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RESEARCH ARTICLE **(Open Access)**

Comparing ET_P calculated by penman-Monteith formulae with the evaporation from a free water table in the field of Kosovo

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Abstract

The study was carried out in two particular areas of "The Field of Kosovo", Komoran and Vushtri, both significantly representing the region. A meteorological station was set up in each location. The meteorological stations were equipped with the necessary devices to measure the sun radiation, relative humidity, wind speed and air temperature. A particular computer program was installed to convert automatically the data measured by the devices into potential evapotranspiration, expressed as mm evaporated water per day, calculated based on the Penman-Monteith formulae. Simultaneously, for each experimental trial, the water evaporated from the evaporimeter Pan A was measured,at least 3 times a day, according to a well determined schedule. Both, the potential evapotranspiration data as it is calculated and the evaporimeter Pan A data were compared to each other at the very same time. The differences were significant in both locations, Komoran and Vushtri.

Keywords: potential evaporation • Penman Monteith formulae • sun radiation • wind velocity • relative humidity • air temperature •modifying coefficients.

1. Introduction

Among various methods to calculate the potential evaporation, the Penman method is considered to be more complex, physically well based [5], [6] and [7] and as a result of this, a method widely applicable. Furthermore, the Penman method was combined with the Monteith effort being summarized in the so called Penman-Monteith method, [10] is already the method recommended by FAO to be used for computing the potential evapotranspiration. This method is also recommended for Kosovo by the scientific foreign advisers in the process of revitalizing the water resources for plant production purposes.

To calculate the potential evapotranspiration by Penman-Monteith method, the information about sun radiation, wind speed, relative humidity and air temperature is necessary. Collecting and using all of these data is certainly a process requiring money and labor, which makes its applicability rather expensive. Therefore, quantifying the relationship between the Penman-Monteith method and some other simpler and less costly methods in potential evapotranspiration computing is required from both scientific and economic point of view. The effort made in this study is focused on establishing the relationship between both: potential evapotranspiration calculated by the Penman-Monteith method and evaporation from a free water table measured by evaporimeter Pan A. Theoretically, the relationship in both mentioned directions is supposed to be a causal relationship [1]; [2]; and [3], which means that factors causing the potential evapotranspiration calculated by Penman-Monteith method are the same as those causing the water evaporation from free water surface of the evaporimeter Pan A. The purpose of this study is to quantify these relationships, find out the strength of dependencies and, of course, differences among them. This effort would help to find out the most realistic method to be used for replacing the Penman-Monteith method (which requires labor and is expensive), at the same time maintaining the accuracy in an acceptable level.

2. Materials and methods

1.1 The study area and devices

To fulfill the aim of this study, two locations were chosen in the Field of Kosovo: Vushtrri and Komoran. The study period includes about 110 days, mainly in summer time, a period in which it is supposed that the evapotransipration prevails over the rainfall. An experimental trial was established in each location. Each experimental trial was comprised of a digitalized meteorological system by which sun radiation, wind speed, relative humidity and air

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temperature were measured continuously, producing the magnitude of ETp calculated based on Penman-Monteith method, memorizing it automatically in the computer. Pan A evaporimeter was installed close to the digitalized system and amount of water evaporated was measured three times a day during the entire period of study. Some other devices were also installed in each experimental location to carry out other measurements not directly related to the subject of this paper.

1.2 Data analysis

The data collected on calculated ETp [8] and on evaporation from the Pan A evaporimeter (E_{evap}) were compared to each other, plotting all of them in the same graph. In each graph, the axis x represents time and the axis y represents mm of evaporated water. It was assumed that there is a dependency between calculated ETp and measured evaporation, ETp-E_{evap}. The strength of this dependency was determined by calculating the correlation between them, based on the principle that the stronger the dependency, the higher the coefficient of correlation. The significance of respective correlations were also calculated and presented.

3. Results and discussions

The results of two year researches for both locations: Komoran and Vushtrri, are presented in the tables below. Each measurement takes into consideration the two years data.

