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Full Length Research Paper

Occurrence pattern of meteorological droughts and associated problems in Cholistan region of Pakistan: A spatio-temporal view

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ABSTRACT

Cholistan is a region highly vulnerable to meteorological and hydrological droughts, primarily because of the occurrence of extremely low and variable intra and inter-annual precipitation and high rate of evaporation. As a result plant, animal and human life is often disturbed badly. Thus, proper investigation of drought occurrence patterns and associated problems is a basic need for the effective future development planning of the region. The study in hand aims to appraise the spatio-temporal occurrence of meteorological droughts and associated problems in Cholistan region of Pakistan. To assess drought severity, the Standardized Precipitation Index (SPI) has been computed using meteorological data of 33 years (from 1981 to 2013) for ten sample areas having unique geographic setup. Time series data of precipitation was obtained from the Pakistan Meteorological Department. Observations about water availability and vegetation conditions etc. were recorded during field visits also. It was found that during major part of the year, the region remains extremely arid and meteorological droughts occur frequently. Repeated threats of droughts make the floral, faunal and human life extremely hard in Cholistan. As a result, ecosystem of the area along with human and animal life is badly affected. Nomadic life is seriously disturbed and nomads are forced to migrate towards relatively safe places to save their animal wealth. If water is made available, impacts of meteorological droughts can be lessened and this desert region of high plant and animal production potential can be converted in to a fertile and productive area. The findings of the study may provide help in preparing an effective strategic plan for overcoming the vulnerability of disaster prone areas and to reduce the damages caused by meteorological droughts.

Keywords: Aridity, Cholistan region, climatic conditions, meteorological droughts, occurrence pattern, spatio-temporal view

INTRODUCTION

Droughts are common natural phenomena that occur periodically all over the globe. They are impermanent natural abnormalities that may happen in any type of climatic regions ranging from low to high rainfall areas. They are also known as deceptive hazard of nature that initiate from an insufficiency of precipitation for a prolonged span of time, usually for a season or periodic rotation. Numerous definitions of drought for different regions, hitherto, have been devised and mentioned by researchers (Slette, et al., 2019; Mishra and Singh, 2010; Tate and

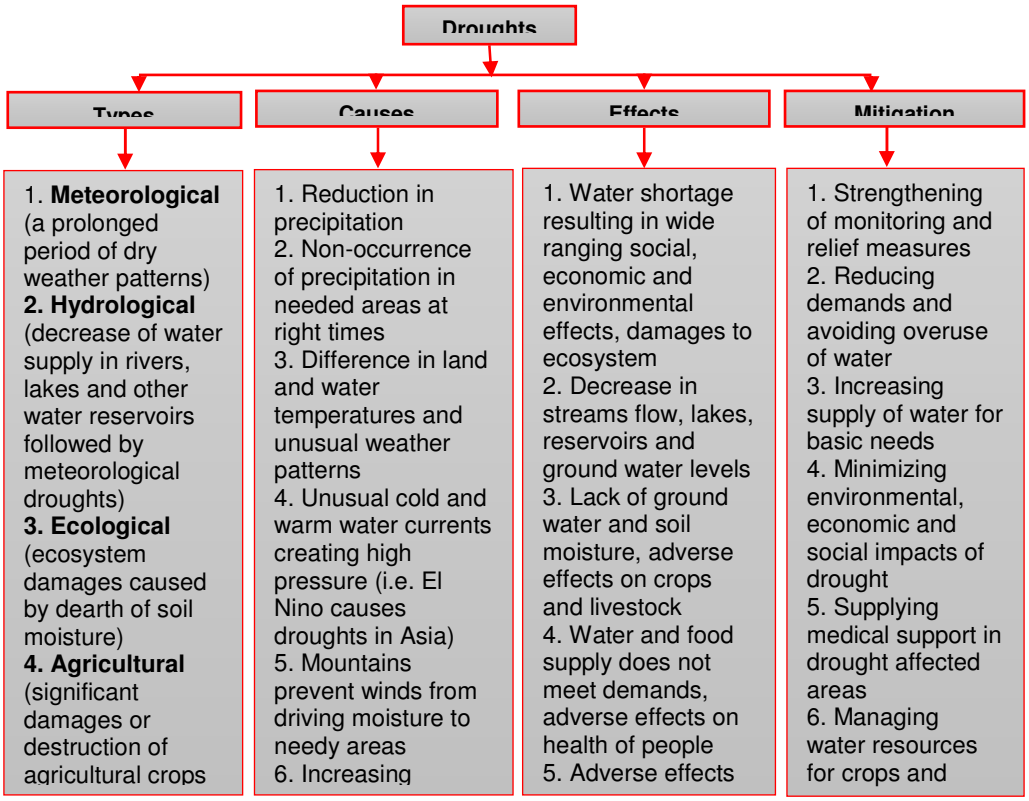

Figure 1. Types, causes, effects and mitigation measures against droughts

Gustard, 2000; Panagoulia and Dimou 1998). In some regions drought definitions are based on the number of days that receive rainfall lower than a specified limit and in some other regions droughts are characterized by seasonal precipitation rate where extended time period and moisture availability are common concerns. The study of droughts based on days without precipitation is, however, unrealistic (Palmer, 1965). An extended period of abnormally little rainfall leading to serious dearth of water for plants, animals and humans is usually referred to as drought. In several ways, droughts differ from other natural hazards. For instance, they are slow onset natural hazard and commonly called as creeping phenomena (Sivakumar et al., 2010). Drought indeed is a complicated hydro-meteorological phenomenon instigated by meteorological aberrations of plummeting precipitation but can also be a human-affected incident. However, it is mainly influenced by the condition of different elements of hydrologic cycle. Precipitation shortfalls result in reduction of surface runoff, soil moisture, streams flow and ground water flow which can upset the entire ecosystem of the affected region. Plants and animals need water to survive. When an area receives lower than its usual amount of precipitation and drier period continues over months or even years, water supply problems develop and dry period turns into a drought (Moreland, 1993). Thus, meteorological droughts are associated with the magnitude and duration of precipitation shortfall event. In Pakistan, history shows that severe moisture deficit with a large areal extent particularly during a climatically wet season leads to the metrological droughts.

