THE REFERENCE EVAPOTRANSPIRATION AND THE CLIMATIC WATER DEFICIT IN THE WESTERN PLAIN OF ROMANIA, NORTH OF THE MUREŞ RIVER

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Abstract. – The Reference Evapotranspiration and the Climatic Water Deficit in the Western Plain of Romania, North of the Mureş River. In the present paper, reference evapotranspiration (ET_0) was calculated by the method proposed by C.W. Thornthwaite. The climatic water deficit, as the difference between atmospheric precipitation and ET_0, has also been calculated and analyzed. In this respect, monthly and annual air temperature and precipitation data from 10 weather stations were used. The analysis period was 1961-2002. The result was that the annual average reference evapotranspiration varies, throughout the Western Plain of Romania, North of the Mureş River territory, between 665 and 700 mm. It decreases from south to north and also from west to east, depending on the territorial distribution of the air temperature. The plain territory reveals an annual climatic water deficit between 63 mm in the north of the plain and 171 mm in its south. Therefore, the predominantly agricultural territory of the plain needs a water surplus from irrigation. Only in the east of the plain, at Holod, there is a surplus of moisture.

Key words: reference evapotranspiration, climatic water deficit, precipitation, air temperature.

1. Introduction

Evapotranspiration is a complex phenomenon, which represents the amount of water evaporated from the soil and eliminated by plants through perspiration. It is subject to several factors: atmospheric precipitation, soil water reserve, solar radiation, air and soil temperature, wind speed, depth of groundwater, type of vegetation etc.

Knowing the amount of water coming from precipitation is not enough to characterize the climate of a region in terms of water requirements for plants. It is therefore important to know *the reference evapotranspiration*, which is the

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maximum amount of water that can pass into the atmosphere by evaporation from soil surface and plant perspiration (Donciu, 1958).

2. Data and Methods

In the present paper, reference evapotranspiration (ET_0) was calculated by ***the method proposed by C.W. Thornthwaite*** in 1948, which takes into account the mean values of air temperature and the latitude of the weather stations. The ET_0 calculation formula is (Fărcaş, 1988):

$$ET_0 = 1.6 \cdot (10\ t/I)^a \quad (mm)$$

where $a = 6.75 \times 10^{-7} I^3 - 7.71 \times 10^{-5} I^2 + 17.92 \times 10^{-3} I + 0.49239$

t = mean monthly air temperature

I = annual heat index, obtained by summing the monthly thermic indices (i).

$i = (t/5)^{1,514}$

ET_0 values have been adjusted according to the latitude of the weather stations (46-48° Northern latitude).

The climatic water deficit (Păltineanu et al., 2007), as the difference between atmospheric precipitation and reference evapotranspiration, has also been calculated and analyzed in the present paper.

To determine these climatic elements we used meteorological data regarding the mean monthly and annual air temperature and the monthly and annual precipitation amounts, from 10 weather stations located within the Western Plain of Romania, North of the Mureş River, or in its proximity. The analysis period was 1961-2002. Some of the stations had shorter data series, because they were set up later or were dismantled early. Such were: Chişineu-Criş (1963-2002), Holod (1968-2002), Salonta (1983-1998), Ineu (1979-1997) and Şiria (1984-2002).

All meteorological data used in this paper come from the National Meteorology Administration.

3. Results and Discussions

The average annual reference evapotranspiration, on the Western Plain of Romania, North of the Mureş River, ranges between *665-700 mm* (Table 1). It *decreases from south to north* and also *from west to east* and its territorial distribution is similar to the air temperature, on which it depends directly. The maximum value is recorded in the south, at the station Sânnicolau Mare (697.4 mm) and the minimum at the northern station Satu Mare (665.0 mm).

