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MAPPING REAL EVAPOTRANSPIRATION IN WINTER WHEAT AND NON-IRRIGATED MAIZE CROPS DURING THE AGRICULTURAL SEASON 2019-2020

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Abstract

Evapotranspiration in agricultural crops is represented by water losses (unproductive) by evaporation from the soil surface and consumption (productive) by transpiration of plants. This study will try to highlight the importance of evapotranspiration (potential and real) in assessing the water consumption of plants, this being an essential parameter, with a particularly important impact on the crops obtained. This study was performed by daily analysis of the evolution of potential evapotranspiration calculated by the Penman-Monteith method (FAO-56 PM), as well as the real evapotranspiration performed in winter wheat and unirrigated maize crops for soil on different depths, in weekly and monthly intervals during the agricultural year September 1st, 2019 - August 31st, 2020. The specialized data analyzed included meteorological parameters: minimum and maximum diurnal temperatures, wind speed, sunlight duration, relative air humidity, crop coefficient, recorded precipitation and soil moisture reserve during the vegetation period of field crops with the most significant share in Romania, respectively winter wheat and unirrigated maize.

Key words*: real evapotranspiration, crop coefficient, agricultural season, water deficit, pedological drought.*

INTRODUCTION

In nature, evaporation is a much more complex process, because in addition to the real physical evaporation, there is also physiological evaporation from plant perspiration. Water evaporated from the soil, together with plant perspiration forms evapotranspiration. At the surface of the soil, evaporation depends on the water content of the soil, capillary water, caloric energy of the soil, atmospheric pressure, air temperature, solar radiation, wind speed and atmospheric humidity.

At the surface of the water, evaporation depends on the concentration in salts, the extent and depth, the dynamism of the surfaces. At the physiological evaporation the main role is played by the water reserve in the soil. There is a big difference between real and potential evaporation, i.e. maximum evaporation under certain conditions. Known as FAO 56 PM, this method is a global standard based on meteorological data (Allen et al., 1998), and it has been found to study well in numerous locations if the required data are available (Allen et al., 1989; Garcia et al., 2004; López-Urrea et al., 2006; Xing et al., 2008).

Evapotranspiration is affected by a number of factors, including weather parameters, crop characteristics, management and environmental issues (Allen et al., 1998; Wang et al., 2014). Evapotranspiration depends primarily on the air temperature and the amount of water in the soil. Evapotranspiration in agricultural crops is represented by water losses (unproductive) by evaporation from the soil surface and consumption (productive) by transpiration of plants. Potential and real evapotranspiration are agrometeorological indicators that provide new information necessary to identify agricultural areas affected by the phenomenon of pedological drought with different degrees of intensity (moderate, strong and extreme pedological drought) and negative effects with direct impact on major crops in Romania, in the context of current climate change.

The study highlights the importance of evapotranspiration (potential and real) in

assessing the water consumption of plants, this being an essential parameter, with a particularly important impact on the crops obtained.

MATERIALS AND METHODS

The conversion of water into vapors returning to the atmosphere through the process of evapotranspiration (evaporation and transpiration) is decisively influenced by the amount of water available, which is why two parameters have been defined. ***Real evapotranspiration*** (ETR), which occurs in conditions of natural humidity and ***Potential evapotranspiration*** (ETP) representing the amount of water that can be evaporated and transpired under conditions of sufficient water reserves to compensate for maximum losses.

The Penman-Monteith method is the standard for estimating reference evapotranspiration and requires several meteorological elements (Dias et al., 2021).

The standard conditions refer to crops grown in large fields under excellent agronomic and soil water conditions. The crop evapotranspiration differs distinctly from the reference evapotranspiration (ET_o) as the ground cover, canopy properties and aerodynamic resistance of the crop are different from grass. The effects of characteristics that distinguish field crops from grass are integrated into the crop coefficient (K_c). In the crop coefficient approach, crop evapotranspiration is calculated by multiplying ET_o by K_c (Guidelines for computing crop water requirements - FAO, 1998).

