Design of agronomical measures for winter wheat and sunflower productivity to mitigate climate changes in South Eastern Macedonia

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Abstract

This work was focused on the assessment of changes occurring on winter wheat and sunflower production in South East (SE) region of Macedonia. The forecasts suggest that without adaptation, the winter wheat biomass will decrease for 23% in 2025 and 27% in 2050, as same as the yield where reduction is between 21 and 25% respectively. For sunflower the reduction in yield will be 30% in 2025 and up to 40% in 2050. The simulations presented indicate that delayed of sowing date (middle until end of November) in combination with sprinkler irrigation allowed to maximize the yield of winter wheat. Irrigation with sprinklers 4 times with norm of 50 mm between 159 and 217 day of the year gave the highest yield of sunflower and would be probably the most appropriate responses to offset the negative effects of a potential increase in temperature which are expected in the period 2025 – 2050.

Key words: climate changes, sowing, irrigation, wheat, sunflower

Introduction

Agricultural crop production is certainly going to be affected under future climate change. Even so, because of regional differences in both natural and anthropogenic factors that control plant responses, the intensity of climate impacts on crop yields can vary depending upon location, climate change scenarios and crop (Tubiello et al., 2002). Several studies show that without adaptation, climate change may create considerable problems related to agricultural production and agricultural economy in many areas. With adaptation, vulnerability can be reduced and there are numerous opportunities to be realized (Rosenzweig and Parry, 1994; Wheaton and McIver, 1999; Smith and Skinner, 2002). Based on these considerations, the objective of this paper is to evaluate a set of adaptation options such as changes in sowing date and irrigation management as adaptation strategies to forecast climate change for the cultivation of winter wheat (*Triticum aestivum* L.) and sunflower (*Helianthus annuus* L.) in the context of Macedonian's agricultural system, specifically in the SE part of the country.

Material and Methods

For the purpose of assessing the agriculture vulnerabilities in SE region of Macedonia to climate change and measuring the impacts of the proposed adaptation measures, the BioMA framework was used developed by the Joint Research Center of the European Commission. BioMA (Biophysical Model Applications) is an extensible platform for running biophysical models on generic spatial units. It is based on discrete conceptual units codified in software components (both for simulation engines and user's interface). Simulations are carried out via modeling solutions, which are discrete simulation engines where different models are selected and integrated in order to carry out simulations for a specific goal. Each modeling solution makes use of extensible components. These features like extensibility are making the BioMA framework suitable for assessing the impact of climate change because it gives the advantage for customization of a model with country specific parameters.

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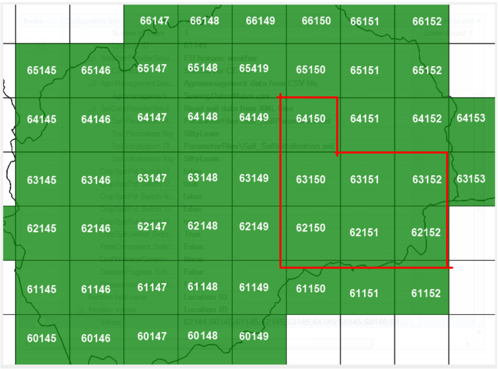

Picture 1. Spatial grid distribution and their codes

According this model the country was divided into 53, 25x25 km grids where the weather parameters in the period of 1993-2057 were calculated. The grid codes of the SE region of Macedonia are: 64150, 63150, 63151, 63152, 62150, 62151 and 62152 (picture 1). The time horizons that are studied are 2025 and 2050, and the comparison is done against a baseline year – 2000, considered as a representative of current conditions. The base agro-management scenario (SC 0) for each crops which will be used as a referent one is without irrigation and with sowing date that corresponds with traditional crop management in the study zones. The additional agro-managements scenarios for winter wheat consist of irrigation with sprinkler (SC 1), with irrigation volume of 60 and 80 mm (SC 2), and 3 different number of irrigation – 1, 2 and ON 20d (on every 20 days) (SC 3 – SC 5). In the case of winter wheat, in order to assess the importance of adapting sowing and harvesting dates to changing climate or weather conditions three additional scenarios are designed: D_0 – which corresponding with 297 day of year (DOY) when sowing is done, D_{0+22} and D_{0+31}, as well H_0 – corresponds with 254 DOY when harvesting is start, H_{0-24}, and H_{0-38} respectively.Agro-management adaptations for sunflower predicted 9 scenarios (SC 0– SC 8), where 3 types of irrigation are implemented: sprinkler, drip irrigation and furrow irrigation, with irrigation volume of 15, 50 and 70 mm respectively with number of irrigation ranked from min. 2 to max. 12 as well as ON 20d, depends from type of irrigation. The aim of the model is the determination of the yield and biomass potential on bought cultivars under base and simultaneous scenarios and to propose some adaptive agronomical measures that will mitigate the forthcoming climate changes.

