



Impacts of Weather Pattern on Pollen Concentration in Islamabad



Prepared By

SOHAIL BABAR CHEEMA

DR.MUHAMMAD AFZAAL

MUHAMMAD AKRAM ANJUM

Table of Contents

Executive Summary.....	1
Chapter 1.....	2
1. Introduction:.....	2
1.1 Geography and Climate of Islamabad:.....	3
1.2 Pollen Monitoring in Islamabad.....	3
1.3 Pollen Sampling:.....	4
1.4 Aim of this study:	6
Chapter 2.....	7
2. Data and Methodology.....	7
2.1 Data and its sources.....	7
2.2 Spatial Distribution of Pollen Tree.....	7
2.3 Methodology.....	8
Chapter 3.....	9
3. Results and Discussion:	9
3.1 Total pollen count analysis:	9
3.2 Number of Total Pollen Days:	10
3.3 Pollen cycle and its Relationship with Weather Parameters:.....	11
Chapter 4.....	13
4 Anomalous behavior of pollen 2016 and heavy rainfall:	13
4.1 Pollen season 2016:	13
4.2 Peak Pollen Days:	14
4.3 Temperature and Precipitation Anomalies.....	14
Chapter 5.....	18
5 Conclusions and Recommendations:.....	18
5.1 Conclusions:	18
5.2 Recommendations:	18

Reference:	19
------------------	----

List of Figures

Figure 1.1: Flower of (a) male and (b) female paper mulberry tree	3
Figure 1.2: (a) Map of Islamabad City; (b) Spatial distribution of pollen allergy plants.....	4
Figure 1.3: Meteorological and Pollen Sampling Site	5
Figure 2.1: No of paper mulberry trees in different sectors of Islamabad.....	7
Figure 3-1 Total pollen count for six years (2011-2016).....	9
Figure 3-2 Total severe pollen days during spring season (2003-2016).....	10
Figure 3-3 Accumulated pollen and weather parameter during onset of pollen season.....	11
Figure 3-4 Accumulated pollen and weather parameter during peak of pollen season	12
Figure 3-5 Accumulated pollen and weather parameter during offset of pollen season	12
Figure 4-1 Accumulated pollen and weather parameter during pollen season 2016.....	13
Figure 4-2 Peak value recod from (2003-2016).....	14
Figure 4-3 (a) Temperature Departure Feb, 2016 (b) Rainfall Departure, Mar, 2016 from Normal (1980-2010)	15
Figure 4-4 : Daily Departure of 2016 (a) Tmax (b) Tmin and (c) Rainfall from Normal (1980-2010).....	17

List of Tables

Table 1.1 Pollen Measurement Scale.....	5
Table 4.2 Temperature Anomalies of Northern Hemisphere for Feb, 2016 from Normal (1981-2010).....	15

Executive Summary

Islamabad is a beautiful city but every year, with the dawn of spring it becomes living hell for pollen allergy victims. Pollen allergy was recognized as a serious health problem in Islamabad in 2003 when the Pakistan Meteorological Department (PMD) took out the first daily pollen count, published in newspapers and broadcast in the media. The ailment is caused mainly by paper mulberry, found in great abundance here. This paper mulberry plant, both male and female, is among the fastest growing trees that caused pollen allergy. The victims suffering from allergy remained in agony throughout March to till mid of April. The spell of rain during March kept the pollen quantity by and large in length and breadth of the city at unbearable level. In peak season pollen count in Islamabad hovers above 30,000 grains per cubic meter. It crosses 40,000 and there have been years (2005) when it got concentration above 48,000 particles per cubic meter. But in spring 2016 the peak concentration value was recorded 32737 per meter cubic. However this year pollen onset and offset behavior was totally different from all previous years.. In 2016 maximum wind speed was observed on 09th April and 17 April respectively. Until 09th April pollen count was round about 2000m³ but on 09th April due to strong wind the pollen count was 1056 m³. Then it strengthens again on 10th April due to humid atmosphere. This year maximum pollen hovers above than 5000 was persist only for a week but after that uniform concentration about 2000 persist for a long time. It went peak early and drop maximum concentration just with in a three days with maximum period of 45 days.

This is the first comprehensive report linking global changes to Pakistan's climate system and its impacts on pollen concentration. It is concluded that whenever the day temperature rose above than 25°C for a week and during this week or before week there is a light rain of 0.05 to 08 mm per day is a sign for onset of pollen in Islamabad. The maximum pollen concentration attains after a week of onset under dry condition. However whenever there is above than 20knts wind speed the maximum grains released from anther. It is also concluded that temperature is highly correlated with pollen concentration. A strong correlation was found between mean temperature and pollen count during peak season. The coefficient of correlation R^2 was above than 70 that is a significant correlation among two variables.

Chapter 1

1. Introduction:

Not so long before, Islamabad the capital of Pakistan was considered to be a health asylum due to its climate conditions. Even people from other major cities seek haven against bronchial and asthma diseases. But there was an antithetical situation after 1990's, now people rushing out from Islamabad to avoid falling prey of allergy. The spring season in capital starts from March. Instead of welcoming the flowers and colours, citizen of Islamabad have to welcome an uninvited guest popularly called 'Pollen'. The concentration of pollen also gradually increases with the onset of spring season till mid of April. Major cause of pollen in Islamabad was the project started by Capital Development Authority (CDA) to enhance greenery in the city. Under this project CDA introduced paper mulberry plants in the capital city. It turned the capital into the pollen capital.

The most abundant pollen types in Islamabad are from 08 trees (i. e. Paper Mulberry, Acacia, Eucalyptus, Pines, Grasses, Cannabis, Dandelion and Alternaria). Out of all these plants Paper Mulberry shares about 97% of the Total Pollen Count (TPC) during spring season. This calculation was made from daily pollen count data available for the period 2003-2016. Data analysis revealed that concentration of Paper Mulberry grains in the atmosphere resulted in pollen allergy related diseases. National Institute of Health Islamabad concluded that paper mulberry was the cause of widespread allergy in the city and its neighbor towns (Bennet et al.,1997). Haroon and Rasul (2008) reported that the paper mulberry tree has been the focus of attention ever since pollen allergy was first recognized as a threat to human health in Islamabad. Most of the people who suffer from severe allergy symptoms, like asthma attack, are allergic to the pollen of paper mulberry (Haroon and Rasul, 2008). According to the World Conservation Union, paper mulberry is one of the worst plant invaders in Pakistan (IUCN, 2004), Argentina (Ghersa et al., 2002) and many other states of United States of America (USDA Forest Service, 2006).

Scientific name of Paper Mulberry is *Broussonetia papyrifera* which was introduced in Islamabad from South East Asia. It is a dioecious tree, its male and female flowers grow on separate trees. Male plant is catkins whereas female flower being greenish with round heads as shown in Figure 1.1. Pollen from male Paper Mulberry tree is considered a major source for pollen allergy. Thus concentration of female plants is not so dangerous for pollen victims

in federal capital. Pollen count more than 15,000 is considered to be dangerous for sufferers in Islamabad.



