CLIMATE CHANGE IN VINEYARDS OF SERBIAN-ROMANIAN BANAT

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Abstract. *Over the past five decades mean annual temperature in Banat region increased for approximately 1.2 °C. At the same time, summer season (June, July, August) became warmer by around 1.8 °C, with more frequent and more intense extreme events, such as droughts, heat waves and heavy precipitation that may be followed by floods and hail. This change has already influenced vineyards across Banat, shifting the Winkler index from the second to the third zone, causing changes in the viticultural practice. Although the analysis of future climate change is done, both in Serbia and Romania, on a national and local level, there is no study covering this bordering region as a whole. Border regions are recognized as places with higher climate change impacts, where cross-border cooperation and exchange of good practice and knowledge may enlarge the capacity of both countries to combat the change and implement adaptation measures. Future climate change impact assessment is done using an ensemble of high-resolution regional climate models from the CORDEX project. High resolution of the projections enables to investigate the diversity across this relatively small region, while the use of multi-model ensemble provides the information on projections uncertainty. Two green house gasses scenarios were selected from the Fifth Assessment Report scenarios of the Intergovernmental Panel on Climate Change, namely RCP8.5 as a "business as usual" and RCP4.5 as a "midline" scenario. Following these two emission pathways, temperature and precipitation are examined within three 20-years long time slices, representing near future, mid-century and end of the century. Viticultural bioclimatic indices that are commonly used to describe climate of wine-growing regions are also analyzed, alongside with a frequency change for certain weather events that may have a negative impact on the grape production and/or wine quality. The results of this study may be used to tailor adaptation measures particularly for vineyards in Banat region involving both short and long-term planning and ensuring their implementation through cross-border cooperation which will be an important step towards the sustainable viticultural development in the region.*

Keywords*: Banat, viticulture, climate change, bioclimatic indices*

INTRODUCTION

Banat is a part of the Pannonian Valley, located between three rivers (the Danube in the south, the Tisa in the west and the Mures in the north) and the Carpathian Mountains in the east. Its eastern and larger part belongs to Romania, western part is in Serbia and a small area in the north is Hunagarian. Due to its mainly flat orography, mostly crops are being produced in both, Serbian and Romanian Banat. However, there are several locations in which grapes are successfully grown and quality wines are produced.

Over the last decades, Banat, as well as the rest of the world, felt a change of its climate through temperature increase, change of precipitation regime and more frequent extreme events (droughts, floods, hail, heat waves, intense rainfall, etc.). Mean annual temperature in Banat increased by approximately 1.2 °C over the last 50 years, while summer season (June, July, August) warmed even more (by 1.8 °C). In the same period mean annual precipitation slightly increased up to 5% in the southern part of Banat and up to 10% in the northern part. Changes in summer precipitation remained within the natural climate variability span, from -5% in the southern part up to +5% in the north (VUKOVIC AND VUJADINOVIC, 2018).

Observed warming trend, especially during vegetation, already influenced vineyards both in Serbia and Romania by changing their suitability for wine production (RUML ET AL., 2012, IRMIA ET AL., 2017, BUCUR AND DEJEU, 2016). Growing season is starting earlier and ending later, thus shifting all relevant phenophases (RUML ET AL., 2016), wines in warmer regions accumulate more sugars and are lacking in acidity (IRMIA ET AL., 2018). This causes need for changes in viticultural and oenological practice, both from wine producers and policy makers, in a way of adopting and timely implementing adaptation measures.

Although there is a number of studies investigating climate change in wine-growing regions of Serbia and Romania on a national and local level (RUML ET AL., 2012, RUML ET AL., 2016., RUML ET AL., 2017, IRMIA ET AL., 2017, IRMIA ET AL., 2018, BUCUR AND DEJEU, 2016 among others), bordering regions, such as Banat, are often not studied thoroughly. This study analyzes climate change in wine-growing regions of Serbian-Romanian Banat using state-of-the art regional climate simulations on a high spatial resolution in order to calculate bioclimatical indices tailored and widely used in viticuluture. It may provide a starting point in defining climate change adaptation measures particularly for vineyards in Banat region, involving both short and long-term planning, as a way towards the sustainable viticultural development in the region.

