Natural Environment Change
Vol. 3, No. 1, Winter & Spring 2017, pp. 71-80
DOI: 10.22059/jnec.2017.216461.54
Print ISSN: 2476-4159  Online ISSN: 2476-4167
Web Page: https://jnec.ut.ac.ir/
Email: jnec@ut.ac.ir

# An estimation of Thornthwaite monthly water-balance in Mighan sub-basin[1]

**Tahereh Ensafi Moghaddam*;** Research Institute of Forests and Rangelands, Agricultural Research Education and Extension Organization (AREEO), Tehran, Iran.
**Shirin Mohammadkhan;** Associate Professor, University of Tehran, Iran (shirin_mohammadkhan@yahoo.com)

Received: September 26, 2016 Accepted: May 06, 2017

## Abstract
Water resources in arid and semi-arid regions are heavily influenced by climate change, water shortage, water regulations, and increased water demands. Monthly discharge is one of the most important factors in hydrological studies. Some of the basins are not equipped with adequate hydrometric equipment. In such a case, average monthly discharge could be estimated by regional monthly water balance models of representative basins. In this study, the following collection of data including: temperature, precipitation and average monthly discharge, and the potential evapotranspiration was calculated by Thornthwaite equations. Remaining parts of water balance equation including: Actual evapotranspiration, soil moisture supply of the area in each month and later months are also estimated via Thornthwaite model. The net water requirements were estimated using the model by assuming that evaporation is the only path for water loss. The results have indicated that timing of recharge is very important in preserving sub-basin hydrology in this region. This modified climate diagram prompts an intuitive understanding of the relationship between recharge and consequent wet spell in Mighan sub-basin of Arak. It may be used as a standard tool to determine adequate water demand in water resources management of the arid regions for wetland protection or restoration.

## Keywords
evaporation, monthly water balance, Mighan sub-basin, Thornthwaite, water resources.

## 1. Introduction
Most of the important climate change impacts in Iran are associated with rainfall and water availability. Changes in climate will be happened particularly in evidence around lakes, river basins and waterways due to the impact of temperature on evaporation and increased variability of rainfall. Declining rainfall and water scarcity will have significant negative impact on agricultural production and on food security. "There are several lakes in the center of Iran which exist at the end basin in dry zones. These are called playa lakes" (Ghanavati et al., 2012). There are many shared river basins and water bodies in Iran with less water and more variability, such as Mighan sub-basin.

The objectives of this study are to simulate the Thornthwaite moisture index (ET) for the zones within a Central province of Iran during 50-year periods in the 21st century, and to estimate the interactive effect of ET, and estimate of Thornthwaite monthly water balance in Mighan sub- basin during the same period. "Due to climate changes, lack of precipitation,

---

1. This paper is a part of Research Project under title: "Influence of Climate Changes on ground and surface water using fifthy years (Case study: Mighan watershed of Arak)" (2014) which is available in Research Institute of Forests and Rangelands, Tehran, Iran, by 2-09-09-89015 Code.

* Corresponding author, Email: Ensafi@rifr-ac.ir

human activity and mismanagement of water resources, entering water has been reduced and caused seasonally or permanently dryness. The drought led to deposition of dissolved salt minerals and the pond has turned into the desert as well. Mighan is a drained catchment area of approximately 5,528 km$^2$, which has been faced with water reduction and desertification phenomena. This study was performed to investigate water balance in the Mighan sub- basin. Mighan, as a wetland is located in the northeast of Arak in Farahan plain. It is made along the fault lines and its water is salty. Its height is 1,660 m above sea level and is composed of two parts: the mountainous area and the sediment plain" (Mohammadi et al., 2014).

## 2. Study area

Mighan water basin is one of the fifth sub-basins of Qom water basin. The adjacent basins of this area are Rudshur, Qomrud, Qarechai, and Kavir-E-Kashan. Mighan basin is composed of the seasonal lake or Mighan desert, alluvial plains around it, and the alluvial fans on the plain edges and the mountainsides. This area is situated in the geographical position of 49.33 to 50.26 eastern longitude and 33.8-34.7 northern latitude (Mohammadi et al., 2014; Fig. 1).

