Drought Analysis for 2007-2008 Agricultural Year of Turkey*

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Drought is among the most significant natural disasters and has severe economical, social and environmental impacts. It is somehow different from the other natural disasters since it is hard to determine exact start and end dates of drought. Drought gradually increases its severity and may keep its effects for years after the end of drought. Effects of drought is initially observed in agriculture and diffused gradually into water-related sectors. The recent global drought and utilization of agricultural crops for bio-fuel production has created significant problems in food supply. For instance, as a result of the drought experienced in the year of 2007, wheat production was not sufficient. Beside this, consumption increased for bio-fuel production and wheat prices in international markets increased by 3 folds. These problems observed in basic agricultural crops like maize and rice has brought forward the significance of continuous drought monitoring and analysis.

In this study, the drought experienced in 2007-2008 Agricultural Year of Turkey was analyzed and contributions were tried to be made for future production activities. The drought was evaluated by using Standardized Precipitation Index (SPI), Percent of Normal Index (PNI) and the analyses of precipitation and temperature analysis.

Key words: Drought, agricultural year, standardized precipitation index, percent of normal index

Introduction

Agricultural sector is like a factory working under atmospheric conditions. Soil, seed, human and climate are the basic factors effecting the agricultural production. In broad terms, these factors except climate may be controlled and improved. The factors of climate continue to affect the agricultural production significantly regardless of the developments and improvements in agricultural techniques. On the other hand, large spatial and temporal variations in meteorological factors cause serious fluctuations in agricultural production. Significant losses in production occur as a result of natural disasters like drought, flood, frost, hail and storm. Therefore, before any agricultural activity, relevant information about the climate of the region should be obtained (Simsek 2006)

Precipitation, temperature, wind, humidity and solar radiation are among the most important meteorological factors affecting agriculture. Due to geographical location and structure, Turkey has very different climate regions and micro-climate areas. Significant variations occur in climate components among the regions. Precipitation has the greatest effect on production and exhibits large spatial and temporal variations. The vicinity of Salt Lake in Central Anatolia has the least precipitation in Turkey with annually average of 250 mm and this value reaches to 2200 mm in Hopa in Black Sea Region. Beside this irregularity in the amounts of precipitation, significant variations also occur among the regions on monthly and annually bases distribution of precipitation. Although average annual precipitation in Turkey is 643 mm, water deficit and drought were experienced in many regions due to irregular distribution of precipitations. Corresponding to this average precipitation, annually 501 billion m^3 of water falls over Turkey. Of this amount of water, 274 billion m^3 returns to atmosphere via evaporation, 41 billion m^3 feeds the underground storages via seepage, and 186 billion m^3 moves away via runoff. Renewable water potential of Turkey is 234 billion m^3 with seven billion m^3 water coming from rivers originated in neighboring countries (Anonim,2001).

Among the extreme meteorological events, drought is the one having the largest effects. It can create significant social, environmental and economical loses. It occurs when the level of precipitation decreased significantly below the normal levels. It is a naturally occurring event causing serious hydrological irregularities and negatively affecting land resources and production systems (Anonim,1997). Drought is a temporary event which is a change or deviation in climate and it is different from aridity. Aridity is a permanent characteristic of climate and indicates the regions with low levels of precipitation.

Severity of drought is depended on rate of soil moisture deficit, duration and area affected by drought. Although several types of drought defined in literature, there are three distinct types of drought. These are meteorological, agricultural and hydrological droughts (Wilhite and Glantz 1987). Meteorological drought is the decrease occurred in amount of precipitation with regard to long-term averages. Agricultural drought takes the amount of available water for plants in plant root zone into consideration. Precipitation, plant water consumption and soil characteristics are the main factors considered in agricultural drought. Hydrological drought is the decrease in surface and ground water resources due to long-term scarcity in precipitation.

In this study, the drought of 2007-2008 Agricultural Year in Turkey was analyzed by using the SPI and PNI drought evaluation methods with the analyses of, precipitation and temperature.

Material and Methods

Material

Four types of analysis were used to analyze drought of 2007-2008 agricultural year. These were SPI and PNI drought analysis, precipitation analysis and temperature analysis. Meteorological data constitute the main input for these analyses.

Monthly averages from daily values and 30-year normals of data observed at the largest 151 climate stations (Table 1) of Turkish State Meteorological Service (DMI) all over Turkey were used as the material of this study (Anonim,2008). The monthly average precipitation values and the normal of these values for the last 30-year period were used to perform drought analysis and make comparisons with long term averages, respectively.