A drought is perceived as a serious disaster when it adversely affects social wellbeing and economic interests of the people and threatens the life. Some other disasters like aridity and desertification also threaten plant, animal and human life almost in similar manner as the droughts do. A general consensus, however, exists to differentiate between the concepts of desertification, aridity and drought (Rossi and Benedini et al., 1992). A lot of studies, hitherto, have been conducted on various aspects of droughts in different parts of the world (e. g. Hamdy and Trisorio-Liuzzi, 2008; Mendez and Magana, 2010; Ahmed et al., 2016; Lorenzo-Lacruz and Moran-Tejeda, 2016; Sharma and Mujumdar, 2017; Gumus and Murat Algin, 2017; Ahmed and Shahid et al., 2018; Amin and Khan et al., 2019; Jamro et al., 2019; Naz and Dars et al., 2020 etc.). Studies on the occurrence pattern and impacts of droughts in Pakistan, specifically in Cholistan, however, are highly sporadic. Only a handful macro-level studies conducted on the arid areas of Pakistan cover just few aspects of droughts including drought status monitoring, seasonal drought severity, spatio-temporal variability in drought,

drought trends and seasonal characteristics of droughts (e. g. Ahmed et al., 2016; Siddiqui and Safi, 2017; Adnan et al., 2018; Ahmed and Shahid et al., 2018; Ahmed et al., 2019; Hina and Saleem, 2019: Jamro and Dars et al., 2019; Naz and Dars et al., 2020 etc.). The present research is a part of efforts being made for bridging the gap in knowledge about arid parts of south eastern Punjab. It takes into account the occurrence pattern of meteorological droughts and associated problems in Cholistan region of Pakistan.

Climatologists define several categories of droughts all taking origin predominantly from meteorological droughts (Figure 1). This means, meteorological droughts are common type caused by substantial reduction of rainfall. Although, several interrelated factors are considered to be responsible for the origin of droughts, they all are primarily caused by the shortfalls of precipitation associated with the dominance of unusual weather patterns. When drought persists for a longer period or happens again after short time, the hydrological, ecological, social and economic systems of the area are badly affected. In such conditions, various mitigation measures, including efficient water supply, are required to be taken on emergency basis to save the plant, animal and human life (Figure 1). Adverse effects of droughts are common in arid and semi-arid regions as they are characterized with high variability of mean annual rainfall from season to season and from year to year. Besides, the drought period is longer in drier lands compared to lands of wetter climates, where rainfall dearth is likely to prevail for a few months only (Chapman, 1999). Metrological droughts result from the changes in climatic conditions. Their determinants are based on the degree of dryness and aridity in comparison to some natural or average amounts and the duration and extension of the dry period (Chapman, 1999). In the perspective of climate change, water shortage and food security, it is vital to improve drought monitoring and early warning methods (Sivakumar et al., 2010), so that losses can be minimized.

Owing to the large latitudinal extent (23.5° N to 37° N) and marked variations in physiography, Pakistan experiences a great seasonal and annual variability in rainfall. The south-central and south-eastern parts of the country, where the study area (Cholistan) is located, climatically are arid and hyper-arid. Meteorological droughts frequently hit this region giving birth to other kinds of droughts. When drought conditions appear, water resources of the region vanish quickly, soil moisture reduces to extreme lower limits and the whole ecosystem is distressed sternly. Cholistan that was once a prosperous center of Hakra civilization when the Hakra River (also known as Ghaggar or Ghagra on Indian side) flowed through it in about 4000 BC (Ahmad, 2011) is now threatened by meteorological droughts quite often. The drying up of the river that formed the Ghaggar-Hakra palaeochannel is thought to be a major cause in the decline and abandonment of settlements in the region (Singh, Thomsen and Sinha et al. 2017). On drying up of the river, perhaps due to climatic change, this region has turned into a desolate sandy desert. Covering an area of about 2.6 million hectares, it extends from 69º 52′ to 73º 05′ East longitudes, and 27º 42′ to 29º 45′ North latitudes (Akhter and Arshad, 2006). It is bounded by Sutlej River in the north-west, Sukkur district in the south and linked with the international boundary between India and Pakistan in the south-east (Akbar and Khan et al., 1996; Kahlown, 2009). Geomorphology of the region shows an intricate pattern of alluvial and Aeolian deposits. Nearly 480 km long and 32 to 192 km wide desert is divided into two distinct geomorphic regions on the basis of landforms, and type of parent material, soil and vegetation. Its northern part known as Lesser Cholistan comprising nearly 7,770 sq. km establishes the desert margins. It consists of a chain of saline alluvial flats alternating with low sandy ridges. Being the fertile portion of division, it is irrigated from rivers, flood canals, tube wells, wells and rains (Auj and Auj, 1991). The southern part with an area of 18,130 km and abundance of big sand dunes is called Greater Cholistan. Spreading over three districts of southern Punjab, almost 50% of the entire desert is located in Bahawalpur, 40% in Rahim Yar Khan and 10% in Bahawalnagar district. Because of arid or hyper arid climate, high temperature, low precipitation, less relative humidity, high rate of evapo-transpiration and prevalence of dry gale winds, it is highly vulnerable to meteorological droughts (Adnan, Ullah and Shouting 2015). The main causes of its dry climate are little and sporadic rainfall, squat relative humidity, extreme temperature and high rate of evaporation. The mean summer temperature ranges from 34ºC to 38ºC. May and June are the hottest months when temperature shoots up to 51.6ºC. Mean maximum winter temperature ranges between 14ºC to 16ºC. December and January are the coldest months when occasionally temperature may fall less than 0ºC (Figure 2). In the summer strong winds blow across the desert creating sand storms with a consequent acceleration of wind erosion in most of the sandy terrain (Ahmad and Athar et al., 2004). Hydrology of the desert is poor. Ground water is found at a depth ranging from 30 to 90 meters. Most of the subsoil water, however, is typically brackish and unhealthy for drinking due to the factors like little rainfall, high consumption of water, low infiltration and high evaporation rate (Ahmad and Athar et al., 2004). Because of high concentration of salts this water is unsuitable for animals and for most of the plants growth also. Rain water is collected seasonally in a system of natural pools known as *Tobas* (water ponds) or in man-made relatively smaller structures locally known as *Kunds* (Akram and Kahlown et al., 2008). The mean relative humidity in the region varies from 50% to 60%. July, August and September are the wettest months. Winter rains in Pakistan are brought by western disturbances which are mainly received by western side of the country and south eastern side