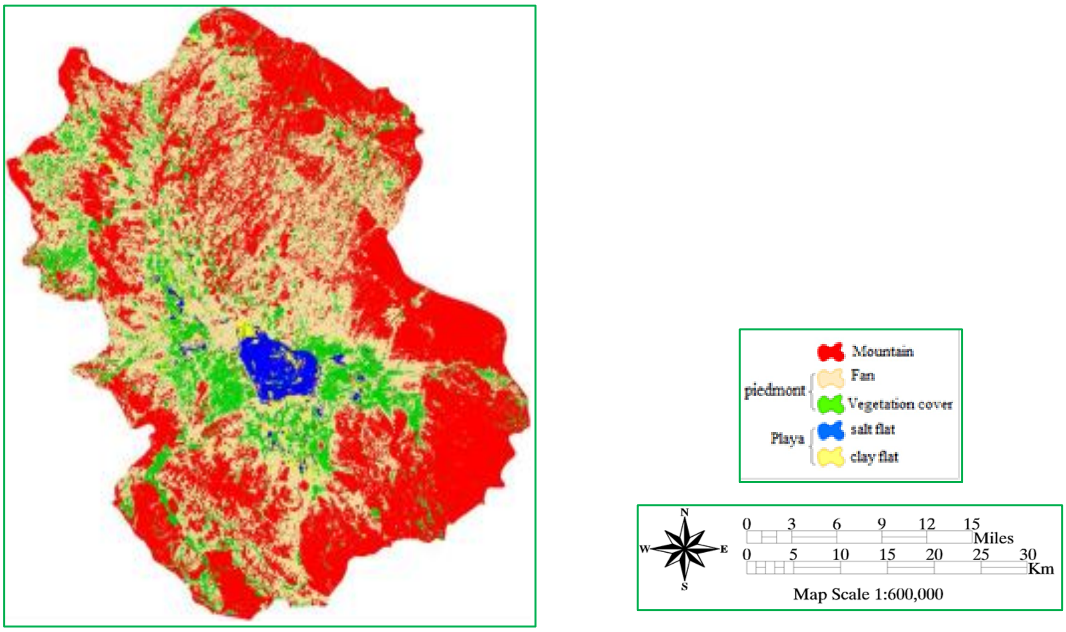


**Fig. 1. Geomorphic map for the study area in time span of 28 years (1972-2002; Mohammadi et al., 2014)**

## 3. Materials and Methods

In 1948, Thornthwaite and Penman, both developed the potential evapotranspiration equation, independently. Here, the Potential ET[1] refers to the maximum ET that can occur from a given crop surface. Penman’s equation was more mechanistic while Thornthwaite’s equation was more empirical. The equation of Thornthwaite (1948) is simpler than that of Penman’s because the method requires less climatic data (Subedi & Chávez José, 2015).

Water balance can be assessed in the area from the results obtained in statistical data computed about precipitation temperature and evapotranspiration. In conformity with Tornthwaite’s method by Equation (1) (Thorntwaite & Mather, 1955; 1957), the following equation is used for estimating the water balance in the area.

$$P - ET + WD - SW = O \qquad (1)$$

where P is precipitation, ET is evapotranspiration, WD[2] is water deficit and WS[3] is water surplus (Mahdavi, 1987).

