INVESTIGATION OF THE RELATIONSHIP BETWEEN THE EVAPORATION AND METEOROLOGICAL VARIABLES FOR DIFFERENT CLASS A PAN TREATMENTS

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Abstract

Evaporation is a key member of the hydrological cycle. Climate change requires a more accurate understanding of the process. In addition to physical processes, the evaporation of open water is also influenced by biological factors (eg aquatic plants). To better understand the phenomenon, an experiment has been set up in 2020 growing season: in addition to the traditional use of Class A pan (WMO), the presence of sediment and submerged macrophyte (*Myriophyllum* sp., *Potamogeton* sp., and *Najas* sp.) was also ensured in the Class A pan's. The Class A pan's were located in an open area at the Agrometeorological Research Station in Keszthely. Meteorological variables were also measured at the Station (air temperature, precipitation, relative humidity, solar radiation, wind speed). The aim of the study was to determine the effect of sediment and macrophyte on evaporation and explore the relationship between evaporation and meteorological variables. The results showed that the presence of both

sediment and submerged macrophyte increased evaporation. Among the meteorological variables, solar radiation and air temperature showed the closest relationship with evaporation.
Keywords: evaporation, class A pan, sediment, macrophytes

Összefoglalás

A párolgás a hidrológiai ciklus kulcsfontosságú tagja. Az éghajlatváltozás következtében a folyamat pontosabb megértése nélkülözhetetlen. A fizikai folyamatok mellett a nyílt víz párolgását biológiai tényezők is befolyásolják (pl. vízi növények jelenléte). A jelenség jobb megértése érdekében egy kísérletet állítottunk be 2020 tenyészidőszakában: a párolgásmérő A kád (WMO) hagyományos alkalmazása mellett az A kádakba üledéket és alámerülten élő, gyökerező hínárnövényeket telepítettünk. Az A kádak a keszthelyi Agrometeorológiai Kutatóállomáson voltak elhelyezve, nyílt területen. Az állomáson a meteorológiai változókat is mértük (levegő hőmérséklete, csapadék, relatív páratartalom, sugárzás, szélsebesség). A vizsgálat célja az iszap és a hínárnövények párolgásra gyakorolt hatásának meghatározása volt. Célkitűzés volt továbbá a párolgás és a meteorológiai változók kapcsolatának vizsgálata is. Az eredmények azt mutatták, hogy mind az üledék, mind a hínárnövények jelenléte fokozta a párolgást. A meteorológiai változók közül a sugárzás és a levegő hőmérséklete mutatta a legszorosabb kapcsolatot a párolgással.
Kulcsszavak: párolgás, párolgásmérő A kád, iszap, hínár

Introduction

Evaporation is a key member of the hydrological cycle that is responsible for water loss. Accurate estimation of evaporation is of great importance, especially in regions with limited water resource. According to some estimates, 61% of the fallen precipitation evaporates

(Alsumaiei, 2020). Therefore, the accurate estimation of evaporation rates using is a vital task for hydrologic engineering, water resources management and agriculture (Deo & Samui, 2017). The effects of climate change are becoming more pronounced, and this process may also have an impact on evaporation.

Lake or water reservoir evaporation is rarely measured directly. Different evaporimeters instruments may be used in different countries to approximate the evaporation of natural water surfaces. The most common indirect method is the measurement of pan evaporation. The World Meteorological Organization (WMO) recommends Class A pan for measuring evaporation.

Since evaporation is a complex operation, a reliable formula to represent all the physical processes involved is difficult to obtain. Several researchers have tried to use meteorological variables to forecast pan evaporation values (Adnan et al., 2020; Alizamir et al., 2020). In addition to physical processes, biological phenomena (plants) present in water can also affect evaporation. Important evaporation differences among open water evaporation and aquatic plant evapo(trans)piration covers have been reported around the world (Pauliukonis & Schneider, 2001; Goulden et al., 2007).

In the present study, we sought to answer how the presence of litter sediment and aquatic macrophyte affects daily pan evaporation. Aim study was to determine the relationship between different pan treatments and meteorological variables in 2020 growing season.

