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Study of reference crop evapotranspiration in I.R. of Iran

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ABSTRACT

Accurate estimation of regional evapotranspiration (ET) is essential for many agricultural water related studies. The data from 81 weather stations, with at least 30 years of data during the period of 1956–2000, were used for estimation of reference crop ET (ET_0) in Iran. Monthly ET_0 values were computed based on corrected mean air temperature for non-ideal conditions. This study focused mainly on the prediction of ET_0 of 7 months of active crop growth season (April–October). Two main objectives of this study were: (i) prediction of mean monthly and annually ET_0 in Iran using the suitable method from the three selected candidates, which are Hargreaves adjusted in 1985, adjusted Thornthwaite and Linacre methods, and (ii) study of spatial variation of annual ET_0. Results showed that long-term mean annual ET_0 vary between 830 mm to over 3627 mm across the country. The lowest monthly and yearly ET_0 belonged to the Caspian Sea shoreline but highest ET_0 belonged to the central and southeast parts of Iran. The mean annual ET_0 in the southeast parts of Iran was about 33 times greater than that of its mean annual precipitation.

1. Introduction

Reliable estimates of reference crop evapotranspiration (ET_0) from irrigated surfaces are required for efficient irrigation scheduling, hydrologic water balance, canal design capacities, regional drainage and water resources planning, reservoir operation studies, potentials for rain-fed agricultural production and crop water requirements studies. Accurate prediction of a given crop evapotranspiration (ET_{crop}) is essential key element in agricultural water management especially in arid and semi-arid areas such as Iran. ET_{crop} is usually calculated based on the ET_0. ET_0 defined as ‘‘the rate of ET from extensive surface of 8–15 cm tall, green grass of uniform height, actively growing, completely shading the ground and not short of water’’ (Doorenbos and Pruitt, 1977). Direct measurement of ET_{crop} and or ET_0 from lysimeter is very difficult for large areas because it is time consuming and expensive. However, other estimation methods were developed for ET_0, which can be related to ET_{crop} by multiplying it to k_c, crop coefficient. k_c mainly depends on the crop growth stages and type of crop. The values of k_c for most crops can be found in works of many investigators like Doorenbos and Pruitt (1977), Wright (1982), Sammis et al. (1985), and Watanabe et al. (2004).

Various ET_0 studies were conducted for many regions across the world (Mohan, 1991; Amatya et al., 1995; George et al., 2002; Chuanyan et al., 2004; DehghaniSanij et al., 2004; Garcia et al., 2004). Review of these studies implies that there is not a single ET_0 estimation method, which is suitable for all times and different stations. It seems that selection of the proper method for any station and/or area depends on many factors such as climate condition, accessibility of data needed, complexity of method, time and cost.

Salih and Sendil (1983) selected the five ET_0 estimation methods for predicting monthly ET_0 in central Saudi Arabia. They showed that considerable differences in ET_0 values exist among proposed methods. They indicated that Jensen–Haise method was the best-calibrated method available for such an arid region. Taghizadeh (1975) used the Penman method to

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predict annual potential evapotranspiration (ETP) in 39 weather stations of Iran. He illustrated the mean annual iso-ETP curves on the country map based only on a 5-year time period. Farshi et al. (1997) predicted monthly ET_{crop} for several crops and fruit trees using CROPWAT software. They used different time periods, from 5 to 40 years, and different ET_0 calculation methods. However, they did not illustrate the iso-ET_{crop} curves on the Iran map. The FAO Penman–Monteith (PM) equation as the only reference method to determine ET_0 (Allen et al., 1989) was studied for 44 stations of Iran by Kheirabi et al. (1997). Other ET related studies in Iran mainly focused on ET estimation for a limited area and/or on a single station in a short time period. From these studies it can be referred to the works of Haghighat-Joo (2003), Hasan-Bagloee and Maghsodi (2003), DehghaniSanij et al. (2004) and many others.

Correction of air temperature for non-reference condition is an important task for reliable estimation of ET_0 (Jensen et al., 1997). Weather stations of Iran are mainly located in non-irrigated areas. Although correction of air temperature for these sites is necessary, however, it seems that such a correction was not performed for previous ET_0 studies in Iran.