Figure 1.1: Flower of (a) male and (b) female paper mulberry tree

1.1 Geography and Climate of Islamabad:

Islamabad the capital of Pakistan is located at 33.43°N 73.04°E at the edge of the Pothohar Plateau at the foot of the Margalla Hills. The climate of Islamabad has a humid subtropical climate, with 5 seasons i.e. spring (March to April), summer (May to June), Rainy Monsoon (July to August), autumn (September to October), and winter (November to February). The hottest month in Islamabad is June, with the average temperature exceeds 40 °C/104°F, while the wettest month is July, with heavy shower and evening thunderstorms. The coolest month is January, in which temperatures vary from cold to mild, rarely dropping below 0 and hills with sparse snowfall. On 23-July-2001, Islamabad received a record breaking 620mm (24inch) of rain fell in just 10 hours. It was the heaviest rainfall in 24 hours in Islamabad and at any locality in Pakistan during the past 100 years. Average monthly sunshine hours from January to March are 08 hours, whereas relative Humidity is 65 %. Open areas in the Islamabad city are occupied by a very dense vegetation of different species of plants and grasses producing various types of pollen grains.

1.2 Pollen Monitoring in Islamabad

Pollen allergy issues were highlighted after 2000 and it was noticed that many patient of pollen allergy has been admitted in different hospitals of Islamabad. After that victims and other people were apprehensive about concentration of pollen grains in the atmosphere. So, Pakistan Meteorological Department took responsibility of monitoring daily pollen count on its shoulders. In this regards first instrument was installed at PMD headquarters building in

2003. Pollen and mold counts measure the amount of airborne allergens from trees, grass, weeds and molds that is present in the air. Pollen and mold spores are collected using a Burkhard sampler which operates continuously for a 24 hour period. Airborne pollen and mold is collected on slides and then analyzed to determine the quantity and type of each pollen or mold present on the slide. The quantity determines the pollen count for the day.

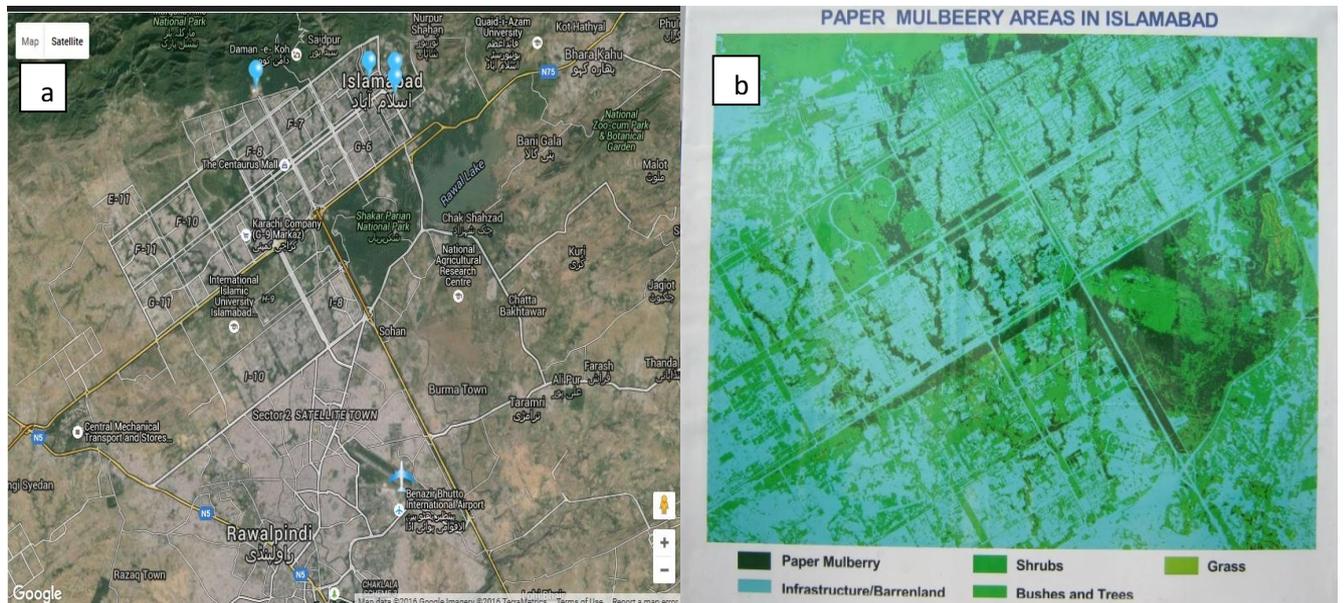


Figure 1-2: (a) Map of Islamabad City; (b) Spatial distribution of pollen allergy plants

There are two factors that related to pollen production, number of allergens trees and climate of that area. In Islamabad there is a lot of wild plants and vegetation which produce pollen in the atmosphere throughout the year at different rate. Although there are some other plants whose pollen are also known to cause allergies in spring season. The maximum number of pollen allergen trees exists in sector H-8 as shown in Figure 12. An aerial overview in Figure 1.2 (b) depicts maximum paper mulberry region in Islamabad and Figure 1.2 (a) is a satellite imaginary which shows different sectors in Islamabad city.

1.3 Pollen Sampling:

A multidata rotor sampler (Model 40) operating on a 10% duty cycle is used to make all pollen counts in Islamabad. These samplers are located at different sectors in the city as shown in Figure 1.3. These sites were selected on the basis of pollen concentration in Islamabad. The highest concentration observed in sector H-8, therefore in this sector there is a perennial monitoring.

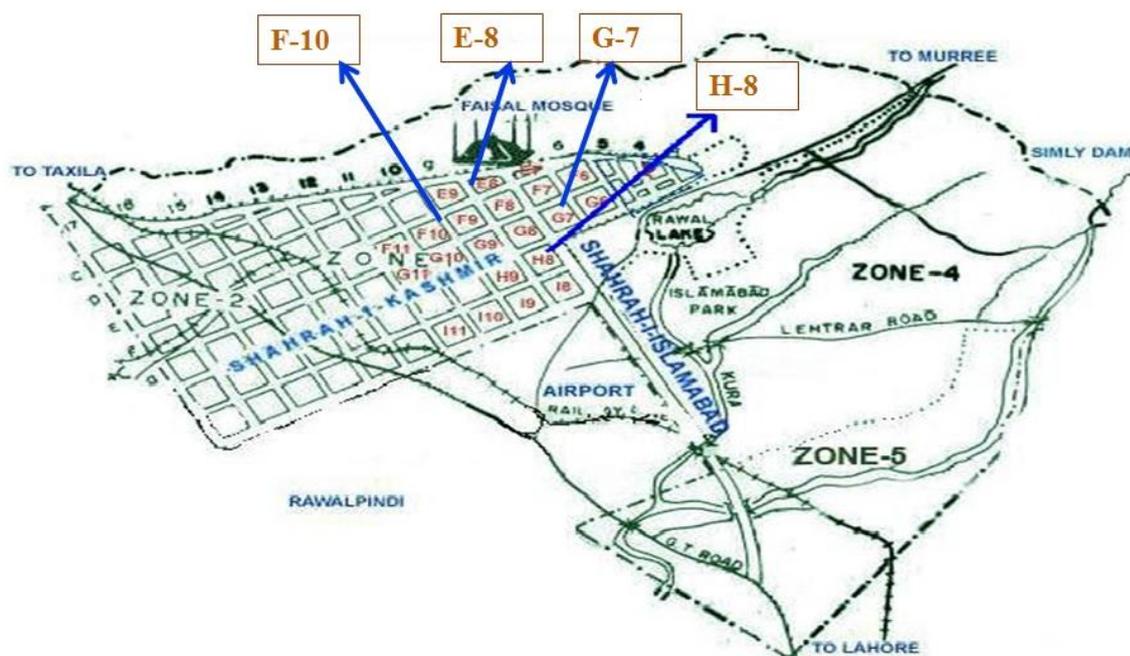


Figure 1-3: Meteorological and Pollen sampling sites.

