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Agricultural Meteorological Properties of Aras Basin in Turkey

Mücahit KARAOĞLU*
Iğdır University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Iğdır, TURKEY

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*Sorumlu Yazar/Correspondence: mucahitkaraoglu@hotmail.com

Abstract: Climate has direct effects on the surface features, vegetation, animals, agriculture, and human behaviours of a region. Agricultural Meteorology is briefly the application of climatology to agriculture. Planning and works to be performed without taking climatic conditions into account might lead to incorrect results and serious damages. Therefore, climate studies of the regions should be made, constantly monitored and renewed in certain periods. In this study; climatic conditions, climate diagrams and water budgets of Erzurum, Ağrı, Iğdır, Kars, and Ardahan provinces in basin of Aras were evaluated using their thirty-year data (1976-2005). The course and the relationships of temperature, rainfall, relative humidity, and evaporation parameters were investigated for the selected period. As a result, the long term annual average temperature of Iğdır is twofold and more than the others. Long-term mean annual rainfalls of all provinces in Aras basin are less than Turkey's average precipitation. Contrary to common belief, Iğdır has the lowest long term monthly and annual relative humidity values in Aras basin. Iğdır and Ardahan provinces have the highest and lowest long term average of total evaporation values, respectively.

Keywords: Aras basin, agricultural meteorology, climate elements, climate diagrams, water budget

Aras Havzası (Türkiye) Zirai Meteorolojik Özellikleri

Özet: İklim, bir bölgenin yüzey şekilleri, bitki örtüsü, hayvanları, tarımı ve insan davranışları üzerinde doğrudan etkilidir. Zirai Meteoroloji, klimatolojinin tarıma uygulanmasıdır. İklim özellikleri dikkate alınmadan yapılacak planlama ve çalışmalar hatalı sonuçlara ve ciddi zararlara sebep olacaktır. Bu sebeple, bölgelerin iklim etüdü yapılmalı, sürekli olarak izlenmeli ve belli sürelerde yenilenmelidir. Bu araştırmada, Aras havzasında yer alan Erzurum, Ağrı, Iğdır, Kars ve Ardahan illerine ait otuz yıllık (1976-2005) veriler kullanılarak iklim özellikleri, iklim diyagramları ve su bütçeleri belirlenmiştir. Seçilen dönem için sıcaklık, yağış, bağıl nem ve buharlaşma öğelerinin gidişi ve ilişkileri araştırılmıştır. Sonuç olarak, Iğdır'ın uzun yıllar yıllık ortalama sıcaklık değeri diğer illerin iki katı ve daha fazlasıdır. Aras havzasındaki illerin yağışları Türkiye uzun yıllar toplam yağış ortalamasının altındadır. Bilinenin aksine, Iğdır, Aras havzasında en düşük bağıl nem değerine sahiptir. Aras havzasında, uzun yıllar toplam yıllık buharlaşma miktarı Iğdır'da en yüksek, Ardahan'da en düşük değerdedir.

Anahtar Kelimeler: Aras havzası, zirai meteoroloji, iklim elemanları, iklim diyagramları, su bütçesi

1. Introduction

Climate is usually described in terms of the mean and variability of temperature, precipitation, and wind over a period of time, ranging from months to millions of years (the classical period is 30 years) (Anonymous, 2007). Since climate is composed of long-term average weather patterns, it includes the average measurements of various meteorological elements.

The climatic elements of temperature, precipitation, and wind are not the only parameters included in a climatology package; however, they are the most significant elements used to express

the climate of a region, climatic elements have a direct effect on the system of animal production, body physiology and animal behaviour, feed supply and quality, proliferation of pests and parasites as well as preservation of animal products (Samson et al., 2011).

Many scientists or climatologists studying on Earth's past and modern climate records try to establish useful climate classification schemes. For example, in the past, climates were determined according to travel, regional knowledge, and latitude whereas today climate classifications are based on the causes and effects of climate.

The World Meteorological Organization (WMO) advises member countries to make climate studies and to determine climate properties according to minimum one climate classification. It is suggested that these studies are required to be supported by maps and charts using a great number of climatic parameters (Anonymous, 1987).

