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Estimates and Zoning of reference evapotranspiration by FAO-Penman-Monteith (Case Study: North West of Iran)

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ABSTRACT

Determination of evapotranspiration in many studies, including the hydrologic balance, design and management of irrigation systems, simulation of product and management of water resources is very important. For this purpose, the data required includes daily temperature, humidity, wind speed, solar radiation pressure and in the period 1990-2013 from the meteorological stations in the area is the area that includes 35 stations were taken. And to estimate evapotranspiration at the regional stations of the area we use Excel and GIS capabilities and its regression equation was obtained. To generalize stations in the region of interpolation we use methods IDW (Inverse Distance Weighting) and the relationship between height and evapotranspiration with a correlation coefficient of linear regression was used 0.52. The study results showed that the IDW method in more accurate than Linear regression relationship between height and evapotranspiration because it has lower RMSE (0.26). The total average reference evapotranspiration in the study area for the above mentioned methods is 988.657 and 1036 respectively and It was also found that the northern, eastern and lake basin, evapotranspiration intensity is more than the North-West, West, South-West and South-East and East of study area.

Keywords: Reference evapotranspiration, FAO - Penman-Monteith, zoning, linear regression.

I. INTRODUCTION

Evapotranspiration is one of the important elements of the hydrological cycle and plays an important role in agricultural research, water resources management plans, network design and construction of irrigation and water drainage (Snyder et al, 2005; Lopez-Urrea et al., 2006; Gundekar et al, 2006). More than 0.72 of water resources by evapotranspiration are unavailable. This suggests a broadly more attention to the issue of evapotranspiration in the country (Sharghi et al, 2011). Therefore, a solution to reduce water losses on farms is irrigation planning that based on the accurate estimation of crop water requirement and therefore the reference evapotranspiration. Study reference evapotranspiration to provide appropriate cropping patterns and optimize the use of available water resources in the coming period is essential (Golkar, HamzeieYazd et al, 2008). According to FAO, reference evapotranspiration is the amount of water that a plant-covered field reference (such as grass) in a specified time period consume So that the plants do not face this farm during the growing season with water shortages (Sharifian et al, 2006). In more ways to measure evapotranspiration provided, the amount of reference evapotranspiration (ETo) estimated Then, according to which evapotranspiration is calculated (Alizadeh et al, 2005). Many studies have been done in this area that some of them will be mentioned below. Committees need watering America Society of Civil Engineers estimates Water irrigation requirements monthly with twenty different regions then compared with the results of lysimeter. The results showed that Penman-Monteith method has its best estimate (Jensen et al, 1990).

Saleh and Sindel (1983) recognized suitable Hayes-Jensen experimental method to calibrate the experimental relations in areas with dry climates like

Saudi Arabia. In another study Jensen-Hayes and Hargreaves methods for arid and semiarid climates were proposed.

Shih (1984) studied the impact of climate variables on reference evapotranspiration Concluded that the daily and monthly estimate evapotranspiration, two parameters alone almost the same numerical result that the use of other parameters-up. The research that has been done in the world in terms of evapotranspiration was as follows (Hargreaves et al, 1985; Samani, 2000; Xu and Singh, 1998; Abtew, 1996; Weiß and Menzel, 2008; Droogers and Allen, 2002; Sethi et al, 2002; Silva et al, 2010; Tabari, 2010).

Entesari et al (1997) in some areas of Iran calculated potential evapotranspiration was by Penman-Monteith And were compared with other experimental methods recommended by Food and Agricultural Organization And reliability of the Penman-Monteith method were analyzed.

Alizadeh et al (2002) calculated the Accuracy of estimation of potential evapotranspiration In Khorasan Hargreaves-Samani and pan evaporation methods they reached to this conclusion Pan method despite the multiple function of weather data, cannot results acceptable estimate potential evapotranspiration.