After measuring pollen, the data is categorized according to the severity index, developed by the American Academy of Allergy, Asthma & Immunology and National Allergy Bureau. In case of low pollen count allergy patient will feel minor symptoms only, at very high concentration patient will feel severe symptoms, like asthma, watery, red and itchy eyes, running, itchy or blocked nose, usually accompanied with sneezing, itchy ears, as well as, itching of the skin on any area of the body leading to redness.

Table 1.1 Pollen Measurement Scale

Pollen Type	Low	Moderate	High	Very High
Trees	1 - 14	15 - 89	90 - 1,499	1,500 +
Grass	1 - 4	5 - 19	20 - 199	200 +
Weeds	1 - 9	10 - 49	50 - 499	500 +
Mold (Spores)	1 - 6,500	6,501-13,000	13,000-50,000	50,000 +

Source: http://www.pmd.gov.pk/rnd/rndweb/rnd_new/enviornmental.php:

1.4 Aim of this study:

The study is focused on the pollen variation and its relation to anomalous weather in winter and spring 2016. This year pollen count gain severity level early and the duration of pollen severity were very short although numbers of pollen days were maximum as compared to previous years. In the year 2016, highest pollen count was recorded as 32737 per cubic meter, while pollen period prolonged for 41daysi. e. record longest period. The main objective of this study is to investigate main causes of this abnormal behavior of pollen period during 2016.

Chapter 2

2. Data and Methodology

2.1 Data and its sources

Two types of data sets were used in this study, number of pollen tree data received from CDA, weather parameter and total pollen account information collected from PMD. In this study daily data from January 1981 to December 2016 were utilized. Daily data for first 30 years were used to calculate daily mean values of thirty years against temperature and rainfall for Islamabad city. The data 2016 were used to find out anomalies in temperature and rainfall w.r.t normal (1981-2010). Daily pollen data were also utilized for 2004 to 2016. This pollen data analyzed to check the behavior of onset, peak and off set of the pollen season.

2.2 Spatial Distribution of Pollen Tree

Spatial distribution information of paper mulberry trees was collected from CDA in 2008.

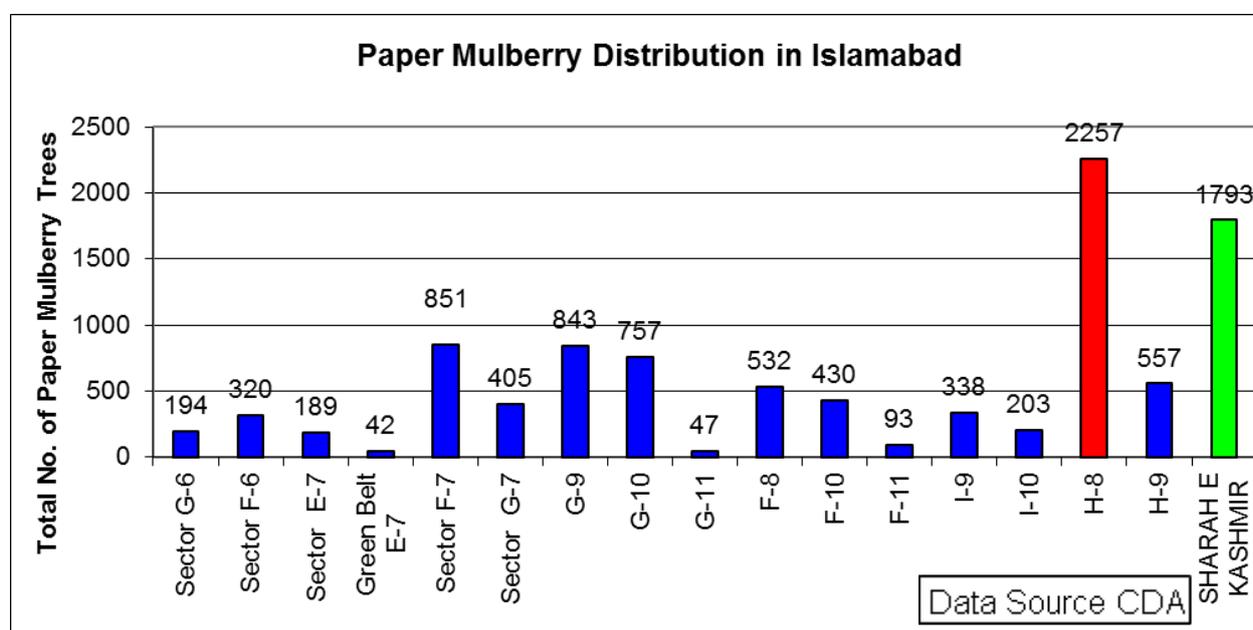


Figure2-1: No of Paper Mulberry trees in different sectors of Islamabad.

The spatial extent of paper mulberry is presented in Figure 2.1; maximum distribution was observed in sector H-8 and along Sharahe Kashmir. Such species can be found along

roads and along forest edges etc (<http://www.invasive.org/browse/subject.cfmsub=5208>, 2006).

2.3 Methodology

The rotor rod sampler technique has been used in this study. These rods are installed at different location as shown in figure 1.3. The samplers are installed at high roof building so that wind is directly in contact with these samplers, because pollen grains are collected from atmosphere through wind. Pollen counts are measured in grains per cubic meter of air sample for last 24 hours. A standard collector rod first coated with silicon grease on its marked surface so that pollen grains stuck with its surface. Sample rods are collected every day and after staining analyzed for pollens under the microscope. This process is repeated daily and pollen count is recorded for last 24 hours. The 24 hours' time period is defined as the standard condition for measuring present pollen grains in the atmosphere according to rotor rod sampler operating instructions (Anonymous, 2002).

Pollen count in the atmosphere reflects number of particles (P) suspended in a particular volume of air (V) by using following equation:

$$\text{Pollen Count} = \frac{P}{V} \quad (1)$$

Under standard operating conditions (24hours) the particular volume of air is considered 3.12 cubic meters (m³). For example on 07th March, 2016, 13304 pollen grains were recovered on a collector rod. Under standard conditions pollen account was 4264 pollen grains per m³ by using equation 1. Daily normal (1981-2010) was calculated from observed data and departure for 2016 was also found by applying following equation:

$$\text{Departure} = \text{Observed (2016)} - \text{Normal} \quad (2)$$

Chapter 3

3. Results and Discussion:

In this section first pollen behavior for 2016 will be discussed and in second part of this section we analyze the cause of this anomalous behavior whether it is due to change in behavior of weather or there may be any other reason.

3.1 Total pollen count analysis:

Above 1500 pollen grains per m³ are believed to be very high concentration. This high concentration generally reported in 2nd week of March every year and concentration of pollen grains attains its peak value normally after 10 days. But in 2016 the very high pollen was record on 04th March, 2016 and within a week highest pollen concentration was observed by PMD. Paper Mulberry Flower blossom season is spring when day time temperature lie between 20-25 °C. For blossom, plant needs a small amount of water during its buds stage and high temperature.

