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Artificial neural network models applied to olive tree phenology in Italy reveal daily insolation control of budbreak

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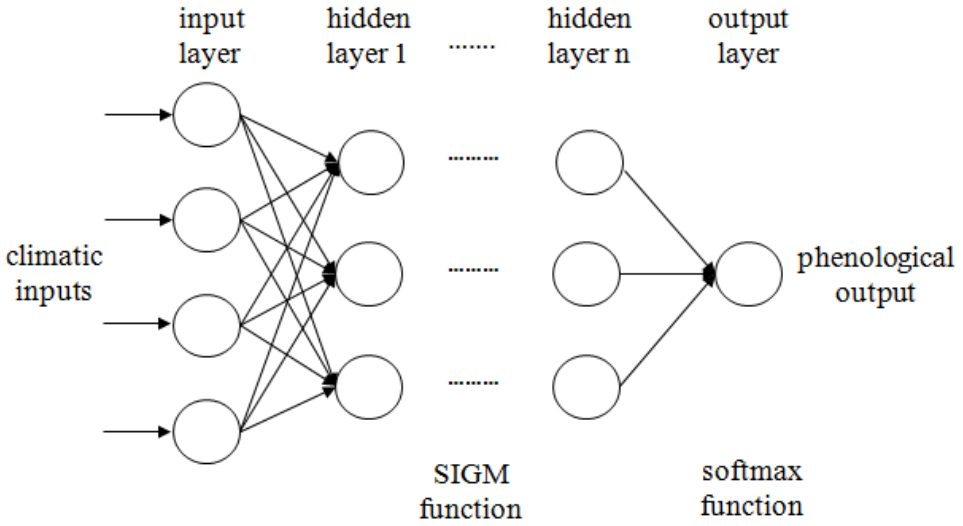
Artificial neural networks for phenology

A complementary tool to mechanistic models?

- ✓ *reproduce non-linear relationships between climatic cues and phenological transitions*
- ✓ *include multiple climatic cues as they control different phenophase transitions*
- ✓ *account for different cultivars*
- ✓ *several applications available*



Feed-forward neural network with stochastic gradient descent

Modified softmax:

$$p_i = \frac{e^{(x_i - \max(x))}}{\sum_j e^{(x_j - \max(x))}} \cdot 365$$

SIGM:

$$y_i = \frac{1}{1 + e^{-x_i}}$$

Olive (*Olea europaea L.)*

An under-studied, evergreen species

- ✓ *A traditional element of the Mediterranean landscape, diet and rural socio-economics*
- ✓ *delivering multiple ecosystem services in arid areas*
- ✓ *under threat in Italy since the outbreak of the bacterium Xylella fastidiosa spp. pauca in Apulia region*

Vegetative phenology comparatively less studied than reproductive phenology

The dataset

An Italian-wide datset, comprising

- ✓ *7 locations in the main olive-grove areas*
- ✓ *4 years of observations in 1997-2000*
- ✓ *16 cultivars*
- ✓ *multiple phenophse transitions during the year*
- ✓ *~132 year-long data sets*

The dataset does not account for the impact on olive phenology of the last 20-year climate change

