CLIMATE CHANGE ADAPTATION IN MAIZE PRODUCTION IN SERBIA

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Introduction

Climate change is noticed and well established phenomenon, described as change in the statistical properties of the climate system, considered over long period of time, regardless of cause (Houghton, 1996). This change has been monitored on global (Rosenzweig *et al.*, 1994; Harrison *et al.*, 1995; Wolf *et al.*, 1995; Watson *et al.*, 1996; Downing *et al.*, 2000; Sathaye *et al.*, 1997; Sirotenko *et al.*, 1997) and regional scale (Alexandrov *et al.*, 2002; Lalic *et al.*, 2012; Vučetić, 2011) by researchers, organizations and part of various programmes (IPCC, UNESCO Climate Change Initiative). In a same time, it was analysed change in agroclimatic indices, soil and water balance, crop development and yield, that quantify climate change impact on agricultural production. In recent regional studies and research projects (COST 734, 2008; ADAGIO, 2009), it was estimated and quantified climate change impact on yield and development in crop production of Central and Eastern European countries and Mediterranean region. The research showed a decrease in yield in several major crops, important in national food production and part of economy. A high variability in yield from year to year and decrease in yield was showed for most cereals.

Maize is one of fundamental cereal crop in human and animal nutrition. It is grown in April – September period in Serbia, and very vulnerable to drought in summer months (June - July – August). Higher temperatures, more days with extreme high temperature, lower precipitation and frequent drought are expected in future climate. Among this reason, it was important and necessary to analyze possible changes in agroclimatic indices and yield.

Current state of climate and expected climate for 2030 and 2050 integration period was analysed for ten widespread locations in Serbia. DSSAT crop model was used as a tool to quantify climate change impact on yield. The model is suitable for adaptation measure simulation, because it works with daily observed or simulated data, and showed daily changes in physiology (Wang *et al.,* 2011). At the first, simulations were done in non irrigated conditions, because major maize fields are grown in non irrigated conditions or with 180 mm added water per season, in experiments on Field and Crop Institute, Novi Sad. The simulated results, using expected climate data, showed very significant decrease in yield in both experiments. In the second step, all management crop practise was the same as in the first step, only irrigation was changed in simulation, as an adaptation measure. In model, irrigation was set on 50 % available water for maize crop. In such irrigation conditions maize is grown under optimum water requirements, 50-60 % of available water (Hoogenboom *et al.,* 2012).

In a paper is presented: a) changes in agroclimatic indices (temperature, the number of days with extreme high temperature, precipitation, sum of effective temperature above 10 °C), b) relative change in yield in non irrigated conditions and 180 mm added water per season, c) relative change in yield in irrigated conditions with 50 % available water.

Material and Method

Location, weather and soil condition

The Republic of Serbia is situated mostly in the central Balkan region, while the northern part is located in the Pannonian lowland. Serbia borders 46°11' 19°40' on the north, 41°53' 20°36' on

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the south, 43°11' 23°00' on the east and 45°55' 18°49' on the west (www.STAT.YEARB.SERB.2011). The analyse of current climate included ten stations widespread chosen, from the northern part to southern part of Serbia, which presents mostly moderate - continental climate of central Balkan region and south-east Pannonian Plain. According to Köppen classification (Kottek *et al.* 2006) climate zones in Serbia, the distributions of mean annual temperature and precipitation in relation to altitude (al) are as follows: 10.9 °C (al <300 m), 10.0 °C (300< al <500 m) and 6.0 °C (al >500 m); 540 – 820 mm (al <1000 m) and 700 – 1000 mm (al >1000 m). Most of Serbia has a continental precipitation regime with higher amounts in warmer part of the year, except the southwestern part, where the highest amount of precipitation is observed in autumn (Mihailović *et al.*, 2014). As shown in Figure 1, the Cfwbx″ climate zone is dominant (81.0% of the territory in Serbia), extending from the north to the south of the Serbia. In southwestern and southeastern regions, there is transition to Dfwbx″ (18.2%), whereas the southwestern high mountain region features ET, i.e. a polar and alpine climate (0.2%). (Mihailović *et al.*, 2014).

