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Sucho a vegetačné obdobie na Slovensku v podmienkach klimatickej zmeny

Drought and growing season on Slovakia in climate change conditions

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Abstract

Climate change impact on drought intensity during the growing season is evaluated on the territory of the Slovak Republic. Climatic water balance is evaluated in the context of water sufficiency in different agricultural production zones. There were applied measured meteorological data of SHMI from series of years 1961-1990 and meteorological data generated according to the RCP 4.5 scenario for time slice 2070-2100. A high diversity of drought impact was found among agricultural productive zones in Slovakia. Vulnerable regions can probably occur all over the territory except for mountainous regions.

Keywords: climatic water balance, agricultural productive zones

Abstrakt

Dôsledky klimatickej zmeny na výskyt sucha vo vegetačnom období sú zhodnotené pre územie Slovenskej republiky. Klimatická vodná bilancia je hodnotená v kontexte zabezpečenia poľnohospodárskych výrobných oblastí. Využité boli merané meteorologické údaje zo siete staníc SHMÚ (1961 – 1990) ako aj generované meteorologické údaje podľa scenáru RCP 4.5. pre časový horizont 2071 – 2100. Zistená bola veľká diverzita dopadov v rámci poľnohospodárskych výrobných oblastí na Slovensku. Zraniteľné regióny sa pravdepodobne budú nachádzať všade okrem horskej výrobnej oblasti.

Kľúčové slová: klimatická vodná bilancia, poľnohospodárske výrobné oblasti

Introduction

Several phenological studies concerning field crops as well as fruit and forest trees have been historically processed for the territory of the Slovak Republic and its regions (Braslavská, 1996, Škvareninová et al., 2009). Phenological data are also presented in the framework of model assessments of the impact of climate change on the agroclimatic potential of field crops such as winter wheat, spring barley and maize (Šiška, Špánik, 1999, Takáč, Šiška, 2008 and others). Phenological observations, especially in agriculture, often refer to varieties of field crops or horticultural cultures, the processing of phenological variables by numerical methods has also gained popularity in the past.

The proposal of agroclimatic regions of the Slovak Republic is also based on the assessment of climatic conditions during the vegetation period with average daily air temperature T> 10 ° C and in relation to drought (Kurpelová et al., 1975). Different aspects of vegetation periods have already been the subject of several types of research (Šiška, Špánik, 2008, Šiška, Takáč, 2009).

Drought phenomena are often evaluated without context on the phenology of field crops and horticultural cultures. Drought causes specific symptoms during the growing season. If we admit that drought takes place in the ecosystem, then we can treat it as an ecosystem response to environmental conditions, and we can categorize it in terms of intensity, onset. In this study, we focused on climate drought expressed by the climatic water balance in two horizons: the 1961-1990 reference period and the climate change conditions in the 2071-2100 period.

Methodology

The selection of climatic stations for the evaluation of changes in the onset and duration of the vegetation period of agricultural productive zones is shown in Tab. 1.

Tab. 1 Selected climatic stations for evaluation of phenological changes (the stations are categorized into agricultural productive zones)

Agricultural productive zone	Climatic stations	Altitude (in m)
Corn maize	**Somotor**	**100**
	Hurbanovo	**115**
	Nitra	**143**
	Piešťany	**165**
	Kamenica n/C.	**178**
Beet	**Rimavská Sobota**	**214**
	Prievidza	**260**
	Košice	**230**
	Sliač	**330**
Potato	**Bardejov**	**304**
	Červený Kláštor	**474**
	Liptovský Hrádok	**640**
Mountainous	**Liptovský Hrádok**	**640**
	Oravská Lesná	**780**
	Telgárt	**901**

To analyze the impact of climate change on the onset and duration of vegetative periods in Slovakia, climatic stations were selected to cover the whole agricultural territory of Slovakia up to 900m a. s. l. Climatic data from selected climatic stations for the $2xCO_2$ concentration period were processed according to the RCP 4.5 scenario.

Climate data ($1xCO_2$) was measured by Slovak Hydrometeorological Institute (SHMI) in Bratislava for the reference time period 1961 – 1990 and various locations. Nosek´s numerical method (1972) has been used for evaluation of the onset and end of the vegetation period.

Meteorological and phenological data were evaluated over two periods (horizons) of CO_2 concentration in the atmosphere as shown in Table 2.