1. evapotranspiration
2. water deficit
3. water surplus, WS=P-ET

**Table 1. Geographic features of examined stations**

| Row | Stations | UTMY | UTMX | Elevation |
|---|---|---|---|---|
| 1 | Kareroud | 3659488 | 373979 | 1900 |
| 2 | Sareabadan | 3845611 | 573249 | 2150 |
| 3 | Gavchelo | 3817035 | 345426 | 1780 |
| 4 | Qezelghash | 3858474 | 378783 | 1516 |
| 5 | Razin | 3877012 | 407497 | 1348 |
| 6 | Ashtian | 3821351 | 407845 | 2080 |
| 7 | Shazand | 3754686 | 351793 | 1944 |
| 8 | Anjedan | 3761355 | 411115 | 2000 |
| 9 | Hoseinabad | 3699567 | 402314 | 2239 |
| 10 | Mazraeyeno | 3714511 | 387076 | 2198 |
| 11 | Dehenoo | 3702311 | 396893 | 2182 |
| 12 | Hoseinabadkhomain | 3720005 | 414427 | 1570 |
| 13 | Naraq | 3773015 | 489268 | 2354 |
| 14 | Shamsabad | 3776428 | 469944 | 1680 |
| 15 | Dodahak | 3777025 | 460045 | 1470 |
| 16 | Varcheh | 3738644 | 401244 | 2060 |
| 17 | Navazan | 3774351 | 392900 | 1800 |
| 18 | Malekabad | 3774230 | 395450 | 1670 |
| 19 | Shanagh | 3765481 | 427735 | 2148 |
| 20 | Savarabad | 3760868 | 389258 | 1947 |
| 21 | Saghi | 3752446 | 404314 | 2048 |
| 22 | Khoogan | 3739415 | 420997 | 1900 |
| 23 | Khomain | 3723080 | 414995 | 1800 |
| 24 | Ebrahimabad | 3773120 | 430181 | 2100 |
| 25 | Hendoodar | 3739160 | 336757 | 2091 |
| 26 | Hezaveh | 3781460 | 365603 | 2093 |
| 27 | Nahremian | 3763590 | 335303 | 1920 |
| 28 | Molabagher | 3744579 | 327436 | 2186 |
| 29 | Mazraeykhatoon | 3762202 | 330145 | 2025 |
| 30 | Govar | 3759496 | 377667 | 1970 |
| 31 | Kamalsaleh | 3722812 | 341478 | 1820 |
| 32 | Qadamgah | 3760315 | 358710 | 1800 |
| 33 | Qasemabad | 3750534 | 381807 | 2126 |
| 34 | Sirkand | 3755328 | 371854 | 2374 |
| 35 | Suraneh | 3750278 | 358200 | 1935 |
| 36 | Senejan | 3769886 | 371898 | 1964 |
| 37 | Deh-e-Kaeed | 3757422 | 319146 | 2230 |
| 38 | Deh-e-Salman | 3727525 | 345608 | 1987 |
| 39 | Hajiabad | 3734261 | 362157 | 2060 |
| 40 | ChalHoma | 3742675 | 341687 | 2320 |
| 41 | Enaj | 3784060 | 347475 | 1790 |
| 42 | Arak | 3774007 | 380085 | 1803 |
| 43 | Astaneh | 3737989 | 352532 | 2253 |
| 44 | Milajerd | 3831552 | 328558 | 1669 |
| 45 | Lenjab-e-Sofla | 3809667 | 343771 | 1945 |
| 46 | Qataraghaj | 3809688 | 353234 | 1960 |
| 47 | Favaran | 3814658 | 329568 | 1678 |
| 48 | Farmahin | 3817401 | 378408 | 1785 |
| 49 | Shirinabad | 3834450 | 370485 | 1870 |
| 50 | Saruq Bala | 3808925 | 361456 | 1800 |
| 51 | Dastjan | 3828240 | 362568 | 1893 |
| 52 | KhondabJooshirvan | 3810748 | 329591 | 1680 |
| 53 | Khondab | 3805791 | 332720 | 1720 |
| 54 | Javarsian | 3793032 | 343492 | 1800 |
| 55 | Eybakabad | 3791930 | 378789 | 1670 |
| 56 | Arjanavand | 3801983 | 347476 | 2078 |
| 57 | Nangard | 3799431 | 423344 | 1680 |
| 58 | Mastar | 3834216 | 388242 | 2074 |
| 59 | Garakan | 3823796 | 389899 | 2170 |
| 60 | Deh-e-Namak | 3790134 | 395906 | 1700 |
| 61 | Davudabad | 3795895 | 394247 | 1660 |
| 62 | Ahoo | 3826361 | 415003 | 2433 |
| 63 | Yatan | 3897847 | 386361 | 1780 |
| 64 | Farak | 3849672 | 390207 | 1780 |
| 65 | Ezoddin | 3857125 | 398719 | 1332 |
| 66 | Razeghan | 3910693 | 405283 | 1860 |
| 67 | Tooreh | 3850102 | 414305 | 1341 |
| 68 | Tafresh | 3856853 | 409749 | 1929 |
| 69 | Amrabad | 3890078 | 401330 | 1660 |

In this research, Tornthwaite's method of Water Balance was conducted with a 50 years record (1958-2008) obtained from 69 stations, including monthly maximum and minimum air temperature and precipitation. "Following collection of data in temperature, precipitation, and average monthly discharge in this sub basin, the potential evapotranspiration was calculated using Thornthwaite formula. Remaining parts of water balance equation including actual evapotranspiration, soil moisture supply of sub basin in each month and later months are estimated from Thornthwaite model" (Mahdavi & Azarakhshi, 2004). Therefore, we calculated monthly evapotranspiration using the Thornthwaite method and also corrected that for local conditions based on evapotranspiration measurements.

The main purpose of this research is to detect the generated changes in water balance of the study area for Climate Impact Assessment by using statistical analysis.

$$\alpha = (0.675\, I^{3} - 77.1\, I^{2} + 17920\, I + 492390)\, 10^{-6} \qquad (2)$$

According to Afzali et al. (2013) α is an exponent which is gotten Equation (2).
where obtained α were 0.1, 0.2, 0.3, 0.5, 0.6, 0.7 and 1, and minus 0.1, 0.2, 0.3, 0.5 from the results, and with these values new potential evapotranspiration data were obtained, and then it was compared with class A pan data in the range of errors of 10%, 20%, and 30% (Afzali et al., 2013).

An estimation of water balance, according to the Equation (1), has been investigated in Mighan sub-basin in two parts of time. One part of time contains the season which rainfall predominates and the other part contains the season that evapotranspiration is predominated. Clearly, the two time periods are explained (further) as follows:

In the first time period, the rainfall season lasts from December to April. During this period, precipitation exceeds evapotranspiration. Thus, there is Water surplus and the value is in excess of rainfall over evapotranspiration, WS=P-ET (Mahdavi, 1987).

This water surplus occurs in Mighan sub-basin in Jaunary, February and March about 8.1, 19.15, and 22.35, respectively (Table 2).

