Del Barrio, G., and Soares, A. (2010) Spatial temporal dynamics of precipitation extremes in southern Portugal: a geostatistical assessment study. Int. J. Climatol. 30, 1526-1537.

Kostopoulou, E. and Jones, P.D. (2005) Assessment of climate extremes in the Eastern Mediterranean. Meteorol. Atmos. Phys. 89, 69-85.

Kyselý, J. (2010). Recent severe heat waves in central Europe: how to view them in a long term prospect?. Int. J. Climatol. 30, 89-109.

Leolini, L., Bregaglio, S., Moriondo, M., Ramos, M. C., Bindi, M., and Ginaldi, F. (2018). A model library to simulate grapevine growth and development: software implementation, sensitivity analysis and field level application. European journal of agronomy, 99, 92-105.

Moriondo, M., Leolini, L., Brilli, L., Dibari, C., Tognetti, R., Giovannelli, A., Rapi, B., Battista, P., Caruso, G., Gucci, R., Argenti, G., Raschi, A., CXentritto, M., Cantini, C., and Bindi, M. (2019). A simple model simulating development and growth of an olive grove. European Journal of Agronomy, 105, 129-145.

Norrant, C. and Douguédroit, A. (2006) Monthly and daily precipitation trends in the Mediterranean (1950-2000). Theor. Appl. Climatol. 83, 89-106.

Sousa, P.M., Trigo, R.M., Aizpurua, P., Nieto, R., Gimeno L., and Garcia-Herrera, R. (2011). Trends and extremes of drought indices throughout the 20th century in the Mediterranean. Nat. Hazard. Earth Sys. 11, 33-51.

Stöckle, C.O., Donatelli, M., Nelson, R . CropSyst, a cropping systems simulation model. European Journal of Agronomy 18, 289–307..

Ulbrich, U., Xoplaki, E., Dobricic, S., García-Herrera, R., Lionello, P., Adani, M. et al. (2013). Past and current climate changes in the Mediterranean region. In: Regional Assessment of Climate Change in the Mediterranean (Navarra A. and Tubiana L., eds.). Springer Science Business Media, Dordrecht.

Vautard, R., Yiou, P., D'andrea, F., De Noble,t N., Viovy, N., Cassou C. et al. (2007) Summertime European heat and drought waves induced by wintertime Mediterranean rainfall deficit. Geophys. Res. Lett. 34, L07711.

Zolina, O., Simmer, C., Gulev, S.K. ,and Kollet, S. (2010). Changing structure of European precipitation: Longer wet periods leading to more abundant rainfalls. Geophys. Res. Lett. 37, L06704.