While performing precipitation analysis, actual monthly average precipitation values of 106 stations were used. Normal of these values for 30 years period was used to make comparisons with long term averages. Actual monthly average temperature values of 130 stations were used for temperature analysis. Normal of these values for 30 years period was used to make comparisons with long term averages.

Method

Two drought analysis methods (SPI and PNI) were used to perform drought analysis for 2007-2008 Agricultural Year.

Standardized precipitation index (SPI)

SPI is basically obtained by dividing deviation of precipitation from average for a certain time period with standard deviation (McKee et al. 1993). Actually, calculation of index is a complex issue since precipitation for 12 months or shorter periods does not fit into normal distribution and therefore precipitation series are initially made to fit to normal distribution.

Table 1. The climate stations, data of which was used in this study

Station Name			
Adana	Denizli	Kaman	Ödemiş
Adıyaman	Develi	Kangal	Pınarbaşı
Afyon	Dikili	Karabük	Polatlı
Ağrı	Dinar	Karaman	Rize
Akçakoca	Divriği	Karapınar	Sakarya
Akhisar	Diyarbakır	Kars	Samsun
Aksaray	Dursunbey	Kastamonu	Sarıkamış
Akşehir	Düzce	Kayseri	Seydişehir
Alanya	Edirne	Kilis	Şanlıurfa
Amasra	Edremit	Kırıkkale	Siirt
Amasya	Elazığ	Kırklareli	Şile
Anamur	Elbistan	Kırşehir	Silifke
Ankara	Ereğli	Kızılcahamam	Sinop
Antakya	Ergani	Kocaeli	Sivas
Antalya	Erzincan	Konya	Siverek
Artvin	Erzurum	Kozan	Sivrihisar
Aydın	Eskişehir	Kuşadası	Solhan
Balıkesir	Fethiye	Kulu	Suşehri
Bandırma	Finike	Kütahya	Tefenni
Bartın	Gaziantep	Malatya	Tekirdağ
Başkale	Gediz	Malazgirt	Tercan
Batman	Gemerek	Malkara	Tokat
Bilecik	Gevaş	Manavgat	Tortum
Bingöl	Giresun	Manisa	Tosya
Bitlis	Göksun	Mardin	Trabzon
Bodrum	Göztepe	Marmaris	Tunceli
Boğazlıyan	Gümüşhane	Mersin	Uşak
Bolu	Güney	Merzifon	Uzunköprü
Burdur	Hakkari	Milas	Ünye
Bursa	Hınıs	Muğla	Van
Ceylanpınar	Hopa	Muradiye	Yalova
Çanakkale	Iğdır	Muş	Yozgat
Çankırı	İnebolu	Mut	Yunak
Çemişgezek	İpsala	Nallıhan	Zonguldak
Cihanbeyli	İskenderun	Nazilli	
Cizre	İslahiye	Nevşehir	
Çeşme	Isparta	Niğde	
Çorum	İzmir	Ordu	
Demirci	Kahramanmaraş	Osmaniye	

Resulting SPI values exhibits increasing and decreasing linear variation with deficit of precipitation. By normalization of SPI values, both dry and wet periods are represented in the same fashion for the selected time period. The value of SPI index is determined by,

$$SPI = (X_I - \bar{X}) / \sigma \quad \text{.....Eq.1}$$

Where;
SPI: Standardized Precipitation Index,
X_i *: Actual precipitation monthly, mm*
$\bar{X}_i$ *: Average precipitation, mm*
σ *: Standart deviation*

In a drought analysis carried out by taking SPI values, the time period with continuously negative index value is defined as a dry period. The month in which index goes down below zero is taken as the initiation of drought and the month in which the value increased to a positive value is taken as the end of drought. The software for SPI analysis was developed in Delphi V programming language. Drought analysis with this software can be performed for the past periods with a single or multiple station options by using monthly total precipitation values and drought estimation for the future periods can be made. In addition, critical precipitation values providing the formation of droughts with various categories can be obtained with this software. The software is able to calculate the time and percent of drought index for 3, 6, 12 and 24 months combinations of the desired station and allows for analysis at various drought severity categories (Komuşcu, 1999;Komuşcu and Erkan, 2000). The classification according to the SPI index was given in Table 2.