3.1 Determination of dependency of water evaporated on time in the two chosen methods

In order to have a visual dependency between the two ways of calculating and measuring the amount of water escaping as vapor from the field and from the free water surface, the data of both tables were put in a system of coordinates in which the evaporated water is expressed over time, as in the graphs below. To find out the strength of dependency, correlation coefficients as well as their respective significance were determined. In each case, blue color represents the calculated ETp by using the Penman-Monteith method and yellow color represents the water evaporated from the evaporimeter Pan A, E_{evap}.

Table1: ET_p, E_{evap} expressed as mm/day for Komoran location

Days	June		July		August		September		October	
	ETp	E_{evap}	ETp	E_{evap}	ETp	E_{evap}	ETp	E_{evap}	ETp	E_{evap}
1	--	--	3.5	1	4.4	2.8	3.8	3	1.9	1
2	--	--	1.8	1	3.7	3.1	3.8	2.7	1.8	1
3	--	--	3.1	3	4.2	2.5	3.8	3.5	2.1	2
4	--	--	5	4	4	1	5.6	3.9	2.1	1.4
5	--	--	3.2	2	3.8	2.8	3.8	2.8	2.1	1
6	--	--	3.9	2.5	4.7	3	3.5	2.7	2	2
7	--	--	4.9	3.5	5.2	3.5	3	2.9	1.7	1.5
8	--	--	5.6	4.3	5.7	5	3.2	2.1	0.8	0.5
9	--	--	5.6	4.4	2.8	1	3.3	2.2	0.8	0.5
10	--	--	5.5	4	1.5	1	3.2	1.9	1.1	1.2
11	--	--	5.5	4.1	4.8	2	3.3	2.9	2.2	1.5
12	--	--	5.2	2.8	4.4	3.2	3.2	2	--	--
13	1.4	--	5.5	3.5	4.4	3.5	3.2	2.6	--	--
14	4.8	--	5.6	4.2	4.4	2.4	3.2	2.4	--	--
15	5.3	--	5.6	4	4.3	4	3.4	2.8	--	--
16	4.7	--	5.4	3.5	4.7	3.5	3	2.8	--	--
17	4.8	3	5.4	4.1	4.7	3.2	3	2.1	--	--
18	5.5	5	5.6	4.2	4.6	3	2.7	2.2	--	--
19	6.4	5	5.9	4.7	4.4	3	3.5	3.1	--	--
20	3.9	3	6	4.2	4.9	4	1.2	0	--	--
21	5.2	4	5.1	3.5	4.9	3	1.5	0	--	--

22	5.5	3.5	5.3	2.1	4	2	2.7	1.9	--	--
23	5.7	4.5	3.2	2	4.1	3	2.2	1.9	--	--
24	5.6	4	5.6	3.2	3.9	2.5	2.5	2.4	--	--
25	2.6	1.5	4.6	2.3	4	2.4	2.5	1.2	--	--
26	4.6	2.5	4.1	3.7	3.9	3	2.6	2.4	--	--
27	4	3	4.9	3	3.6	3	3.3	2.5	--	--
28	2.8	2.5	5.3	4	4.1	3	2.9	1.5	--	--
29	2.6	2	3.6	2.2	3.3	2	2.4	1.8	--	--
30	3.4	2	3.3	2.5	3	1	2.4	2.1	--	--
31			4.3	3	4.1	1.5				
Sum	**78.8**	**45.5**	**147.1**	**100.5**	**128.5**	**83.9**	**91.7**	**68.3**	**18.6**	**13.6**
Mean	**4.37778**	**3.25**	**4.74**	**3.24**	**4.14**	**2.70**	**3.05**	**2.27**	**1.69**	**1.23**
Stdev	**1.34**	**1.12233**	**1.05478**	**0.99122**	**0.77925**	**0.94373**	**0.78901**	**0.83982**	**0.53377**	**0.507**
min	**1.4**	**1.5**	**1.8**	**1**	**1.5**	**1**	**1.2**	**0**	**0.8**	**0.5**
max	**6.4**	**5**	**6**	**4.7**	**5.7**	**5**	**5.6**	**3.9**	**2.2**	**2**

