Assessment of climate change impact on downy mildew appearance in Serbia using ECHAM5 climate model outputs

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Abstract. Climate change and variability is natural phenomena. The latest changes of Earth's climate significantly affect human ability to remain food production sustainable. All aspects and phases of plant production, including management of harmful organisms is affected by some aspects of CC. Expected climate changes will influence environmental conditions suitable for diseases, pests and wides appearance. Results obtained in this assessment study indicate that, meteorological conditions which can be expected in Serbia in 2030 and 2050 according to ECHAM climate model will significantly affect time of appearance and probability of attack of *plasmopara viticola* which is causal agent of downy mildew of grapevine. Most important impact supposes to lead to earlier appearance of disease in vulnerable regions. However number of period with meteorological conditions suitable for appearance of downy mildew of grapevine is expected to vary differently in different regions reducing vulnerability of one region and increasing of another.

Key words

Climate change, biometeorological modeling, downy mildew of grapevine, adaptation

Introduction

Plant response to effects of CC is complex and non-linear. Changes in amount, intensity and distribution of temperature and precipitation will affect not only plant development and yield formation but also plant-related pests, diseases and weeds. Appearance and intensity of attack of harmful organism is a result of favourable meteorological conditions, growing phase and stress conditions of host plant and presence of organism itself. Expected climate changes suppose to influence harmful organism environmental conditions and, at the same time, to make significant impact on plant development and harmful organism existence in the region of interest (Trnka, 2007; Altermatt, 2010; Eastburn, 2011; Pugliese et al., 2011; Caffara et al., 2012; Eitzinger et al., 2012).

For many decades (or even centuries) downy mildew caused by *Plasmopara viticola* is the one of most important grapevine diseases in the Serbia (Kispatic, 1972). It affects both, quantity of fruits and quality of vine. Time of appearance and intensity of attack of this organism is highly influenced by weather conditions directly and indirectly, through its impact on fruit development and conditions. Therefore, it is expected that, long term changes in meteorological conditions, i.e. climate change (CC) will induce shift in production regions (Vukovic et al., 2010; Ruml et al., 2012) as well as its vulnerability to downy mildew disease.

The present case study is an attempt to estimate the sensitivity of downy mildew of grapevine to CC by analyzing the time and probability of appearance of this disease. On the bases of results obtained a vulnerability analysis is made and appropriate adaptation measures are suggested. Since climate conditions typical for Serbian production areas can be found in majority of grapevine production areas of Western Balkan (WB), Serbia was selected as an area of interest in this assessment study.

Material and methods

Location:

Serbia is landlocked country located in the Western Balkans (southeastern Europe) and in the Pannonian Plain (a region of central Europe). It lies between latitudes 41°52' N and 46°11'N and longitudes 18°51'E and 23°01'E. Northern part of country is mostly flat terrain which belongs to Panonian Plain with Danube River dominating the region. In central parts of Serbia, the terrain consists of hills, low and medium-high mountains, interspersed with numerous rivers and its, often wide, valleys. Due to its geographical position and meridional orientation climate in Serbia varies from moderate continental at northern to continental in central part of country. Southern and southwestern parts of country are subjected to Mediterranean influences while on high mountains can be find typical mountain climate. Annual air temperature varies from 6 ^oC (on mountains above 1000 m) to 12 ^oC (on some regions bellow 300 m altitude). Annual temperature variation can reach 23 ^oC in some eastern and northeastern regions of the country. Precipitation regime is continental and Danubian with annual amount varying from 570 mm (lowlands) to 1000 mm (high mountains).

Present and future climate data and models used

Current climate conditions for 12 locations, uniformly distributed in Serbia (Tab. 1), are considered using daily

Table 1. *Geographical position of selected locations in Serbia.*

Location	Longitude	Latitude	Altitude
Sombor (SOM)	19.08 ^oE	45^o 47 ^oN	88
Novi Sad (NOV)	19.50 ^oE	45^o 15 ^oN	80
Pozarevac (POZ)	20.03 ^oE	43.83 ^oN	310
Kraljevo (KRA)	20.70 ^oE	43.72 ^oN	215
Krusevac (KRU)	21.35 ^oE	43.57 ^oN	166
Cuprija (CUP)	21.37 ^oE	43.93 ^oN	123
Nis (NIS)	21.90 ^oE	43.33 ^oN	201
Zajecar (ZAJ)	22.28 ^oE	44.88 ^oN	144
Dimitrovgrad (DIM)	22.75 ^oE	43.02 ^oN	450
Prizren (PRI)	20.73 ^oE	42.22 ^oN	402
Vranje (VRA)	21.90 ^oE	42.48 ^oN	432