Tab. 2 Concentrations of CO_2 for evaluated time horizons

CO_2 concentrations		**Time horizon**
$1xCO_2$	330 ppm	1961 – 1990
$2xCO_2$	660 ppm	2071 – 2100

To assess the onset of drought, atmospheric precipitation (P) and potential evapotranspiration (ET_0) were selected. These were then cumulatively calculated as cumulative climatic water balance CWB = P-ET_0 in the monthly step. The criterion for the onset of the drought was the occurrence of a negative cumulative value for a certain month. We evaluated the drought intensity by extreme value during the year.

Results

Onset, end, and duration of the vegetation period in the territory of Slovakia are limited by climatic conditions from great lowlands and mountains in Slovakia. Lowlands are usually represented by the climate station Hurbanovo on Danubian lowland or Somotor on East-Slovakian lowland respectively. The locations with the highest altitude are represented by the climate station Telgárt in this study. The onset of GVP is accelerating, ending is delaying and duration is changing significantly in evaluated time horizons (Figure 1).

Tab. 3 Onset, end, and duration of vegetation period for the agricultural productive zone and CO_2 concentrations ($1xCO_2$ and $2xCO_2$)

Agricultural productive zone	Onset T ≥ 5 °C		End of T ≥ 5 °C		Duration T ≥ 5 °C	
	$1xCO_2$	$2xCO_2$	$1xCO_2$	$2xCO_2$	$1xCO_2$	$2xCO_2$
Corn maize	< 21.3	< 22.2	> 9.11	> 24.11	> 235	> 275
Beet	22.3-30.3	23.2-2.3	5.11-8.11	17.11-23.11	215-235	255-275
Potato	31.3-11.4	3.3-16.3	26.10-4.11	8.11-17.11	200-215	240-255
Mountainous	> 12.4	> 17.3	< 25.10	< 7.11	< 200	< 240

