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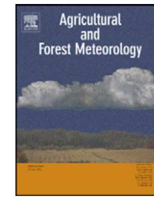

On the use of regional climate models: Implications of climate change for viticulture in Serbia

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ABSTRACT

Climate projections obtained from the coupled regional climate model EBU–POM (Eta Belgrade University – Princeton Ocean Model) driven by the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (SRES), showed that the vineyard regions of Serbia tend to become warmer and dryer toward the end of 21st century. To evaluate how Serbian viticulture could be affected by a projected climate regime, several climatic variables and agro-climatic indices describing the suitability of a particular area for grapevine production were calculated, after a statistical bias correction was applied to the daily temperature and precipitation data from EBU–POM outputs. Comparison between climatic variables and agro-climatic indices for the reference period 1961–1990 and predicted values for the 2001–2030 period (under the SRES A1B scenario) and the 2071–2100 period (under the SRES A2 scenario) was made for 18 climatological stations placed mostly within, but also outside traditional viticultural regions. According to the obtained change trends it is likely that no significant disturbances in Serbian viticulture will occur over the next few decades, but considerable changes are expected by the end of the 21st century. Warmer and prolonged growing season with greater heat accumulation and longer frost-free period with decline in frost frequency would likely affect the yield and ripening potential of grapes and induce shifts in varietal suitability and wine styles. Projected changes may bring on the need for additional vineyard irrigation, but also open up the possibility that marginal and elevated areas, previously too cool for cultivation of grapevines, become climatically suited for viticulture.

1. Introduction

Among the all cultivated plants, the grapevine (*Vitis vinifera* L.) is considered one of the most responsive to its surrounding environment. Compared with 16 crops analyzed over a 58–75 year period, grapevine was found to have by far the highest seasonal variation in yield (32.5%), nearly twice that of the next closest crop (Chloupek et al., 2004). Climate is one of the most important factors controlling grape and wine production from selection of a suitable grapevine varieties to the type and quality of wines produced (Gladstones, 1992). Recent climate change with the 100-year (1906–2005) linear warming trend of 0.74 °C (IPCC, 2007), has been found to affect viticulture and wine industry across the world having positive or negative effects depending on the region and the ways in which the climate changes (Jones and Davis, 2000; Jones et al., 2005; Laget et al., 2008; Nemani et al., 2001; Ramos et al., 2008). Since anthropogenic climate change is likely to continue into the future (IPCC, 2007), clarity on impacts by specific region is essential for creating adaptation and mitigation strategies for upcoming climatic conditions.

The objective of this paper was twofold: first, to evaluate the possible effects of climate change on viticulture in Serbia, the region not much studied in this regard, and second, to outline how climate models outputs should be properly utilized in impact assessment studies.

There are quite a number of studies assessing the potential effects of climate change on European viticulture (e.g. Neumann and Matzarakis, 2011; Malheiro et al., 2010; Santos et al., 2011), but little research has been focused on the part of Europe where Serbia is located. IPCC (Intergovernmental Panel on Climate Change) Forth Assessment Report (IPCC, 2007) indicated a precipitation increase in high latitudes and a decrease in the Mediterranean area for a future warmer climate. A position of boundary between these two areas with different precipitation trends varies in climate projections, depending on the emission scenario or model used. Serbia is

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located right in that part of Europe, where this transition zone in precipitation trend is expected to be positioned, which makes this region particularly interesting in the context of climate change.

The general procedure for evaluating the impacts of climate change on any physical or biological system is (Bae et al., 2011): (1) project future climate change with global climate model simulations; (2) downscale climate projections from global to regional scale; (3) create impact assessment by linking problem-specific (e.g. hydrological, crop) model and climate change projections.

Global Climate Models (GCMs) are the numerical models representing the large-scale physical processes of the land-atmosphere-ocean system. Nowadays, they are basic tools to explore the impact of human activities on future climate based on various emission scenarios. The IPCC SRES (Special Report on Emission Scenarios) scenarios, commonly used in the analysis of possible climate change and its impacts, include a wide range of the main driving forces of future emissions, from demographic to technological and economic developments (Nakicenovic et al., 2000). GCMs are usually run at coarse-grid resolution, and as a result, their output does not have a spatial scale fine enough for most impact assessments. Two types of downscaling from GCM simulations to regional-scale output are employed: statistical and dynamical (regional climate models). Advantages and disadvantages of both downscaling techniques have been widely discussed in literature (see, e.g. Haylock et al., 2006; Wilby and Wigley, 1997; Wood et al., 2004). In this study, the dynamical downscaling approach was applied. The Coupled Regional Climate Model (CRCM) EBU–POM (Eta Belgrade University – Princeton Ocean Model), that may generate useful climate forecasts for the part of Europe where Serbia is located (Djurdjevic and Rajkovic, 2008; Gualdi et al., 2008), increases the horizontal resolution of the climate outputs from ~125 km (obtained by driving Atmosphere Ocean Global Circulation Model SX-G) to ~30 km.