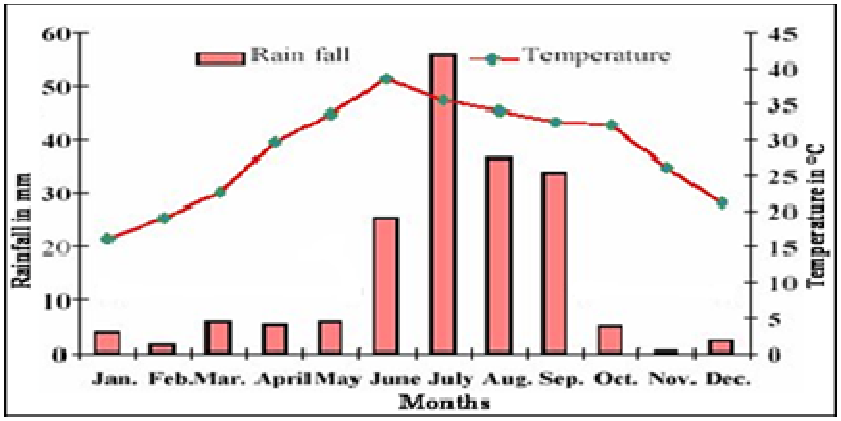

Figure 2. Average monthly rainfall and temperature conditions in Cholistan

including Cholistan remains dry (Soharwardi and Ali et al., 2012). This situation is found quite often and aridity becomes worst during April and May when temperature rises to high degree. Summer rains are caused by the monsoon winds that originate over Arabian Sea and Bay of Bengal and hardly get in to Cholistan from the south. Moving towards northern and north western direction, these winds reach to the country's mountainous north without any hurdle and produce most of the rainfall there on eastern and southern slopes. Many times, Cholistan receives no monsoon rains and remains critically dry throughout the year. Annual rainfall in the region ranges between 10mm to 100mm whereas annual loss of moisture through evapo-transpiration reaches to 200mm. The ratio of precipitation to evapo-transpiration varies from 1% to 10%. The mean annual rainfall thus fails to meet 75% to 90% of mean annual evaporation (Soharwardi and Ali et al., 2012). The prevalence of such type of geographic conditions has made the Cholistan a drought prone region. It is thus imperative to prepare research based mitigation planes to save the plant and animal resources of the region to meet the increasing future food and other demands of expanding population.

METHODOLOGY

Several methods and indices are available to analyze the drought occurrence and severity (Heim, 2000). Some of the commonly practiced indices in various parts of the world are Palmer Drought Severity Index (PDSI) developed by Palmer (1965), Rainfall Anomaly Index (RAI) by van Rooy (1965), Deciles Index (DI) by Gibbs and Maher (1967), Standardised Precipitation Index (SPI) devised by McKee et al. (1993 and 1995), Percent of Normal Index (PNI) by Willeke et al. (1994), China-Z Index (CZI) developed by the national climate center of China (1995) and mentioned by Ju and Yang et al (1997), Effective Drought Index (EDI) by Byun and Wilhite (1999), Z-Score Index (ZSI) etc. However, SPI was chosen for the current study due to its advantages of the simplicity of computation using just rainfall data for a long period of time, standardisation which ensures that the frequency of extreme events at any location on any time scale is consistent and variable time scale which is helpful for the analysis of drought dynamics and severity. This index is based on the conversion of long term rainfall data to probabilities, which are then transformed to standardised series with an average of 0 and a standard deviation of 1. SPI also allows analysing drought impacts at different temporal scales. It serves as a multipurpose tool for drought monitoring and analysis and can better depict and analyze the precipitation data while performing temporal assessment of metrological droughts (Table 1). The assessment of spatio-temporal occurrence and intensity of metrological droughts in Cholistan has been thus made by SPI calculation using temporal climatic data for the period from 1981 to 2013.

The SPI is based on the probability of precipitation for any time scale (McKee, Doesken, and Kleist, 1993) and requires long-term precipitation data of 30 to 50 years. First, it calculates the probability of precipitation for any time scale and then probability of observed precipitation is transformed into index (McKee, et al., 1993). The positive index values indicate higher than the median precipitation and negative values tell less than the median precipitation. The SPI can be calculated for different time scales like 3, 6, 12, 24 and 48 months. These time scales tell the impact of drought on the availability of different water resources. SPI also provides early warning and severity of drought (Hayes, et al., 1999). McKee et al (1993) used the drought classification given in Table 1 to show the drought intensities of an area. A drought starts in the area when its SPI value reaches at -1.0 or less and ends when SPI value becomes positive. Ten different sample sites arid and hyper arid in nature were selected from the entire region to study the pattern of metrological droughts by the time of their occurrence and severity in the given time period

Table 1. Classification of drought intensities according to SPI values

Index values	Drought intensities/conditions
2.0+	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

Table 2. Sample areas of Cholistan selected for study

Sr. No.	Area	Longitude	Latitude
01	Fortabbas	29.25º	72.75º
02	Hasilpur	29.50º	72.50º
03	Dingarh	29.00º	71.75º
04	Derawar	28.75º	71.25º
05	Bhagla	28.25º	70.50º
06	Islamgarh	28.00º	70.75º
07	Bijnot	28.00º	71.75º
08	Kandera	28.00º	70.00º
09	Nawankot	28.50º	71.50º
10	Kudwala	28.50º	72.00º