Material and method

In this study, pan evaporation (E_p) and meteorological data in the Agrometeorological Research Station of Keszthely (latitude: 46° 44′ N, longitude: 17° 14′ E, elevation: 124 m above sea level) investigated. The station follows standard methods of observation for data collection as per the World Meteorological Organization guidelines (WMO, 2012). The combined sensor was placed at a standard height 2 m above ground level. Signals from air temperature (T_a, °C), relative humidity (*RH*, %), wind speed (*u*, m s^{-1}) and solar radiation (*Rs*, W m^{-2} day^{-1}) were collected every 2 s, and 10-min averages were logged. The height of the anemometer was 10.5 m above ground level. The Class A pan are circular cylinders of 1.21 m diameter and 0.255 m depth mounted on an elevated 0.15 m height open frame wooden grid set on the ground (Figure 1). Daily E_p rates, which were adjusted to precipitation, were measured manually at 7.00 a.m. every morning.

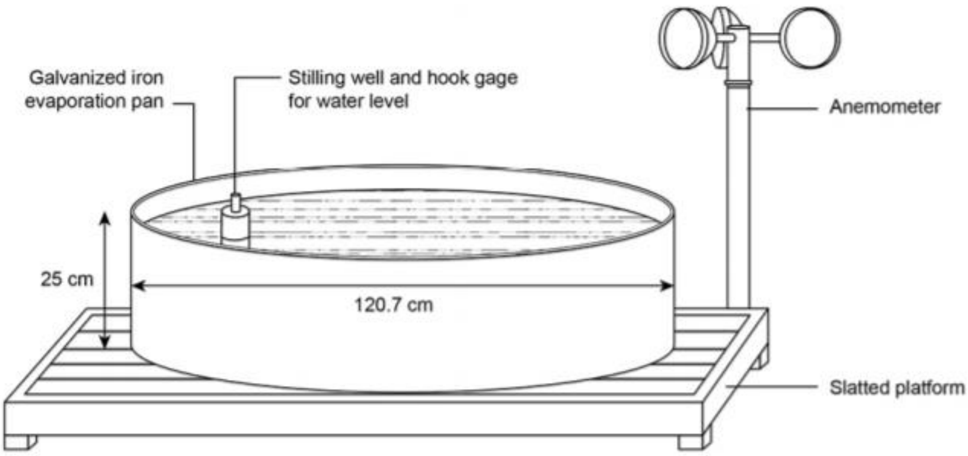

Figure 1 Illustration of a standard Class A pan (Alsumaiei, 2020)

Three pan treatments have been set:

- control pan, *C*;
- pan was supplemented with a 0.05 m thick littoral sediment layer that covered the bottom, *S*;
- pan was planted with littoral sediment and submerged macrophytes (*Myriophyllum* sp., *Potamogeton* sp., and *Najas* sp.), *SM*.

We used three submersed macrophyte species in the *SM* pan treatment, which can be found in the Keszthely-Bay in the summer season.

We used Microsoft Excel and SPSS software packages to evaluate the data.

Results and discussion

The highest daily maximum E_p rates were always measured in Class A pan with macrophytes, while the lowest in the "empty" pan (control). The daily measured E_p rate for *C*, *S* and *SM* averaged 3.17±0.95, 3.39±0.98 and 3.65±1.05 mm day^{-1}, respectively, during in 2020 growing season. A paired-type t-test was conducted to explore the impact of the studied pan treatments on E_p rates. There was significant difference neither between the E_p of *C* and *S* (p=0.1014) nor between E_p of *S* and *MS* (p=0.0700). However, E_p of *C* treatment was significantly different from that of *SM* (p<0.001). The E_p of *S* fitted better to E_p of *C* (R^2=0.9597), while in the case of *SM* the relationship is less close (R^2=0.9268) (Figure 2).

