Scientific Papers. Series A. Agronomy, Vol. LXVII, No. 1, 2024
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

AN EXPERIMENTAL STUDY ON CROP EVAPOTRANSPIRATION IN ROMANIA

Florentina MINCU, Gianina NECULAU

National Institute of Hydrology and Water Management,
97 E Bucuresti-Ploiesti Road, Bucharest, Romania

Corresponding author email: florentina.mincu@hidro.ro

Abstract

In Romania, evapotranspiration at bare soil or covered by crops is monitored within the experimental evapotranspiration stations: Căldărușani, Voinești and Poiana Brașov. Many experimental researches are carried out, in order to analysed the variation of crop evapotranspiration, in relation to the climatic parameters and soil moisture. The experiments carried out in recent years, have shown that starting from 2021 until 2023, at the level of G1 lysimeters, no more infiltrated water quantities were recorded, so all the amount of water was evaporated. It was also observed that in the year 2022 the sunflower and maize crops did not reach the stage of maturity. In 2023, an experiment was carried out that aimed to compare the maize evapotranspiration in a natural regime and exposed to additional watering (Căldărușani station). The water addition rate was established based on specialized literature and by applying CropWat model. Additional waterings generated different evapotranspiration values. The waterings changed the values of soil moisture and helped the plant not to reach the wilting point before ripening.

Key words*: evapotranspiration, crop, maize, irrigation, Romania.*

INTRODUCTION

Climate change affects water resources worldwide, and causes delays in the development of any type of vegetation: forests, crops or even aquatic vegetation. Plants are frequently exposed to many stresses, such as extreme climate events (drought, floods) or related to changes in soil chemistry (low temperature of soil, oxidative stress and heavy metal toxicity) (Jaleele et al., 2009; Butler et al., 2013; Vicente-Serrano et al., 2014; Zukovska et al., 2016; Velea et al., 2021).

Drought is an extreme meteorological phenomenon, describe like a period without significant rainfall and with atmospheric conditions which leads to water losses by transpiration or evaporation. In order to complete the water requirements of the plants, especially in dry periods, additional watering is needed, as to ensure the optimal development of the plant and the maximum crop yield.

The agriculture of the current century is in permanent development, based on adaptation to climate changes and to limited water resources (OECD, 2014; Allan et al., 2020; Anderson et al., 2020; Smuleac et al., 2020; Rolbiecki et al., 2022; Wu et al., 2023). Recent studies have focused on the analysis of soil-plant-atmosphere interactions (Yao et al., 2023; Drăguleasa et al., 2023). Evapotranspiration is a process with great impact on the reduce of water in soil and on the amount of water needed for the optimal development of plant. The main indirect methods used to determine crop evapotranspiration are still debated, and also developed (Allen et al., 1998; Al Domany et al., 2013; Anda et al., 2014; Stan et al., 2014; Cunha et al., 2023). The direct determination of crop evapotranspiration is really insufficient in the whole world and generally carried out experimentally. The direct measurement of this process is focused on lysimeters method, with different size and depth, and on measuring the water vapour values and the turbulent exchange (Anda et al., 2014; Stan et al., 2014; Neculau et al., 2016; Stan et al., 2016; Ruth et al., 2018).

In Romania, direct measurements for the study of evapotranspiration started in the 70s, through the construction and installation of some types of lysimeters located within four experimental stations Căldărușani, Voinești, Poieni and Cilibia. Currently, measurements of evapotranspiration at bare soil and covered with different local crops (maize, wheat, oats, apples, potatoes), at daily time step (G1

lysimeter) or pentadic (Z-500 lysimeter), are still carried out at the experimental stations Căldărușani (alt. 82 m), Voinești (alt. 440 m) and Poiana Brașov (alt. 939 m). The experiments carried out, in previous years, at these stations indicated a decrease in the daily values of evapotranspiration and soil infiltration. Starting with the year 2021 and until March 2023, at the level of the G1 lysimeters at Căldărușani experimental station, no more infiltrated water was recorded, all the amount of water coming from precipitation, was evaporated.