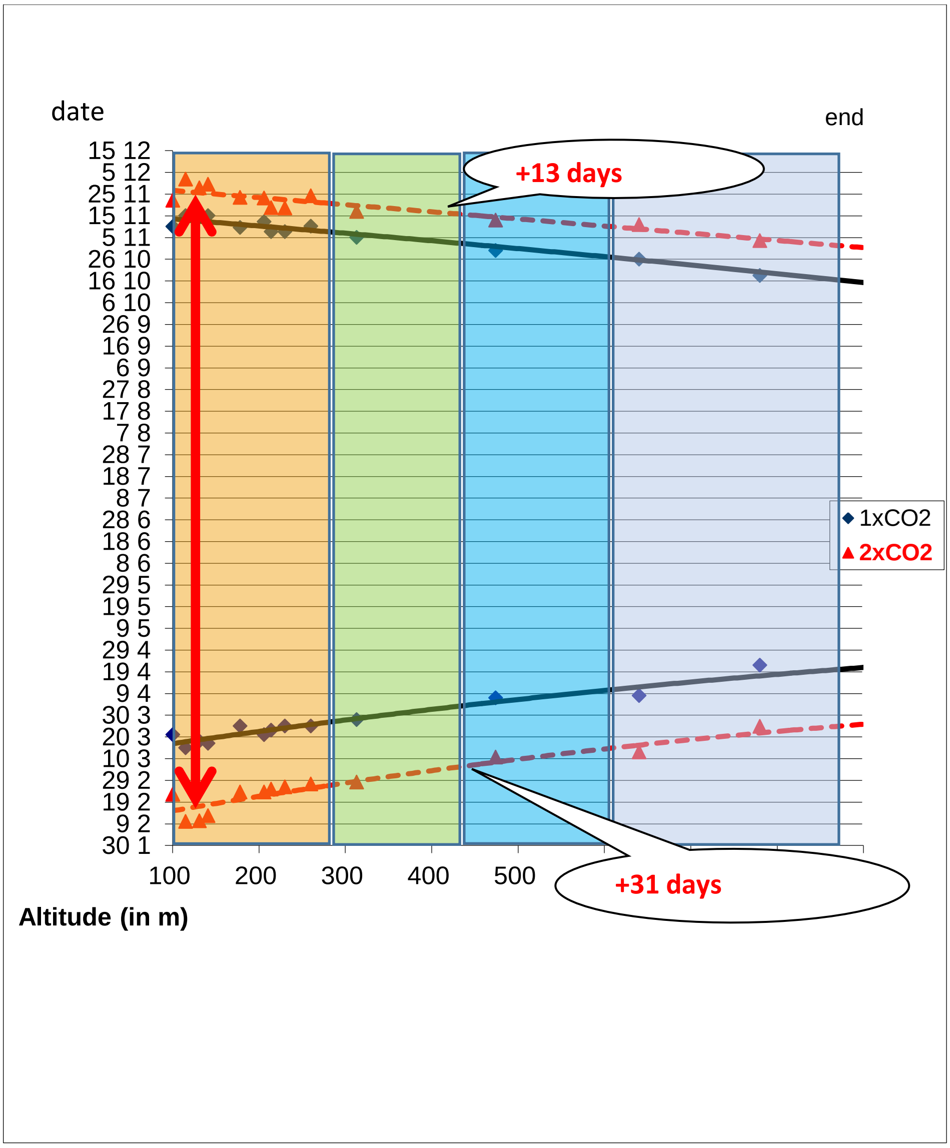

Fig. 1 Dependence of onset and end of the vegetative period on altitude for $1xCO_2$ and $2xCO_2$ climate

The changes in the onset, end, and duration of the vegetation period and changes in climate conditions will have an impact on the zonation of agricultural production and the planting of crops. The sum of active temperatures in the vegetative period (TS5) will probably increase by 22 % on lowlands in future climate $2xCO_2$. These sums will increase up to 45 % with increasing altitude in mountainous regions.

According to the RCP 4.5 scenario, the expected changes in precipitation during months of the year are not the same. Differences in rainfall are also depended by the altitude. Beside it, the time factor plays an important role. During a longer vegetative period can be more precipitation accumulated. In fact, the increase in precipitation for climate change scenario $2xCO_2$ is by 65 – 80 mm (15 – 20 %) in lowlands and by 65 – 128 mm (12 – 20 %) in mountainous regions is supposed.

The increase of air temperature, as well as lengthening of the vegetative period, will cause an increase of potential evapotranspiration (E_0) in the $2xCO_2$ climate. In the corn maize growing areas, the increase of E_0 will be by about 150 mm (23 %) in comparison to the reference period. In the mountainous E_0 will increase by 127 mm (30%). E_0 totals exceeding 800 mm could be expected in the warmest areas of Danubian Lowland and the lowest parts of the East-Slovakian Lowland. The water demand for field and horticultural crops will increase significantly and a new water management strategy would be highly needed.

Climatic water balance

There are many indicators for the evaluation of water availability for primary agricultural production in the landscape. The climate water balance (CWB) indicator has been introduced for purposes of agro-climatic zonation in Slovakia. This indicator is a difference between potential evapotranspiration and precipitation in three summer months (Kurpelová et al., 1975). In fact, summer days occur frequently during spring and autumn months too, so the CWB was evaluated for the whole vegetative period in this study. Climatic water balance (CWB) is significantly changing as the sums of potential evapotranspiration and precipitations are changing in the altitude profile of the Slovak Republic. We found differences in the increase of the indicator by 30 % (70 mm) in corn maize growing areas in the $2xCO_2$ climate. The zero values of CWB will move from 550 to 650 m (Fig. 2). In the reference period 1961 – 1990 ($1xCO_2$) there was short of water 21 300 km^2 of agricultural land, in $2xCO_2$ climate is expected increase of vulnerable land by 42 % with total area 30 300 km^2. The average deficit E_0-R > 250 mm will occur the most important agricultural areas of Slovakia (Fig. 6). Such water shortages were practically absent in the 1961 – 1990 reference period. Another consequence of climate change is likely to be a diverse response in Slovakia. While in the reference period of 1961 - 1990 there were defined 6 areas according to water needs of plant production, at the end of the 21st century another 2 very dry areas should be added.

