Investigation of Rainfall Variability for Pakistan

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Abstract

Pakistan is an agricultural country mainly dependant on irrigation through the Indus water system. The country has developed the world's largest contagious canal network. Monsoon precipitation is the lifeline of Pakistan which not only caters the national power supply and standing crops water demands but help gathers the reserves to meet the requirements of low flow period in the next 4-5 months. Future projection of weather indicates towards the dry land agriculture for Pakistan. The purpose of the present study was to investigate and analyze the variability in precipitation occurred in the past times. Rainfall variability coefficient is utilized to analyze the past time situation and the study covers the period from 1960-2009. The results of the decadal analysis showed that the high value of the variability coefficient has been observed in Balochistan (251%), Sindh (247%) and Punjab (208%) regions. However the annual analysis showed the increasing trend of variability coefficient from North to South in Pakistan. According to the inter seasonal analysis of fifty years data (1960-09) variation in the coefficient of variability was highest in post monsoon and pre monsoon seasons as compared to the winter and monsoon seasons. These analysis showed that forecasting is a challenging job for the forecasters where the variability is prominently high. It revealed in the study that most of the northern areas have safeguarded except in the post monsoon period. While the southern half has been suffered throughout the year in terms of rainfall variability.

Keywords: Variability Coefficient, Precipitation, Standard deviation, Summer Monsoon

Introduction

The two-third of Pakistan lies in semi-arid to arid zones according to Pakistan's agro climatic classification (Chaudhry et al., 2004). Hence, majority of the people depend on arid and semi-arid areas to support their livelihoods through agro-pastoral activities. Agriculture in Pakistan is not only dependant on rainfall but also on the irrigation water, which comes from seasonal rainfall as well as melting of snow and ice. Pakistan has developed the world's largest contiguous canal irrigation system. Pakistan is covered on the north by Himalaya, Karakoram and Hindukush which host the world's third largest snow/ice reserves. These mountains are the water tanks over the roof, which provides water to the reservoirs. The environment has given the operational control of this tank in terms of temperature after the strong buildup of greenhouse gases (Chaudhry et al., 2007).

Climate variability and change profoundly influence social and natural environments throughout the world, with consequent impacts on natural resources and industry that could be large and far-reaching. For example, seasonal to inter-annual climate fluctuations strongly affect the success of agriculture, the abundance of water resources, and the demand for energy, while long-term climate change may alter agricultural productivity, land and marine ecosystems, and the resources that these ecosystems supply (Adnan, 2009). According to the report of IPCC the precipitation during the 20th century (1900-2000) has increased an average +20% in Northern Pakistan +10% in central part and 40% in Southeast. (IPCC technical paper V, 2002).

Climate variability and change, its impacts and vulnerabilities are growing concern worldwide. The climate of Bangladesh is changing and it is becoming more unpredictable every year. Global warming induced changes in temperature and rainfall are already evident in many parts of the world, as well as in our country (Huq et al., 1999). Hazards like floods, droughts, cyclones and others, which are aggravated by climate change and its variability being experienced more frequently in Bangladesh than ever before. Uncertainty of rainfall and uneven temporal and spatial distribution in one hand, creating flooding and of the other hand longer dry spells evoking droughty conditions (Lai et al., 1998). Although in some parts of Asia and Africa the frequency and intensity of drought have been increased in recent decades, large no of

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evidence shows that precipitation has also parade long term change in many places of the world (Wang et al., 2001).

Monsoon precipitation is the lifeline of Pakistan's water resources which falls in summer from July to September. It not only caters the peak power supply demands but also fulfills the highest water demands of field crops and gather the reserves to meet the requirements of low flow periods in next 4-5 months. Being the agro-based economy, it is highly sensitive to any shock wave in the form of weak monsoon or mismanagement of available water resources.

Rainfall variability of Indian summer monsoon and east Asian summer monsoon as well as their relationship with southern oscillation has been extensively studied by Walker (1923, 1924) , Rasmusson and Carpenter, 1983; Shukla and Paolino, 1983; Mooley and Shukla, 1987; Yasunari, 1990;Webster and Yang, 1992; Lau and Yang, 1996; Ju and Slingo, 1995; Soman and Slingo, 1997; Liu and Yanai, 2001; Lau and Nath, 2000.

