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Which is the response of soils in the Vojvodina Region (Serbia) to climate change using regional climate simulations under the SRES-A1B?

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ABSTRACT

Climate change has different manifestations in various regions all over the world. Such changes strongly affect ecosystem services, environmental and agricultural stability. Soils play a crucial role in the complex system that generates climate change. However, the nature and structure of response of different soils to climate change is still distant to be interpreted. Bearing in mind that climate simulations can help us to comprehend soil balance in the future, we defined the purpose of this study: to project temporal and spatial changes of temperature and moisture in four different soils under A1B scenario for the periods 2021–2050 and 2071–2100 with respect to the period 1961–1990. For this analysis climate data obtained by the ECHAM5 model simulations, dynamically downscaled by the coupled regional climate model EBU-POM (Eta Belgrade University-Princeton Ocean Model), were used. The 43 sites in Vojvodina region (Serbia) were analyzed for pedological parameters and climate elements. The projected changes at the end of 21st century (2071–2100) can be summarized as follows: (i) increase in the mean annual soil temperature up to 3.5 °C in the surface layer 0–10 cm and up to 1.8 °C in average for 0–200 cm depth and decrease in the mean soil moisture up to 0.039 kg kg^{-1} in the subsurface layer 40–100 cm and up to 0.019 kg kg^{-1} in average for 0–200 cm depth, which corresponds to decrease of 16% and 7%, respectively; (ii) Chernozerms proved to be more sensitive to temperature increase in contrast to water affected soils (Fluvisols, Gleysols and Vertisols) that showed the lowest susceptibility; (iii) Chernozems also showed higher sensitivity to moisture loss than Cambisols, Arenosols and Umbrisols that showed the lowest susceptibility; and (iv) it was assumed that predicted changes in soil temperature and moisture will cause significant changes in soil respiration, release of CO_2, soil processes, agriculture, biodiversity and ecosystem functioning.

1. Introduction

Climate changes in Serbia region, over the past few decades, are characterized by higher temperatures and weather extremes (Lalić et al., 2013; Malinović-Miličević et al., 2016). Therefore, it is more difficult to deal with the impact of CC on the part of ecosystem that is affected with climate parameters such as the pedosystem (soils). Climate change can increase soil erosion through its impact on rainfall, vegetation and patterns of land use (Hillel and Rosenzweig, 2011). The A1 scenario supposes rapid economic growth followed by rapid introductions of new and more efficient technologies with the projected global average surface warming of 1.4–6.4 °C until 2100 (IPCC, 2007), and maybe more pronounced 6.4–9.5 °C than previously suggested (Tokarska et al., 2016). The impact of CC on soils is expected (EEA-JRC-WHO, 2008), but the interactions between CC and changes in soil processes are complex and deeply unknown. Soil as one of the essential part of ecosystem could be strongly endangered natural resource by CC. The advent of predicted weather extreme events will have greater impacts on sectors with closer links to climate, such as water, agriculture and food security, forestry, health, and tourism (IPCC, 2012) and will increase soil degradation processes such as soil erosion, desertification and salinisation and thus the loss of soil functions (Rounsevell et al., 1999). Soil temperature increase can make disbalance in soil respiration and thus release of CO_2 (Davidson et al., 1998) and microbial processes (Rankinen et al., 2004), increase soil organic matter decomposition (Conant et al., 2008), disrupt soil processes (Paul et al., 2004), agricultural production, biodiversity and ecosystem functioning.

Soils are finite resources that provide most of food for mankind and animals, fuel in some parts of the world and filter water and supply nutrients for plants (Oliver and Gregory, 2015). Soils are dynamic even

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in short periods of time (Schaetzl and Anderson, 2005). Soil climate (temperature and hydric regime) will change dramatically in both Central Europe and the central plains of the United States with consequences for soil genesis (Trnka et al., 2013). Even Dokučhaev (1883) in 19th century recognized climate as one of the key soil forming factors. In the Vojvodina region (northern part of Serbia) an increase of the frequency of hot days (29.4 to 50%), decrease of the frequency of cold days (11.8 to 27.8%) and decrease of mean annual precipitation (8.1 to 14.2%) are expected (Malinovic-Milicevic et al., 2013). Mihailović et al. (2015) have found that in future there will be shifts in Koppen climate zones at whole Serbia. A number of factors influence on soil temperature: solar radiation, air temperature, topography, soil water content, soil texture and the plant cover (Paul et al., 2004). The land use change is considered as one of the most influential factors on CC (Nakicenovic and Swart, 2000). Land use is driven by socioeconomic and climatic factors, potentially with complex feedbacks (Oliver and Morecroft, 2014). Potential warmer and drier climate in future may lead to climate switch from semiarid to arid, which at much will affect soils with lower resilience. Simultaneously we can expect human response in terms of land use change and cropping system change in order to protect soils and the environment, which should vary depending on soil type.

Bearing in mind above mentioned facts, we inferred that response of soils to climate change and its future behavior is highly uncertain and unknown. So the authors are optimistic regarding the use of climate simulations in order to comprehend the destiny of soils in the future.

One of the main concerns regarding the soil degradation throughout the future CC is soil organic carbon (SOC). At higher temperatures increased SOC decomposition is expected followed by increased CO_2 emission from soils and acceleration of CC (Dalias et al., 2001; Sanderman et al., 2003). After the oceans and carbonate rocks, soils represent the third largest reservoir of carbon on the Earth, which plays a key role in terrestrial ecosystems (Zhang et al., 2008). Total carbon stocks in soils on the planet consists of 2500 Gt, which includes about 1550 Gt of soil organic carbon and 950 Gt of soil inorganic carbon (Lal, 2004).