In the present study three low data demanded ET_0 prediction methods were selected and used in Iran. These were: (i) adjusted Thornthwaite method hereafter referred to as ATW (Pereira and Pruitt, 2004); (ii) Hargreaves method adjusted in 1985, hereafter referred to as HG-1985 (Hargreaves and Allen, 2003); (iii) Linacre method (Linacre, 1977). For all arid sites air temperature was corrected for non-reference condition. Since the active growth of most crops and trees in Iran are limited to 7 months, April–October, therefore, this study focused computation of ET_0 on these months. Two main objectives of this study were: (i) prediction of long-term mean monthly and annually ET_0 in Iran using the suitable method among the three candidates and (ii) study of spatial variation of long-term mean annual ET_0 across the country.

2. Materials and methods

2.1. Location

The area under study covered whole extent of Iran, which lies approximately between 25°N and 40°N in latitude and between 44°E and 64°E in longitude. Based on the Koppen climate classification, most parts of Iran's area are categorized as generally having arid (BW) and semi-arid (BS) climates. Iran's important mountains are Alborz and Zagros, which play an important role in non-uniform spatial and temporal distribution of precipitation in Iran. According to Dinpashoh et al. (2004) the mean annual precipitation of Iran is about 241 mm. The area, which receives more than 500 mm/year, is only 8%. Over half of the annual precipitation occurs in winter. The annual precipitation CVs vary from 18% in the north to 75% in the southeast of the country.

2.2. Station selection and data

Eighty-one weather stations, which had at least 30 years of monthly data in a similar time period, were selected for this study. Criteria for selection of sites were: (i) having at least 30 years of monthly data; (ii) lack of missing data up to 20% of the total number of data for a given variable; (iii) creating a suitable density of sites on the country map area; (iv) accessibility of data needed for calculation of ET_0. The location of selected stations can be seen from Fig. 1. Monthly time series of required data provided in digital form kindly from the Meteorological Organization of Iran. Missing data were estimated using the inverse distance interpolation method (Xia et al., 1999). Double mass analysis was conducted for quality control of data.

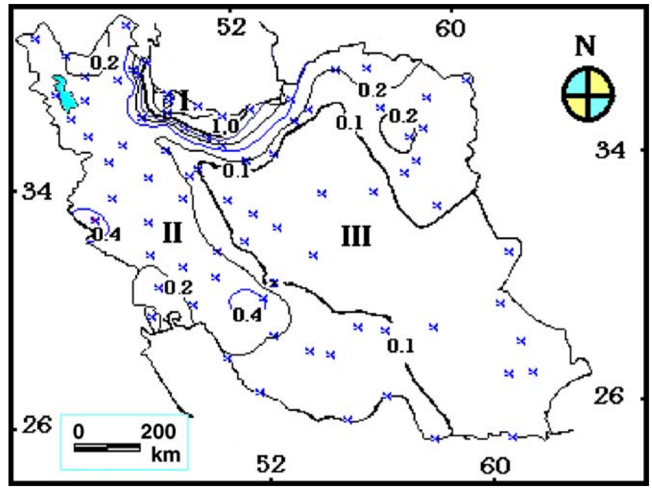

Fig. 1 – Mean annual iso-P/ET_0 curves of Iran (1956–2000).

2.3. Methodology

The methodology used herein for computing the monthly ET_0 for different stations of Iran is as follows. In the first step, Hg-1985 method was selected and used for preliminary estimation of the mean long-term monthly ET_0. This model was chosen because it was recommended to estimate ET_0 in the arid and semi-arid areas (Hargreaves, 1989; Hargreaves and Allen, 2003; Chuanyan et al., 2004). ET_0 was calculated for all sites and for each of the 12 months of year separately, using the long-term mean data. Summing monthly ET_0 for a given station yielded the long-term mean annual ET_0 in mm/year. In the second step, mean annual relative wetness, which is defined here as the long-term mean annual P/ET_0 ratio, was computed for all sites, in which P is the long-term mean annual precipitation in the same units of ET_0. Based on the calculated annual relative wetness, Iran's area was then divided subjectively into three distinct climatic regions. These regions were defined as: (i) humid, in which all located sites have annual relative wetness of equal 1 or above; (ii) arid and semi-arid, having sites with annual relative wetness between 0.1 and 1; (iii) extreme arid, with annual relative wetness of equal or less than 0.1. In the third step, only one of the three candidate ET_0 calculation methods were selected and used for each of the three distinct regions. These methods were as: (i) ATW; (ii) Hg-1985; (iii) Linacre.