Rahimzadegan (1992), measured the plant reference evapotranspiration using Lysimeter drains in Isfahan during the year, Was corrected by the result of 12 computational ChristianSen, Hargreaves, Blaney & Criddle methods and Penman introduced as the most appropriate method for this area.

Samadi and Majdzadeh (2004) measured the reference evapotranspiration (grass) by lysimeter in Kerman and were evaluated number of computational methods (Blaney & Criddle, Torrent White and Monteith-Penman FAO) and Concluded that Blaney equation is most appropriate for use in dry areas. The aim of this study was to estimate plant grass reference evapotranspiration, using FAO Penman - Monteith for selected stations and other areas and zoning study area in the northwest of the country, including the provinces of Ardabil, in East Azerbaijan and West Azerbaijan respectively.

II. METHODS AND MATERIAL

Case Study

The study area includes the provinces of Ardebil, East Azerbaijan and West Azerbaijan and 101051.49 square kilometer area in northwest Iran in the geographical range, is located between the orbits of 36 degrees and 54 minutes to 39 degrees 27 minutes north latitude and 44 degrees, 7 minutes to 49 degrees and 20 minutes east of Greenwich. This area is neighboring to the north of Azerbaijan, from the West with Turkey, from the south of Kurdistan, Zanjan and Guilan. Also in the area, is Iran's largest saltwater lake that is the complete drying due to unauthorized wells around the lake, creating a dam on the river where the shed and increased evaporation (due to climate change) from the lake (Figure 1).

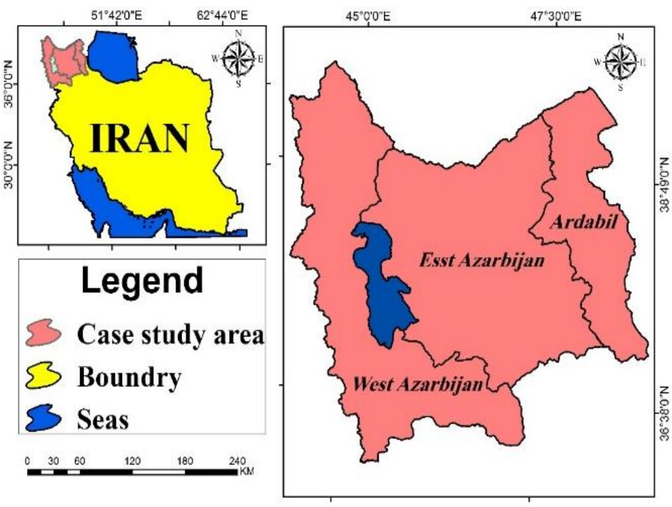

Figure 1: Case study area

Data and information

To study and zoning of reference evapotranspiration using the Penman-Monteith FAO, the daily temperature, humidity, wind speed, solar radiation pressure and stations in the region were obtained. Then, taking into account different criteria in the selection of stations, including statistical vacuum, the length of Statistics, good distribution at the regional level, 35 stations by the year 1990 was 2013 were chosen (table 1). Figure 2 show the distribution of weather stations is used. With the conditions in the area usually by increases in common statistical period, a smaller number of these stations are in the final maps were used.

TABLE 1

CHARACTERISTICS OF SELECTED STATIONS TO EVALUATE THE REFERENCE EVAPOTRANSPIRATION IN NORTH WEST IRAN.