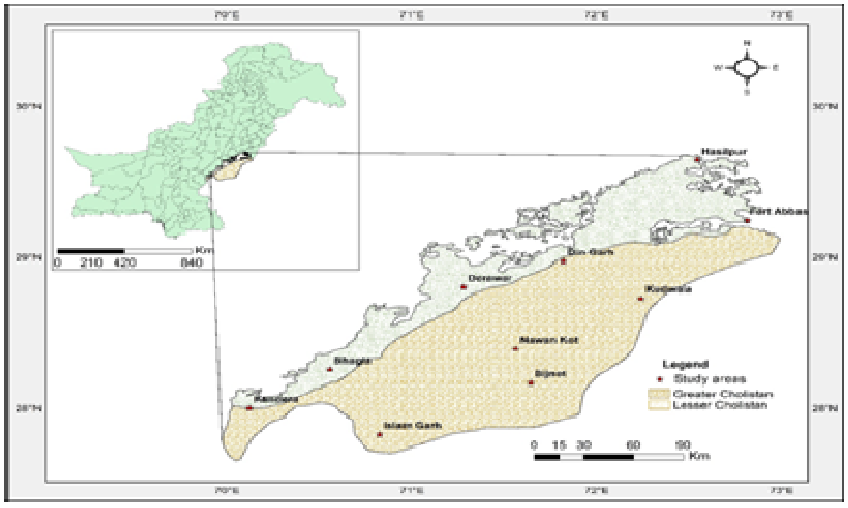

Figure 3. Location of selected study areas in Cholistan

(Table 2 and Figure 3). Rainfall data of 10 sample areas (Table 2) according to their latitudinal and longitudinal positions was acquired from Pakistan Meteorological Department (PMD) and analysis was carried out at a 3-months temporal scale using SPI. In addition, field visits of the sample sites were also arranged and local nomads were interviewed to study the impact of droughts on the water, plant, animal and other resources of the region and on the nomadic lives of the people.

RESULTS AND DISCUSSION

Figure 4 shows the mean annual rainfall in Cholistan from 1981 to 2013. It indicates the highly variable pattern of rainfall occurrence in the region over the period of time selected for the study. It reveals that for a period of 21 years from 1981 to 2001, the region received very small amount of average annual rainfall. The rainfall was extremely low during the years of 1986, 1989, 1990 and

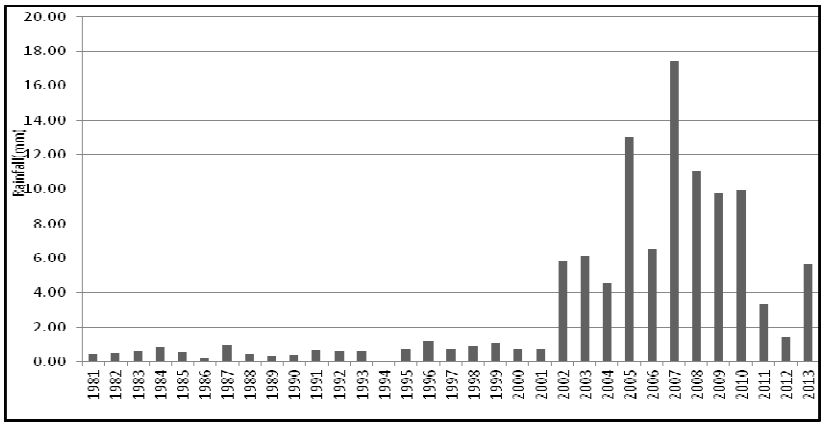

Figure 4. Mean annual rainfall of Cholistan desert from 1981 to 2013

1994. The entire year of 1994 remained almost dry because no rain occurred in the region in this year. Extreme arid conditions remained prevalent throughout the region during this period causing serious water shortage and dearth of forage. During field visits, some elderly local inhabitants told that their livestock was badly affected during this period and several animals were died just because of the shortage of water and forage, and lack of supportive mitigation measures. From the year 2003 onwards, an increasing trend in the amount of rainfall is evident from the Figure 4. However, marked fluctuations are also obvious and a little increase in the amount of rainfall was not sufficient indeed for fulfilling the water needs of the region and for the normal functioning of ecosystem. According to local inhabitants, almost similar trends continued from the year 2013 onwards. However, during the current year of 2020, the region has received some encouraging amount of rainfall that may cause an increase in the amount of forage production. For the estimation of the severity of drought and its influence on flora, fauna and people of the region at micro-level, the rainfall data for different sites of Cholistan has been analyzed by calculating SPI (Table 3 and Figures 5-14).

Table 3 presents a spatio-temporal analysis of the ten study sites made by using SPI. It explains the pattern of meteorological droughts by the time of their occurrence and tells whether the drought is seasonal in occurrence and is there any periodic increase or decrease in its severity with the variations in rainfall pattern. It reveals the severity of droughts in the given time period. The index values calculated for the sample sites from 1981 to 2013 are positive as well as negative (Table 3). Positive values represent the little amount of rainfall in selected sample areas of Cholistan while negative values represent the years without or very low amount of rainfall. Results show that the region remained under serious threat of drought from 1981 to 2002. The severe drought and prolonged scarcity of water badly affected the human, plant and animal life including livestock which is main source of earning in the region. The usable water resources vanished all over the affected areas. The nomadic life was seriously stunted and people were forced to migrate towards safer places for an unknown period of time in search of water and forage. They also faced animal losses and their already poor economic conditions turned out to be worse. However, after 2002 Cholistan received some rainfall occurring mostly in monsoon months which was, though, not adequate to fulfill water needs of the area but provided some respite to the desert life.