The table shows that the average annual ET_0 is higher at the station Salonta compared to the more southern station Chişineu-Criş. The reason is the short sequence of observation years for the first station that overlapped the last warm

years. Also at Săcueni, the value is higher than at most of the stations located to its south. That is because of the low altitude of the station Săcueni and its position in the narrow and stuffy sector of Ierului meadow, where air overheats during summer. As a result, the average multi-annual temperature is higher here than at the more southern stations and consequently so are the ET_0 values.

Table 1. Annual reference evapotranspiration (mm) in the Western Plain of Romania, North of the Mureş River (1961-2002).

Station	Satu Mare	Săc.	Orad.	Sal.	Holod	Chiş Cr.	Ineu	Şiria	Arad	Sânn. Mare
Mean	665,0	688,1	683,3	687,3	677,2	684,6	687,9	673,7	687,2	697,4
Max.	724,3	748,9	746,5	730,6	743,8	749,0	739,1	746,8	756,0	768,1
Min.	618,9	631,8	629,6	661,5	631,9	641,6	653,2	628,1	636,7	648,4

Over the years ET_0 varied, as the air temperature varied. The maximum values reached 725-770 mm (Table 1). One will observe that they also drop towards north and also towards east. The highest value belongs to the station Sânnicolau Mare (768.1 mm) and corresponds to the year 2000. In fact, for most of the stations the maximum ET_0 value occurred in the warmest year, 2000. Only in Satu Mare it occurred in 2002, another excessively warm year. At the stations with a short observation period – Salonta and Ineu – which did not include the last years, the maximum ET_0 occurred in 1994. That was also an excessively warm year.

The minimum annual ET_0 values ranged between 620-660 mm (Table 1). The lowest value was recorded, as expected, at the most northern station Satu Mare, where the air temperature values are also the lowest. The year when this value was recorded was 1980, the coldest year. At many stations the lowest value was recorded in 1978 – a very cold year – but also in 1980, and at two stations which had a short observation sequence – Şiria and Salonta – in 1984 and 1997.

Through the year, ET_0 has a course similar to the air temperature, with an increase from January to *July*, when it reaches a *maximum*, followed by a drop of the values until the winter months (Fig. 1-10). *The minimum* is recorded in *January*, when in many years evapotranspiration is missing and the values stay at 0 mm. Thus, throughout the plain, the values rise in July at 132-139 mm, higher at Sânnicolau Mare and Salonta (because of the short sequence of observation years) and lower to the north and east of the plain. In June and August, ET_0 comes to about 112-124 mm, in May about 91-98 mm, in September about 74-79 mm, in December 2-4 mm and in January 0.5-1.7 mm.