Reference evapotranspiration is a term more frequently used for potential evapotranspiration in the usual literature in our country (Păltineanu et al., 2007).

The need for irrigation water for a given crop structure is determined proportionally on the basis of what is needed for each crop. The influence of climate on crop water needs: this influence is given by the evapotranspiration of reference crops (ETR).

Crop type and the stage of growth related to the water needs of the field plants give the expressed term crop coefficient (K_c) (Figure 1).

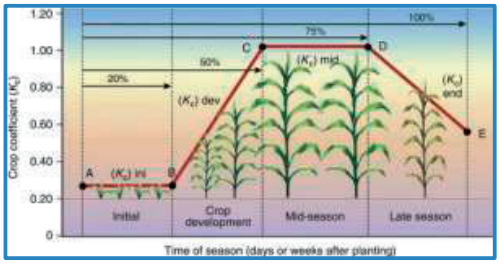


Figure 1. Crop coefficient -K_c-season (Source: Jan Pokorny, in Encyclopedia of Ecology, Second Edition), 2019

The real evapotranspiration (ETR) is determined for each crop, and with the obtained values the soil water balance calculations are performed and the monthly water requirement for the crops within the plant assortment specific to the area is determined. Crop water requirement (ETR) is defined as the depth (or amount) of water required to meet water loss through evapotranspiration. In other words, it is the amount of water needed by different crops to grow optimally.

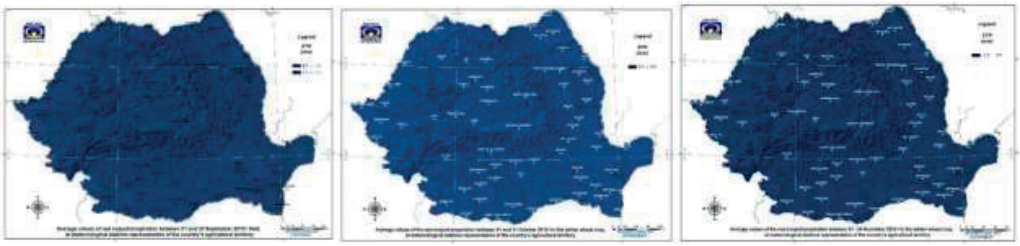
This study was performed by daily monitoring of the evolution of potential evapotranspiration (ETP) calculated by the Penman-Monteith method (FAO-56 PM), as well as of the real evapotranspiration (ETR) performed in winter wheat and non-irrigated maize crops, using meteorological data from NMA network, in weekly and monthly intervals during the agricultural season September 1st, 2019 - August 31st, 2020.

RESULTS AND DISCUSSIONS

The evolution of real evapotranspiration in the winter wheat crop in the agricultural year 2019-2020

In the autumn of 2019, the real evapotranspiration (ETR) dynamics in the winter wheat crop, showed low values throughout the country, being between 0.7-1.2 mm in September 2019, 0.4-0.6 mm in October 2019 and 0.2-0.7 mm in November 2019 (Figure 2 a, b, c).

During winter season and first month of the spring time (march), real evapotranspiration values are very low (close to zero), because of reduced activities of the crops.



a) b) c)

Figure 2. Average Real evapotranspiration (ETR) in the winter wheat crop, in September 2019 (a), October 2019 (b) and November 2019 (c)

The average values of this agrometeorological indicator on April 2020, in the winter wheat crop, on the soil depth 0-100 cm, ranged between 2.9-3.0 mm, isolated in northern and eastern Transylvania, southeastern Dobrogea. Locally in the south, northeast and center of Transylvania, isolated north of Oltenia, east of Dobrogea, central Moldova there were limits between 3.1-3.5 mm. In Maramureș, on large agricultural areas in Banat, Crișana, locally south and east of Oltenia, north, west, center, southwest and south of Muntenia, south, southwest, southeast, northwest and center of Transylvania, north, center, east, isolated southwest of Moldova, southwest of Dobrogea, values ranged from 3.6-4.0 mm. Locally in the south, southeast, east, center and west of Moldova, north and center of Dobrogea, east and center of Oltenia, south and southeast of Muntenia, isolated west of Crișana, northwest of Banat, the recorded data were between 4.1 - 4.5 mm. Higher limits (4.6-5.1 mm) were reported locally in northern, northeastern and eastern of Muntenia, isolated in Moldova area (Figure 3).