The first study site is Fort Abbas which is located on the border between Lesser and Greater Cholistan. Due to the shortage of rains for prolonged periods its climate is dry and arid. Temperature remains high and surpasses 45ºC in summer causing excessive loss of moisture and cracked and exfoliated soil structure. SPI values for Fort Abbas indicate that both severe and moderate droughts prevailed in the area during the near past (Figure 5). A severe dry episode in 1994 led to meteorological drought stunting the plant and animal life seriously. Some wet episodes were also recorded in 2005 and 2007 with a little amount of rainfall that supported the life to some extent. Second place, Hasilpur is sited on the northern boundary of the Cholistan desert. The fringes of this area receive some monsoon rains but in most part of the year, it remains dry and arid. SPI values reveal that 1986, 1989, 1990 and 1994 were the severe meteorological drought years in Hasilpur (Figure 6). According to mean monthly precipitation data this area received very little amount of monsoon rain and because of no accumulation of water in storages such as *tobas* and *kunds*, a number of animals died with thirst. Almost all the pasture lands dried up and became barren that severely affected the livestock production. Whilst, 2005 and 2007 were relatively wet years, as some of the moist monsoon winds entered in the southern Punjab that brought rains in this area. The third site Dingarh is located in the Greater Cholistan. It is associated with arid to hyper arid climate. In most part of the year, it remains dry due to excessive heat, high rate of

Table 3. Standardized precipitation index values for study sites of Cholistan

Years	Fortabbas	Hasilpur	Dingarh	Derawar	Bhagla	Islamgarg	Bijnot	Kandera	Nawankot	Kudwala
1981	-0.63	-0.64	-0.52	-0.5	-0.5	-0.49	-0.54	-0.52	-0.49	-0.52
1982	-0.27	-0.4	-0.36	-0.32	-0.28	-0.33	-0.4	-0.91	-0.32	-0.38
1983	-0.52	-0.54	-0.54	-0.43	-0.4	-0.4	-0.49	-0.46	-0.49	-0.56
1984	-0.07	-0.04	-0.15	-0.25	-0.32	-0.35	-0.27	-0.25	-0.29	-0.26
1985	-0.38	-0.34	-0.24	-0.21	-0.24	-0.29	-0.27	-0.23	-0.23	-0.27
1986	-0.88	-0.84	-0.8	-0.75	-0.74	-0.76	-0.87	-0.7	-0.79	-0.87
1987	-0.37	-0.35	-0.28	-0.22	-0.19	-0.22	-0.2	-0.18	-0.24	-0.31
1988	-0.22	-0.25	-0.24	-0.12	-0.05	-0.13	-0.13	0.01	-0.12	-0.17
1989	-0.86	-0.88	-0.84	-0.74	-0.73	-0.74	-0.86	-0.64	-0.83	-0.93
1990	-0.86	-0.82	-0.85	-0.75	-0.7	-0.69	-0.69	-0.61	-0.72	-0.7
1991	0.15	0.15	0.02	-0.06	0.03	-0.1	-0.15	0.08	-0.1	-0.19
1992	-0.47	-0.48	-0.54	-0.56	-0.57	-0.59	-0.54	-0.53	-0.61	-0.52
1993	-0.44	-0.44	-0.15	-0.15	-0.23	-0.18	-0.17	-0.2	-0.13	-0.16
1994	-1.38	-1.41	-1.38	-1.35	-1.29	-1.24	-1.17	-1.09	-1.26	-1.2
1995	-0.68	-0.7	-0.65	-0.54	-0.47	-0.43	-0.54	-0.36	-0.6	-0.64
1996	0.13	0.18	0.13	0.13	0.13	0.15	-24.47	0.07	0.1	0.18
1997	-0.38	-0.22	-0.16	-0.14	-0.32	-0.25	-0.17	-0.35	-0.07	-0.18
1998	-0.08	-0.13	-0.17	-0.12	-0.07	0.07	0.07	-0.07	-0.02	0.08
1999	-0.22	-0.16	-0.25	-0.25	-0.18	-0.19	-0.31	-0.07	-0.32	-0.23
2000	-0.48	-0.43	-0.41	-0.41	-0.44	-0.4	-0.41	-0.36	-0.47	-0.5
2001	-0.1	0.06	0.06	0.02	0.13	0.03	0.03	0.14	0.03	-0.03
2002	0.15	0.05	0.05	-0.07	-0.04	0.02	0.02	-0.04	0.07	0.16
2003	0.13	0.19	0.1	0.04	0.05	-0.05	0.19	0.04	0.07	0.1
2004	0.62	0.58	0.48	0.52	0.49	0.5	0.41	0.52	0.49	0.47
2005	1.32	1.31	1.66	1.47	1.27	1.2	1.44	1.32	1.43	1.44
2006	0.83	0.85	0.77	0.78	0.72	0.81	0.86	0.59	0.75	0.73
2007	1.26	1.32	1.29	1.4	1.46	1.44	1.29	1.42	1.32	1.32
2008	1.05	1.06	1.01	0.98	0.9	0.93	0.92	0.9	0.98	1.01
2009	0.28	0.39	0.31	0.25	0.32	0.3	0.16	0.39	0.25	0.31
2010	0.84	0.79	0.74	0.75	0.79	0.81	0.83	0.78	0.75	0.77
2011	0.83	0.87	0.76	0.81	0.74	0.89	0.55	0.67	0.84	0.8
2012	0.05	0.01	-0.04	-0.1	-0.12	-0.12	-0.04	-0.09	-0.12	0.04
2013	0.36	0.29	0.14	0.25	0.33	0.38	0.18	0.4	0.15	0.14

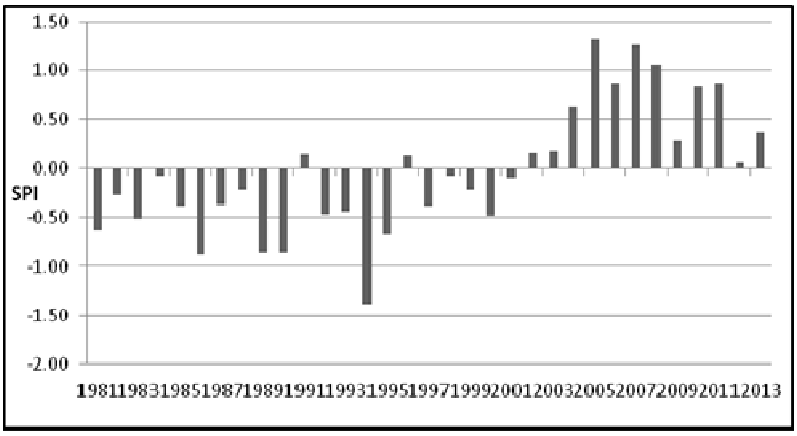

Figure 5. The SPI values for Fort Abbas

evapo-transpiration and unavailability of water. Its soils are cracked and fissured because of low moisture. SPI values point out that the period from 1981 to 2000 was very dry and arid (Figure 7). Because of almost complete absence of rains, the intensity of dry period reached to its apex during 1997 to 1999. Extreme shortage of water stunted agricultural activity which gave birth to famine like situation. After the year 2001, a wet spell fetched the area with water that filled the *tobas* and gave a hope of life to pasture lands too. The fourth site Derawar is located at the southern margin of Lesser Cholistan and historically is prominent due to the presence of famous Derawar Fort. This site usually remains dry and receives very low amount of rainfall. Climatically it is arid and hyper arid in nature and

