An Investigation of Blowing Dust in Adana and Konya, Turkey from 2007 to 2015

by

Aykut Caglar

A Thesis

In

Geography

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

MASTER OF SCIENCES

Approved

Jeffrey A. Lee
Chair of Committee

Kevin Mulligan

Guofeng Cao

Mark Sheridan
Dean of the Graduate School

August, 2017

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Blowing dust is an environmental issue that affects soil fertility (Zobeck & Fryrear, 1986; Zobeck et al., 1989; Ravi et al., 2006) and public health (WHO, 2013) in arid and semi-arid regions of the world. Dust particles can be carried for long distances and can affect regions far from the source (Pye, 1987; Prospero et al., 2002). In both marine and terrestrial ecosystems, nutrient dynamics and bio-geochemical cycling are impacted by blowing dust (Goudie and Middleton, 2001). Factors that influence wind erosion include surface soil moisture, vegetation cover, and climatic factors such as wind speed and precipitation (Grini *et al.,* 2002; Washington & Todd, 2005). The research reported in this thesis involves blowing dust in Turkey, which has been affected by African and Middle East dust sources. In the Southeast Anatolia Region, Konya - Karaman Basin, and especially cities which have borders with Syria and Iraq are the most affected regions from dust transport (Dundar et al., 2013). This research is builds on a methodology used by Lee & Tchakerian (1995) and Venner (2016) who applied it to Lubbock, Texas, USA.

Adana and Konya, Turkey have been chosen for this research. The meteorological station in Konya is located about 38°N, 33°E at an elevation of 1031 meters (Figure 3.1). Konya has the largest surface area of Turkey which is about 41,684 km^2 without lakes (Tubitak Mam Cevre Enstitusu, *n.d.*). Konya is a part of the great Konya Basin which covers about 1 million hectares and it is

surrounded by uplands and mountains. The central part of the basin is flat and contains several plains. The climate of Konya Basin is semi-arid with cold wet winters and hot dry summers. Due to the limited water supply, the farmers are dependent on natural rainfall and they use dry farming in this area (Meester, 1970). The ground cover is formed by loose chemical and detrital lacustrine deposits. When weak vegetation covers and erosion-inducing agricultural methods have been encountered, these materials are very susceptible to wind activities (Elsen, 2007). Konya Basin has faced severe wind erosion in 1960s and conservation practices with wind erosion has been started in 1962 by Ministry of Agriculture, General Directorate of Soil-Water. This district is generally studied against losing the fertile soil and physical conditions of the topsoil (General Directorate for Combating Erosion and Desertification, *n.d.*). In this region, Northwest and Northeast oriented winds are the most effected (Tubitak Mam Cevre Enstitusu, *n.d.*)

The meteorological station in Adana is located about 37°N, 35°E at elevation of about 20 meters (Figure 3.1). The surface area of Adana is about 14,030 km^2 and one third of this area is used for farmland. Adana is located in Cukurova region of Mediterranean region. The whole plain is called Adana Plain, but the south of this region is also called Cukurova and the north side is Yukariova. Cukurova is the largest delta plain of Turkey. Cukurova is consisted of alluvium that is brought by Seyhan, Ceyhan, and Berdan Rivers. Because

Cukurova has Terrestrial, limnic, and marine ecosystems, that enables to ecological diversity on this fertile coastal plain (Yilmaz, 1998).

Adana and Konya contain two big basins which are important in terms of agricultural production. These sites are chosen by their agricultural importance.

1.1 Problem Statement

In agricultural production, productivity and sustainability are the most significant factors concerning soils and erosion affects both. Konya Basin is susceptible to wind erosion due to basin's climate, the physical features of soils, and the land management practices used. In Adana, Turkey, Cukurova is the most productive agricultural region in Turkey. Due to its location, Adana sometimes faces dust storms from the Middle East and North Africa.

1.2 Purpose

The purpose of this study is to analyze the blowing dust records in Konya and Adana, Turkey and to see if there is a correlation between blowing dust amounts and drought from 2007 to 2015. These years are chosen by the availability of data. Also fallowing practices in agricultural land in Turkey is a wide-ranging situation. Leaving the ground without vegetation cover makes the soil defenseless to blowing dust. Calculating the blowing dust amount, and drought will help us to determine the relationship between these years. In another perspective, these results will also help us to determine the future management approaches in these sites because these two basin have an impact on agricultural

production of Turkey.

1.3 Significance

There have been few studies of blowing dust in Turkey. This study will show temporal trends in blowing dust in two locations.

1.4 Research Question

What is the long-term correlation between annual blowing dust amounts and drought in Adana and Konya, Turkey from 2007 to 2015? How do the blowing dust amounts change during these years?

1.5 Hypothesis

The hypothesis tested in this study is that the amount of dust blowing is significantly correlated with drought.

2. LITERATURE REVIEW

Blowing dust and drought are among the most dangerous weather phenomena in the countries of the Middle East. Studying the conditions of occurrence and spread of dust storms continues to be relevant due to their adverse impacts on agriculture, transport, and public health. Dust storms pollute the air, which adversely affects human health, including respiratory systems (Miri et al., 2007). Nonetheless, few studies were conducted to examine different types of dust events in region. In fact, there are different seasonal cycles related to dust events in different Middle Eastern regions (Rezazadeh, Irannejad, & Shao, 2013; Alizadeh-Choobari, Ghafarianb & Owlad, 2016). To this end, although blowing dust is a meteorological phenomenon, it is associated with the state of the soil cover, the terrain, and type and amount of vegetation (Floyd & Gill, 2011; Lee et al., 2012). Its occurrence requires a strong wind and a sufficiently dry soil unprotected by vegetation. Dust storms occur in the Arctic, but most common in the so-called "dust belt" stretching from the western outskirts of North Africa through the Near and Middle East, Central and South Asia to China (Prospero et al., 2002).

2.1 Anthropogenic Variables

Mahowald et al. (2007) argued that the temporal changes in dust sources are driven by both climate variability and human land use. In fact, land management practices may have a more significant impact on the dust blowing

variations as compared to climatic variables alone (Lee, Wigner & Gregory, 1993). Anthropogenic and natural changes such as conversion of large rangeland to cropland in the western United State (Field et al., 2010) and severe vegetation shifts of desert grasslands in southwestern United States (Schlesinger et al.,1990) could give rise to more frequent and dramatic dust emissions from these regions (Seager et al., 2007; Munson et al., 2001). Dust transported from these drylands causes different problems such as increasing traffic accidents (Ashley & Black, 2008) and the incidence of asthma (Clausnitzer & Singer, 1996).

Turkey is a country where land use affects wind erosion. Farmers in the Konya Closed Basin agricultural lands, for example, employ fallow as a common practice due to concerns about low precipitation and this contributes to wind erosion and intensifies dust emissions. Namely, 465 913 ha of land area in Turkey had been reported to exposed to wind erosion making the latter a leading problem in the basin (Basaran et al., 2017). On the other hand, the efforts to restore and mitigate the degraded lands resulted in a reduction of dust activities in Konya Basin, which, nevertheless, remains a hot wind erosion zone (UNEP, WMO, UNCCD, 2016).

2.2 Atmospheric Variables

The analysis of various meteorological variables related to blowing dust events may contribute to the development of forecasting templates and even long-term planning (Novlan, Hardiman & Gill, 2007). The key characteristics of a

climatic regime of any region are air temperature, precipitation, and wind speed. Blowing dust is particularly affected by precipitation and wind (Lee, Wigner & Gregory, 1993). It should be noted that mitigating such phenomena as dust storms requires studying not merely the conditions, under which they had already occurred or are possible, but also the set of factors contributing to their formation. The season of the year, the duration of the observed high temperatures, the absence of precipitation, the condition of the soil surface, and a number of other seemingly small-scale factors may have an indirect effect on the process and yet play a significant role (Lee et al., 1994; Lee et al., 2009; Lee & Gill, 2015). In addition, research has not still finalized a comprehensive list of the causes of the occurrence of blowing dust. It is known that the formation of dust storms is possible due to the thermodynamic instability of the atmosphere caused by strong heating of the soil or the invasion of cold air masses in connection with the motion of the cold front (Rivera Rivera, 2012).