Türkeş (2010) presented the regions of rainfall regime in Turkey by using maps and tables. He stated that Aras basin in continental eastern Anatolia has middle amount of rainfall in spring and at the beginning of summer, and it has a very cold and snowy winter, and a dry-semi humid and humid steppe highland. Karaoğlu (2010 and 2011) examined the climate data of Bingöl and Iğdır provinces, and the data and findings were discussed on agricultural meteorology. Yeşilnacar et al. (1998) calculated water budget of provinces within Southeastern Anatolia Project according to Thornthwaite method.

The aim of this study is to present climate characteristics of Aras basin in terms of agricultural meteorology. The study uses long term mean temperature and total rainfall data to prepare climatograms, applies Thornthwaite method to calculate water budget.

2. Material and Methods

The study area, Aras Basin, cover The River Aras in which rises near Dağkale hill, located in the middle of the Erzurum, Bingöl and Muş triangle in Turkey, meets with River Arpaçay coming from the north, and flows along the Turkey-Armenia border.

The Aras basin has an Eastern Anatolia type continental climate. Winters are rather cold and long, and summers are cool. During the cold period, this region is snow-covered and frost occurrence is more often. Plain parts of the province of Iğdır are not affected by the severe continental climate as much as the other parts of Eastern Anatolia region. The average temperature in January, which is the coldest month, is -4.2 °C, and the average temperature is 24.2 °C for the warmest month of July; annual average temperature is 10.2 °C. The average of total annual precipitation is 579.4 mm, and the rainfalls are mostly observed in winter and spring.

The thirty-year (1976-2005) controlled data of the temperature, precipitation, humidity, and evaporation values of Erzurum, Ağrı, Iğdır, Kars, and Ardahan provinces were taken from the databank of the Turkish State Meteorology Service.

2.1. Climate classification of Aras basin

Şensoy et al. (2008) examined the climate classifications of Turkey according to De Martonne, Trewartha, Aydeniz, Erinc, Thornthwaite, and explained the results. Table 1 illustrates the climate of the provinces located in Aras basin in terms of different climate classifications.

According to Table 1, all provinces in Aras basin are very cold in winter except for Iğdır where winter is cold and summer has a hot climate. While Iğdır has semi-arid, arid, and very arid climate in terms of humidity, the others are more humid. There is no excess water for Iğdır according to Thornthwaite classification.

2.2. The frost calendar and frost maps of Aras basin

Determination of the frost calendar will make a great contribution primarily to agricultural activities and other planning and studies (Connor, 1949). Cold period, vegetative period, and the riskiest and the safest periods in the longest vegetative period are reported in frost calendar by Karaoğlu (2002) who prepared the frost calendar of Turkey for the period of 1978-2000, and updated (2014 in press) this study for the period of 1978-2012.

While Table 2 (Karaoğlu, 2014) presents frost calendar and critical periods for Aras basin, Figure 1 shows the monthly distribution of late spring and early fall frosts for Aras basin. In this table, the value of 0 °C refers to early and late frosts, the value of 5 °C refers to the lowest early and late daily average temperature of vegetative period, and the grass minimum values for 0 °C refer to early and late hidden icing.

When data of frost calendar in Table 2 are examined, Iğdır province is earlier in spring and later in autumn than the other provinces for all specified dates. It means that the longest vegetative

Table 1. The climate of Aras basin based on different climate classifications (Şensoy and Ulupınar, 2007)

Provinces	Averages of long years data				Trewartha classification		Aydeniz classification	Erinc classification	De Martonne classification
	A.T.Ja.	A.T.Ju.	A.A.T.	A.P.	W	S			
Iğdır	-3.5	25.8	11.8	256.5	Cold	Hot	Very arid	Arid	Semi arid
Ağrı	-11.2	21.3	6.0	541.0	Very C.	Warm	Semi humid	Humid	Step-Semi humid
Ardahan	-11.8	16.3	3.5	509.2	Very C.	Temperate	Humid	Humid	Semi humid
Erzurum	-9.5	19.4	5.4	402.5	Cold	Warm	Semi humid	Semi humid	Step-Semi humid
Kars	-10.8	17.6	4.6	443.5	Very C.	Temperate	Semi humid	Semi humid	Step-Semi humid