Table 2. Index values and classification based on SPI method

SPI index values	**Classification**
2.0 and more	Exceptionally Moist
1.60 ile 1.99	Extremely Moist
1.30 ile 1.59	Very Moist
0.80 ile 1.29	Moderately Moist
0.51 ile 0.79	Abnormally Moist
0.50 ile -0.50	Near Normal
-0.51 ile -0.79	Abnormally Dry
-0.80 ile -1.29	Moderately Dry
-1.30 ile -1.59	Severely Dry
-1.60 ile -1.99	Extremely Dry
-2.0 and less	Exceptionally Dry

Percent of normal index (PNI)

PNI is the simplest drought index and obtained as percentage by dividing amount of precipitation for a certain period with the average. Precipitations for 12 months and shorter periods can also be used in PNI calculations. The value of PNI index is determined by,

$$PNI : (Pi / \bar{Pi}) * 100 \quad \text{.....Eq.2}$$

Where;

PNI : *Percent of Normal Index (%)*

Pi : *Actual precipitatio, mm*

$\bar{Pi}$:*Average precipitation, mm*

In a drought analysis carried out by taking PNI values into consideration, the period with an index value continuously below a threshold value is defined as dry period. The first value below the threshold is taken as initiation of drought and the first value above the threshold after the initiation is taken as the end of drought. (Hayes 1998). Drought severity with this method is classified into categories as given Table 3.

Precipitation analysis

Comparisons with this analysis were made by using the precipitation value of months and 12-month period for each station and analysis year, previous year and longer times. Stations were classified and evaluated regionally and generally for the entire country. Percent increase and decrease rates of precipitation values of the last year with regard to long-term averages were determined.

Long-term averages for 106 stations used in precipitation analysis were calculated one by one. Then, 25% limit intervals were determined by taking long term normal for all considered stations. Comparison map was drawn with normal by using these intervals.

Temperature analysis

Monthly average and maximum temperature values of 130 stations were used for temperature analysis. Values of analysis year and long terms were compared. Results of analysis were presented in a graph and a map.

Table 3. Index values and classification based on PNI method

Period	Normal and above (No risk)	Slight drought (Start to monitoring)	Moderate drought (Warning)	Severe drought (Emergency)
1	>% 75	% 65 – % 75	% 55 – % 65	<% 55
3	>% 75	% 65 – % 75	% 55 – % 65	<% 55
6	>% 80	% 70 – % 80	% 60 – % 70	<% 60
9	>% 83.5	% 73.5 – % 83.5	% 63.5 – % 73.5	<% 63.5
12	>% 85	% 75 – % 85	% 65 – % 75	<% 65

Results and Discussions

Results of precipitation analysis

Cumulative precipitations between October 1'st of 2007 and September 31'st of 2008 are generally less than normal and more than the precipitation of previous year for the analyzed stations. Bar charts for country and region-wide were prepared by using 12 months total precipitation values. Long-term averages wereindicated by a red line in the graphs (Figure 1) and 5 years moving average curve was drawn.

The average of cumulative precipitations country-wide during 2007-2008 season is 596.0 mm, the normal was 652.2 mm and the average for the same period of the previous year (2006-2007 season) was 550.2 mm. There is 8.6% decrease in cumulative precipitations with regard to normal and 8.3% increase with regard to previous year (Figure 2).

