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COMPARATIVE STUDY OF CLIMATIC PARAMETERS AFFECTING EVAPORATION IN CENTRAL AND SOUTHERN COASTAL AREAS IN IRAN

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Abstract

Evaporation is one of the most important variables influencing on water resources management and agricultural activities. In this study, the most important factors affecting evaporation using Factor Analysis (FA) was identified by considering the climatic data of 14 stations in warm and humid southern coastal areas and arid central part of Iran. At first, Cluster Analysis technique (CA) was used to separate the Homogeneous Regions (HRs) at the study areas. Then, the relationship between climatic factors and evaporation for monthly time scale was derived in each region. Finally, by the regional regression equations, evaporation was calculated and MAE or RMSE statistics were applied to determine the validity of each equation. It was found that, in each month, one of the climatic parameters had a more prominent role on the amount of evaporation. At the coastal warm and humid regions the temperature related parameters (Tmax – Tmin, Tmax, and Tmean) were the main variables. In spite of the other homogenous regions located at arid areas, due to the high relative humidity at southern coastal parts of Iran, wind speed is not an important variable on evaporation rate. At the arid regions, wind speed, Tmax and Hmax – Hmin were identified as the main parameters.

Keywords: Evaporation, Cluster Analysis, Multiple regression, Evapotranspiration, Factor Analysis, Central Iran.

1 INTRODUCTION

Evaporation is one of the most important factors in climatic issues and agricultural activities. This factor is absolutely depended by different climatic parameters. Pan Evaporation measurements have been used worldwide as a means of estimating evapotranspiration and free water surface evaporation. In many situations it is advantageous to calculate, rather than measure, pan evaporation. This is often the case in developing countries or remote locations where costs are prohibitive. Unfortunately, it is rather difficult to directly measure evaporation (e.g. Brutsaert, 1982) and indirect approaches are used to estimate it from variables directly related to evaporation (Huntington 2006; Dewi et al., 2009). Many relationships that predict pan evaporation or potential evapotranspiration as a function of limited meteorological observations have been developed (Cahoon and et al, 1991). Evaporation is an element of hydrologic cycle, which can be generally estimated by the indirect methods such as mass transfer, energy budget, and water budget methods. Many researchers have tried to estimate the evaporation through the indirect methods using the climatic variables, but some of these methods require the data which can not be easily obtained (Kim et al. 2008), and (Rosenberry et al, 2007). Principal Component Analysis (PCA) and Factor Analysis (FA) are among the most famous and most applicable multivariate data analysis methods. These techniques are capable of describing observed relationship between several variables, in the form of some relatively simple relations, as well as presenting an idea based on the relative importance of different affecting factors on the phenomenon under study (Matalas and Reiher, 1967). Molina et al. (2006) developed and validated a simulation model of the evaporation rate of a Class A evaporation pan.

This investigation attempted to study the relations between evaporation and other climatic parameters within the template of different factors. Moreover, through reviewing these relations, the most important climatic parameters affecting evaporation of central and southern parts of the country were determined. Then, through cluster analysis, investigating regions were divided into smaller homogeneous parts and the most important climatic parameters affecting evaporation and the relating regression equations were determined for each month and at each homogeneous region.

2 MATERIALS AND METHODS

The selected meteorological stations are located at main agricultural plains in center and southern coastal areas of Iran. Maximum time period for these stations was from 1953 to 2003 and minimum available data was from 1966 to 2003. All the monthly evaporation data and other climatic parameters influencing on evaporation, available at each station, were used for the analysis processes. The climatic data affecting evaporation (E) including cloudiness, max, min and mean temperature, difference between max and min temperature, mean relative humidity, max and min humidity, and difference between max and min humidity and wind speed were used for identifying and prioritizing their relative importance on evaporation. At the first step, factor analysis (FA) with Varimax rotation was used to identify the main factors affecting evaporation and consequently, all parameters were divided in four factors. This approach has been used in many studies, i.e., Mohan and Arumugan (1996) and Masoudian (2004). At the next step, cluster analysis (CA) approach was applied to identify the climatically homogeneous regions, using mean values of long-term data of investigated meteorological stations (14 stations). Three homogeneous regions (HRs) were defined according to climatic parameters. Once again, the three top and most important factors affecting E were identified using FA at each homogeneous region.