According to Economic Survey, 2007-08; Pakistan like most of the developing world, is faced with the challenges of being affected by land degradation and desertification, which are causing environmental problems, including soil erosion, loss of soil fertility, flash floods, salinity, deforestation and associated loss of biodiversity and carbon sequestration.

Scope of Study

Winter brings lot of snow over the northern mountains which melts in early summer and maintains the sustainable river flows for power generation and irrigation before the onset of the summer monsoon. In addition to solid precipitation over hilly areas, winter rain bearing systems yield substantial rainfall in sub-mountainous and low elevation plains including arid plains of Balochistan. Generally northern half gets about five times more precipitation in winter than southern half.

In fact, besides the intensity the timing of precipitation is much more important for hydrology and agriculture of a country. Pakistan is a country which gets the major share of its total rainfall through summer monsoon. This rainfall system provides the main contribution in Indus water network that benefits the Kharif as well the up coming Rabi crops.

The intensity and frequency of Precipitation has increased in Asian region(IPCC, 2007).The consequences of climate change and global warming includes uncertainty in the occurrence and intensity of precipitation. Future projection of weather indicates towards the dry land agriculture for Pakistan. In this scenario if rainfalls become unreliable then we would have to mould our national planning keeping in view the current era. In the light of above situation this project has been initiated. The purpose behind was to investigate and analyze the variability in precipitation occurred in the past times.

Data & Methodology

The monthly area weighted rainfall data of 44 national meteorological stations of Pakistan for the period 1960-2009 (from data archive of PMD) has been incorporated and were shown in the Figure 1.Pakistan is a country of diverse climatic features ranging from very dry/hot desert like climate in the south to snow/ice covers world's highest mountain peaks in the north. Due to diversified climates , the precipitation regime differs qualitatively in time and space. For better representation of precipitation zones , the provincial extents have been divided into similarity matrices.

The main focus was given on precipitation occurrence on decadal, annual and as well as seasonal basis, Pakistan has four seasons: Winter from December, January, February and March; Pre monsoon April, May and June; Monsoon July August and September & Post monsoon October and November respectively. There are numerous methods in practice ranging from simple time series approach by excel to highly complex modes. However, the focus is to develop commonly understandable method which

could be adopted easily to tackle this complex issue. For the core study, the method being utilized is coefficient of variability of precipitation, in percentage.

Mathematical Relationship

The following mathematical relationship is used to calculate the coefficient of variability

$$C.V = \left(\frac{SD_i}{R_i} \right) \times 100$$

Where

SD, Monthly standard deviation

R, Monthly Rainfall average

i, The subindex (ranging from 1 to 12),the particular month of the year. (Camerlengo and Somchit, 2000)

Figure 1: Location of the Stations of Pakistan used in this investigation and the geographical regions demarked for discussion

Pakistan is having a variety in terms of topography, geography as well as in climatology. To cope with the situation the country is being divided into nine parts, every province has been presented in two parts (upper and lower) and one part constitutes on northern areas & AJK. Also to elaborate the situation, the discussion in the following section focused mainly on the decadal, seasonal and annual analysis of rainfall variability.

Results and Discussion

The discussion is being started with the northern parts of the country, comprises of northern area and Azad Jammu Kashmir. The area has core importance regarding the hydrological and environmental conditions of the country. In a recent study at PMD (Chaudhry et.al, 2009) it is revealed that under the influence of El Nino, precipitation dropped drastically throughout Pakistan resulting into scanty rainfall

both in the summer and winter seasons. That El Nino induced shortfall of precipitation triggered Pakistan history's worst drought in terms of length and intensity which prevailed from fall of 1998 to spring 2003.