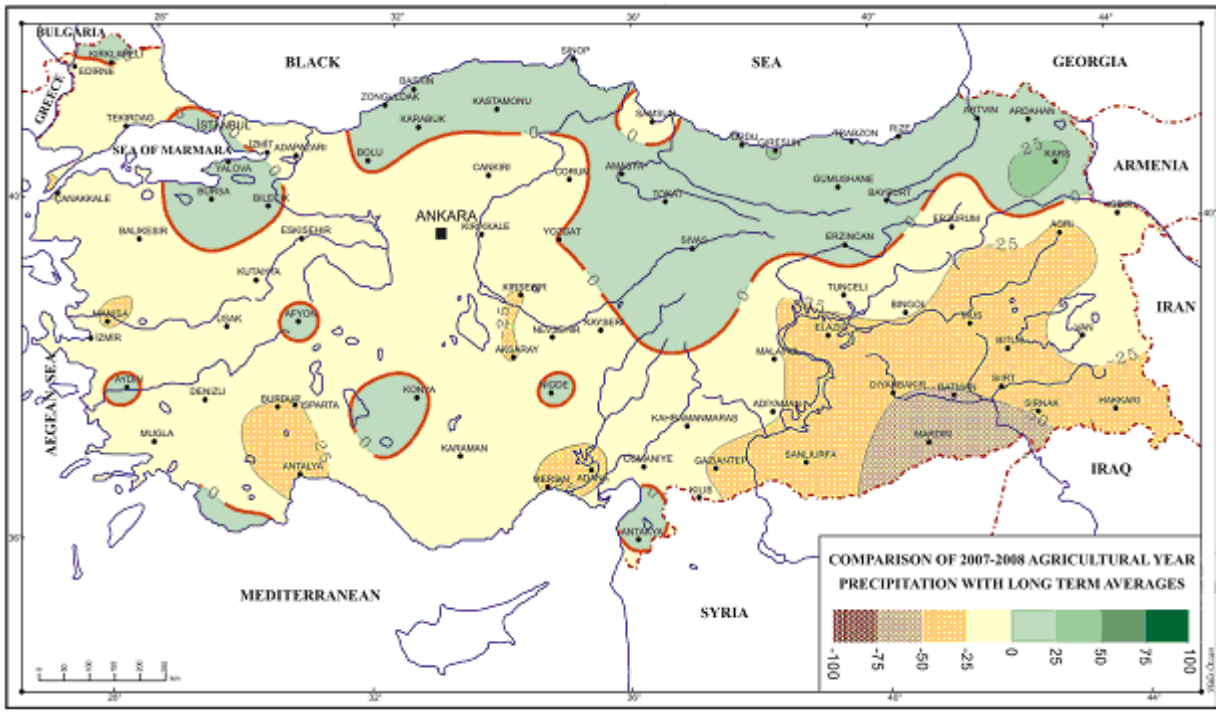

Figure 1. Comparison map of 2007-2008 Agricultural Year precipitation with long term averages

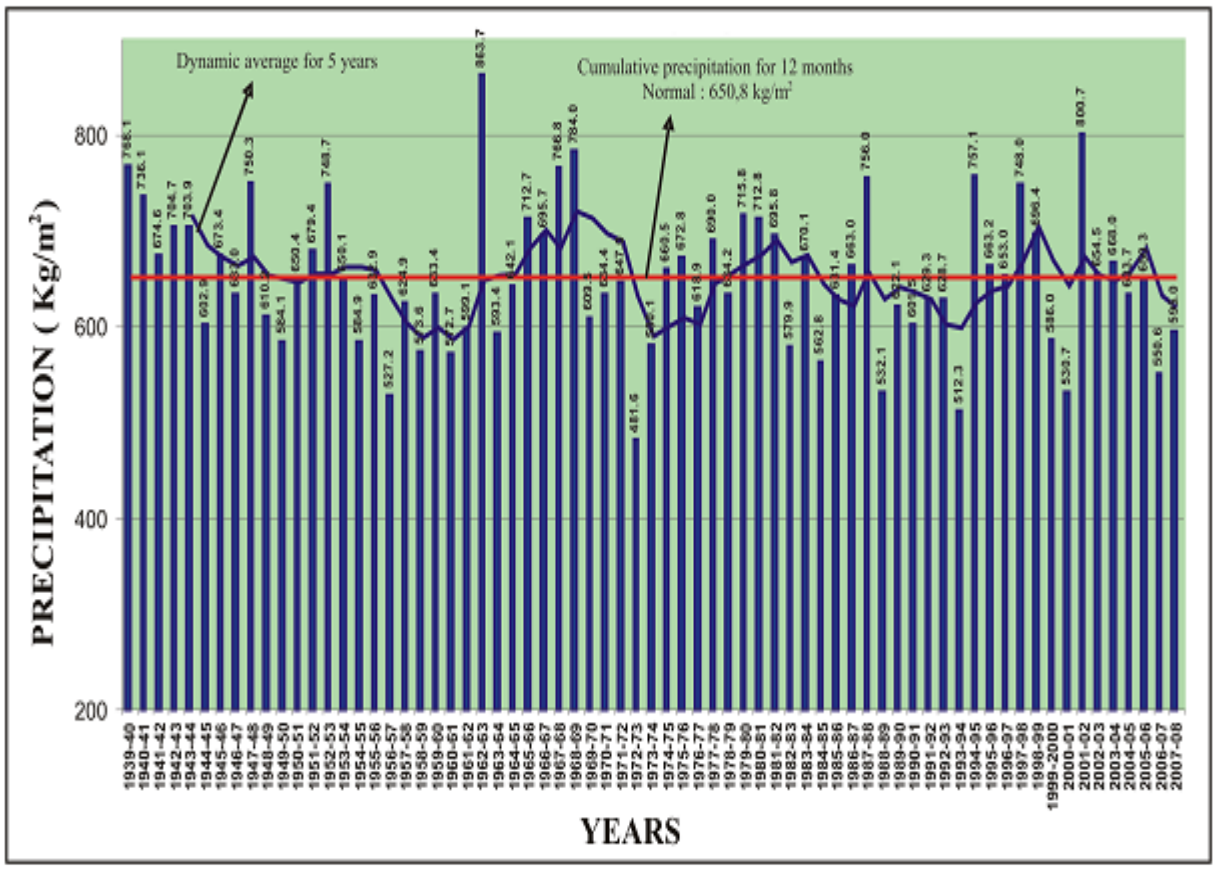

Figure 2. Variation graph of precipitation of Turkey for 1940-2008 Agricultural Years

As it can be seen from the Figure 3, South-eastern Anatolia region experienced the second most severe drought of the last 69 years in 2007-2008 Agricultural Year. That has significantly affected the agricultural activities of the region and serious decreases in yields have been observed (Anonim, 2008b).

