Rainfall Patterns over Punjab, Khyber Pakhtunkhwah and Kashmir during El Nino and La Nina Years 1960-2008

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Abstract

This paper investigates the six months (April- September) rainfall patterns over Punjab, Khyber Pakhtunkhwah and Kashmir during El Nino and La Nina years from 1960-2008. The major amount of water is attained in Pakistan all through the six month period selected for the study. The month wise and seasonal analysis from April to September has been carried out over the study area to find the probability of above and below normal rainfall during El Nino and La Nina years statistically in the 49 years of study. The month wise analysis showed that April and May have 53 % probability of above normal average rainfall and 47 % probability of below normal average rainfall during El Nino years. The El Nino years has shown the probability of above normal average rainfall around 26.6 % and the below normal average rainfall probability around 73 % has been observed in June, July and September over the study region. The El Nino years in August showed above normal rainfall with 33.3 % probability and below normal average rainfall with probability 66.6 %. The La Nina years with above normal rainfall showed 38.5 % probability in April May, September and 54 % probability in the months of June, July and August. The probability of La Nina years with below normal average rainfall is 61.1 % in April, May, 46 % in June, July, August and 61.5 % in the month of September. The cumulative seasonal analysis (April-September) has shown that the inadequate amount of rainfall during El Nino years and excess amount of rainfall during La Nina years has been experienced over the study domain from 1960-2008. In nutshell the monsoon success and failure can be linked with the El Nino and La Nina years in Pakistan.

Key words: El Nino, La Nina, monsoon, probability and rainfall

Introduction

The term El Niño refers to the large-scale ocean-atmosphere climate phenomenon linked to a periodic warming in sea-surface temperatures across the central and east-central equatorial Pacific (between approximately the date line and 120° W). El Niño represents the warm phase of the El Niño/Southern Oscillation (ENSO) cycle, and is sometimes referred to as a Pacific warm episode. El Niño originally referred to an annual warming of sea-surface temperatures along the west coast of tropical South America. The El Nino Southern Oscillation (ENSO) episodes affect weather, climate, marine and terrestrial ecosystems worldwide. The climatologists have tried to figure out the coupling of the Indian Monsoon with the Southern Oscillation in order to predict the monsoon rainfall over South Asia. The historical background of Monsoon and ENSO coupling has been reviewed by (Webster and Yang, 1992). The behavior of the Indian Ocean to El Nino Southern Oscillation (ENSO) varies from season to season. El Nino years have shown the increase in frequency of monsoon depressions over Bay of Bengal during July and August. (Singh et al., 2000). At present, El Nino and La Nina have no clear cut impact on Pakistan precipitation. However in many cases, summer monsoon and winter precipitation are suppressed by El Nino and La Nina conditions respectively (Rasul, 2012).

El Niño has been known to be one of the most important forcings of the Indian summer monsoon variability and studied by various authors (Sikka, 1980; Pant and Parthasarathy, 1981; Rasmusson and Carpenter, 1983; and Webster et al. 1998) around the world. The impact of ENSO over rainfall varies from region to region (Bhalme and Jadhav, 1984). It is well known fact that the Indian summer monsoon is adversely affected by ENSO and Indian subcontinent seems to receive below normal rainfall during ENSO years (Shukla and Paolino, 1983; Thapliyal, 1990). The monsoon rainfall is the major source of

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water in South East Asian regions. The success and failure of monsoon adversely affect the livelihoods of many people who depend upon it for agricultural activities. The monsoon is a thermally driven circulation system; it should intensify during global warming and produce more rains over India. On the contrary the decline in monsoon rainfall over India, particularly over Indo-Gangetic plains and central India has been experienced during ENSO years.

