CLIMATE CHANGE PROJECTIONS IN SERBIAN WINE-GROWING REGIONS

Mirjam VUJADINOVIC[1,2], Ana VUKOVIC[1,2], Darko JAKSIC[3], Vladimir DJURDJEVIC[4,2], Mirjana RUML[1], Zorica RANKOVIC-VASIC[1], Zoran PRZIC[1], Branislava SIVCEV[1], Nebojsa MARKOVIC[1], Bojan CVETKOVIC[2], Pierfederico LA NOTTE[5]

[1]Department of Viticulture, Institute of Horticulture, Faculty of Agriculture, University of Belgrade, 11080 Belgrade, Nemanjina 6., Serbia
[2]South East European Climate Change Center, RHMSS, 11000 Belgrade, Bulevar Oslobodjenja 8, Serbia
[3]Ministry of Agriculture and Environmental Protection, 11000 Belgrade, Nemanjina 22-26, Serbia
[4]Institute of Meteorology, Faculty of Physics, 11000 Belgrade, Dobracina 16, Serbia
[5]Institute for Sustainable Plant Protection, National Research Council of Italy, I-70126 Bari, Via Zmendola 122/D, Italy
**Corresponding author: Vujadinovic. E-mail: mirjam@agrif.bg.ac.rs*

Abstract
Changes in bioclimatic indices in wine-growing region of Serbia are analyzed under the RCP 8.5 IPCC scenario. Results of a global climate model are dynamically downscaled on a horizontal resolution of about 8 km, using a regional model NMMB for a period 1971-2100. Statistical bias correction of regional climate model's daily outputs of precipitation, minimum and maximum temperature are done for an entire territory of Serbia, using a dataset of daily observation on a regular 8 km grid. Four of bioclimatic indices widely used in viticulture were calculated from the observations in the period 1971-2000 and from the bias corrected model output for two periods in the future, 2011-2040 and 2071-2100.

Results show temperature increase, especially during the vegetation period. By the end of the century precipitation amount during the growing season will significantly drop, alongside with a change of the intramural precipitation distribution towards the Mediterranean climate characteristics. Consequently, climate characteristics of Serbian wine-growing regions will drastically change towards a very warm and moderately dry climate categories.

Keywords: climate change, wine-growing regions, Serbia, regional climate model, high resolution, viticulture

1 INTRODUCTION

Climate conditions and appropriate selection of grape varieties are of the most importance for the successful grape and wine production. In the Fifth report of the Intergovernmental Panel on Climate Change (IPCC, 2013) Southeast Europe and West Balkans are pointed out as one of the regions most vulnerable to the climate change. Increase in temperature and change in the precipitation distribution and character especially during the growing season, as well as increase of the intensity and frequency of the extreme events (droughts, floods, extreme precipitation, heat waves, etc.) have already been observed in Serbia (SNC, 2015).

Changes in a phenological stages of many white and red grape varieties have been noted in some wine-growing regions in Serbia, mostly as a consequence of the change in the thermal conditions (Ruml et al. 2016). Flowering, veraison and harvest advanced significantly, while smaller change was found for budburst (Ruml et al. 2016).

Analysis of climate change impacts on wine-growing regions in Serbia for the future was extensively done during the past several years. For this purpose a dynamically downscaling of a coupled regional climate model EBU-POM (Djurdjevic and Rajkovic 2008), under the A1B and A2 IPCC scenarios (Nakicenovic et al. 2000) of the greenhouse gasses (GHG) emission was used. However, in these studies model's output has been bias corrected and analyzed only in a number of observational points, some of which were located within the Serbian wine-growing regions (Ruml et al. 2012).

Through a detailed study that was preformed within the renewal of the viticultural zoning in 2014 a notable diversity of climate characteristics among the Serbian wine-growing regions, and even between some wine-growing districts of the same region, was determined. Therefore, a need emerged for spatially detailed in-depth investigation and assessment of climate change impacts on grape and wine production. Following the state-of-the-art climate change research this analysis is done using a simulation under the RCP 8.5 scenario (IPCC, 2013) dynamically downscaled with an atmospheric model of the latest generation, Non-Hydrostatic Multiscale Model on the B grid (NMMB) on a very high horizontal resolution of about 8 km. This paper, along with Vukovic et al. 2015a, Vukovic et al. 2015b and succeeding studies should help to recognize risks and vulnerability of viticultural sector in Serbia and set up a basis for identifying climate change adaptation measures that will be then included in national documents such as the National Climate Change Strategy and National Adaptation Plan.

