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Modelling different cropping systems

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Abstract/Executive summary

Grapevine is a worldwide valuable crop characterized by a high economic importance for the production of high quality wines. However, the impact of climate change on the narrow climate niches in which grapevine is currently cultivated constitute a great risk for future suitability of grapevine. In this context, grape simulation models are considered promising tools for their contribution to investigate plant behavior in different environments. In this study, six models developed for simulating grapevine growth and development were tested by focusing on their performances in simulating main grapevine processes under two calibration levels: minimum and full calibration. This would help to evaluate major limitations/strength points of these models, especially in the view of their application to climate change impact and adaptation assessments. Preliminary results from two models (GrapeModel and STICS) showed contrasting abilities in reproducing the observed data depending on the site, the year and the target variable considered. These results suggest that a limited dataset for model calibration would lead to poor simulation outputs. However, a more complete interpretation and detailed analysis of the results will be provided when considering the other models simulations.

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Introduction

Grapevine (*Vitis vinifera* L.) is a valuable crop characterized by a relevant economic importance and is widely cultivated around the world (Australia, Chile, Argentina, South Africa, USA and China). However, the largest vineyard area and the highest wine production are still represented by Europe (Fraga et al., 2012; OIV, 2016) in which grapevine cultivation has a long history of development and adaptation (Terral et al., 2010). Besides its economic importance, the cultivation of this crop provides a number of services for the society, including landscape maintenance and improvement, enhancement of the quality of life, and ecological and environmental services (Parry et al., 2007). However, the impact of climate change and the increase in the frequency of extreme events determines a great risk especially for the traditional wine regions located in narrow geographical areas characterized by specific climate and environmental conditions (Fraga et al., 2016; Moriondo et al., 2013). The impact of climate change on grapevine growth was already showed by several authors (Duchêne and Schneider, 2005; Jones et al., 2005; Jones and Davis, 2000; Moriondo et al., 2011; Moriondo and Bindi, 2008) that highlighted the detrimental effects of warming temperature on grape phenology, growth and yield.

In this context, the contribution of grape simulation models plays a key role for investigating the effects of climate change on plant development and growth through the integration of existing knowledge of plant physiology relating to changing environmental conditions (Moriondo et al., 2015). Currently, the grape simulation models follow two main approaches: empirical and process-based. The first approach is based on simple relationships between a dependent variable (i.e. grape yield) and many independent variables (i.e. weather variables) (Jones et al., 2005; Nemani et al., 2001; Santos et al., 2011). On the other hand, the process-based approach is characterized by the detailed description of the main physiology processes able to reproduce the crop behavior in terms of growth, yield and quality (Bindi et al., 1997; Brisson et al., 1998; Nendel and Kersebaum, 2004; Stockle et al., 2003,version for grapevine).

More specifically, the adoption of this last type of models is useful for evaluating the effect of climate change on grape yield and quality, as well as to evaluate different adaptation options for reducing or exploiting the effects of a changing climate. As such, grape models were extensively applied to assess the potential on regional and continental scales (Duchêne and Schneider, 2005; Fraga et al., 2016; Hannah et al., 2013; Moriondo et al., 2013). Despite their widespread use in studying grape productivity for both the present and future scenarios, relevant limitations are found in the applicability of these models for investigating the effect of warmer temperature and increase CO_2 concentration (Moriondo et al., 2015). Indeed, as mentioned for annual crops, the application of different models in similar environmental conditions may provide different results (Palosuo et al., 2011; Rötter et al., 2012). These differences are usually related to the specific approach used to describe a certain process that may be either over-simplified or even incorrectly outlined (Eitzinger et al., 2013).

Based on these premises, this exercise aims at testing different models developed for simulating grapevine growth and development by focusing on their performances in simulating main grapevine processes under 2 calibration levels: minimum and full calibration. This would help to evaluate major limitations/strength points of these models, especially in the view of their application to climate change impact and adaptation assessments.

Methods

A common set of observed phenological and growth data from sites covering different pedo-climatic environments were used for calibrating and validating the selected models. In particular, in the first iteration we provided only a basic information on phenology (depending on the datasets, up to half of the available dates of bud-break, flowering, veraison and maturity) and plant growth data (e.g. yield for just one or few years). Local appropriate soil information (i.e. texture, soil hydraulic properties, initial content of water, nitrogen and soil organic carbon) were provided for model soil parameterization and initialization. At the second step, all available data for calibration will be provided to test the improvement of model performances when provided with high detailed dataset for calibration.

Model results are compared, in terms of yield, LAI, quality, soil nitrogen and water balance, to observed data to evaluate the effect of a limited dataset for calibration on model performances. What we expect is that process based models fed with ever growing accurate dataset for calibration will result into more accurate results in term of biomass accumulation and soil water and nitrogen dynamics.