3 RESULTS

Since the nine climatic parameters had different dimensions, all data sets were standardized. This rescaling effectively gives equal weight to each site characteristics in determining main variables and clusters. The 14×9 matrix of standardized selected variables was subjected to factor analysis. The first four factors, accounting for 85.8% of total variance, were selected and subjected to Varimax Normalized Rotation. This method of rotation is widely accepted as the most appropriate type of orthogonal rotation and for climate data. Loadings greater than 0.7 (Dinpashoh, 2004) were considered as important loadings. Factor scores for each of the 14 stations were calculated from the standardized variables and the associated factor loadings. Factor analysis technique was utilized to analyze variables in 14 stations in each month. It was identified that the variables are summarized to 4 factors. For instance, the result of FA in April was shown in table 1. The first four more effective variables on E contain 84.8 percent of the variations. The method of principal components and Varimax Rotation was used to extract the factors loading matrix.

Table 1. Weights for climatic parameters of each factor in April (as an instance)

variable	*Factor 1*	*Factor 2*	*Factor 3*	*Factor 4*
Average Temperature (Tmean)	0.552	0.61	-0.198	0.032
Maximum Temperature (Tmax)	**0.977**	0.056	-0.092	0.003
Tmax-Tmin	0.946	-0.145	-0.044	-0.048
Mean relative humidity (Hmean)	0.696	0.576	0.181	-0.101
Hmax- Hmin	-0.37	-0.089	**0.821**	-0.196
Wind speed (WS)	-0.106	**0.918**	0.033	0.031
Cloudy percentage (C)	0.084	-0.004	0.097	**-0.978**
Variance	3.3773	1.8269	1.3698	1.0364
Variance Percentage	0.375	0.203	0.152	0.115
Cumulative Variance Percentage	0.375	0.578	0.73	0.845

Where the Tmax, Tmin and Tmean are maximum, minimum and mean monthly temperature, Hmax and Hmin are maximum and minimum of monthly relative humidity, respectively. C represents the cloudiness and WS is the mean monthly wind speed. As it is shown in the table 1, temperature plays a prominent role in evaporation of all months of a year and it is determined as the most important parameter in the first factor. Temperature parameter also plays a role in the form of temperature min and max variation (Tmax - Tmin) and in some months maximum temperature (Tmax) imposes the highest effect. Then, considering climatic factors affecting evaporation, homogeneous regions were clustered in the form of a dendrogram. Figure 1 shows this dendrogram.

The number of homogeneous groups depends on the similarity value in ward cluster approach. Therefore, three homogeneous regions can be defined with the similarity value of about 25. Obviously, considering the larger value of similarity causes less number of stations to be located at a homogeneous area. Through factor analysis the most important parameters affecting evaporation in every month were determined and finally the regional regression equations of evaporation were derived for three HRs. For instance table 2 represents the monthly equation for the coastal stations located at southern Iran. The regional monthly evaporation equation for the arid region 3 is shown in table 3. The results showed that not only the three main factors affecting E but also the priority of them are not the same at different months of a year at each homogeneous region.

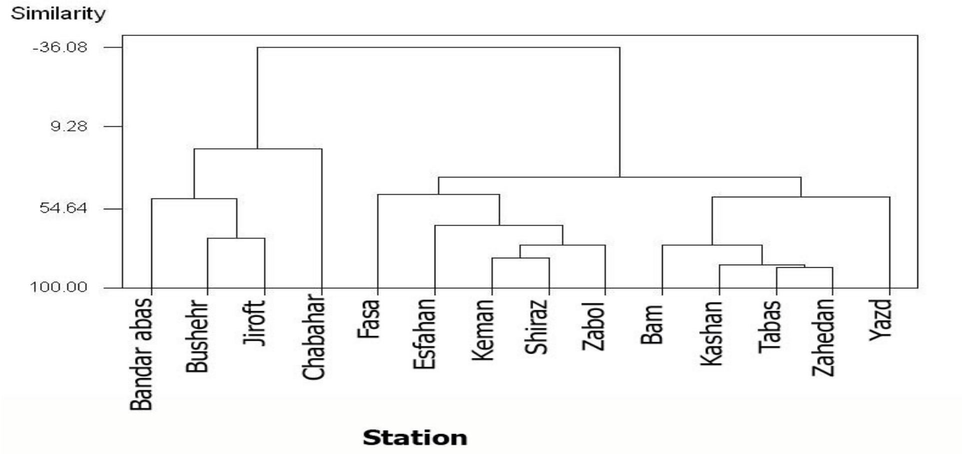

Figure 1. Dendrogram of homogeneous regions, regarding climatic parameters affecting evaporation.