Provinces	Thornthwaite classification				
	Letters	1st Letter	2nd Letter	3rd Letter	4th Letter
Iğdır	D,B'2,d,b'2	D Semi arid	B'2 Mesothermal	d: No excess water or less than	b'2: close continental
Ağrı	C2,B'1,s2,b'2	C2 Semi humid	B'1 Mesothermal	s2: Summer water deficit and too much	b'2: close continental
Ardahan	C2,C'2,r,b'2	C2 Semi humid	C'2 Microthermal	r: No water deficit or less than	b'2: close continental
Erzurum	C1,C'2,s,b'2	C1 Semi arid-less humid	C'2 Microthermal	s: Winter excess of water and moderate	b'2: close continental
Kars	C1,C'2,d,b'2	C1 Semi arid-less humid	C'2 Microthermal	s: Winter excess of water and moderate	b'2: close continental

A.T.Ja.: Average temperature of January, A.T.Ju.: Average temperature of July, A.A.T.: Annual average temperature, A.P.: Annual precipitation

Table 2. Frost calendar of Aras basin (1978-2012) (Karaoğlu, 2014)

Provinces	Late spring						Early autumn					
	Min.		Hidden icing		Vegetative period				Hidden icing		Min.	
	0 °C E.	0 °C L.	G.M. E.	G.M. L.	5°C E.	5 °C L.	5 °C E.	5 °C L.	G.M. E.	G.M. L.	0 °C E.	0 °C L.
Iğdır	04/03	25/04	27/03	08/05	15/03	22/04	18/10	23/11	24/09	13/11	07/10	13/11
Ardahan	01/05	25/06	10/05	29/06	26/04	20/06	04/08	28/10	01/08	24/09	16/08	09/10
Erzurum	18/03	22/06	10/05	29/06	12/04	04/06	25/09	04/11	17/08	07/10	19/08	19/10
Kars	15/04	11/06	03/05	12/06	10/04	23/05	26/09	05/11	05/09	13/10	05/09	18/10
Ağrı	09/04	16/06	14/04	05/07	29/03	13/05	27/09	11/11	01/09	19/10	19/09	30/10

G.M.: Grass minimum (0 °C), 5 °C: Daily average temperature, E.: Earliest date of occurrence, L.: Latest date of occurrence

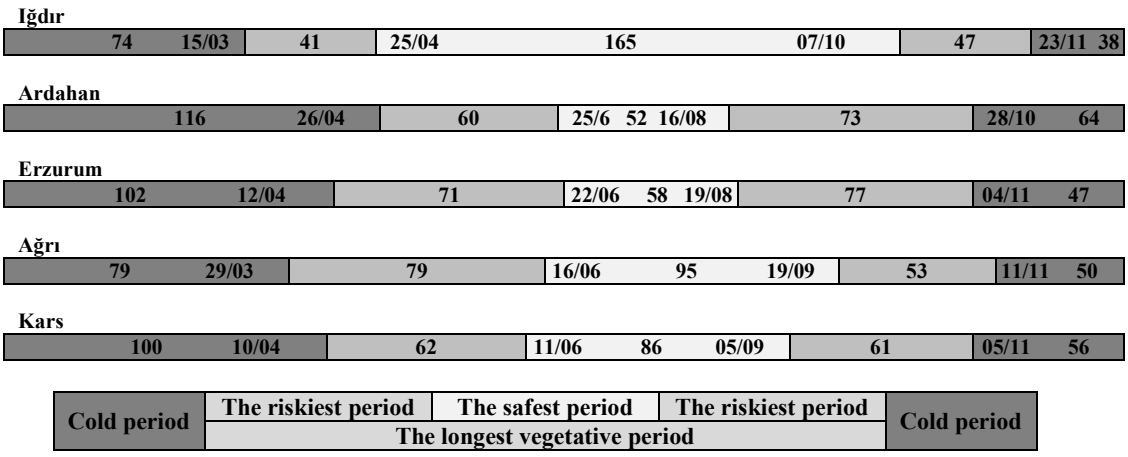

Figure 1. Critical periods for provinces in Aras basin

period and safe period of Iğdır are longer than the others. Iğdır province has minimal risk in terms of risk of hidden icing. There are hidden icing of 42 days and 50 days for spring and autumn, respectively. Ağrı province has hidden icing of 50 days and 34 days for spring and autumn, respectively. At first glance, it seems that Ağrı province has a low risk in terms of hidden icing, but this risk period starts earlier than the risk period of Iğdır in autumn. Figure 1 illustrates exactly and clearly these results.