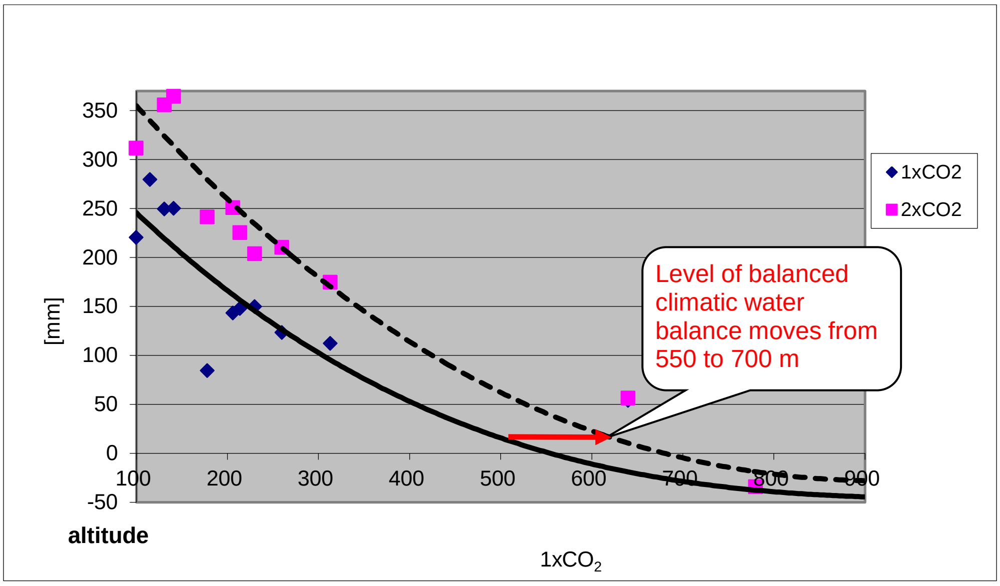

Fig. 2 Climatic water balance in the altitude profile of Slovakia for $1xCO_2$ and $2xCO_2$

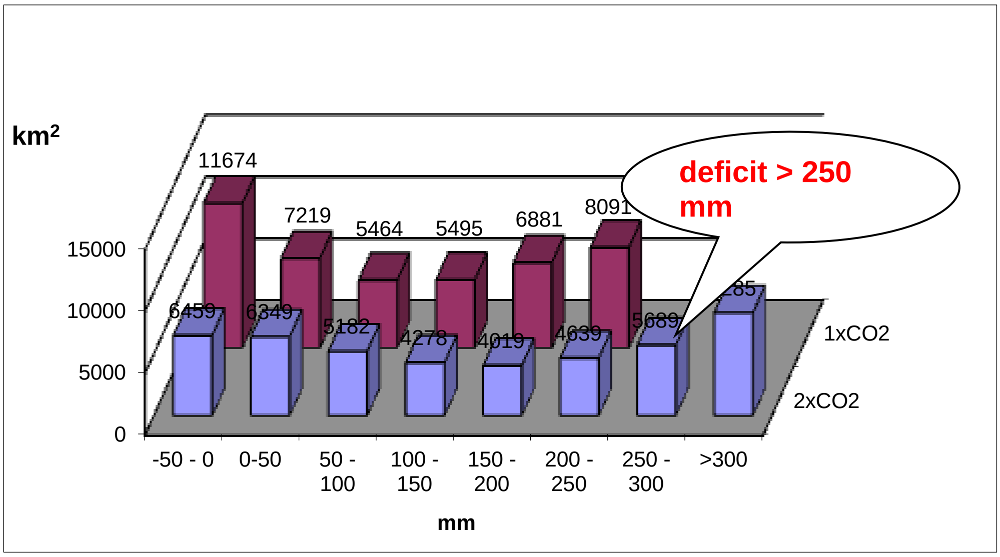

Fig. 3 Spatial distribution of CWB in the for $1xCO_2$ and $2xCO_2$

Onset, end and intensity of drought in agricultural productive zones of Slovakia

The onset of drought and its intensity varies considerably in individual production zones. The reference climatic period 1961 - 1990 was characterized by an excess of water in agrocenosis at the beginning of the year in the period of vegetation rest. However, as the vegetation period begins, the situation changed sharply in the warmest corn production zone, when surplus precipitations passed into water scarcity around 10th of March and the cumulative climate water balance reached maximum water scarcity expressed by CWB = -120 - -200 mm in August (Fig. 4A). The balanced cumulative climatic water balance was observed again at the end of the year in the lowlands of Slovakia. This trend showed up also in beet production zone (Fig. 5A) when the drought was observed in the first days of May with the peak of water scarcity in August. The cumulative climate water balance was CWB=-100 mm and a balanced cumulative climate balance was observed at the end of October. Negative CWB values did not appear in potato and mountain production zone during the reference period (Figures 6A and 7A).

The deficit of water occurred from June in the potato production zone. Relatively stable was the only mountain production zone with altitude above 700 m. According to the GCM models, higher precipitation and negative CWB are expected in corn and beet production zones about 12 days later compared to the 1961-1990 reference time period.