Table 1. Available datasets used for the intercomparison

Datasets	***Coordinates***	***Variety***	***Years***	***Treatment***	***Tillage***	***Fertilisation***	***Irrigation***	***Phenology***	***Soil moisture***	***Soil N***	***Yield***	***AGB***	***LAI***	***Pruning***	***Quality***
France	44.75°N 0.55° W	Merlot	2004-2005	Same site, same variety, different soils	Y	N	N	Y	Y	N	Y	Y	Y	Y	N
		Merlot	2004-2005		Y	N	N	Y	Y	N	Y	Y	Y	Y	N
Italy 1	39.9°N 8.61°E	CanNnau	1997-2005	Same site, different varieties	N	N	Y	Y	N	N	Y	N	N	Y	Y
		VermentiN	1997-2005		N	N	Y	Y	N	N	Y	N	N	Y	Y
Italy 2	44.62°N 7.97°E	Nebbiolo	2008-2010	Same variety, different sites	N	N	N	Y	N	N	N	N	Y	N	Y
	44.95°N 8.42°E	Nebbiolo	2008-2010		N	N	N	Y	N	N	N	N	Y	N	Y
	45.08°N 8.03°E	Barbera	2008-2010	Same variety, different sites	N	N	N	Y	N	N	N	N	Y	N	Y
	44.95°N 8.42°E	Barbera	2008-2010		N	N	N	Y	N	N	N	N	Y	N	Y
Germany	49.84°N 7.86°E	Riesling	1999-2001	Same variety, different sites	N	N	N	Y	Y	Y	Y	N	N	Y	N
	43.39°N 8.19°E	Riesling	1999-2001		N	N	N	Y	Y	Y	Y	N	N	Y	N
Spain 1	40.13°N 3.38°W	Cabernet-SauvigNn	2003-2006	Same site and variety, different irrigation	N	N	Y	Y	N	N	Y	Y	Y	Y	N
		Cabernet-SauvigNn	2003-2006		N	N	Y	Y	N	N	Y	Y	Y	Y	N
		Cabernet-SauvigNn	2003-2006		N	N	Y	Y	N	N	Y	Y	Y	Y	N
Spain 2	41.48°N 1.8°E	Chardonnay	1997-2012	Same site, different varieties	Y	Y	N	Y	Y	N	Y	N	N	N	N
		Macabeo	1997-2012		Y	Y	N	Y	Y	N	Y	N	N	N	N

Table 2: List of models participating to the intercomparison

Growth model	Growth model code	Institution
GRAPEMODEL	**GRA**	UNIFI
NVIN	**NVI**	ZALF
STICS	**STC**	INRA
EPIC	**EPI**	UNISS
UTOPIA	**UTO**	Regione Piemonte
Cropsyst	**CST**	UPM

Dataset description and participating models

Six datasets were provided for the grape model intercomparison: France, Italy_1, Italy_2, Germany, Spain_1 and Spain_2. These datasets are organized considering different grape varieties (Merlot, Cannonau, Vermentino, Nebbiolo, Barbera, Cabernet S., Chardonnay, Macabeo), locations (France, Italy, Germany and Spain) and treatments (i.e. irrigations, sites and soils) such as described in Table 1. For each dataset, weather data consisting of daily minimum and maximum temperature, precipitation, radiation, relative humidity and wind speed relative to the period of the experiments were extracted from weather stations close to the field experiments.

Six modelling groups using six grape simulation models of different complexity contributed to this study as reported in Table 2.

Results

So far, we have received simulations results from two out of six models (GRA and STC). Further submission are expected during June 2017. Only some preliminary results of some target variables are presented here.

Preliminary results from GRAPEMODEL and STICS have been analyzed for three sites (*France, Germany* and *Spain_1*). Depending on the site, the year and the target variable considered, the two models showed contrasting abilities in reproducing the observed data and no clear pattern in model responses may be identified. For instance, both models provided similar results in France with a good correspondence between simulated and observed LAI, AGB and yield. In contrast, STICS simulated correctly the soil water dynamics in one of the two french soils and UNIFI-GrapeModel in the other one (Fig. 1). In Germany, UNIFI.GrapeModel reproduced observed yields better than STICS, which tended to generally overestimate fruit biomass accumulation, while the models were equivalent in term of simulated water soil dynamics (Fig. 2). In Spain, both models evidenced a poor estimation especially in most drought years 2005 and 2006 (Fig. 3). These results suggest that a limited dataset for model calibration would lead to poor simulation outputs affected by greater uncertainty. However, a more complete interpretation and detailed analysis of the results will be provided when considering the other models simulations.