weather data (air temperature and humidity, precipitation, wind speed and sunshine duration) measured during the 1971-2000 period on main climatological stations of Hydrometeorological Service of Serbia. Assessment study was carried out using projections of the future climate taken from the ECHAM5 global climate model (GCM) with the SRES-A2 scenario for greenhouse gas (GHG) emissions for the 2030 and 2050 integration periods. To synthesize daily weather data series from GCM simulations Met&Roll weather generator (e.g. Dubrovsky, 1997) was used as a tool for statistical downscaling. Weather generator is trained using 1971-2000 period as a reference climatology.

Daily data of present and future climate are used as input data for BAHUS biometeorological model (Mihailovic et al., 2001; Lalic et al., 2007). This model is fully developed at Center for Meteorology and Environmental Modelling at University of Novi Sad. It is designed as a standalone model for providing the messages of occurrence and severity of following plant diseases: apple scab, fire blight of apples and pears and downy mildew of vine grape. Components of model are: (1) input module – providing meteorological and biological data; (2) modelling module – consisting of several submodules for listed diseases. Each submodule is based on empirical relations and conditions related to the diseases occurrence and severity of infection and (3) output module – giving following messages: the risk of infection, the duration of incubation period, the time of the first symptoms, etc. Depending on the method selected in the modelling module, following meteorological data should be provided: maximum and minimum air temperature, daily air temperature and relative humidity, precipitation and duration of leaf wetness. In the PLASMOPARA submodule, BAHUS uses method defined by Miler (Group of authors, 1983) with air temperature and precipitation as input meteorological data in order to calculate day of appearance of first incubation period (DAN_IP) and number of incubation periods (IP) during the growing season under the present and changing climate.

Results and discussion

In order to quantify CC impact on time of appearance and intensity of attack of downy mildew, changes in DOY of first day of incubation period and number of periods during the growing season suitable for disease appearance are calculated using PLASMOPARA submodule for 2030 and 2050 compared to the 1971-2000 long-term mean.

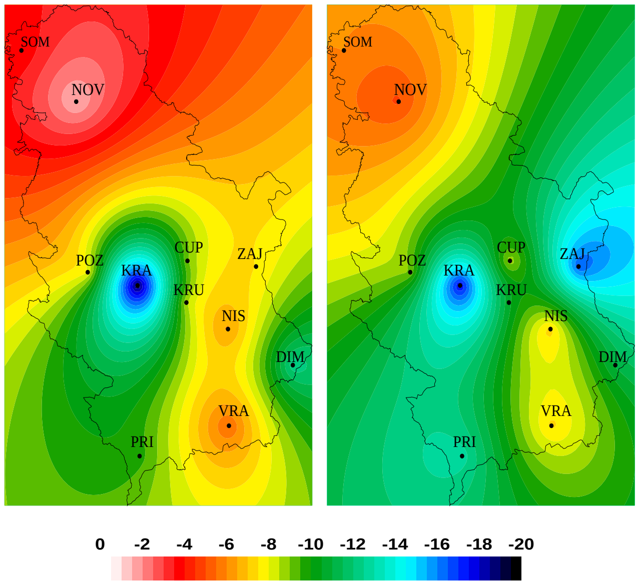

Figure 1. *Expected shift in DAN_IP in 2030 and 2050 compared to the 1971-2000 long-term mean.*

In all calculations made for the purpose of this assessment study, March 1st is set as a day when all biological conditions for downy mildew appearance were satisfied. Calculated shift of DAN_IP in 2030 in respect to reference period (Tab. 1) indicates up to 3 days (in average) earlier appearance of

Table 2. Relative change of DAN_IP in 2030 and 2050 compared to the 1971-2000 long-term mean.

Location	2030	2050
Somber (SOM)	-2.9	-4.4
Novi Sad (NOV)	-1.0	-3.4
Pozarevac (POZ)	-5.4	-6.2
Kraljevo (KRA)	-13.0	-12.0
Krusevac (KRU)	-5.8	-7.2
Cuprija (CUP)	-6.5	-6.2
Nis (NIS)	-4.4	-5.1
Zajecar (ZAJ)	-5.3	-11.7
Dimitrovgrad (DIM)	-8.3	-7.5
Prizren (PRI)	-6.7	-8.8
Vranje (VRA)	-3.8	-5.1

downy mildew in Vojvodina region (Northern Serbia) (SOM, NOV) in comparison to even 13 days earlier appearance in central Serbia (KRA) and 7-10 days in the rest of the country (Fig. 1). In the year 2050 regional distribution of DAN_IP is remained but with more pronounced shifts in all regions. It brings, also, to higher average values of DAN_IP in 2050 (7 days) in comparison to 2030 (5.7 days).