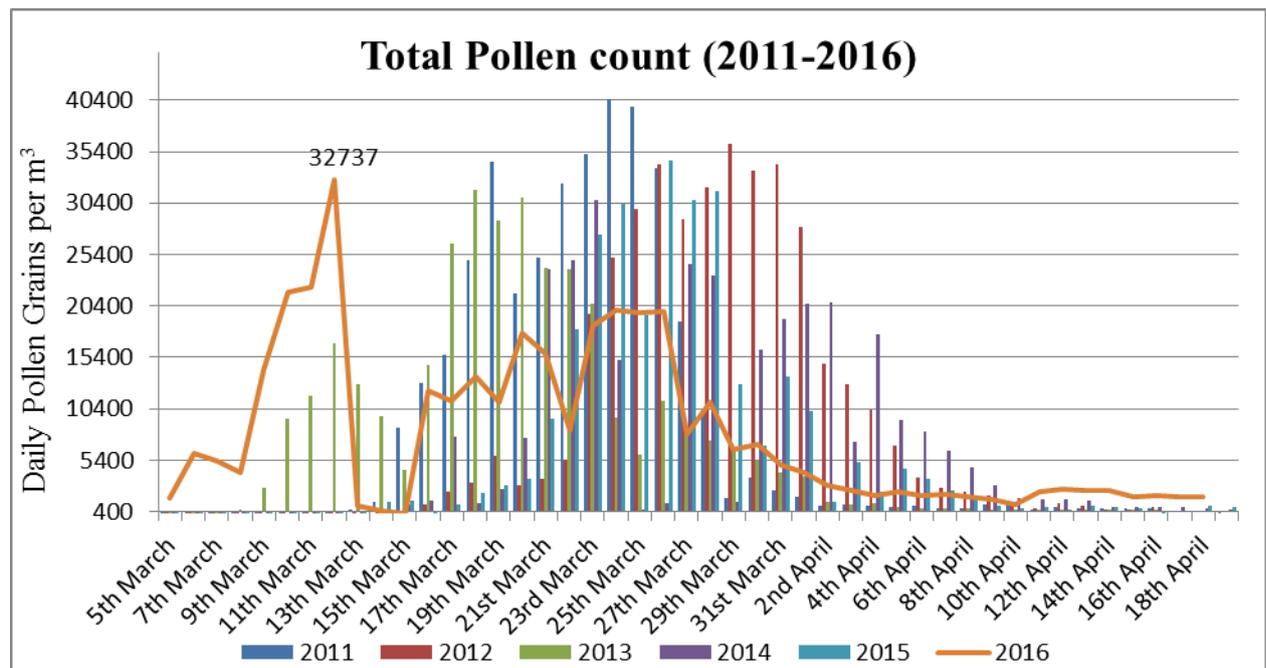


Figure 3-1 Total pollen count for six years (2011-2016)

In 2016 there was a light rain in last decade of February. This type of weather pattern provided suitable conditions for flower grooming. As a result pollen season start early as compared to all other pollen season. Not only pollen concentration gains its maximum peak soon but also dissipates within two days. At 11th March highest concentration was recorded but soon after two days it was lower than threshold concentration of 1500 per cubic meter,

then pollen intensity rose up again and almost 2000 pollen grains per m³ persisted for consecutive two weeks. Figure 3.1 demonstrates that effective concentration of pollen grains in the atmosphere come to end after 10th April every year. But in 2016 this period prolong up to 18th April.

3.2 Number of Total Pollen Days:

Pollen season duration from 2003 to 2016 is shown in Figure 3.2. Pollen season is count only for those days for which TPC is more than 1500 per m³. This figure illustrates that after 2009 pollen season duration has become shorter but in 2016 the longest duration in terms of number of pollen days is recorded. Average duration of spring pollen season is 29 days. However this year pollen concentration of more than 1500 persisted for 45 days which is 43 percent more than average period of pollen season. The overall behavior of the data sets for 2003 to 2016 represents a decreasing trend in total pollen days in Islamabad.

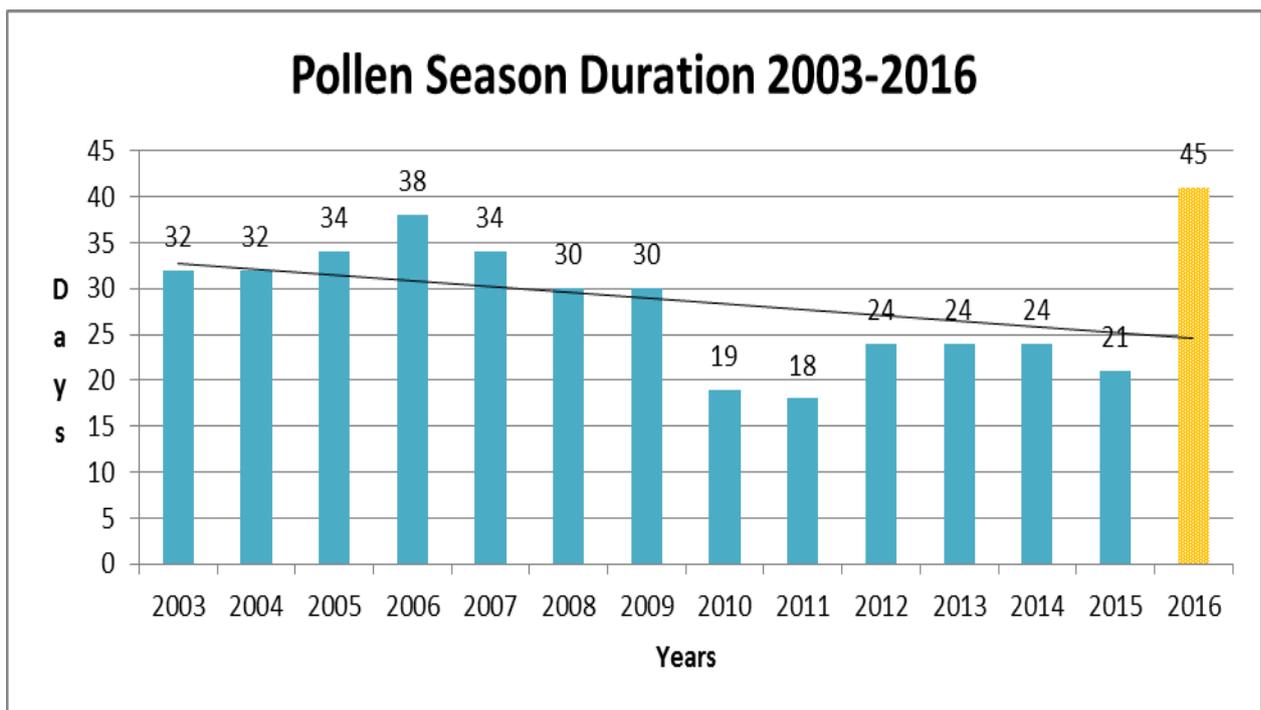


Figure 3-2 Total severe pollen days during spring season (2003-2016)

It is speculated that this drastic change may be due to incensement in vegetation cover area in Islamabad, but in opinion of Amina et al (2012) the vegetation cover area during thirty years (1992-2012) has been reduced from 69% to 43% hectare of total land cover area of Islamabad. Thus the main cause of this change is only due to changing behavior of spring weather system.

3.3 Pollen cycle and its Relationship with Weather Parameters:

Although pollen productivity is an intrinsic characteristic of a pollen tree but the maturing process of grains as well as opening of the anthers, is strongly related to the climatic condition of that area (Basani et al. 1994, Frenguelli et al. 1994, Tormo et al. 1996). Previous many studies have pointed out that precipitation and air temperature are two main parameters that have greatest influence on the fall of pollen and duration of pollen grains to remain in the air (Frenguli et al. 1991, Caramiello et al. 1994, Dahi & Strandhede 1996).