ATW method was selected and used for humid region of Iran, because Hasan-Bagloee and Maghsodi (2003) found that this method was more appropriate than other 13 available candidate methods for the Rasht station. This station is located near the Caspian Sea and its mean annual precipitation was about 1350 mm. For arid and semi-arid regions of Iran Hg-1985 method was selected and used. This is due to the simplicity and readily availability of required data. This method was used by many investigators for ET_0 studies such as Salih and Sendil (1983), Hargreaves (1989), Mohan (1991), Amatya et al. (1995), Samani (2000), George et al. (2002), Hargreaves and Allen (2003), Chuanyan et al. (2004), DehghaniSanij et al. (2004), Garcia et al. (2004), Martínez-Cob and Tejero-Juste (2004), Vanderlinden et al. (2004) and Watanabe et al. (2004). For extreme arid region of Iran Linacre method was used. Haghighat-Joo (2003) found that this model agrees well with lysimeteric data in the Zahak station, located in the extreme arid region of southeast part of Iran. The mean annual precipitation for these parts of Iran is less than 100 mm (Dinpashoh et al., 2004). PM outputs were available for some stations of Iran from the work of Kheirabi et al. (1997). They used different time periods for different stations. Results of this study were compared with those of PM for several stations.

For the purpose of temperature correction for non-reference condition of stations, mean monthly relative wetness was investigated for all sites. ET_0 was calculated without any correction for mean air temperature (TC), if the monthly relative wetness was equal or above 1. But, where it was less than 1, TC was corrected for non-reference condition and then monthly ET_0 was calculated based on the corrected TC. Correction of TC performed by calculating T_{bias}, which is defined here as the increase in measured air temperature relative to well-watered environment (°C). T_{bias} calculated from equation (Jensen et al., 1997):

$$T_{bias} = K\left(1 - \sqrt{\frac{P}{ET_0}}\right) \quad (1)$$

where K is a coefficient that depends on the degree of aridity of the site. K is assumed to be 4 in Iran as for Utah region, which was used by Jensen et al. (1997). Subtracting T_{bias} from measured TC yielded the corrected TC. Mean annual ET_0 for a given site recalculated using equation:

$$ET_{0,year} = \sum_{i=1}^{12} (ET_{0,month})_i \quad (2)$$

where $ET_{0,year}$ is the mean annual amount of ET_0 (mm/year) and $(ET_{0,month})_i$ is the mean monthly value of ET_0 for the ith month (mm/month). Calculations were performed using the EXCELL spreadsheet software. The iso-ET_0 curves were drawn on the map using the SURFER 7.0 software.

2.3.1. *HG-1985 method*

The HG-1985 equation is one of the simplest and most accurate empirical equations used to estimate ET_0 (Jensen et al., 1997). This equation expressed by Hargreaves and Allen (2003) as:

$$ET_0 = 0.0023 R_a (TC + 17.8) TR^{0.5} \quad (3)$$

where ET_0 is the reference evapotranspiration (mm/day), R_a daily value of extraterrestrial radiation in equivalent mm of water evaporation for a day (mm/day), TC average daily air temperature (°C) and TR is the daily temperature range (°C) ($TR = T_{max} - T_{min}$ where T_{max} is the mean daily maximum temperature and T_{min} is the mean daily minimum temperature). The average values of TC and TR for a given month were used in Eq. (3). Monthly ET_0 (mm/month) was calculated using Eq. (3) multiplying by the number of days for a given month.

Various equations for prediction of R_a for a given month and latitude, L_a, were developed by many investigators such as Allen et al. (1989), Yitaew and Brown (1990), Allen (1996), Kotsopoulos and Babajimopoulos (1997) and Chuanyan et al. (2004). In this study R_a was estimated using the equation recommended by Kotsopoulos and Babajimopoulos (1997). This equation, which was developed for latitudes $0 \le L_a \le 50°$N, is expressed as:

$$R_a = M + C_1 \cos\left(\frac{2\pi J}{12} + C_2\right) + C_3 \cos\left(\frac{4\pi J}{12} + C_4\right) \quad (4)$$

where

J = order of the month,
$M = 14.9425 - 0.0098 L_a - 0.00175 L_a^2$,
$C_1 = -0.5801 + 0.1834 L_a - 0.00066 L_a^2$,
$C_2 = 3.1365 - 0.00489 L_a + 0.000061 L_a^2$,
$C_3 = 0.597 - 5.36 \times 10^{-6} L_a^3$,
$C_4 = 2.9588 - 0.00909 L_a + 0.00024 L_a^2$. (5)