2 MATERIALS AND METHODS

Simulation of a climate change over the Southeast Europe by the end of 21st century was done under the RCP 8.5 scenario (IPCC, 2013), the one that assumes the most intensive green house gasses emissions, so called "business as usual". Global simulation of the CMCC-CM model was used as an initial and boundary conditions for the dynamical downscaling by a regional model NMMB. Downscaling was done on a high resolution of about 8 km, covers the period 1970-2100, and it was a part of the ORIENTGATE project (Djurdjevic and Krzic 2014). In this paper analysis is divided in three 30-years long periods: 1971-2000 as a referent, base period, 2011-2040 representing near future and 2071-2100 as a far future.

In order to study climate change impacts to the wine-growing regions in Serbia, it was necessary to statistically correct bias of the regional climate model (Ruml et al. 2012). It is a statistical error that exists in all numerical climate models and it is caused by parameterization of processes of sub-grid scales within a model and imperfections of input data such as land cover, soil type, initial conditions, etc. Bias is not uniform across the model domain and time of a year, therefore it requires a specific approach for every location and every season.

There are several bias correction techniques which all require a comparison of model results and observations at the same location. For this purpose we used a high-resolution dataset of gridded daily observations of minimum and maximum temperature and precipitation in Serbia. The technique for spatial interpolation of pbserved data was created within the project of the renewal of viticultural zoning in Serbia (Ivanisevic et al. 2015) by using 135 meteorological stations in Serbia and bordering countries for the period 1971-2000 (Vukovic et al. 2015a).

In this study a version of a quintile mapping bias correction method for daily minimum and maximum temperature and precipitation was applied (Vujadinovic et al. 2012, Ruml et al. 2012, Vukovic et al. 2015a). Corrective functions were constructed through a comparison of a modeled and observed cumulative density functions of daily data during the referent period 1971-2000, for each model grid point, each month of the year and each parameter separately. Results were verified and obtained corrective functions were applied to the results for the two future periods.

Bias corrected daily model results were then used to calculate some of the viticultural bioclimatic indices in order to assess the climate change impact to viticulture and wine production in Serbia. Chosen are Huglin heliothermal index (Huglin 1978), Cool night index (Tonietto 1999) and Drought index (Riou et al. 1994) that together compose a multicriteria climatic classification system for the wine-growing regions (Tonietto and Carbonneau 2004) and as such are adequate for the comparison of present and future climate conditions in the viticultural areas. In addition, Winkler index (Winkler et al. 1974) is also analyzed since it describes thermal potential for the grape production and optimum choice of grape varieties.

3 RESULTS AND DISCUSSION

After almost 40 years, viticultural zoning in Serbia has been renewed and wine-growing regions were redefined in 2014. A map of 22 current Serbian wine-growing regions is presented in Figure 1.