The areas in the high land here received snow in terms of precipitation, normally in the winter months. It accumulates initially and after wards melts in the post monsoon season because of increasing temperatures. From the graph it can be observed that rainfall variability coefficient (*V.C*) in the first decade of the study was 75 % and then the percentage of variability coefficient gradually increases till the fourth decade and after that it suddenly decreases in the last decade. However, the highest value of variability coefficient was recoded in third and fourth decade i.e. 115 % and 118 %. This is that period of the year when the frozen snow in the region melts and augments the river flow in the downstream areas.

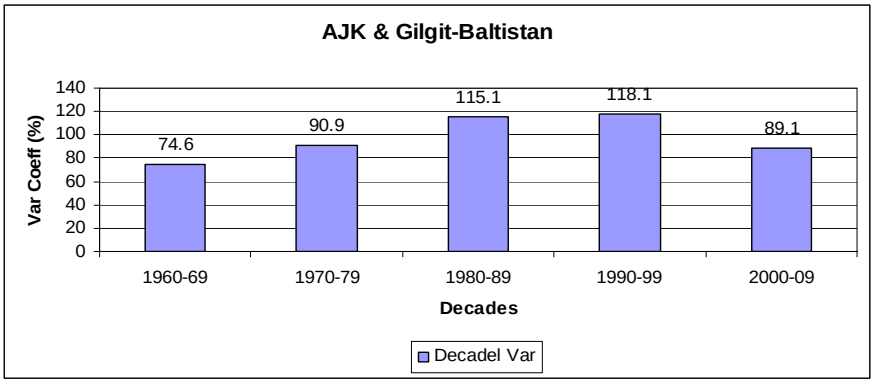

Figure 2: Rainfall Variability for Azad Jammu Kashmir and Gilgit-Baltistan divided in decades

Upper Khyber Pakhtoonkhwah (KPK) is the area where lies the basins for some important rivers. The area is mainly covered with one of the northern mountains i.e. the Hindukush. Therefore, like the former area (discussed earlier) this region also has importance in terns of agro-hydrology. It can be observed from the graph that the value of *V.C.* in the first decade is high and in second decade was less as compared to the first. However after that *V.C* gradually increases till the last decade.

In lower KPK the situation is much safe regarding the variability of rainfall. Most of the time variability coefficient remained less then 100 % but in the last decade under study highest value of variability coefficient was recorded like 115 %.

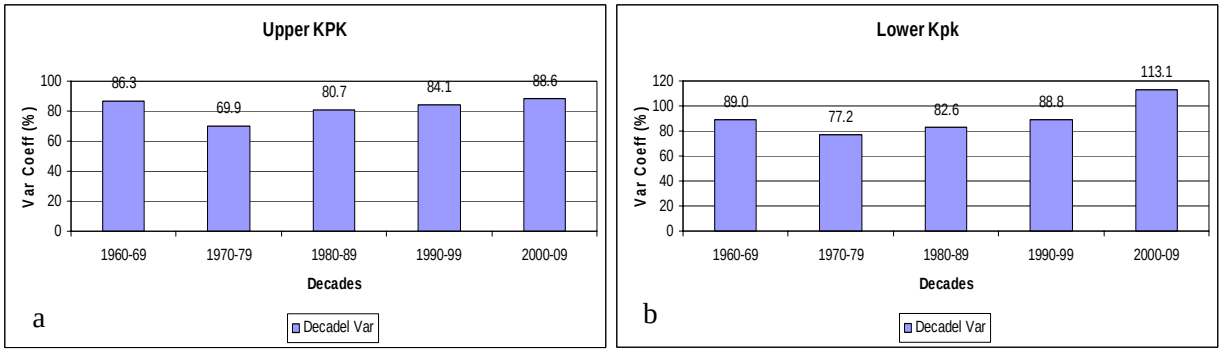

Figure 3: Rainfall variability of upper half of Khyber Pakhtoonkhwa divided in decades (a) and lower half (b)

In the upper Punjab, *V.C* remained with in the range like 75-95%, but during the third and fourth decade of the study the percentage of variability coefficient was highest like 105 % and 113 %, The area lies with in the monsoon belt where most of the rain occurred during the months of July-September, also it provides the basin for some major rivers of the province like Indus and Jhelum. During winter also the

area remained under the influence of western disturbances. But it is to be noted that due to present scenario of climate change, the ENSO episodes affects the timing and intensity of rainfalls in the region. This graph projects that the major variability is observed during the third and fourth decades of the study, however the situation remained calm during the last decade.