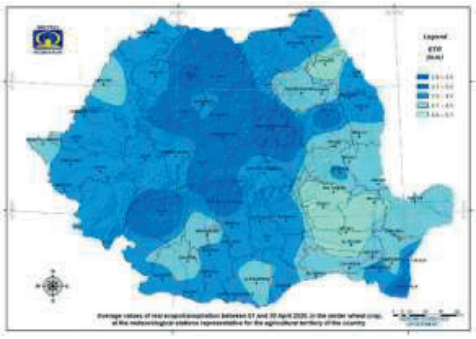


Figure 3. Average real evapotranspiration (ETR) - winter wheat crop, April 2020

Figure 4 shows the real evapotranspiration (ETR) in the winter wheat crop, between 01st-30 June 2020, with the lowest values between 3.3-4.0 mm, in Maramureș, Transylvania, Banat, most of Crișana, locally north, isolated center of Moldova, north and east of Oltenia, southeast of Dobrogea, northeast of Muntenia. On large agriculture areas in Moldova, Muntenia, locally south and east of Oltenia, center, east, isolated southwest of Dobrogea, south of Crișana, the limits ranged between 4.1-4.5 mm. Locally in the north, east and south of Muntenia, isolated north and center of Dobrogea, central and southwest of Oltenia, values between 4.6-4.9 mm were recorded.

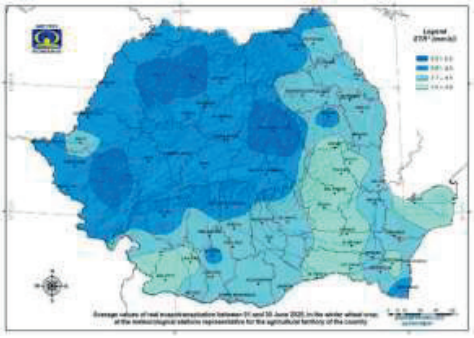


Figure 4. Average real evapotranspiration (ETR) - winter wheat crop, June 2020

The evolution of the daily average of the real evapotranspiration ETR (mm/day), calculated for the winter wheat crop, between 01-30 June 2020 at the meteorological stations with agrometeorological program, showed a tendency to increase the values, the daily averages being between 2.9-6.0 mm (Figure 5).

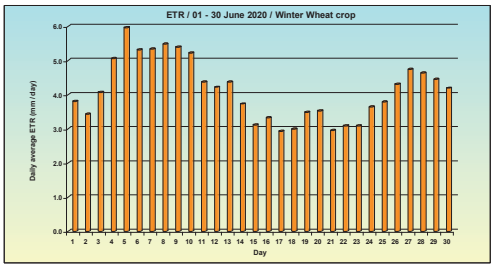


Figure 5. The evolution of real evapotranspiration 01st-30 June 2020

The comparative analysis of the values of potential evapotranspiration (ETP) with the average monthly rainfall regime, from September 1st, 2019 to June 30, 2020, shows that water consumption by evapotranspiration frequently exceeded the amount of precipitation recorded in September 2019, October 2019, January 2020, March 2020, April 2020, May 2020 and June 2020, except for the months of November 2019, December 2019 and February 2020, where the monthly average of the recorded precipitation quantities exceeded the evapotranspiration values (Figure 6).