Table 2. Correlation between evaporation and main climatic factors at the homogeneous region 1.

Month	*Regression relations*
Jan.	Log (E)= 6.1 - 0.18 Log (Tmax-Tmin) - 3.47 Log (Hmax-Hmin) + 1.13 Log (C)
Feb.	Log (E)= 2.3 + 1.10 Log (Tmax-Tmin) + 0.3 Log (Hmax-Hmin) - 2.04 log (C)
Mar.	Log (E)= 1.86 + 0.291 Log (Tmax)+ 0.0675 Log (WS) - 0.128 Log (C)
Apr.	Log (E)= 2.28 + 0.00388 Log (Tmax)+ 0.0222 Log (WS) + 0.0298 Log (C)
May	Log (E)= 2.51 + 0.0584 Log (Tmax-Tmin)- 0.148 Log (Hmax-Hmin)- 0.0108 Log (WS)
Jun.	Log (E)= 2.28 + 0.00388 Log (Tmax) + 0.0222 Log (WS) + 0.0298 Log (C)
Jul.	Log (E)= 6.78 - 2.52 Log (Tmean)- 0.312 Log (Tmax-Tmin) - 0.085 Log (WS)
Aug.	Log (E)= 0.476 + 1.31 Log (Tmean)- 0.00470 Log (Tmax-Tmin)+ 0.0132 Log(C)
Sep.	Log (E)= 5.54 - 2.01 Log (Tmax)+ 0.91 Log (WS)- 0.19 Log (C)
Oct.	Log (E)= 0.21 + 0.761 Log (Tmax-Tmin)- 0.171 Log (WS)+ 0.264 Log (C)
Nov.	Log (E)= 1.62 + 0.247 Log (Tmax) + 0.0850 Log (WS)+ 0.0811 Log (C)
Dec.	Log (E)= 0.956 + 0.178 Log (Hmax-Hmin) + 0.497 Log (Tmax) + 0.0784 Log (WS)

Table 3. Correlation between evaporation and main climatic factors at the homogeneous region 3.

Month	*Régression relations*
Jan.	Log (E)= 1.65 - 0.76 Log (C) - 4.92 Log (Hmax - Hmin) + 8.14 Log (Tmax - Tmin)
Feb.	Log (E)= - 5.28 + 7.35 Log (Tmax-Tmin) + 2.58 Log (C) - 2.48 Log (Hmax - Hmin)
Mar.	Log (E)= - 0.166 + 2.56 Log (C) + 0.705 Log (WS) - 0.750 Log (Tmax)
Apr.	Log (E)= - 4.66 - 0.657 Log (C) + 0.643 Log (WS) + 5.05 Log (Tmax)
May	Log (E)= 0.668 - 0.415 Log (WS) - 4.33 Log (Hmax - Hmin) + 6.91 Log (Tmax-Tmin)
Jun.	Log (E)= 0.097 + 1.60 Log (C) + 0.396 Log (Tmax) + 0.211 Log (WS)
Jul.	Log (E)= 5.26 + 0.067 Log (WS) -1.07 Log (Tmax - Tmin)-0.94 Log (Tmean)
Aug.	Log (E)= - 2.4 + 0.117 Log (WS) + 5.0 Log (C) - 1.5 Log (Tmax)
Sep.	Log (E)= 15.4 + 5.64 Log (Tmax) - 14.8 Log (C) + 0.061 Log (WS)
Oct.	Log (E)= - 3.20 - 0.279 Log (WS) - 0.187 Log (Tmax - Tmin) + 4.21 Log (C)
Nov.	Log (E)= - 0.348 + 2.63 Log (Tmax) - 0.110 Log (WS)- 0.670 Log (C)
Dec.	Log (E)= 3.25 - 0.875 Log (Hmax - Hmin) + 0.106 Log (WS) + 0.071 Log (Tmax)

Tables 4 to 6 show the factor analysis results for determining the three main climatic parameters affecting evaporation at the 3 HRs. Thus, the correlation between evaporation as a dependent variable and first (F1) and second (F2), and also, first, second and third (F3) more effective independent variables, R^2_{II} and R^2_{III}, respectively, were calculated at each HR. The high correlation between E and the first three more effective variables indicates that the derived equations can be applied for sites with low or no recorded evaporation data located at three identified HRs.

