Asian Journal of Applied Sciences (ISSN: 2321 – 0893)
Volume 03 – Issue 06, December 2015

Determining Hourly Evaporation Measurement Accuracy of Small Pans in Comparison with Class-A Pan

Mohammad Amir Azimi[1], Mohammad Javad Manshti[2,*], Amir Ghods Motahari[3], Amin Karami[4], Kourosh Rostami[5]

[1]Department of Water Resources Engineering, College of Agriculture and Natural Resources
Kermanshah, Iran

[2]Department of Water Resources Engineering, College of Agriculture and Natural Resources
Kermanshah, Iran

[3]Department of Water Resources Engineering, Isfahan University of Technology
Isfahan, Iran

[4] Department of Water Resources Engineering, College of Agriculture and Natural Resources
Kermanshah, Iran

[5] Department of Water Resources Engineering, College of Agriculture and Natural Resources
Kermanshah, Iran
kouroshrostami_71@yahoo.com

[*]*Corresponding author's email: Mjmanashti [AT] gmail.com*

ABSTRACT— ***Because of their convenience and low costs, various types of evaporation pans have been used as a common instrument for measuring evaporation. These pans differ from each other in terms of shape and size. When it comes to tropical areas with high evaporation and short supply of water, refilling evaporation pans on a daily basis is a big challenge. Thus, big pans cannot be easily used in such environments because long term data collection requires proximity to water resources near the weather station. An alternative solution in such conditions is utilizing smaller pans. The present study aimed at comparing the accuracy of evaporation data obtained from evaporation pans with minimized diameters and those collected from standard Class-A pan. It also intended to find out the factors that could influence the accuracy of the collected data. To this end, four cylindrical evaporation pans with diameters of 60, 45, 30, and 15cm and the depth of 25cm were designed. Evaporation heights of these pans were compared with that of Class-A. RMSE and MBE indices as well as t-test results showed that minimizing pan diameter will increase evaporation height, hence reducing the accuracy of obtained data. It was also discovered that, out of all the small pans, the pan with the 60cm diameter is the most suitable evaporation measurement instrument.***

Keywords—evaporation pans, weather station, small pans, water resources, Class-A pan

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1. INTRODUCTION

Measuring water evaporation from the ground surface is of crucial importance to a wide range of research areas and sciences including water resource management, agriculture, and meteorology. Out of numerous direct and indirect methods proposed for evaporation measurement, using evaporation pan is the most common method because of its low manufacture and maintenance costs (Stanhill, 2002). In fact, evaporation pans constitute one of the main instruments in weather stations for determining water requirements, estimating evaporation from lakes and dam reservoirs and many more water resource management studies. There are different types of evaporation pans, the most popular of which are American Class-A evaporation pan, Russian GGI-3000 pan, English standard evaporation pan, and Russian 20 m^2 tank. The most common type of evaporation pan in many countries is Class-A, which is made of galvanized iron and has a diameter of 1207mm and a depth of 254mm (WMO). Evaporation pans differ from each other in terms of size, shape, and installation practices. Russian GGI-3000 pan, for example, has a depth of 60cm and is buried in the ground, while Class-A pan rests on a 15cm high wooden base. Evaporation pans' specific features have brought them advantages and disadvantages. For instance, with respect to the pans that are buried in the ground, there is no energy exchange between the atmosphere and the pans. Also, the advantage of pans which are installed above the ground level is that existing leakage in their body can be easily detected and repaired (WMO).

A large number of studies have compared evaporation pans. Masoner et al. (2008)made a comparison between floating and Class-A pans and concluded that, for lakes smaller than an area of 10000 m^2, floating pan evaporation was significantly lower than that of Class-A pan. They also indicated that the evaporation ratios of floating to Class-A pan were 0.82, 0.87, 0.85, 0.79, and 0.69 for March, April, May, June, July, and August, respectively.

One of the main challenges in the course of conducting a research project is having access to a water resource to refill the pans on a daily basis. This problem is exacerbated in distant, tropical areas, particularly during hot months. The current study was an attempt to investigate the influence of minimizing the evaporation pan diameter on the accuracy of obtained data. Class-A pan was used as the reference evaporation measurement tool. Designing smaller evaporation pans reduces manufacturing, maintenance, and relocation costs (especially in automatic models). It also facilitates the refilling process in regions where water resources may not be available for long periods of time.

2. MATERIALS AND METHODS

In order to study the effect of pan size on evaporation height, four different pans with diameters of 60, 45, 30, and 15cm (known as A, B, C, and D pans) were designed. For making the comparison possible, their depth was the same as that of standard Class-A pans and all were made of galvanized iron. The experiments were conducted in the research station of Faculty of Agriculture, Razi University of Kermanshah (34°19'26.88"N and 47° 5'55.73"E).The surrounding environment was covered with soil. Data collection took place on an hourly basis from October 1, 2013 through November 23, 2013. Evaporation height was measured through taking photos of ducts connected to evaporation pans. More precisely, each of the pans was connected to a glass duct and changes in the height of the water inside these ducts were the indicators of evaporation height.