For ten selected weather stations (Fig. 2) the observed data were included: maximum and minimum temperature, precipitation, solar radiation, wind and vapour pressure for 1971-2000 period, assimilated from the Republic Hidrometeorological Service of Serbia (RHSS). For expected climate conditions, 2030 and 2050 integration period, output results were used from the global climate model ECHAM5, developed at the Max Planck Institute for Meteorology (Roeckner *et al.*, 2003) under A2 scenario for greenhouse gas (GHG) emissions. The CO_2 concentrations were based on IPCC Report, 2007. The out GCM results were statistically downscaled with the “Met & Roll” weather generator. It was calculated absolute change in temperature and relative change in precipitation for April – September period and June-July-August months for 2030 and 2050 period, according to 1971-2000 reference period. Also for summer months (June-July-August) are given the number of days with extreme temperatures, the tropical days, which maximum temperature is higher than 30 °C, which describes a stressful phisyiologicaly conditions for maize. Effective temperature sum, above 10 °C is calculated for April – September growing period, as a main condition for phenology phases and growing season duration, that is indirectly responsible for yield quantity and quality.

Soil data, including mechanical and chemical characteristics, were collected in the vicinity of weather stations and assimilated from the Agency for Environmental Safety in Belgrade. Soil data set presents four main soil types in Serbia: chernozem, cambisol, fluvisol and vertisol. Tab. 1. Soil experiment included profile depth, mechanical (clay, silt, sand percentages) and chemical characteristics (organic carbon and nitrogen concentration). Ten chosen locations selected for this experiment: Novi Sad (NS), Sombor (SO), Pozega (PO), Kraljevo (KR), Krusevac (KU), Cuprija (CU), Nis (NI), Zajecar (ZA), Dimitrovgrad (DM) and Vranje (VR), are presented in Fig. 2.

Cropping management

For DSSAT model validation, the cropping management and observed maize yield, were obtained from the Institute of Novi Sad for Field and Vegetable Crops long - term field experiment (1997-2005) (Pejic, 2009). The crop was sown on April 20, 1997, with NSSC 640 medium season maize variety. In this trial NSSC 640 was sown in rows with density of 5.7 plants/m^2 (57.143 plants/ha), on 5 cm depth at 70 cm distance between rows and 25 cm between plants in a row. Mineral fertilizers were applied in fall (135 kg/ha of N, 135 kg/ha of P and 175 kg/ha of K) and spring (46 kg/ha of N with urea). Standard agronomic practices for maize growing were applied. There were two experiments with different irrigation management. One field was in non irrigated conditions and other with 180 mm added water per season.

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Six genetic coefficients were defined in maize simulations (Tab. 2) and describe varieties phenological characteristics. They were calculated by the temperature sum for each vegetation phenophase (Ritchie *et al.,* 1993).

DSSAT model calibration, validation and outputs

DSSAT v. 4.2. is a crop model developed by Tsuji *et al.* (1998). It is based on weather-soil-plant interaction and may simulate development and yield for sixteen various crops which play important part in economy. DSSAT model was used in many research projects (COST 734, Eitzinger et al, 2009 and CECILIA, 2006), and successfully calibrated and validated in various environmental (weather and soil) conditions and for various genetic varietes. It has three main components: input part, submodels and out part. For input part, it is collected minimum data set for weather conditions, soil characteristics, crop management data and genetic coefficients.

As a cereal crop model, CERES simulate development and maize yield. Model has components that simulate phenology, soil-water and plant-nitrogen balance. Phenology development calculate phenophases using information from genetic file which contains cardinal temperature values, as well as information from the cultivar and ecotype files, which contain physiological day durations for respective life cycle phases.