In the year 2022 it was observed that the sunflower and maize did not reach the stage of maturity, the maximum height or maximum productivity, because the withering point of the crop was reached in the stage of grain formation. This occurred at the end of July 2022, the growing season was reduced by over 30 days. Thus, the purpose of the research is to analyze the variability of maize evapotranspiration measured at the level of two lysimeters, one exposed to natural climate changes and the other exposed to additional watering, and taking into account the relation with soil moisture and the development stage of the plant. In this sense, in the year 2023, at the Căldărușani station, the planting date of the maize was May 11.

During the vegetation periods in the year 2023, it was proposed to carry out controlled watering on the maize crop (in one of the lysimeter), in order to obtain as much information as possible on evapotranspiration and water infiltration into the soil under natural and irrigated conditions. The watering rate was estimated based on other studies and on the modelling carried out for the period 2021-2022, in terms of evapotranspiration and water requirement for crop irrigation, by applying CropWat model by FAO (Food and Agriculture Organization). The experimental watering from 2023, come for the purpose of following the processes that make the connection between crop and soil, in the context of climate changes from the last decade.

MATERIALS AND METHODS

The present study is based on daily data measured in the period 2021-2023 at the Căldărușani experimental station, which consist of hydrometerological data: evapotranspiration, precipitation, air temperature, wind speed, sunshine duration and air humidity, but also soil information: soil moisture and temperature. The data were obtained at the level of two G1 lysimeters, which have an area of 1 m^2, a depth of 150 cm, and they work on the principle of weighing the soil weight, every day. Also, some of the data used in this study came from an automatic meteorological station, as well as from soil moisture and temperature sensors. The CropWat model was applied (Allen et al., 1998; Stăncălie, 2010; Knezevic et al., 2013; Stan et al., 2016), in order to identify the amount of water requirement for crop irrigation, in the climatic conditions of the previous years, 2021 and 2022.

The model estimates the potential evapotranspiration and effective rain, based on climatic data (air temperature, relative humidity, precipitation, wind speed, duration of sunshine). To estimate crop evapotranspiration, the model takes into account the date of planting and harvesting, the crop coefficient determined for each vegetation stage, the rooting depth, the critical depletion (fraction), the crop height and the yield response. These are joined by data on soil name, total available soil moisture, maximum rain infiltration rate, maximum rooting depth, initial soil moisture depletion and available soil moisture.

To estimate the amount of water requirement for irrigation, the model takes into account two parameters, evapotranspiration at the level of agricultural crops and effective precipitation. Thus, when precipitation cannot cover the yielded values from the soil level through evapotranspiration, irrigation is considered necessary. Regarding the irrigation yield, it is selected at the percentage of 70%, which means that, the remaining 30% of the irrigated volume is lost through evapotranspiration. Watering is requested at critical depletion, the moment of reaching the maximum exhaustion of the culture of 100%. In agricultural practice, watering cannot be done at the critical depletion because it is not known in real time.

The Căldărușani experimental station is located in the southern part of Romania, in Vlăsia Plain (Figure 1), at 40 km distance from Bucharest. This experimental station was established in

1968 with the aim of research the evaporation and evapotranspiration processes on the water and soil surface. For this purpose, daily measurements were made on evaporation and evapotranspiration from bare soil and covered with different types of vegetation, as well as, on the determining climatic parameters (precipitation, soil and water temperature air temperature and humidity, atmospheric pressure, sunshine duration, wind speed and radiative factors). The soil within the station has a medium loamy and clay texture, with a composition of over 35% clay, over 30% fine sand and 30% dust; the composition of humus is 4%, making it a fertile soil.