La Nina is the reverse of El Nino event and is triggered due to alteration of Sea Surface Temperature (SST) in Pacific Ocean. The La Nina cycle is a complex interaction between random atmospheric phenomenon and oceanic processes. In the La Nina event the trade winds push warm water toward west and cause it to accumulate in the western Pacific. The walker circulation controls the atmospheric conditions. Indonesia and adjoining region experience heavy rainfalls due to low-level convergence, large scale rising motion and convective activities. The subtropical high-pressure system weakens as north-south Hadley circulation weakens which implies a weak vorticity transport from the tropics to the subtropics. The variability of dynamically interlined climate system among different regions of the world has been reported by (Meehl, 1994). Ranade et al., 2010 stated that the La Niña phenomenon provides vital information for extreme rainfall activities across Indian sub continent. While the rainfall conditions during El Nino years are considerably adverse over almost the entire hydro-ecosystems in different countries compared to that during La Nina years.

Pakistan is also vulnerable to the variability of summer monsoon. It is an agrarian country and 80 % of the population depends on the proper monsoon Rainfall is quite essential for the better production of crop yields. The suppressed monsoon rainfall during El Nino years and surplus monsoon rainfall during La Nina years both affects the crop yield badly. The impact of El Nino over monsoon rainfall of Pakistan has been studied by very few authors (Mahmood et al., 2004 and Rashid, 2004). Therefore more detailed study is required. The main aim of this study is to investigate the relationship between El Nino, La Nina and summer monsoon rainfall of Pakistan on a monthly and seasonal scale from April to September 1960-2008. The output of the result will reveal the fact about the impact of El Nino and La Nina years over monsoon precipitation in Pakistan.

Data and Methodology

The monthly rainfall data has been acquired from Pakistan Meteorological Department for the period of forty nine years (1960-2008). The 15 El Nino years and 13 La Nina years have been considered during the study period 1960-2008 from the website (http://www.cpc.ncep.noaa.gov/products/analysis _monitoring/ensostuff/ensoyears.shtml).The Punjab, Khyber Pakhtunkhwah and Kashmir have been

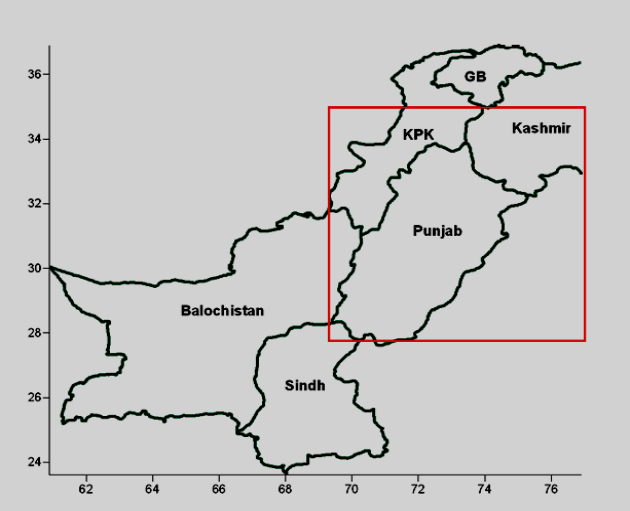

Figure 1: Map of study domain in Pakistan

selected as a study site illustrated in Figure 1. The study domain is comprised of twenty stations well representing Punjab, Khyber Pakhtunkhwah and Kashmir. The month wise analysis has been done over the time scale of six months i.e. April to September in the study. The months selected for the study also cover the Pre monsoon (April-June) and monsoon (July-September) period well. The average rainfall from each province (Punjab, Khyber Pakhtunkhwah and Kashmir) is accumulated to compare with the El Nino and La Nina episodes from 1960-2008. The cumulative analysis has also been done from April to September over the study domain to get the better picture of seasonal average rainfall scenario during El Nino and La Nina years. The Climate Normals from 1960-1990 have been used to define the normal averaged monthly rainfall from April to September. The probability of average rainfall during El Nino and La Nina years has also been calculated in each month from April to September. Surfer has been used to map the study domain and analysis has been carried out in Microsoft MS Excel.