**Table 2. Months potential and actual evapotranspiration in the Mighan sub-Basin**

| Months | ET actual (mm) | ET potential (mm) | Range (mm) |
|---|---|---|---|
| Jan. | 28.10 | 0.00 | -28.10 |
| Feb. | 18.05 | 0.00 | -18.05 |
| Mar. | 24.95 | 0.00 | -24.95 |
| Apr. | 113.34 | 71.00 | -42.35 |
| May | 225.51 | 116.57 | -108.95 |
| Jun. | 341.78 | 143.79 | -198.00 |
| Jul. | 403.82 | 145.41 | -258.42 |
| Aug. | 394.47 | 114.65 | -279.82 |
| Sep. | 343.15 | 67.06 | -276.09 |
| Oct. | 232.54 | 32.85 | -199.69 |
| Nov. | 144.58 | 8.27 | -136.31 |
| Dec. | 60.53 | 0.00 | -60.53 |
| Total | 2330.84 | 699.58 | -1631.26 |

The second period conforms to dry season, April to November. During these months evapotranspiration exceeds precipitation. In these conditions, there is a water deficit (WD) which can be represented as WD= P- ET (Mahdavi, 1987).

Water balance can be presented by another method as follows:

P>ET for the periods called humid during Desember, January and February when the mean annual rainfall exceeds evapotranspiration and P<ET/2 for moist periods.

Potential evapotranspiration is one of the important agroclimatic factors. It is defined as the combined loss of water by evaporation from water surfaces, soil and transpiration by vegetation under conditions of unlimited or plentiful water supply. The classic definition of potential evapotranspiration was provided by Penman (1956) who considered it as the "… evaporation from an extended surface of short green crops, actively growing, completely shading in the ground, of uniform height and not short of water".

In an agroclimatology study, direct measurement and accurate estimates are necessary. Unfortunately, there is no direct measurement of this element in the area. It has been made of various formula which have been devised for its estimation from routine meteorological observation.

$$\mathrm{PE} = \mathrm{ET} = (\frac{h}{12})(\frac{D}{30}) \quad (3)$$

The methods of evapotranspiration estimation may be divided into three main groups: Theoretical methods, empirical methods, and water balance methods. In the first stage, we have used empirical methods to estimate evapotranspiration in this region. We have suggested various empirical formula for prediction of evapotranspiration. The development of these equations has been based on correlation of evapotranspiration with two or more climate factors (Mahdavi, 1987).

# 4. Results and Discussion

In this paper Tornthwaite's method, which suits the available meteorological observations has been selected. In fact, it is not the best method because it has been criticized for neglecting vital meteorological factors, such as solar radiation, humidity, wind speed, etc. which directly affect evapotranspiration. Unfortunately, solar radiation, humidity, wind speed, etc. have not obtained long-term records in the region. Because of the lack of long-term records information on these meteorological factors, and in spite of certain deficiencies, the Tornthwaite's method has been chosen, which is still actively using in arid areas.

Tornthwaite suggested an empirical equation for estimation of potential evapotranspiration. The simplicity of the formula and the availability of temperature and rain data for long periods at many stations have been the main reason of its widespread use. In fact, it is the best known and most widely used of all the empirical formula in the places where there is insufficient data on other meteorological factors (Mahdavi, 1987). Tornthwaite's formula is as Equation (4).

$$\mathrm{ET} = 1.6(10\frac{T}{I})^{m} \quad (4)$$

where ET is the potential evapotranspiration in mm, T is the monthly mean of air temperature in °C and I is annual heat indices, which is as Equation (5).

$$I = \sum\nolimits_{t}^{12} \quad \text{where } \mathrm{t} = (\frac{T}{5})^{1.514} \quad (5)$$

where m is cubic function of I and is empirically determined being equal.

Et is unadjusted potential evapotranspiration based on a 12 hour period, and a 30 days month. By adjusting of actual day length (h), Table 2, and the true number of days in the month (D), the actual evapotranspiration is obtained from the expression: Potential and actual evapotranspiration has been calculated by the authors according to the above method for Mighan sub-basin (Table 3).