Table 2 ET_p, E_{pan} expressed as mm/day, for Vushtrri location

Days	**June**		**July**		**August**		**September**		**October**	
	ETp	**E_{evap}**	**ETp**	**E_{evap}**	**ETp**	**E_{evap}**	**ETp**	**E_{evap}**	**ETp**	**E_{evap}**
1	--	--	4.1	1	4.8	2.8	3.8	2.9	2	1.5
2	--	--	2.7	1.5	4.5	2.6	3.8	2	2.1	2.3
3	--	--	3.9	3	6	3.7	3.8	3	2.5	2
4	--	--	5.6	3.2	4	2.6	4.6	3.2	2.4	2
5	--	--	3.8	2.7	4.6	2.7	5.3	3.8	2.4	1.8
6	--	--	5.7	2	7.3	4.5	3.2	2.8	2.2	2.5
7	--	--	5.8	3.9	6.5	4	5.1	4	2.2	1
8	--	--	6.5	4	7.6	4.5	3.9	2.5	0.7	1
9	--	--	6.3	3.5	4.5	2.8	3.6	2.5	0.8	1
10	--	--	5.7	3.8	3.2	2.8	5.2	3.8	1.4	1.5
11	--	--	5.7	2.7	5.8	3.1	5.3	3.9	1.7	1.5
12	--	--	4.5	2.9	5.6	3.7	4.1	3	**--**	--
13	3.9	--	6.4	5.4	6.7	4.3	4.4	3.6	--	--
14	3.9	--	6	4.1	6.2	4.5	4.7	3.5	--	--
15	5.3	--	5.9	4.2	5.9	3.5	4.1	4	--	--
16	4.7	--	6.2	4.5	5.5	3.2	4.4	3.5	--	--
17	4.5	--	5.8	4.4	5.9	4.4	3.5	2.5	--	--
18	5.9	--	6.4	4.2	5.7	4.5	2.8	1.5	--	--
19	6.6	--	6.3	4.1	5.8	4.2	3.7	2.9	--	--
20	4.5	3.8	6	2.3	5.5	4.4	1.2	1	--	--
21	5.6	4.8	3.7	2.4	6.4	5.5	1.2	1	--	--
22	6.1	3	3.9	1.5	6.2	4.8	3.7	1.8	--	--
23	6.1	5	3.5	2.4	5.4	3.1	2.3	1.8	--	--
24	5.5	4	7	4.3	5.1	3.8	3.3	2.4	--	--
25	3.2	2.5	5.1	3.3	4.8	3	3.1	2.5	--	--
26	5.1	4	4.6	4.7	5.5	4	2.8	1.9	--	--

27	3.6	1.9	5.6	3.8	4.7	3.5	2.8	2.4	--	--
28	3.6	3	6.9	4	5	2.5	2.7	2.7	--	--
29	3.2	2	4.1	2.4	5.2	4	2.4	1.5	--	--
30	4	1.5	4.3	2.8	4.2	3.6	2.1	1	--	--
31			5.5	3.8	4.1	3.4				
Sum	**85.3**	**35.5**	**163.5**	**102.8**	**168.2**	**114**	**106.9**	**78.9**	**20.4**	**18.1**
Mean	**4.73**	**3.22**	**5.27**	**3.31**	**5.42**	**3.67**	**3.56**	**2.63**	**1.85**	**1.64**
Stdev	**1.07**	**1.18**	**1.13**	**1.34**	**0.97**	**0.77**	**1.09**	**0.91**	**0.63**	**0.52**
min	**3.2**	**1.5**	**2.7**	**1**	**3.2**	**2.5**	**1.2**	**1**	**0.7**	**1**
max	**6.6**	**5**	**7**	**5.4**	**7.6**	**5.5**	**5.3**	**4**	**2.5**	**2.5**

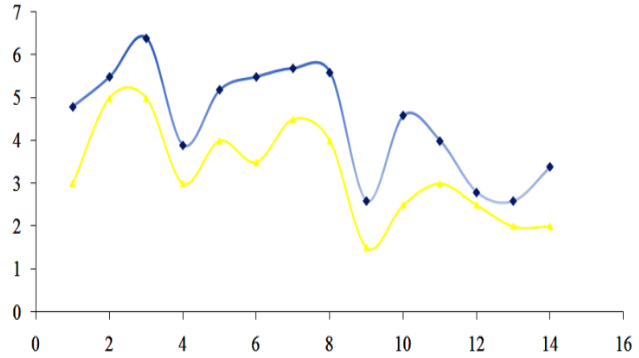

Figure 1 ETp and E_{evap} calculated and measured over time for Komoran, June.