Figure 2 presents two frost maps (Karaoğlu, 2014) for spring and autumn in order to show monthly distribution of frost events in Aras basin for 0 °C.

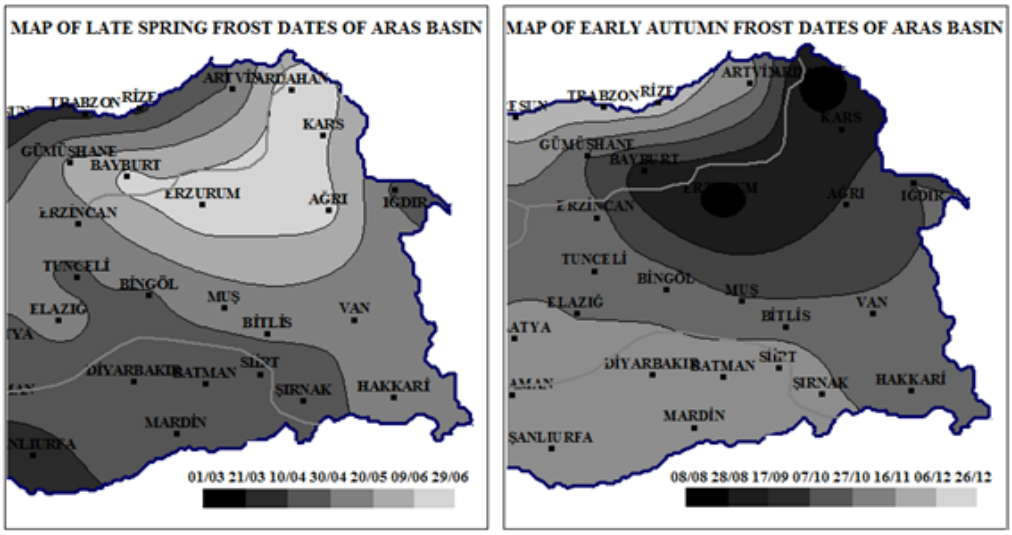

Figure 2. The monthly distribution of late spring and early autumn frosts of Aras basin

2.3. The processing and analysis of climate data

The monthly and/or annually long-term mean data were obtained by using daily data of all climatic factors. Tables and graphics used in determining the course of climatic factors were prepared by processing the long-term data. These tables and graphics were interpreted in order to reveal the course of climatic factors.

For each province in the Aras basin; temperature, precipitation, humidity, and evaporation values were compared on the basis of many years by determining their results.

2.4. Preparation of climatograms

Climatograms show monthly variations in only two climatic factors; precipitation and temperature. Other factors also affect climate, but a climatogram gives a rough idea regarding the climate in a particular area. By daily observation you can associate the climate with the biome of your own locality (Milani, 1994). The values of a climatogram are obtained from data collected over a period of thirty years or more; thus, they reflect the climate -the average weather over a long time- not just the current weather (Walker and Wood, 2010). In order to prepare climatograms for the provinces in Aras basin, long-term average temperature and total rainfall data (Karaoğlu, 2011) were used. Rainfall and temperature data were represented in column and line graphics, respectively in diagrams.

2.5. The calculation of potential evapotranspiration (PET) and water budget

The water vapour amounts released into atmosphere by transpiration and evapotranspiration are different; therefore it is difficult to calculate these amounts one by one. A water budget reflects the relationship between input and output of water in a region. The water balance graph shows precipitation and potential evapotranspiration in line graphs. Thus, we have a direct comparison between supply of water and the natural demand for water. It is possible to identify the periods for plenty of precipitation and scarcity of precipitation (Ritter, 2011).