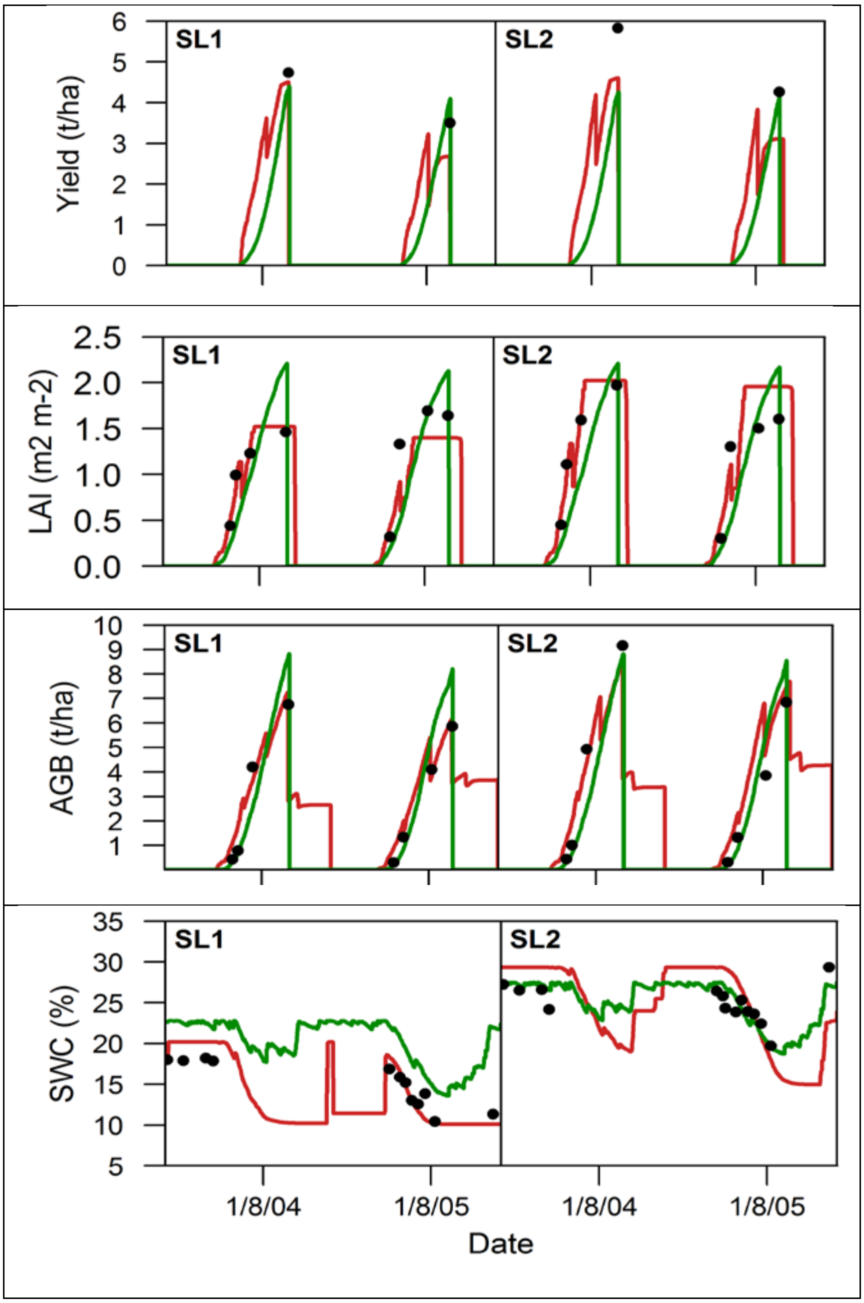

Figure 1: Comparison between observed (dots) and simulated (lines) yields, leaf area Index (LAI), above-ground biomass (AGB) and soil water content (SWC) from two models GRAPEMODEL (🟩) and STICS (🟥) in two soils (Sandy-loam, SL1 and Sandy-clay-loam, SL2) in France

