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Changes in crop evapotranspiration and irrigation water requirements

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A b s t r a c t. This paper deals with the trend for Penman-Monteith reference evapotranspiration, crop evapotranspiration and irrigation water requirements of some crops during the first decade of the 21st century versus the 20th century. These indices were calculated for three weather stations in various regions of southern Romania. Monthly distribution of reference evapotranspiration showed that for the first half of the year, these values were higher than the means of the 20th century. In the first decade of century XXI, crop evapotranspiration specifically increased in May, June and July, while the increase was negligible in August and it decreased in September. High crop evapotranspiration values were especially met for alfalfa and sugar beet. Irrigation water requirements increased in May and June. It had practically the same values in July and August, whereas irrigation application decreased in September. There is no need to irrigate during this month except in severe droughts.

K e y w o r d s: arid conditions, dryland, reference evapotranspiration, field crops

INTRODUCTION

Marica and Busuioc (2004) predicted the fact that crop evapotranspiration (ET_c) would increase especially during the crop growing season in the southern parts of Romania. In this context, Paltineanu *et al*. (2007a,b; 2009), among others, have reported data on arid or drought-affected areas, including water-crop response and irrigation water requirements (*IWRs*) for various regions of Romania.

However, this problem has worldwide various approaches. There is a debate about global warming, showing that warming (if any) is just part of natural geological cycles (Kutilek and Nielsen, 2010). In the same context Hansen *et al*. (2007) carried out climate simulations for 1880-2003 with GISS model. Some authors have predicted that little or no change in reference evapotranspiration (*ETo*) is likely to occur due to increasing temperature, as effect of increasing air humidity and higher CO_2 concentrations which both tend to reduce transpiration and counteract the higher temperature effects on *ETo*. Depending highly on air temperature, ET_c would remain unchanged if crop coefficients were stable. More recently, based on experimental data, Kirkham (2011) has reported that there will be no increase in crop evapotranspiration, as the carbon dioxide in the atmosphere increases.

The purpose of this paper is to show the new trends for crop evapotranspiration and irrigation water requirements for some field crops during the first decade of the 21st century in some areas of Southern Romania.

MATERIALS AND METHODS

The crops investigated here are among the most representative for the southern and south-eastern part of Romania: winter wheat, maize, alfalfa, sunflower, sugar beet and soybean. This region was chosen for this study due to the fact that it is the most arid region of this country.

Mean daily, monthly and annual weather statistics were calculated for three weather stations in various relief regions of southern Romania: Pitesti, Bucharest-Baneasa and Constanta. Constanta is representative for the south-eastern part of the country – the Dobrogea Plateau region with most of its territory between 100 and 300 m a.s.l. – whereas Bucharest-Baneasa and Pitesti are representative for the central part of the Romanian Danube Plain (mainly between 60 and 100 m a.s.l.) and the northern part of the same plain (the High Plain of Pitesti, mainly around 300 m a.s.l.).

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The data set used in this paper consisted of mean daily data for temperature and precipitation, as well as for other climatic parameters needed in calculating the FAO recommended Penman-Monteith reference evapotranspiration (ET_o) like: sunshine hours, air humidity, as well as wind speed at 10 or 2 m height. Wind speed measured at a height of 10 m was transformed into wind speed values at 2 m height using regressions equations given by Paltineanu *et al*. (2007b) for these regions. The period of investigation was one decade, from 2000 to 2010, and these data were compared to similar data obtained for century XX (Paltineanu *et al*., 2007b).

The quality of data set was reliable because they were recorded in the national network, and standard quality control methods were applied to the data set used. Calculations, statistics and graphs were made using Microsoft Excel Programe (2003).

Penman-Monteith method (Allen *et al*., 1998; Jensen *et al*., 1990; Monteith, 1965) was used to calculate daily and monthly values of ET_o. Crop coefficient (K_c) for mid-season ($K_{c\ mid}$) and final plant stage ($K_{c\ end}$) was calculated according to the formulae given by Allen *et al*. (1998). The procedure was similar to that presented by Doorenbos and Pruitt (1977). Crop coefficients for each 10-day period in the growing season were then plotted versus time for all months of interest.