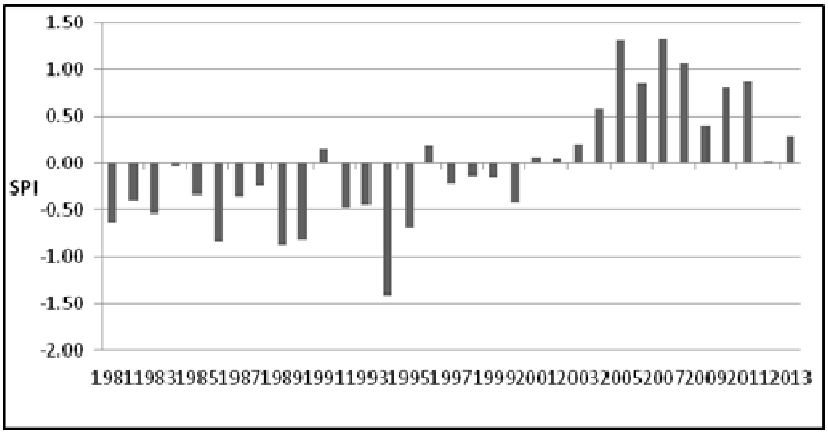

Figure 6. The SPI values for Hasilpur

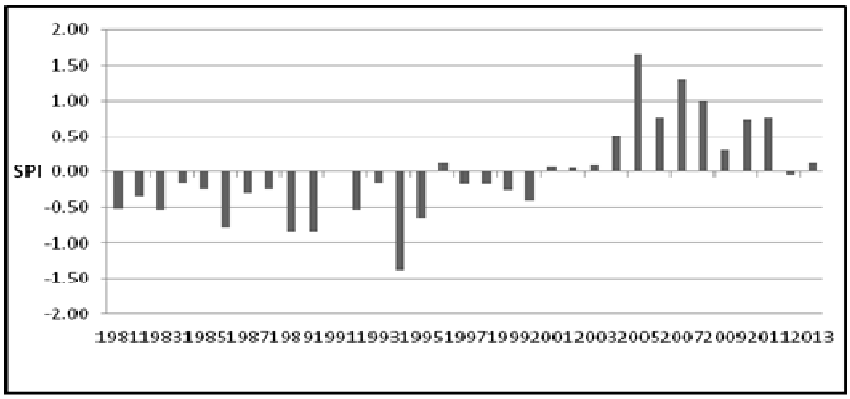

Figure 7. The SPI values for Dingarh

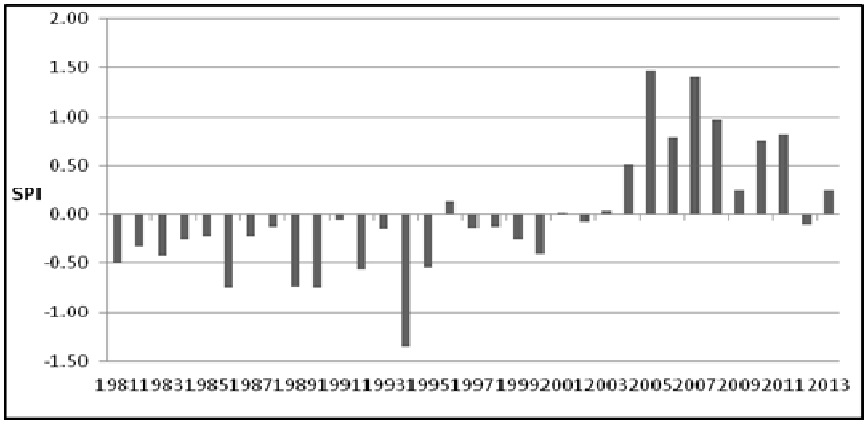

Figure 8. The SPI values for Derawar

consists of large flat plains of cracked and broken soil locally known as *dahars*. SPI values shown in Figure 8 tell that an extremely dry episode incessantly prevailed in the area showing apex in the year 1994 with an index value of -1.35 (Table 3). This situation badly affected human, animal and plant life. Due to extreme shortage of water and soil moisture, almost all the signs of life were vanished. The soil of the area became cracked and rugged and agricultural activity declined to its lowest extreme. Due to excessive heat and high rate of evaporation, all the *kunds*