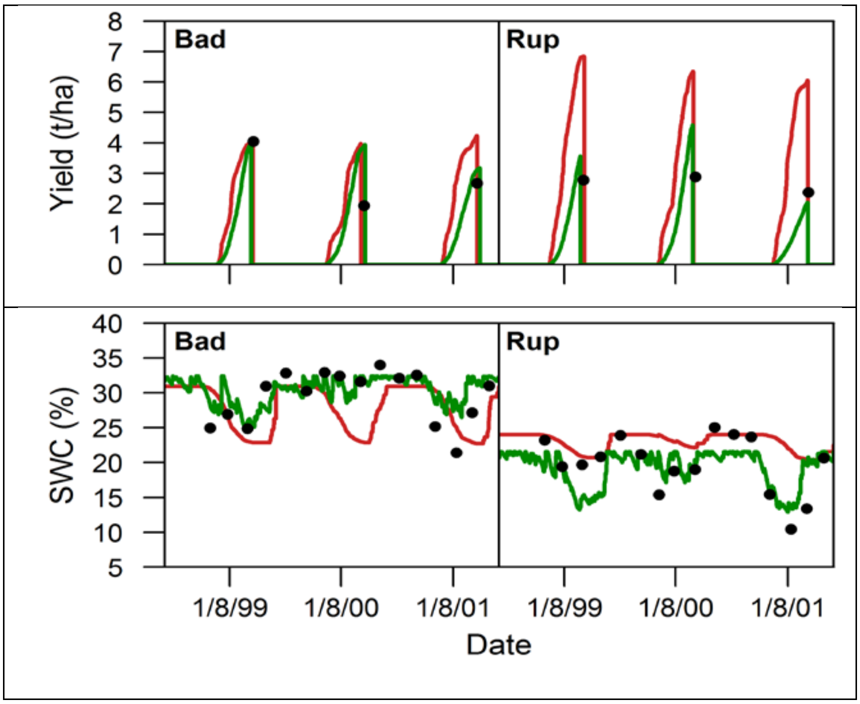

Figure 2:Comparison between observed (dots) and simulated (lines) yields and soil water content (SWC) from two models GRAPEMODEL (🟩) and STICS (🟥) in two sites (Bad Kreuznach, Bad and Ruppertsberg, Rup) in Germany

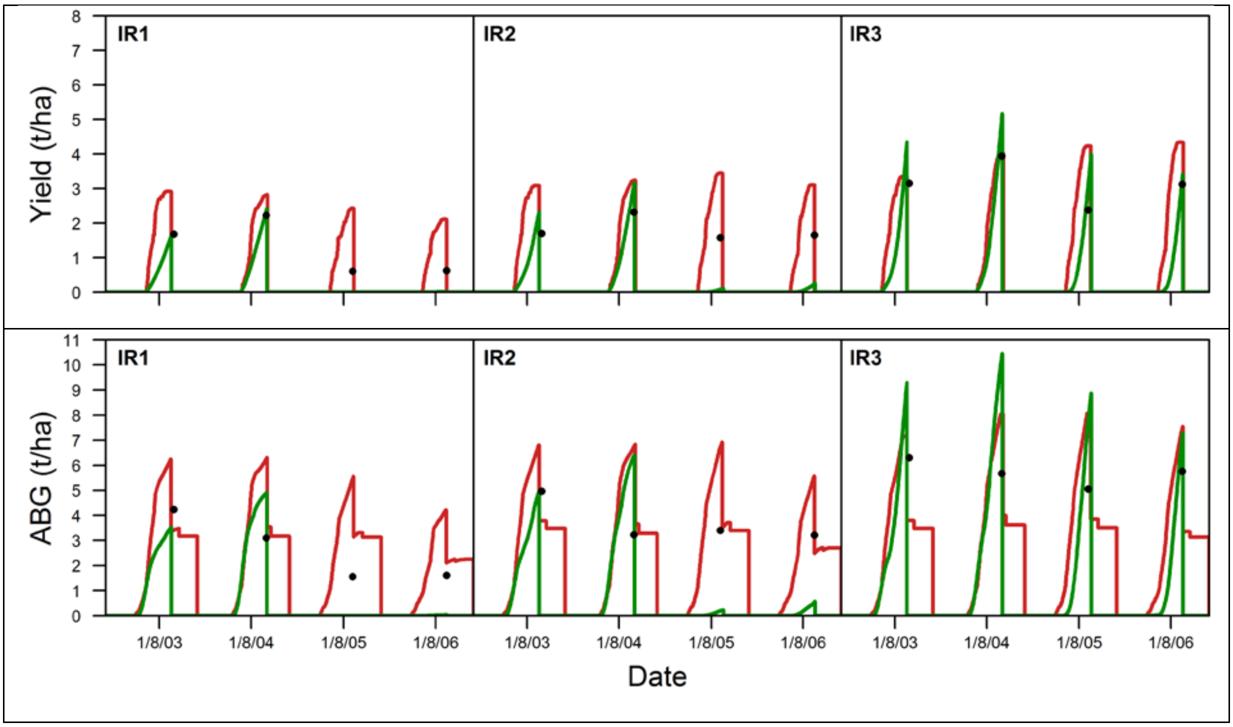

Figure 3: Comparison between observed (dots) and simulated (lines) yields and above-ground biomass (AGB) from two models GRAPEMODEL (🟩) and STICS (🟥) under three irrigatioin treatments (rainfed, IR1, medium irrigation ~120mm, IR2 and high irrigation ~270mm, IR3) in Spain

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