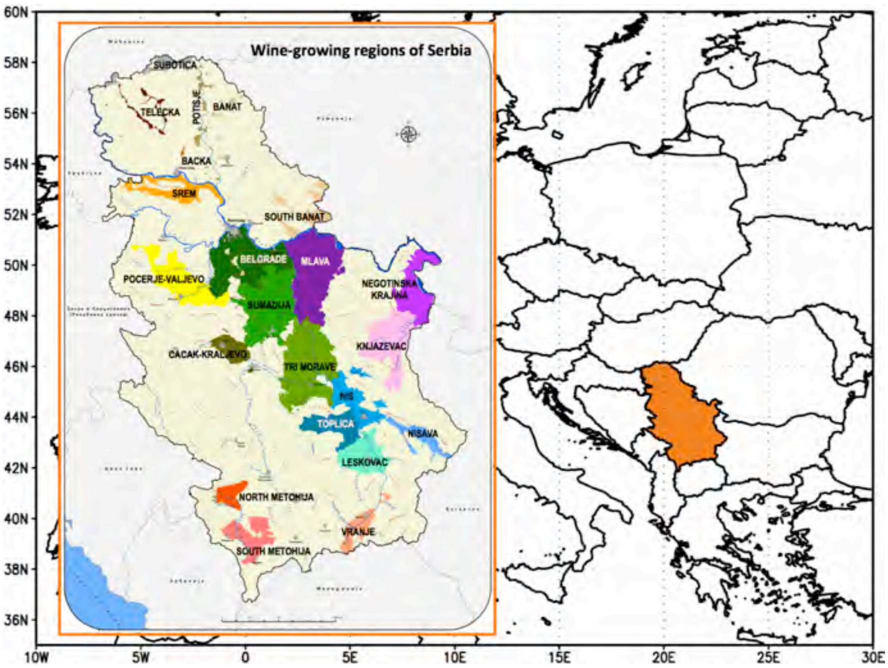

Figure 1. Wine-growing regions in Serbia (Viticultural zoning of Serbia, 2014)

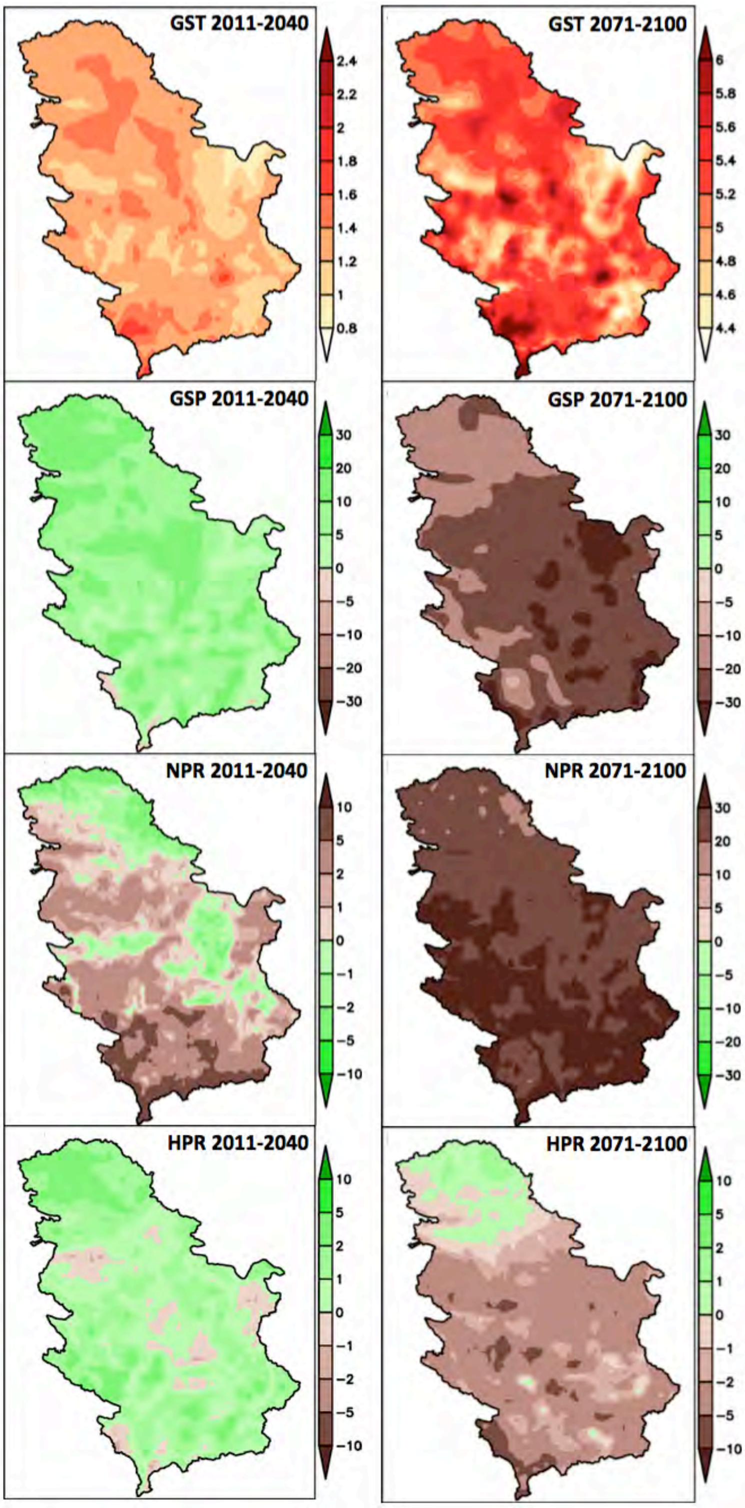

Figure 2. Projected changes of mean growing season temperature (GST), accumulated growing season precipitation (GSP), number of days without precipitation (NPR) and number of days with precipitation larger than 10 mm (HPR) for two periods 2011-2040 and 2071-2100 in respect to 1971-2000.