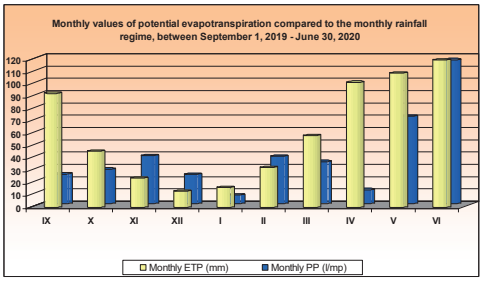


Figure 6. The evolution of potential evapotranspiration between September 1st, 2019 - June 30, 2020

The evolution of real evapotranspiration in non-irrigated maize crop in the agricultural season 2019-2020

Figure 7 shows the spatial zonation of the average real evapotranspiration (ETR) in the non-irrigated maize crop, on the soil profile 0-50 cm, between 01st-31st May 2020. Average values were recorded between 1.8-2.1 mm, locally in the north, northeast, center and east of Transylvania, isolated northwest, east and center of Moldova, southeast of Dobrogea. In Maramureș, Banat, Crișana, most of Transylvania, Oltenia, Muntenia and Moldova, locally the center, the east, isolated southwest of Dobrogea, the limits were between 2.1-2.5 mm. Locally in the north, east and south of Muntenia, east and center of Oltenia, isolated north and center of Dobrogea, average values between 2.6-3.0 mm were reported.

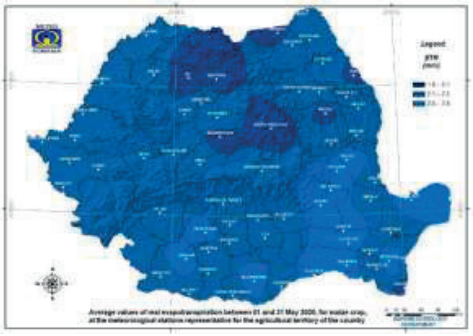


Figure 7. Average real evapotranspiration (ETR), non-irrigated maize crop, between 01-31 May 2020

The average values of the real evapotranspiration from 01-30 June 2020, on the soil depth 0-100 cm, in the non-irrigated maize culture, were between 3.3-3.5 mm, in Maramureș, Transylvania, locally west of Crișana, isolated north- west and northeast of Banat, northwest of Muntenia, southeast of Dobrogea. On large agricultural areas in Muntenia, Oltenia and Moldova, locally north and west of Banat, center, east, isolated southwest of Dobrogea, there were limits between 3.6-4.0 mm. Locally in the north, east and south of Muntenia, central and southwest of Oltenia, isolated north and center of Dobrogea, the values ranged between 4.1-4.4 mm (Figure 8).

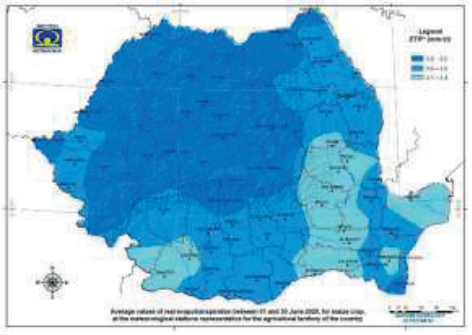
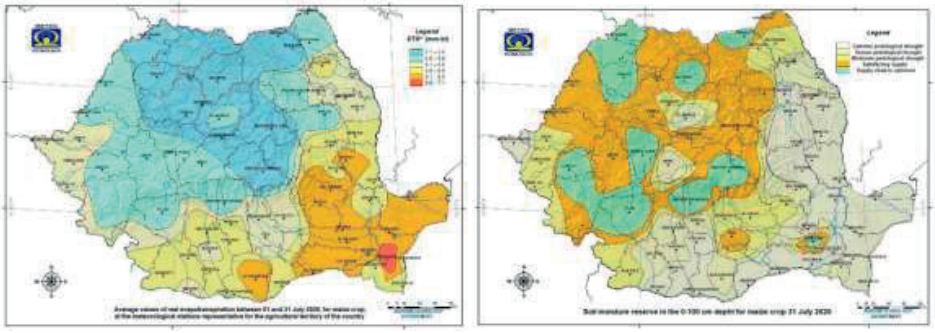