Crop evapotranspiration (ET_c) was then estimated by multiplying the ET_o values with the K_c values, and *IWRs* data resulted from subtracting effective precipitation from ET_c (CROPWAT Programme; Smith, 1992), without taking into account the variation in soil water content. The method given by Allen *et al*. (1998) was previously checked in Romania by Paltineanu *et al*. (2007b).

RESULTS AND DISCUSSION

The mean values of reference evapotranspiration (ET_o) ranged between 3.34 and 3.39 mm day^{-1} during the growing season and between 4.38 and 4.52 mm day^{-1} in the summer time. The highest mean values occurred in Constanta, due to sunshine hours and wind speed alike. Using annual values as replicates, test *t* analysis revealed no significant differences between the ET_o means in the case of the growing season in spite of the fact that their altitudes and relief positions are quite different, and highly significant differences between Constanta on the one hand and the other two locations on the other hand in the case of summer time.

Monthly distribution of ET_o for the three locations studied and the comparison between the mean values of the first decade of the 21st century and the ones of the 20th century are shown in Fig. 1. For all the three stations studied, for the first half of the year (March through July period) it can be noted that the monthly values are higher for the first decade of the 21st century versus the means of the 20th century. The opposite happens in the second part of the year.

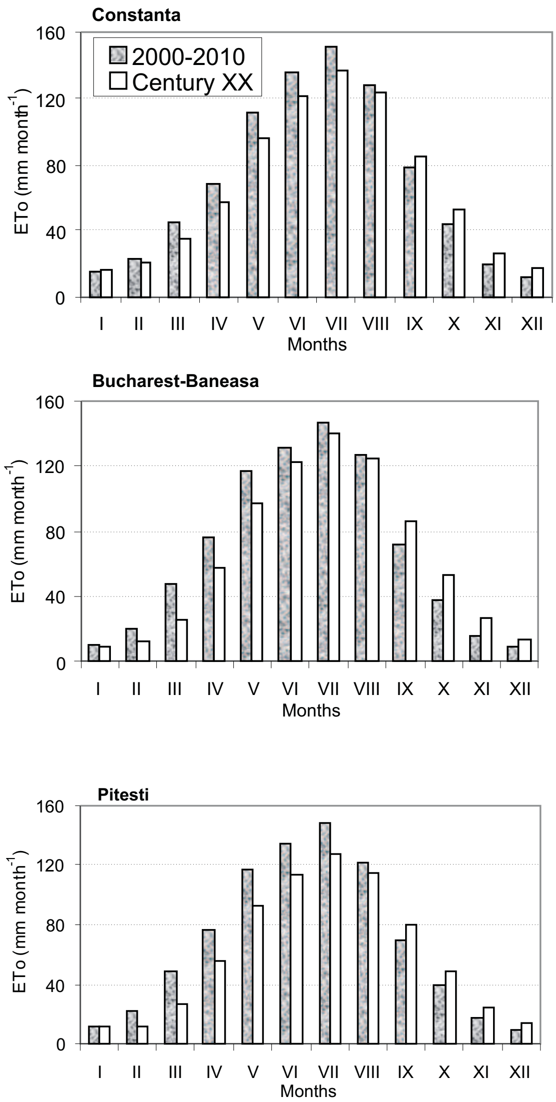

Fig. 1. Monthly distribution of Penman-Monteith ET_o for the three locations studied, comparison between the mean values of the first decade of the 21st century and the ones for the 20th century.

For the main months regarding the magnitude of ET_c *eg* May through September period, in the first decade of century XXI versus century XX, ET_c specifically increased in May, June and July, while the increase was negligible in August. The ET_c decreased in September (real values – Fig. 2, as percentage – Fig. 3). Remarkable high ET_c values were especially met for alfalfa and sugar beet in July: around 180 mm month^{-1} in Constanta, 170-175 mm month^{-1} in Bucharest-Baneasa and Pitesti (Fig. 2).