The situation in the lower Punjab is comparably different from the upper half of the province. In this region variability coefficient remained less then of 100 % except in third and fourth decade coefficient of variability remained 105 % and 113 % respectively. This is the region where very low precipitation occurred throughout the year and this variability may project negative impact on agro-hydrological sector in the region.

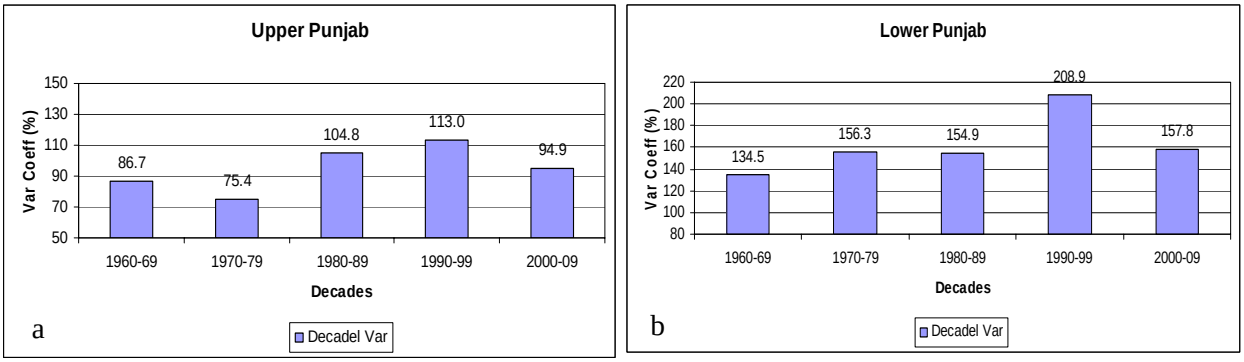

Figure 4: Rainfall variability of upper half of Punjab divided in decades (a) and lower half (b).

In Upper Sindh region V.C has shown much fluctuations in different decades. The area is connected with the lower Punjab and eastern side of Baluchistan plateau. This region not lies in the track of summer or winter monsoon systems, local agriculture is mainly dependant on the water from the tributaries of Indus River. The lowest percentage for variability coefficient is observed in third and last decade as 180 & 183 % respectively, and on the other hand highest percentage for variability coefficient recorded in fourth decade like 245 %.

In the Lower Sindh region sharp variation have been observed throughout the period. Most of the time variability coefficient remained within the range of 180-200 % while the highest percentage recorded during the first and forth decade as 220 % and 248 % respectively. In this region rained occurred normally due to disturbances in the Arabian Sea during summer but rarely occurred during the winter season etc.

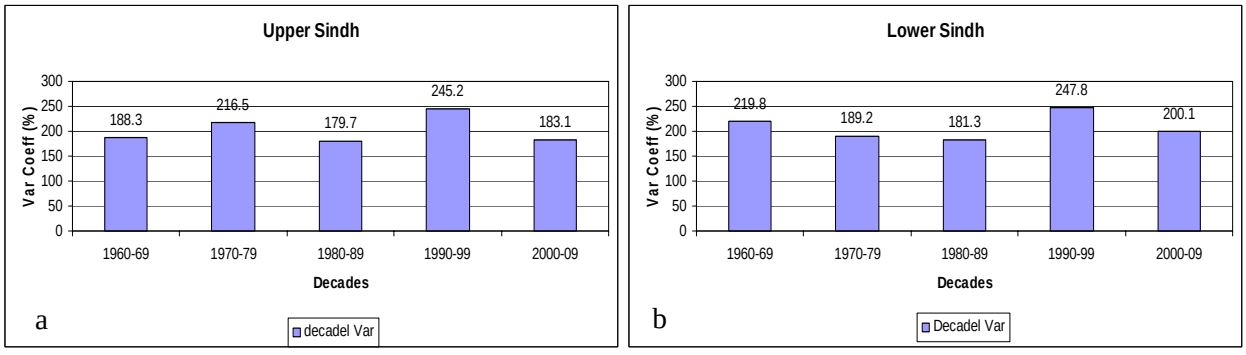

Figure 5: Rainfall variability of upper half of Sindh divided in decades(a) and lower half (b).