Results of Temperature Analysis

Maximum temperatures of 2007-2008 Agricultural Year was generally less than the averages of long-term.

Maximum temperatures over the normal were observed only in March and June (Figure 4). It seems that non-existance of excessive temperatures did not affected the agricultural production negatively. Beside this, average temperatures (8 months) were generally over the normal (Table 4). That may increased the plant water consumptions and decrease the yield in areas with insufficient precipitation.

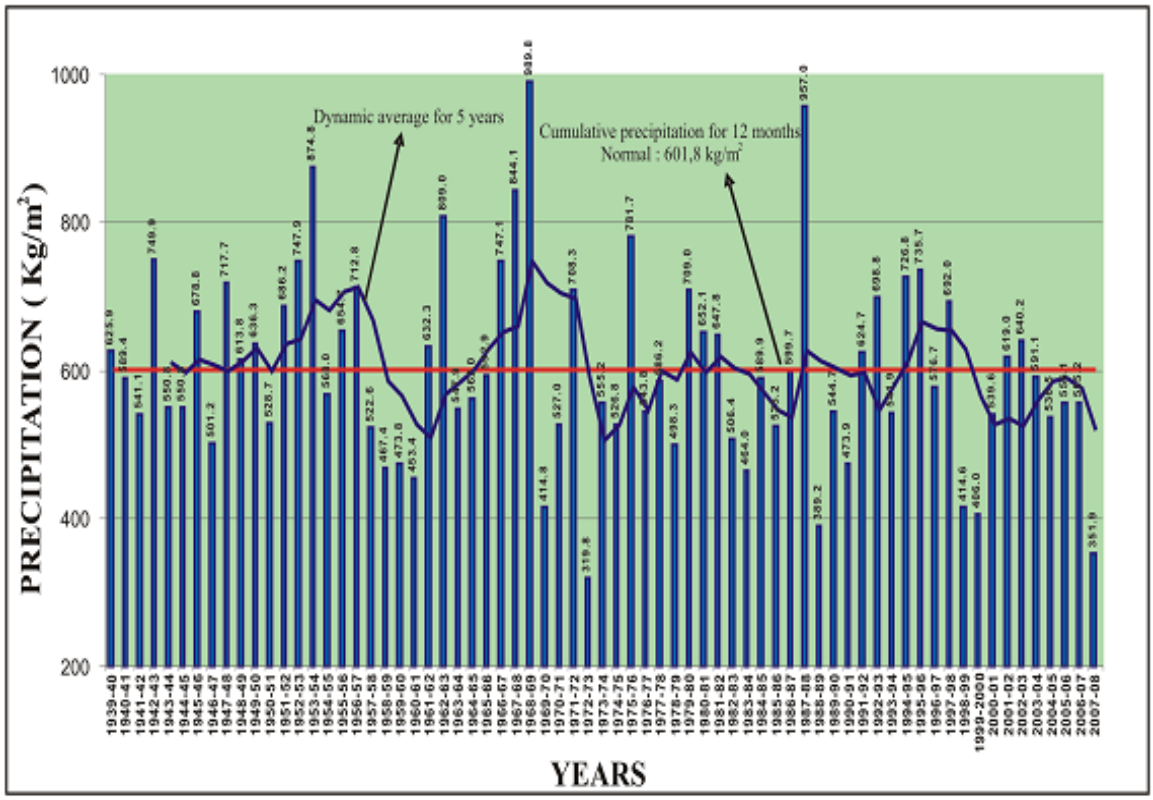

Figure 3. Variation of precipitations in South-eastern Anatolia Region for 1940-2008 Agricultural Years