MATERIAL AND METHODS

The analysis of future climate conditions in Banat's vineyards is done using results of regional climate models (RCMs) under the RCP8.5 scenario (IPCC, 2013) available through the Euro-CORDEX project (JACOB ET AL., 2014). The chosen scenario is of a high-end and it anticipates constant increase of green house gases emission by the end of the 21st century, thus often referred to as a „business as usual" scenario. A multi-model ensemble is constructed of nine RCMs with high spatial resolution of about 10 km. Daily bias-adjusted fields of minimum and maximum temperature and precipitation are used to calculate changes in mean temperature and precipitation, as well as several bioclimatological indices that are important for climate characterization in viticulutral practice. Period 1986-2005 is defined as the base (referent) for the present climate, while three periods are defined for the future, namely 2016-2035, 2046-2065 and 2081-2100, representing the near future, the middle and the end of the century, respectively. Changes in mean temperature and precipitation are presented relatively to the base period, while bioclimatological indices are given in absolute numbers, so the future change may be easily followed through the change of their category. All values are shown as the median of the multi-model ensemble.

Chosen bioclimatological indices are: Winkler index (WIN, WINKLER ET AL., 1974), Huglin index (HI, HUGLIN, 1978), Cool nigth index (CI, TONIETTO AND CARBONNEAU, 2004) and Drought index (DI, RIOU ET AL., 1994). Winkler index is important for viticultural production since it is being used in regulation of procedures allowed in oenological practice (percent of alchol, (de)acidification, minimum grape maturity requirement, etc.). The remaining three indices consist the Multicriterium climatic classification system for grape-growing regions (TONIETTO AND CARBONNEAU, 2004). It covers all important aspects of grape and wine production: HI describes amount of heat available during the daylight, DI estimates amount of available soil water, while CI may indicate potential wine quality in terms of color and aroma development in berries.

RESULTS AND DISCUSSIONS

In Serbian Banat there are two wine-growing regions, namely Banat (covering North and Middle Banat) and South Banat. Vineyards are located near Kikinda (North Banat), Zrenjanin (Middle Banat), Vrsac, Bela Crkva and around Deliblato Sands, near Banatski Karlovac (South Banat). Vineyards cover 1862.72 ha in total, of which 132.03 ha are in Banat wine-growing region and 1730.69 ha are in South Banat (IVANISEVIC ET AL., 2015). All Romanian vineyards in Banat belong to the wine region Hills of Banat (Dealurile Banatului) and are located near Minis (Arad), Recas, Buzias, Berzovia (Timis) and Moldova Noua (Caras-Severin). With the surface of total 2928.4 ha under vineyards, it is the smallest Romanian wine region (ANTOCE ET AL., 2013). In both countries wine-growing regions in this area, according to the actual viticultural zonings, fall into Winkler region II or EU C I zone (ANTOCE ET AL., 2013, IVANISEVIC ET AL., 2015). Approximate location of vineyards is shown in Figure 1, alongside with Banat's topography.

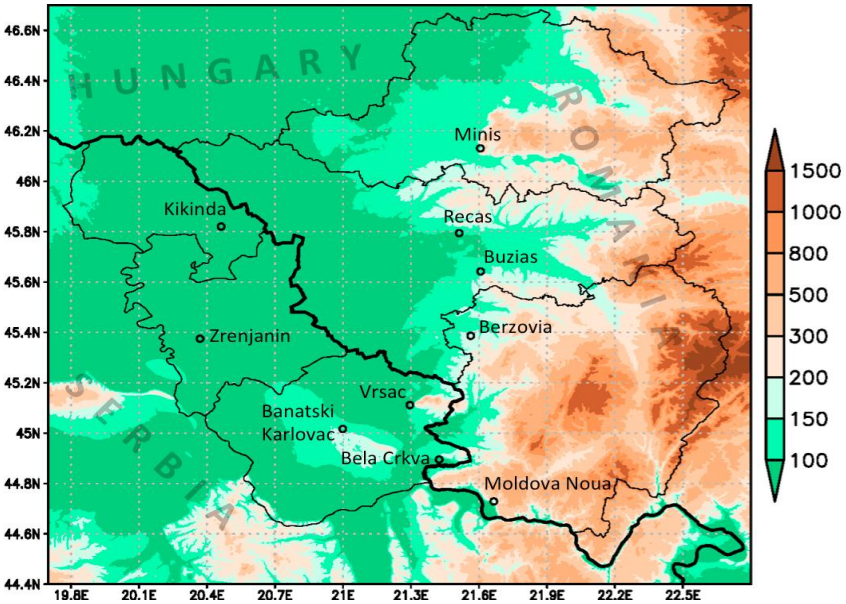

Fig. 1. Topography and administrative counties of Banat. Vineyards are located in vicinity of marked towns.

