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Determining Best Empirical Relation in Order to Measure Monthly Potential Evapotranspiration of Qazvin in Iran

[1]Saeed Kazemi Mohsenabadi and [2]Mohammad Reza Biglari

[1]*Department of Civil Engineering, College of Engineering, Buinzahra Branch, Islamic Azad University, Buinzahra, Iran.*
[2]*Department of Civil Engineering, College of Engineering, Buinzahra Branch, Islamic Azad University, Buinzahra, Iran.*

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ABSTRACT

A considerable portion of water resources in dry and semiarid areas get inaccessible due to evapotranspiration, this is why estimation of this phenomenon has been always very crucial. A precise method to estimate evapotranspiration is using Lysimeter data, although, since Lysimeter data is not available for all areas, using empirical relations has become a common method to estimate evapotranspiration. In this paper, 14 empirical methods are applied to estimate potential evapotranspiration of Qazvin plain. The aim of this research is to compare results related to empirical relations with the values gained from evaporation pan, to determine best empirical monthly method. Considering results from this research, Blaeny-Criddle method to measure potential evapotranspiration of Qazvin plain during July, June and October and Romanenko method for August and September are recommended. It was also specified that Jensen-Haise is the most inappropriate method to estimate potential evapotranspiration in the area considered.

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INTRODUCTION

Evapotranspiration has major applications in agriculture and civil engineering e.g. runoff prediction, designing water canals, estimation of dams water loss, man-made lakes water loss and … With a rainfall level less than one third of global average and a three time evapotranspiration compared to global average, the disadvantages of this phenomenon is evident more and more in Iran. According to data from Water Resources Organization of Iran, around 70% of the rainfall during 2012 is inaccessible due to evapotranspiration. In addition, based on studies performed by Kazemi *et al* in Qazvin and in a 20-year statistical period (1991-2011), potential evapotranspiration amount during first 8 months of the year, has been 4.9 times more than total annual rainfall in this area. Up to now, many researches have been carried out on evapotranspiration and measuring it using empirical methods. In Fokuawa, Japan, Othman *et al* found out that results from Thorenthwait method are much similar to Fao-Penman-Monteith's. xu & Sing, in Canada, carried out a research on Rawson and Atikokan lakes and comparing results from empirical methods, they declared Blaeny-Criddle as the best method to estimate potential evapotranspiration of the lakes. In a comprehensive and similar research on Qazvin plain during a 16-year statistical period, Kazemi *et al*, comparing results from 14 empirical methods with evaporation basin data, suggested Romanenko and Blaeny-Criddle methods, in order, as the most appropriate methods to measure potential annual evapotranspiration of the area studied.

MATERIALS AND METHODS

Characteristics of the study area:

Airport station is located in Qazvin Plain at longitude 50 degrees and 0.03 minutes east and latitude 36 degrees 15 minutes north and height from sea level to 1279.2 meters. The average annual rainfall (1992-2012) of the station is 323 mm and the amount of evapotranspiration potential in the first 8 months of the year (1992-2012) is 4.9 times the amount of rainfall annually. The average number of frost days during the study period has been recorded 83 days. The average maximum monthly temperature (1997-2012) of August is 35.48 ° C and the average minimum monthly temperature (1997-2012) of February is -3.06° C. The highest average monthly

Corresponding Author: Saeed Kazemi Mohsenabadi, Department of Civil Engineering, College of Engineering, Buinzahra Branch, Islamic Azad University, Buinzahra, Iran.
Tel: +982824220838; E-mail: s.kazemi@buiniau.ac.ir

evaporation (1997-2012)recorded is in June with 312.09mm and average minimum monthly evaporation records (1997-2012) in the first eight months of the year is in November with 61.62 mm.

Research method:

As a major element in hydrologic cycle, evapotranspiration estimation has been always important and using Lysimeter to do this estimation is the most precise method, besides, application of Lysimeter will be time consuming and costly which are among limitations of using this device.