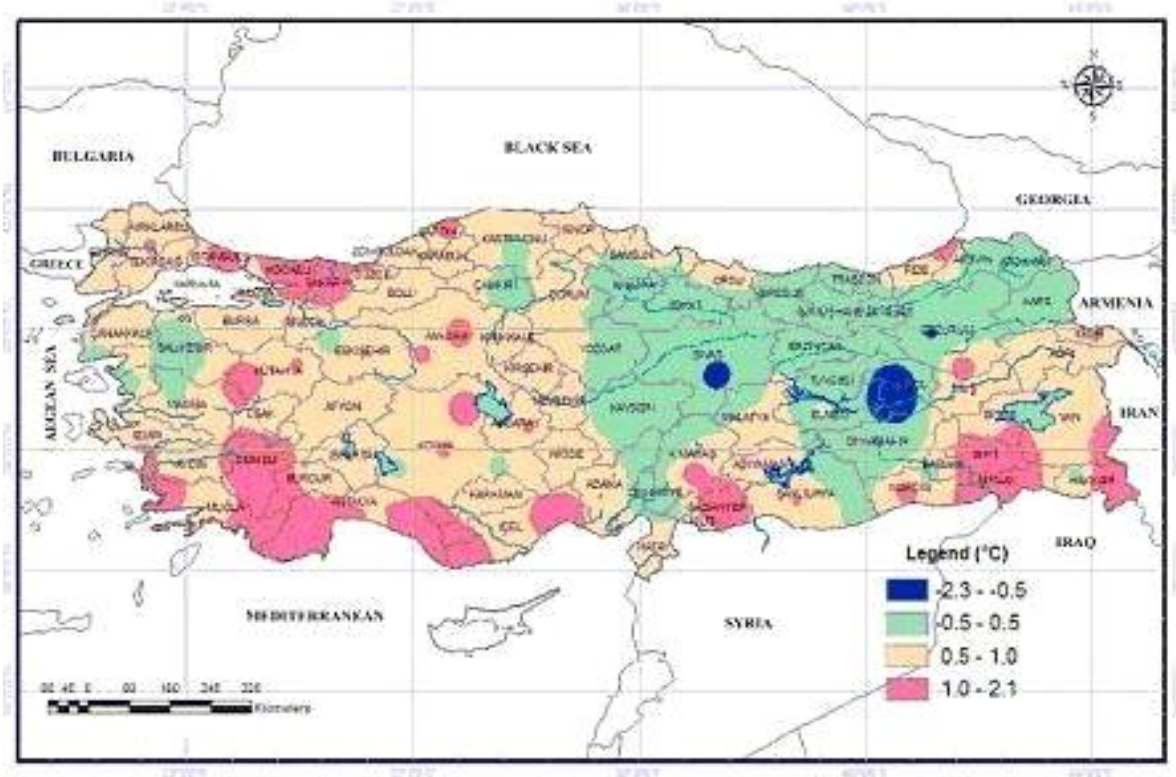

Figure 4. The map showing the difference of 2007-2008 Agricultural Year temperatures from long-term averages

Table 4. Comparison of average and maximum temperatures

Months	Average temperature of long-years(ºC)	Average temperature of 2007-2008 Agricultural Year(ºC)	Maximum temperature of long-years(ºC)	Maximum temperature of 2007-2008 Agricultural Year (ºC)
10	14.7	*16.4*	41.5	37.5
11	8.7	*8.9*	35.6	30.4
12	4.5	3.8	29.7	22.0
1	2.4	-0.2	27.5	19.6
2	3.5	1.9	29.5	23.4
3	6.7	*10.7*	35.2	*37.0*
4	11.9	*14.5*	39.0	38.7
5	16.6	16.4	42.5	39.9
6	21.1	*22.4*	45.6	*45.7*
7	24.2	*25.2*	48.6	48.1
8	23.8	*26.0*	47.8	47.4
9	20.0	*20.7*	45.4	43.7
Average	13.2	13.9	39.0	36.1

Results of SPI Drought Analysis

When 12 months SPI drought map was evaluated, it was observed that severe drought was seen in the South-eastern Anatolia and south of Estern Anatolia Region, but the other regions were not effected much from the drought. It can be stated that meteorological drought in these regions has turned into agricultural and hydrological drought. Spatial dry regions were seen in central, south and western regions. Spatial wet regions were seen in Northern parts(Figure5).