Results and Discussion

The month wise analysis reveals that in April the rainfall over Punjab, Khyber Pakhtunkhwah and Kashmir showed a lot of variations. The study domain usually has average normal rainfall of about 55.56 mm for the month of April over the entire 49 years (1960-2008) displayed in Figure 2. It is a general perception that the El Nino events are usually associated with the drought conditions accompanied by the suppressed rainfall in Pakistan and La Nina prevail with flooding situation due to heavy rainfall associated with it (Rashid, 2004). The results showed that the trends of rainfall during El Nino years are dynamic, sometime the average rainfall goes above normal and sometimes the average rainfall goes below normal conditions in the study domain (Punjab, Khyber Pakhtunkhwah and Kashmir). Figure 2 shows that in April out of fifteen El Nino episodes during the study period (1960-2008) the above normal average rainfall has been experienced during eight El Nino years (1966, 1970, 1983, 1988, 1992, 1995, 1998 and 2004). However, the below normal average rainfall has been observed during the remaining seven El Nino years (1969, 1973, 1986,1987,1991,1994 and 2003). This reflects that there is a probability of about 53 % of above normal average rainfall and 47 % probability of below normal rainfall over Punjab, Khyber Pakhtunkhwah and Kashmir during the month of April from 1960-2008.

Similarly La Nina yeas also showed variation in average rainfall during April. Out of thirteen La Nina years the above normal rainfall has been experienced over the Punjab, Khyber Pakhtunkhwah and Kashmir in five years (1964, 1967, 1984, 1985, and 1996) while below normal rainfall in the remaining eight years (1971, 1972, 1974,1975,1976,1979, 1989 and 2007). Therefore there is 38.5 % probability of above average rainfall and 61.5 % probability of below normal average rainfall over the study domain during the month of April.

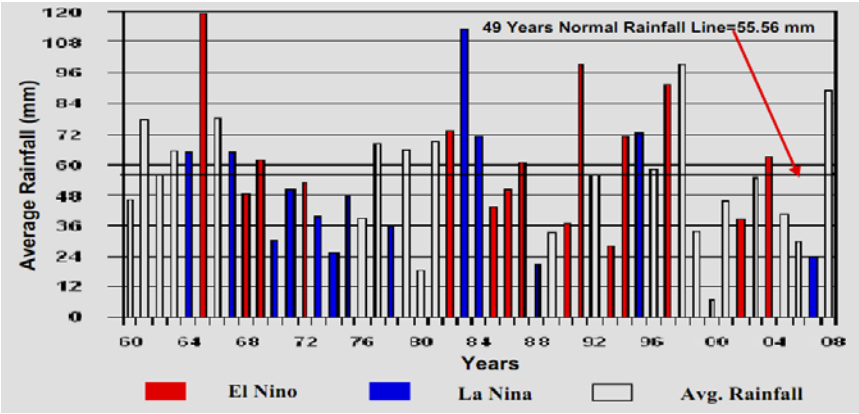

Figure 2: Average Rainfall with El Nino (Red) and La Nina (Blue) episodes in April over Punjab, Khyber Pakhtunkhwah and Kashmir from 1960-2008

Summer sets in Pakistan with the month of May when day time temperatures cross 40°C. Most of the heat waves conditions have usually experienced during May. May and June are the driest and hottest months in Pakistan. Monsoon sets in July and brings lots of cloudiness and moisture in the lower atmosphere due to which temperatures stay lower than May and June levels (Zahid and Rasul, 2012). The average normal rainfall of May over Punjab, Khyber Pakhtunkhwah and Kashmir during the study period (1960-2008) is 38.42 mm. The results of the analysis for the month of May are quite similar to the month of April. Figure 3 shows that the above normal average rainfall occur during years 1966, 1970, 1983, 1988, 1992, 1995, 1998 and 2004 and below normal average rainfall in 1969, 1973, 1986, 1987, 1991, 1994 and 2003 all these years had shown El Nino events. The probability of surplus downpours is 53 % and that of meager amount of rainfall is 47 % in the study area from 1960-2008. La Nina years 1964, 1967, 1984, 1985, and 1996 depicted heavy rainfall events with probability 38.5 % and scanty rainfall as compared to normal rainfall of the regions with probability 61.5 % has been examined in the years 1971, 1972, 1974, 1975, 1976, 1979, 1989, 2007