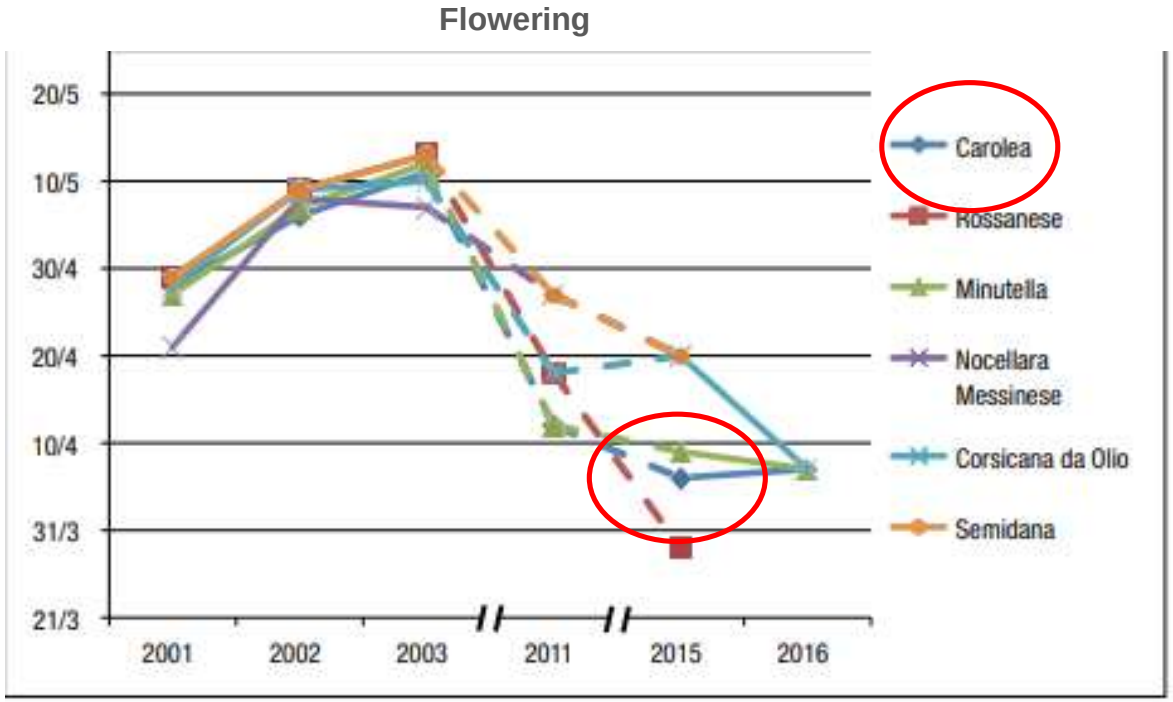
Site ID	Location	Latitude	Longitude	Observation years
1	Montepaldi (Firenze)	43°40'02"	11°8'53"	1997-1998-1999
2	Villasor (Cagliari)	39° 25' 12"	8° 47' 24"	1997-1998-1999-2000
3	Valenzano (Bari)	41°02'11"	16°51'29"	1997-1998-1999-2000
4	Torre Allegra (Catania)	37°25'10"	15°00'36"	1997-1998-1999
5	Belice Mare (Trapani)	37°36'03"	12°51'20"	1997-1998-1999
6	Rende (Cosenza)	39°21'55"	16°13'50"	1997-1998-1999-2017*-2018*
7	S. Apollinare (Perugia)	43° 00' 13"	12° 18' 08"	1997-1998-1999-2000

Model training and validation

- ✓ *A k-fold cross validation was used to optimize the model (number of layers, activation function, convergence method) and hyperparameters*
- ✓ *Model performance is dependent on number of available observations*

Overall RMSE of ~ 4 d at both training and validation when joining together all the cultivars (comparable with the state-of-the-art of mechanistic models).

However, phenological response to climate change is cultivar-dependent



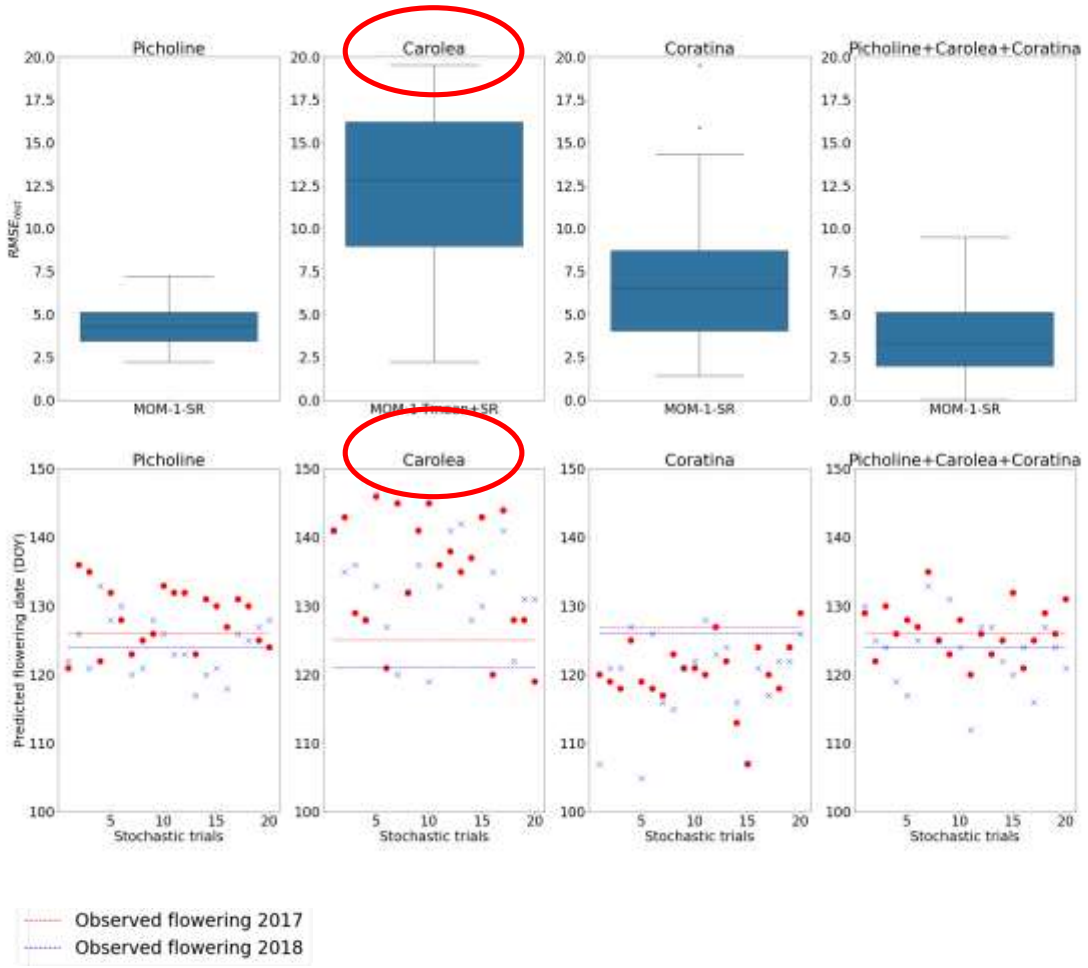
Salimonti et al., 2017, n. 6/2017 OlivoeOlio• 27