Drought Analysis

When 12 months (October 2007-September 2008) PNI drought map was evaluated, it was observed that severe and mild drought were seen in South-eastern Anatolia; a slight drought was observed in Central Anatolia Region (Ankara, Konya, Cankiri, Kirsehir, Nevsehir), Mediterranean Region (Adana, Mersin, Antalya), Aegean

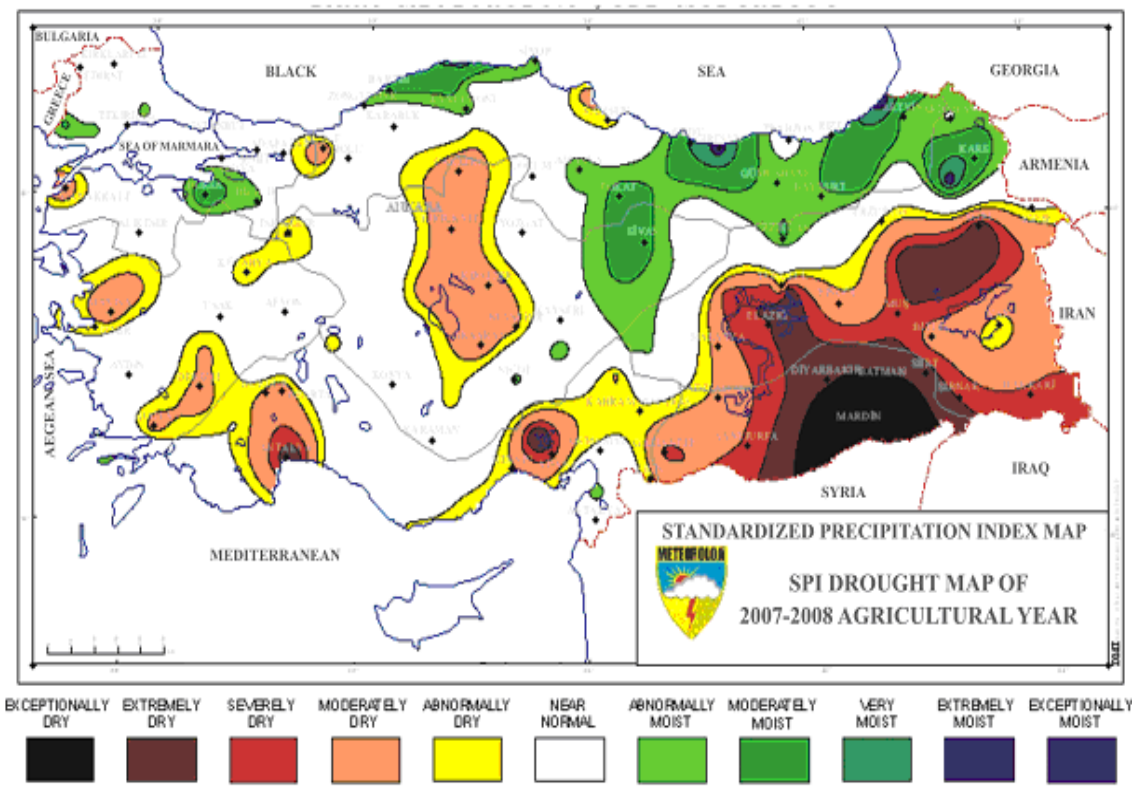

Figure 5. Drought analysis by using SPI method for 2007-2008 Agricultural Year

Region (Izmir, Manisa, Canakkale), and the other regions were normal and above the normal.

The PNI drought map given in Figure 6, indicates similar to the results of the SPI drought map given in Figure 5 both of which indexed that severe drought was experienced in Southeastern and Eastern Anatolia Regions.