Station	latitude	longitude	Elevation	Station	latitude	longitude	Elevation
Pars Abad	39 39	47 55	44	Ardabil	38 15	48 17	1332
Boranghanbarloo	39 21	47 29	240	Sarighamish	36 29	46 29	1353
Meshkinshahr	38 42	47 31	653	Tabriz	38 5	46 17	1361
Gharaagaje	39 2	47 42	700	Ahar	38 26	47 4	1391
Jolfa	38 45	45 40	736	Ajichie	38 7	46 24	1400
Firozabad Khalkhal	37 35	48 13	1090	Makoo	39 20	44 26	1411
Gharangho	37 33	47 34	1100	Piranshahr	36 40	45 8	1455
Khoy	38 33	44 58	1103	Marageh	37 24	46 16	1478
Miyane	37 27	47 42	1110	Barundozchie	37 23	45 14	1520
Ajabshir	37 28	45 43	1180	Saghez	36 15	46 16	1523
Tazekand	37 4	47 58	1220	Marand	38 26	45 46	1550
Bandar Shrafkhane	38 11	45 28	1302	Khalat Posh	38 3	46 27	1567
Oromieh	37 32	45 5	1313	Sardasht	36 9	45 30	1670
Miandoab	36 58	46 9	1314	Sarab	37 56	47 32	1682
Bostanabad	37 50	46 50	1720	Tikme Dash	37 43	46 56	1870
Sareyn	38 9	48 5	1740	Darretakht	33 22	49 22	2000
Tekab	36 23	47 7	1765	Lighvan	37 50	46 26	2100
Khalkhal	37 38	48 31	1796	-	-	-	-

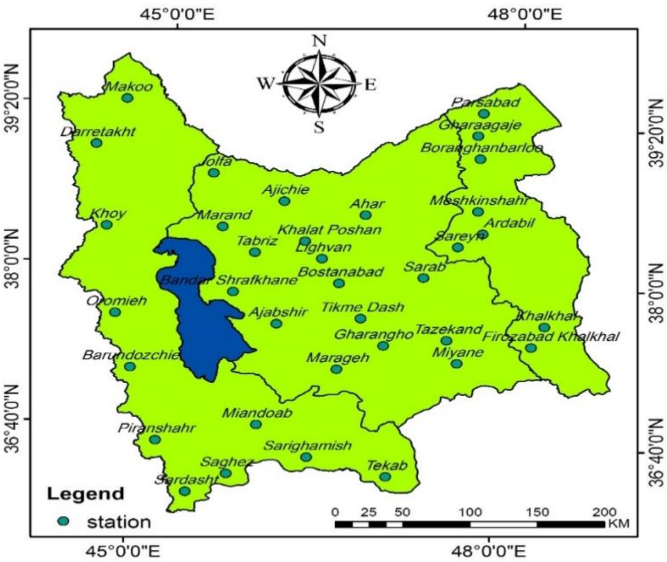

Figure 2 : Distribution of used meteorological stations

Calculate potential evapotranspiration in FAO-Penman-Monteith method

Penman - Monteith by FAO account as the standard method for determining ETo, and compared to other methods is recommended. In this study were used as the basis for assessment. This is the equation for the following equation:

$$ET_O = \frac{0.408\Delta R_n + \gamma \frac{900}{T_a + 273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad (1)$$

In the above equation, ETo: reference evapotranspiration (mm d-1), Ta: air temperature (c◦): U2 wind speed at a height of 2 meters (ms-1), Rn: net radiation at the surface (MJ m-2 d-1), $e_s - e_a$: saturation vapor lack of air pressure (KpaC-1), γ: psychometric constant (KpaC-1), Δ: The slope vapor pressure with temperature. All the above parameters are calculated using equations proposed by Allen et al. (1998, 1994). Based on climate information provided and using above equation, the annual values of reference evapotranspiration was estimated in each of the stations.

Zoning Maps Potential Evapotranspiration

There are various methods for classification on points that have information in specific component that often are based on interpolation. The purpose of these methods is the generalization of data of points or lines to a surface. In this study, two-way communication between the parameter with high evapotranspiration and also based on geostatistical methods, evapotranspiration zoning map of the study area was developed.