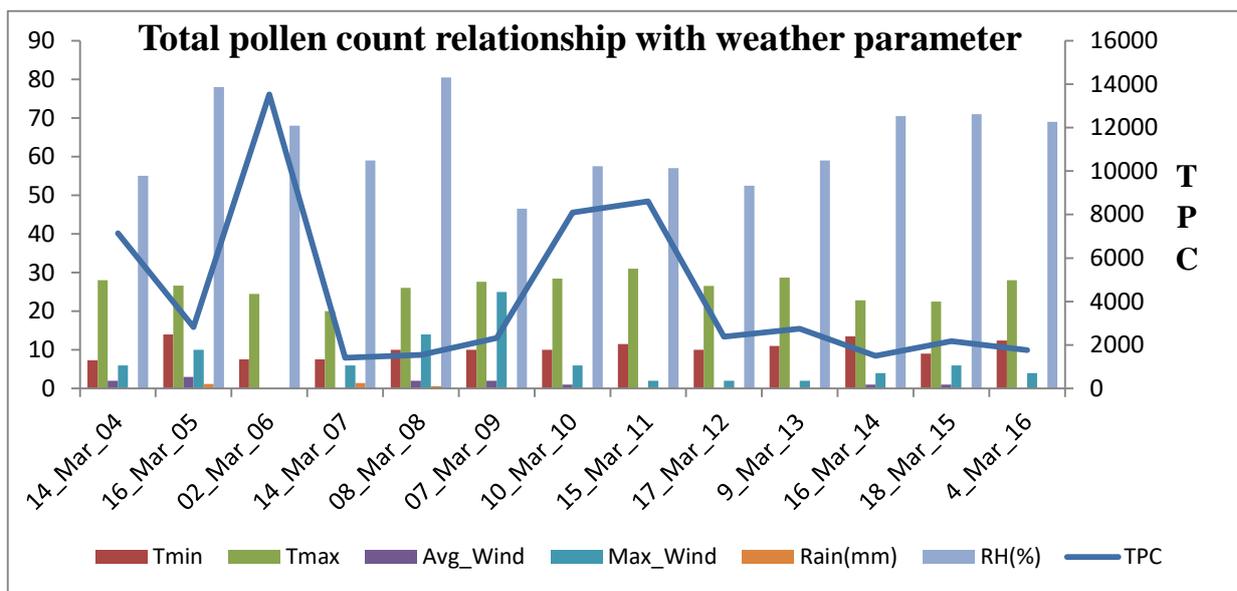


Figure 3-3 Accumulated pollen and weather parameter during onset of pollen season

An analysis of the correlation between pollen productivity and weather parameters reveals that pollen period start under such climate conditions in which minimum temperature is below $10^{\circ}\text{C} \pm 1^{\circ}\text{C}$, Maximum temperature should be greater than 20°C . These temperatures (Maximum and minimum) fulfill the heat unit requirement for pollen grains inside the anther. Figure 3.3 shows that other weather parameter like wind, relative humidity and rainfall are not so important to predict pollen onset in spring.

In general pollen concentration gradually increases in spring season although peak is reached during first fortnight of March. The maximum concentration of pollen has been experienced in dry climatic conditions. Its concentration touches the extreme limits under following conditions as shown in Figure 3.4. For extreme limits maximum temperature range was recorded between $20\text{-}30^{\circ}\text{C}$, RH lies between $50\text{-}70\%$ and there must be no rain for more than a week. However wind is not so affected to gain extreme limit although its average speed is $2\text{-}5$ knots and maximum wind speed recorded $12\text{-}20$ knots respectively.

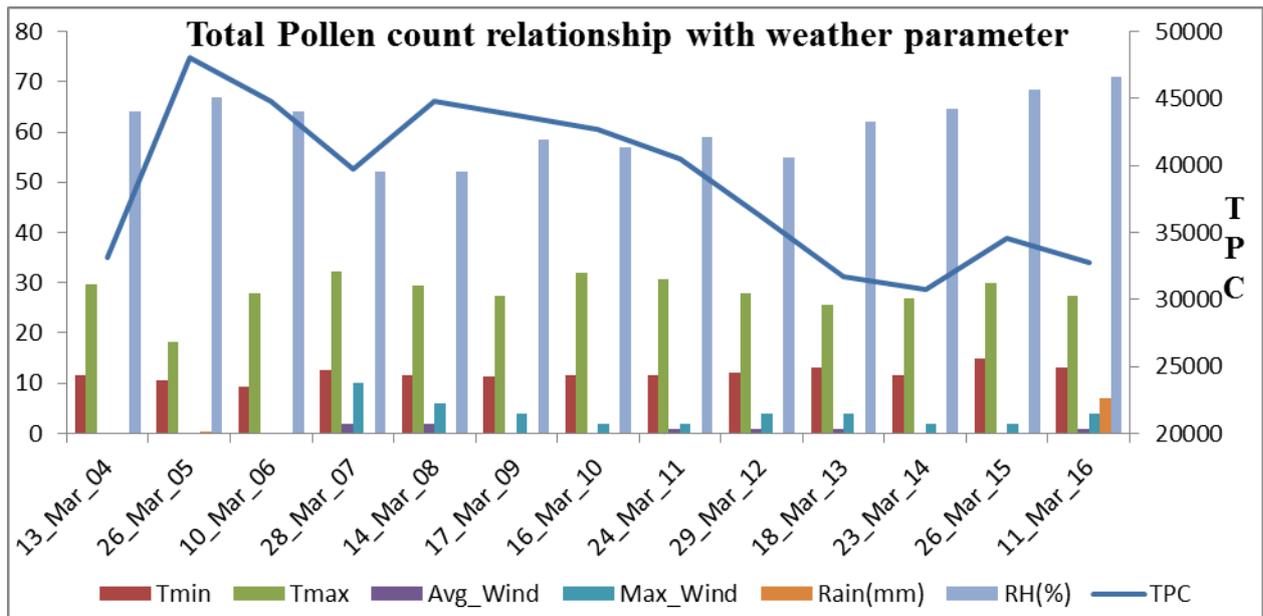


Figure 3-4 Accumulated pollen and weather parameter during **peak** of pollen season

Weather is highly influence allergy symptoms. Allergy sufferers often find relief on rainy, cloudy or windless days because pollen movement is limited during these days. It is observed that dormancy period of pollen start after first week of April.