In the event of strong winds, tornadoes, and dust storms, a large number of dust particles can rise from the ground. Their concentration, mineral composition, and size distribution depend on the wind speed, soil type, humidity, availability and type of vegetation, etc. The transfer and fallout of formed aerosols is determined by the meteorological situation, elevation in the atmosphere, dispersity, and other causes (Nicholson, 1988; Goudie, 1983). Dust storms are typical for arid and sub arid regions. There are favorable conditions in these areas

contributing to the development of such phenomena, including great dryness and crushing of the surface layer of the soil, low humidity of the air, and strong winds (Yang et al., 2016). The mentioned environments are also particularly vulnerable to wind erosion (Basaran et al., 2017). The resulting turbulent vortices raise dust material, which is then picked up by wind currents and carried to different distances. When the wind increases, the amount of dust raised in the air amplifies and visibility deteriorates. Depending on the structure of the surface layer of the soil, different wind speeds are required to lift and transfer dust. In the countries of the Middle East, where the surface layer consists of very small and light particles of sandy loam soil, wind speeds of 10 m/s can be sufficient for the occurrence of dust storms (Modaihsh, 1997; Hamidi, Kavianpour & Shao, 2014).

Patterson and Gillette (1977) argued that no single value could relate visibility and mass of soil-derived aerosols thereby predicting mass concentration. However, depending on the visibility and wind speed, one can distinguish between blowing sand, sandstorm, and floating dust events (Fengmei & Chongyi, 2010). Furthermore, a relative index of the amount of blowing dust in an area can be calculated based on visibility reduction records. In particular, National Weather Service determines visibility as its observer's ability to see objects of known distance during the day or lights at night from the former's eye height of approximately 1.7 m above the ground, as well records wind speed and time at hourly intervals. A dust-blowing event can be said to occur, once the horizontal

visibility falls below the point of 11 km. Using the above visibility data, v (km), the concentration of dust in the air, M (kg m^{-3}), can be estimated as: $M = \frac{c}{v^y}$, where c and y are empirically calculated constants (Lee & Tchakerian, 1995).

A number of papers examined issues related to the study of meteorological and synoptic conditions for the origin and development of dust storms in Asian countries, the mineralogical composition of the dust, the methods for their identification, and the effects of dust on the human body (UNEP, WMO, UNCCD, 2016). According to Mei et al. (2006), in recent years the frequency of dust storms has increased amplifying the corresponding damage. Wind direction and wind speed can be employed as a weather variable in studying dust, including for the purposes of investigating the magnitude of blowing dust (Lee, Wigner & Gregory, 1993). The amount of blowing dust is slightly affected by precipitation, including in the periods of drought (Lee, Wigner & Gregory, 1993). The intensification of global warming and climate change will likely lead to more frequent droughts (Koken et al., 2015).

Drought is defined as drops in the amount of precipitation which adversely affect field and water resources and cause the disturbance of hydrological balance(BMCMS1,1997). Drought can be categorized into 3 groups in literature (Wilhite & Glantz, 1987);

- Meteorological drought

- Agricultural drought
- Hydrological drought.

There are different methods that have been used to determine the intensity of drought. Most common drought indexes are Standardized Precipitation index (SPI) and Palmer Drought Severity Index (PDSI). PDSI was developed by Palmer (1965) and it is based on water balance calculating approach to climatic analysis, which provides a better picture of temporal distribution of moisture deficiencies and excesses (Palmer,1965). PDSI and time of potential erosion to predict mass transport of blowing dust in Lubbock, Texas was used by Lee et al. (1993).

PDSI is generally monthly calculated and temperature, precipitation and soil water-holding capacity are used as input. Table 2.1 illustrates the classification of PDSI values ranging from -4 to 4. Positive values are for wet conditions while negative values demonstrate drought.

Table 2.1: Classification of PDSI

DROUGHT CATEGORY	PDSI VALUES
EXTREME DROUGHT	-4.0 or less
SEVERE DROUGHT	-3.0 to -3.9
MODERATE DROUGHT	-2.0 to -2.9
NEAR NORMAL	-1.9 to 1.9
UNUSUAL MOIST SPELL	2.0 to 2.9
VERY MOIST SPELL	3.0 to 3.9
EXTREMELY MOIST	4.0 and above

Source:

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/palmer.gif

Standardized precipitation index (SPI) also is used to calculate drought. McKee et al. (1993) developed SPI to identify and monitor local drought. Because precipitation is the only input, SPI is easy to calculate, and is reliable, SPI is used all over the world (Keskin et al., 2009; Salvati et al., 2009; Zin et al., 2013). SPI allows users to measure different time scales such as 1, 3, 6, 12, 24, and 48 months. It is calculated with the formula below (McKee et al. 1993);

$$\mathrm{SPI} = (x_i - \bar{x})/\sigma$$

where SPI is Standardized Precipitation Index, x_i is actual precipitation, $\bar{x}$ is the mean of precipitation and σ is standard deviation. Unlike PDSI, SPI ranges from -2 to 2 (Table 2.2).

Table 2.2: SPI Drought Classifications

DROUGHT CATEGORY	SPI CLASSIFICATION
EXTREMELY WET	2.00 or more
VERY WET	1.50 to 1.99
MODERATELY WET	1.00 to 1.49
NEAR NORMAL	0.99 to -0.99
MODERATELY DRY	-1.00 to -1.49
SEVERELY DRY	-1.50 to -1.99
EXTREMELY DRY	-2.00 and less

(Guttman, 1999)

SPI has been used in different studies in Turkey. Caldas et al. (2004), showed by using SPI that severe drought happened around Istanbul from 2000 to 2001. With using SPI, Yegnidemir (2005) calculated the intensity of drought in Central Anatolia from 1953 to 2008 extracted from 28 stations and also found out that agriculture is affected by precipitation deficiencies. In another study, drought was calculated using SPI (1970-1999) and the result revealed that drought was increasing (Li et al.2008). The study carried out for Konya using SPI puts forward

that there will be a drought period in every two years and a longer drought period than a rainy period (Atmaca, 2011).

3. METHODOLOGY

3.1 Study Area

3.1.1 Adana

Adana Province in Figure 3.1 is located in the Cukurova region of the Mediterranean region of Turkey. The surface area of Adana is about 14,030 km^2 and one third of this area is used for farmland. The sum of cultivated areas of Adana is about 2.8% of the sum of cultivated areas of Turkey. Thirty-eight percent of surface area is agricultural use, 40% is forest, 3% is pasture and meadow, and 19% is "other". The main agricultural products are wheat, cotton, and corn. However, most agricultural products can be planted in Adana because of its favorable climate (Cifci & Karatas, 2009). Adana has a Mediterranean climate. Because winter is warm, it is possible to plant in the winter seasons (Sonmez, 2012).

3.1.2 Konya

Konya province in Figure 3.1 is located in the Central Anatolia Region of Turkey. The total surface area is about 41,694 km^2 and Konya, which covers around 5.2% of Turkey's total surface area. Sixty-three percent of surface area is agricultural use, 17% is pasture and meadow, 12.2% is forest, and 7% is non-agricultural sites. Approximately 57% of agricultural areas are planted and 41% is left for fallow (Tubitak Mam Cevre Enstitusu, *n.d.*). Agricultural areas are

generally used for grain farming. The main products are wheat, barley, sugar beet, and sunflower. While terrestrial ecosystem is dominant, the region takes most of the rain in fall and winter.

Figure 3.1 Location of Study Areas

3.2 Research Design

This study contains two different study sites, Adana and Konya, Turkey, and it covers the time period from 2007 to 2015. To carry out this study, wind speed, visibility, wind direction, land use, and precipitation datasets are used. Each site has unique features and mass transport of dust, Standardized Precipitation Index (SPI), and wind direction will be evaluated to determine if there is a correlation over time. SPI index will be also calculated for each site

using precipitation data. Land cover use maps will be created specifically for each sites by using ArcMap. All these calculations are made by using Microsoft Excel 2016. Mass transport, SPI, and wind direction formula are explained in Unit of Analysis section.

3.3 Research Question and Hypothesis

Question: What is the long term correlation between annual blowing dust amounts, drought, and wind speed from 2007 to 2015 in Adana and Konya, Turkey? How do the blowing dust amounts change during these years?

Hypothesis: The amount of dust blowing is significantly correlated with drought.

3.4 Data

National Climatic Data Center's (NCDC) Integrated Surface Database provides global hourly climatic data. The database records hourly wind speed, visibility, wind direction, and other weather phenomena. Data columns are showed in Table 3.1.

Table 3.1: Data Columns

YR—MODAHRMN	Year, Month, Date, Hour, Minute (UTC)
SPD	Wind Speed in Miles per Hour
VSB	Visibility in Statute Miles to Nearest Tenth
DIR	Direction in compass degree

Wind Speed, visibility, and wind direction data are downloaded for 2007 to 2015 from the website; https://www7.ncdc.noaa.gov/CDO/cdopoemain.cmd?datasetabbv=DS3505&countryabbv=&georegionabbv=&resolution=40.