The irrigation water requirements (*IWRs*) for all crops and months of the growing season are depicted in Fig. 4.

Even if for May farmers do not usually irrigate crops, as is the practice resulted from century XX, *IWRs* generally increased in the decade investigated, in all the locations:

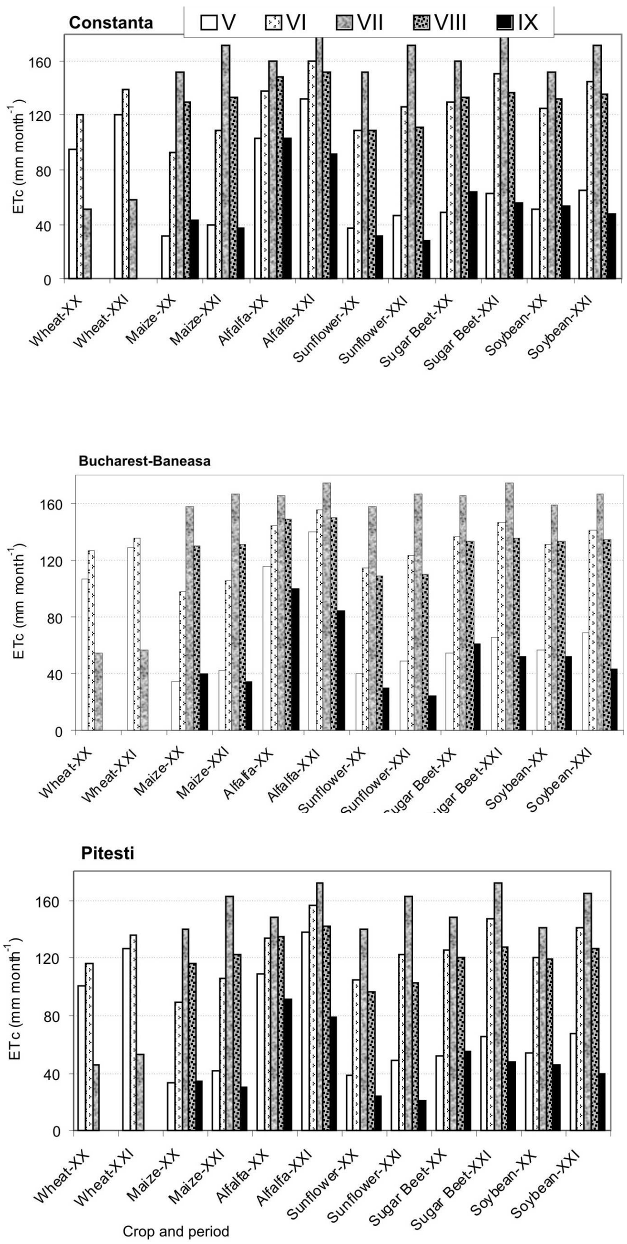

Fig. 2. Comparison between crop evapotranspiration (ET_c) for decade I of century XXI and century XX, monthly values, for five months and three locations of southern Romania; crops studied: winter wheat, maize, alfalfa, sunflower, sugar beet and soybean.

Constanta, Bucharest-Baneasa and Pitesti. The increase in *IWRs* has generally occurred for all crops in: May, June and July, whereas it has been decreased in August and September (mainly in September).

Wheat is the crop showing the lowest *IWRs* values. At Constanta *IWRs* are 90 mm in May, and 110 mm in June. For Bucharest-Baneasa these values reach as much as 90 mm in May and 80 mm in June. The 70 mm of water are *IWRs* for both May and June at Pitesti.