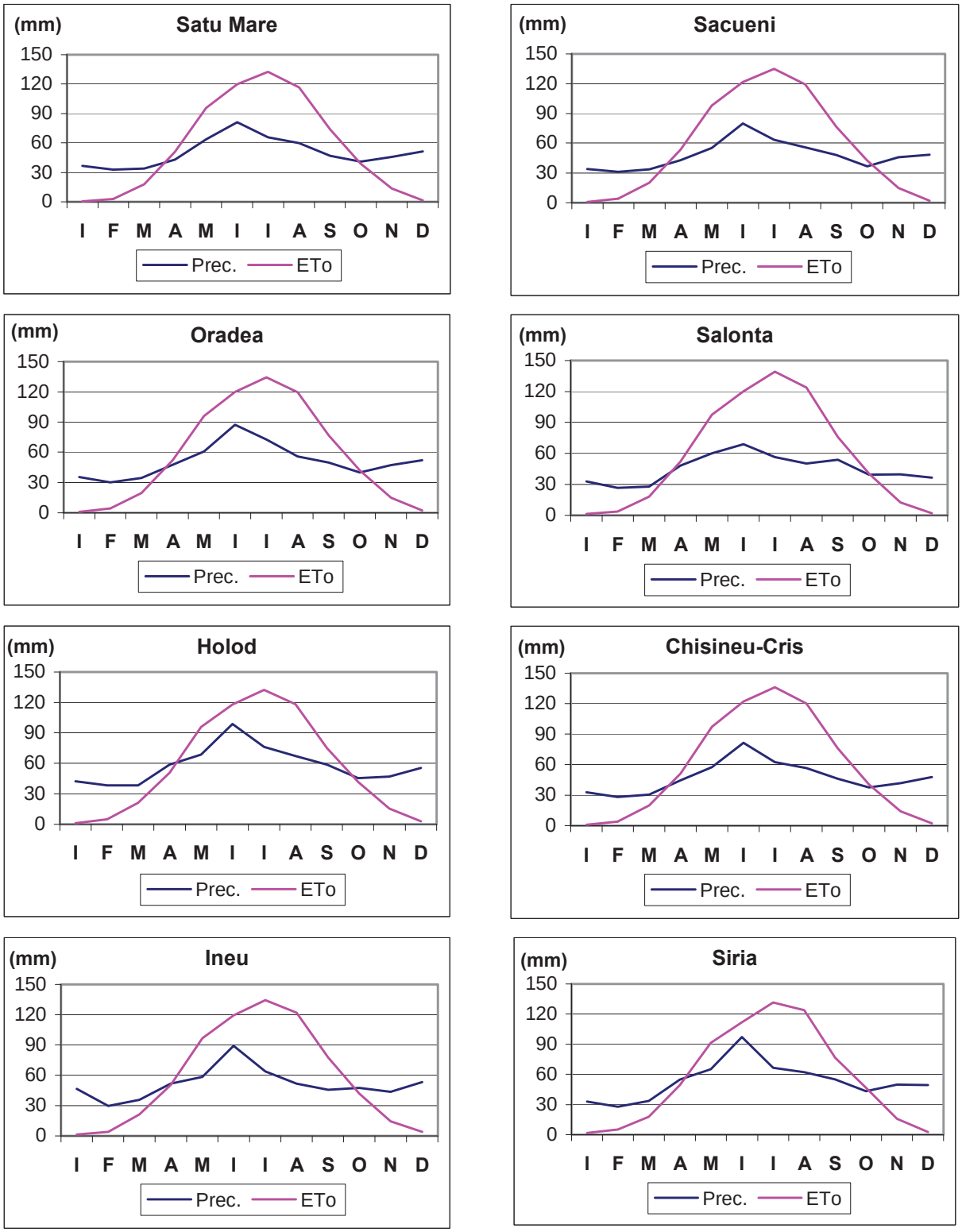

Fig. 1-8. Average monthly reference evapotranspiration compared to average monthly precipitation amounts, in the Western Plain of Romania, North of the Mureş River (1961-2002).

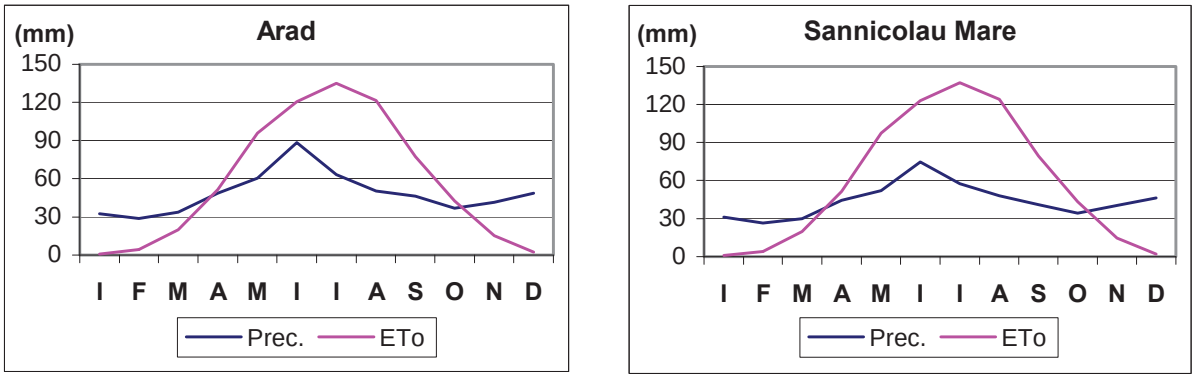

Fig. 9-10. Average monthly reference evapotranspiration compared to average monthly precipitation amounts, in the Western Plain of Romania, North of the Mureş River (1961-2002).