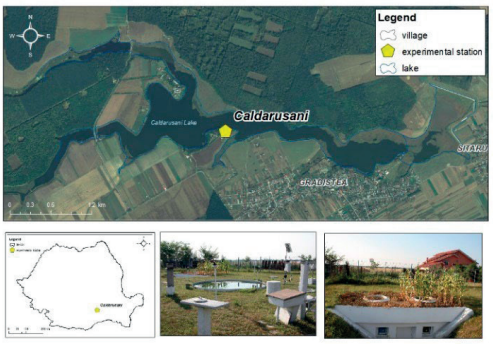

Figure 1. Căldărușani experimental station

The area around the station is covered by crops, such as: wheat, maize, sunflower and legumes. The climate for the period 2021-2023 indicates an increase of air temperature and solar radiation. Regarding the air temperature, the differences exceed 2°C, compared to multiannual averages (reference period 1981-2010). Also, the precipitation regime during this period (2021-2023) was deficient, the average precipitation was 400 mm and they were concentrated during the months of April-June. The crop evapotranspiration was ~340 mm for the maize, ~420 mm for the sunflower and ~455 mm for the oat (during the period of April-September). At daily step, the values of maximum crop evapotranspiration exceed 9-10 mm/day, on the days when the air temperature was 35°C, the humidity had values of 70-80% and the sunshine duration reached 10-12 hours/day.

RESULTS AND DISCUSSIONS

Thus, during the years 2021 and 2022, the experimental planted crops were: sunflower, maize and oats. For the modelling of evapotranspiration and irrigation requirements by using CropWat model, some information related to soil was specified: chernozem soil type, maximum infiltration rate of 24 mm/day and initial depletion percentage of 10% (analyzing infiltration data from previous years).

To identify the periods with crop requires irrigation, the model takes into account the effective rain and the evapotranspiration during each development stage. The results are presented in Table 1.

Table 1. CropWat model results for experimental crops during the period 2021-2022, planted at Căldărușani experimental station

Time (year/month)		Crop (type)	ETc	Eff. Rain	Irr. Req.	Net Irr.	
2021	1-Apr	Sunflower	9.6	45.5	0	21-Jul	108.9
	1-May		56.1	71.7	1.8		
	1-Jun		113.9	107.7	10.7		
	1-Jul		158.4	37	121.4		
	1-Aug		76.2	29.6	44.2		
	1-Apr	Oat	14.8	45.5	0	24-Jul	133.1
	1-May		102.5	71.7	30.8		
	1-Jun		118.7	107.7	14		
	1-Jul		138.4	37	101.3		
	1-Aug		19.9	15.4	5.6		
2022	1-Apr	Sunflower	11.3	45.5	0	16-Jul	110.8
	1-May		59.5	71.7	4.4		
	1-Jun		135.9	107.7	28.1		
	1-Jul		157.4	37	120.4		
	1-Aug		74.3	29.6	42.6		
	1-Apr	Maize	22.6	45.5	0	16-Jul	133.3
	1-May		73.6	71.7	9.3		
	1-Jun		148.7	107.7	41.1		
	1-Jul		171.8	37	134.8		
	1-Aug		86	29.6	54		

*ETc= crop evapotranspiration (mm), Eff. Rain. = effective rain (mm), Irr. Req. = irrigation requirement (mm), Net Irr. = net irrigation (mm)

For the crops planted experimentally in 2021-2022 in the G1 lysimeters, it is observed that the CropWat model indicates only one additional watering per year, in the second part of July (Table 1).

The maize has a period of vegetation of ~150 days. In 2022 the direct measurements of maize evapotranspiration summarized ~350 mm, while the CropWat model estimated an evapotranspiration of 500 mm and an amount of water requirement for irrigation of 240 mm. The differences are caused by reaching the critical depletion 100% and reducing the amount of water in soil to support the crop need, in order to reach the harvest period. Thus, it was observed that in the months of June and July, the differences between the values of evapotranspiration measured (by lysimeter) and estimated (by CropWat model) varied from 50 to70 mm (Figure 2).