The change in the soil temperature and soil moisture regime certainly affects the concentration and turnover rate of SOC (Hillel and Rosenzweig, 2011). These changes will be more or less pronounced depending on texture and water content in soil. It is expected that heavy textured, deep soils (Vertisols), SOC rich, well structured, calcareous soils (Chernozems), will act as less sensitive to CC than water affected soils (Gleysols, Gleyic Chernozems), coarse textured (Arenosols), shallow (Umbrisols) and low SOC soils (Fluvisols, Cambisols). Also, soils under natural vegetation might be suffering in the lesser extent due projected CC than the soils under intensive agricultural practice. Soil types in the Scandinavian regions have an elevated vulnerability to SOC loss, western and eastern parts of the EU have considerable areas at high risk, while soils in southern parts of the EU have complex pattern of regions with low and high risks of SOC loss (Stolbovoy et al., 2008). Determining response of soils to CC based on different soil types provides useful information on potential soil degradation, use and management in future and might thus be used as a guideline for soil protection. Different soils are expected to show different sensitivity to CC depending on its properties. Similarly, the concept of sustainable intensification of agriculture is based on particular soil susceptibility to agricultural intensification i.e. soil resilience (Schiefer et al., 2015), as well as soil quality rating that consider performance of particular soil type (Mueller et al., 2007). Coarse-textured soils that are characterized as poorly aggregated and structurally weak, with high erosivity degree (Salako, 2003) will be especially affected by weather extremes expected due the CC. Change of climatic and hydrological regime is considered as one of the main pressures on soil biodiversity in future (Gardi et al., 2008). The effects of CC on soil processes and properties are explored in a small extent, but it is evident that CC will impact SOC dynamics, soil organisms and the multiple soil properties that are tied to SOC, soil water, and soil erosion (Brevik, 2012). The specificity and magnitude of these changes will strongly dependent on soil type and land cover. Since each soil type has a different reaction to any environmental change, response properties may also vary thus influencing the stability of the performance (or adaptability to external impacts) to a great extent (Tóth, 2008). Variation of temperature and precipitation in combinations with soil types makes climate response of soils difficult to predict.

The purpose of this study was to predict thermal and moisture regimes of different soil types through 200 cm depth in two following periods: 2021–2050 and 2071–2100 versus the 1961–1990 reference period. These projections include simulations of temporal trends and spatial distribution of soil temperature and moisture using data from regional climate simulations obtained by EBU-POM model under the A1B scenario (Djurdjević and Rajković, 2012).

2. Materials and methods

2.1. Study area

Vojvodina covers an area of 2,150,600 ha. This region is characterized by intensive agriculture and a conventional tillage system. Vojvodina is located in the southernmost part of the Pannonian Basin (46°11′- 46°37′N, 18°51′- 21°33′E), representing its warmest and the driest part.

The mean annual temperature is 11.1 °C, with the mean of 88 frost days and the mean annual precipitation of 606 mm (Hrnjak et al., 2014). In terms of geomorphology Vojvodina is characterized by loess terraces, loess and sand plateaus and river plains (Danube, Tisza and Sava rivers).

Soil genesis and evolution in the Vojvodina have been strongly influenced by biological and climatic factors, the steppe-forest vegetation and moderate continental climate. Overall, Vojvodina is predominately agricultural land (1,790,000 ha or 83%), most of which is cropland (1,650,000 ha or 77%). Forest area comprises 140,717 ha, so the actual level of afforestation amounts to only 6%.

2.2. Investigated soils

Eight most common soil types in Vojvodina, according to the classification by IUSS Working Group WRB (2014) are used in the study. In order to make a better insight in soil properties under projected climate change, we separate RSGs on the basis of geomorphology, water influence and properties in the four groups: (1) Chernozems (15 sites), (2) Gleyic Chernozems (12 sites), (3) Fluvisols, Gleysols and Vertisols (12 sites) and (4) Cambisols, Arenosols and Umbrisols (4 sites) (Fig. 1).

(1) First group represents typical terrestric Chernozems that occupied loess plateau (90–120 m) and part of the loess terraces with groundwater lower than 3 m (Table 1; Fig. 2). Chernozems in Vojvodina exist only under arable land and are characterized with well-developed dark-brown humic horizon developed mainly on glacial-eolian sediments (loess), eolian sands or alluvial deposits under steppe and forest-steppe vegetation. Loamy texture, neutral pH, presence of $CaCO_3$, illite clays, well structural stability and considerable concentration of organic matter makes these soils very valuable for intensive agricultural production due the ideal air-water-nutrient regime.
(2) Second group is represented by Gleyic Chernozems predominantly spreaded on the loess terraces with appreciable influence of groundwater in parent material (loess). Gleyic Chernozems are very similar to Chernozems. Main difference is that Gleyic Chernozems are slightly affected with groundwater while Chernozems entirely have terrestrial pedogenesis. Gleyic Chernozems appeared at 80–90 m elevation and are more frequently leached, non-carbonaceous and heavy-textured soil than Chernozems.
(3) The common characteristic of Fluvisols, Gleysols and Vertisols in