To produce the land use map for each site, Corine Land Cover (CLC) 2012 is used. Land cover use map contains 44 land use classes. In the last version of CLC 2012, Turkey was completed and published by European Environmental Agency. The data is downloaded from the website: http://land.copernicus.eu/pan-european/corine-land-cover/clc-2012/view

To calculate the drought for these sites, Standardized Precipitation Index is used. For the accurate precipitation data sets, we directly contacted the local meteorological stations and data sets are provided up to date and the most accurate way (Meteorological Stations in Adana and Konya).

3.5 Unit of Analysis

Adana and Konya, Turkey are used for this study. For each location, mass transport, SPI, and wind direction data are calculated from 2007 and 2015. Before calculating mass transport data, all units are converted to metric system. Visibility records are converted from miles to kilometers, wind speed is converted from miles per hour to meters per second and time is converted from minutes to second.

Mass transport data is calculated by using;

$$E_{1.7} = (M)\ (u_{1.7})\ (t)$$

Mass concentration is showed by (M), recorder height is determined to 1.7 meter for this study and $u_{1.7}$ means the average wind speed between readings. (t) also represents the period of time. $E_{1.7}$ is a measure of blowing dust at observer height. Lee et al., (1993) called the unit of $E_{1.7}$ "kilograms of dust passing through a square meter centered at observer height". It is a relative measure of the amount of blowing dust.

The concentration of dust is determined by using;

$$M = c / v^{y}$$

In this study c is a constant number (2×10^{-5} kg m^{-3}), v is the average visibility reading for each hour, and y is also constant as 1.07 (Patterson and

Gillette, 1977). Even though these constant numbers were determined for the Southern High Plains of the United States, it is assumed appropriate for this research. However, values have not been tested yet for these locations. Mass transport is calculated for each observation and annual total blowing dust amounts are used as an indicator of study sites.

After the raw wind speed and visibility records are downloaded, the records are modified in several ways. These wind speed and visibility data are recorded every hour and each three hours one more data is put in the data column. Also, some days more data is recorded by observer in order to signify a weather event. In this study, first of all, one day records are considered as 24 hours daily observation and missing data is filled by previous records. After that, mass transport data is calculated by using the formula and mass transport when visibility is under 12 km, which is considered as a limit is used as blowing dust indicator.

Corine Land Cover map is categorized into 5 classes such as urban areas, agricultural sites, forest and semi-natural areas, wetlands, and water bodies, using ArcMap. The raster data is clipped for each site using extract by mask feature. Then, the final map is created in ArcMap.

SPI drought index is categorized by seven different scales from extremely wet (2.0 or more) to extreme drought (-2.0 and less) in Table 2.2. For each station,

precipitation records were obtained from local meteorological stations by contacting them personally. Drought index is measured by using the formula:

$$\mathrm{SPI} = (x_i - \bar{x})/\sigma$$

for each year from 2007 to 2015. In this equation, x_i is actual precipitation, $\bar{x}$ is the mean of precipitation, and σ is standard deviation.

Wind direction data is also obtained from the same website which wind speed and visibility records are taken. Wind direction data was recorded in compass degrees with 36 directions. When wind direction is variable and when air is calm, data was recorded like 990 and ***. To get a better result, these records were removed from data set.

3.6 Variables

Annual total mass transport, SPI, and wind direction are considered as a main concept of this study.

3.7 Statistical Analysis

A correlation coefficient will be determined between mass transport and SPI for each location. If there is a statistically significant correlation between mass transport and SPI, the hypothesis will be accepted. If the correlation is not statistically significant, the hypothesis will be rejected.

4. RESULTS

4.1 Annual Values of Mass transport in Adana

Figure 4.1 shows annual blowing dust amounts from 2007 to 2015 in Adana. Relatively high amounts of blowing dust are found in year 2008, 2012, 2013, and 2014. As can be seen from the graph, the amount of blowing dust is at the highest level in 2013. The graph shows a slight decrease from 2008 to 2009. It is also noted that the lowest amount of blowing dust is seen in 2011.

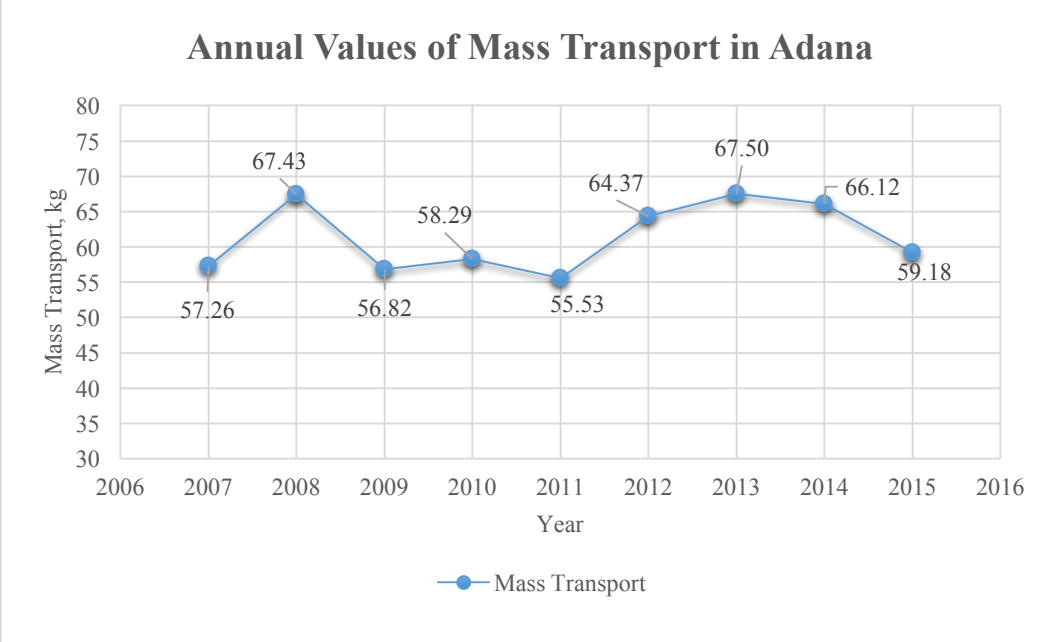

Figure 4.1 Annual Values of Mass transport in Adana

4.2 Annual Values of Mass Transport in Konya

Annual blowing dust amounts are shown in Figure 4.2 from 2007 to 2015. As is illustrated by the graph, relatively high amounts of blowing dust are

observed in 2012 and 2015. Blowing dust reaches its peak in 2015 with 187.27 kg and around 85 kg more dust is transported from previous year. As can be seen in the figure from 2009 to 2012, blowing dust amount is increasing. In 2012 there is a dramatic drop at blowing dust comparing to 2012. In the graph, it is seen that the lowest amount is calculated in 2009 with 74.4 kg.

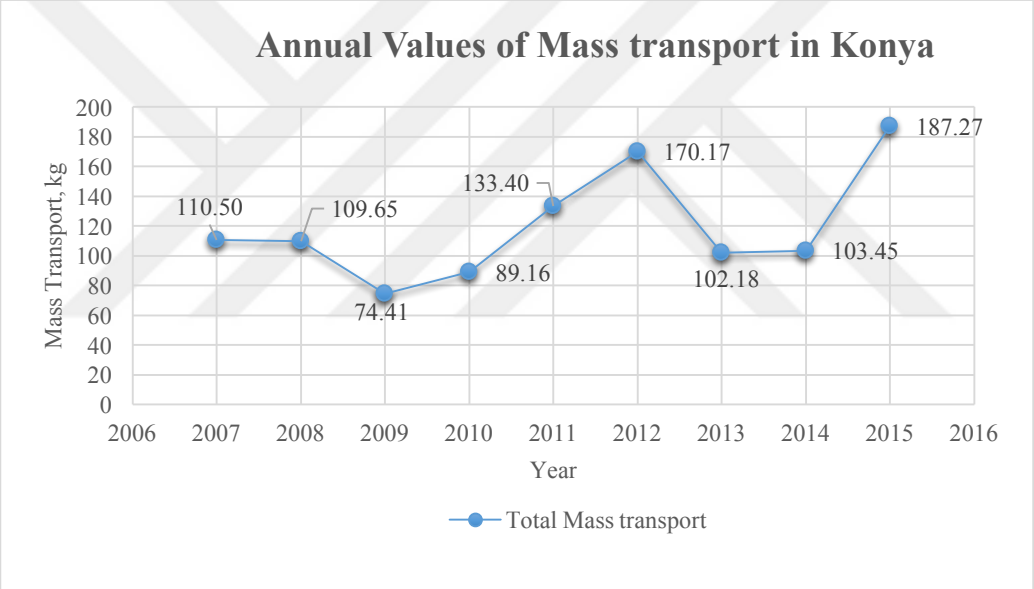

Figure 4.2 Annual Values of Mass Transport in Konya

4.3 Annual SPI Results in Adana

Figure 4.3 shows that Standardized Precipitation Index indicates extremely wet period with a value of 1.94 in 2012. 1065 mm rainfall is calculated in 2012 and it is almost as twice as the closest rainfall. As is shown by the graph below, there are moderately dry periods in 2008 and 2013 with a value of -1.46

and - 1.12. The graph shows a tendency in approaching normal values almost all over the years except 2008, 2012, and 2013.