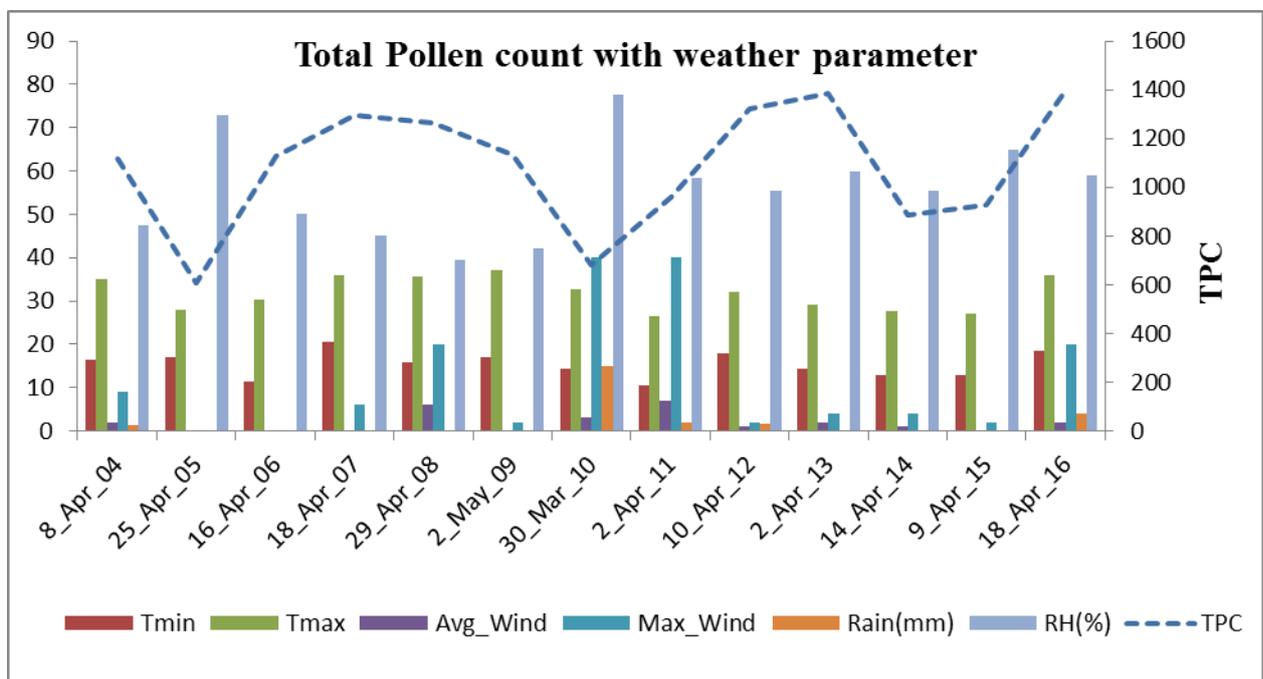


Figure 3-5 Accumulated pollen and weather parameter during **offset** of pollen season

When there is a heavy rain and after rain strong wind blow for two to three days then dormancy period start. It is observed if there is a rain with strong wind for two to three days the pollen period comes to an end under such conditions. TPC and its relationship with weather parameters is shown in Figure 3.5.

Chapter 4

4 Anomalous behavior of pollen 2016 and heavy rainfall:

4.1 Pollen season 2016:

This year pattern was totally different in 2016 as compared to all previous seasons. Not only onset start early but also pollen grains suspended in the air for long time. This year pollen period extended for 41 days that is the longest period since pollen monitoring. The graph (Figure 3.6) depicts maximum pollen value attains within a week. Although this time maximum pollen record was not so high and graph sharply shift towards lower value. There is a sharp decrease after peak and then pollen grains strengthen again and persist in the air for near one month. Maximum concentration was registered 32737 cubic meters (m^3). The major causes for this anomalous behavior are change in weather pattern during spring season. The high rate of precipitation during spring, 2016 indicates that this long period associated with rainfall and humidity. There are different episodes of rainfall in March due to this rainfall pattern pollen grains did not release soon. From figure 3.7 it is cleared that during February the daily maximum temperatures were above than normal. This change was significant with 95% confidence level. Rainfall recorded above than normal during current pollen season. But this change in rainfall was not significant with 95% confidence level.

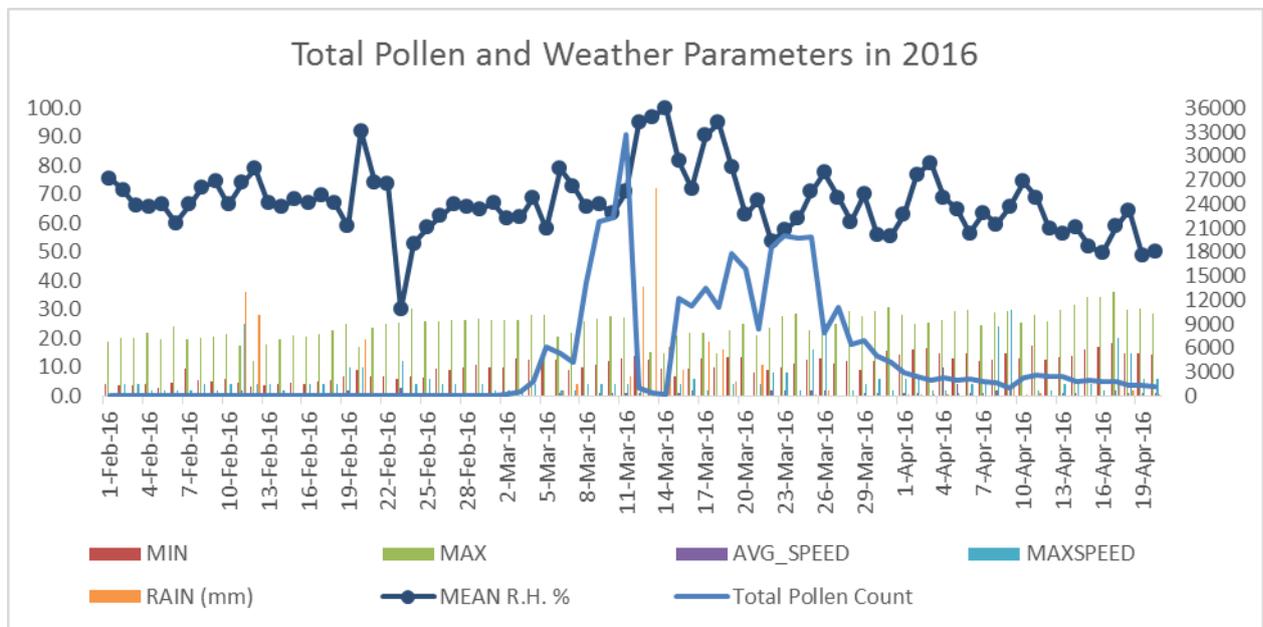


Figure 4-1 Accumulated pollen and weather parameter during pollen season 2016

4.2 Peak Pollen Days:

A peak value comparison is presented in Figure 3.7. The average peak is above than 40,000 (m³) during the season. TPC of spring 2016 is the 2nd lowest pollen count value since 2003.

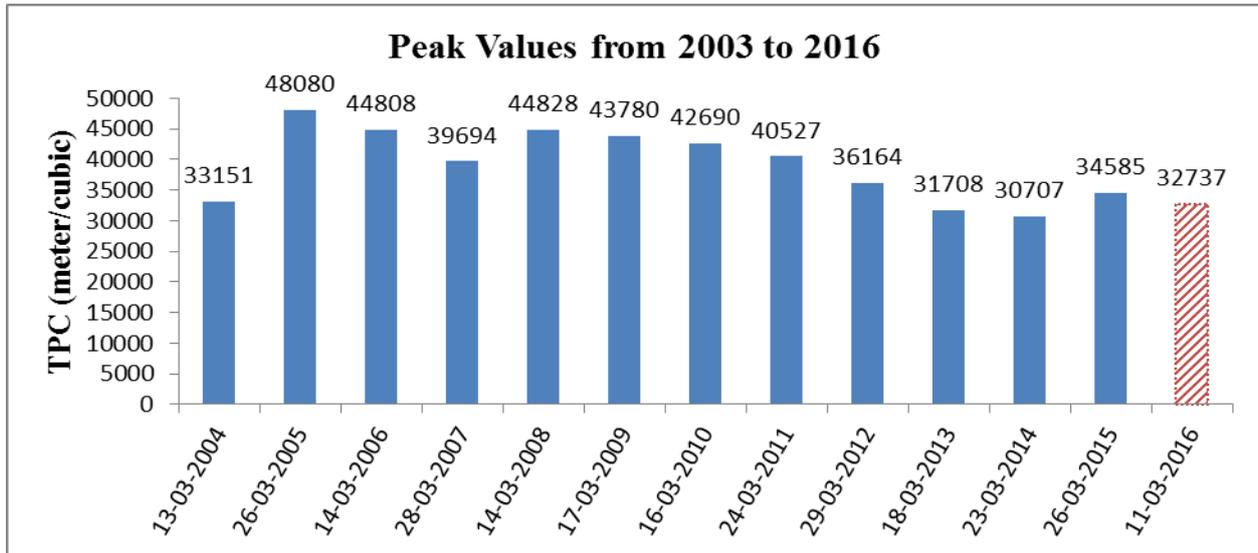


Figure: 4-2 Peak value record from 2003-2016

. It mean extreme value attain for a short period. In case of long period of peak days TPC record cross 40,000 like during 2006,207 etc. It is concluded that heavy rainfall after peak caused a three days break in pollen concentration. After that there are some more episodes of rainfall, these rainfall prolonged the period.