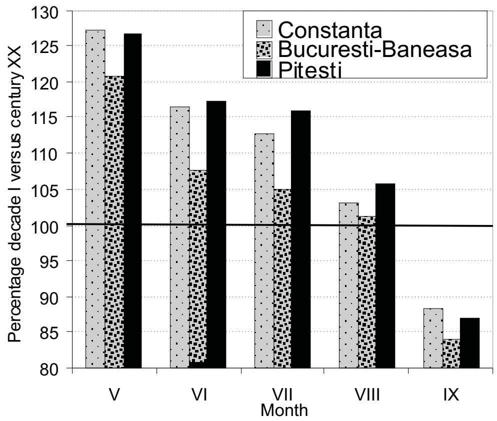

Fig. 3. Comparison between the percentage of crop evapotranspiration (ET_c) for decade I of century XXI versus century XX, for five months and three locations of southern Romania; averages for all crops studied.

IWRs for maize have the following values:

– 80 mm in June, 140 mm in July and about 90-100 mm in August at Constanta;
– at Bucharest-Baneasa for the same months 50, 110, and 80 mm, respectively,
– whereas at Pitesti *IWRs* values are 40, 70-80, and 60 mm, respectively.

Alfalfa is one of the crops with the highest *IWRs* values. Thus for:

– Constanta they are: 100 mm in May, 130 mm in June, 150 mm in July, 110-120 mm in August and 40 in September, the last two months showing a decrease in *IWRs* both here and in the other two locations;
– Bucharest-Baneasa and the same months *IWRs* values are: 100, 100, 110-120, 100, and 30 mm, respectively,
– while for Pitesti these are: 70-80, 90, 80-90, 70, and 20 mm, respectively.

For sunflower, *IWRs* during June, July and August at the three locations studied are:

– at Constanta with 90-100, 140, and 70-80 mm, respectively;
– at Bucharest-Baneasa with 70, 110, and 60-70 mm, respectively,
– and at Pitesti with 50-60, 70-80, and 40-50 mm, respectively.

Sugar beet and soybean require for the same three months from above the following *IWRs* values:

– at Constanta, 110-120 mm in May, 140-150 mm in June and 100 mm in August;
– at Bucharest-Baneasa 90, 110-120, and 80-90 mm, respectively,
– and at Pitesti 80, 70-90, and 60 mm, respectively.

The higher values are for sugar beet. The *IWRs* are very low in September, only some years need irrigation application during this month, especially in Constanta.

The percentage of *IWRs* in the first decade of XXI century versus XX century is shown in Fig. 5. Due to the complex trend in ET_c and precipitation dynamics, *IWRs*