In this study, Thornthwaite method was used. Water budget was shown by using a graphic (Yeşilnacar et al., 1998) for each province located in Aras basin. While the months are placed on horizontal axis, precipitation and corrected PET values are placed on vertical axis as two different curves. Deficit or excess of water, accumulated water, and supplied water are shown on the shape formed by these two curves. Water budget graphs use number I for excess of water, number II for making use of ground reserve, number III for water deficit and number IV for completing of ground reserve.

3. Results and Discussion

3.1. Temperature

Table 3 illustrates long term monthly and annual average temperatures for the provinces located in the Aras basin. When the Table 3 is examined, it is clearly seen that Iğdır province is much hotter than the others. For all of the provinces in Aras basin, January is the coldest month, and July is the hottest one. The coldest province is Ardahan.

Table 3. The long term monthly and annual average temperatures of the Aras basin (^{o}C)

Provinces	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Iğdır	-2.6	-0.1	6.2	13.3	17.3	21.9	25.8	25.1	19.8	12.6	5.5	0.5	12.1
Ağrı	-10.4	-9.3	-3.3	6.4	11.8	16.6	21.3	21.3	16.3	9.1	1.4	-5.9	6.3
Erzurum	-9.6	-8.6	-2.9	5.3	10.4	14.8	19.3	19.2	14.3	7.5	0.2	-6.4	5.3
Kars	-10.1	-8.5	-2.5	5.5	10.0	13.8	17.6	17.6	13.6	7.2	0.2	-6.3	4.8
Ardahan	-11.3	-10.2	-3.5	4.3	9.2	12.7	16.3	16.3	12.3	6.5	-0.2	-7.1	3.8

3.2. Precipitation

Table 4 illustrates the monthly and annual average precipitation values of the provinces in Aras basin for many years. Iğdır province has much less precipitation compared to the other provinces. In fact, Iğdır province has minimum precipitation in Turkey. All provinces in Aras basin have an average precipitation less than 650 mm that is the average precipitation of Turkey.

April, May, and June have the most average precipitation. This period is unstable. due to thunderstorms. The months of spring have more average precipitation.

Table 4. The long term monthly and annual precipitation values of the Aras basin (mm)

Provinces	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Iğdır	12.8	15.9	24.3	34.5	47.0	33.7	13.0	8.6	9.6	24.5	19.4	12.7	256.0
Erzurum	20.3	25.3	32.4	56.8	71.1	41.6	26.1	15.4	19.7	47.5	32.4	23.5	412.1
Kars	18.9	22.6	29.1	50.9	76.9	73.0	52.9	42.2	25.3	42.2	26.8	21.9	482.7
Ağrı	39.4	53.3	52.1	75.7	76.2	48.8	17.9	10.4	15.5	54.3	51.2	44.2	539.0
Ardahan	17.3	21.9	29.9	52.8	82.5	88.3	67.5	55.4	32.7	40.3	29.4	25.2	543.2

3.3. Climatograms of Aras basin

Temperature and precipitation factors are used in order to prepare a climate diagram. Climate diagrams have significant climate features. The climate diagrams of provinces located in Aras basin are seen in Figures 3-7.

The precipitations of Iğdır have sinusoidal distribution. The distribution of temperature is typical. The warmest months have the lowest precipitation. Although the distribution of temperature and precipitations of Erzurum resemble those of Iğdır, the precipitations of Erzurum are more than Iğdır and its temperatures are less than Iğdır.

Kars and Ardahan have similar properties in terms of temperature and precipitation; however, the precipitations of Ardahan are more than Kars. Ağrı has completely different properties. In the basin, Ağrı is the second warmest and rainy province. Majority of precipitation values are observed in winter and spring months.