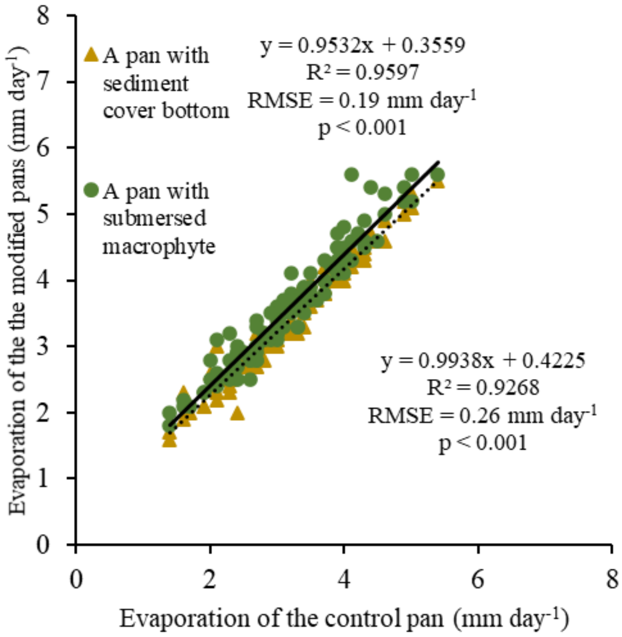

Figure 2. Relationship between evaporation of standard Class A pan and modified Class A pan's

To date, there is few information about the impact of submerged macrophytes on pan/open water E_p rate. According to a previous study aquatic plants evapotranspirated 26% more water than that of the free water surface (Brezny et al., 1973). Anda et al. (2016; 2018a,b) have shown that the presence of sediment increases the evaporation of the Class A pans by an average of 12.7% and the submerged aquatic macrophytes by an average of 21.3%. Jiménez-Rodríguez et al. (2019) reported that the observed E_p were higher for aquatic plants than the open water cover.

The relationship between E_p and meteorological variables (Figure 3) is very complicated, for that reason it's difficult to analyse (Wang et al. 2017, Kisi, 2015; Kim et al., 2015). The highest correlation coefficients were observed between E_p rates of *C* and *Rs* (R=0.6159). Meteorological variables related to available energy (such as *Rs*, T_a), the most relevant factor in E_p of Class A pan (Chen et al., 2019). A positive correlation was observed with most meteorological variables (T_a, *Rs*, *u*), while a negative correlation was observed with *RH* (R=-0.1942 for *SM* and R=-0.2286 for *C*). This result is supported by other research in the literature (Sheffield et al., 2006; An et al., 2017). In this study, *u* hardly affected the E_p rates of each treatment. This does not confirm the conclusions made by earlier studies (McVicar et al., 2012).