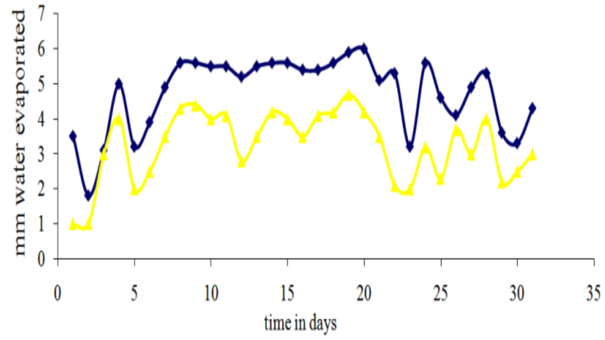

Figure 3 ETp and Eevap calculated and measured over time in Komoran, July

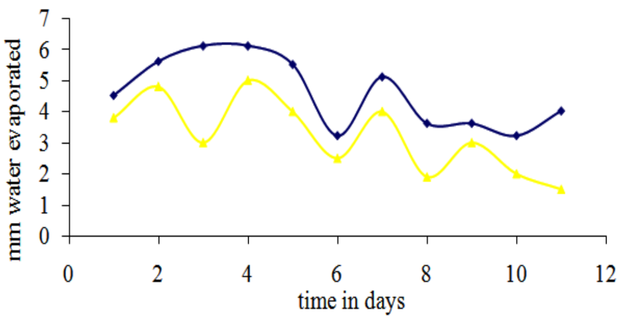

Figure 2 ETp and E_{evap} calculated and measured over time for Vushtrri, June.

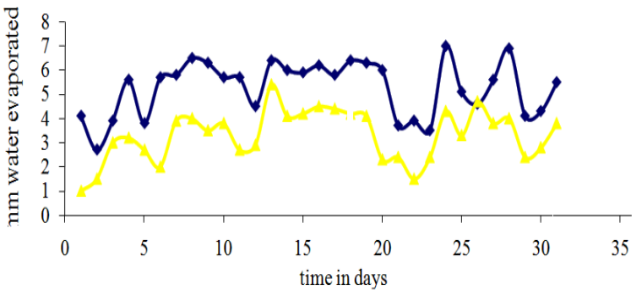

Figure 4 ETp, ETpatm and Eevap calculated and measured over time in Vushtrri, July

Table 3 Correlation coefficient (r) and coefficient of determination (r^2) for June in Komoran and Vushtrri

Location	**Correlation coefficient r**	**Coefficient of determination r^2**
	$r_{ETp-evap}$	$r^2_{ETp-evap}$
Komoran	0.9**	0.81
Vushtrri	0.76**	0.58

**Correlation is significant at the 0.01 level (2-tailed)

Table 4 Correlation coefficient (r) and coefficient of determination (r^2) for July, in Komoran and Vushtrri

Location	**Correlation coefficient r**	**Coefficient of determination r^2**
	$r_{ETp-evap}$	$r^2_{ETp-evap}$
Komoran	0.814**	0.66
Vushtrri	0.71**	0.504