One of the most important methods of interpolation is linking parameter (reference evapotranspiration) as a dependent variable and an independent variable such as height. Of course, if it is at least a statistically significant correlation. If there is meaningful relation between parameters based on independent variable (elevation) we can calculate amount of evapotranspiration in other point of study area using Digital Elevation Model (DEM). In this study, based on the relationship between height and evapotranspiration and the significance of the relationship between these parameters in 0.1 (based on the correlation coefficient (R2 = 0.52), a simple linear regression between height parameter and reference evapotranspiration were obtained (Figure 3).

It is also possible to carry out interpolation between points and then zoning in the study area based on geostatistical methods. The most common methods can be used are the Kriging method and Cokriging. Of course, one of the conditions of use of these methods is the normal input data. Analysis of the data reference evapotranspiration, based on the histogram and Normal Q_Qplot diagram showing the data was not normal and also by using logarithm and applying function BOX-COX, data did not show to be normal. Therefore for applying the interpolation we used IDW (Inverse Distance Weighting) method.

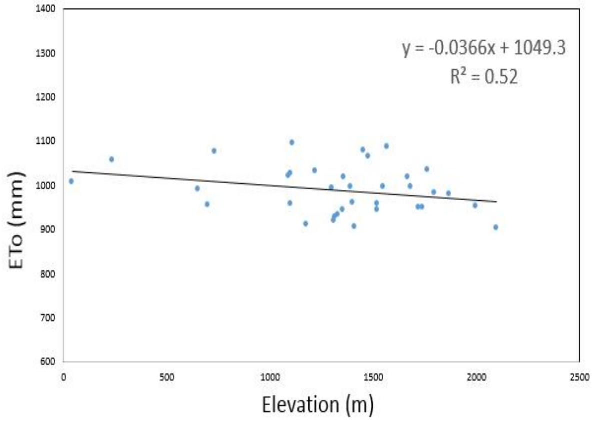

Figure 3 : Linear regression between height and mean annual reference evapotranspiration.

III. RESULTS AND DISCUSSION

To analyze the condition of evapotranspiration in the study area, the annual average values of reference evapotranspiration stations surveyed in period 1990-2013 has been prepared (Table 2).

TABLE 2
ANNUAL AVERAGE VALUES OF REFERENCE EVAPOTRANSPIRATION FOR SURVEYED STATIONS.

Station	ETo (mm/year)	Station	ETo (mm/year)
Pars Abad	1008.6	Piranshahr	1079.1
Boranghanbarloo	1155.9	Marageh	1164.8
Meshkinshahr	891.1	Barundozchie	857.5
Gharaagaje	954.7	Saghez	944.6
Jolfa	1275.5	Marand	1086.1
Firozabad Khalkhal	1122.2	Khalat Posh	1086.7
Gharangho	1125.5	Sardasht	1318.5
Khoy	857.2	Sarab	897.1
Miyane	1196.5	Bostanabad	950.2
Ajabshir	912	Sareyn	800.1
Tazekand	1030.9	Tekab	1135.3
Bandar Shrafkhane	993.9	Khalkhal	882.9
Oromieh	918.7	Tikme Dash	980.2
Miandoab	928.7	Darretakht	951.4
Ardabil	832.2	Lighvan	902

Sarighamish	943.8	Ajichie	1059.7
Tabriz	1218.9	Makoo	805.5
Ahar	996	-	-

Based on digital number (DN) of pixels the annual average reference evapotranspiration in the study area for interpolation methods; linear regression relationship between height and reference crop evapotranspiration and inverse distance method 988.657 and 1036 mm per year was estimated respectively. Figures 4 and 5 shows the contour line for amount of reference evapotranspiration area resulted by tow method; regression relation between elevation and reference evapotranspiration and Inverse Distance Weighting. Also table 3 shows estimated values by two interpolation method, real values (values calculated at each station) and estimation error of two interpolation methods.