A common method to determine best empirical equation in a specified area is using Lysimeter data, in case of lacking which, one can use Fao-Penman-Monteith results (recommended by Fao 56 Review) as a source to compare other methods with. Since many empirical methods measure potential evapotranspiration and lack of Lysimeter data for all areas, comparison of empirical methods output with evaporation basin data to determine best empirical equation, has grown as a common and reasonable issue. In this research, using 14 empirical methods of evapotranspiration estimation in monthly scale for the area concerned and eventually, comparing outputs and data from evaporation pan, best empirical relation for each month is suggested. In table (1) regional parameter average in a 16 years times statistical period (1996-2012) for the study area is observable.

Table 1: Regional parameter average in a 16 years times statistical period (1996-2012) for the study area.

Parameter Month	The Mean Of Maximum Temperature (° C)	The Mean Of Minimum Temperature (° C)	Maximum Possible Sunshine	Actual Sunshine Hours	Percent Relative Humidity	Wind Speed At 2m Height (m.S)	Extraterrestrial Radiation (mm.day)	Maximum Incoming Solar Radiation (mm.day)
April	18.59	5.24	13.15	7.30	53.93	2.58	14.34	11.87
May	24.28	9.34	14.10	8.59	54.87	2.62	15.46	12.68
June	31.22	13.63	14.63	11.16	44.20	2.56	16.77	13.68
July	35.20	17.30	14.40	11.47	42.99	2.58	16.38	12.98
August	35.48	17.88	13.53	11.54	41.00	2.40	15.06	11.82
September	32.26	14.66	12.40	10.71	42.13	2.39	13.00	10.15
October	26.73	10.31	11.28	9.03	45.33	2.24	10.17	7.89
November	17.46	4.88	10.23	6.54	58.08	2.25	7.68	6.25
December	10.29	-0.19	9.68	5.37	63.80	2.25	6.45	5.07
January	5.45	-3.05	9.96	5.20	66.73	2.26	7.00	5.64
February	7.78	-3.06	10.93	5.61	65.93	2.54	9.21	8.21
March	13.64	0.6	11.9	6.63	54.17	2.81	11.75	9.45

RESULT AND DISCUSSION

As was mentioned, in this research 14 empirical methods are used. Outputs from these methods and pan data are provided in table 2.

Table 2: Result of all these Method and measurement pan data.

Method /Month	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Penman-Fao	104.8	131	183.1	192.1	182	145.1	89.3	46
Jensen-Hais	292.4	378.1	489.6	530.9	493.7	390.9	254.9	146.5
Thorenthwait	41.2	79.0	143.6	164.2	158.6	114.1	73.7	28.9
Linecar	160.2	199.5	281.5	332.4	344.4	299.6	229.0	142.6
Romanenko	113.0	142.0	225.8	269.5	283.6	244.0	186.4	98.7
Priestly-Taylor	100.7	129.8	182.1	189.4	176.2	133.5	73.1	33.6
Turc	94.2	124.7	183.7	193.2	190.0	156.1	100.5	53.4
Hargreaves-Samani	69.7	147.5	201.7	217.7	200.4	160.4	103.3	54.0
Irmak 1	98.1	120.6	155.8	162.0	156.7	134.2	97.9	58.1
Irmak 2	116.6	135.4	169.6	170.7	160.8	131.9	86.6	53.9
Blaeny-Criddle	135.7	187.0	259.5	295.2	282.9	263.8	158.8	90.9
Fao-penman-monteith	109.4	135.2	195.7	213.2	204.4	166.5	107.0	56.9
Makkink	91.1	113.2	151.9	155.1	147.7	122.2	85.8	49.0
Penman-monteith	106.3	136.1	187.6	208.3	200.9	164.6	110.4	62.4
Pan	82.4	167.0	265.8	312.1	303.3	244.0	157.7	61.6

In order to compare results from empirical methods with pan data, the following diagrams are used:

According to table 2 and figure 1, best method to measure monthly potential evapotranspiration is determinable. In order for this, the error from each method, compared to measured values, is obtained through following relation:

$$Error = \left(\frac{ET_M}{ET_{PAN}} - 1\right) \times 100 \qquad (1)$$

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In this equation, **Error** is that of each method compared to pan data on percent basis, $\mathbf{ET_M}$ is the amount of evaluative evapotranspiration using empirical methods on millimeter basis in a month and $\mathbf{ET_{PAN}}$ is the potential evapotranspiration on millimeter in each month. Table 3 shows error amounts of all methods.