For sunflower and oat, the evapotranspiration values measured by using lysimeter reach 400-450 mm, and the irrigation requirement for them was about 150-200 mm.

The months with highest values of evapotranspiration for the Romanian Plain, are June and July (Figure 2), when plants go through the development stage. The precipitations of June and July 2021 and 2022, were up to 3 times lower than the water losses given through evapotranspiration.

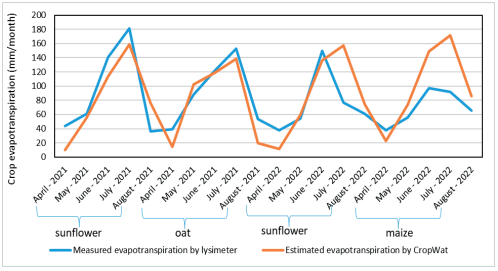

Figure 2. Monthly variation of evapotranspiration from different crops during 2021-2022, measured by lysimeter (blue line) and estimated by CropWat model (orange line)

For the year 2023, in order to estimate the additional watering carried out at the level of the maize, it was taking into account the monthly results obtained in the last years (2021-2022), and the climatic change, as well as the soil moisture dynamics.

The maize evapotranspiration, recorded during the period May-August 2023, was 325.5 mm for the crop grown under natural conditions and 400.2 mm for the one exposed to watering. High values of crop evapotranspiration were observed in July, approximately 150 mm, being cause by maximum air temperature (>39°C) and sunshine duration (11 -13 hours/day). The precipitation during July had low amount (11 mm), only three episodes of rain have been registered on the 5th, 14th and 27th. The precipitation did not cover the water need for the development of the maize, so, two additional watering were carried of 10 liters in the second half of July 2023 (Figure 3).

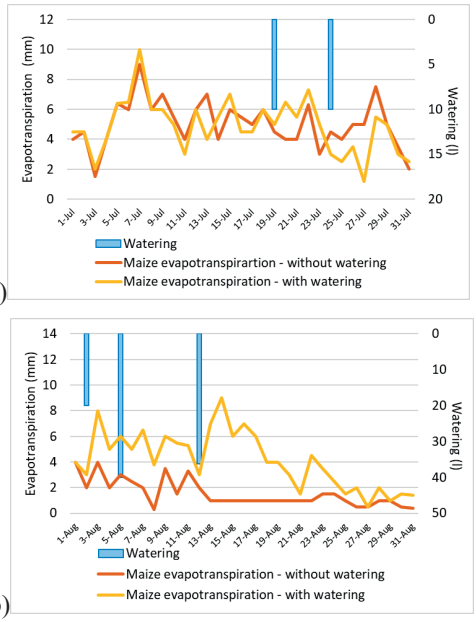

Figure 3. The daily variation of maize evapotranspiration measured at two lysimeters G1, and the watering carried out in July (a) and August (b) 2023, at Căldărușani station

In August 2023, other waterings was carried out, that totaled 100 liters. Additional waterings generated very different evapotranspiration values from one lysimeter to another. Thus, in August, the maize evapotranspiration without waterings was 50 mm, while the maize exposed to additional waterings had an evapotranspiration of 129 mm. In August, the intensification of air and soil temperature (the soil temperature at 40 cm depth, reach 27-28°C), and the amounts of precipitation were insufficient to allow the plant to develop properly, respectively they were short and had small amounts (4-5 mm/day).

According to others studies, the irrigations necessary for the optimal development of the maize are starting from the third decade of

June, and 1-5 watering can be applied with an amount between 650-3250 mc/ha (depending of the annual precipitations regime) (Groza et al., 2004). However, taking into account the fact that, the sowing of maize in 2023 at Căldărușani experimental station, was carried out with a delay of about 20-30 days, also the development stages have different period, compared to other crops from the southern part of Romania. The normal period for the sown of maize is April, when the soil temperature is around 8°C, but for this experiment, the planted date was May 11, when the soil temperature already reached 14°C. That thing causes a delay of watering, starting by the middle of July, when the maize is in the full stage of grain formation.