**Correlation is significant at the 0.01 level (2-tailed)

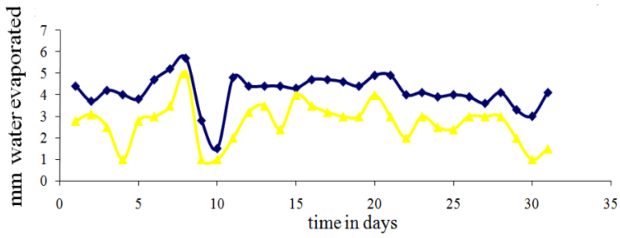

Figure 5 ETp and Eevap calculated and measured over time in Komoran, August

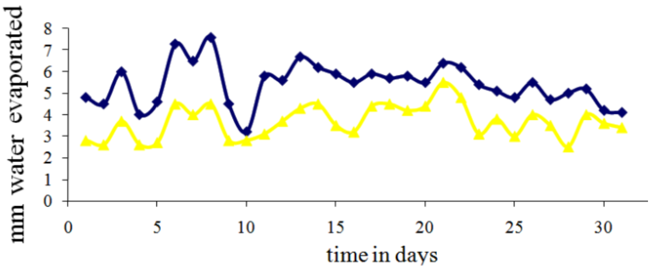

Figure 6 ETp and Eevap calculated and measured over time in Vushtrri, August

Table 5 Correlation coefficient (r) and coefficient of determination (r2) for August, in Komoran and Vushtrri

Location	**Correlation coefficientr**	**Coefficient of determinationr^2**
	$r_{ETp\text{-}evap}$	$r^2_{ETp\text{-}evap}$
Komoran	0.73**	0.53
Vushtrri	0.724**	0.52

**Correlation is significant at the 0.01 level (2-tailed)

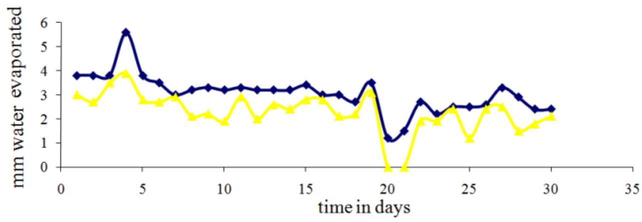

Figure 7 ETp and Eevap calculated and measured over time in Komoran, September

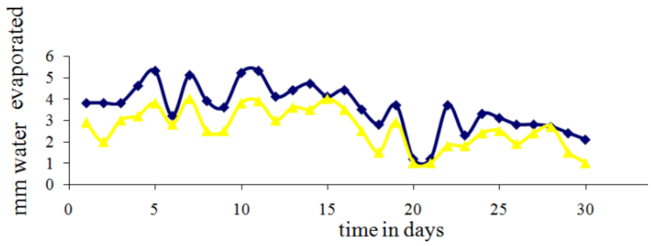

Figure 8 ETp and Eevap calculated and measured over time in Vushtrri, September

Table 6 Correlation coefficient (r) and coefficient of determination (r2) for September, in Komoran and Vushtrri

Location	**Correlation Coefficient r**	**Coefficient of Determination r^2**
	$r_{ETp\text{-}evap}$	$r^2_{ETp\text{-}evap}$
Komoran	0.852**	0.73
Vushtri	0.9**	0.81

**Correlation is significant at the 0.01 level (2-tailed)

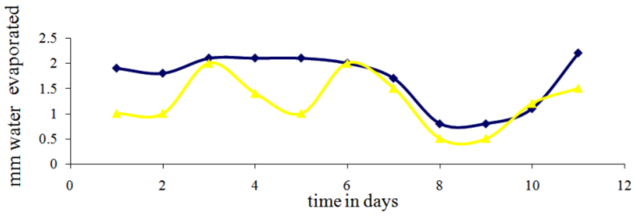

Figure 9: ETp and E_{evap} calculated and measured over time in Komoran, October

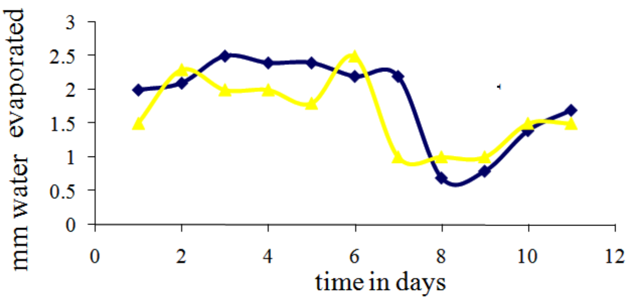

Figure 10 ETp and E_{evap} calculated and measured over time in Vushtrri, October

Table 7 Correlation coefficient (r) and coefficient of determination (r^2) for October, in Komoran and Vushtrri