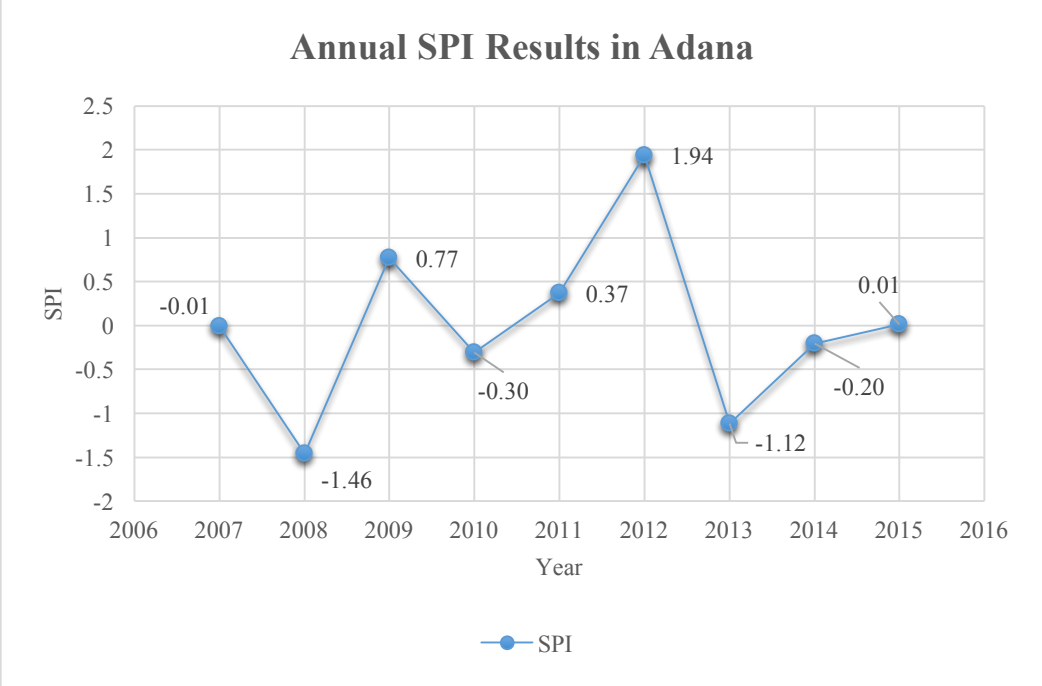

Figure 4.3 Annual SPI Results in Adana

4.4 Annual SPI Results in Konya

The results in Figure 4.4 below show that in 2014 it is found very wet period with a value of 1.88. For the following periods in 2007 and 2013, results are closer to each other with a value at moderately dry. From the graph it is clear that SPI results have a similar value at near normal (0.99 to -0.99).

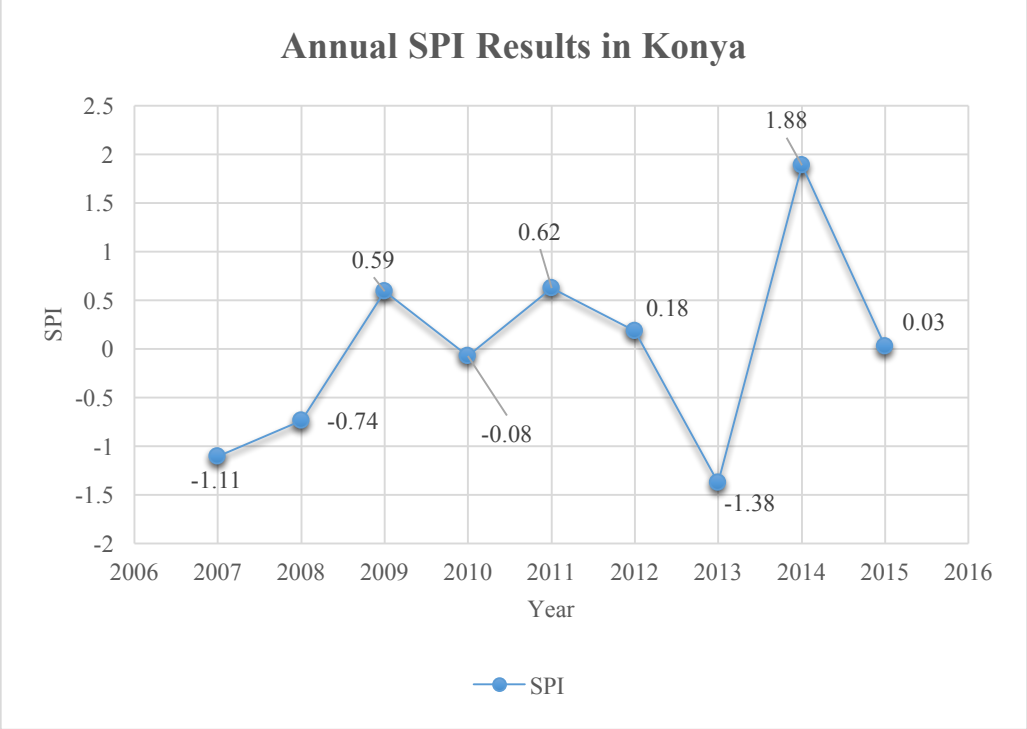

Figure 4.4 Annual SPI Results in Konya

4.5 Adana Land Use Map

Figure 4.5 below shows land use features of Adana in 2012. As can be seen in the map, East and South side of meteorological station is generally covered by agricultural areas. The North side has majorly forest and semi-natural areas. On the Seyhan river, there are two significant dams which are Seyhan and Catalan Dam. These are the water sources for agricultural production of the basin.

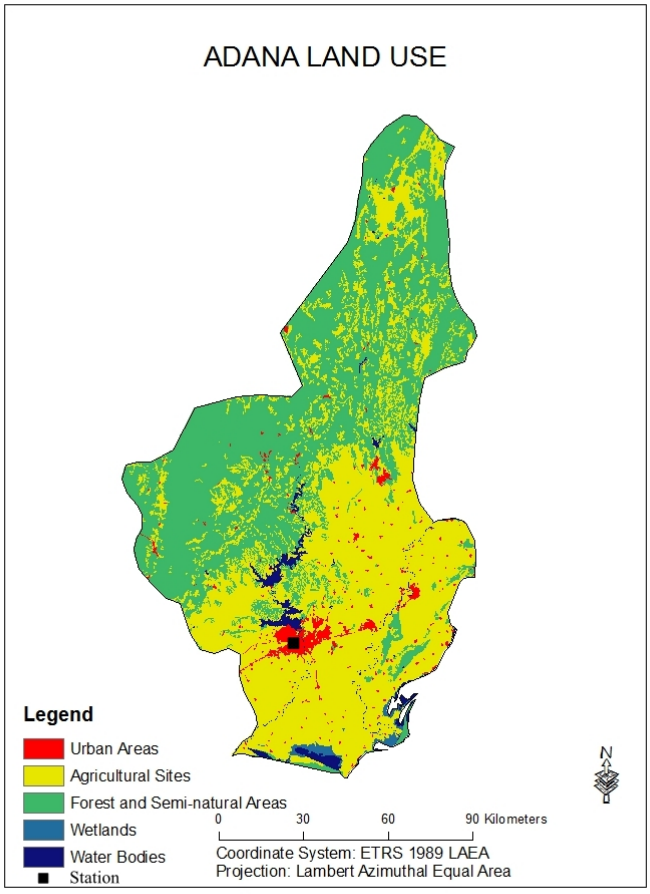

Figure 4.5 Adana land use map

4.6 Konya Land Use Map

Figure 4.6 illustrates land use features of Konya in 2012. On the map, it is obvious that agricultural areas have a big portion of the basin. The South side of the map contains forest and semi-natural areas. As can be seen in the map, the

meteorological station is located in the middle of basin. Also in Northeast and Southwest side of the map has two small lakes.