High-resolution regional climate projection under the RCP 8.5 scenario shows constant temperature increase during the 21st century across the entire country (Figure 2). Largest change in temperature and precipitation will be during the vegetation, so it will influence largely, not only grapes, but also all other plants. Mean temperature during the growing season for the period 2011-2040 is expected to increase between 0.8 and 1.6 °C in respect to 1971-2000. Smaller change is predicted for higher altitudes, while the largest one is across wine-growing regions. At the same time precipitation in growing season is expected to increase mostly from 5 to 10%, but even up to 20% in some areas on the north and central Serbia. For the period 2071-2100 the projected warming of the vegetation period is more pronounced (4 to 6 °C) and followed by significant drying across the country. Growing season precipitation deficit is between -10 and -30% for the largest part of Serbia, however in some wine-growing regions simulated decrease is larger than -30%. In addition to vast precipitation shortage, number of dry days will increase in comparison to the period 1971-2000, as well as number with precipitation larger than 10 mm. In other words, drought periods will be longer, especially during the summer, and interrupted by more intense precipitation. This may create significant stress for plants, while extremely high temperatures during the ripening may negatively influence to color and aroma of grapes, thus lower quality of wine.

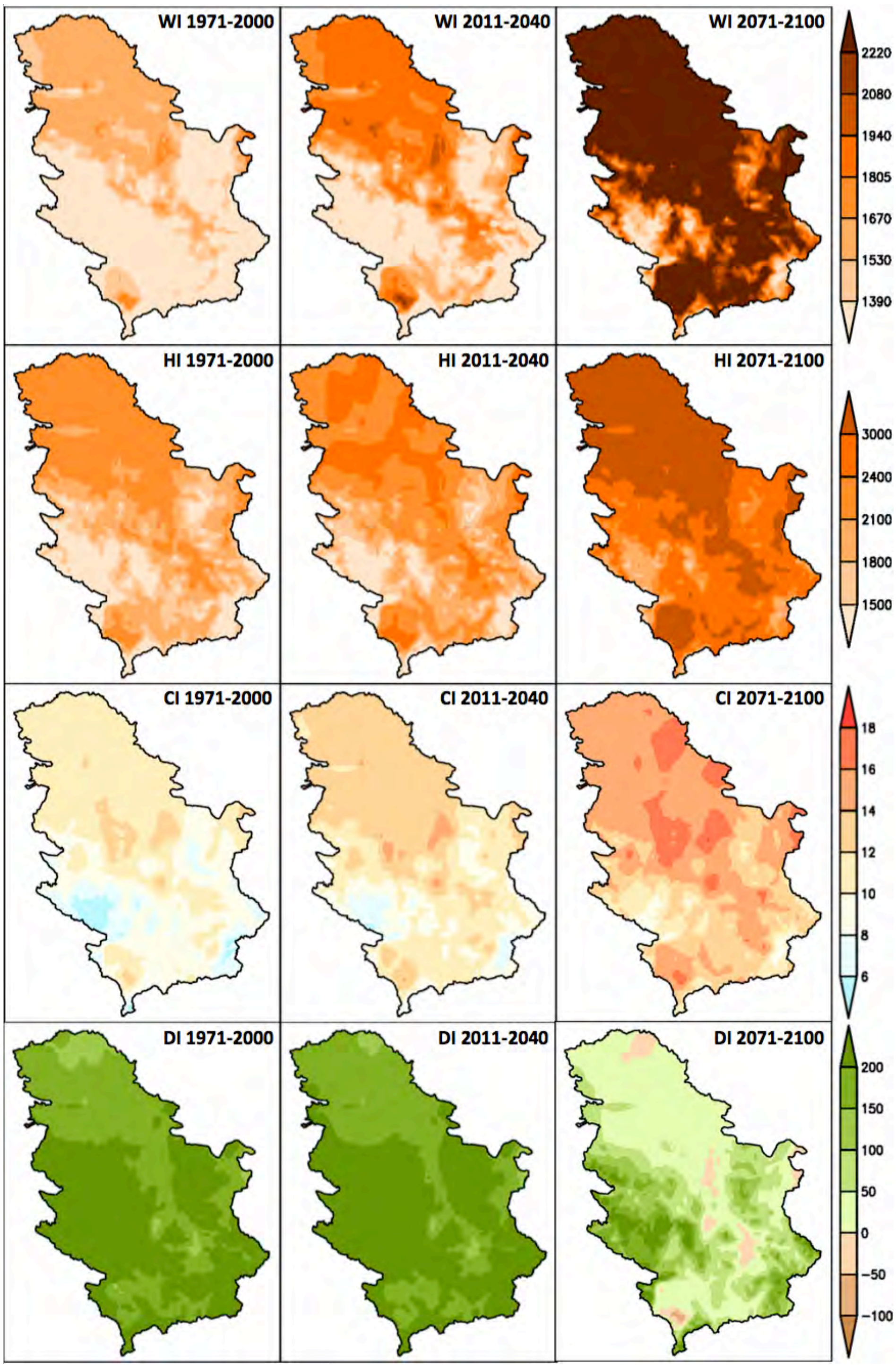

Figure 3. Winkler index (WI), Huglin index (HI), Cool night index (CI), Drought index (DI) for periods 1971-2000 (left column), 2011-2041 (middle column), 2071-2100 (right column).

Climate classification of current wine-regions is presented in Figure 3 (left column) through four bioclimatic indices that are commonly used in viticulture. Most of Serbian wine-growing regions belong to II or III climatic zone according to Winkler index. Parts of Belgrade, Mlava, Šumadija and South Metohija wine-growing regions are a bit warmer in comparison to the others and fall into the category III. According to Huglin index all of Serbian wine-regions are within temperate and temperate warm category. Most of the wine-growing regions have very cool nights based on Cool night index values. Only parts of Belgrade, Mlava, Negotin and Tri Morave wine-growing regions are in cool nights category. Almost all wine-growing regions fall into a humid category of the Dryness index, except for some parts of Negotinska Krajina, Niš, Telečki and Subotica wine-growing regions.