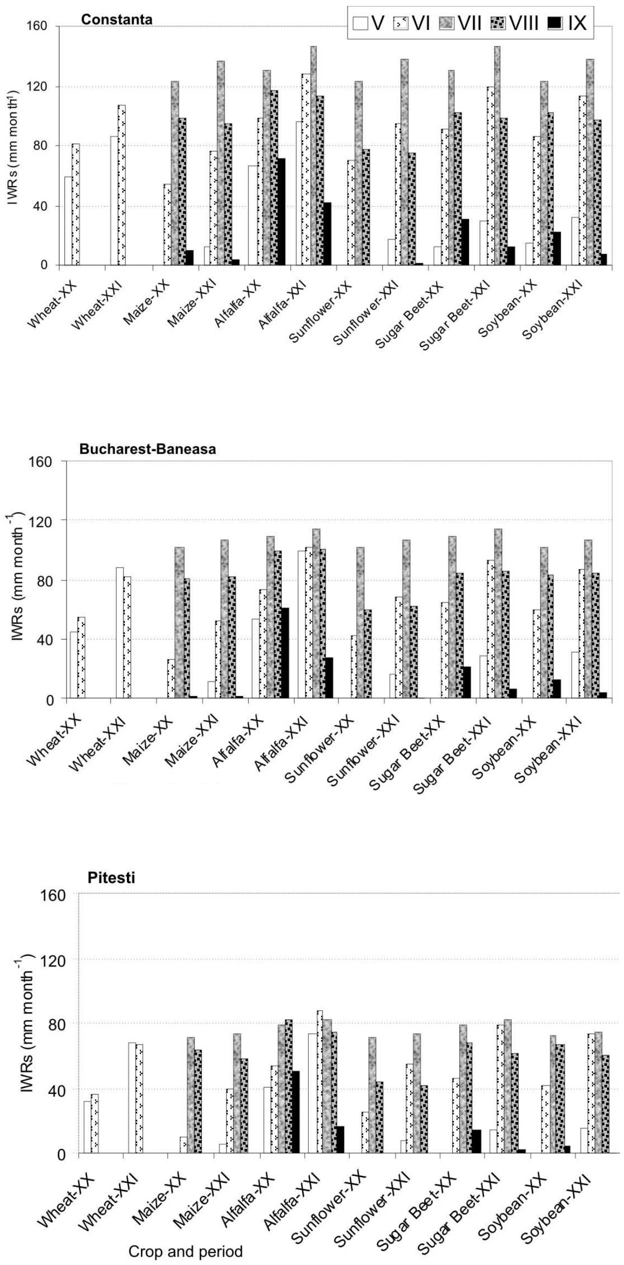

Fig. 4. Comparison between irrigation water requirements (*IWRs*) of the crops studied for decade I of century XXI and century XX, monthly values, for five months and three locations of southern Romania.

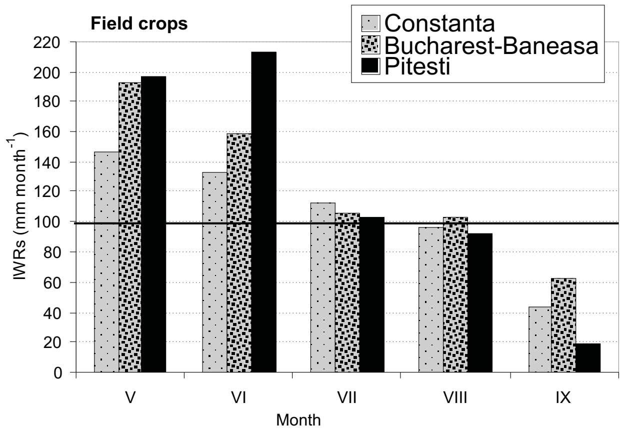

Fig. 5. Comparison between the percentage of the irrigation water requirements (*IWRs)* for decade I of century XXI versus century XX, for five months and three locations of southern Romania; averages for all crops studied.

increased in May (especially in Constanta) and June, and this latter month was the month showing the maximum increase versus century XX for Constanta. July and August show practically the same *IWR* values as in century XX, with a small decrease in the latter, whereas September is the month where irrigation application decreased (about 40-80% *versus* last century).

CONCLUSIONS

1. For the three locations studied, the monthly distribution of reference evapotranspiration showed that for the first half of the year the values were higher for the first decade of the 21st century versus the means of the 20th century.

2. Crop evapotranspiration specifically increased in the first decade of century XXI versus century XX in May, June and July, while in August the increase was negligible, while in September it decreased. Remarkable high values were especially for alfalfa and sugar beet, around 180 mm month^{-1} in Constanta and Bucharest-Baneasa, and 170 mm month^{-1} in Pitesti.

3. For the peak month, July, irrigation water requirements reached as much as 150 mm in Constanta, 110-120 mm in Bucharest-Baneasa and 80-100 mm in Pitesti, respectively, for alfalfa and sugarbeet, while for the other crops investigated here the values were much lower.

4. Due to the complex trend in crop evapotranspiration and precipitation dynamics, irrigation water requirements increased in May and June, especially in Constanta and Bucharest-Baneasa. The following months: July and August have practically the same values, whereas September is the month where irrigation application decreased and is not necessary except in severe droughts. For scenarios using irrigation under soil water stress conditions, as regulated deficit irrigation, irrigation water requirements are substantially lower.

5. The extreme south-eastern part of the country located near the Black Sea (Constanta) maintained large irrigation water requirements differences versus the central part of the Danube Plain (Bucharest) and the High Plain of Pitesti.

6. Because this study only refers to one decade from a new century, and this decade showed high dynamics in global warming, these changes versus century XX could also have either a cyclic or a long term character.

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