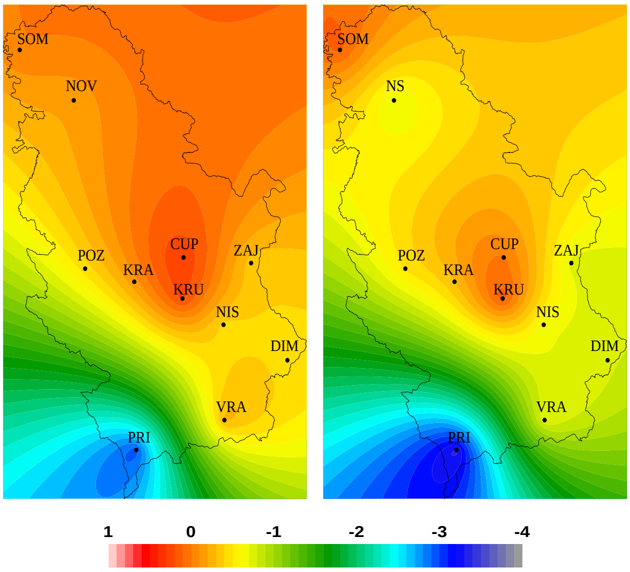

Figure 2. *Expected changes in number of IP's in 2030 and 2050 compared to the 1971-2000 long-term mean.*

Changes in number of IP's during the vegetation period can be used as a good indicator of changes in regional vulnerability in respect to harmful organism of interest. Results obtained for downy mildew appearance in Serbia indicate significant spatial differences but for all locations and all integration periods reduction in number of periods with meteorological conditions suitable for disease appearance can be notified. This trend is closely related to reduction of precipitation events and expected drier conditions in the future. The most pronounced reduction in number of IP's in both, 2030 and 2050 is related to the southern part of country (NIS, DIM, PRI) while in the central and northern part decrease is up to 10 % for 2030 and up to 20 % for 2050.

Table 3. *Relative change of number of IP's in 2030 and 2050 compared to the 1971-2000 long-term mean.*

Location	2030	2050
Sombor (SOM)	-0.3	-3.6
Novi Sad (NOV)	-4.0	-16.4
Pozarevac (POZ)	-10.2	-10.9
Kraljevo (KRA)	-2.6	-6.0
Krusevac (KRU)	-6.0	-4.0
Cuprija (CUP)	-7.3	-0.3
Nis (NIS)	-11.6	-17.8
Zajecar (ZAJ)	-8.2	-16.9
Dimitrovgrad (DIM)	-11.6	-20.4
Prizren (PRI)	-46.6	-52.6
Vranje (VRA)	-8.2	-21.8

Conclusions

Expected changes of climate in Serbia will have different impact on regional level but common characteristic of these changes suppose to be exerted in increased temperature variations and regional heterogeneity of distribution of precipitation on all time scales.

Climate change effects rising complexity of integrated plant protection management by increasing uncertainty of plant - harmful organism - environment triangle. Additionally it is expected that some new pests will appear, while other will become less important in some regions. In case of downy mildew of vine grape expected meteorological conditions in upcoming growing seasons suppose to be less favorable even first symptoms can appear earlier during the year. If it happens it can decrease regional vulnerability of production regions in Serbia. However, there is a secondary impact of CC on vulnerability to certain plant disease - stress effect. Namely, according to all climate change scenarios, increased number of extreme weather events suppose to be most pronounced feature of CC effects in Serbia. It will tremendously affect stress conditions of plants and therefore their vulnerability to diseases. Hence, short-term adjustments and long-term adaptation measures in plant protection, regarding CC, suppose to be directed in two ways. One way is related to increase "phisiological conditions" of plant as a whole through fertilization, irrigation, use of hail nets, weeds control, permanent shoots cutting. Since oospores can overwintering in debris, its removal will reduce inoculums presence in vine yard. It will lead to reduced potential of disease appearance in forthcoming growing season. Another one should be focused on actions with prime aim to avoid or at least reduce negative effects of extreme weather events.

Expected outcome of this study is focused on: (a) minimisation of losses caused by changed climate conditions, (b) increase of the effectiveness of disease management strategies and (c) tracking of the geographical distribution of downy mildew of grapevine in Serbia.

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