Climate projection for the period 2011-2040 shows changes in all viticultural indices across the country (Figure 2, middle column). Winkler index is projected to shift to zone III for the most of wine-regions and zone IV in South Metohija and parts of Mlava, Negotinska Krajina, Tri Morave, Belgrade wine-regions. Huglin index is also predicted to move towards warmer climate in a way that almost all wine-growing regions will have temperate warm, and parts of Telečki, Potisje, Banat, Vrsac, Mlava, Tri Morava, Nišava, Negotinska Krajina, South Metohija. Mean minimum temperature in September will fall into the cool nights category for the most of the wine-growing regions, parts of Mlava and Tri Morave wine-growing regions will have temperate nights, while Knjaževac, Niš, Leskovac, Toplica and Vranje will stay in the very cool nights category. Projected changes in Dryness index for this period are small, and all wine-regions will stay in the humid climate category.

Changes projected for the end of the 21^{st} century (2071-2100) are very distinctive (Figure 3, right column). All wine-growing regions in Serbia are predicted to shift to V climate zone of Winkler index and very warm climate category of Huglin index. Most of the wine-growing regions will have temperate values of Cool night index, except for Vranje wine-growing region and higher altitudes that are currently outside of wine-growing regions. The temperature rise will be followed by precipitation decrease, especially during the vegetation period. Therefore, Dryness index predicts a sub-humid climate for the largest part of Serbian vineyards and moderately dry category for Nišava, Čačak-Kraljevo and part of Knjaževac wine-growing region. In the period 2071-2100 climate characteristics of present wine-growing regions will be found only in small areas at higher altitudes.

4 CONCLUSION

Spatial analysis of climate change in Serbian wine-growing regions through the four well-established viticlutural indices indicates only a slight shift towards warmer climate in the next decades and a significant change of important climate characteristics by the end of 21^{st} century. In the first period (2011-2040) projected change could be beneficial for the grape and wine production. However, warming and drying expected in the later period (2071-2100) will cause a large change in selection of grape varieties that will be suitable for production under the new climate conditions, subtropical climate prevailing with Mediterranean characteristics of precipitation annual distribution. This requires a systematical identification and implementation of adaptation measures in Serbian vineyards. Cultivation of present grape varieties will have to relocate to higher altitudes that are already included in some wine-growing regions according to the latest viticultural zoning in Serbia.