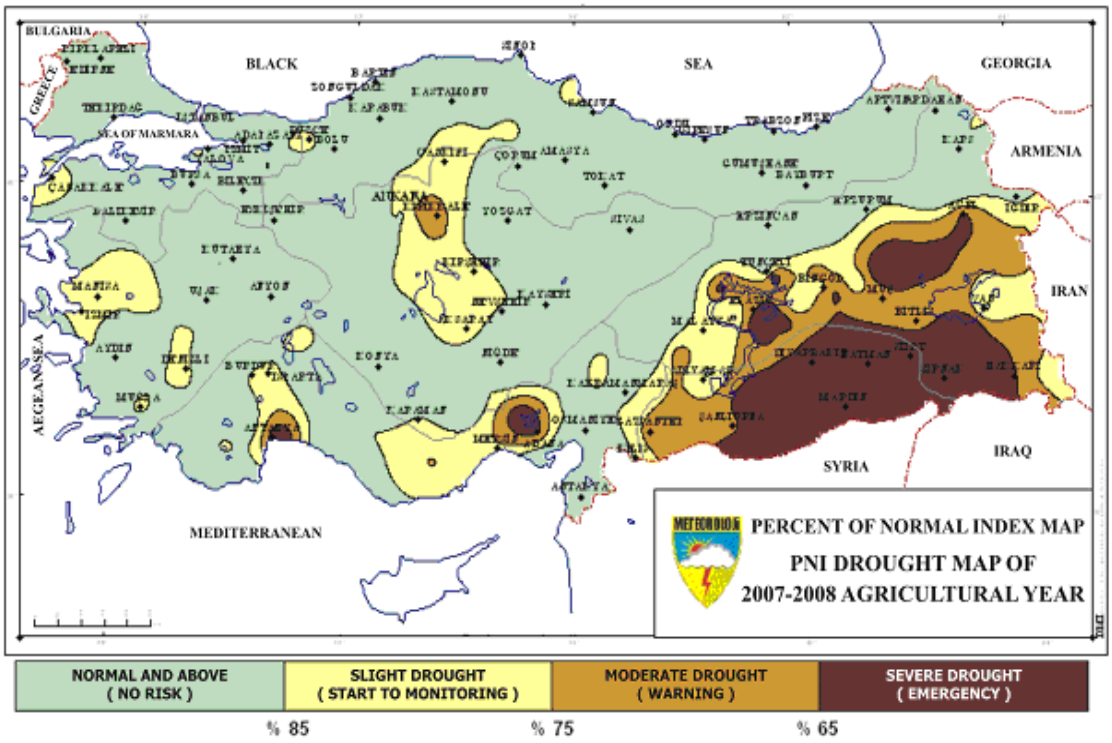

Figure 6. Drought analysis by using PNI method for 2007-2008 Agricultural Year

Conclusions and Recommendations

The average of cumulative precipitations country-wide during 2007-2008 Agricultural Year is 596.0 mm, the normal was 652.2 mm and the average for the same period of the previous year (2006-2007 season) was 550.2 mm. There is 8.6% decrease in cumulative precipitations with regard to normal and 8.3% increase with regard to previous year. Cumulative precipitations between October 1'st of 2007 and September 31'st of 2008 are generally less than normal and more than the precipitation of previous year.

Maximum temperatures of 2007-2008 Agricultural Year was generally less than the averages of long-term. Maximum temperatures over the normal were observed only in March and June. It seems that non-existance of excessive temperatures did not affected the agricultural production negatively. Beside this, average temperatures (8 months) were generally over the normal. That may increased the plant water consumptions and decrease the yield in areas with insufficient precipitation.

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When 12 months (October 2007-September 2008) PNI drought map was evaluated, it was observed that severe and mild drought were seen in South-eastern Anatolia; a slight drought was observed in Central Anatolia Region (Ankara, Konya, Cankiri, Kirsehir, Nevsehir), Mediterranean Region (Adana, Mersin, Antalya), Aegean Region (Izmir, Manisa, Canakkale), and the other regions were normal and above the normal.

Turkey is located in semi-arid climate zone in which drought is a continuous threat over the world. Past droughts have caused serious loses in Turkey. Significant fluctuations were observed especially in agricultural production exposed to natural conditions, shortage of food supplies and high costs were other severe consequences of past droughts.

During the last four agricultural year of Turkey (2005–2009), average precipitations are 631.8 mm, 646.7 mm, 548.4 mm and 595.5 mm, respectively. This drought has turned into

agricultural and hydrological drought especially during the last two years.

While the wheat production, a basic crop of Turkey, was 21 500 000 tons in the year of 2005, it was 17 234 000 tons in 2007 and 17 782 000 tons in 2008. Imports were made during the last two years since domestic production was not able to meet the demand. Severe drought of 2007-2008 agricultural year experienced in Southeastern Anatolia Region caused series yield loses in common crops of the region. For instance, while red lentil production was 520 000 tons in the year 2005, it decreased to 111 502 tons in 2008. Normally red lentil exporting Turkey had to import lentil in the year 2008. Cotton production also decreased from 2 240 000 tons to 1 938 000 tons and Turkey had to import much more cotton (Anonim, 2008b).

Also, significant decreases were observed at water levels of lakes and dams in Turkey. Rate of storage in 191 irrigation dams decreased to 14.76% by the data date of 14.11.2008. This caused serious problems in agricultural irrigation activities. Serious decreases were also observed at water levels of domestic water supply dams of Ankara and Istanbul. Water saving measures had to be taken in Ankara in 2007 and drinking water demands of Ankara was tried to be met by taking water from Kizilirmak River.

Problems still exist in water supply for irrigation and domestic purposes and it is expected that drought to be brought by climate change in 21st century would increase the severity of these problems. Therefore, droughts should be continuously monitored by a national center; relevant warning should be made on time and loses should be minimized by taking required measures.

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