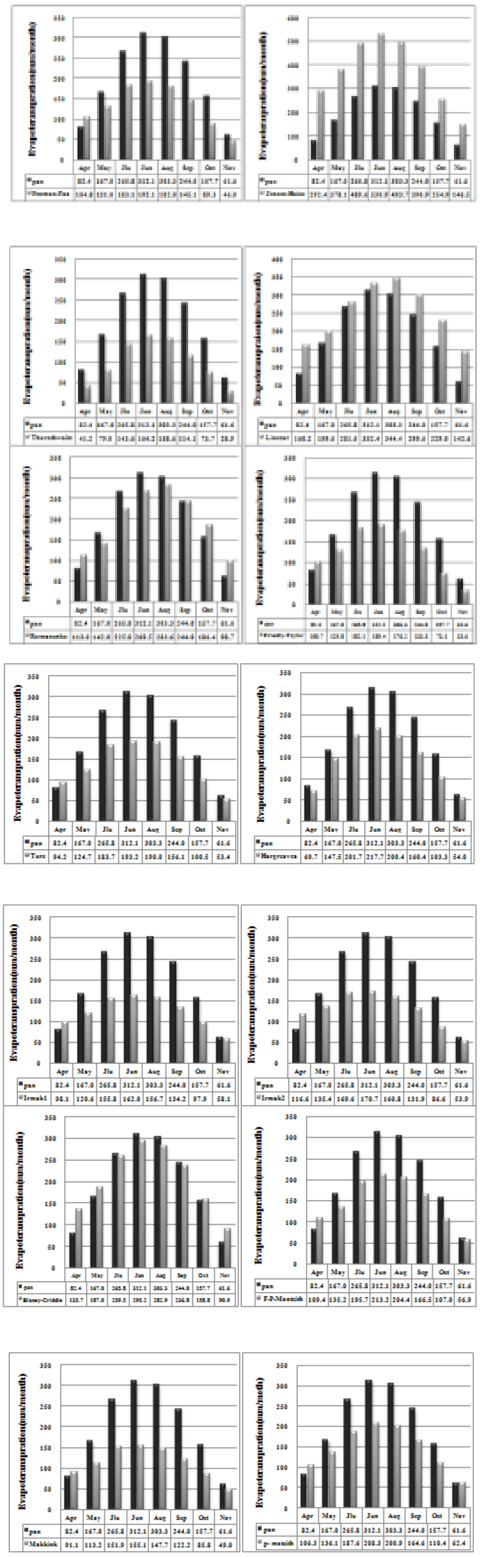

Fig. 1: Comparison of empirical methods results with pan data.

Table 3: Error amounts of all methods.

Month method	Apr Error %	May Error %	Jun Error %	Jul Error %	Aug Error %	Sep Error %	Oct Error %	Nov Error %
Penman-Fao	27.22	-21.58	-31.09	-38.44	-40.00	-40.53	-43.37	-25.35
Jensen-Hais	254.85	126.39	84.21	70.10	62.74	60.17	61.64	137.76
Thorenthwait	-49.96	-52.70	-45.98	-47.39	-47.72	-53.23	-53.30	-53.07
Linecar	94.40	19.42	5.92	6.49	13.54	22.75	45.19	131.40
Romanenko	37.15	-14.99	-15.03	-13.64	-6.49	0.00	18.17	60.20
Priestly-Taylor	22.26	-22.32	-31.47	-39.30	-41.91	-45.28	-53.63	-45.55
Turc	14.35	-25.35	-30.89	-38.09	-37.36	-36.03	-36.27	-13.36
Hargreaves-Samani	-15.46	-11.72	-24.10	-30.26	-33.95	-34.26	-34.52	-12.37
Irmak 1	19.03	-27.80	-41.37	-48.10	-48.35	-45.01	-37.95	-5.64
Irmak 2	41.55	-18.95	-36.18	-45.32	-47.01	-45.95	-45.09	-12.56
Blaeny-Criddle	64.68	11.97	-2.37	-5.41	-6.74	-2.95	0.71	47.47
Fao-penman-monteith	32.80	-19.06	-26.35	-31.70	-32.62	-31.76	-32.14	-7.70
Makkink	10.51	-32.21	-42.86	-50.30	-51.30	-49.92	-45.63	-20.48
Penman-monteith	29.02	-18.52	-29.41	-33.26	-33.77	-32.55	-30.00	1.27

Once measured and computational amounts of fig. 1 and also error amounts in table 3 are specified and compared with each other, best monthly results compared to pan data are obtained. A short report of these results is provided in fig. 2 and table 4.