Results and discussion

Wheat scenario

Figures 1 and 2 summarized the relationship between biomass and grain yield for winter wheat in SC 0 scenario.

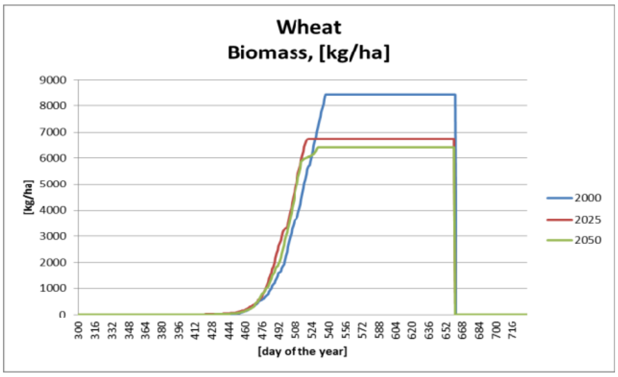

Figure 1. Total biomass production in 2000th, 2025th and 2050th, [kg/ha]

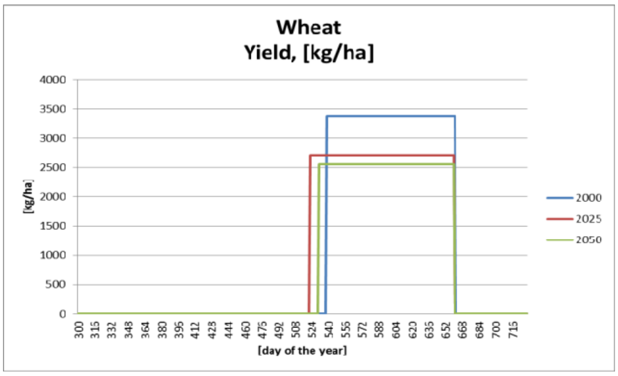

Figure 2. Total yield production in 2000th, 2025th and 2050th, [kg/ha]

In 2000, the peak for the yield of biomass was achieved 524 DOY and for grain 540 DOY. Compared those data with the targeted years, the winter wheat biomass will decrease for 23% in 2025 and 27% in 2050, as same as the yield where reduction is between 21 and 25% respectively. Obviously, a progressive increasing of the average air temperature in all sub localities (2.0 - 2.43 °C), will lead to decreasing of the yield, although it is difficult to explain how the slight decreasing of the temperature in the period between 2000 and 2025 and between 2040 and 2050 has negative impact on high of the yield overall. Also, these data especially for the grain yield are inconsistent with those set out in section Project Crop Yield Impacts as a part of the Second National Communication of Climate Change (2008), where for rain-fed wheat, the major growing areas in the continental and Mediterranean agro-ecological zones are projected to experience a moderate increase in yields of up to 10% for both 2025 and 2050. One reason is that could be a trend which is strictly influence from climate change, concretely from the temperature and refers only for SE region. The other explanation in reducing of the yield may be required in the fact that the concentration of CO_2 as a variable was not considered in this study. In the context of these observations Alexandrov and Hoogenboom (2000) estimated the impact of typically predicted climate changes on wheat production in Bulgaria in the 21st century, finding that a doubling of the air's CO2 concentration would likely enhance wheat yields there between 12 and 49% in spite of a predicted 2.9 to 4.1°C increase in air temperature.

The scenarios of applying different agro-managements (SC 1 – SC 5) are presented in figures 3and 4.

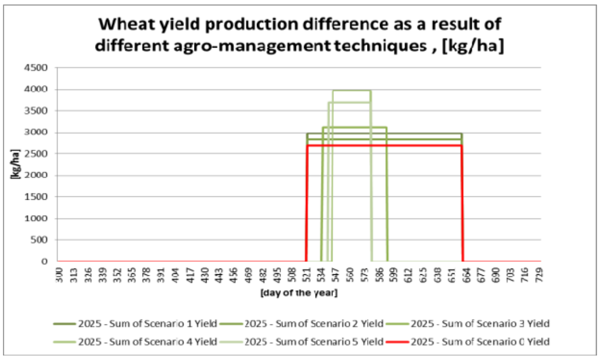

Figure 3. Yield production difference as a result of different agro-management techniques for 2025 year