Soil-water balance simulates effective irrigation, soil evaporation, transpiration and evapotranspiration, while nitrogen balance includes nitrogen uptake, fixation and mobilization results (Hoogenboom *et al.*, 1990). Out part of model gives yield, phenology, soil water and nitrogen results.

When calibrated maize in non irrigated conditions, relative deviation between simulated and observed yield was 28.7 %. The highest relative deviation was for 2000, 2002, 2003 and 2004 year in which the number of dry days were above long-term average in growing season. This significant difference between simulated and observed yield values is a consequence of model inability to simulate the plant reaction to stress in extreme conditions, such as high variations in daily air temperature and precipitation sum in short time intervals (Lalić *et al.*, 2011). If the yield values in dry years were excluded from calculation, the relative deviation in yield will be 8.8 % in rainfed conditions. In irrigated conditions with 180 mm water added per vegetation season, relative deviation between simulated and observed yield was 3.6 %.

This study included threee different types of analyses: (a) relative change in maize yield in non irrigated and with 180 mm added water per season for 2030 and 2050; (b) relative change in yield with 50 % available water as an adaptation measure in maize production.

Results

Climate conditions in 1971-2000 period and 2030 and 2050

Maize has grown season from April to September and during this period, the observed temperature was from 16.5 to 18.4 °C and the precipitation was from 317.5 to 435.6 mm (Tab. 3). As the maize is most vulnerable on drought during summer months, the temperature and precipitation regime for 1971-2000 were also showed in Tab. 3. The temperature ranged from 19.3 to 21.2 °C and precipitation from 150.9 to 233.8 mm in June-July-August period. The lowest precipitation was observed in NI, VR and ZA, while the highest temperature was observed in NI location, which is located in southern part of Serbia. The analyses of average tropical day number showed that in June – July – August was observed 19 to 33 days. The highest number was also observed in southern location NI. The effective temperature sum above 10 °C was observed from 1131.0 °C in eastern location DM to 1514.5 °C in southern location NI (Tab. 6).

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In Tab. 4 and 5, are presented results for expected climate conditions. It was calculated absolute change in temperature and relative change in precipitation, for 2030 and 2050 for ECHAM model under A2 scenario against to a 1971-2000 reference period. During the AS growing period, the change in temperature is expected to increase for 1.3 to 1.8 °C in 2030 and for 2.5 to 3.0 °C in 2050, and relative change in precipitation was expected to be lower from 14.0 to 22.5 % in 2030 and from 23.2 to 37.1 % in 2050. During JJA period temperature is expected to be from 1.5 to 2.0 °C higher in 2030 and from 2.9 to 3.5 °C higher in 2050 year against to 1971-2000 period. The precipitation is expected to be lower from 19.9 to 31.2 % in 2030 and from 32.1 to 47.5 % in 2050 year. Analyzing the average tropical day number, it is showed that in June – July – August period is expected higher number for 12 to 15 days in 2030 and for 23 to 26 days in 2050 (Fig. 3). The sum of effective temperatures above 10 °C also showed higher values. In 2030 it is expected to be from 1471.6 to 1837.9 °C and from 1753.8 to 2139.4 °C in 2050 year (Tab. 6).

Crop model runs and outputs

Climate change impact on maize yield in non irrigated conditions and irrigated conditions with 180 mm added water per season

At the first step, DSSAT model simulated maize yield in non irrigated conditions. It was calculated relative change yield for 2030 and 2050 with ECHAM5 model under A2 scenario against 1971-2000 yield. All simulations were done with considering CO_2 effect from IPCC Report, 2007. For all locations, results analyses showed very significant decrease in yield (Tab. 7). In 2030 the yield is expected to be lower from 33 % in eastern location DM to 63 % in one northern and one central location. In 2050 it is expected lower yield from 50 % in DM to 77 % in northern location.