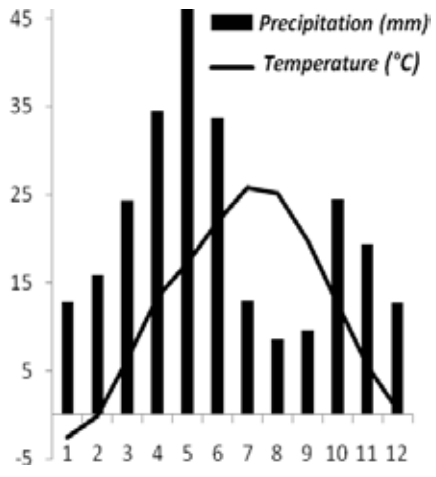

Figure 3. The climate diagram of Iğdır

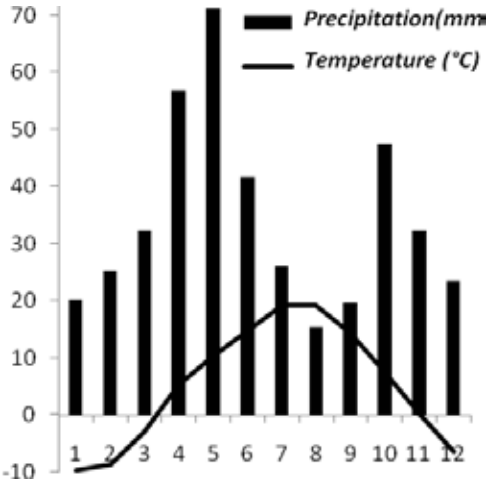

Figure 4. The climate diagram of Erzurum

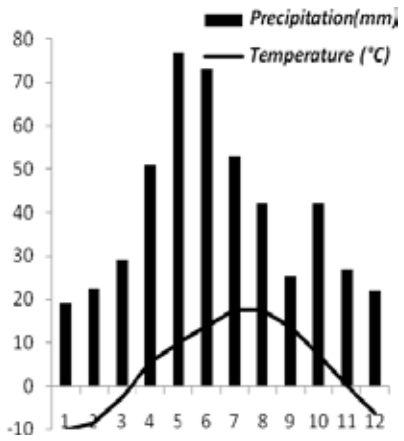

Figure 5. The climate diagram of Kars

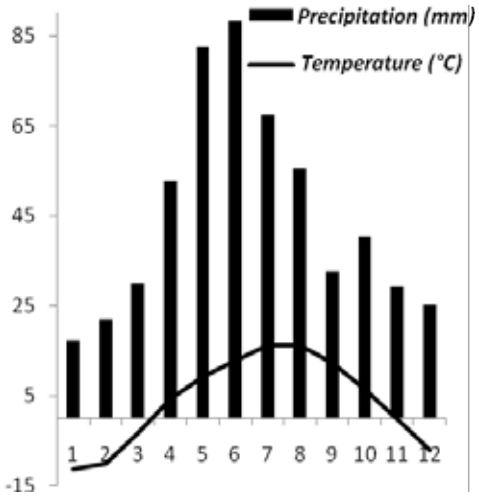

Figure 6. The climate diagram of Ardahan

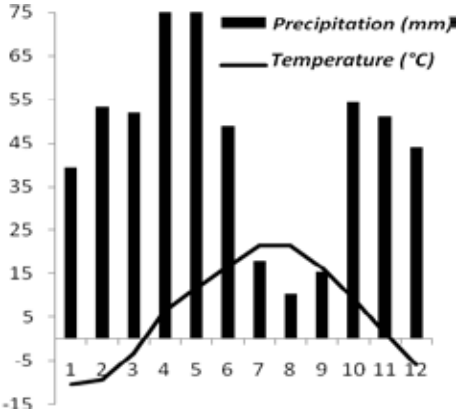

Figure 7. The climate diagram of Ağrı

3.4. Water budget

Table 5 illustrates the major parameters of water budgets (Yeşilnacar et al., 1998) of provinces located in Aras basin. As is seen in this table, total potential evapotranspiration and water deficit are the most, and there are no excess of water and surface runoff for Iğdır. Kars, Ağrı and Ardahan provinces have higher precipitation and excess of water, for this reason, they have maximum surface runoff. Kars and Ardahan provinces have no water deficit. This table shows evidently the interaction between high temperature and low precipitation, and between low temperature and high precipitation.