**Table 3. Monthly soil water balance using Thornthwaite for PET**

| Month | T (°C) | P (mm) | PET | AET | PAW | DS | Surplus | Deficit |
|---|---|---|---|---|---|---|---|---|
| Jan. | 0 | 34 | 5 | 5 | 45 | 28 | 0 | 0 |
| Feb. | 1 | 42 | 8 | 8 | 48 | 3 | 31 | 0 |
| Mar. | 5 | 35 | 40 | 40 | 43 | -5 | 0 | 0 |
| Apr. | 10 | 53 | 78 | 78 | 18 | -24 | 0 | 0 |
| May | 15 | 35 | 119 | 54 | 0 | -18 | 0 | -65 |
| Jun. | 20 | 6 | 151 | 6 | 0 | 0 | 0 | -145 |
| Jul. | 24 | 2 | 172 | 2 | 0 | 0 | 0 | -170 |
| Aug. | 24 | 2 | 127 | 2 | 0 | 0 | 0 | -125 |
| Sep. | 21 | 2 | 121 | 2 | 0 | 0 | 0 | -119 |
| Oct. | 15 | 12 | 86 | 12 | 0 | 0 | 0 | -73 |
| Nov. | 9 | 38 | 50 | 38 | 0 | 0 | 0 | -12 |
| Dec. | 4 | 39 | 23 | 23 | 17 | 17 | 0 | 0 |

Source: Field survey by authors

Constructing a water balance is one of the first tasks in understanding the water regime of a specific area. In simple terms, a water balance is a budgeting exercise that assesses the proportion of rainfall that becomes stream flow (or runoff), evapotranspiration, and drainage (or groundwater recharge). Result of PE estimation indicated clearly that July and August have the highest values of evapotranspiration. In contrary, December, January, February, and March have the lowest values of evapotranspiration in the study area. In seven months of the year including January, February, Mars, April, May, November, and December, the ET is less than rainfall in this sub-basin (Fig. 2).

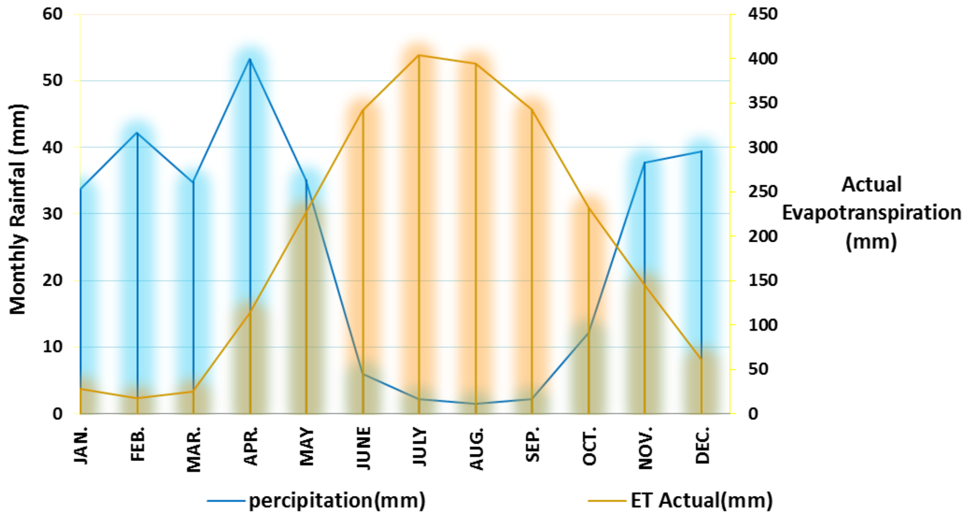


**Fig. 2. Pan evaporation data (mm) in the Mighan sub-basin**

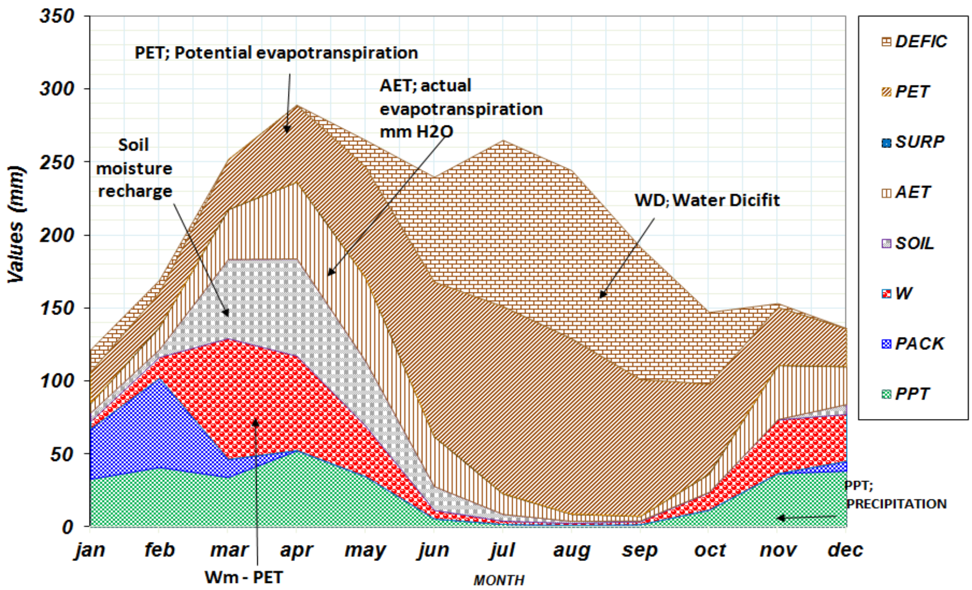


**Fig. 3. Monthly water balance for Mighan sub-basin**
**Source: Field Survey by Authors**

Figure 3 represents a simple diagram representation of a water balance, which could be represented by Equation (6), where SW[1] is the change in soil water over the time step.