Conclusion

The vegetative period could persist through the whole winter in the Danubian lowland. This can adversely affect agricultural production especially when drought has already occurred in combination with increased evaporation and lack of precipitation even at a statistically defined period of vegetation rest. The vegetative period will appear in the month with the frequent occurrence of frost. It can be a key factor for field crop yields. The analysis revealed that onsets of the vegetative period will be sooner by about 28 days on average in the $2xCO_2$ climate as compared to the $1xCO_2$ (reference period) climate. The differences between potential evapotranspiration and precipitation varied significantly in altitude. In the $2xCO_2$ climate, the zero values of the CWB will move from altitude 550 m to 650 m above sea level.

The GCMs expect a higher amount of precipitation during the winter period which means that drought can be expected about 12 days later in comparison to the reference time period 1961 – 1990. However, total negative value will increase by 40 % (CWB = -350 mm). According to this indicator, drought should not occur in the mountain zone with altitude above 700 m.

The expected warming and subsequent prolongation of the vegetation period will significantly affect the current regionalization of agricultural production and the planting of field and horticultural crops in certain areas.

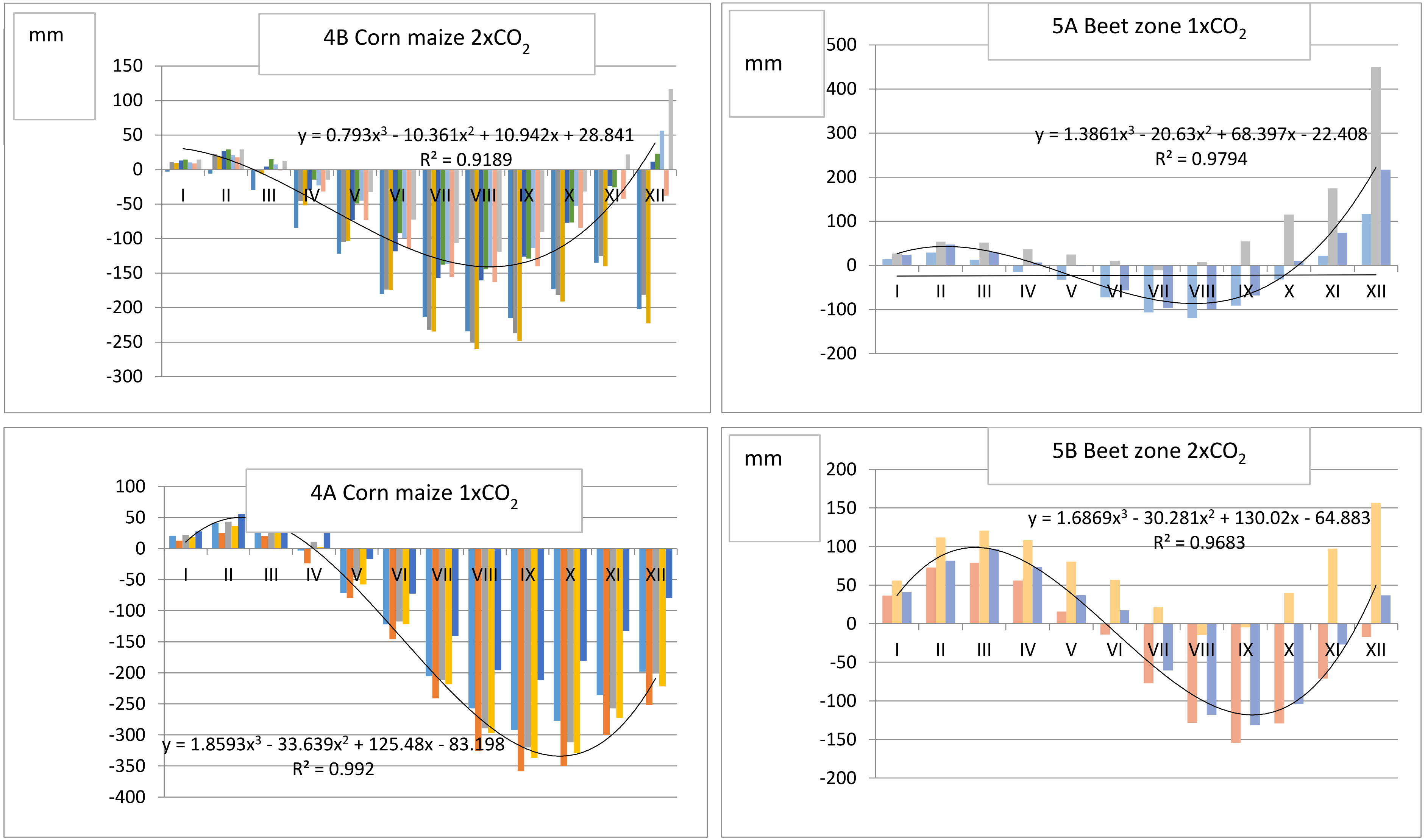

Fig. 4 a 5 Cumulative water balance (CWB) for corn maize zone (Fig.4) a beet zone (Fig.5) in for $1xCO_2$ (A) $2xCO_2$ (B) in Slovakia