The water budget graphs for each province in Aras basin are present in Figures 8-12. The annual changes of precipitation and corrected potential evapotranspiration are observed.

3.5. Relative humidity

Table 6 illustrates the monthly and annual average relative humidity values of the provinces in Aras basin for many years. Iğdır has the lowest relative humidity values as expected. However, Ardahan and Ağrı, which have the most precipitation values, do not have the most relative humidity values. The most relative humidity values belong to Kars province.

3.6. Evaporation

If evaporation values occurring in open water surface are higher in Aras Basin, it means that there are higher sunshine duration and temperature and lower cloudiness, precipitation and wind. Table 7 illustrates the long-term average of total evaporation values in months of observation. Iğdır and Ağrı provinces have higher evaporation values than the others, and Ardahan has the lowest one.

4. Conclusions

1. Iğdır is cold, and Ağrı, Ardahan, Erzurum and Kars are very cold in winter. Iğdır is hot, and the others are warm in summer.

2. Iğdır is semi-arid, arid and very arid; Erzurum and Kars are semi-humid; Ağrı and Ardahan are semi-humid and humid.

3. Iğdır has lower frost risk and longer vegetation period compared to the others.

4. Long-term mean annual rainfalls of all provinces in Aras basin are lower than those of Turkey.

Table 5. The major parameters of water budgets of provinces in Aras basin

Provinces	T (°C)	P (mm)	∑ PET	∑ EW	∑ WD	∑ RUNOFF
Iğdır	12.1	256.0	624.0	0	378.0	0
Erzurum	5.3	412.1	298.4	178.1	121.6	148.8
Kars	4.8	482.7	249.2	267.1	0	253.0
Ağrı	6.3	539.0	358.8	284.3	117.4	247.1
Ardahan	3.8	543.2	216.3	327.7	0	315.8

P: Precipitation, PET: Potential evapotranspiration, EW: Excess water, WD: Water deficit

Table 6. The long term monthly and annual relative humidity values of Aras basin (%)

Provinces	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Iğdır	66.3	59.9	51.8	49.4	51.2	47.3	44.7	46.7	51.0	62.2	65.6	67.2	55.3
Erzurum	77.7	77.2	75.1	66.4	63.2	58.1	52.2	49.7	51.7	64.9	73.2	78.8	65.7
Ağrı	80.1	80.1	80.2	73.1	67.7	62.0	56.4	53.7	55.4	68.6	76.7	81.2	69.6
Ardahan	78.3	77.4	76.3	70.3	70.5	71.0	69.2	67.2	65.4	70.8	75.2	79.7	72.6
Kars	81.5	80.4	79.0	72.1	71.3	70.3	68.7	66.5	64.2	71.3	77.4	81.6	73.7