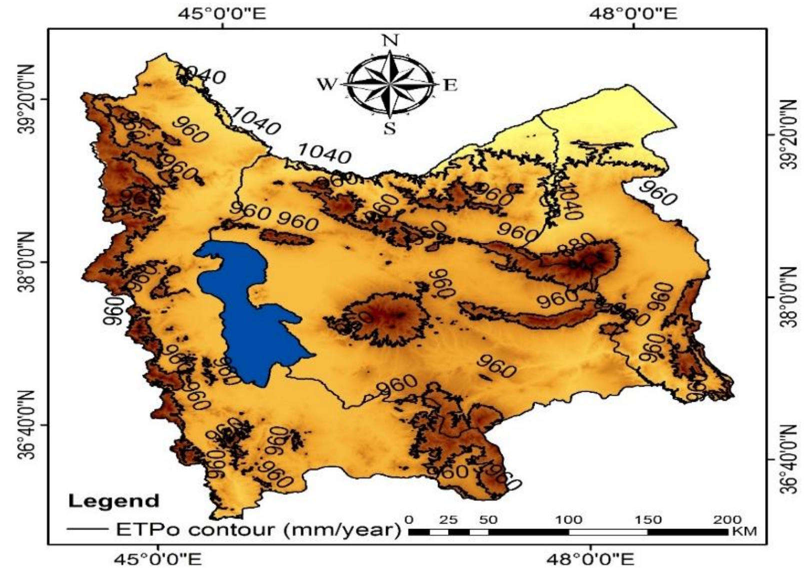

Figure 4: Map zoning average potential evapotranspiration in the study area using linear regression relationship between height and reference crop evapotranspiration.

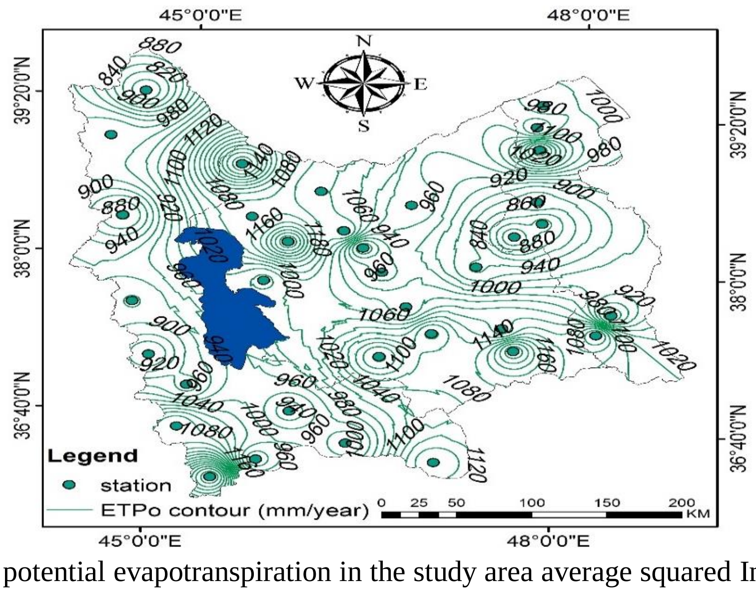

Figure 5: Zoning map of potential evapotranspiration in the study area average squared Inverse Distance Weighting.

TABLE 3 ESTIMATED AND ACTUAL VALUES (MM/YEAR) AND THE ESTIMATION ERROR OF TWO INTERPOLATION METHOD.