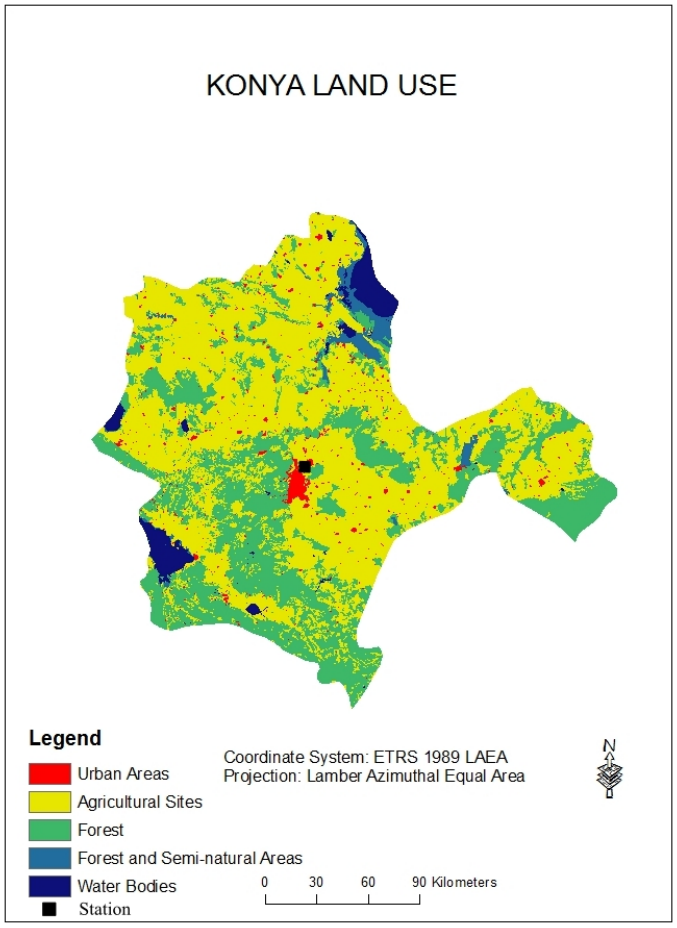

Figure 4.6 Konya land use

4.7 Wind Direction Map in Adana

Figure 4.7 illustrates percentage of wind direction from 2007 to 2015 in Adana. As can be seen in Figure 4.7 below, frequency of wind direction can be observed mostly in North and

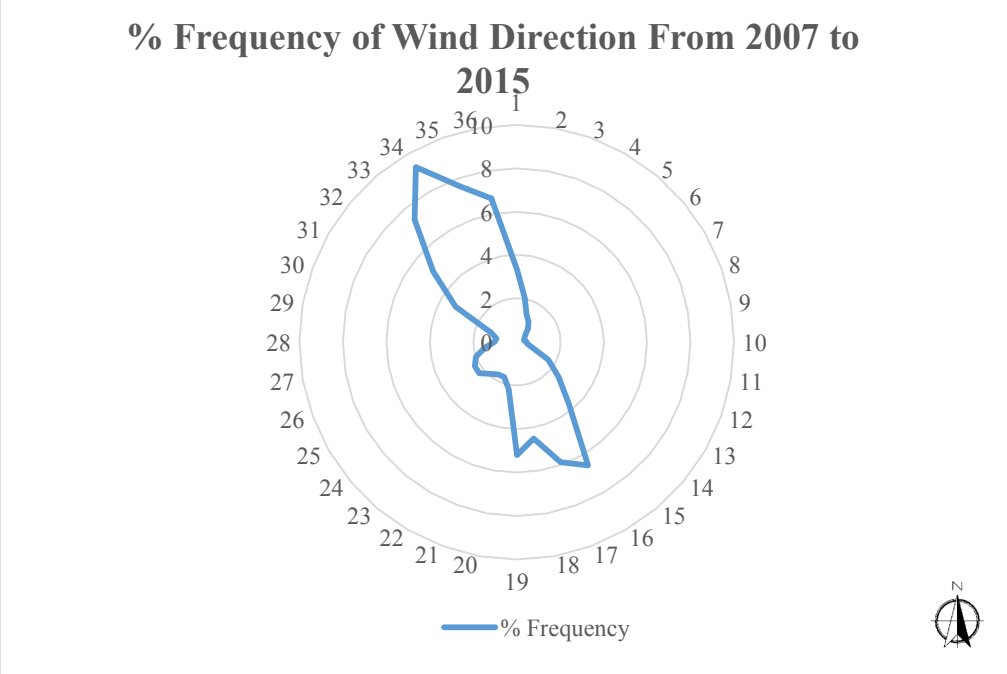

Figure 4.7 Wind Direction Map in Adana

Northwest direction. However, frequency of wind direction can be found less in South and Southeast direction. Frequency of wind is slightly higher in North and Northwest direction comparing to South and Southeast direction.

4.8 Wind Direction Map in Konya

Percentage of wind direction from 2007 to 2015 in Konya is shown in Figure 4.8. As is shown by the figure below, frequency of wind direction can be

seen dominantly in North and Northeast direction. On the other hand, frequency of wind direction is noted less in South direction.

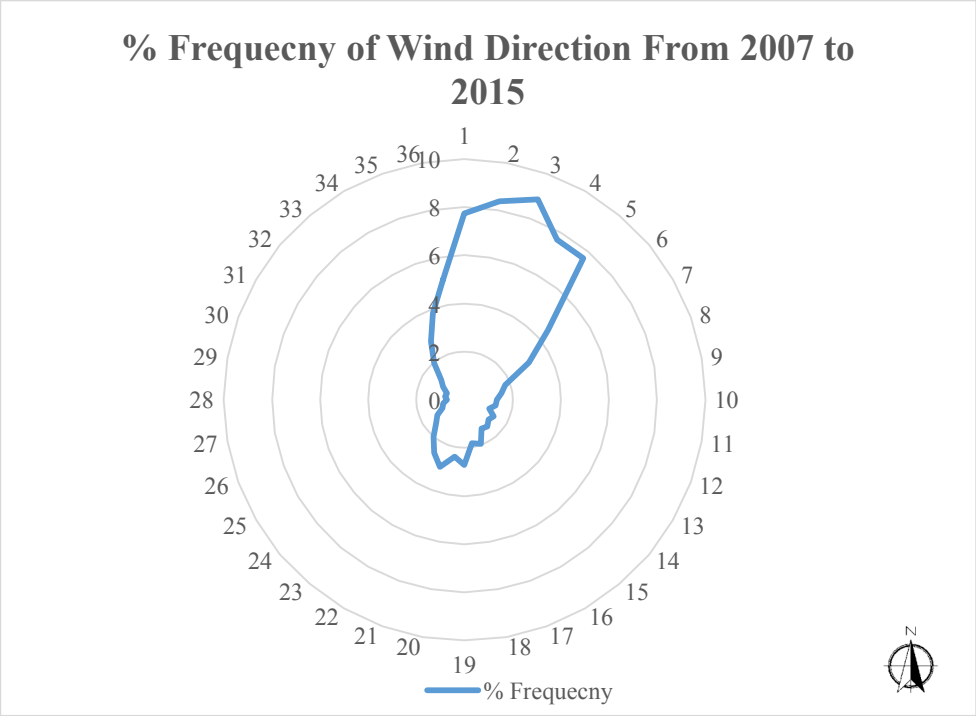

Figure 4.8 Wind Direction Map in Konya

4.9 Correlation in Adana from 2007 to 2015

Figure 4.9 below shows the correlation matrix between annual values of mass transport and SPI from 2007 and 2015 in Adana. It is found that simple regression between mass transport and SPI is a r^2 of 0.1549 for years 2007 – 2015. As can be seen in Table 4.1 below, the relationship is not significant at the $p = 0.05$ level($p > 0.05$).