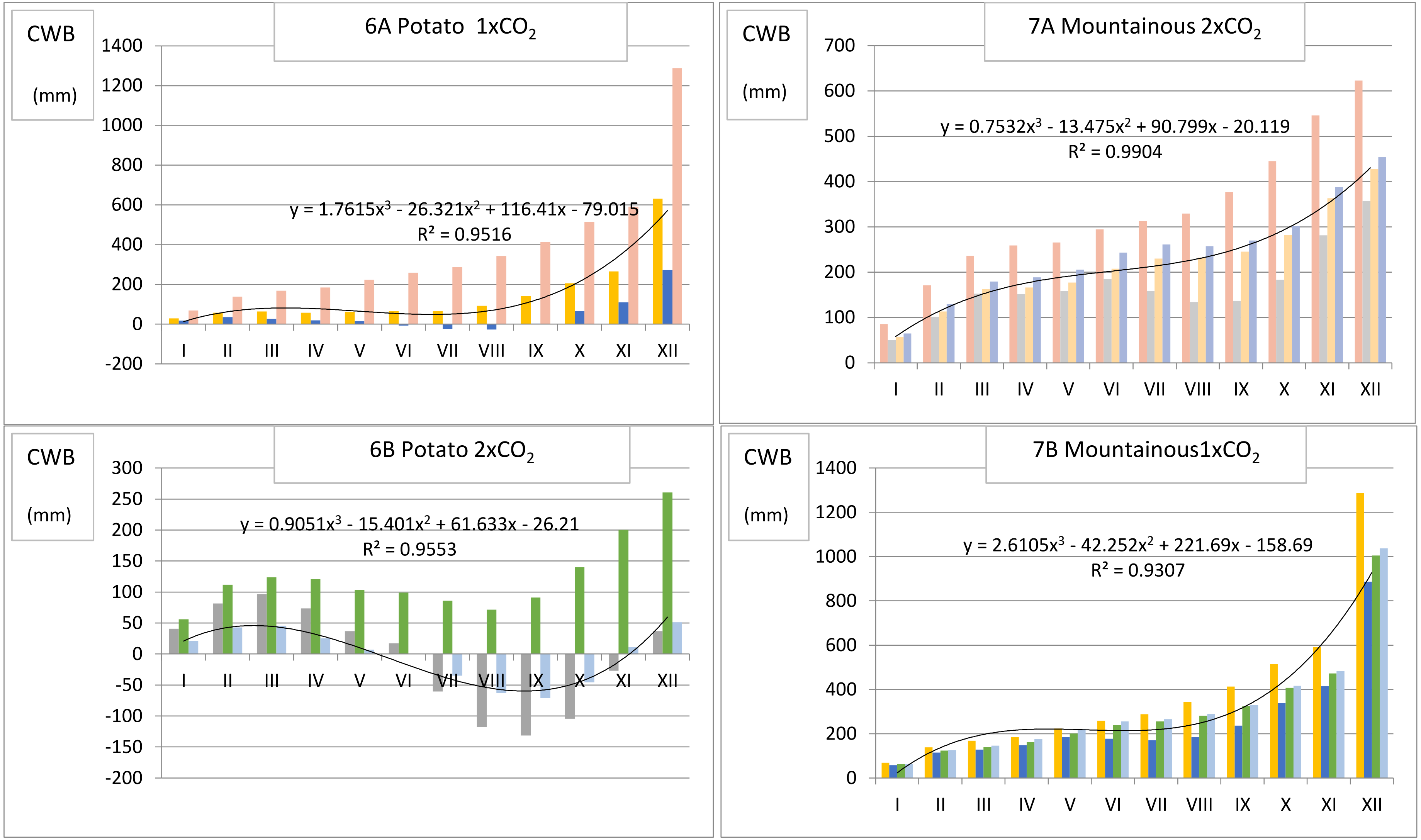

Fig. 6 a 7 Cumulative water balance (CWB) for potato zone (Fig.6) a mountainous zone (Fig.7) for 1xCO_2 (A) 2xCO_2 (B) in Slovakia.

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