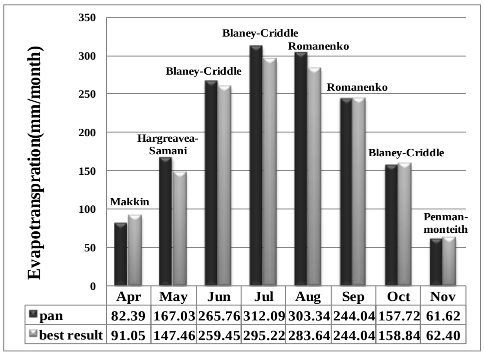

Fig. 2: Best monthly results compared to pan data.

Table 4: Percentage error of the best monthly experimental methods.

Month	The Best Method	Percentage Error
Apr	Makkink	10.51
May	Hargreavs-Samani	-11.72
Jun	Blaeny-Criddle	-2.37
Jul	Blaeny-Criddle	-5.41
Aug	Romanenko	-6.49
Sep	Romanenko	0
Oct	Blaeny-Criddle	0.71
Nov	Penman-monteith	-1.27

As is observed in table 4, during June, July and October, Blaeny-Criddle with 2.37%, 5.41% and 0.71%, in order, had lowest error and during August and September, Romanenko with 6.5% and 0.0% error level, provided best results. In addition, during April, May and November, with 10.5%, 11.7% and 1.27%, in order, Makkink, Hargreaves-Samani and Penman Monteith showed responses best fitted to measured amounts.

Due to the fact that to use empirical methods, different climatic parameters need to be measured, lack of any of these parameters can act as an obstacle to use best method suggested. Besides, according to table 3, methods with low error level can be suggested for variable months and in the case best suggested method is not applicable; these methods can be replaced. As an example, in June and August, instead of Romanenko, Blaeny-Criddle is applied. Additionally, in November, it is recommended that Irmak 1 and Fao-Penman-Monteith, as replacing methods with low error level, are applied. Considering table 3, one can say that Jensen-Haise is the most inappropriate method to measure evapotranspiration in the area studied. Since this method, with best and worst monthly response, contains the error level of 60.17% and 254.85%; therefore this method is not recommended for the area considered.

In case which a sum of evapotranspiration measured by best relations provided in table 4 is applied as annual evapotranspiration estimation, 16.04% error level will be obtained. Beside this, in last researches carried out by Kazemi *et al* on the same area, Romanenko with 1.94% error level was suggested to estimate annual

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evapotranspiration. As a result, measurement of monthly evapotranspiration by methods suggested in table 4 and a sum of these values as annual potential evapotranspiration is not recommended.

Conclusion:

- In order to determine best empirical equation when a lack of Lysimeter data occurs, through a comparison between method outputs and evaporation basin data, best empirical equation to measure monthly potential evapotranspiration of each area is determinable.
- To measure monthly potential evapotranspiration of Qazvin plain, Romanenko and Belaeny-Criddle relations provided best results, in a way that with 0.0% and 0.71% error level for September and October, they show the lowest monthly error compared to other methods.
- According to table 3, for June, July and October, Blaeny-Criddle and for August and September, Romanenko, are the best methods suggested to measure monthly potential evapotranspiration. Makkink, Hargreaves-Samani and Penman-Monteith are best methods for April, May and November to measure potential evapotranspiration in the area considered.
- The most inappropriate method to measure monthly potential evapotranspiration in the area is Jensen Haise method with an error level of 60% and 255%, in order, for best and worst monthly response and using this method for Qazvin plain is not recommended.
- Since variable climatic parameters are needed to use any empirical relation, in case they do not exist, other relations are replaceable. As an example, Penman-Monteith is suggested to measure potential evapotranspiration in November. If climatic parameters considered do not exist, to use this method, Irmak 1 showing low error level (5.64%), compared to other methods, in November, can be applied.

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