
Emerging Climate Changes and Water Resource Situation in Pakistan

_____ M. H. Bukhari
_____ Ejaz Ahmad Sayal

Pakistan is located in a semi-arid climatic region, and the rainfall is not equally divided over the year. The country's average rainfall is less than 375mm. It gets maximum rainfall during monsoon season. The importance of rainfall as a source of water is an established fact. A large part of rainfall (approximately 70%), floods various areas or flows into the sea without being of much and often causing miseries to villages and towns by floods. In addition, monsoon failure also occurs due to the El Nino effect. Even without the latter, around 30% of surface water supplies, available from different sources run waste in sea. It is essential to assess the impact of climatic changes on the sea level, rainfall pattern, aridity, changes in land use, forestry & agriculture and water resources for the development of the region. In the fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) global warming has continued to increase. The Water resources' depletion crisis may have resulted partly from the climate change and partly due to the mismanagement of water resources by the concerned authorities. In arid and semi-arid regions of the world, even smaller changes in climate would affect the water supply enormously. It is essential to invest in research

and adopt all sorts of measures to save and conserve water at all levels. Reservoirs are necessary to preserve water because regular water flow cycle would change with a changing climate scenario. New agricultural skills to save water must be introduced and practiced comprehensively.

Key words: Climate change, water resources

Introduction

The Significance of climatology is well-recognized since World War II, and is well-documented in different fields; it has particular utility in economics, social planning, water management and agriculture management. Climatology is the study of the average spatial distribution of different climatic elements, e.g. temperature, rainfall, pressure, winds, humidity, evaporation, etc., and their relation to man's activities. (Anandeshwari, 1995: xxv) At the meeting of UN Security Council on 20th July 2011, climate change was discussed as an agenda item. Climate change has impact on sectors like water, agriculture, energy, health and trade. It is also clearly evident that climate change has wide implications: the security repercussion of climate change is first felt at the local level, and this is where they need to be understood. The devastating floods that paralyzed Pakistan last year increased political unrest. The losses were huge, and resettlement is still incomplete. (Vivekananda, 2011) The majority of scientists now consider there has been a considerable rise in temperature. There are also signs that over the next fifty years there will be considerable shifts in the distribution of rainfall and other climate-change effects such as sea-level rise or drought. In a conference held at Lahore on 8-9 July 2011 'Climate Change and Disaster Risk Management-Managing Risks: Sharing Benefits' it was ascertained that climate change is a major threat for the region. (Sahi, 2011)

Whilst discussing Pakistan's general climate, it is important to note that diverse types of climates exist in the country, marked by great contrast between high mountains and broad plains.

Climate of Pakistan

Sethi (2007) describes the climatic divisions of Pakistan with reference to topography. The Highland climate of mountainous areas and rainfall are associated with altitudes. The northern mountains experience maximum rainfall in the highland climatic zone whereas the Western Mountains get the least rainfall. Temperature conditions also vary from north to west depending on the altitude. The plain climate zone includes the whole of the Indus plains except the coastal areas. It has a semi arid to arid climate, hot summers with summer monsoon rainfall, and mild winters. The amount of rainfall also varies from north to south. The coastal climatic zone comprises of the coastal belt and the Indus Delta. The daily temperature range is low.

Sajjad (2004) describes the climate of Pakistan as dry and hot near the coast, becoming gradually cooler toward the northeastern uplands. The winter is generally cold and dry. The hot season starts in April, and by end of June, temperatures may reach 49° C. Between July and September, the monsoon provides an average rainfall of 38cm (15inches) in the northern areas. Rainfall can differ immensely from year to year, and a successive pattern of flooding and droughts appear.

Pakistan lies entirely outside the tropics although the climate is classified as a tropical climate, more specifically tropical monsoon climate. However, the monsoon is short lived, so the climate comes to be continental semi-arid. (Kheli, 1997: 577-590) During the summer Pakistan is considered meteorologically to be a tropical climate region, and in winter, subtropical. The country has a continental climate with little rainfall. Characteristics of tropical weather systems are different to extra-tropical weather systems.

Weather Control over Water Resources

Four main weather systems control water resources in the region in which Pakistan lies, western disturbances, monsoon system, development of local convectional currents and tropical cyclone. The Western system is formed over the Mediterranean Sea or the North Atlantic Ocean between November and April; it begins to move in an easterly or north easterly direction, eventually causing rainfall over northern Pakistan. Gradually these western lows move from the extreme north to lower latitudes as the season advances. The wet monsoon from the south-east to the east enters the region and cause rainfall. Local moist weather conditions of northern Punjab and Khyber Pakhtoon Khawa (KPK) produce convectional currents, causing rainfall in the area. Tropical cyclones are experienced in the pre-monsoon (May) and post-monsoon (October-November) periods.

Many factors are responsible for the failure of weather systems: 1) The eastward movement of the Anti-cyclone over Tibet (200 mb) (ii) little differential heating (iii) weak Somali jet at 1 to 5 km (iv) Monsoon axis shift towards the foot hills of the Himalayas (v) Himalayan snow (vi) feeble westerly stream shifting to higher latitude, (vii) low temperature gradient is present in the upper air between 30°N and equator (viii) At higher latitude lows are formed (ix) Failure due to El-Nino and La-Nina effects.