Of these, rainfall and runoff (as stream flow) are directly measured. However, to close the water balance, either drainage (or ground water recharge) or Evapotranspiration (ET) also need to be estimated/measured.

1. SW: change in soil water over the time step

Water budgeting is frequently accomplished through water balance models, of which there are a vast number. A rather simple, graphical method to determine the probability or frequency of occurrence of yearly or seasonal rainfall was described in this paper. The first step is to obtain annual rainfall totals for the cropping season from the area of concern. In locations where rainfall records do not exist, the figures from the nearby stations may be used with caution. It is important to obtain long-term records. The variability of rainfall in arid and semi-arid areas is considerable. An analysis of only a few observations is inadequate as these values may belong to a particularly dry or wet period and hence may not be representative for the long term rainfall pattern. In this paper, 50 annual rainfall totals from Mighan sub-basin were used for the analysis (Table 3).

$$P = ET + RO + dSW + D \qquad (6)$$

Calculations to determine SW and APWL was performed for each time step using monthly precipitation (P) and potential evapotranspiration (PET)[1] in all of the stations in Mighan sub-basin.

Excess water, i.e., net precipitation (ΔP) in excess of the soil's water holding capacity (AWC)[2] leaves the soil and is stored in the watershed and eventually released to the river. Table 4 summarizes the calculations.

The Water surplus (WS)[3] does not recharge the ground storage (GS)[4] and so, run off, does not occur in the area (the ground storage assumed to be the maximum amount of water which could be stored in the ground). It is realized that this storage capacity varies with the texture and structure of the soil. Specific storage capacity can only be taken into account in local study and this has been taken to be 100 mm in the region by the Ministry of Power of Iran.

**Table 4. Annual water balance for Mighan sub-basin [5]**

| Month | D | N | O | S | A | J | J | M | A | M | F | J | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PPT | 38.8 | 36.9 | 12.0 | 2.1 | 1.5 | 2.3 | 6.0 | 34.8 | 52.7 | 34.4 | 41.2 | 33.2 | 296 |
| Temp | 3.5 | 9.3 | 15.0 | 20.5 | 23.5 | 23.7 | 20.1 | 15.1 | 10.3 | 4.9 | 0.8 | 0.5 | |
| F | 0.59 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.82 | 0.13 | 0.08 | |
| Rain | 23 | 37 | 12 | 2 | 2 | 2 | 6 | 35 | 53 | 28 | 5 | 3 | 207 |
| Snow | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 36 | 31 | 88 |
| Pack | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 61 | 34 | |
| Melt | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 55 | 9 | 3 | 88 |
| Input | 32 | 37 | 12 | 2 | 2 | 2 | 6 | 35 | 65 | 83 | 15 | 5 | 296 |
| Pet | 26 | 39 | 61 | 93 | 120 | 128 | 106 | 76 | 52 | 34 | 24 | 21 | 781 |
| W- Pet | 7 | -3 | -49 | -91 | -118 | -126 | -100 | -41 | 12 | 49 | -9 | -16 | |
| Soil | 7 | 0 | 0 | 1 | 1 | 5 | 16 | 44 | 67 | 54 | 5 | 6 | |
| ΛSoil | 7 | 0 | 0 | -1 | -3 | -12 | -28 | -22 | 12 | 49 | 0 | -1 | |
| AET | 26 | 37 | 12 | 3 | 5 | 14 | 34 | 57 | 52 | 34 | 15 | 6 | 296 |

1. PET: potential evapotranspiration.
2. AWC: available water capacity of the soil
3. WS : water surplus, WS=P-ET
4. GS : ground storage
5. The first computation of the water-balance model is the estimation of the amount of monthly precipitation (P) that is rain (Prain) or snow (Psnow), in millimeters. When mean monthly temperature (T) is below a specified threshold (Tsnow), all precipitation is considered to be snow. If temperature is greater than an additional threshold (Train), then all precipitation is considered to be rain. Within the range defined by Tsnow and Train, the amount of precipitation that is snow decreases linearly from 100% to 0% of total precipitation. This relation is expressed as:

$$P_{snow} = P \times \left[ \frac{T_{rain} - T}{T_{rain} - T_{snow}} \right]$$

Prain then is computed as:

$$P_{rain} = P - P_{snow}$$

Based on an analysis of water-balance results for a number of sites, a useful value for Train is 3.3 °C (McCabe & Wolock, 1999). Useful values for Tsnow appear to vary by elevation. For elevations below 1,000 m, Tsnow= -10 °C seems to work best, and for locations above 1,000 m Tsnow= -1 °C is more appropriate. (These values were determined from previous model calibrations during testing and evaluation for streamflow-gage sites in the conterminous United States. (David Wolock, U.S. Geological Survey, Lawrence, Kans., personal commun). Psnow accumulates as snow storage (snostor).(McCabe & Markstrom, 2007).