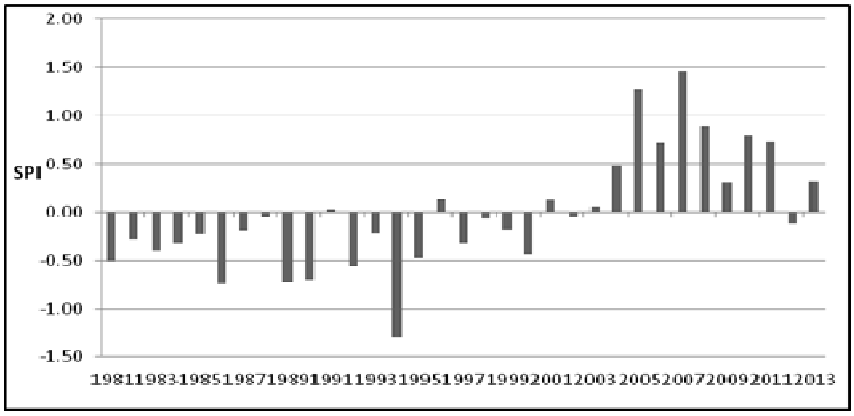

Figure 9. The SPI values for Bhagla

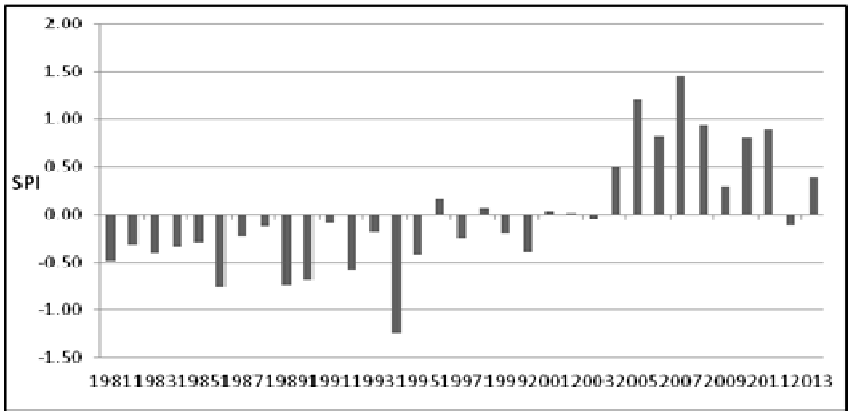

Figure 10. The SPI values for Islamgarh

and *tobas* were dried out. The most evident effect was on floral and faunal life. No pasture land and local fodder was available resulting in life threatening conditions and extremely low production of livestock. Because of the prevalence of such kind of adverse environmental conditions, most of the nomads were forced to migrate towards safer places along with their livestock. In 2006 and 2007 the area received little amount of monsoon rains that filled the *tobas* and provided some support to nomadic life. However, it has been noted during the field visits that this area is very arid and usually remains under the influence of long dry spells. Rainfall is highly sporadic and whenever comes is very low insufficient to support the life for longer time. The fifth site Bhagla lays on the southern boundary of Lesser Cholistan where rainfall is very low. The summer temperature exceeds 46ºC causing high rate of evapotranspiration. SPI values indicate the prevalence of moderate drought conditions from 1981 to 2003 (Figure 9). Some of the years like 1986, 1994 were the episodes of severe drought due to absence of rains. Scarcity of water created famine like situation. However, from 2005 onwards the area received little rainfall that filled *tobas* with water and provided some support for the survival of human and animal life. The sixth site Islamgarh is located in southern part of Cholistan near Rajasthan Desert of India. It is associated with a hyper arid type of climate and is a typical drought prone area. SPI values indicate the prevalence of a serious dry spell from 1981 to 2003 when it was hit by moderate to severe droughts for a number of times (Figure 10). Severe shortage of rainfall for a long period, excessive heat and high rate of evapotranspiration resulted in the discontinuity of plant production. However, the area received a relatively wet episode in 2007 which convinced the nomads to move inside the desert from the fringes and restart their normal life. But unluckily, another dry episode occurred in 2012 that disturbed the area again and depressed the nomadic activity. Such oscillations seem to be a permanent feature of this area and force the nomads to adjust their lives accordingly. Seventh area Bijnot is located in deep Greater Cholistan. It is basically a hyper arid area and remains dry almost all over the year. Large cracked plains (*dahars*) with dry broken and fissured soils are found here. The SPI value (-24.47) for 1996, indicates that a severe dry spell badly affected the area. It is evident