Regarding the evapotranspiration values, after each watering, the lysimeter exposed, yielded a greater amount of vapors to the atmosphere, reaching higher daily evapotranspiration values (> 9 mm/day).

The analyses of soil moisture values over the water supply during the development stage, indicate decreases values in July, from 25% to 18.5%, for the lysimeter without watering (Figure 4).

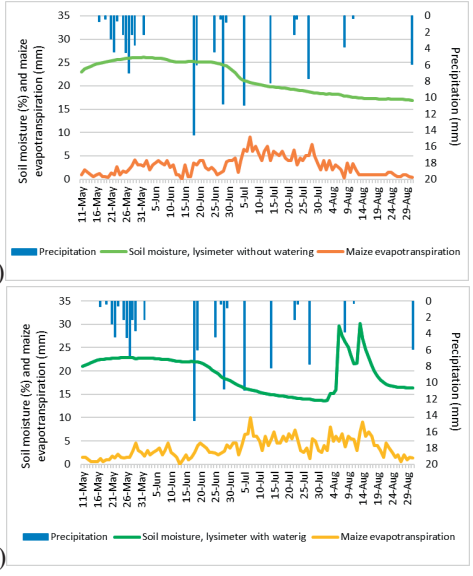

Figure 4. The daily variation of soil moisture and maize evapotranspiration from two lysimeters G1 (a - without watering; b - with watering) at Căldărușani station

The two-waterings carried out in the second half of July did not change the degree of soil moisture, but helped the plant not to reach the wilting point before the grain development.

In August it was observed that for the lysimeter without watering, the soil moisture had an average of 17.5% and varied from day to day in a percentage of 1-2%. At the level of the lysimeter exposed to watering, the average soil moisture was 19.8%, and the difference between the minimum and maximum values were about 15-20%. Throughout the experimental watering, it was observed that the soil moisture remains at high values for a period of 1-2 days, then it gradually decreases, and after 5-6 days it returns to the value held before watering. For example, on August 12, the watering added were about 40 liters; the soil moisture before the watering was 19%, and after watering 39%; the soil moisture returned to the initial value after 6 days (Figure 4).

In august 2023, at daily time step, the evapotranspiration reaches 4 mm/day in the lysimeter where no additional intervention was made, and over 9 mm/day, for the lysimeter exposed to watering (Figure 5). Thus, the large water reserves from the soil are reflected in the high values of evapotranspiration.

The difference between the evapotranspiration for crops exposed to watering, and for ones in normal climatic and pedological conditions, represents the amount of water used by plant to reach all development stages, until harvest.

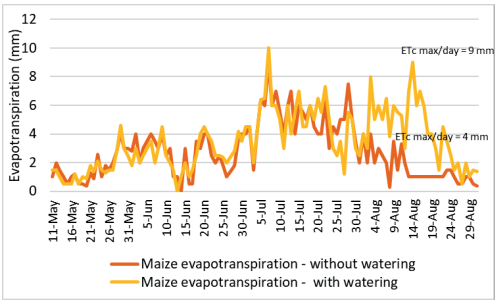

Figure 5. The daily variation of maize evapotranspiration measured in 2023, at Căldărușani station (orange line - without watering, yellow line - with watering)

This experiment proved that waterings allow crops to have normal development and to be harvested at the beginning of September. Crops with no intervention are affected by the lack of

water so, their leaves will be already dry in July and the grain will not be formed as the normal size (Figure 6).
In the context of international research, the evapotranspiration measured at Căldărușani station in the last few years (350-450 mm/year), is lower than the mean values estimated for the central and east part of Europe (between 400-800 mm/year) (Nistor et al., 2018). Due to the increase of air temperature, also an increase over the evapotranspiration values (about 50-200 mm/year) is expected at the level of Europe, only in the mountainous areas lower values are predicted.