	Inverse Distance Weighting (IDW)			Linear regression between height and potential reference evapotranspiration		
station	**Measured**	**predicted**	**Error**	**Measured**	**predicted**	**Error**
Pars Abad	1008.6	1007.719829	-0.007039	1008.6	1008.49	-0.17577
Boranghanbarloo	1155.9	1142.161756	-0.202868	1155.9	1050.584835	-0.215214
Meshkinshahr	891.1	891.761648	0.016836	891.1	1010.504447	0.318778
Gharaagaje	954.7	962.550556	0.070271	954.7	954.58845	-0.14763
Jolfa	1275.5	1270.436241	-0.055092	1275.5	1004.068849	-0.158385
Firozabad Khalkhal	1122.2	1110.221343	-0.144990	1122.2	1093.277605	-0.057600
Gharangho	1125.5	1120.271501	-0.056258	1125.5	1118.016077	-0.001135
Khoy	857.2	861.029009	0.051348	857.2	860.813889	-0.000137
Miyane	1196.5	1188.987869	0.001907	1196.5	1169.965026	-0.066956
Ajabshir	912	914.326886	-0.013141	912	912.464172	0.032714
Tazekand	1030.9	1033.176796	0.019936	1030.9	1030.845245	-0.07321167
Bandar Shratkhne	993.9	997.233451	-0.001412	993.9	994.2524346	0.300408213
Oromieh	918.7	919.612169	0.010973	918.7	920.1328378	1.390406157
Miandoab	928.7	930.60432	0.032664	928.7	929.764842	1.051218936
Ardabil	832.2	832.186803	-0.012905	832.2	838.911356	0.065469
Sarighamish	943.8	947.016638	-0.000757	943.8	944.1141701	0.261325861
Tabriz	1218.9	1215.895371	-0.093032	1218.9	1209.797563	0.039262
Ahar	996	995.789341	0.00211	996	995.691261	-0.002709
Ajichie	1059.7	1060.002309	-0.002208	1059.7	1059.918142	0.008963
Makoo	805.5	805.523737	0.023004	805.5	806.133316	0.014297
Piranshahr	1079.1	1077.883164	-0.035903	1079.1	1077.266587	-0.025405
Marageh	1164.8	1158.652096	0.0061	1164.8	1160.164638	-0.035679
Barundozchie	857.5	858.371452	0.031791	857.5	935. 679658	0.825652
Saghez	944.6	949.486	0.032143	944.6	944.5784	-0.0648
Marand	1086.1	1086.815599	-0.005934	1086.1	995.654856	0.790842
Khalat Posh	1086.7	1078.626881	-0.039867	1086.7	972.94924	-0.878030
Sardasht	1318.5	1309.328861	-0.003780	1318.5	1389.328861	0.368285
Sarab	897.1	898.113662	-0.008653	897.1	901. 626793	0.548565
Bostanabad	950.2	951.205674	0.021775	950.2	950.6252377	0.38842131
Sareyn	800.1	800.150457	0.046941	800.1	1010.433253	-0.542821
Tekab	1135.3	1134.793644	-0.000912	1135.3	1150.698642	-0.100912
Khalkhal	882.9	891.867417	0.038865	882.9	882. 150457	0.048865
Tikme Dash	980.2	981.696983	-0.058816	980.2	981.4852435	1.274000871
Darretakht	951.4	951.002737	-0.000376	951.4	951.8177866	0.364905746
Lighvan	902	906.440517	0.056972	902	978.009646	1.020816

IV.CONCLUSION

In order to produce maps of evapotranspiration relation between transpiration and evapotranspiration with elevation and Inverse Distance Weighting have been used then according to RMSE index the best interpolation method for produce map was chosen. Value of this index for tow mentioned method was calculated 0.53 mm and 0.23 mm respectively that shows more accuracy in IDW method for interpolating amount of reference crop evapotranspiration. Zoning maps for the values of reference evapotranspiration show amount of evapotranspiration in study area is various.

On the zoning maps reference evapotranspiration values it was found that northern, Eastern of catchment Lake of Oromieh have greater Intensity evapotranspiration than North West, West, South-West and South-East and East areas. Therefore, it should be noted that these areas ecosystems are extremely fragile and factors such as land degradation and improper change, overgrazing, over-harvesting and groundwater resources as well as factors related to global warming and climate change and destructive droughts, widely affect ecosystems such areas. Therefore, continuous monitoring of ecosystem conditions in northern, eastern and catchment in the area is recommended. Produced map can be considered important locating many agricultural and natural resources projects as well as development in the region as a base map.

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