Location	**Correlation Coefficient r**	**Coefficient of Determination r^2**
	$r_{ETp\text{-}evap}$	$r^2_{ETp\text{-}evap}$
Komoran	0.71*	0.5
Vushtrri	0.67*	0.45

*Correlation is significant at the 0.05 level (2-tailed)

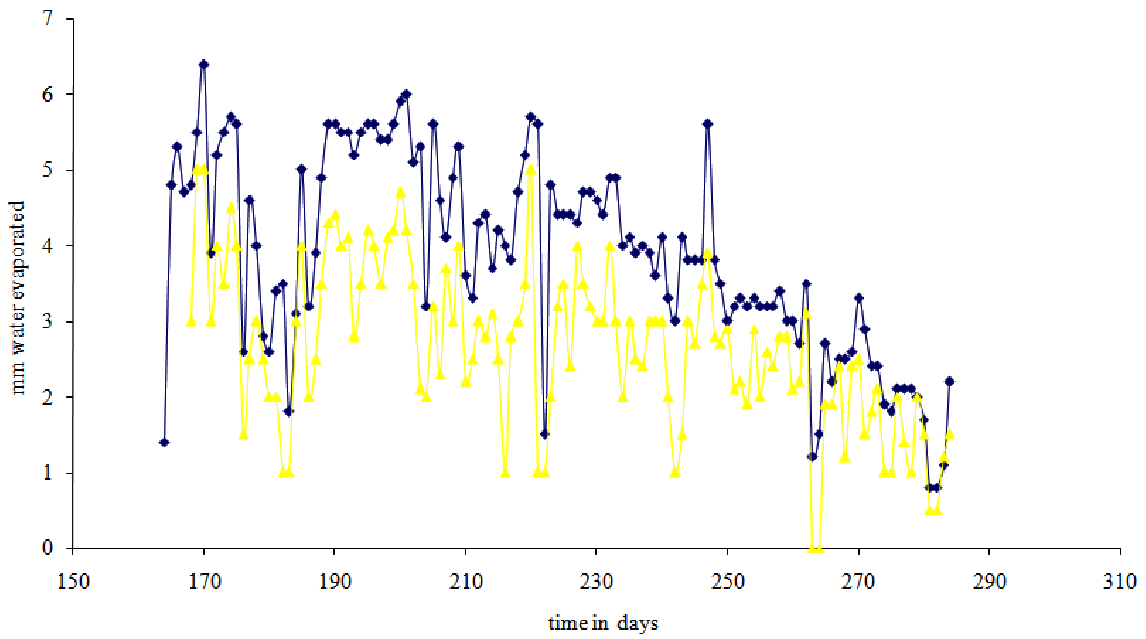

Figure 11 ETp and E_{evap} calculated and measured over the entire period of measurements, Komoran

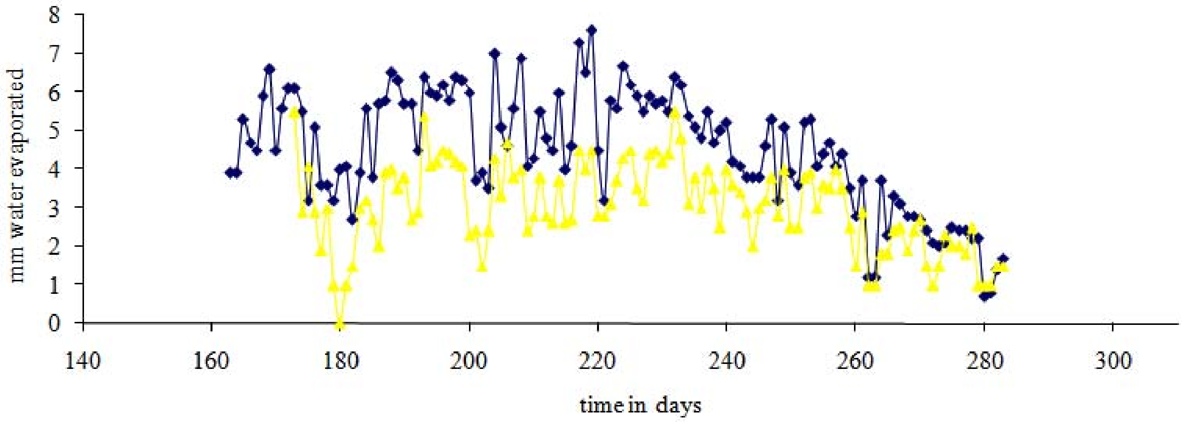

Figure 12 ETp and E_{evap} calculated and measured over the entire period of measurements, Vushtri