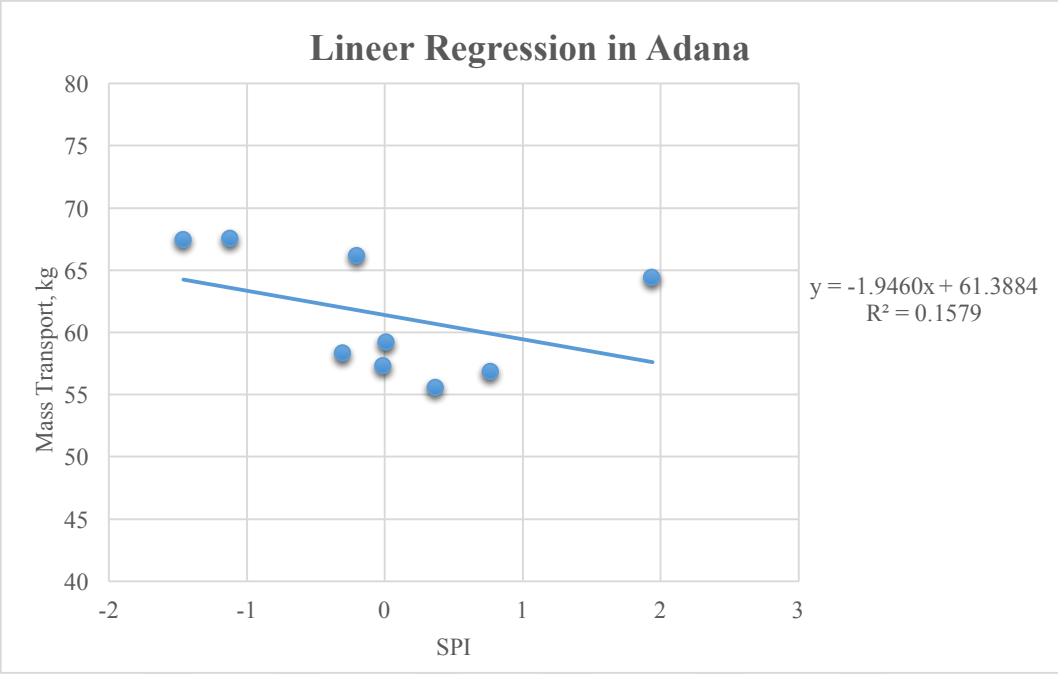

Figure 4.9 Correlation for annual values of Mass Transport and SPI from 2007 to 2015 in Adana

4.10 Correlation in Konya from 2007 to 2015

The correlation matrix between annual values of mass transport and SPI from 2007 and 2015 in Konya is shown in Figure 4.10. It is found that simple regression between mass transport and SPI is a r^2 of 0.0005 for years 2007 – 2015. As can be seen in Figure 4.10 below, the relationship is not significant at the p = 0.05 level ($p > 0.05$).

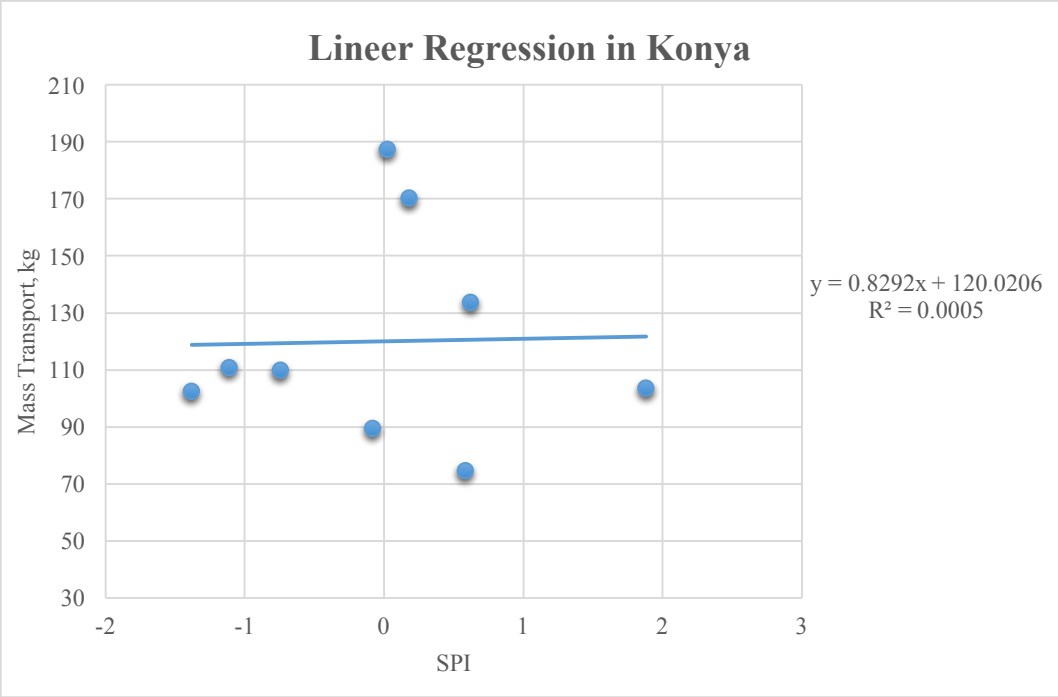

Figure 4.10 Correlation for annual values of Mass Transport and SPI from 2007 to 2015 in Konya

4.11 Overall Results

Blowing dust is more common in Konya between 2007 and 2015 than in Adana. In Adana, the amount of blowing dust calculated is very low compared to Konya. Relatively high amount of dust is observed in Konya for years 2012 and 2015. Relatively little dust is transported for each location in 2009. While in Adana the amount of blowing dust is at the highest level in 2013, blowing dust reaches its peak in 2015 with 187.27 kg in Konya. While Standardized Precipitation Index indicates very wet period with a value of 1.94 in Adana for year 2012, it is found very wet period with a value of 1.88 in Konya for year 2014. Moreover, in Adana and Konya, it is observed that there is a moderately dry

period in common for year 2013. As a conclusion, the results show that both cities have a similar trend in drought index for these years. Wind direction in Konya is found to be much more stable compared to Adana. Since frequency of wind direction can be seen dominantly towards North and Northeast direction in Konya, in Adana frequency of wind direction can be seen both in North and South between 2007 and 2015. According to the results, minimal relationship of casualty has been found for 2007 to 2015 in Adana and Konya.

5. DISCUSSION AND CONCLUSION

Blowing dust and drought are among the most dangerous weather phenomena in the countries of the Middle East. In this study, Adana and Konya have been examined in term of blowing dust and drought from 2007 to 2015. According to the results, the amount of blowing dust in Konya has been found significantly higher than in Adana. This is due to the fact that approximately 40% of agricultural sites have been left for fallow every year and also UNEP, WMO, UNCCD, (2016) reported that even though there had been a lot of reduction of dust activities in Konya, but it still remains a hot wind erosion zone in the Middle East region. However, most agricultural products can be planted in Adana due to favorable weather conditions throughout the year which means there are fewer agricultural sites which have been left for fallow compared to Konya. This fact leads the reason why Adana has less blowing dust amount for these years.

According to the results, the hypothesis is rejected that the amount of dust blowing is significantly correlated with drought. In this research, only 9 years period have been used and that can be a reason why correlation is found weak. Although the relationship between drought and mass transport for both sites seems to be statistically trivial, this study has an importance to study areas for several reasons. First of all, studies that have been carried out on dust emission in these areas are pretty limited and so this study may shed light on the perspective of future studies or give an idea to researchers as well as be a literature source.

Second, dust blowing is a substantial problem worldwide and mostly caused by anthropogenic activities (such as land use, recreation activities in dry lands etc.). This study will relatively provide the information about the extent of the issue which will help managers take action for future management approaches.

BIBLIOGRAPHY

Alizadeh-Choobari, O., Ghafarianb, P., & Owlad, E. (2016). Temporal variations in the frequency and concentration of dust events over Iran based on surface observations. *International Journal of Climatology, 36*, 2050–2062. Doi:10.1002/joc.4479

Ashley, W. S., & Black, A. W. (2008). Fatalities associated with nonconvective high-wind events in the United States. *Journal of Applied Meteorology and Climatology*, *47*, 717-725. Https://doi.org/10.1175/2007JAMC1689.1

Atmaca, D. (2011). *Standartlastirilmis Yagis Indeksi (SYI) ile Konya ilinde bölgesel kuraklık analizi (Yuksek Lisans Tezi)*. Gaziosmanpasa Universitesi, Tokat, Turkiye. Retrieved from http://ulusaltezmerkezi.com/standartlastirilmis-yagis-indeksi-syi-yontemi-ile-konya-ili-bolgesel-kuraklik-analizi/

Bacanli, U. G., Dikbasa, F., & Baran, T. (2011). Meteorological drought analysis case study: Central Anatolia. *Desalination and Water Treatment, 26*, 1-10. Doi:10.5004/dwt.2011.2105