2.1 Statistical analysis

Mean hourly evaporation from all pans during experiment is shown in figure 1. It is obvious that decreasing pans diameter resulted in increase of evaporation .The method proposed by Jacovides C.P (1995) was used to compare the evaporation data obtained from 60, 45, 30, and 15cm pans with those of the Class-A pan. In this method, the following equations are used to calculate RMSE (root mean square error), MBE (mean bias error), r (correlation coefficient) and t (t-test):

Equation 1:

$$r = \frac{\sum_{i=1}^{n}(O_i - O_m)(P_i - P_m)}{\sqrt{\sum_{i=1}^{n}(O_i - O_m)^2 (P\_i - P\_m)^2}}$$

Equation 2:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}}$$

Equation 3:

$$MBE = \sum_{i=1}^{n}(P_i - O_i)/n$$

Equation 4:

$$t = \sqrt{\frac{(n-1)MBE^2}{RMSE^2 - MBE^2}}$$

In these equations, n refers to the number of data, P_i and P_m are the evaporation height and evaporation mean of the studied pans, respectively. Also, O_i is the evaporation height and O_m refers to the evaporation mean in the Class-A pan.

3. RESULT AND DISCUSSION

As mentioned above, data obtained from Class-A pan were considered as the reference against which the accuracy of data collected from smaller pans was assessed. Table 1 illustrates statistical indices proposed by Jacovides C.P. et al. (1995) for the 60, 45, 30, and 15cm pans.

	Mean	**RMSE**	**MBE**	***r***	***t***
A	0.240	0.226	0.050	0.527	6.287
B	0.279	0.273	0.092	0.523	9.703
C	0.292	0.266	0.098	0.571	10.832
D	0.362	0.361	0.159	0.538	13.530

Table 1: The Results of Statistical Analyses Related to Each Pan

RMSE and MBE parameters indicate the proximity of data obtained from studied pans and those gathered from the reference (Class-A) pan. In fact, the more the RMSE and MBE values get to zero, the more desirable the results would be. Thus, all designed pans (including A, B, C, and D) yielded suitable values for these two indices. The fact that MBE values are positive demonstrates that evaporation height was higher in the small pans compared to Class-A pan. The RMSE and MBE values for pan A are 0.226 and 0.05, respectively. These are good values indicating the accuracy of the designed pan in measuring evaporation height (in comparison with Class-A pan). Furthermore, RMSE values for the other pans (B, C, and D) were 0.273, 0.266, and 0.361, respectively, while MBE values for these pans were 0.092, 0.098, and 0.159, in the same order. Therefore, the two indices of RMSE and MBE yielded proper values for all the pans. Additionally, from A to D (save for C), a decreasing trend in the abovementioned values could be observed.

3.1 Final judgment

Although RMSE and MBE are suitable indices for determining the reliability of the experiment, the final judgment is made on the basis of t-test results since both RMSE and MBE parameters are taken into account in its formula. The smaller the t value, the closer the measured evaporation height to that of the benchmark pan. As the results indicate, pan A is the most similar one to Class-A pan in terms of evaporation height. The increasing trend in evaporation height and the declining tendency of t from pan A to D demonstrate that as pan diameter gets smaller, evaporation height goes up and, compared to Class-A pan, measurement reliability reduces. The correlation index, which was 0.527 for pan A, experienced a downfall trend, reaching 0.289 for pan D. None of the correlations between the studied pans and the benchmark one were satisfactory, which may be attributed to the measurement instrument (i.e. the installed camera). That is, in each evaporation duct photo, a pixel is equal to 0.22mm, meaning that registered numbers for evaporation are a multiple of 0.22mm. This big value leads to huge jumps in the evaporation diagram. Given that during the experiment period (from the 1st to the 23rd of October) hourly evaporation was slow, these big jumps have significantly reduced correlations.

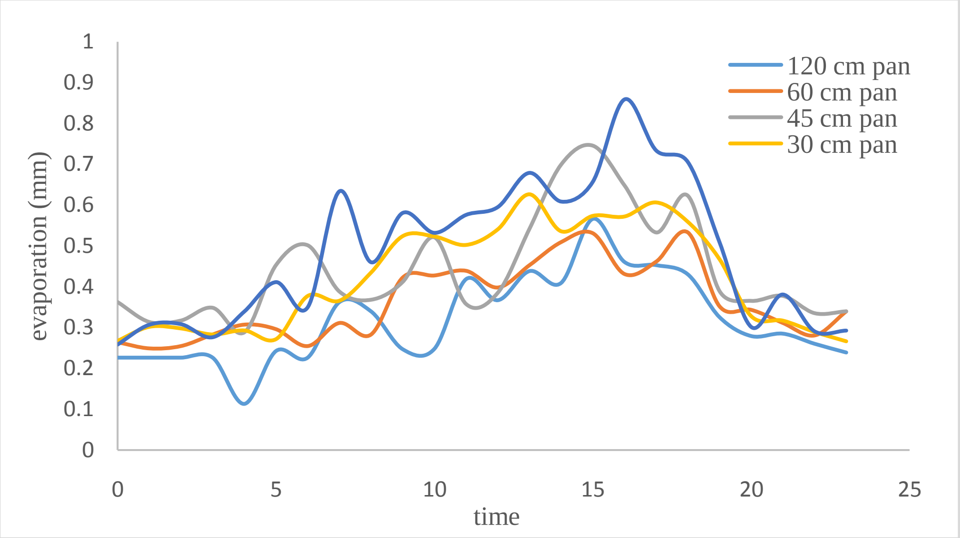

Figure 1:Mean Hourly Evaporation

3.2 Future studies

In order to enhance correlation up to the desirable value, in future studies, the measurement unit will be reduced by 0.01 mm. This will be achieved through replacing the current camera with another one that has a higher pixel density. As it was observed, minimizing pan diameter reduces evaporation height.

Furthermore, in future studies, attempts will be made to find an equation for converting evaporation height of small pans to pure evaporation height of Class-A pan. This will help us calculate evaporation and transpiration for Class-A pan based on the evaporation height obtained from smaller pans.

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