Figure 8. Average real evapotranspiration (ETR), non-irrigated maize crop, between 01-30 June 2020

In the non-irrigated maize crop, on the soil profile 0-100 cm, the values of real evapotranspiration between 01-31 July 2020, were between 4.1-4.5 mm in Maramureș, local north, center, east and southeast of Transylvania, north and northwestern Moldova. In most of Crișana, locally northeast, north, west and center of Moldova, south, southwest, isolated center of Transylvania, north of Oltenia, northwest of Muntenia, limits between 4.6-5.0 mm were reported. The highest values (5.1-7.1 mm) were recorded in Dobrogea, most of Oltenia, Muntenia, Moldova, Banut and isolated areas from southern Crișana, Figure 9 (a), thus resulting in a pedological drought with different degrees of intensity (moderate, strong and extreme), in these agricultural areas (Figure 9 b).



a) b)

Figure 9. Average real evapotranspiration (ETR) - (a) and soil moisture depth 0-100 cm (b) non-irrigated maize crop, 01-31 July 2020

The evolution of the daily average of the real ETR evapotranspiration (mm/day), calculated for the non-irrigated maize culture, between 01-31 July 2020 at the meteorological stations with agrometeorological program, shows a tendency to increase the values, the daily averages being between 3.9-6.9 mm (Figure 10).

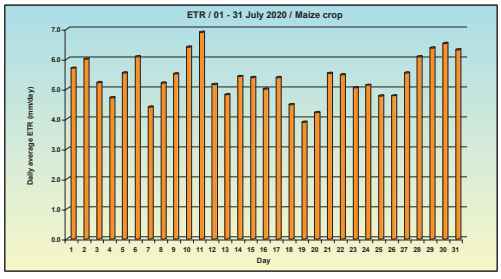


Figure 10. Real evapotranspiration 01-31 July 2020

The lowest values of real evapotranspiration (ETR) in the culture of unirrigated maize, on the soil depth 0-100 cm, between 01-31 August 2020, were between 3.1-4.0 mm, in Maramureș, Transylvania, the largest part of Crișana and Banat, locally north, northwest, west and center of Moldova, isolated northwest of Muntenia. Locally in the north, west, center, northeast, southwest and south of Muntenia, north, south and east of Dobrogea, east, center, northeast, southeast and southwest of Moldova, south, isolated east of Oltenia, west and the northwest of Banat, the southwest and the west of Crișana, limits between 4.1-4.5 mm were reported. Values between 4.6-5.0 mm were registered, locally in the east and center of Oltenia, north, south, southeast and west of Muntenia, south, east and center of Moldova. Locally in the center of Dobrogea, north, east, isolated south of Muntenia, the limits ranged between 5.1-5.4 mm (Figure 11).

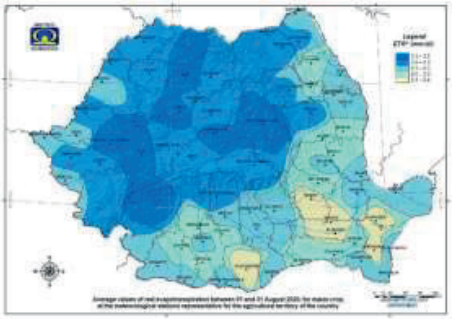


Figure 11. Average real evapotranspiration (ETR), non-irrigated maize crop, 01-31 August 2020

Figure 12 shows the evolution of the daily average of the real ETR evapotranspiration (mm/day), calculated for the non-irrigated maize crop, between 01-31 August 2020 at the meteorological stations with agrometeorological program. This shows an increasing trend of values, the daily averages being between 2.3-6.7 mm.