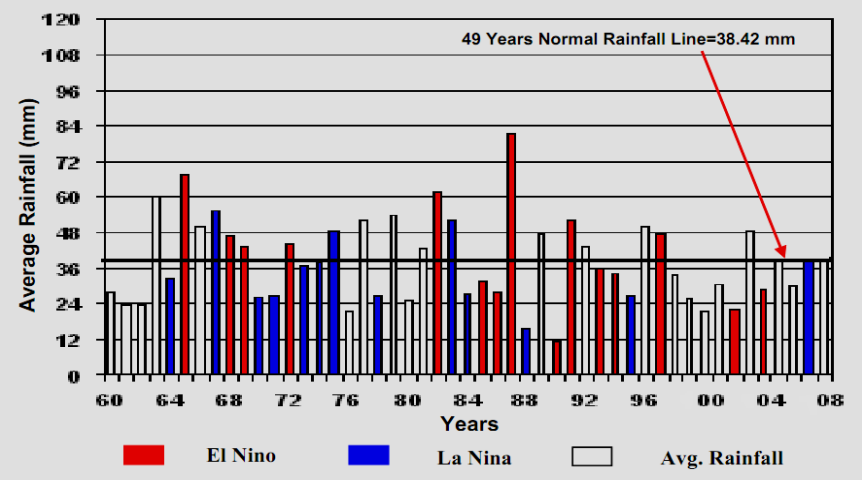

Figure 3: Average Rainfall with El Nino (Red) and La Nina (Blue) episodes in May over Punjab, Khyber Pakhtunkhwah and Kashmir from 1960-2008

The June is a Pre-Monsoon period and the average normal rainfall over Punjab, Khyber Pakhtunkhwah and Kashmir from 1960-2008 is 87.81 mm. The analysis shows that the number of El Nino years for above normal and below normal average rainfall has changed as compared to previous months. The El Nino years showing above normal average rainfall years has decreased and the El Nino years with below

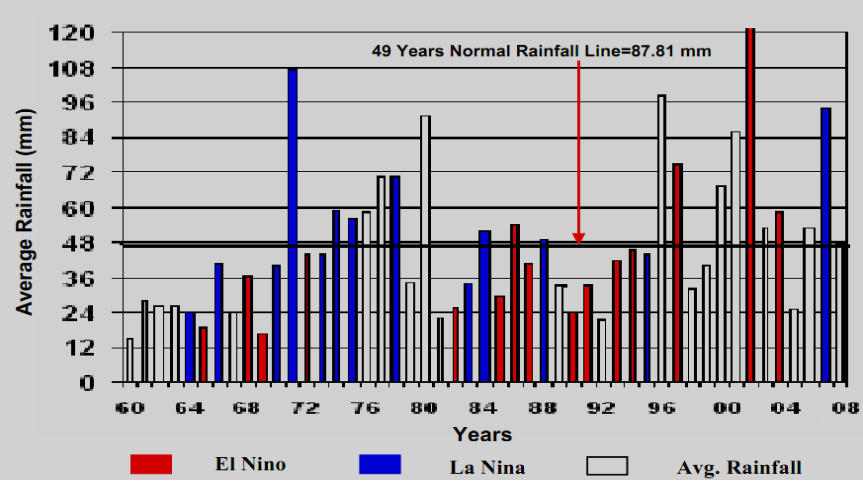

Figure 4: Average Rainfall with El Nino (Red) and La Nina (Blue) episodes in June over Punjab, Khyber Pakhtunkhwah and Kashmir from 1960-2008

normal average rainfall has increased. Figure 4 illustrates that the above normal average rainfall has been investigated in four El Nino years (1986, 1997, 2002 and 2004) and below normal average rainfall has been experienced in eleven El Nino years (1965, 1968, 1969, 1972, 1982, 1985, 1987, 1990, 1991, 1993 and 1994) over the study domain from 1960-2008. Therefore probability of above normal average rainfall is 26.6 %and below normal average rainfall is 73 % in El Nino years during June over the time span of 49 years. The La Nina years have also shown variability in above and below normal rainfall events. During June the seven La Nina years (1971, 1974, 1975, 1978, 1984 1988 and 2007) have shown above normal average rainfall. While the remaining six years showed below normal average rainfall (1965, 1967, 1971, 1974, 1984 and 1996) during the study period. The probability of above normal average rainfall in June during La Nina is 54 % and probability of below normal average rainfall during La Nina is 46 % over the study domain from 1960-2008.