Barnum, B. H., Winstead, N.S., Wesely, J., Hakola, A., Colarco, P. R., ... , Toth, B. (2004). Forecasting dust storms using the CARMA-dust model and MM5 weather data. *Journal of Environmental Modelling & Software, 11*, 129-140. Retrieved from https://www.gfdl.noaa.gov/bibliography/related_files/bhb0401.pdf

Basaran, M., Uzun, O., Kaplan, S., Gormez, F., & Erpul, G. (2017). Tillage-induced wind erosion in semi-arid fallow lands of Central Anatolia, Turkey. *Soil and Water Research, 1*, 1-7. Doi: 10.17221/73/2016-SWR

Clausnitzer, H., Singer, M. J. (1996). Respirable-dust production from agricultural operations in the Sacramento Valley, California. *J. Environ. Qual*., *25*, 877 – 884. doi:10.2134/jeq1996.00472425002500040032x

Ciftci, M., Karatas, A. (2009). Adana tarim sektoru analizi ve vergi potansiyeli. Retrieved from https://www.muhasebenet.net/makale_mehmet%20ciftci-adnan%20karatas_tarimsektoru%20analizi%20ve%20vergi%20potansiyeli.doc

Dundar, C., Oguz, K., & Gullu, G. (2013). Dogu akdeniz havzasında kum ve toz fırtınalarının (SDS) incelenmesi. *10.Ulusal Cevre Mühendisliği Kongresi*, 343-348. Retrieved from https://www.mgm.gov.tr/FILES/genel/makale/5-2013_Dogu_Akdeniz_Havzasinda_SDS_Incelenmesi.pdf

Elsen, E. v. (2007). *Desire-Project*. Retrieved from www.project.eu/index69d5.html?option=com_content&task=view&id=40&Itemid=40

Fengmei, Y., & Chongyi, E. (2010). Correlation analysis between sand-dust events and meteorological factors in Shapotou, Northern China. *Environmental Earth Sciences, 59*, 1359–1365. Doi:10.1007/s12665-009-0123-4

Field, J. P., Belnap, J., Breshears, D. D., et al. (2010). The ecology of dust. *Front. Ecol. Environ., 8*(8), 423–430. http://dx.doi.org/10.1890/099050

Floyd, K. W., & Gill, T. E. (2011). The association of land cover with Aeolian sediment production at Jornada Basin, New Mexico, USA. *Aeolian Research, 3*, 55–66. Https://doi.org/10.1016/j.aeolia.2011.02.002

Goudie, A. S. (1983). Dust storms in space and time. *Progress in Physical Geography, 7*(4), 502–530. Doi: 10.1177/030913338300700402

Goudie, A. S., & Middleton, N. J. (2001). 'Saharan dust storms: nature and consequences'. *Earth-Science Reviews* 56, 179–204. Https://doi.org/10.1016/S0012-8252(01)00067-8

Grini, A., Zender, C. S., Colarco, P. R. (2002). Saltation Sandblasting behavior during mineral dust aerosol production. *Geophysical Research Letters, 29*(18), 1868. Doi:10.1029/2002GL015248

Guttman, N. B. (1999). Accepting the Standardized Precipitation Index: a calculation algorithm. *Journal of the American Water Resources Association, 35*(2), 311–322. Doi:10.1111/j.1752-1688.1999.tb03592.x

Hamidi, M., Kavianpour, M. R., & Shao, Y. (2014). *Numerical simulation of dust events in the Middle East. Aeolian Research, 13*, 59–70. Doi: 10.1016/j.aeolia.2014.02.002

Havza Koruma Eylem Planlarının Hazırlanması – Konya Kapalı Havzası. (n.d.).*Tubitak Mam Cevre Enstitusu.* Retrieved from http://www.cygm.gov.tr/cygm/files/guncelbelgeler/havza_final/konya/konya_kapali_havzasi.pdf

Keskin, M. E., Terzi, O., Taylan, E. D., & Yilmaz, A. G. (2007). Isparta bolgesi meteorolojik kuraklık analizi. *I. Türkiye iklim Degişikligi Kongresi-TIKDEK 2007*, Istanbul, Türkiye, 350-359. Retrieved from http://docplayer.biz.tr/24767055-Bildiri-kitabi-editorler-ahmet-oztopal-zekai-sen.html

Koken, E., Duygu, M. B., Kirmencioglu, B., & Aras, M. (2015). Essential tools to establish a comprehensive drought management plan: Konya Closed Basin as a case study. *Turkish Journal of Water Science and Management*, 54-70. Retrieved from http://dergipark.gov.tr/tjwsm/issue/27948/297087

Lee, J. A., Wigner, K. A., & Gregory, J. M. (1993). Drought, wind and blowing dust on the southern High Plains of the United States. *Physical Geography, 14*, 56 – 67. Accessed September 20, 2016.

Lee, J. A., Allen, B. L., Peterson, R. E., Gregory, J. M., & Moffett, K. E. (1994). Environmental controls on blowing dust directions at Lubbock, Texas, USA. *Earth Surface Processes and Landforms, 19*(5), 437-451. Doi:10.1002/esp.3290190505

Lee, J. A., & Tchakerian, V. P. (1995). Magnitude and frequency of blowing dust on the southern High Plains of the United States, 1947–1989. *Annals of the Association of American Geographers, 85*(4), 684-693. Doi:10.1111/j.1467-8306.1995.tb01820.x

Lee, J. A., Gill, T. E., Mulligan, K. R., Acosta, M. D., & Perez, A. E. (2009). Land use/land cover and point sources of the 15 December 2003 dust storm in southwestern North America. *Geomorphology, 105*, 18–27. https://doi.org/10.1016/j.geomorph.2007.12.016

Lee, J. A., Baddock, M. C., Mbuh, M. J., & Gill, T. E. (2012). Geomorphic and land cover characteristics of Aeolian dust sources in West Texas and eastern New Mexico USA. *Aeolian Research, 3*, 459–466. https://doi.org/10.1016/j.aeolia.2011.08.001

Lee, J. A., & Gill, T. E. (2015). Multiple causes of wind erosion in the Dust Bowl. *Aeolian Research, 19*, 15–36. Doi:10.1016/j.aeolia.2015.09.002

Li, W., Fu, R., Juárez, R. I., Fernandes, K. (2008). Observed change of the standardized precipitation index, its potential cause and implications to future climate change in the Amazon region. *Philos Trans R Soc Lond B Biol Sci, 363*(1498), 1767–1772. Doi:10.1098/rstb.2007.0022

Mahowald, N. M., Ballantine, J. A., Feddema, J., & Ramankutty, N. (2007). Global trends in visibility: Implications for dust sources. *Atmospheric Chemistry and Physics, 7*, 3309-3339. Retrieved from https://hal.inria.fr/file/index/docid/296267/filename/acp-7-3309-2007.pdf

McKee, T. B., Doesken, N. J. and Kleist, J. (1993). The relationship of drought frequency and duration to time scales. *Proceedings of the 8th Conference on Applied Climatology*, Anaheim, CA, USA, 179–184. Retrieved from https://pdfs.semanticscholar.org/c3f7/136d6cb726b295eb34565a8270177c57f40f.pdf

Meester, T. d. (1970). Soils of the Great Konya Basin, Turkey. *Centre for Agricultural Publishing and Documentation Wageningen*.

Mei, S., Xiushan, S., Lin, S., & Ping, W. (2006). A dust-storm process dynamic monitoring with multi-temporal modis data. *Journal of Progress in Geography, 4*, 45-52. Retrieved from http://www.isprs.org/proceedings/XXXVII/congress/7_pdf/5_WG-VII-5/39.pdf

Miri, A., Ahmadi, H., Ghanbari, A., & Moghaddamnia, A. (2007). Dust storms impacts on air pollution and public health under hot and dry climate. *Journal of Energy and Environment, 2*(1), 101-105. Retrieved from http://www.naun.org/main/NAUN/energyenvironment/ee-18.pdf

Modaihsh, A.S. (1997). Characteristics and composition of the falling dust sediments on Riyadh city, Saudi Arabia. *Journal of Arid Environments, 8*, 211-223. Doi:10.1006/jare.1996.0225

Nicholson, K. W. (1988). A review of particle resuspension. *Journal of Atmospheric Environment, 22*(12), 2639-2651. Https://doi.org/10.1016/0004-6981(88)90433-7

NOAA Satellite and Information Service. (2015). *NNDC Climate Data Online*. Accessed August 10, 2016. Retrieved from https://www7.ncdc.noaa.gov/CDO/cdopoemain.cmd?datasetabbv=DS3505&countryabbv=&georegionabbv=&resolution=40.