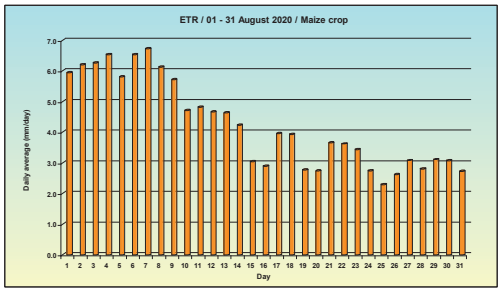


Figure 12. Real evapotranspiration 01 and 31 August 2020

In the culture of non-irrigated maize, on the soil profile 0-100 cm, between 03-09 August 2020, the real evapotranspiration showed limits between 4.6-5.0 mm, isolated in eastern Transylvania. In Maramureș, Banat, local north, northwest, center, south, southwest and southeast of Transylvania, isolated northwest and center of Moldova, west of Crișana, north of Oltenia, northwest of Muntenia, the values ranged between 5.1-5.5 mm. Locally in the northeast, center and south of Transylvania, north, west and east of Moldova, southeast, east, isolated southwest and north of Dobrogea, south of Crișana, there were limits between 5.6-6.0 mm. The highest values of real evapotranspiration were between 6.1-8.4 mm, in most of Muntenia, Oltenia, Dobrogea and Moldova, isolated west of Crișana (Figure 13).

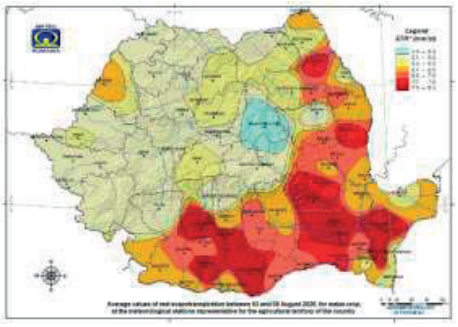


Figure 13. Average real evapotranspiration (ETR), non-irrigated maize crop, 03-09 August 2020

The comparative analysis of the values of potential evapotranspiration (ETP) with the average monthly rainfall regime, from September 1, 2019 to August 31, 2020, shows that water consumption by evapotranspiration frequently exceeded the amount of precipitation recorded in September 2019, October 2019, January 2020, March 2020, April 2020, May 2020, June 2020, July 2020 and August 2020, except for November 2019, December 2019 and February 2020, where the monthly average of precipitation exceeded the evapotranspiration values (Figure 14).

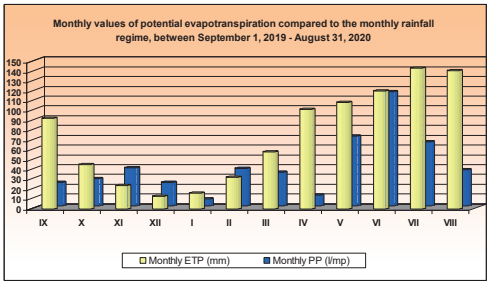


Figure 14. Potential evapotranspiration September 1, 2019 and August 31, 2020

CONCLUSIONS

Evapotranspiration in agricultural crops is represented by water losses (unproductive) by evaporation from the soil surface and consumption (productive) by transpiration of plants.

The study was performed by daily monitoring of the evolution of the calculated potential evapotranspiration (ETP), as well as the real evapotranspiration (ETR) performed in winter wheat and non-irrigated maize crops for soil depths 0-20 cm, 0-50 cm and 0-100 cm, in weekly and monthly intervals during the agricultural year 01 September 2019 - 31 August 2020.

For this purpose, the potential of the agro-climatic resources available for agriculture at the level of the country's agricultural territory was analyzed and agrometeorological data were processed based on the values registered at the meteorological stations with agrometeorological program in Romania.

For the spatial zoning of the average real evapotranspiration (ETR), the monthly maps were represented, during the entire agricultural year for each of the two crops analyzed.