As specified above, in many years in January ET_0 may be absent, as very low air and soil temperatures do not allow water evaporation. ET_0 was also absent in many years in December and February. In some years it was absent even in November and March.

The ET_0 maximum monthly values rose up to 153.4-161.9 mm and occurred either in August, when clear weather prevails and soil surface warms up strongly due to solar radiation, or in July, the hottest month of the year.

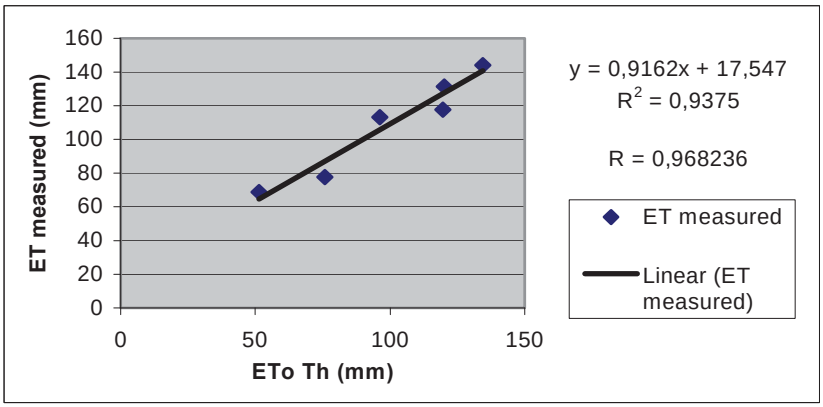

Fig. 11. Correlation between the calculated reference evapotranspiration (Thornthwaite method) and the measured evapotranspiration (Bac evaporimeter method), for the period April-September, in Oradea (1976-2001).

Figure 11 shows the correlation between the reference evapotranspiration calculated by Thornthwaite method and evapotranspiration measured by the Bac evaporimeter method (Domuța, 2005), in the interval 1976-2001 and throughout the vegetation period, April-September, in Oradea. Evapotranspiration has been measured by the author at the Oradea Agrozootechnical Research Station, which is

placed in the vicinity of the Oradea weather station, in the same climatic conditions. The *Simple Correlation Coefficient (Bravais-Pearson)* calculated (r = 0.9682) shows that there is a *very good correlation* between the two rates. The values of the measured evapotranspiration are slightly higher than of the calculated ET_0.

On the analyzed territory, the ET_0 annual average values exceed those of precipitation by about 63 mm in the north of the plain and 171 mm in its south, at the station Sânnicolau Mare (Table 2). In the mountain sector (Şiria), the difference is of only 37 mm as precipitations are richer. The fact shows *the deficient character of precipitation throughout the Western Plain of Romania, North of the Mureş River* and this deficit is called *the climatic water deficit* (Păltineanu et al., 2007). Only in the east, at Holod, there is a surplus of moisture. ET_0 does not exceed the multi-annual precipitation amount here.

Table 2. Annual climatic water deficit (mm) in the Western Plain of Romania, North of the Mureş River (1961-2002).

Station	Satu Mare	Săcueni	Oradea	Salonta	Holod
Average	-63,2	-113,0	-68,6	-146,4	+17,7
Maximum/ Year	-309,6 1961	-357,4 2000	-382,3 2000	-312,6 1992	-366,2 2000
Station	**Chişin.Criş**	**Ineu**	**Şiria**	**Arad**	**Sânnic.Mare**
Average	-116,7	-70,2	-37,0	-107,0	-171,3
Maximum/ Year	-451,3 2000	-269,9 1994	-370,4 2000	-504,0 2000	-500,4 2000

Therefore, the predominantly agricultural territory of the plain needs a water surplus from irrigation, necessary for the purpose of a proper biological cycle of the crop plants. However this surplus is not necessary on clay substrate land, affected by moisture excess or where the groundwater is near surface.