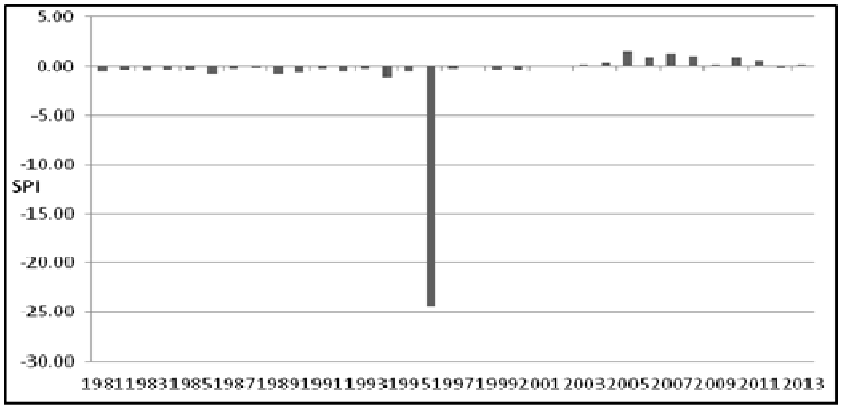

Figure 11. The SPI values for Bijnot

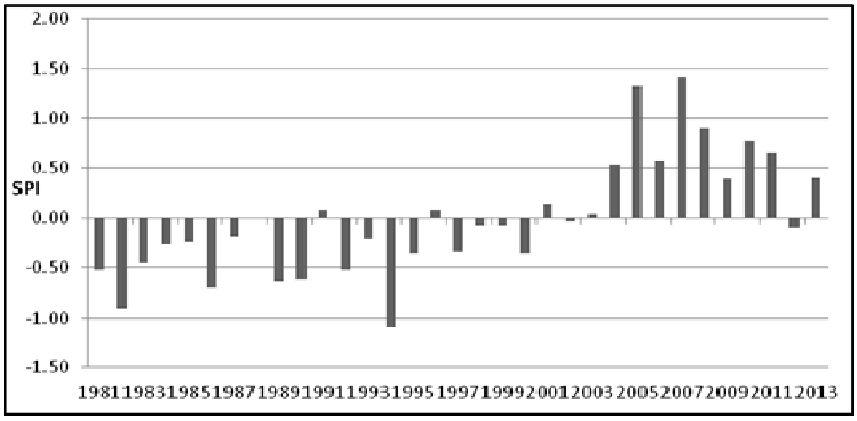

Figure 12. The SPI values for Kandera

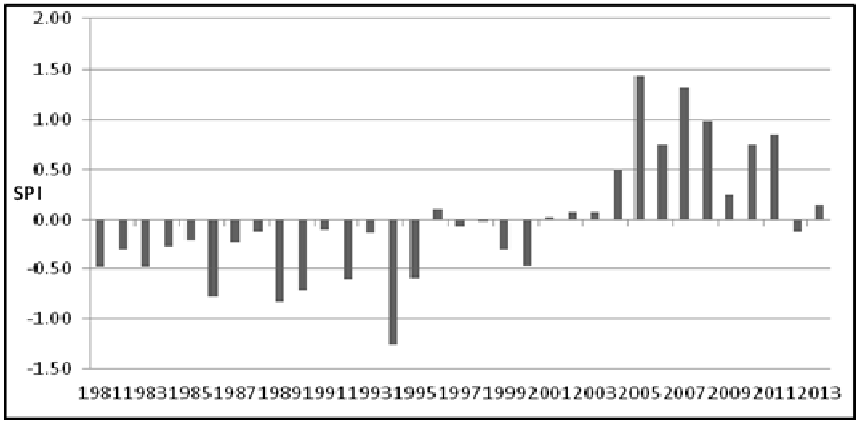

Figure 13. The SPI values for Nawankot

from the results that since the year 1981 the area has received very little amount of rainfall and remained seriously dry from 1981 to 2013 (Figure 11). These conditions badly affected all kinds of life and human activities. The eighth site Kandera is situated at the margin of Lesser and Greater Cholistan on southern side of the desert. It receives very little rainfall and remains rugged and dry in almost all over the year.Index values indicate prolonged and extremely dry spells in 1982 and 1994 which severely affected the area (Figure 12). Dry and badly

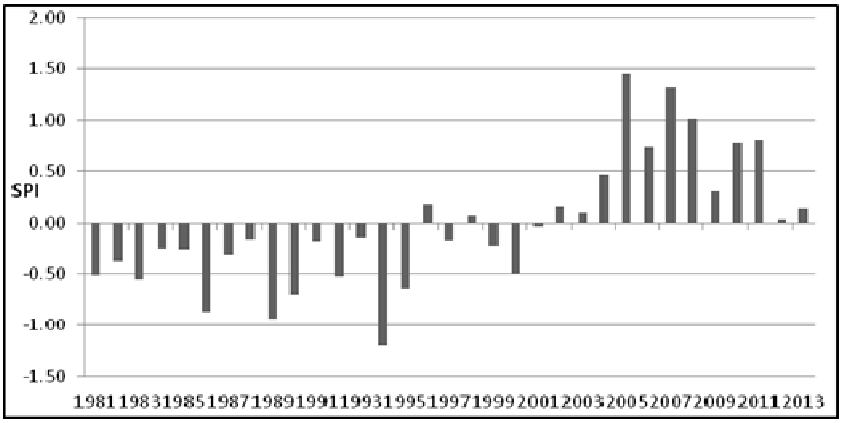

Figure 14. The SPI values for Kudwala

cracked land has restricted any form of agricultural activity and created a famine like situation. However, in 2005, 2007 and 2009 little monsoon rains brought a ray of hope and some inspiration for plant, animal and human life. In 2012, again a dry spell started to rise and ruined the hopes of prosperity in the area (Table 3). The ninth site Nawankot is located in the middle of the Greater Cholistan. It mainly consists of dry and flat broken plain having few *tobas* and *kunds* for water storage. The SPI values indicate that driest years in this area were 1986, 1989 and 1994 which gave birth to severe drought conditions (Figure 13). In 2002 and 2003 moderate drought conditions prevailed in the area while in 2012 an extreme dry spell badly affected the eco-system and live-stock raising activity. The last site is Kudwala lies near the eastern boundary of Cholistan and extends up to Rajasthan desert. Due to location in the deep desert it is associated with hyper arid climate. The SPI values indicate that the years 1986, 1998 and 1994 faced severely dry episodes imposing negative imprints on the flora, fauna, livestock and people of this area (Figure 14). However, the year 2005 was relatively better for the retrieval of life the provided some respite to the local people as well (Table 3).

In sum, based on the analysis of secondary data and observations during field visits of above mentioned 10 study sites, significant temporal and spatial variations in the temperature and rainfall conditions have been observed in Cholistan. Occurrence of drought conditions is a common and frequent phenomenon in the region. The impact of fluctuations in temperature and rainfall is prominent on the ecosystem. Plant and animal life and human activities fluctuate along with the fluctuations in climatic conditions. In such conditions, opportunities, options and economic activities are limited and life is intrinsically hard in the region. All the study sites of Cholistan region viewed above are characterized with arid or hyper arid climate, very low rainfall, shortage of usable water and forage, and lack of facilities for the nomads to serve reasonable and satisfactory life. The results of the study demonstrate that Cholistan is frequently threatened by the meteorological droughts that make the all kinds of life very tough. The past data indicates that this natural hazard has become almost a regular feature of the region as it may reappear after some years. It is obvious that severe drought conditions follow a cyclic pattern throughout the region. However, these cycles can be of the any interval and duration that are hard to predict. When the drought can reoccur, is also difficult to forecast exactly.

CONCLUSION

The study concludes that Cholistan is basically a hot arid area located in the region of sub-tropical continental desert type climate associated with extreme aridity and temperature conditions where summer temperature may rise above 50ºC and rate of evaporation exceeds the amount of precipitation. Such conditions have made the Cholistan a drought prone area. SPI values, field observations and recorded information revealed that prolonged dry spells and resultant meteorological droughts are frequent in the region that affects badly the floral, faunal and human life. In some years, extended drought spans created serious problems of water shortage which are always threatening for flora, fauna, humans and their livestock which is the only source of earning in the region. During extreme drought conditions, the inhabitants migrate along with their livestock to safer areas for protection and survival. Rainy years provide lot of sustenance to all kinds of life and bring happiness. In contrast, rainfall deficient years cause many threats to life and melancholy starts to prevail everywhere in the region. However, the region can be turned in to a significant productive area by overcoming the negative effects of droughts and if water is made available through canals. On the basis of findings it is suggested that Cholistan Development Authority and other concerned departments should make effective strategic plan to reduce the vulnerability of the disaster prone areas

and to overcome the damages caused by meteorological droughts.

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