Model bias is an individual characteristic of model, due to the presence of systematic errors caused by various reasons such as incorrect physical parameterization, numerical dispersion or imperfect boundary conditions. It is different over model domain and usually depends on the season. The effect of bias is detected when specific aspects of the model climatology differ from actual climatology derived from observations. The EBU–POM has a bias in the Pannonian plain, exhibited as too dry and too warm simulations of climate during summer. This problem is known as Summer Drying Problem in South-Eastern Europe and it is typical for many RCMs (Hagemann et al., 2004; Hagemann and Jacob, 2007). Also, it has been acknowledged that climate models often exhibit a grid-scale tendency to underestimate the number of dry days and overestimate the number of drizzle days (Dettinger et al., 2004; Piani et al., 2010). We faced one more problem related to the CRCM simulations, although its origin is not associated with the model itself and its performance. EBU–POM outputs were available every 6 h (00, 06, 12 and 18 UTC). Since Serbia is located within the UTC + 1 time zone, it is almost certain that, especially in the summer, minimum daily temperature would be observed between two model's outputs (00 and 06 UTC) and thus not well represented by the model.

The easiest way to overcome some of the bias problems is to use the "delta change approach", i.e. to present model results as a difference between future and present model simulations, not as absolute values calculated by the model (Graham et al., 2007). This simple bias correction assumes that the bias is the same in all model simulations (i.e. constant in time), and that by subtracting the model results for two periods, the bias is annulled. This kind of bias correction is applicable when climatological values of model output variables are needed (e.g. growing season temperature averaged over a 30-year period), but when daily or monthly values of meteorological variables are required (e.g. in calculation of dryness index), more sophisticated correction technique has to be used. The method for bias correction applied in this study is based on the assumption that both observed and simulated data are well approximated by the same probability distribution function and that the relationships between them do not vary under climate change conditions. This approach, in literature referred to as "quantile mapping", "histogram equalization" or "statistical bias correction", originates from the empirical transformation of Panofsky and Brier (1968). It has been successfully applied in hydrological studies (Dettinger et al., 2004; Wood et al., 2004) and lately also for bias correction of RCMs outputs (Piani et al., 2010).

Climatic conditions (solar radiation, heat accumulation, rainfall, frost intensity and duration, diurnal temperature ranges, humidity, etc.) have a strong impact on viticulture, affecting grapevine growth and development, occurrence of plant diseases, chemical and sensory characteristics of wine. Out of all the climatic factors, temperature appears to be the most important. Temperature during the winter dormancy affects the budding during the subsequent growing season (Jones, 2005). The grapevine starts its annual growth cycle in the spring with bud break initiated by prolonged average daytime temperatures above 10 °C (Winkler et al., 1974). Low frost risk in spring and fall, and a long frost-free period are favorable for grapevine. Frost occurrence can reduce bud fruitfulness, leading to lower yields and quality of grapes. Sustained higher temperatures can have negative impact on grape and wine quality (Winkler et al., 1974; Mullins et al., 1992), while relatively constant intermediate temperatures and minimal day to day variability during the growth and ripening months are beneficial (Gladstones, 1992). Higher temperatures may initially improve the early to mid-season ripening, but rise in minimum daily temperatures as grapes approach maturity, may affect the formation and ratio of grape components that give the color, aroma and flavor characteristics (Tonietto and Carbonneau, 2004). Precipitation and its seasonal distribution are also very important. Water is very crucial for the vine at the beginning of the growing season, from budburst to inflorescence development, while dry and stable conditions are needed from flowering to ripening (Jones and Davis, 2000; Nemani et al., 2001; Ramos et al., 2008).

The agro-climatic indices, based on simple relationships of crop suitability or potential to climate, are commonly used in vineyard zoning, site assessment and vine varieties selection. Also, they have been used to provide an initial evaluation of the climate change impacts on viticulture and shifts in viticultural suitable areas (e.g. Hall and Jones, 2009; Malheiro et al., 2010). In our study, we used growing season related variables (average temperature and precipitation, start, end and length of the growing season, growing degree-days and the number of dry days and significant wet days), frost related variables (the dates of first fall and last spring frost, the number of days with frost, and the number of days with temperatures below −15 °C), and the heliothermal, dryness and cool night index as used in the Geoviticulture multicriteria climatic classification system (Tonietto and Carbonneau, 2004). After a statistical bias correction was applied to the daily temperature and precipitation data from EBU–POM outputs, aforementioned climatic variables and agro-climatic indices were calculated and their present and future values were compared.

It has to be noted that the assessment of the possible implications of climate change for viticulture in Serbia was based on meteorological factors alone, namely, the temperature and precipitation. The effects of humidity, rain-bearing winds or other possibly relevant meteorological parameters were not considered. Also, the other influencing environmental factors, such as soil characteristics and topography were not taken into account, as well as the direct effects of elevated levels of atmospheric carbon dioxide.