As the correlation between Thornthwaite data and class A pan was determined. The study shows that in order to use the Thornthwaite method in Iran, we must add 0.5 to 0.7 to the exponent of the formula until the data of this method to the class A pan in the error range of 30%. And the α was obtained to be 0.1, 0.2, 0.3, 0.5, 0.6, 0.7 and 1, and minus 0.1, 0.2, 0.3, 0.5 from the result and with these values new potential evapotranspiration data was obtained and then it was compared with class A pan data in the range of errors of 10%, 20%, and 30%. We concluded that if we use Thornthwaite method for estimating evaporation in this region of Iran, we must add 0.5 to exponent formula, until the results have a better correlation with class A pan evaporation in 30% error range (Afzali et al., 2013).

Thornthwaite's water balance method is not based on strong mathematical and physical principles, since it is purely empirical. However, as it is simple to use and gives acceptable results, this method is still used to estimate irrigation water requirement in many parts of the world. Kumar et al. (1987) compared the Thornthwaite and Penman methods, in India, to calculate potential ET. They also reported that Penman's potential evapotranspiration estimates were higher than Thornthwaite's estimates during the winter and pre-monsoon months and lower during the monsoon months, at most of the Indian stations. Pereira and De Camargo (1989) concluded that Thornthwaite's method was not appropriate for estimating ET in in all climatic conditions; however, they indicated that the method could be used for irrigation scheduling purposes when the fetch requirement is met. Bautista et al. (2009) concluded that Thornthwaite's method worked very well during the rainy months in both of their research sites; however, for drier months the use of Thornthwaite's method was not recommended without the adjustment of its coefficient (Subedi & Chávez José, 2015).

The calculated data were compared with 50 years observation data which showed quality of the Thornthwaite model was satisfactory and this is approximately same as the results of Mahdavi (1987) in Dasht-E- Kavir, Centeral Iran, i.e, "a case study of the Kashan meteorological station". He has compared monthly simulated with observed runoff data as Statistical and graphical representation, and his study on arid climate have had same conclusions. Thus, the implications can confirm the results of this research. Some terms of the water balance were calculated, and found to have similar magnitudes, but very different distributions. Averaged over local areas in the Central basin of Iran namely, Mighan sub-basin, the seasonal cycle is a balance between changes in E-P, and entrainment, with advection playing a relatively minor role in water resources management.

Afzali et al. (2013) concluded that Thornthwaite method data have more errors than class A pan in Iran. In spite that class A pan data are corrected fairly (because it is an empirical method) but they don't use it because it may be cracked and destroyed in cold months. Therefore, correction mathematical formula such as Thornthwaite method is more comfortable for estimating evapotranspiration. They don't use this formula in climate condition of Iran without surveying and calibration, because it belongs to other region and climate conditions. They concluded that if we use Thornthwaite method for estimating evaporation in this region of Iran, we most add 0.5-0.7 to exponent formula, until the results have a better correlation with class A pan evaporation in 30% error range.

The results of the study which was done by Afzali et al. (2013) show that for using Thornthwaite method in central region of Iran such as Mighan sub basin, we must add 0.5 to the exponent of the formula to adjust the data of this method to the class A pan in the error range of 30% (Afzali et al., 2013).

This work highlights the potentially significant role of surface and ground water in the hydrologic cycle formation. We hope it can also help us interpret measurements that will be available soon from the Aquarius satellite missions.

## 5. Conclusion

Monthly water-balance models have been used to examine the various components of the hydrologic cycle (for example, precipitation, evapotranspiration, and runoff; McCabe & Markstrom, 2007). Potential evapotranspiration (ETo) is widely used in hydrology and is essential for agriculture water resource. Unfortunately, some weather variables, is often missing which could impede the estimation of ETo. Since, the objective of this study was to examine whether it is possible to attain the reliable estimation of ETo by empirical model and satellite data for daily time step (Asarehmostaghim et al., 2011).

In order to calculate the main results of this study on water balance, evapotranspiration should be taken into account. Evapotranspiration has been calculated for the area and its value exceeds 2330.8 mm and it is 7.8 times the mean annual rainfall. The annual potential evapotranspiration value is high in the crop growing season, being about 2.3 times that the rainfall in this period. Evapotranspiration goes up dramatically before the heading of winter crops, just at the time when they require irrigation more than at the other time. At this time, water deficit for irrigation usually reduces crop production. With the start of summer season the evaporation value increase greatly, and it limits the development of summer crops in the area.