In the present climate (base period 1986-2005), vineyards in Romanian Banat belong to the region II according to WIN, as well as Bela Crkva in Serbia (Figure 2). Climate in other vineyards in Serbian Banat is currently shifting towards WIN region III, while in Zrenjanin it already falls into region III. This is a change in comparison to the Serbian viticultural zoning in which all of Banat's vineyards are in the WIN region II. However, the zoning is based on 50-years climate averages in the period 1961-2010, thus not reflecting good enough actual climate in the past few decades. According to HI, all Serbian vineyards in the area, except for Bela Crkva, falls into warm temperate climate, while Romanian are somewhat cooler, with temperate climate. CI and DI have uniform categories showing very cool nights in September (CI) and sub-humid climate (DI) across the all vineyards in the area. Presently cultivate varieties, both in Serbian (IVANISEVIC ET AL., 2015) and Romanian (https://lege5.ro/Gratuit/ha2dmnzq/ordinul-nr-225-2006-privind-aprobarea-zonarii-soiurilor-nobile-de-vita-de-vie-roditoare-admise-in-cultura-in-arealele-viticole-din-romania) Banat's vineyards are listed in Table 1.

Table 1

Recommended and allowed grape varieties in Serbian and Romanian Banat wine-regions.

Varieties	**White wines**		**Red wines**	
	Serbia	**Romania**	**Serbia**	**Romania**
International	Chardonnay, Riesling Italico, Sauvignon Blanc, Muscat Ottonel, Semillon, Pinot Blanc, Pinot Gris, Riesling, Chasselas, Bouvier, Sylvaner	Chardonnay, Riesling Italico, Sauvignon Blanc, Muscat Ottonel	Pinot Noir, Cabernet Sauvignon, Merlot, Gamay Noir, Cabernet Franc, Rebo	Pinot Noir, Cabernet Sauvignon, Merlot
Regional and autochthone	Ruzica, Muskat krokan, Sremska zelenika, Neoplanta, Sila, Kreaca, Tamjanika, Zupljanka	Feteasca alba, Feteasca regala, Majarca, Furmint de Minis	Portugieser, Limberger, Skadarka, Probus	Feteasca neagra

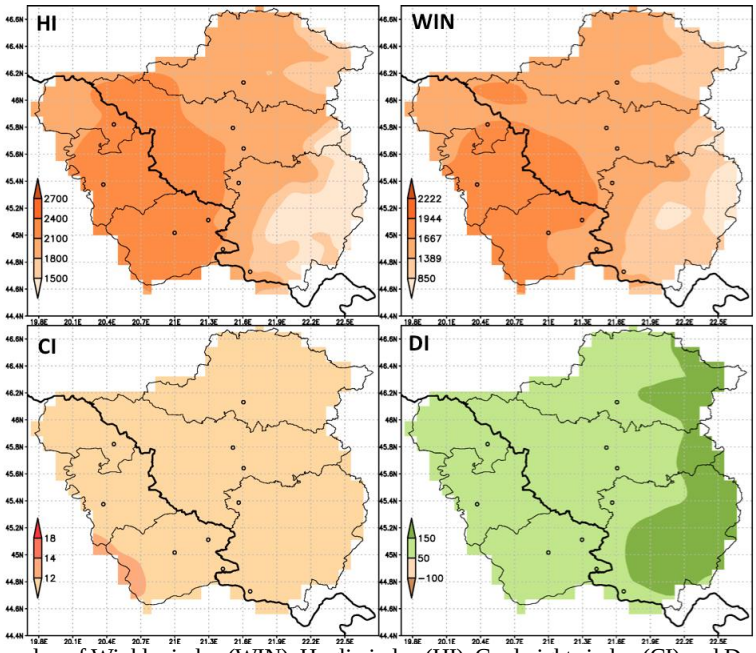

Fig. 2. Median value of Winkler index (WIN), Huglin index (HI), Cool nights index (CI) and Dryness index (DI) in Banat in the present climate (1986-2005).

If the present trend in green house gases emission persists, Banat, as well as the rest of the world, will suffer from the continuous warming. In the near future it will be up to 1 °C in respect to the base period (1986-2005) across Banat, between 1.5 and 2.5 °C in the mid-century and from 3 to 4.5 °C by its end (Figure 3). At the same time, annual precipitation amount will change more or less in the limits of its natural variability. More importantly, summer season (June, July, August) will warm even more (up to 1.5°C in the near future, from 1.5 to 2.5 in the mid-century and from 4 to over 4.5°C in the end-century) and become dryer (Figure 4). Until the middle of the century summer precipitation changes will be mainly in the range of +/-5%, while at the end of the century there could be from 10 to 20% less precipitation. Predicted warming, alongside the change in interannual precipitation distribution will certainly cause change of climate suitability in present Banat's vineyards.