The highest values of the annual average deficit occur in the south of the plain, where temperatures are higher and precipitation lower as a result of the Mediterranean influence. High values also occur in the low, alluvial plains (110-145 mm), where the air overheats in summer and there are fewer rains because of low altitude (Chişineu-Criş, Salonta, Săcueni). The eastern stations, which generally get the highest precipitation amounts, have lower values of the annual average deficit (35-70 mm).

Therefore, it appears that within the Western Plain of Romania, North of the Mureş River, *the climatic water deficit decreases from the south to the north and also from the west to the east*, as the air temperature values drop and precipitation amounts rise. *The most arid area is Arancăi Plain*.

Over the years, the climatic water deficit has varied widely at the weather stations (Fig. 12-14 and Table 2). Its highest values have risen at 300-500 mm (less at Ineu: 270 mm). They occurred in 2000, the driest year and only in north, at Satu Mare, in 1961 (the second driest year of the analyzed period). In the lower Someşului Plain, the drought of the year 2000 was not as intense as in the rest of the territory (the deficit reached 182 mm at Satu Mare). At the stations with short observation sequences, the maximum values were recorded in the years 1992 or 1994, two hot and dry years.

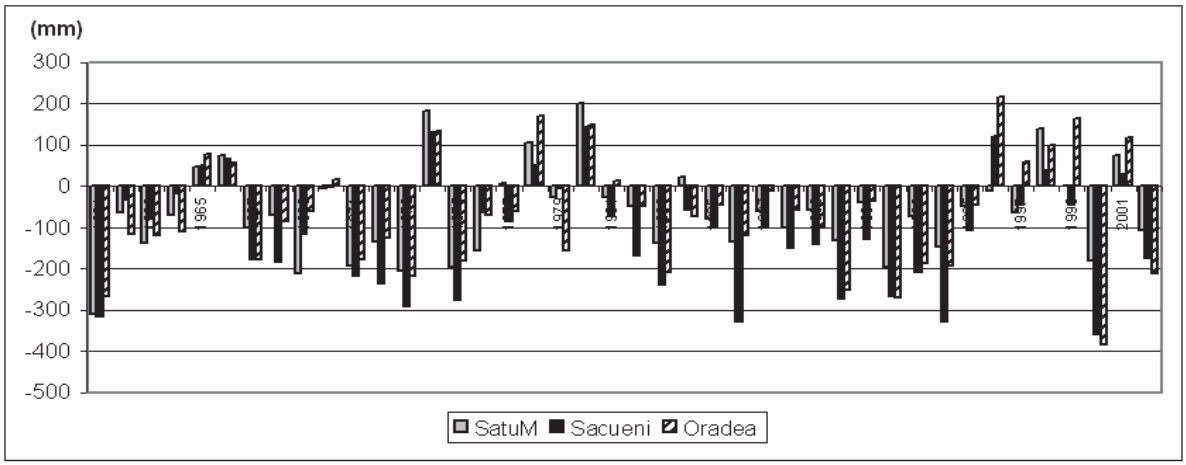

Fig. 12. Annual climatic water deficit in the Western Plain of Romania, North of the Mureş River (1961-2002).