2.3.2. *Adjusted Thornthwaite method*

The ATW method, which was proposed by Pereira and Pruitt (2004), can be expressed as:

$$ET_{0,i} = \begin{cases} -415.85 + 32.24 TC_i - 0.43 TC_i^2, & TC_i > 26\,°C \\ 16(10 TC_i / I)^a, & 0\,°C < TC_i \le 26\,°C \\ 0, & TC_i \le 0 \end{cases} \quad (6)$$

where $ET_{0,i}$ is the reference crop evapotranspiration and TC_i is the long-term mean effective temperature (°C) which was defined by Pereira and Pruitt (2004) as:

$$TC_i = 0.5k(3T_{max,i} - T_{min,i}) \quad (7)$$

where k = 0.72 and the index i is referred to as the number of months. "I" in (6) is referred to as the thermal index and computed from equation as:

$$I = \sum_{i=1}^{i=12} (0.2 TC_i)^{1.514}, \quad TC_i > 0\,°C \quad (8)$$

in which "a" in (6) is computed from equation as:

$$a = 6.75 \times 10^{-7} I^3 - 7.71 \times 10^{-5} I^2 + 1.7912 \times 10^{-2} I + 0.49239 \quad (9)$$

The correction factor, $L_{d,i}$ depending on the astronomical duration of the day N_i and the number of days ($N_{d,i}$) of the considered month was calculated using the following equation:

$$L_{d,i} = \frac{N_{d,i}}{30} \times \frac{N_i}{12} \quad (10)$$

The adjusted $ET_{0,i}$ was computed using the $L_{d,i}$ multiplied by $ET_{0,i}$, which was calculated from (6).

2.3.3. *Linacre method*

The Linacre equation can be expressed as:

$$ET_0 = \frac{(500 T_m / (100 - L_a)) + 15(TC - T_{dew})}{80 - TC} \quad (11)$$

where $T_m = TC + 0.006Z$ and Z is the elevation of the site in meters above the mean sea level. T_{dew} is the dew point temperature and is computed herein using the equation proposed by Howell and Dusek (1995) as:

$$T_{dew} = \frac{237.3}{1/([\ln(RH/100)/17.27] + [TC/(237.3 + TC)]) - 1} \quad (12)$$

where RH = air relative humidity in %.

3. Results and discussion

3.1. Relative wetness

Fig. 1 shows the long-term mean annual relative wetness isopleths of Iran, in which ET_0 was calculated using the HG-1985 method. The large values (>1) belong to the north part of Iran, while the small values (less than 0.1) belong to the vast areas located in central, east and southeast parts of Iran. Based on two distinct isopleths (0.1 and 1.0) Iran's area was subjectively divided into three distinct climatic regions. Region 1 is humid and located in the north of Iran. The main natural ground cover of this region is forest. Region 2 is arid and semi-arid and located mainly in the south, northwest and northeast parts of the country. Alborz and Zagros mountains are located here. Region 3 is extreme arid and lies primarily on the central and southeast part of Iran. The main feature of this region is its local winds, called "120-day Sistan winds" blow, primarily, in summer hot months. The ground mainly is bare, however, there may be found very sparse desert vegetation in some parts of this region. The number of stations in the Regions 1–3 were 5, 59 and 17, respectively (Fig. 1). The Regions 1–3 cover 1.7, 57.4 and 40.9% of Iran's area, respectively. Recalculation of ET_0 by the selected method of each region cause minor changes in boundaries of regions. Table 1 gives some useful climatic information for Regions 1–3 after mentioned recalculation.

3.2. Long-term mean monthly and annually ET_0

The long-term mean monthly ET_0 was computed for all months and stations. However, iso-ET_0 curves for each of the seven active crop growth months, April–October, were illustrated (not shown) on Iran's map. It was found that the pattern of these curves is considerably similar from month to month. The rate of change of ET_0 varied from month to month. The monthly ET_0 increased from April to July, however, the rate of increase was more rapid for earlier months. On the contrary, monthly ET_0 decreased from July to October, however, the rate of decrease was slow for earlier months, while rapid for the later. Table 2 summarized some useful information about the monthly ET_0 of Iran.