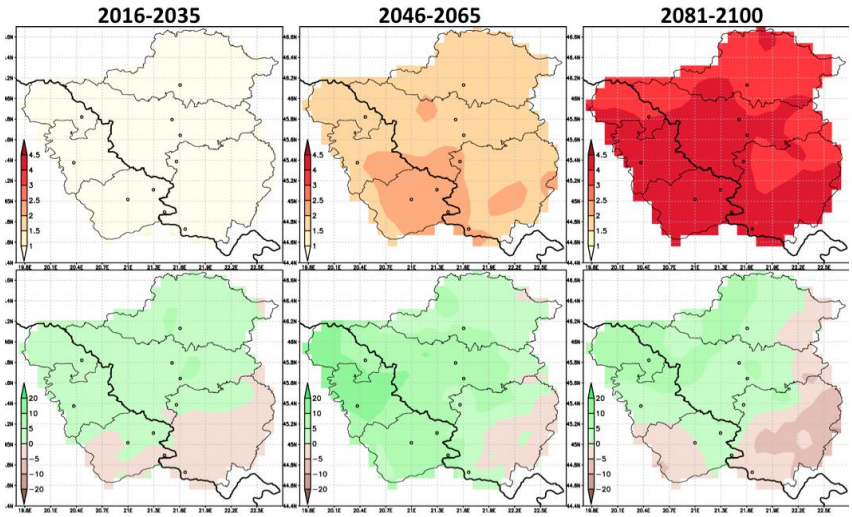

Fig. 3. Median value of mean annual temperature (first row) and annual precipiation (second row) in Banat in the future climate under the RCP8.5 scenario in comparison to the base period.

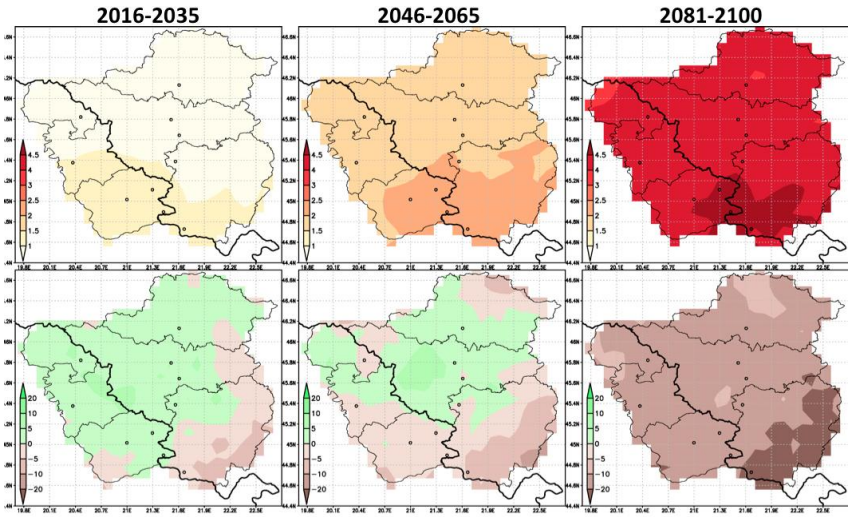

Fig. 4. Median value of mean summer temperature (first row) and summer precipiation (second row) in Banat in the future climate under the RCP8.5 scenario in comparison to the base period.

According to the median value of regional climate multi-model ensemble under the RCP8.5 scenario all vineyards in Banat in the next 10 to 15 years will be in the WIN region III, with an exception of Moldova Noua that will be on the border between regions II and III. Warm temperate climate (HI) will advance to the east. Only Moldova Noua will stay on the border between temperate and warm temperate climate. In Serbian vineyards, as well as in Berzovia, nights in September will become warmer and fall into cool nights CI category. At the same time, soil water availability will remain the same, according to DI.

In the middle of the century, all present vineyards will transfer to the WIN region IV, except for Moldova Noua and Minis which will be in the III region. Serbian vineyards will shift to warm climate, while Romanian will remain warm temperate, although Recas, Buzias and Berzovia will be on the bortder between the

two categories of HI. September nights will be temperate in Vrsac and Zrenjanin, while other wineyards will have cool nights. Kikinda and Zrenjanin could fall into moderately dry category of DI, while others will remain sub-humid.

By the end of the century, all present Banat's vineyards will fall into the WIN region V, with very warm climate, except for Moldova Noua and Minis that will have warm climate and be on the border between WIN regions IV and V. All of present vineyards in Banat will have temperate nights in September and moderately dry soli water conditions, except for Minis that will be on the border with present conditions.