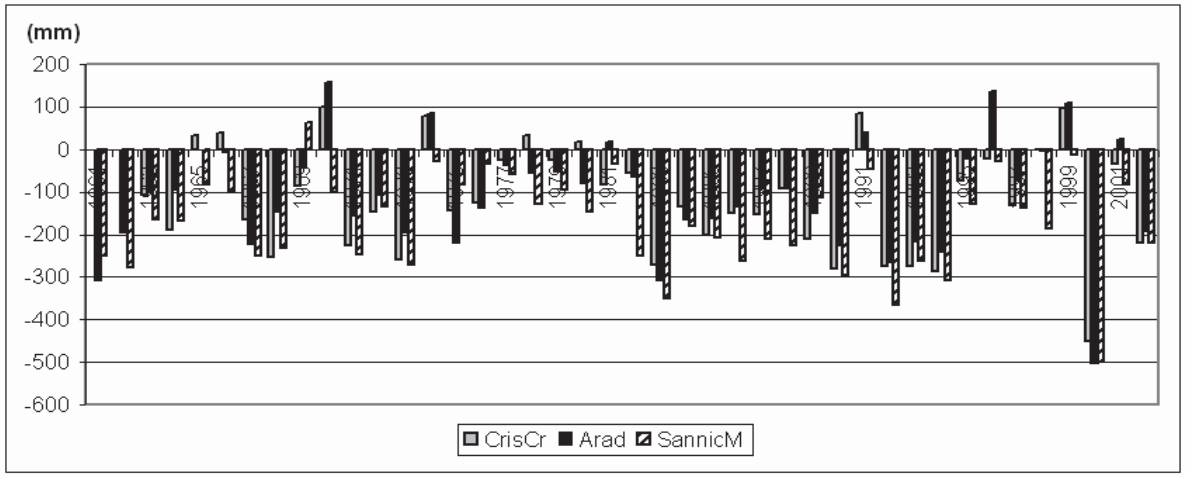

Fig. 13. Annual climatic water deficit in the Western Plain of Romania, North of the Mureş River (1961-2002).

The charts show the great drought of the year 2000 and also that of the year 1961, as well as the long period with deficit 1982-1995. In fact, *most of the years within the period 1961-2002 were with deficit, at all weather stations.* There were very few years with surplus, when annual precipitation amounts exceeded the ET_0:

1 year at Sânnicolau Mare and Salonta, 5-8 years at the stations in Aradului, Crişului Alb and Ierului Plains, 10-12 years at Şiria, Oradea and Satu Mare, 19 years at Holod. As already mentioned, Holod is the only station that records water surplus, hence the highest number of years without deficit.

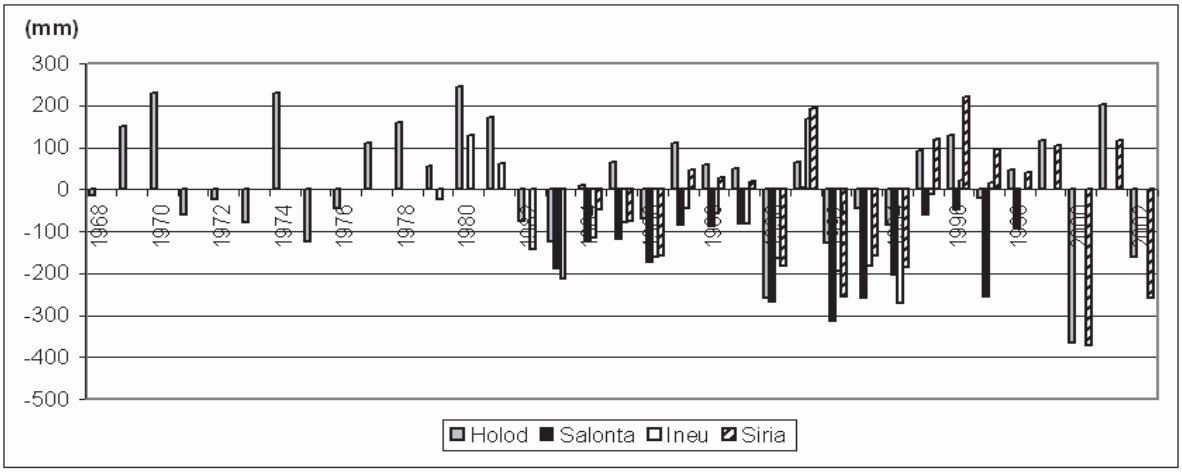

Fig. 14. Annual climatic water deficit in the Western Plain of Romania, North of the Mureş River (1968-2002).