Olive cultivars matter for climate change impact investigations

- *The model was tested on independent flowering observations collected in 2017 and 2018.*
- *The model trained in the period 1997-2000 showed some cultivar-specific overprediction.*

In particular, Carolea c. flowering was overpredicted

Carolea flowering has been anticipated after the 1997-2000 training period, by roughly the same amount of days observed by Salimonti et al. (2017).

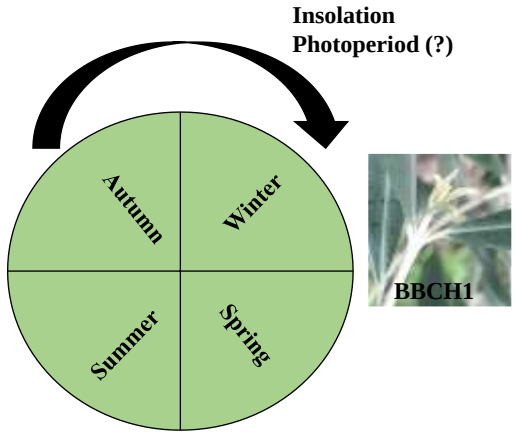


Daily insolation as budbreak predictor?

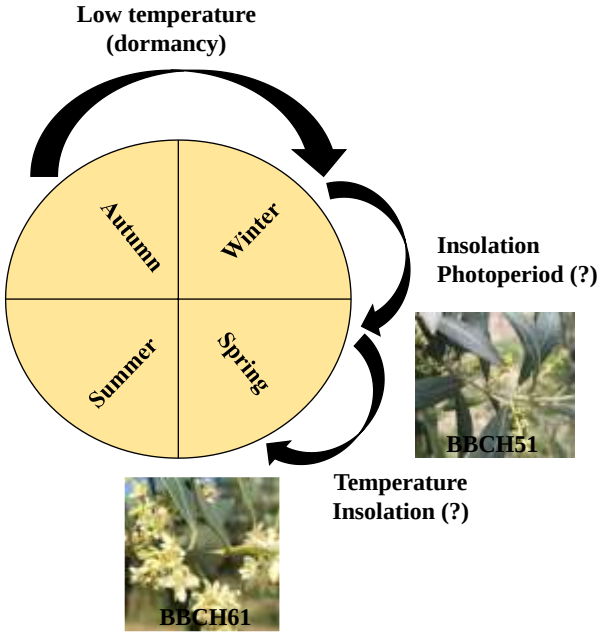
Daily mean temperature was replaced and/or complemented with:

- ✓ *Daily minimum temperature*
- ✓ *Daily maximum temperature*
- ✓ *Daily insolation*
- ✓ *Photoperiod*

Daily insolation consistently improved budbreak prediction for all the cultivars, while photoperiod effect was not consistent.



Budbreak transition



Inflorescence and flowering transitions

Way forward

- ✓ finalizing the investigation of climatic cues
- ✓ widening the dataset
- ✓ coupling olive phenology with pathogen phenology

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