Acknowledgments

This study is a part of the project "Studying climate change and its influence on the environment: impacts, adaptation and mitigation" (no. 43007) financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia within the framework of integrated and interdisciplinary research for the period 2011-2016.

5 LITERATURE CITED

Djurdjevic V and Krzic A. 2014. Analysis of the downscaled CMCC-CM projections preformed with the NMMB model, ORIENTGATE project report.

Djurdjevic V and Rajkovic B. 2008. Verification of a coupled atmosphere-ocean model using satellite observations over the Adriatic Sea. Annales Geophysicae 26:1935-1954.

Huglin P. 1978. Nouveau mode d'evaluation des possibilites heliothemiques d'un milieu viticole. In: Proceedings of the Symposium International sur l'ecologie de la Vigne. Ministere de l'Agriculture et de l'Industrie Alimentarie, Contanca.

IPCC. 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York, USA.

Ivanisevic D, Jaksic D and Korac N. 2015. Atlas of Viticulture (in Serbian). Statistical Office of the Republic of Serbia, Belgrade, Serbia.

Nakicenovic N. et al. 2000. Special Report on Emissions Scenarios, Contribution to the Intergovernmental Panel

on Climate Change, Cambridge University Press, Cambridge, United Kingdom.
Riou CH, Becker N, Sotes Ruiz V, Gomez-Miguel V, Carbonneau A, Panagiotou M, Calo A, Costacurta A, Castro de R, Pinto A, Lopes C, Carnieiro L and Climaco P. 1994. Le deteminisme climatique de la maturation du raisin: application au zonage de la teneur em sucre dans la communaute europeenne. Office des Publications Officielles des Communautes Europeennes, Luxembourg.
Ruml M, Korać N, Vujadinovć M, Vuković A and Ivanišević D. 2016. Response of grapevine fenology to recent temperature change and variability in the wine producing area of Sremski Karlovci, Serbia. Journal of Agriculture Science. 154(2):186-206.
Ruml M, Vukovic A, Vujadinovic M, Djurdjevic V, Rankovic-Vasic Z, Atancakovic Z, Sivcev B, Markovic N, Matijasevic S and Petorvic N. 2012. On the use of regional climate models: Implications of climate change for viticulture in Serbia. Agricultural and Forest Meteorology, 158:53-62.
SNC 2015, The Second National Communication on Climate Change under the United Nations Framework Convention on Climate Change. Ministry of Agriculture and Environmental Protection, Belgrade, Serbia (in preparation).
Tonietto J. 1999. Les macroclimats viticoles mondiaux et l'influence du mesoclimat sur la typicite de la Syrah et du Muscat de Hambourg dans le sud de la France: methodologie de caracterisation. PhD Tesis. Ecole Nationale Superieure Agronomique, Montpellier.
Tonietto J. and Carbonneau A. 2004. A multicriteria climatic classification system for grape-growing regions world wide. Agricultural and Forest Meteorology 124:81-97.
Vujadinovic M, Vukovic A, Djurdjevic V, Rankovic-Vasic Z, Atanackovic Z, Sivcev B, Markovic N and Petrovic N. 2012. Impact of climate change on wine growing season and dormant period characteristics for the Balkan Region. Acta Horticulturae. 931:87-94.
Vukovic A, Vujadinovic M, Djurdjevic V, Cvetkovic B, Rankovic-Vasic Z, Przic Z, Ruml M and Krzic A. 2015a. Fine scale climate change analysis: From global models to local impact studies in Serbia. In: Proceedings of the 7th International Conference on Information and Communication Technologies in Agriculture, Food and Environment, Kavala, Greece, Septmeber 17-20 2015. Eds Z Andreopoulou and D Bochtis, 892-901.
Vukovic A, Vujadinovic M, Ruml M, Przic Z, Rankovic-Vasic Z, Cvetkovic B, Djurdjevic V and Krzic A. 2015b. Climate change impact on grape growing in Serbia, Third Balkan Symposium on Fruit Growing, 16- 18 September 2015, Belgrade, Serbia.
Winkler AJ, Cook JA, Kliwe WM and Lider LA. 1974. General viticulture, University of California Press, California, USA.