Fig. 2 shows the long-term mean annual ET_0 isopleths of Iran. The mean annual ET_0 for over 20% of Iran's area was more than 2600 mm. In the same way, for about half of the Iran's area the mean annual ET_0 was more than 1600 mm. The mean annual ET_0 of Iran varied between 832 mm in the Ramsar station, located in the Caspian Sea shoreline, and up to 3627 mm in the Iranshahr station, located in the southeast part of the country. The long-term regional mean annual precipitations for these two parts of Iran were about 1225 and 108 mm, respectively (Dinpashoh et al., 2004). This implies that the mean annual ET_0 in the southeast parts of Iran was about 33 times greater than that of the mean annual precipitation. On the other hand, the mean annual ET_0 in the coastal region of the Caspian Sea was about two thirds of its mean annual precipitation. Hence, it can be concluded that the Caspian Sea shoreline almost experience surplus water, while, the southeast parts of Iran usually confront with severe water deficit, especially in summer hot months.

Kheirabi et al. (1997) reported the results of monthly ET_0 by FAO-56 PM model for 4, 26 and 11 stations in the Regions "I" to "III", respectively. In the present study results of the selected methods for each of the regions were compared with the PM model as reported by Kheirabi et al. (1997). It was found that the absolute difference of annual ET_0 between the PM and chosen model for Regions "I" and "II" was relatively low, but this was not true for the Region "III". For example, the mean annual ET_0 for the Ramsar station located in the Region "I" was about 827 mm using PM but 833 mm computed by ATW. Similarly, the mean annual ET_0 for the Rasht station was about 943 mm using PM, whereas, 876 mm computed by ATW. Hence, it can be concluded that the regional average of difference between the PM and ATW outputs for Region "I" was about 5%. It was found that for all sites of the Region "I", ATW yielded ET_0 somewhat great than that of the PM for hot

Table 1 – Some characteristics of the three distinct climatic regions of Iran

Characteristic	Region 1 (humid)	Region 2 (arid and semi-arid)	Region 3 (extremely arid)
No. of sites in the region	5	55	21
Mean annual precipitation (mm)	1415	316	110
Regional mean annual ET_0 (mm)	886	1300	2794
Regional mean annual relative wetness	1.51	0.25	0.07
Mean annual RH (%)	79.2	52.7	41.7
Mean annual TC (°C)	15.8	16.1	19.9
Max. annual temperature (°C)	19.5	22.7	27.2
Min. annual temperature (°C)	12	9.2	12.9
Percent of Iran's area	1.7	56.4	41.9
Selected model for ET_0	ATW	HG-1985	Linacre

ET_0: reference crop evapotranspiration; RH: relative humidity; TC: average daily temperature; Max: maximum; Min: minimum; ATW: adjusted Thornthwaite; HG-1985: Hargreaves adjusted in 1985.

Table 2 – Some information about long-term mean monthly ET_0 (mm) of seven crop growth months for some stations of Iran

Station	Region	Latitude	Longitude	Altitude (m)	April	May	June	July	August	September	October
Anzali	1	37 28	49 28	−26	53	92	135	153	134	95	59
Astara	1	38 25	48 52	−18	55	101	148	171	147	99	57
Rasht	1	37 15	49 36	−7	68	112	154	169	148	105	63
Ramsar	1	36 54	50 40	−20	55	91	127	145	130	95	61
Gorgan	1	36 51	54 16	13	104	141	155	154	140	113	85
Ardebil	2	38 15	48 17	1314	89	123	137	139	125	97	67
Tabriz	2	38 05	36 17	1361	88	126	153	170	153	114	71
Sanandaj	2	35 20	47 00	1373	107	149	185	208	190	142	94
Mashad	2	36 16	59 38	990	106	148	176	186	167	125	83
Shiraz	2	29 33	52 36	1488	124	169	196	206	191	153	113
Iranshahr	3	27 12	60 42	591	294	415	484	458	441	397	309
Zahedan	3	29 28	60 53	1370	221	292	360	376	345	293	221
Zabol	3	31 13	61 29	489	213	303	391	438	413	334	225
Kashan	3	33 59	51 27	982	229	315	426	506	473	364	249
Tabas	3	33 36	56 55	711	233	318	431	471	429	363	248

summer months. However, it was in reverse order for cold months. For example, the maximum difference of two models for the Rasht station, which belongs to July, was about 1.25 mm per day.