In irrigated conditions with 180 mm added water per season, the results also showed very significant lower yield in all locations, from 2 to 43 % in 2030 and from 15 to 60 % lower in 2050 year (Tab. 8). On the base of given crop model yield results, it is concluded that is necessary to test and include some adaptation measure in maize production in Serbia.

Climate change impact on maize yield under 50 % available water condition as an adaptation measure

As an adaptation measure in maize production, irrigation was set on 50 % available water with no changes in crop management operations. The detailed analyses showed no changes in yield or higher yield in all locations, except one central location (Tab. 9). In 2030 and 2050 crop model results analyses showed no change or no significant change in yield in six locations (CU, KU, NI, NS, SO, VR), an increase in yield in two locations up to 5 % (DM, PO) and decrease in yield in only two locations (KR, ZA).

Discussion

Current climate and maize production 1971-2000

Maize is native to tropical regions. It is termophilic plant, which minimum soil temperature is 10 °C and air temperature 13 °C. It is mostly grown in flat area to 400 m altitude (Faculty of Agriculture, Osijek). Agrometeorological indices which presents constraits and limits for maize production are: soil water reserves, precipitation, drought during JJA period and number of days with extreme high temperatures (Olesen *et al.*, 2011; Jancic, 2016). Maize has

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good developed root and is very tolerate on drought. It is only vulnerable on drought in period from anthesis to maturity, June – July – August period. The expected more days with extreme high temperatures and lower precipitation in summer months may have very significant impact on decrease in yield.

In 1970-2000 period, observed temperature for JJA period was higher than 20 °C and precipitaion was between 150.9 to 233.8 mm. In some years (2000, 2002, 2003 and 2004) there were observed deficit in precipitation during summer months accompaning with 10 to 13 days with extreme high temperatures. In that conditions the climate led to curtail the maize yield in non irrigated production. In 1970-2000 period, when maize is grown in irrigated conditions with 180 mm water added per season, the yield was high and stable from year to year.

For 2030 and 2050, it is shown that air temperature in growing season is expected to rise from 1.3 to 1.8 °C and from 2.5 to 3.0 °C in 2050, with very significant decrease in precipitation. Also is expected more days with extreme temperature and higher effective temperature sum above 10 °C.

All changes in climate indices, were enough to suppose that expected climate may curtail maize production in future conditions. DSSAT crop model simulation gave very significant lower yield in both field experiments: non irrigated conditions and 180 mm added water per season. After analyze of expected climate conditions, every crop management practice was not changed, except irrigation. It is supposed that the irrigation in adequate time and quantity, may be the wright adaptation measure in expected climate coditions and was set in crop model on 50 % plant available water. The yield has no change or was higher for 2030 and 2050 in a comparison with reference 1971-2000 period. Only in one location the yield was lower.

Conclusions

After the detailed result analyses, the main conclusions are as followes:

- Temperature is expected to rise during growing season (AS period) and especially in sumer months (JJA period) for 1.5 to 2.0 °C in 2030 and for 2.9 to 3.5 °C in 2050, what is one of conditions for drought present.
- Precipitation is expected to be very significant lower during summer months, from 19.9 to 31.2 % in 2030 and from 32.1 to 47.5 % in 2050. The significant lower precipitation has directly negative impact on yield.
- More days with extreme high temperature has negative influence on physiology during anthesis.
- Higher effective temperature sums are response for earlier maturity, shorter time for grain filling and advance in maturity. That has a direct negative effect in yield quality and quantity.
- Maize yield in non irrigated conditions was shown very significant lower yield for 2030 and 2050 year.
- Maize simulation in irrigated conditions with 180 mm added water per season also showed very significant lower yield for future conditions.
- 50 % plant available water was chosen to test as adaptation measure on maize yield in climate change conditions
- Maize yield under 50 % plant available water conditions shown no change or higher yield for 2030 and 2050 year in most location.