Monsoon sets in Pakistan in July and it is the major source of water in Pakistan (Rasul and Chaudhry, 2010). The success and failure of monsoon badly affects the lives of people in Pakistan. The heavy monsoon rains results in flooding and suppress monsoon rains creates drought in this region. The average normal rainfall for the study domain during July is 153.86 mm. The probability of average rainfall is almost same as the month of June like for above normal rainfall in 4 El Nino years (1986, 1997, 2002 and 2004) the probability is 26.6 %. However the probability of below normal average rainfall during 11 El Nino years (1965, 1968, 1969, 1972, 1982, 1985, 1987, 1990, 1991, 1993 and 1994) is 73 %. The probability of above normal average rainfall in 7 La Nina years (1971, 1974, 1975, 1978, 1984 1988 and 2007) during July is 54 % and the probability of below normal average rainfall in 6 La Nina years (1965, 1967, 1971, 1974, 1984 and 1996) during July is 46 % as shown in Figure 5.

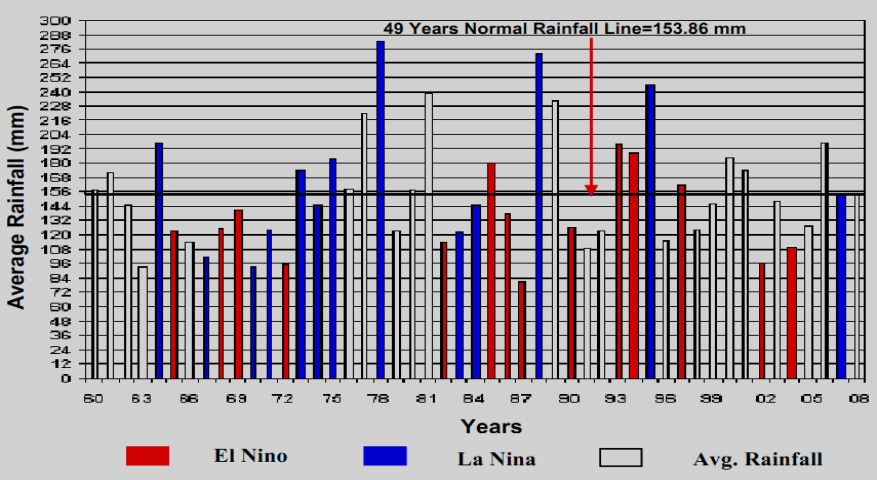

Figure 5: Average Rainfall with El Nino (Red) and La Nina (Blue) episodes in July over Punjab, Khyber Pakhtunkhwah and Kashmir from 1960-2008

The average normal rainfall for the month of August over Punjab, Khyber Pakhtunkhwah and Kashmir is 140 mm. The distribution of above and below normal average rainfall again changes during El Nino and La Nina years from 1960-2008 during August. Figure 6 clearly shows that in five El Nino years (1982, 1986, 1990, 1994 and 1997) above normal average rainfall has been observed over Punjab, Khyber Pakhtunkhwah and Kashmir regions. The probability of above normal rainfall events occurrence has been calculated around 33.3 % and below normal average rainfall probability 66.6 % during August in El Nino years. On contrary the below normal average rainfall has been analyzed in the rest of the ten El Nino years (1965, 1968,1969, 1972, 1985, 1987, 1991, 1994, 2002, 2004) in August during the 49 years of the study. The probability of above normal average rainfall of La Nina (1971, 1974, 1975, 1978, 1984 1988 and 2007) in August is 54 % and the probability of below normal average rainfall during six La Nina years(1965, 1967, 1971, 1974, 1984 and 1996) is 46 % over the study domain from 1960-2008.