4.3 Temperature and Precipitation Anomalies

A strong El Niño that evolved in 2015 continued to impact global weather and temperatures at the beginning of 2016. The average global temperature across land surfaces was 2.31°C (4.16°F) above the 20th century average of 3.2°C (37.8°F), the highest February temperature on record, surpassing the previous records set in 1998 and 2015 by 0.63°C (1.13°F) and surpassing the all-time single-month record set in March 2008 by 0.43°C (0.77°F) (NOAA,2016). Most of the earth land surface was warmer than average or much warmer than average in major chunk of Southeast Asia. of the temperature Strong west and southwest winds contributed to an average February maximum temperature in Islamabad that was 3.0 °C above the 1981-2010 average maximum temperature.

The map below represents precipitation departure of March 2016 and temperature departure for February, 2016 with respect to 1981-2010 based data. Precipitation anomalies during March 2016 varied significantly around the world.

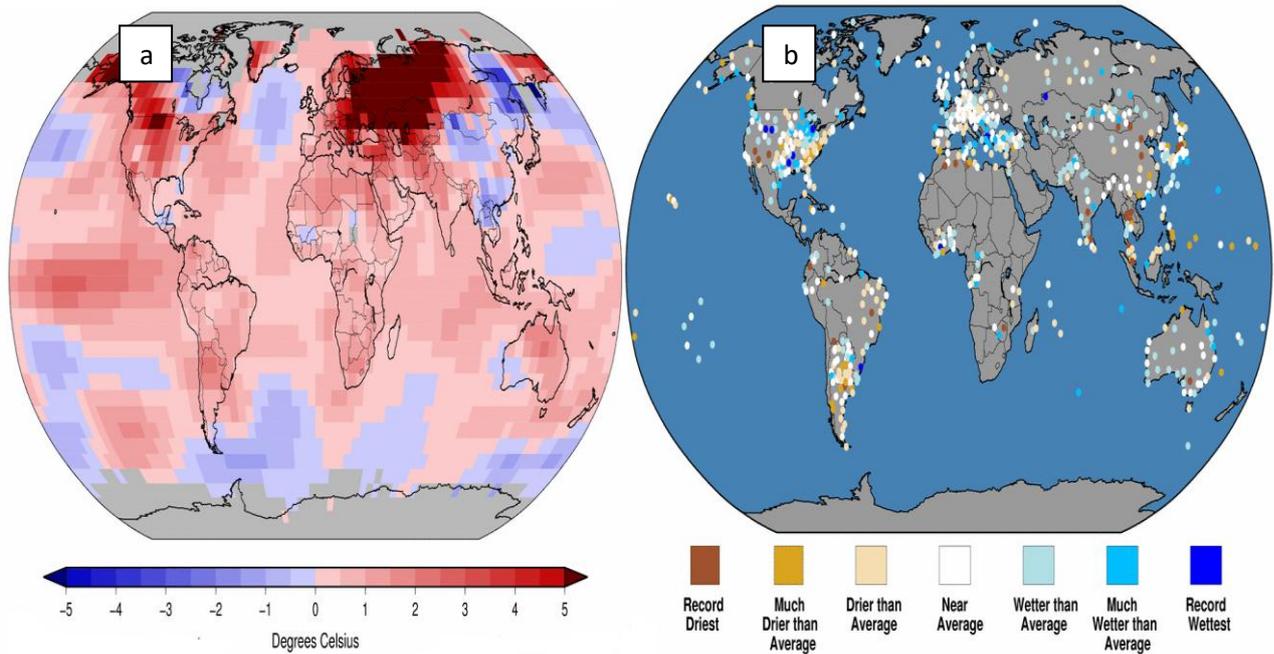


Figure 4-3 (a) Temperature Departure Feb, 2016 (b) Rainfall Departure, Mar, 2016 from Normal (1980-2010)

March precipitation was notably wet than normal across various parts of south Asia. Most tropical and continental air masses in February and March not only brought warm temperatures but also significant rainfall to some parts of central and northern areas of the country, Pakistan. Rainfall was more than 150 percent of the monthly normal in Islamabad. Islamabad experienced it's much wetter than normal.

Table 4.2 Temperature Anomalies of Northern Hemisphere for Feb, 2016 from Normal (1981-2010)

	Anomalies		Rank out of 137 Years			Records	
	°C	°F				°C	°F
<u>Land</u>	$+2.66 \pm 0.12$	$+4.79 \pm 0.22$	Warmest	1 st	2016	2.66	4.79
			Coollest	137 th	1893	-2	-3.6
<u>Ocean</u>	$+0.87 \pm 0.14$	$+1.57 \pm 0.25$	Warmest	1 st	2016	0.87	1.57
			Coollest	137 th	1911	-0.48	-0.86
<u>Land and Ocean</u>	$+1.55 \pm 0.13$	$+2.79 \pm 0.23$	Warmest	1 st	2016	1.55	2.79
			Coollest	137 th	1893	-1	-1.8

Strong El-Nino phase not only impact on global temperature but also it shades its effect at regional level. In federal capital the February temperature in 2016 was above than normal (1981-2010). For the whole month temperature was 40 percent above than normal. This year temperature breaks the previous records of February temperature. A t-test table shows that this departure was significant with 95% confidence level. The Hypothesis was set at 0.05 and p- value is 0.002 which is below than 0.05. Rainfall was also above than normal during March and April as shown in Figure3.9. In case of rainfall statistical indices shows that this change was not significant for the whole season. But the rainfall departure from 25th March to 15 April was significant with 95% confidence level.