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Maize is very vulnerable to drought stress in JJA period. For future climate, is expected very significant decrease in maize yield, produced in non irrigated conditions and with 180 mm added water per season. There was a need to test adaptation measures, which sholud give a high yield. The controlled 50 % available water irrigation method, estimated by DSSAT 4.2. crop model, showed positive effect on yield quantity in climate change conditions. The next step in reasearch is to estimate quantity of irrigation water, crop water productivity and economic aspect.

ACKNOWLEDGEMENT

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FIGURES AND TABLES

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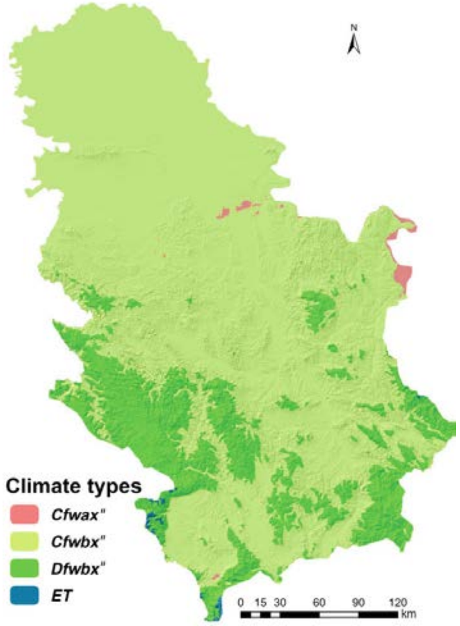

Fig. 1. Climate zones over Serbia according to the Köppen classification obtained from to climate normals for the period 1961–1990.
(Mihailović et al., 2014)

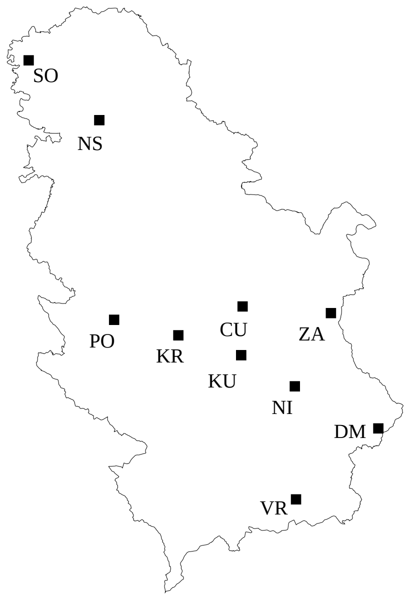

Fig. 2. The weather station locations (Jancic et al., 2015)