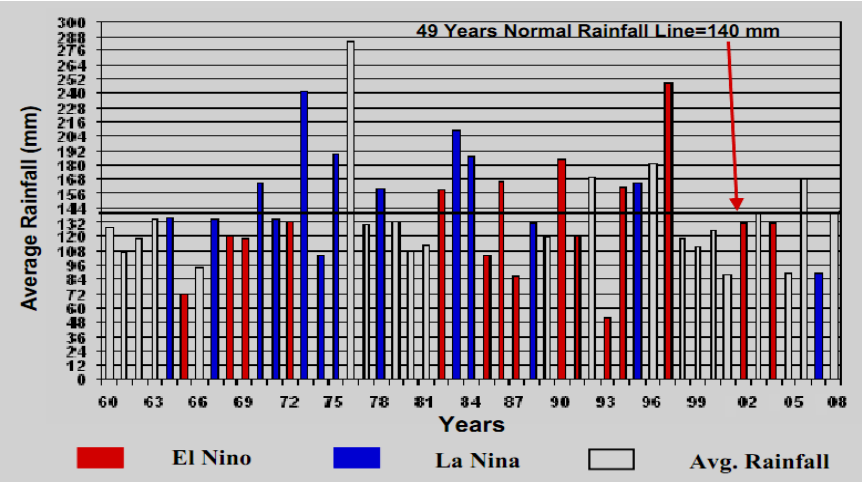

Figure 6: Average Rainfall with El Nino (Red) and La Nina (Blue) episodes in August over Punjab, Khyber Pakhtunkhwah and Kashmir from 1960-2008

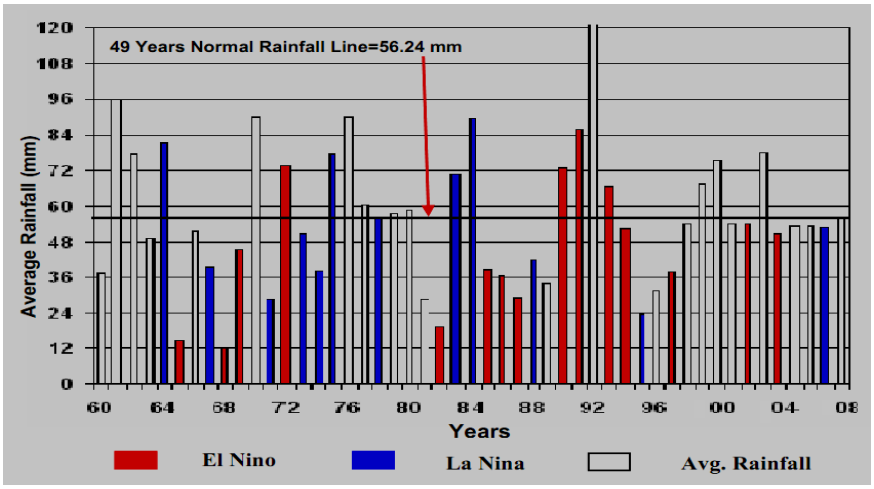

Figure 7: Average Rainfall with El Nino (Red) and La Nina (Blue) episodes in September over Punjab, Khyber Pakhtunkhwah and Kashmir from 1960-2008

Figure 7 showed that the average normal rainfall over Punjab, Khyber Pakhtunkhwah and Kashmir in the 49 years for the month of September is 56.24 mm. The results depicted above normal average rainfall during four El Nino years (1972, 1990, 1991, and 1993) over the study domain from 1960-2008. The below normal average rainfall has been experienced in these regions during the eleven El Nino years (1965, 1968, 1969, 1982, 1985, 1986, 1987, 1994, 1997, 2002 and 2004). The probability of above normal average rainfall is 26.6 % during El Nino years from 1960-2008. Whereas the probability for the below normal average rainfall is 73 %. Five La Nina years (1965, 1976, 1978, 1984 and1985) showed the above normal average rainfall in the study domain with 38.5 % probability of occurrence of these events in September from 1960-2008. The rest eight La Nina years (1967, 1971, 1973, 1974, 1988, 1995 and 2007) has shown below normal average rainfall with 61.5 % probability of these events during September over the study period.