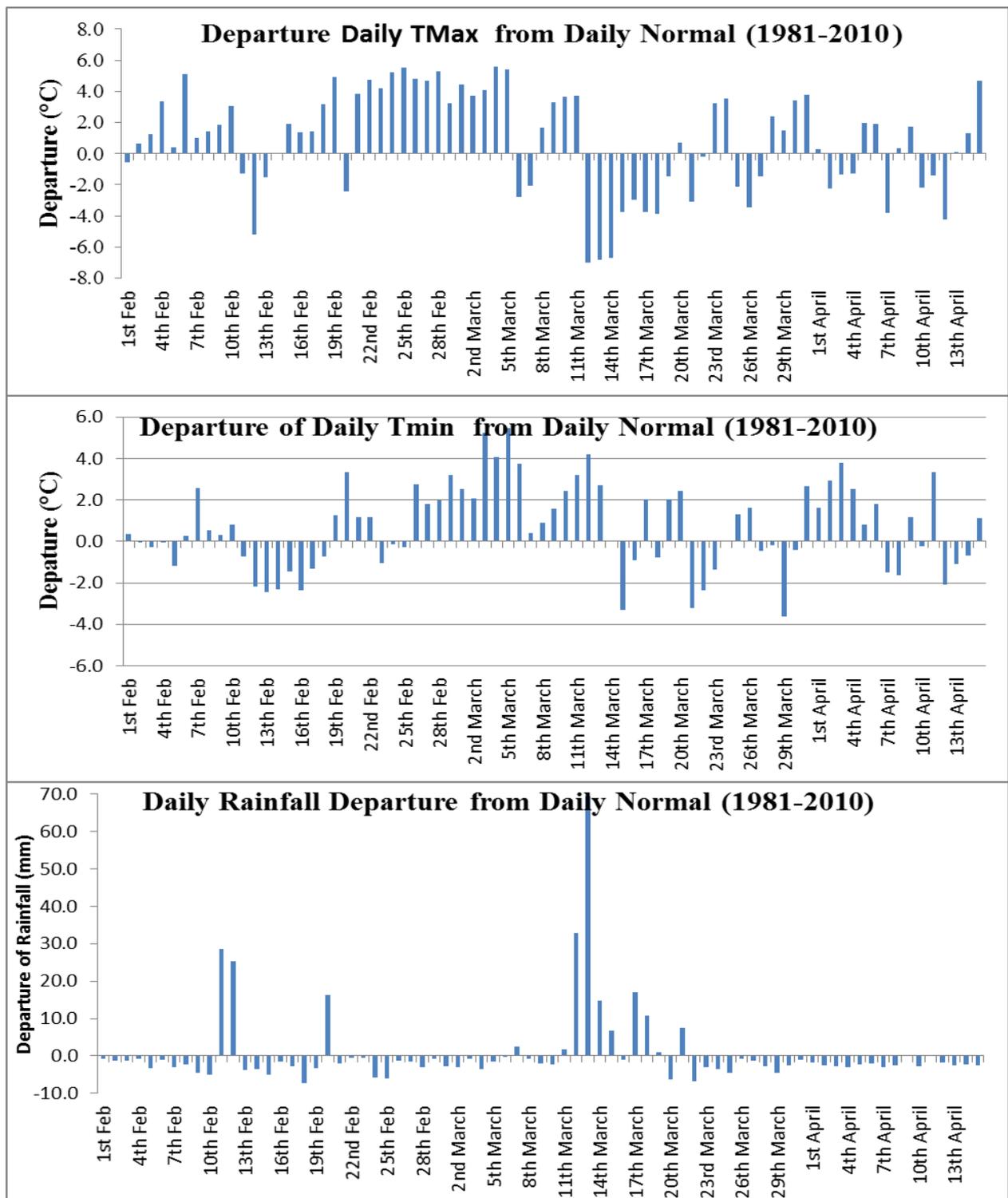


Figure 4-4 : Daily Departure of 2016 (a) Tmax (b) Tmin and (c) Rainfall from normal (1981-2010)

Chapter 5

5 Conclusions and Recommendations:

5.1 Conclusions:

During the pollen season 2016 most of the weather parameters like wind speed, air temperature, rainfall and R.H was normal to above normal. It favored flowers released early from pollen plant as a result onset start before time. The finding of this study revealed that whenever the day temperature rose above than 25°C for a week and during this week or before week there is a light rain of 0.05 to 08 mm per day. It is a sign for onset of pollen in Islamabad. A strong correlation was found between mean temperature and pollen count during peak season. The coefficient of correlation R^2 was above than 70 that is a significant correlation among two variables. In general maximum pollen attains after a week of onset under dry condition. Maximum pollen released when there is a continuous increase in day temperature and no rain for more than a week. In 2016 these conditions also fulfill although the day temperature are much higher than normal, so maximum pollen was record with in a week. In case of offset season wind speed played a major role. Whenever there is above than 20knts wind speed the maximum grains released from anther. In 2016 maximum wind speed was observed on 09th April and 17 April respectively. Until 09th April pollen count was round about 2000m³ but on 09th April due to strong wind the pollen count was 1056 m³. Then it strengthens again on 10th April due to humid atmosphere. This year maximum pollen hovers above than 5000 was persist only for a week but after that uniform concentration about 2000 persist for a long time. The pollen buds release when these pollen buds become fully dry, but due to continue rainfall episode in March buds did not dry soon and enhance pollen duration up to 45 days.

5.2 Recommendations:

The future scope of this study is to expand the relationship between El-Nino and pollen counts in Islamabad. The approach used in this study can be applied for one week lead time forecast by using numerical weather prediction forecast data. The same analysis should be done for some other pollen years. Rainfall impacts after peak season should be analyzed in another study.

Reference:

Anonymous 2002. Rotor rod sampler operating instructions. Multidata LLC 4838 ParkGlen Road, St. Louis park, MN.

Butt,A., R.Shabir,S.S.Ahmad and N.Aziz. 2015: Land use change mapping and analysis using Remote Sensing and GIS: A case study of Simly watershed, Islamabad, Pakistan, The Egyptian Journal of Remote Sensing and Space Sciences , (15) 18, 251–259.

Caramiello, R., Siniscalco, C., Mercalli, L. & Potenza, A. 1994: The relationship between airborne pollen grains and unusual weather conditions in Turin (Italy) in 1989, 1990 and 1991. *Grana* 33: 327 ± 332.

Dahl, A. & Strandhede, S. 1996: Predicting the intensity of the birchpollen season. *Aerobiologia* 12: 97 ± 106.

Frenguelli, G., Spieksma, F.Th.M., Bricchi, E., Romano, B.,Mincigrucci, G., Nikkels, A.H., Dankkaart, W. and F. Ferranti, 1991: The influence of air temperature on the starting dates of the pollen season of *Alnus* and *Populus*. *Grana* 30: 196 ± 200.

Ghersa, C. M., E. de la Fuente, S. Suarez, and R.J.C.Leon. 2002. Woody species in the Rolling Pampagrasslands, Argentina. *Agriculture, Ecosystems and Environment*. 88:271-278.

Haroon, M. A and G.Rasul, 2008: Effect of meteorological parameters on pollen concentration in the atmosphere of Islamabad, Pakistan *Journal of Meteorology*,4(8),27-36.

<http://www.invasive.org/browse/subject.cfm?sub=5208,2006>

http://www.pmd.gov.pk/rnd/rndweb/rnd_new/R%20&%20D.php

<https://www.ncdc.noaa.gov/sotc/global/201602>

International Conservation Union Website. 2004. List of Invasive Species in Pakistan. (<http://www.edu.iucnp.org/alist.htm>)

Jato,V,A.Dopazo and M.J.Aira.2002: Influence of precipitation on airborne pollen concentration in Santiago de Compostela (Spain), *Grana* 41: 232± 241.

Bennett,J, M. Qazilbash and Ali A. Qazilbash 1997: A Survey of Pollen Allergies in Six Villages of Islamabad, *Sustainable Development Policy Institute* 25: 1± 19

Bassani, M., Pacini, E. and G.G. Franchi, 1994. Humidity stress responses in pollen of anemophilous and entomophilous species. *Grana* 33: 146 ± 150.

Frenguelli, G., Spieksma, F.Th.M., Ferranti, F., Fornaciari, M.,Nikkels, H. and B. Romano, 1994. Preliminary data about the growth of birch catkins in relation to pollen

development. ± In:5th Int. Conf. Aerobiol. Bangalore 1994. Abstracts (ed. S.N. Agashe et al.), p. 1, No. AB10. ± Org. Comm., Bangalore.

Tormo, R., Muñoz, A., Silva, I. and F. Gallardo, 1996. Pollen production in anemophilous trees. ± Grana 35: 38 ± 46.



Published by:

PAKISTAN METEOROLOGICAL DEPARTMENT

Pitrus Bukhari Road, Sector H-8/2,

Islamabad-Pakistan

URL: <http://www.pmd.gov.pk> E-mail: pmd@pmd.gov.pk

Ph: +92 51 9250367 Fax: +92 51 9250368