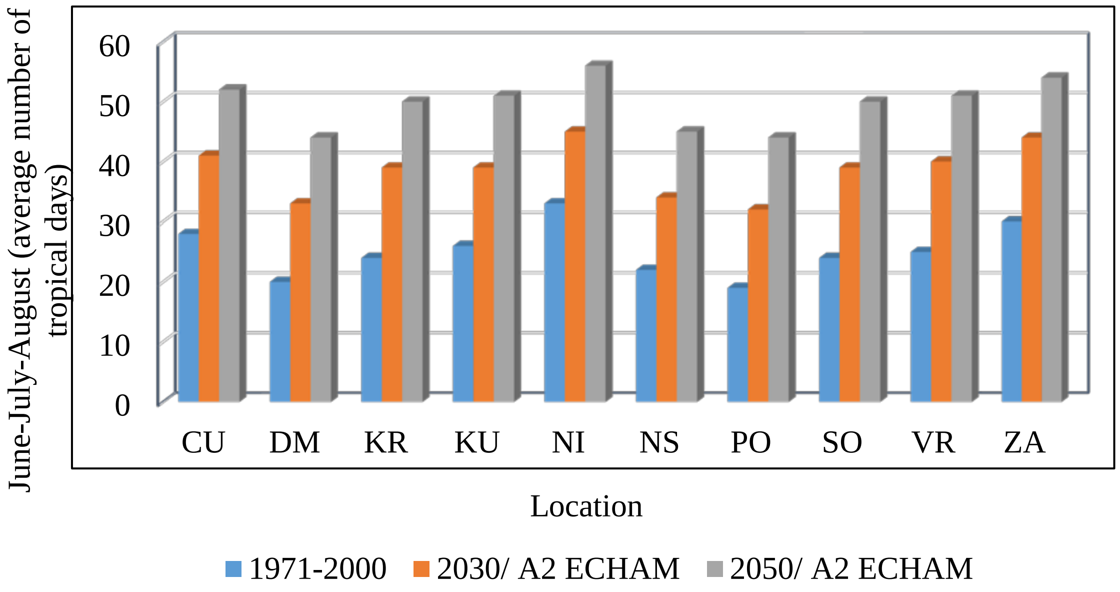

Fig. 3. The effective temperature sum above 10 °C in 1971-2000, 2030 and 2050 with ECHAM5 model under A2 scenario

Tab. 1. Location of weather stations and soil type (Jancic, 2016)

Number	Location of weather station[1]	Longitude (° E)	Latitude (° N)	Altitude (m)	Soil type (www.fao.org. /ag/agl/agll/wrb/doc/ wrb2007_corr.pdf)
1.	NS	19° 30”	45° 12”	84	Calcareous Chernozem
2.	SO	19° 03”	45° 28”	88	Calcareous Chernozem on the loess
3.	PO	20° 02”	43° 49”	310	Loamy Fluvisol
4.	KR	20° 42”	43° 43”	215	Clayic Fluvisol
5.	KU	21° 21”	43° 34”	166	Cambisol
6.	CU	21° 22”	43° 55”	123	Cambisol
7.	NI	21° 54”	43° 19”	201	Eutric Cambisol
8.	ZA	22° 16”	44° 52”	144	Eutric Cambisol
9.	DM	22° 45”	43° 01”	450	Eutric Cambisol
10.	VR	21° 54”	42° 28”	432	Vertisol

Tab. 2. Genetic coefficients for medium season maize

Genetic coefficients	Values
Thermal time from seedling emergence to the end of the juvenile stage (degree days above the base temperature of 8 °C in the juvenile stage) (P1)	220.0 °C
Photoperiod sensitivity associated with delayed growth under the unfavourable long-daylight condition (P2)	0.400
Thermal time from silking to physiological maturity in degree days above the base temperature of 8 °C in mature stage (P5)	980.0 °C
Potential maximum number of kernels per plant (G2)	800.0 kernel/ear
Kernel filling rate under optimum conditions (G3)	8.50 kernel/day
Interval in thermal time between successive leaf tip appearances in degree days above the base temperature of 8 °C (PHINT)	38.90

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[1] Novi Sad (NS), Sombor (SO), Pozega (PO), Kraljevo (KR), Krusevac (KU), Cuprija (CU), Nis (NI), Zajecar (ZA), Dimitrovgrad (DM) and Vranje (VR)

Tab. 3. Current climate (1971-2000) in Serbia: AS and JJA period (Jancic *et al., 2015)*

	Present (1971-2000)			
Location	AS		JJA	
	t (˚C)	p (mm)	t (˚C)	p (mm)
CU	17.6	365.1	20.3	182.6
DM	16.5	353.4	19.3	184.2
KR	17.8	432.7	20.6	231.6
KU	17.7	364.8	20.5	190.4
NI	18.4	319.6	21.2	150.9
NS	17.9	359.4	20.7	208.0
PO	16.7	435.6	19.4	233.8
SO	17.6	339.0	20.4	194.6
VR	17.4	317.5	20.3	151.8
ZA	17.6	322.3	20.5	158.3

Tab. 4. Absolute temperature values in Serbia for 2030 and 2050 in AS and JJA period