a)  (b) 

Figure 6. Maize crop - with watering (a) photo taken on July 26, 2023 and maize crop - without watering (b) photo taken on July 29, 2022

The experiment carried out in 2023 in Romania, at Căldărușani station, indicated that evapotranspiration over this part of the county, has a decreasing trend, cause by the reduce of precipitation and soil water content. Similar results were obtained in the work of Matev and Petrova, 2011, in Bulgaria, the experiment carried out at the level of maize indicated evapotranspiration differences between irrigated crop and non-irrigated crop, of more than 140 mm per vegetative season. The biggest differences are specific to the months of July and August, when the plant needs maximum water quantities.
At the same time, the previous results are in accordance with the studies carried out at the national level, that aimed to estimate the water requirements for agricultural crops and the spatialization of evapotranspiration for different crops (Groza et al., 2004; Păltineanu et al., 2007; Stan et al., 2016).

CONCLUSIONS

Evapotranspiration is the process that can explain the connection between soil-plant-atmosphere. The importance of knowing the variation of evapotranspiration is supported by ensuring the water requirement for the optimal development of agricultural crops and increasing their yield, but also for estimating the water reserve in the soil and obtaining information regarding to hydropedological changes. The experiment carried out in 2023 draws attention to the fact that a soil with large quantities of water, produces more intense water loss in the atmosphere by intensifying evapotranspiration values (up to 9 mm/day).
The experiment carried out analysed the maize crop, and the results showed that the daily evapotranspiration can be doubled, if additional waterings are carried out especially in the months with high water need. Low precipitation values, especially in July and August months, lead to the withering of the plant, before developing the grain and ripening.
In recent years, in the southern part of Romania, the decrease of water resources, based on the reduction of precipitation - infiltration - soil moisture, leads to the decrease of evapotranspiration values. Thus, among the reducing factors of evapotranspiration, the precipitation and the soil moisture are counted.

ACKNOWLEDGEMENTS

This research work was carried out with the support of Ministry of the Environment, Waters and Forests (MEWF), within the Department of Experimental Hydrology, National Institute of Hydrology and Water Management, financed from MEWF Research thematic directions A/2023.

REFERENCES

Al Domany, M., Touchart, L., Bartout, P., Nedjai, R. (2013). The evaporation from ponds in the French Midwest, *Lakes, reservoirs and ponds*,7(2), 75–88.
Allen, R., Pereira, L., Raes, D., Smith, M. (1998). *Crop evapotranspiration - Guidelines for computing crop water requirements* - FAO Irrigation and drainage paper 56, Rome, p. 301.

Allen, R.G., Barlow, M., Byrne, M., Cherchi, A., Douville, H., Fowler, H., Gan, T., Pendergrass, A., Rosenfeld, D., Swann, A., Wilcox, L., Zolina, O. (2020). Advances in understanding large-scale responses of the water cycle to climate change, *Annals of the New York Academy of Sciences*, vol. 1472, 49–75.

Anda, A., Teixeira da Silva, J., Soos, G. (2014). Evapotranspiration and crop coefficient of common reed at the surroundings of Lake Balaton, Hungary. Aquat Bot, 116, p. 53-59.

Anderson, R., Bayer, P., Edwards, D. (2020). Climate change and need for agricultural adaptation, *Current Opinion in Plant Biology*, Vol. 56, 197–202.

Bojariu, R., Bîrsan, M., Cică, R., Velea, L., Burcea, S., Dumitrescu, A., Dascălu, S., Gothard, M., Dobrinescu, A., Cărbunaru, F., Marin, L. (2015). *Schimbările climatice – de la bazele fizice la riscuri și adaptare*, Ed. Printech.

Butler, e., Huybers, P. (2015). Variations in the sensitivity of US maize yield to extreme temperatures by region and growth phase. *Environ. Res. Lett. 10*.