Upper Balochistan is the area which is dominated by winter precipitation due to western disturbances but some parts near the border with Southern Punjab like Barkhan rainfall occurred during summer monsoon.

The percentage for variability coefficient recorded as lowest in the first decade was 99 % and the highest was observed during fourth decade 242%, however in the rest of the decades range of variability coefficient remained 120-150 %. The area contributes very low share in the national agriculture crop production but holds the major contribution in terms of fruit products, especially in the winter season.

In the Southern parts of Balochistan the situation is different from the northern half. In this region range of variability coefficient was very high in fifty years i.e.130-250 %. The area obtained rainfall in the summer monsoon season from the Arabian Sea.

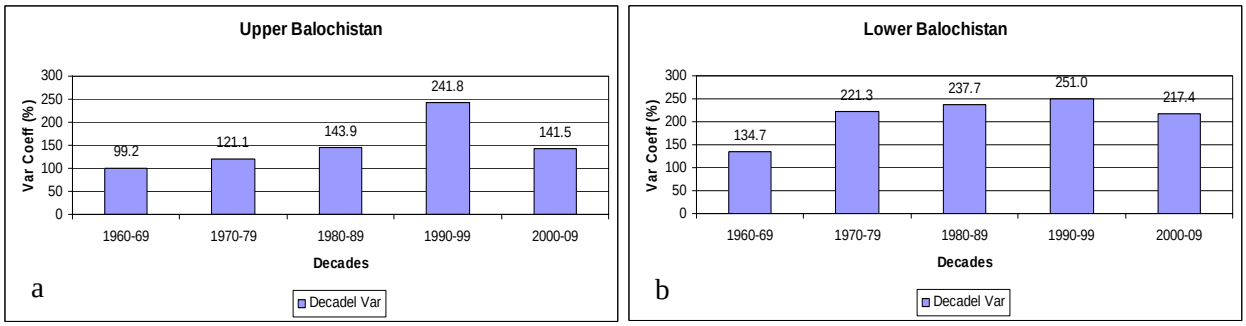

Figure 6: Rainfall variability of upper half of Balochistan divided in decades (a) and lower half (b).

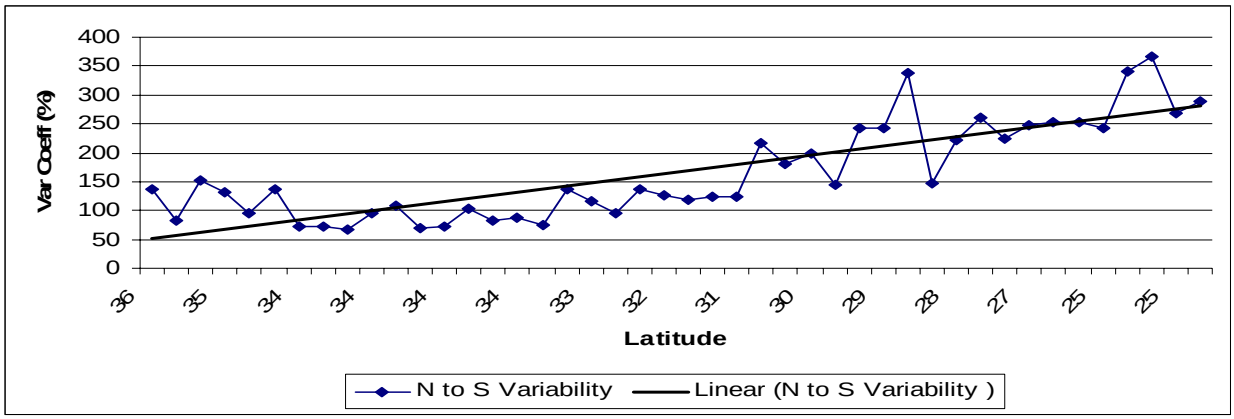

Figure 7: North (Left) to South (Right) graph of Precipitation Variability of Pakistan for Period (1960-09)

Figure 7 shows variability increase from North to South in general in the period of fifty years i.e. 1960-09, except for extreme northern parts i.e. Gilgit Baltistan which reveals that monthly/seasonal forecasting is a challenging job for meteorologist where variability is prominent i.e. southern half of Country.