In the Region ''II'' it was found that the output of the selected model, HG-1985, was somewhat less than that of the FAO-56 PM method for all months and stations. For example, the mean annual ET_0 of the Sanandaj station was about 1453 mm using PM but 1303 mm using HG-1985. Similarly, for the Shiraz station it was reported about 1600 mm using PM, whereas, it was computed about 1484 mm using HG-1985. Therefore, it can be concluded that in overall average of the Region ''II'', HG-1985 model was underestimated annual ET_0 (about 8%) compared to PM. However, the difference between the two above-mentioned models was relatively high for hot summer months, whereas, it was small for cold months. For example, maximum absolute difference between two models for the Tehran station belonged to August, which was about 1.12 mm per day.

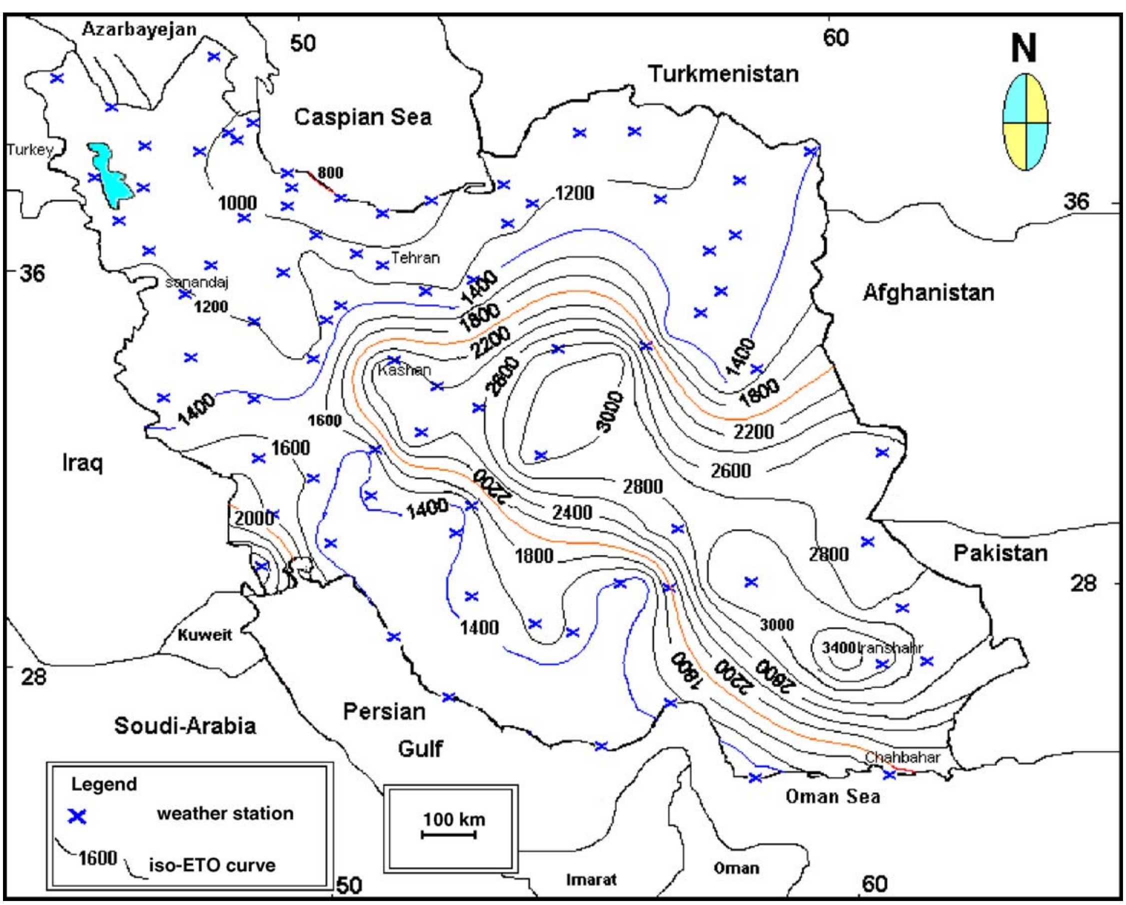

Fig. 2 – Mean annual reference crop evapotranspiration (mm) in Iran (1956–2000).