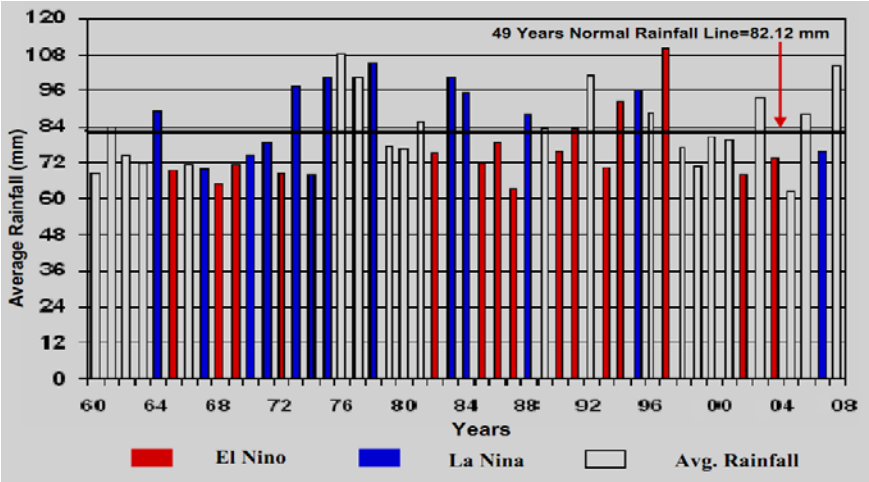

Figure 8: Average Rainfall with El Nino (Red) and La Nina (Blue) episodes April- September over Punjab, Khyber Pakhtunkhwah and Kashmir from 1960-2008

The cumulative analysis from April to September over Punjab, Khyber Pakhtunkhwah and Kashmir has also been done to check the seasonal behavior of average rainfall during El Nino and La Nina years in the 49 years (1960-2008) of study period. Figure 8 depicts that the average seasonal normal rainfall for the Punjab, Khyber Pakhtunkhwah and Kashmir is 82.12 mm. The results showed above normal average rainfall in three El Nino years (1991, 1994 and 1997) and below normal average rainfall in the remaining twelve years (1965, 1968, 1969, 1972, 1982, 1985, 1986, 1987, 1990, 1993, 2002 and 2004) from 1960-2008. The seasonal analysis predicted probability of above normal rainfall 20 % and that of below normal average rainfall 80 % during El Nino years during the study period over Punjab, Khyber Pakhtunkhwah and Kashmir. The analysis has shown above normal average rainfall in five La Nina years (1964, 1973, 1975, 1978, 1983, 1984, 1988, and 1995) with 61.5 % probability of occurrence from 1960-2008. The below normal average rainfall occurred in the rest of five La Nina years (1967, 1970, 1971, 1974, and 2007) considered in the study with 38.5 % probability of over the time scale of 49 years.

Conclusion

The month wise analysis of April and May showed that the probability of occurrence of above normal average rainfall is 53 % and probability of below normal average rainfall is 47 % during El Nino years over Punjab, Khyber Pakhtunkhwah and Kashmir during the from 1960-2008. The La Nina years have shown above normal rainfall with 38.5 % probability and below normal average rainfall with 61.1 % probability over the study domain during April and May. The above normal average rainfall during El Nino years has probability 26.6 % and below normal average rainfall has probability 73 % during June and July over the time span of 49 years. Similarly the 54 % probability of La Nina years with above normal average rainfall 46 % probability of below normal average rainfall has been analyzed in June and July. The August showed the above normal average rainfall during El Niño years with 33.3 % probability and below normal average rainfall during El Nino years with probability 66.6 %. The La Nina years have shown probability of 54 % for above normal average rainfall and 46 % probability for below normal average rainfall in August. The September showed the 26.6 % probability of above normal rainfall and 73 % probability of below normal rainfall during El Nino events. 38.5 % probability for above normal rainfall and 61.5 % probability for below normal rainfall have been calculated in September. The cumulative seasonal (April to September) analysis showed the suppressed rainfall during El Nino and surplus amount of rainfall in La Nina years. Therefore it is concluded that drought conditions can be associated with the El Nino years and floods with La Nina years during monsoon in Pakistan.

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