Table 4. Factor analysis results in homogeneous region 1

Month	*Factor 1 (F1)*	*Factor 2 (F2)*	*Factor 3 (F3)*	*a**	*b***
Jan	Tmax-Tmin	C	Hmax-Hmin	98.8	97.7
Feb	Tmax-Tmin	Hmax-Hmin	C	98.7	79.3
Mar	Tmax	C	WS	99.7	96.3
Apr	WS	C	Tmax	99.7	89.3
May	Tmax-Tmin	Hmax-Hmin	WS	99.5	56.8
Jun	WS	C	Tmax	99.7	79.4
Jul	Tmean	Tmax-Tmin	WS	97.9	97.5
Aug	Tmean	Tmax-Tmin	C	98.8	41.5
Sep	Tmax	WS	WS	96.7	52.1
Oct	Tmax-Tmin	WS	Tmax-Tmin	99.0	45.0
Nov	Tmax	WS	C	96.3	93.7
Dec	Tmax	Hmax-Hmin	WS	99.7	86.4

**a: Correlation coefficient (R^2_{III}), ET as a function of F1, F2, and F3*
**b: Correlation coefficient (R^2_{II}), ET as a function of F1, and F2*

Table 5. Factor analysis results in homogeneous region 2

Month	*Factor 1(F1)*	*Factor 2 (F2)*	*Factor 3 (F3)*	*a**	*b***
Jan	Hmax-Hmin	C	Tmax-Tmin	99.0	79.9
Feb	Hmax-Hmin	C	Tmax-Tmin	99.9	76.7
Mar	Tmax	WS	C	96.4	94.9
Apr	Tmax	WS	C	99.0	98.1
May	Hmax-Hmin	Tmax-Tmin	WS	74.8	44.2
Jun	Tmax	WS	C	99.0	98.1
Jul	Wind	Tmax-Tmin	Tmean	98.2	83.5
Aug	Tmax-Tmin	C	Tmean	73.3	24.6
Sep	WS	C	Tmax	99.0	96.1
Oct	Tmax-Tmin	C	WS	97.1	62.7
Nov	WS	Tmax	C	99.3	99.1
Dec	WS	Hmax-Hmin	Tmax	80.6	71.5

Table 6. Factor analysis results in homogeneous region 3

Month	*Factor 1 (F1)*	*Factor 2 (F2)*	*Factor 3 (F3)*	*a**	*b***
Jan	C	Hmax-Hmin	Tmax-Tmin	99.5	98.4
Feb	Tmax-Tmin	C	Hmax-Hmin	97.7	85.3
Mar	C	WS	Tmax	69.9	25.7
Apr	WS	C	Tmax	68	67.3
May	WS	C	Tmax-Tmin	96.5	80.1
Jun	Tmax	C	WS	30.8	81
Jul	WS	Tmax-Tmin	Tmean	94.8	31
Aug	WS	C	Tmax	81.5	81
Sep	WS	Tmax	C	83.1	30.8
Oct	WS	Tmax	C	99.3	27.1
Nov	Tmax	WS	C	83.1	73.6
Dec	WS	Hmax-Hmin	Tmax	96.9	37.4

Figures 2 shows the most important variable and figure 3 shows the second important variable affecting evaporation for three HRs. The results in these two figures show the difference between maximum and minimum temperatures (Tmax – Tmin), is the the most effective parameter influencing monthly evaporation at homogeneous region 1 (HR1). HR1 is spread along Iran's water borders having a warm and humid climate. Generally, the temperature related parameters (TPR) including Tmax – Tmin, Tmax, Tmin and Tmean at the HR1 are found as the main factors affecting E. In spite of the other homogenous regions located at arid areas, due to the high relative humidity at southern coastal parts of Iran, wind spead is not an important variable on evaporation rate. At the HR2 and HR3, wind speed, Tmax and Hmax – Hmin are identified as the main parameters and cloudiness as the second one. These two regions are spread at the arid central Iran. The results showed that the wind speed and cloudy times of day have a more effective role on the amount of evaporation rather than the temperature related factors. Being situated near the sea is the main reason of homogeneous region 1 for having lower potential evaporation than others. Higher relative humidity lowers evaporation of this region.