August was characterized by deficient rainfall in most parts of the country, moisture reserve on the soil depth 0-100 cm, in the non-irrigated maize crop, showing low and particularly low values (moderate, strong and extreme pedological drought), especially in the south, east and south-east of the country, resulting in high ETR values in these areas.

In this study we tried to highlight the importance of evapotranspiration (potential and real) in assessing the water consumption of plants, this being an essential parameter, with a particularly important impact on the crops obtained.

REFERENCES

Allen, R., Pereira, G.L.S., Raes, D. and Smith, M. (1198). Crop evapotranspiration: guidelines for computing crop water requirements. FAO Irrigation and Drainge Paper 56, Rome, Italy.

Bâlteanu, Gh. (2001). *Phytotechnics*. Vol. 1, Ceres Publishing House, Bucharest.

Berbecel, O., Ciovică, N., Stancu, M. (1970). *Agrometeorology*. Ceres Publishing House, Bucharest.

Berbecel, O., Socor, E. (1982). *Agrometeorological guide*. Publishing House of the Institute of Meteorology and Hydrology, Bucharest.

Berca, M. (2011). *Agrotechnics. The modern transformation of agriculture*. Ceres Publishing House, Bucharest.

Budoi, G., Penescu, A. (1996). *Agrotechnics*. Ceres Publishing House, Bucharest.

Dias, S.H.B., Filgueiras, R., Fernandes Filho, E.I., Arcanjo, G.S., Da Silva, G.H., Mantovani, E.C., França da Cunha, F. (2021). Reference evapotranspiration of Brazil modeled with machine learning techniques and remote sensing. *Plos One Collenction. Public Health Implications of a Climate Change.*

Garcia, M., Raes, D., Allen, R.G., Herbas, C. (2004). Dynamics of reference evapotranspiration in the Bolivian highlands (Altiplano). *Agricultural and Forest Meteorology, 125*(1-2), 67–82.

López-Urrea, R., Martín de Santa Olalla, F., Fabeiro, C., Moratalla, A. (2006). Testing evapotranspiration equations using lysimeter observations in a semiarid climate. *Agricultural Water Management, 85*(1-2), 15–26.

Păltineanu, C.R., Mihăilescu, I.F., Seceleanu, I., Dragotă, C., Vasenciuc, F. (2007). *Aridity, drought, evapotranspiration and water requirements of agricultural crops in Romania*. Ovidius University Press, Constanța.

Wang, W., Zou, S., Luo, Z., Zhang, W., Chen, D. Kong, J. (2014). Prediction of the Reference Evapotranspiration Using a Chaotic Approach. *The Scientific World Journal,* Vol. 2014, Article ID 347625, 13 pages, 2014. https://doi.org/10.1155/2014/347625.

Xing, Z., Chow, L., Meng, F.-R., Rees, H.W., Steve, L., Monteith, J. (2008). Validating evapotranspiration equations using Bowen ratio in New Brunswick, Maritime, Canada. *Sensors, 8*(1), 412–428.

Zamfirescu, N., Velican, V., Săulescu, N., Safta, I., Canțăr, F. (1965). *Phytotechnic*s. Vol. II, Second Edition, Agro-Forestry Publishing House, Bucharest.

***Archive of Agrometeorological Bulletins (2019-2020). Agrometeorology Department, National Meteorological Administration Bucharest.

***Agrometeorological database of the National Meteorological Administration.

***http://www.fao.org/3/X0490E/x0490e06.htm#TopOfPage.

***http://www.fao.org/3/X0490E/x0490e08.htm.

***https://www.agrimedia.ro/articole/relatiile-dintre-sol-apa-planta-si-conditiile-meteorologice.

***http://www.fao.org/3/s2022e/s2022e07.htm.

***http://www.fao.org/3/X0490E/x0490e07.htm#TopOfPage.

***http://www.ahgr.ro/media/117168/5_factori-naturali-apa.pdf.