The maximum annual water surplus recorded at the weather stations had much lower values than the annual maximum deficit. Thus, compared to the values of 270-504 mm of the maximum deficit, the maximum surplus was of only 100-245 mm at most stations, dropping to values of 63.1 mm at Sânnicolau Mare and only 5.1 mm at Salonta. The highest surplus was recorded at Holod (243.7 mm) in the colder year of 1980. The years with a surplus were: 1965-1966, 1969-1970, 1974, 1980-1981, 1996-1999, 2001, which were either rainy or cooler years, when ET_0 was low.

The number of years with a high climatic water deficit – over 200 mm – is very high, but it decreases a lot from the south of the plain (18 years at Sânnicolau Mare), to its north (3 years at Satu Mare) and east (2 years at Ineu and Holod). A great number of years with a deficit of over 200 mm is recorded at Chişineu-Criş and Săcueni (12 years), but also at Arad (9 years) and Oradea (7 years). There are records of even greater deficit, over 300 mm: only 1 year for most of the stations, but the number is higher at Sânnicolau Mare (4 years), Săcueni (4 years) and Arad (3 years). Years with a deficit over 300 mm are missing only in Ineu, because of the short observation period.

Consequently, on the territory of the Western Plain of Romania, North of the Mureş River, *the climatic water deficit has higher values than the water surplus*.

A comparison between the ET_0 average monthly values and the average monthly precipitation values shows that ET_0 exceeds the precipitation amounts

within the interval *April-October*, which corresponds exactly to plants vegetation period (Fig. 1-10). In the north, at Satu Mare, the monthly climatic deficit occurs within the interval April-September and in the east, at Holod, Ineu and Şiria in May-September (possibly May-October). So, *the annual interval of recording the climatic water deficit is shorter in the northern and eastern areas of the analyzed territory*.

The interval April-October sums up an average climatic water deficit of 170-300 mm. It is higher at the southern stations Sânnicolau Mare (304.0 mm) and Arad (247.1 mm), and also at the stations located on alluvial plains – Chişineu-Criş, Salonta, Săcueni – where it sums up to 257-273 mm. In the north the total deficit drops to 220 mm, and eastwards to 170-193 mm (Holod and Şiria).

The deficit reaches its maximum in *July* (60-80 mm) and *August* (55-75 mm) – when the anticyclone baric regime prevails, with stable air masses and clear weather – and the minimum at the beginning and the end of plants vegetation period.

The months within the interval *November-March* present a climatic water surplus, when the ET_0 is less than the amount of precipitation. In these months the surplus totals, on average, about 130-190 mm, lower to the south of the plain and higher to its north and east. Its total values are lower than the total values of the climatic deficit. The surplus has its peak in *December* (45-50 mm), when there is the secondary pluviometric maximum and air moisture and nebulosity maximum.

Conclusions

The annual average reference evapotranspiration (ET_0) – calculated by Thornthwaite method – varies, throughout the Western Plain of Romania, North of the Mureş River territory, between 665 and 700 mm. It decreases from south to north and also from west to east, depending on the territorial distribution of the air temperature. The simple correlation coefficient (Bravais-Pearson) calculated between the calculated reference evapotranspiration and measured evapotranspiration, during the vegetation period April-September, shows that there is a very good correlation between them. The values of the measured evapotranspiration are slightly higher than of the calculated ET_0.

The plain territory reveals an annual climatic water deficit between 63 mm in the north of the plain and 171 mm in its south. Only in the east of the plain, at Holod, there is a surplus of moisture. The most arid area is Arancăi Plain.

Because of the great number of years with climatic water deficit recorded on the plain territory, its high values and mostly because its overlapping the plants vegetation period, the use of irrigation in agriculture is required. However they are not necessary on clay substrate lands, affected by an excessive humidity or where groundwater is near surface.

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