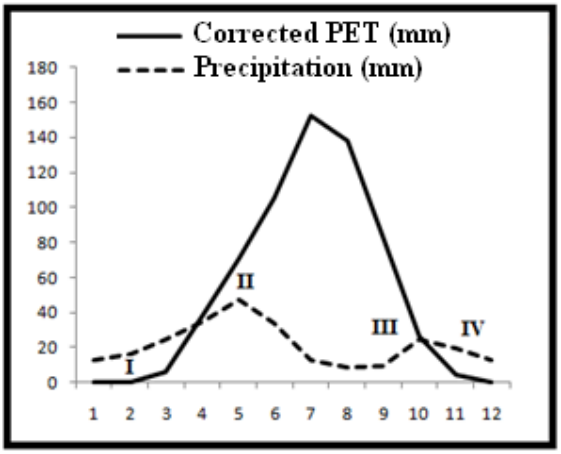

Figure 8. The water budget graph of Iğdır

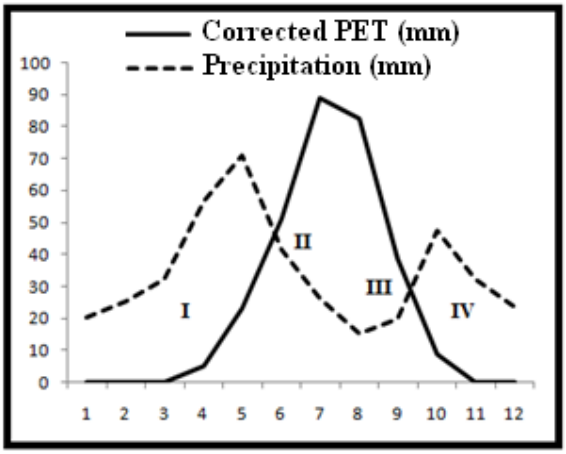

Figure 9. The water budget graph of Erzurum

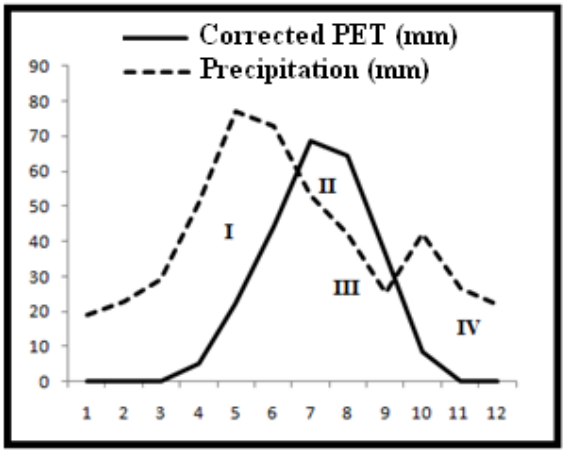

Figure 10. The water budget graph of Kars

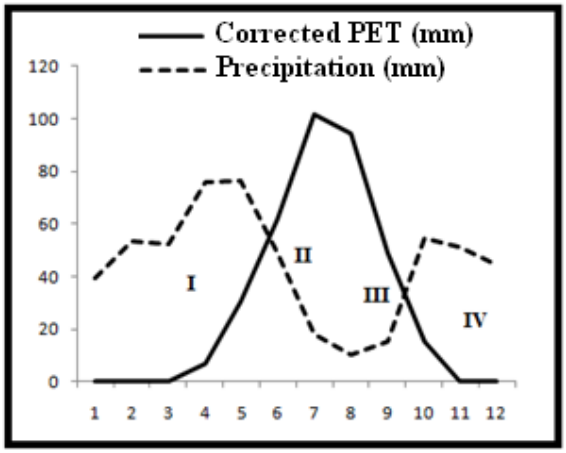

Figure 11. The water budget graph of Ağrı

Table 7. Long term average of total evaporation values for Aras basin (mm)

Months / Provinces	5	6	7	8	9	Annual
Iğdır	162.1	228.1	278.6	258.8	188.7	1116.3
Ağrı	139.3	199.4	261.4	275.7	192.0	1067.8
Kars	125.7	178.3	242.7	253.1	185.3	985.1
Erzurum	126.4	165.2	232.6	231.2	172.4	926.8
Ardahan	108.7	137.1	156.6	145.9	108.3	656.5

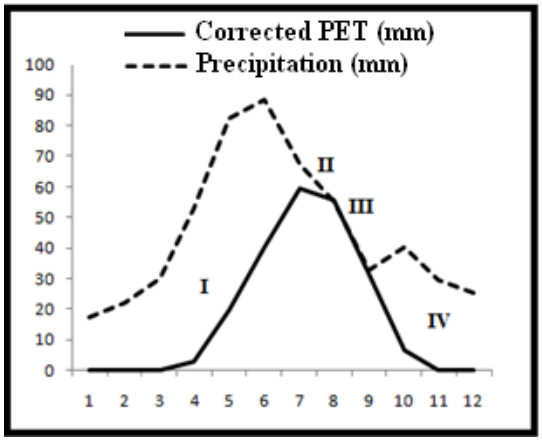

Figure 12. The water budget graph of Ardahan

5. Iğdır has no excess of water. Kars and Ardahan have no water deficit. In order to determine exact annual water exchange, climate data should be used as ten-day averages instead of a monthly average.

6. On the contrary of common belief, Iğdır has the lowest relative humidity values in Aras basin. Kars and Ardahan have the highest ones.

7. As expected, Iğdır has the highest evaporation values. Ardahan has the lowest values.

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