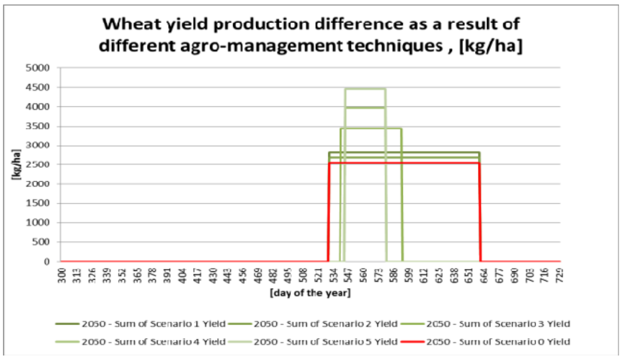

Figure 4. Yield production difference as a result of different agro-management techniques for 2050 year

Comparing with the baseline scenario, the maximum yields will be obtain by i) delaying the sowing at 319 DOY applying two irrigation between 165 and 191 DOY, when the grain yield is increased by 33% in 2025 (scenario SC 3), and ii) when the sowing is delay 328 DOY and irrigation is practice every 20nd days, starting from 130 and finishing at 190 DOY when the yield will be increased by 43% in 2050 (scenario SC 5). Also, these yields are higher for 14% and 28% respectively, comparing with the year 2000. However, the vegetation period in bought cases will not be decrease. Another important conclusion is that in the rest scenarios the yield is higher compared with the reference sowing time. It may conclude that winter wheat sown later has the best chance of optimal temperature during flowering and low water stress during grain filling which is supplemented by irrigation, contributing to greater yields.

Sunflower scenario

The climate change analysis describes the strong effect of temperature increment on sunflower production. The achene yield will be considerably reduced with increasing temperatures up to 2 °C in the area. Compared with present scenario, there will be reduction in yield to 30% in 2025 (expected yield 1190 kg/ha) and up to 40% in 2050 (expected yield 990 kg/ha) for sunflower crop (figure 5). In the same time, higher temperature affects the rate of plant development (vegetative growth), and the vegetation period will be shorter for approximately 13 days in 2050 where the peak of the yield will be 217 DOY.

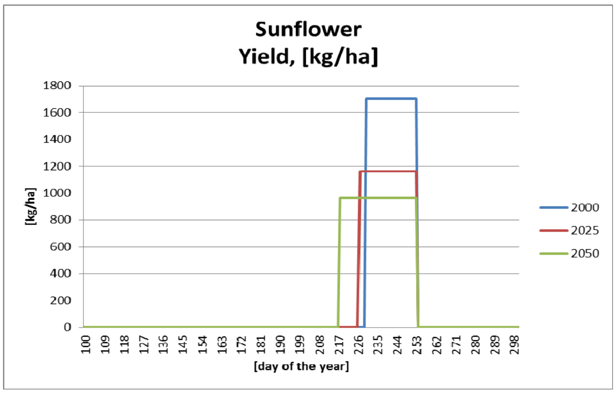

Figure 5. Sunflower yield produced in the South-Eastern region in the years 2000th, 2025th and 2050th, [kg/ha]

These data are identical with those obtaining from different regions in Europe where the yield of sunflower will be lower from 10 – 30% by 2030. The assertion can be summarized by higher temperature coupled with less rainfall which cause increased development rates and, hence shorter growing period length which lead to less time to accumulate dry matter and thus, lower yield (Harrison and Butterfield, 1996).

As in the case of wheat we set the same task: analyze the response of sunflower crop to several irrigation water regimes, types and number of irrigation, evaluating the sunflower yield and how it relates to projected climate changes. Nine scenarios have been developed. Figures from 6 to 9 summarized the relationship between sunflower yield and irrigation as agro-management practice.

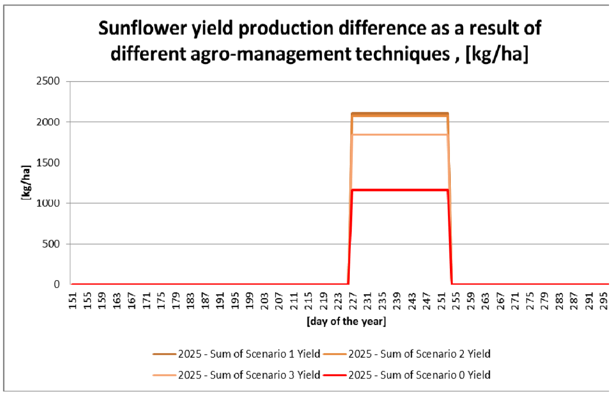

Figure 6. Yield production difference as a result of different agro-management techniques for 2025