	AS		JJA	
	ECHAM5 A2 scenario		ECHAM A2 scenario	
	2030	2050	2030	2050
Location	t (°C)	t (°C)	t (°C)	t (°C)
CU	1.5	2.7	1.8	3.4
DM	1.5	2.8	1.8	3.4
KR	1.5	2.8	1.8	3.3
KU	1.5	2.8	1.8	3.4
NI	1.5	2.8	1.8	3.4
NS	1.3	2.5	1.5	2.9
PO	1.5	2.7	1.9	3.4
SO	1.8	3.0	2.0	3.4
VR	1.6	2.9	1.9	3.5
ZA	1.4	2.6	1.6	3.1

Tab. 5. Relative change in precipitation in Serbia for 2030 and 2050 in AS and JJA period

	AS		JJA	
	ECHAM A2		ECHAM A2	
	2030	2050	2030	2050
Location	p (%)	p (%)	p (%)	p (%)
CU	-16.4	-27.4	-24.7	-38.9
DM	-22.5	-36.2	-27.8	-43.6
KR	-19.9	-32.9	-28.5	-40.1
KU	-19.4	-31.4	-25.8	-40.7
NI	-20.1	-33.1	-27.3	-42.7
NS	-18.0	-29.7	-26.3	-42.4
PO	-21.3	-34.9	-29.9	-47.5
SO	-19.0	-30.1	-31.2	-45.7
VR	-22.3	-37.1	-29.0	-46.0
ZA	-14.0	-23.2	-19.9	-32.1

Tab. 6. Effective temperature sum above 10 °C for 1971-2000 period, 2030 and 2050 year

Location	1971-2000. (°C)	2030 (°C)	2050 (°C)
NS	1432.2	1728.0	1988.0
SO	1400.6	1764.9	2011.1
PO	1194.1	1528.0	1792.5
KR	1409.8	1714.4	2012.4
KS	1393.3	1700.4	1994.6
CU	1345.5	1661.9	1946.9
NI	1514.5	1837.9	2139.4
ZA	1359.1	1654.8	1913.7
DM	1131.0	1471.6	1753.8
VR	1346.8	1668.1	1974.7

Tab. 7. Relative yield change (%) in non irrigated conditions in 2030 and 2050 using ECHAM5 model under A2 scenario, from the Special Report on Emissions Scenarios for ten locations with CO_2 effect (2030 year = 451 ppm for A2 scenario; 2050 year = 532 ppm for A2 scenario)

	Relative yield change (%) in non irrigated conditions	
	ECHAM A2 scenario	
Location	2030	2050
CU	-59	-68
DM	-33	-50
KR	-50	-65
KU	-63	-74
NI	-49	-67
NS	-63	-77
PO	-54	-74
SO	-56	-70
VR	-62	-76
ZA	-48	-56

Tab. 8. Relative yield change (%) with 180 mm added water per season in 2030 and 2050 using ECHAM5 model under A2 scenario, from the Special Report on Emissions Scenarios for ten locations with CO_2 effect (2030 year = 451 ppm for A2 scenario; 2050 year = 532 ppm for A2 scenario)

	Relative yield change (%) with 180 mm added water	
	ECHAM A2 scenario	
Location	2030	2050
CU	-31	-42
DM	-26	-44
KR	-19	-32
KU	-28	-38
NI	-16	-15
NS	-19	-29
PO	-2	-16
SO	-25	-34
VR	-43	-60
ZA	-15	-25

Tab. 9. Relative yield change (%) under 50 % available water irrigated conditions in 2030 and 2050 using ECHAM5 model under A2 scenario, from the Special Report on Emissions Scenarios for ten locations with CO_2 effect (2030 year = 451 ppm for A2 scenario; 2050 year = 532 ppm for A2 scenario)

	Relative yield change (%) under 50 % available water irrigated conditions	
	ECHAM A2 scenario	
Location	2030	2050
CU	2	-3
DM	8	5
KR	-9	-17
KU	0	-3
NI	0	-1
NS	-1	-3
PO	7	5
SO	2	0
VR	0	-4
ZA	-2	-8