Busuioc, A., Caian, M., Cheval, S., Bojariu, R., Boroneant, C., Baciu, M., Dumitrescu, A. (2010). *Variabilitatea si schimbarea climei in Romania*, Ed. Pro Universitaria.

Croitoru , A. E., Piticar, A., Dragota, C. S., Burda, D. C. (2013). Recent changes in reference evapotranspiration in Romania. *Global and Planetary Change*, 111, 127–132.

Daniel, D.F., Dallacort, R., Barbier, J.D., Camillo de Carvalho, A., Seabra Junior, A., Fenner, W. (2020). Evapotranspiration and Dual Crop Coefficient of Maize Second Season Intercropped with Crotalaria. *Journal of Experimental Agriculture International*. 42(1), 142–157.

Draguleasa, I.A., Nita, A., MAZILU, m., Curcan, G. (2023). Spatio-Temporal Distribution and Trends of Major Agriculture Crops in Romania Using Interactive Geographic Information System Mapping. *Sustainability*, 15, 14793.

Dumitrescu, A., Bojariu, R., Bîrsan, M., Manea, A. (2014). Recent climatic changes in Romania from observational data (1961-2013). *Springer - Theor Appl* 122, 111–119.

FAO (2017). Land resource planning for sustainable land management.

Gonçalves, I., Neale, C., Suyker, A., Marin, F. (2023). Evapotranspiration adjustment for irrigated maize–soybean rotation systems in Nebraska, USA, *International Journal of Biometeorology*, 67, 1869–1879.

Groza, N., Petrescu, E., Vatamanu, V. (2004). *Irigarea Culturilor – Veriga Tehnologica pentru o agricultura prospera si ecologica*, Editura Sitech.

Igbadun, H.E.; Tarimo, A.K.; Salim, B.A.; Mahoo, H.F. (2007). Evaluation of selected crop water production functions for an irrigated maize crop. *Agric. Water Manag*, 94, 1–10.

Jaleel, C.A., P. Manivannan, A. Wahid, M. Farooq, R. Somasundaram & R. Panneerselvam, 2009. Drought stress in plants: a review on morphological characteristics and pigments composition. *Int. J. Agric. Biol*., 11, 100–105.

Knezevic, M., Perovic, N., Zivotic, L., Ivanov, M., Tapalovic, A., (2013). Simulation of winter wheat water balance with CROPWAT and ISAREG Models. *Agriculture and Forestry*, 59, 41–43.

Matev, A., Petrova, R. (2011). Evapotranspiration of grain maize grown in the region of Plovdiv. *Journal of Mountain Agriculture on the Balkans*, Vol. 14, 740–752.

Neculau, G., Stan, F. (2016). Evaporation and evapotranspiration in Romania. *Forum Geografic*, Vol. XV, 39–48.

Nistor, M. M. (2018). Seasonal and annual crop evapotranspiration in Europe over 2011-2070. *Applied Ecology and Environmental Research*, 16(3), 2149–2168.

Nobre Cunha, F.N., Nobre Cunha, G., Teixeira, M.B., Da silva, N.F., Lopes, A.A. (2023), Production potential and crop evapotranspiration estimation for bean, soybean and maize using the Sebal Algorithm. *International Journal of Agriculture and Biology*, 28, no. 3, 496–506.

OECD, 2014, *Climate Change, Water and Agriculture. OECD Studies on Water*, OECD Publishing

Păltineanu, C., Chitu, E., Mateescu, E. (2012). New trends for reference evapotranspiration and climatic water deficit. *International Agrophysics*, 26, 159–165.

Rolbiecki, R., Yücel, A., Kocięcka, J., Atilgan, A., Markovic, M., & Liberacki, D. (2022), Analysis of Drought During Maize Growing Period - a Case of Çukurova Region (Türkiye). *Sustainability*, 14.