Table 8 Correlation coefficient (r) and coefficient of determination (r^2) for the entire period of measurements in Komoran and Vushtrri

Location	Correlation coefficient r	Coefficient of determination r^2
	$r_{ETp\text{-}evap}$	$r^2_{ETp\text{-}evap}$
Komoran	0.83**	0.69
Vushtrri	0.801**	0.64

**Correlation is significant at the 0.01 level (2-tailed)

As it can be seen, there is a correlation between evapotranspiration calculated by the Penman-Monteith and the evaporation measured by the Pan A evaporimeter. In most cases the correlation is significant at the 0.01 level, which gives us the right to think that by using just the evaporation measured by Pan A evaporimenter, it becomes possible to find out potential evapotranspiration calculated by the Penman-Monteith method. However, there is a noticeable difference in the absolute values between the ETp calculated by the Penman-Monteith method and the evaporation measured by using evaporimeter Pan A, which brings the need to find out the ratios between them. The coefficients which present the ratio ETp (Penman-Monteith) and evaporation (Pan A evaporimeter) are given in the following table:

Table 9 The ratio E/ETp for each month under consideration and for the entire period of year.

Month	E/ETp	Etp (mm)	E (mm)
	Komoran		
6	0.58	78	45
7	0.68	147	100
8	0.65	128	83
9	0.75	91	68
10	0.72	18	13
Total	**0.67**	**462**	**309**
Month	**Vushtrri**		
6	0.42	85.3	35.5
7	0.63	163.5	102.8
8	0.68	168.2	114
9	0.74	106.9	78.9
10	0.88	20.4	18.1
Total	**0.64**	**544.3**	**349.3**

The above findings are presented in the following graph. The regression analysis was done to find out the relationship that exists between the ratio E/ETp and time (over the period of year under investigation). However, right now, it can be noticed that, mostly, the ratio gets stabilized around the digits 6.5 – 7.0

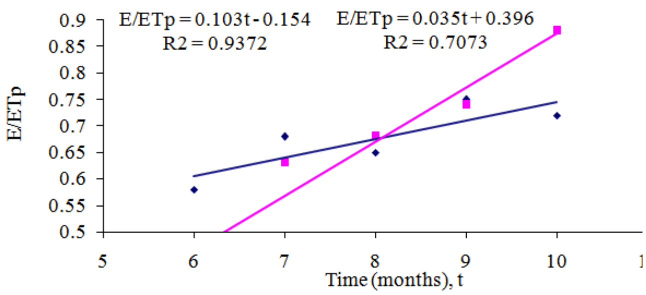

Figure 13 The function of the ratio E/ETp over time (numbers represent months) in Komoran and Vushtrri (purple color presenting Vushtrri and blue color presenting Komoran).

As it can be seen, the relationship is presented by a straight line, whose slope is greater in the case of Vushtrri. In each case, the lines show an increase of ratio over time. In the case of Vushtrri, this increase is more distinguishable than in the case of Komoran.

4. Conclusions

- The potential evapotranspiration calculated based on the Penman-Monteith method during the entire time of investigation indicates higher values compared to the results taken by the evaporimeter Pan A method.
- There is a relationship between the results generated by using the two methods and this relationship (dependency) is significant in high levels of probability.
- Clearly, the Penman-Monteith method of computing potential evaporation based on sun radiation, wind speed, relative humidity and air temperature, being that it produces greater values than those measured by Pan A evaporimeter, should be corrected in the conditions of the Field of Kosovo by using the ratio E/ETp given in this study.
- The relationship E/ETp – time is represented by a straight line, whose slope gets increased over time. It means that the Pan A evaporimeter produces closer results to Penman-Monteith method as the time goes by.

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