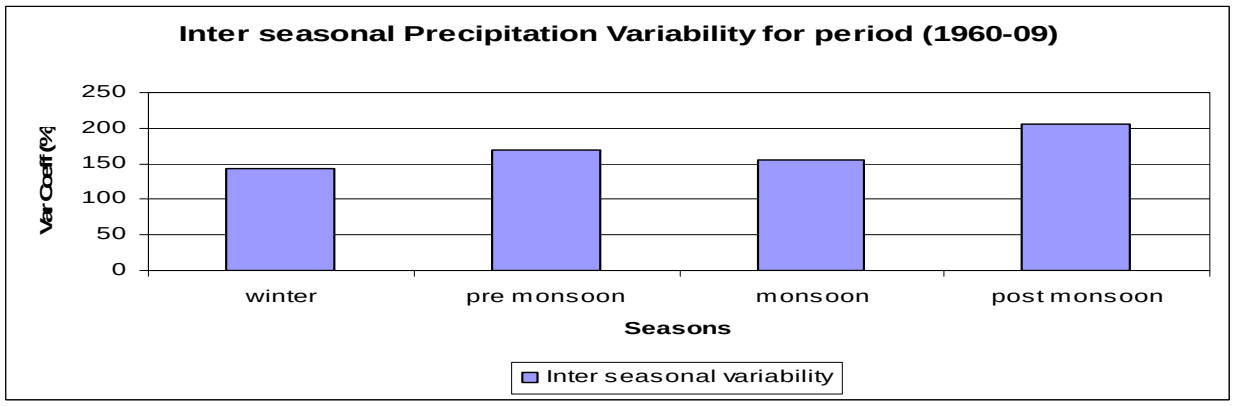

Figure 8: Contribution of Seasons in Precipitation Variability for Pakistan

Above Figure 8 shows that precipitation variation is high in post monsoon and pre monsoon seasons as compared to the winter and monsoon seasons. Due to higher contribution of post monsoon precipitation variability, qualitative and quantitative predication is difficult for forecasters. This is the season when sowing of winter crops is undertaken. Highly variable behavior of precipitation poses challenges for farming communities in rainfed areas. Delayed precipitation or no rain situation in sowing season leave the farmers without crops resulting to increase their socio-economic sufferings.

Conclusions

Past analysis of precipitation data has shown a slightly decreasing trend of precipitation variability for the northern parts of the country. On the other hand the situation for southern parts of the country is becoming better, in terms of precipitation and temperature as well. The purpose of the present study was to investigate and analyze the variability in precipitation occurred in the past times. Rainfall variability coefficient is utilized to analyze the past data situation and the study covers the period from 1960-2009. It was revealed in the study that most of the northern areas have safeguarded except in the post monsoon period while the southern half has suffered throughout the year in terms of rainfall variability. Especially in the southern Balochistan it has been observed that rainfall remained fluctuating throughout, irrespective of the seasons. The decadal analysis of rainfall variability showed that the highest value of variability coefficient has been observed during the fourth decade of the study i.e. 1990-99 most probably due to the strong ENSO episodes. Due to high variability in lower part of the country seasonal as well as extreme events prediction is difficult. The results obtained in this study may help investigating the future scenario of rainfall in the region but more detailed and area specific study is still required. It is foreseen from the increasing trend of precipitation variability over temporal and spatial scales that climate variability will be more serious challenge then climate change. It will be easier to adopt climate changes in terms of changing precipitation regime but climate variability embedded with extreme (wet/dry) precipitation episodes will be hard to manage by practitioners.

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