Novlan, D. J., Hardiman, M., & Gill, T. E. (2007). A synoptic climatology of blowing dust events in El Paso, Texas from 1932-2005. *16th Conference on Applied Climatology*. Retrieved from https://ams.confex.com/ams/87ANNUAL/techprogram/paper_115842.htm

Palmer, W. C. (1965). Meteorological drought. *U.S. Department of Commerce,* 1-58. Retrieved from: https://www.ncdc.noaa.gov/tempand-precip/drought/docs/palmer.pdf.

Patterson, E. M., & Gillette, D. A. (1977). Measurements of visibility vs mass-concentration for airborne soil particles. *Atmospheric Environment, 11*, 193-196. Doi:10.1016/0004-6981(77)90226-8

Prospero, J. M., Ginoux, P., Torres, O., Nicholson, S. E., & Gil, T. E. (2002). Environmental characterization of global sources of atmospheric soil dust identified with the NIMBUS 7 Total Ozone Mapping Spectrometer (TOMS) absorbing aerosol product. *Reviews of Geophysics, 40*(1), 1-31. Retrieved from https://www.researchgate.net/publication/281477411_Environmental_characterization_of_global_sources_of_atmospheric_soil_dust_identified_with_the_NIMBUS_7_Total_Ozone_Mapping_Sectrometer_TOMS_absorbing_aerosol_product

Prudunce, V. A. (2016). *Temporal change of blowing dust in Lubbock, Texas 1947-2013*. (unpublished master's thesis). Texas Tech University, Lubbock, Texas.

Pye, K. (1987). Aeolian Dust and Dust Deposits. *Academic Press Inc. London. 334*. Doi:https://doi.org/10.1017/S0016756800013121

Ravi, S., Zobeck, T. M., Over, T. M., Okin, G. S., & D'Odorico, P. (2006). On the effect of moisture bonding forces in air-dry soils on threshold friction velocity of wind erosion *Sedimentology, 53*(3), 597- 609. Doi:10.1111/j.1365-3091.2006.00775.x

Rezazadeh, M., Irannejad, P., & Shao, Y. (2013). Climatology of the Middle East dust events. *Aeolian Research, 10*, 103–109. Doi:10.1016/j.aeolia.2013.04.001

Risk Assessment of wind erosion project: Konya Altinova - Gozlu agricultural enterprises model work [Brochure]. (n.d.). General Directorate for Combating Erosion and Desertification. Retrieved from http://www.cem.gov.tr/erozyon/Libraries/su/RUZGAR_BROS_ING.sflb.ashx

Rivera Rivera, N. I. (2012). *Analysis and modeling of dust event data from El Paso, Texas* (Doctoral dissertation). Retrieved from http://digitalcommons.utep.edu/dissertations/AAI3552257/.

Seager, R., Ting, M., Held, I., Kushnir, Y., Lu, J., Vecchi, G., … Naik, N. (2007). Model projections of an imminent transition to a more arid climate in southwestern North America. *Science*, *316*, 1181–1184. Doi:10.1126/science.1139601

Salvati, L., Venezian-Scarascia, M. E. & Zitti, M. (2009). Monitoring drought severity in agriculture through a synthetic index based on dry periods: a case study in the Mediterranean basin. *Irrigation and Drainage*, *58*, 596–606. Doi:10.1002/ird.441

Schlesinger, W. H., Reynolds, J. F., Cunningham, G. L., Huenneke, L. F., Jarrell, W. M., Virginia, R. A., & Whitford, W. G. (1990). Biological feedbacks in global desertification. *Science, 247*(4946), 1043–1048. Doi:10.1126/science.247.4946.1043

Sonmez, M. (2011). The urban expansion in Adana, Turkey, and relationship between land use changes in its surroundings. *Turk Cografya Dergisi, 57*, 55-69. Retrieved from http://dergipark.gov.tr/tcd/issue/21224/227779

Stout, J. E., & Lee, J. A. (2003). Indirect evidence of wind erosion trends on the Southern High Plains of North America. *Journal of Arid Environments, 55*, 43–61. https://doi.org/10.1016/S0140-1963(02)00266-5

European Environmental Agency. (2016). Corine Land Cover (CLC) 2012, Version 18.5.1. Accessed June 10, 2017. Retrieved from http://land.copernicus.eu/pan-european/corine-land-cover/clc-2012/view

UNEP, WMO, UNCCD. (2016). Global assessment of sand and dust storms. *Nairobi. Kenya: United Nations Environment Programme*. Retrieved from https://uneplive.unep.org/media/docs/assessments/global_assessment_of_sand_and_dust_storms.pdf

Washington, R., Todd, M.C. (2005). Atmospheric controls on mineral dust emission from the Bodélé Depression, Chad: The role of the low level jet. *Geophysical Research Letters, 32*, L17701. Doi:10.1029/2005GL023597.

WHO. (2013). Review of evidence on health aspects of air pollution; REViHAAP Project, Technical Report. *World Health Organization*. Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0004/193108/REVIHAAP-Final-technical-report-final-version.pdf?ua=1

Wilhite, D. A. & Glantz, M. H. (1985) "Understanding the Drought Phenomenon: e Role of De nitions". *Drought Mitigation Center Faculty Publications*, 20. http://digitalcommons.unl.edu/droughtfacpub/20

Yang, X., Shen, S., Yang, F., He, Q., Ali, M., ... , Liu, X. (2016). Spatial and temporal variations of blowing dust events in the Taklimakan Desert. *Theoretical and Applied Climatology, 125*, 669–677. Doi:10.1007/s00704-015-1537-4

Yegnidemir, M. K. (2005). *Ic anadolu bolgesinin standartlastırılmış yagis indeksi metodu ile kuraklık analizi* (Yüksek Lisans Tezi). Kirikkale Universitesi, Kırıkkale, Turkey. Accessed June 15, 2017.

Yılmaz, K. T. (1998). Ecological diversity of the Eastern Mediterranean region of Turkey and its conservation. *Biodiversity & Conservation*, *7*, 87- 96. Doi:10.1023/A:1008811829956

Zin, W. Z. W., Jemain, A. A. & Ibrahim, K. (2013). Analysis of drought condition and risk in Peninsular Malaysia using Standardised Precipitation Index. *Theoretical and Applied Climatology*, *111*, 559–568. Doi:10.1007/s00704-012-0682-2

Zobeck, T. M. & Fryrear, D. W. (1986). Chemical and physical characteristics of wind blown sediment. II. Chemical characteristics and total soil and nutrient discharge. *Transactions of the ASAE*, *29*, 1037–1041. Doi:10.13031/2013.30266

Zobeck, T. M., Fryrear, D. W. & Pettit, R. D. (1989). Management effects on wind-eroded sediment and plant nutrients. *J. Soil Water Cons.*, 44, 160–163. Retrieved from https://www.researchgate.net/publication/246753631_Management_effects_on_wind-eroded_sediment_and_plant_nutrients

APPENDIX A

Calculations

Table A.1 Calculations

Column	Formula Samples
A	This is the date in number format
B	This is the hour of the day
C	This is the minute of the hour
D	This is the second of the minute (always zero)
E	This is the wind speed in mph
F	This is the visibility in miles per hour
G - Mass Concentration	=2*POWER(10,- 5)/POWER(IF(AVERAGE(CONVERT (F1,"mi","km"),CONVERT(F2 ,"mi","km"))=0,".1",AVERAGE(CONVERT (F1,"mi","km"),CONVE RT(F2,"mi","km"))),1.07)
H - Law of the wall	=(CONVERT(CONVERT(E2,"mph","m/h"),"m/h","m/s")) *LN(1.7/0.01)/ LN(10/0.01)
I - Mass Transport	=H30751*G508*((A508+TIME(B508,C508,D508))-(A507+TIME(B507,C507,D507)))*86400

1. Excel>Open>Text file (simplified version)
    - I. Fixed width (original data file type)
    - II. Add extra column divider between HH and MM
    - III. Add extra column between MM and Direction
    - IV. Add only these columns
        - I. YYYYMMDD
        - II. HH
        - III. MM I
        - IV. (blank) labeled SS for seconds
        - V. SPD
        - VI. VIS
2. Change time to numbers
    - I. Highlight Column A, and convert to a number format
    - II. Label Column D “SS” (for seconds)
    - III. Highlight columns B, C, and D and convert to a text format

APPENDIX B

Glossary

NCDC National Climatic Data Center

NOAA National Oceanic and Atmospheric Administration

PDSI Palmer Drought Severity Index

SPI Standardized Precipitation Index

CLC Corine Land Cover