Rolbiecki, R.; Rolbiecki, S.; Figas, A.; Jagosz, B.; Prus, P.; Stachowski, P.; Kazula, M.J.; Szczepanek, M.; Ptach, W.; Pal-Fam, F.; Sadan, H.A.; Liberacki, D. (2021). Response of Chosen American Asparagus Officinalis L. Cultivars to Drip Irrigation on the Sandy Soil in Central Europe: Growth, Yield, and Water Productivity. *Agronomy*, *11*, 864.

Ruth, C., Michel, D., Hirschi, M., Seneviratne, S. (2018). Comparative Study of a Long-Established Large Weighing Lysimeter and a State-of-the-Art Mini-lysimeter. *Vadose Zone Journal*, 17, 1–10.

Sanchez-Lorenzo A. (2014), Evaporation trends in Spain. Acomparison of Class A pan and Pich´e atmometer measurements. *Clim. Res,* 61 (3), 269–280.

Smuleac, L., Rujescu, C., Smuleac, A., Imbrea, F., Radulov, I., Manea, D., Ienciu, A., Adamoc, T., Pascalau, R. (2020). Impact of Climate Change in the Banat Plain, Western Romania, on the Accessibility of Water for Crop Production in Agriculture. *Agriculture,* 10, 437.

Stan, F, Neculau, G. (2014). Implementation of some calculation methods of the evaporation in the catchments of Prut and Bârlad Rivers. *Air and water components of the environment*, 219–226.

Stan, F., Zaharia, L., Neculau, G., Ioana-Toroimac, G. (2015). Variabilité spatiale et temporelle de l'évaporation dans la Plaine roumaine. *Actes du Colloque de l'Association Internationale de Climatologie, 28*, 621–626.

Stan F., Neculau G., Zaharia L., Ioana-Toroimac G., Mihalache, S. (2016). Study on the evaporation and evapotranspiration measured on Căldărușani lake. *Procedia Environmental Sciences, 32*, 281–289.

Stăncalie, G., Marica, A., Toulios L. (2010). Using earth observation data and CROPWAT model to estimate the actual crop evapotranspiration. *Physics and Chemistery of the Earth*, 35, 25–30.

Straffelini, E., Tarolli, P. (2023). Climate change-induced aridity is affecting agriculture in Northeast Italy. *Agricultural Systems* 208, 103647.

Velea, L., Bojariu, R., Burada, C., Udristoiu, M., Paraschiv, M., Burce, R. (2021), Characteristics of extreme temperatures relevant for agriculture in the near future (2021-2040) in Romania. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*. Vol. X, 70–75.

Vicente-Serrano, S.M., Lopez-Moreno J.I., Begueria S., Lorenzo-Lacruz J., Sanchez-Lorenzo, A., Garcia-Ruiz J.M., Azorin-Molina C., Moran-Tejeda, E., Revuelto J., Trigo R.M., Fatima Espirito Santo Coelho, Espejo F. (2014). Evidence of Increasing Drought Severity Caused by Temperature Rise in Southern Europe. *Environmental Research Lettres*, 9(4), 1–9.

Wu, L., Elshorbagy, A. M., Helgasoon, W. (2023). Assessment of agricultural adaptations to climate change from a water-energy-food nexus perspective. *Agricultural Water Management*, 284, 1–13.

Xu, K.; Yang, D.; Yang, H.; Li, Z.; Qin, Y.; Shen, Y. (2015). Spatio-temporal variation of drought in China during 1961–2012: a climatic perspective. *J. Hydrol*., 526, 253– 264.

Yao, Y., Liao, X., Xiao, J., He, Q., Shi, W. (2023). The sensitivity of maize evapotranspiration to vapor pressure deficit and soil moisture with lagged effects under extreme drought in Southwest China. *Agricultural Water Management*, 277, 1–11.

Zukowska, G., Myszura, M., Baran, S., Wesolowska, S., Pawlowska, M., Dobrowolski, L. (2016). *Agriculture Vs. Alleviating the Climate Change, Problems of Sustainable Development* (2), 67–74.