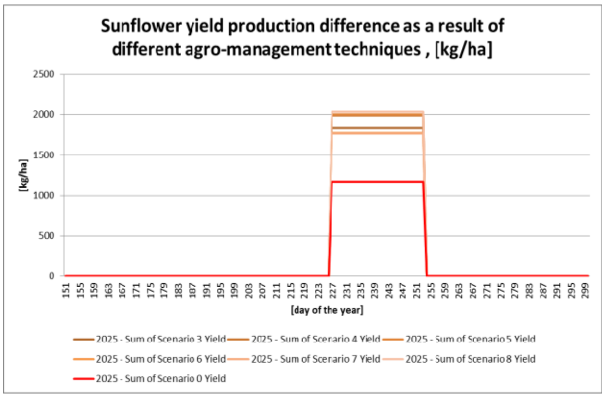

Figure 7. Yield production difference as a result of different agro-management techniques for 2025

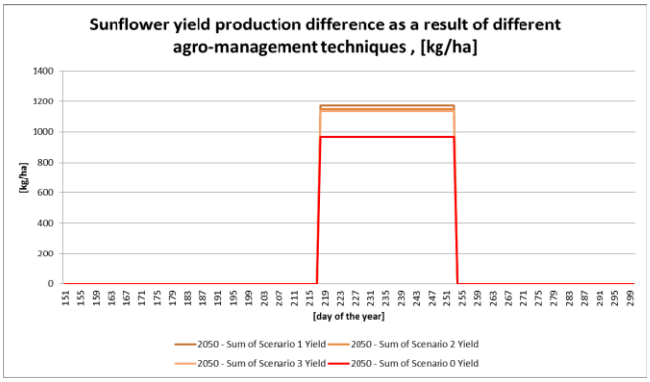

Figure 8. Yield production difference as a result of different agro-management techniques for 2050

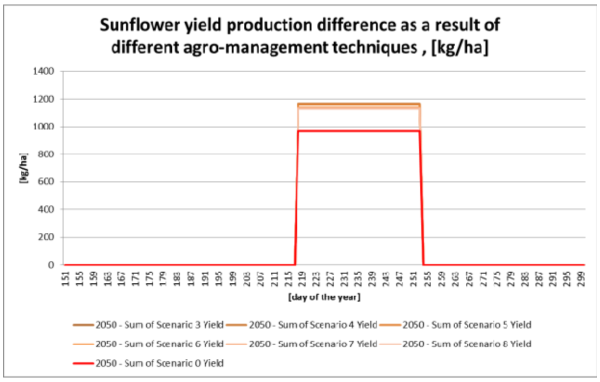

Figure 9. Yield production difference as a result of different agro-management techniques for 2050

The simulated impact of irrigation against increased temperature determined increasing trend of sunflower yield in all scenarios. The data recorded in Figures 6 targeted 2025 show that the average sunflower yield for all nine scenarios is 1925 kg/ha which is higher for 38% compared with base scenario – SC 0 in the same year, but also higher for 12% compared with the base scenario from year 2000, respectively. Irrigation with sprinklers 4 times with norm of 50 mm between 151 and 223 DOY gave the highest yield of around 2200 kg/ha (SC 1). Starting with irrigation 4 days later and breaking 9 days earlier compared with SC 1 using sprinklers and dividing the sum by150 mm in 3 irrigations also have positive effect to the yield – 2100 kg/ha. In other scenarios the yield is between 1700 and 2000 kg/ha. The data also show that the irrigation with sprinkler is more acceptable for sunflower because even with the same amount of water the yield is higher compared with furrow irrigation. By 2050 it's predicted that sunflower yield will decreased by approximately 17% compared to the 2025 average yields, although the irrigation as agro-measure increased the yield for 17% in all scenarios compared with SC 0 when 2050 is analyzed separately (Figures 9). In regard with these predictions some climate models suggest that even the slowest warming scenario will influenced to the grater yield losses on sunflower which can be up to 29 percent before the end of the century (Juhwan and Johan, 2010).

Conclusions

Exploring beneficial options to avoid or reduce negative effects of climate changes is an imperative in climate-sensitive activities. The simulations presented above indicate that adjustment in sowing dates as well as irrigation could produce substantially improved yield of wheat and sunflower in the SE region of the country under future climate changes. Delaying the sowing date in the case of wheat while using certain irrigation techniques with certain number and time of beginning and breaking of irrigation for sunflower would probably be the most appropriate responses to offset the negative effects of a potential increase in temperature through the period 2025 – 2050.

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