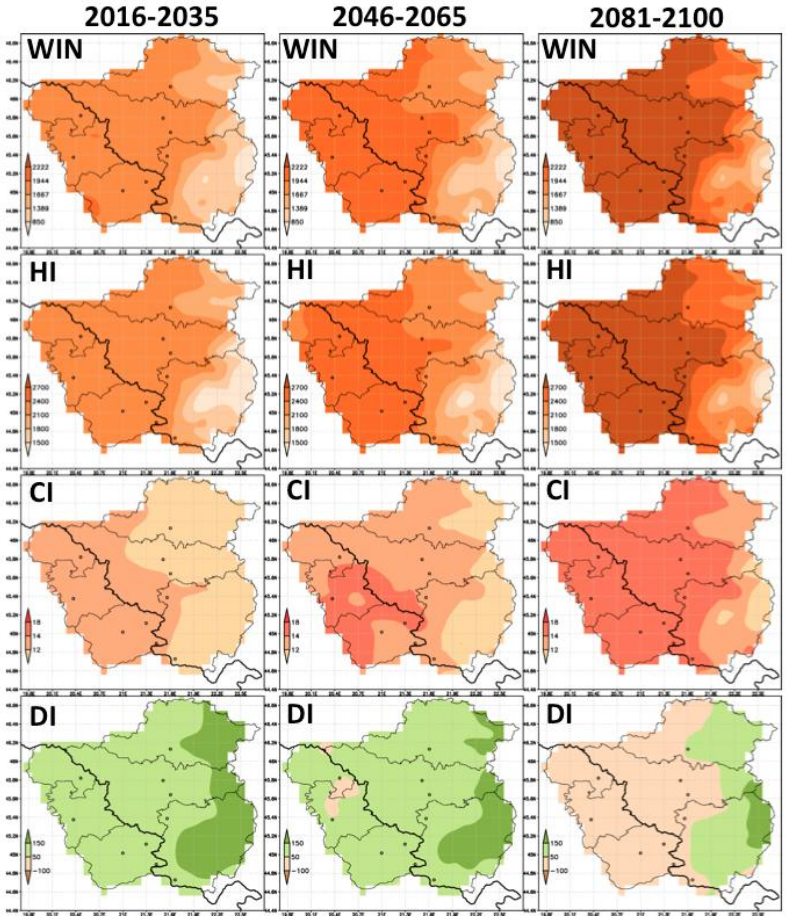

Fig. 5. Median value of Winkler index (WIN), Huglin index (HI), Cool nights index (CI) and Dryness index (DI) in Banat in the future climate under the RCP8.5 scenario.

CONCLUSIONS

Change of viticultural bioclimatic indices in wine-growing regions of Serbian and Romanian Banat indicate climate continual shifting by the end of the century. Thermal conditions during vegetation in the past few decades already have change towards warmer climate in comparison to longer-term means in most vineyards of Serbian Banat. In the next 10 to 15 years all Banat's vineyards are projected to fall into the WIN region III, which gives an optimal climate for high production of quality wines. By the end of the century today's Banat wine-growing regions will shift into WIN region V, which will require change of varieties and/or relocation of vineyards. At the same time, soil water availability will change slowly, providing moderately dry

conditions by the end of the century. All projected changes will advance from the west towards east, and will be the slowest in the easternmost vineyards of Moldova Nousa and Minis.

In both Serbia and Romania there is a strong need for sectoral climate change vulnerability, impact and risk assessment, followed by adoption and implementation of adaptation measures. In the wine sector, producers intuitively follow weather conditions on a year-to-year basis and change their practice accordingly, in order to make high quality wines, while national policies often do not keep up with fast changing climate, thus not providing appropriate support.

Through the new viticultural zoning in Serbia that is adopted in 2013, climate change tendencies are counted for with the increase of a maximum allowed altitude of vineyards (changed from 600 m to 800 m) and allowing cultivation of grape varieties with later maturation. However, the climate changes are happening very fast and there is a need for constant monitoring of climate conditions in wine-growing regions and periodically update of the zoning. Since border regions are recognized to have possible high climate change vulnerability, this study provides an opportunity to overview Banat as a whole, jointly implement solutions and enlarge the capacity of both countries to combat the climate change. The results of this study could be used as a starting point in defining short and long-term adaptation measures in order to make the best use of favorable climate conditions in thee following years, as well as timely prepare for significant climate shift by the end of the century.

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