In the Region ‘‘III’’, the Linacre model was yielded ET_0 considerably greater than that of FAO-56 PM, especially for stations located relatively far from the Oman Sea. For example, the mean annual ET_0 of the Iranshahr station was reported 2424 mm using PM, whereas, it was computed here about 3627 mm using the Linacre model. In the same way, the mean annual ET_0 of the Kashan station was about 1626 mm using PM, whereas, it was computed here about 2684 mm using the Linacre model. However, for the Chahbahar station located near the Oman sea, the mean annual ET_0 was reported 1778 mm using PM, while, it was computed about 1710 mm using the Linacre method. Furthermore, difference of the two models was relatively small for cold months than those of hot months. Taghizadeh (1975) reported that the annual ET_0 of the southeast parts of Iran is about 2500 mm using Penman method, bearing in mind that he used only a 5-year time period. It could be concluded that the Linacre model estimated the mean annual ET_0 of the Region ‘‘III’’ about 1.5 times more than that of PM. For coastal stations the difference between the two models, PM and Linacre, was relatively small. On the other hand, according to Haghighat-Joo (2003), in an average of a 3-year time period there exists only little difference (say 20 mm per year) between the Linacre and direct lysimeteric measurements in the Zahak station. This station is located in an extreme arid region near the Iranshahr station. Sudden spatial variation in the mean annual ET_0 can be seen from Fig. 2 in the boundaries of the Regions ‘‘II’’ and ‘‘III’’. The difference between the outputs of the Linacre and the PM models were relatively too high, especially for extreme arid stations. On the other hand, it was found that the HG-1985 model yielded ET_0 less than PM. Therefore, It could be stated that the mentioned discontinuities is mainly due to the application of two distinct ET_0 models, i.e. HG-1985 and Linacre, for the Regions of ‘‘II’’ and ‘‘III’’, respectively. In addition, climate conditions of these two large distinct regions were obviously different.

This study had some limitations, which affect the accuracy of results. The first is that the ET_0 of all sites in a given region was computed with a single ET_0 model. However, except the Region ‘‘I’’ the area of the other two regions was relatively too large. It is not impossible that such large regions, like Region ‘‘II’’, can be divided into other sub-regions with different climates. This needed more information on climatic data of several other locations, which was not available to include them in the study. Furthermore, more knowledge on direct ET_0 measurements was needed for choosing the best model for such sub-regions. Unfortunately, this type of additional information was not available at this time. The second limitation is that the recommended model by referred works was assumed best. However, since referred researchers did not compare all ET_0 models with lysimeteric data, therefore, it may be possible that the chosen model was not best. The other limitation is that the iso-ET_0 curves were illustrated based on the selected models and climatic information of the selected 81 stations. There are many high altitude regions with cold climate in Iran, especially in Region ‘‘II’’. From these regions it can be referred to high altitude areas of the Damavand, Dena, Binalood, Zardkooh, Sabalan and Sahand mountains. Such regions were not included in the study. This was also due, mainly, to the unavailability of data. Hence, ET_0 of such cold areas were somewhat less than that of Fig. 2. Such limitations may affect the accuracy of this type of studies to some degree.

4. Conclusion

Irrigation efficiency can be increased in Iran based on accurate estimate of ET_0. Monthly ET_0 were estimated for 81 stations using the proper method from the three candidates. In essence, the monthly ET_0 was increased from April to July, but it was decreased from July to October. The highest value of the monthly ET_0, which occurred in July, belonged to the Kashan station. It was about 506 mm (about 4.4 times greater than that of the reciprocal lowest value for the Jask station for the same month). The ratio of highest/lowest ET_0 varied from month to month. The maximum ratio belonged to the cold month of growth season (about 5.56 for April) but the minimum ratio belonged to the hot dry month (4 for June). Annual ET_0 varied between 832 mm in coastal region of Caspian Sea to over 3627 mm in southeast part of Iran. It can be concluded that the southeast parts of Iran, which had low amount of annual rainfall and high annual ET_0, often confront with water deficit.

The fact that the present study was used only three distinct ET_0 models has both advantages and disadvantages. The main advantage is that the models do not require intensive data, which was not available for most locations of Iran. ET_0 of these areas can be interpolated from iso-ET_0 curves. The main disadvantage is that using limited (say 3) models for such an extensive country like Iran is questionable. Perhaps, there may be another better models for different parts of Iran. However, it seems that they cannot be found before conducting various lysimeteric experiments, which is not available at this time, but, strongly recommended for further studies.

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