There is a water surplus (WS) during the winter season, but its value is small, and it is unable to recharge the ground storage (the ground storage has been determined at 100 mm in the area). Therefore, runoff does not occur. In this situation, with the start of summer season, the rainfall no longer recharges the ground storage and water deficit (WD) occurs for six months of the year. When WD starts, crops usually should be irrigated at short intervals. Under these conditions, agricultural production is limited by quantity of water available in the area. WD is one of the biggest problems for agriculture in the arid and semi-arid areas, in general, and in the Mighan Sub-Basin, in particular.

We could make some changes in α in order to gain better results. But these results were not under the influence of the determined climate using De Martonne method. Since the less percentages of the obtained data from Thornthwaite method was in the error ranges of 10% to 20%, the data were studied in the error range of 30% pan. According to Afzali et al. (2013) Mighan sub-basin stations could indicate the Thornthwaite data percentages, in 30% error range of pan in $\alpha + 0.3$ and Thornthwaite data percentage with $\alpha + 0.5$ ($\alpha + 0.3$: 64% and $\alpha + 0.5$: 56%). Therefore, this sub basin stations has less Et than the other stations (Afzali et al., 2013).

### Acknowledgement
We express our gratitude to the anonymous reviewers for their valuable suggestions and comments that helped improve this paper significantly. The funding of this research was provided by the Research Institute of Forests & Rangelands, Iran.

## References
1. Afzali A.; Mahdavi, M.; Zare Chahoki, M.A. (2013). Calibration of Thornthwaite method with class A pan in the catchments of central plateau of Iran. Technical Journal of Engineering and Applied Sciences, Available online at www.tjeas.com, TJEAS Journal-2013-3-20/2755-2758.
2. Asarehmostaghim, M.; Rahimikhoob, A.; Asarehmostaghim, L. (2011). Assessment of Thornthwaite equation for calculating agricultural water use in sugarcane fields with NOAA/ AVHRR data. Proceedings of 1st International and 3rd National Conference on Dams and hydropower, Tehran, Iran.
3. Bautista, F., Bautista, D., & Delgado-Carranza, C. (2009). Calibration of the equations of Hargreaves and Thornthwaite to estimate the potential evapotranspiration in semi-arid and subhumid tropical climates for regional applications. Atmosphera, 22(4), 331-348.
4. GHanavati, E.A.; Mirzakhani, B.; Asgari, A. (2012). Geomorphology of Meyghan basin the survey of geomorphological landforms and range of their development. Journal of Physical Geography, Fall 5(17): 1-12.
5. Kumar, K. K., Kumar, K. R., & Rakhecha, P. R. (1987). Comparison of Penman and Thornthwaite methods of estimating potential evapotranspiration for Indian conditions. Theor. Appl. Climatol., 38, 140-146. http://dx.doi.org/10.1007/BF00868097.
6. McCabe, G.; Markstrom, J.; Steven, L. (2007). A monthly water-balance model driven by a graphical user interface. U.S. Geological Survey, Reston, Virginia, Open-File Report, 2007-1088.
7. Mahdavi, M. (1987). A statistical analysis of the climate in the margin of the Dasht-E-Kavir, Centeral Iran (A case study of the Kashan meteorological station). Desert(Scientific Research), Tehran University and Director: Iran Desert Research Center, No:18, P: 30-35.

8. Mahdavi, M.; Azarakhshi, M. (2004). A determination of an appropriate monthly water balance in small watersheds of Iran (Case study: Eastern Azarbayejan and North of Khorasan). Iranian J. Natural Res., 57(3): 415-427.
9. Mohammadi, M.; Seif, A. (2014). Change detection of geomorphic units of Mighan basin using multi-temporal satellite data. J. Appl. Environ. Biol. Sci., 4(2): 89-97.
10. Penman, H.L. (1956). Estimating evaporation. American Union Transactions, 37(1): 43-50.
11. Pereira, V., de Camargo Smidt, E. & Leite Borba, E. (1989) Plant Syst. Evol. ... Biologia reprodutiva de Pseudolaelia corcovadensis (Orchidaceae): melitofilia e autocompatibilidade em uma Laeliinae basal. ... Gill DE (1989).
12. Subedi, A.; Chávez José, L. (2015). Crop Evapotranspiration (ET) Estimation Models: A Review and Discussion of the Applicability and Limitations of ET Methods. Journal of Agricultural Science, 7(6).
13. Thorntwaite, C.W.; Mather, J.R. (1955). The water balance. Publ. Climatol., 8(1).
14. Thorntwaite, C.W.; Mather, J.R. (1957). Instructions and tables for computing potential evapotranspiration and the water balance. Publ. Climatol., 10(3).
15. Thornthwaite, C.W., 1948. An approach toward a rational classification of climate. Geographical Review, 38: 55–94. Trewartha, G.T., 1961