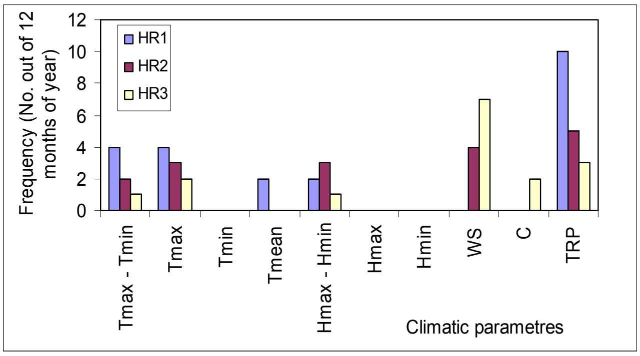

Figure 2. Frequency of the first important climatic climatic parameter affecting on ET

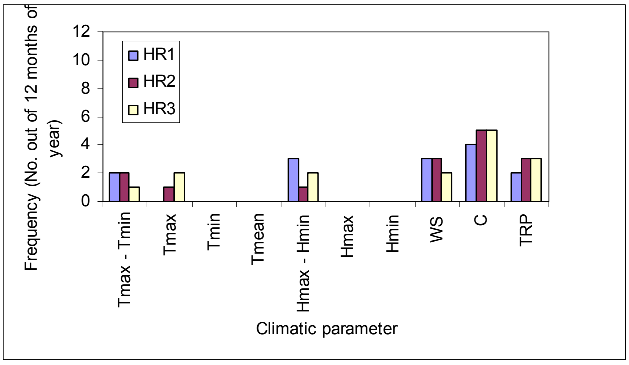

Figure 3. Frequency of the second important parameter affecting on ET

3.1 Statistical analyses

Table 7 shows the RMSE and MAE values regarding the comparison of observed and predicted evaporation by regression equation for each month at any homogeneous region. As it is shown by this table, the amount of error statistics in some months is a little more than the others. In these months, it seems that selected parameters in regression model are not able alone to predict the more real amount of evaporation and therefore more important parameters should be sought.

Table 7. diversified monthly RMSE and MAE amounts at each of homogeneous region

Month	*HR1*		*HR2*		*HR3*	
	RMSE	MAE	RMSE	MAE	RMSE	MAE
Jan.	0.23	15.95	0.12	12.79	0.12	8.73
Feb.	0.52	47.74	0.09	9.42	0.05	3.69
Mar.	0.11	1.67	0.05	6.6	0.21	1.82
Apr.	0.21	1.44	0.02	3.95	0.11	3.06
May	0.24	3.48	0.26	62.21	0.04	11.41
Jun.	0.14	1.44	0.02	3.97	0.23	5.44
Jul.	0.17	46.57	0.21	2.27	0.15	47.84
Aug.	0.21	3.09	0.04	11.54	0.18	66.77
Sep.	0.41	77.87	0.16	24.86	0.11	27.49
Oct.	0.35	79.99	0.22	4.11	0.06	14.08
Nov.	0.13	0.34	0.12	2.14	0.13	4.97
Dec.	0.1	0.03	0.48	57.18	0.15	4.62

4 CONCLUSIONS

The results showed the load of climatic parameters for all factors obtained using factor analysis procedure were extremely high and appropriate. The regression correlation coefficient between the selected factors and evaporation in each month was very high. It indicates factor analysis is a appropriate technique for deriving the relations between evaporation and climatic parameters. Due to the results of the present investigation, it was found that, in each month, one of the climatic parameters had a more prominent role on the amount of evaporation. At the coastal warm and humid regions the temperature related parameters (Tmax – Tmin, Tmax, and Tmean) were the main variables. In spite of the other homogenous regions located at arid areas, due to the high relative humidity at southern coastal parts of Iran, wind speed is not an important variable on evaporation rate. At the arid regions, wind speed, Tmax and Hmax – Hmin were identified as the main parameters and cloudiness as the second one. The knowledge of the most important factors affecting monthly evaporation in each region can be used for a better management of water resources and agriculture planning.

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