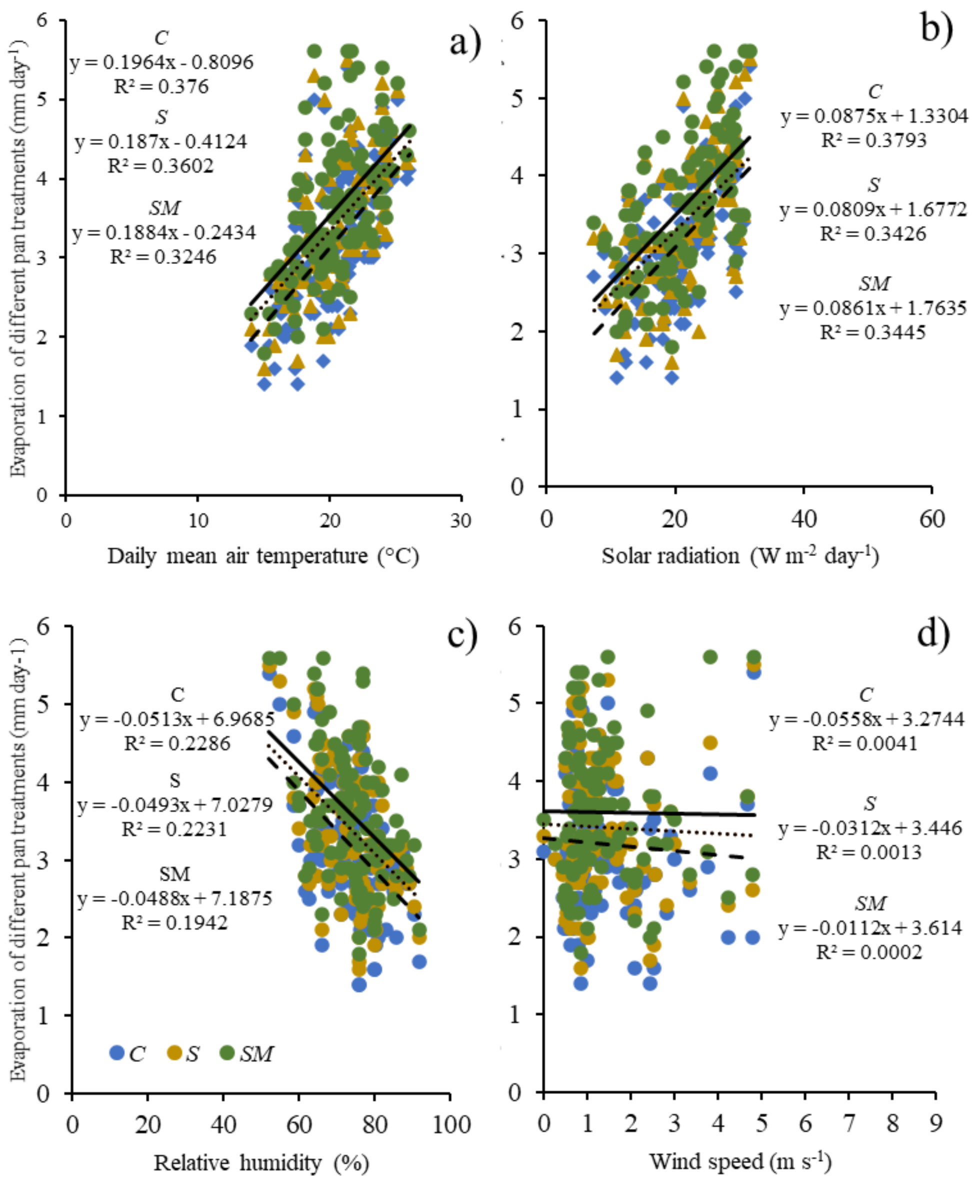

Figure 3. Relationship between evaporation of different pan treatments (control pan, C, pan with sediment cower bottom, S and pan with submersed macrophyte, SM) and meteorological variables (air temperature, °C – a), solar radiation, W m^{-2} day^{-1} – b), relative humidity, % – c), wind speed, m s^{-1} – d))

This may be due to the fact that Keszthely (and Agrometeorological Research Station) is sheltered by surrounded mountains causing lower wind speeds (Anda et al., 2016). Jiménez-Rodríguez et al. (2019) described a lower value for the correlation between evapotranspiration of *T. geniculata* and *u*. Stepwise regression analysis showed that *Rs* and *RH* impacted the E_p rate the most, regardless of treatment (Table 1).

Table 1 Multiple stepwise regression analysis between meteorological elements and measured Class A pan evaporation: "empty" pan (C), pan with sediment (S) and pan with macrophyte (SM) during 2020 growing season

	R^2	F	F sig.	SE	Regression equation
C					
Model 1	0.484	96.76	0.000	*Konst.* = 0.251 *Rs* = 0.011	$E_p = 0.111Rs + 0.796$
Model 2	0.552	62.73	0.000	*Konst.* = 0.937 *Rs* = 0.013 *RH* = 0.01	$E_p = 0.06Rs - 0.039RH + 4.34$
S					
Model 1	0.511	107.74	0.000	*Konst.* = 0.250 *Rs* = 0.011	$E_p = 0.116Rs + 0.892$
Model 2	0.571	67.89	0.000	*Konst.* = 0.938 *Rs* = 0.013 *RH* = 0.01	$E_p = 0.087Rs - 0.038RH + 4.315$
SM					
Model 1	0.585	154.46	0.000	*Konst.* = 0.247 *Rs* = 0.011	$E_p = 0.133Rs + 0.777$
Model 2	0.654	96.44	0.000	*Konst.* = 0.903 *Rs* = 0.014 *RH* = 0.01	$E_p = 0.099Rs - 0.043RH + 4.711$

Conclusion

In this study increased evaporation was measured in the modified Class A pans, a larger increment at the submerged macrophytes and lower at the sediment cover use. The relationship between evaporation of different Class A pan treatments and meteorological variables was similar. Higher R^2 values were usually observed in *MS*. Higher R^2 values between the E_p of *SM* and R_s and T_a implied that evaporation was mainly controlled by available energy in 2020 growing season. The regression equations in Table 1 provide an opportunity to estimate the E_p of different Class A pan treatments from meteorological variables.

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