The entire means of irrigation are linked with activeness of weather and droughts occur due to the failure of weather system. (Riaz, 2002: 47-48)

Climatic Change

Parry and Crater claim that like the weather, climate is also changeable. The climate of any region is not precisely the same from one year to another. The climate change can be defined as the 'change in the average climate (or its variability) from one averaging time to the next.' Overall, it is evident that the 20th

century has been the most warm century for 1400 years. (Parry et al, 1998: 5-22)

It is essential to review the impact of climatic change on sea level, rainfall pattern, aridity, changes in land use, forestry & agriculture, and that of water resources for the improvement of the region.

From the world climatic record since 1861, it is evident that temperature rise is between 0.3°C to 0.6°C. However, this significant change is irregular, as high latitude maritime regions and the tropics were affected differently. The global warming of the 20th century is evident.

Worldwide climate change is affecting different fields of life. Global surface air temperatures have increased by about 0.30-0.60C since the late 19th century and 0.20- 0.3 oC during last 40 years. Pakistan, as part of South Asia has also observed warming in spite of less discharge of green house gasses as compared to industrialized developed countries. (Pant and Kummar, 1997:18)

Temperature as an Independent variable

Among climatic elements, temperature is considered to be an independent variable. The temperature difference develops related changes in the pressure distribution, and as a result, in wind direction and velocity, which in turn control atmospheric humidity, condensation, formation of clouds and their draft in the sky, precipitation and storms. Whether directly or indirectly, temperature governs all other weather elements (Anandeshwari, 1995:14, 23) The surface temperature over South Asia shows a variety of trends in its seasonal and diurnal pattern, and is greatly modified by altitude, location in relation to the sea, and geographical features. (Pant and Kummar, 1997: 110-111)

Savant August Arrhenivs, a Swedish physical chemist (1859-1927) was first to suggest the theory of global warming. He

argued that doubling mixing ratios due to the increased burning of coal in the UK would increase the temperature by 5°C. (Jacobson, 2002: 310-350) Environmental threats are increasing tremendously. Climate change and global warming are linked with these environmental degrading scenarios. Global warming and climate change are used synonymously but climate change gives a wider sense of the meaning. Being a global phenomenon, the impact of climate change has become critical for the world. Underdeveloped or developing countries like Pakistan would have to face additional damages because of their unstable situation.

Some pollutants produced by different human activities are increasing the percentage of greenhouse gasses (GHG) emission in the atmosphere. The most important of these are CO₂, CH₄, N₂O, CFCs, water vapour and other industrial gases. Solar radiation reaches the outer limits of the atmosphere without loss. But afterwards reduction starts by reflection, depletion and absorption in different parts of atmosphere. The Earth radiates long wave or infrared radiation back to the space in relevant proportion. But GHG act as cover for outgoing weak long wave radiation. This radiation is trapped by clouds and GHG, and enhances the warming of atmosphere, causing global warming. Global warming is no more just a theory: it is affecting millions of people around the world in terms of harsh weather, droughts, flood, heat waves, cyclones and anti cyclones. (Mustafa, 2007: 91-114)

In 2006 it was measured that the average surface temperature of the earth had increased warmed by 0.7°C in the last 125 years due to CO₂ and other green house gasses (GHG). It is obvious that this global warming is man induced. (Ruddiman, 2008:341) Many impacts of climate change are observed over the entire globe. The warming of the globe causes snow and ice melting, rises in the sea level and changes in weather systems.

Rise in Sea level

In the précis for Policy Makers in the Fourth Assessment Report of Intergovernmental Panel on Climate Change (IPCC) eleven years between 1995-2006 rank among the warmest years. Since 1850 as per instrumental record, the rise in sea level was measured at an average 1.8 mm per year from 1961-2003. However during the decade 1993-2003 a faster rate was observed, at an average 3.1 mm year. In the last century, sea level has risen 17 cm (0.17m) approximately on average (IPCC, 2007), which contributed 4cm to thermal expansion, 5cm to mountain glaciers, 2cm to Greenland and Antarctica. It also reveals global warming. During the 1900s, the average sea level rise was 1.7 mm / year, since 1992 this has increased to 3mm/year.

Retreating Mountain Glaciers

Mountain glaciers cover 680 Km² of the earth's land surface and make 4% of the total surface area of land covered by ice on Earth. Mountain glaciers make 1% of land ice, however, 99% of mountain glaciers have been retreating since the mid-19th century. The rate of ice melting has increased since 1990s in Greenland. (Ruddiman, 2008:321) The changes in sea level, snow cover, ice extent, and precipitation are consistent the with warming climate near the Earth's surface.

Temperature: The Pakistan Scenario

The annual surface temperature of South Asia has been slightly increasing since 1940. Accounts of different meteorological stations report warming in the annual surface air temperature observed at different meteorological stations in South Asia. Climatic changes over the Asian monsoon regions, of which the sub-continent is a major part, are of international worry, mainly in view of the high concentration of the human population. There is enough evidence to propose that South Asia has a share of global warming.

Karachi shows a regular increase in the temperature. The temperature is rising on 0.37% per decade. In Karachi, the temperature has increased almost 1.01% through last 53 years. In Nawabshah, temperature has been increasing fast since 1997: in recorded Temperature increases of 0.21% during 1971-2001. Jacobabad has seen little change in the mean temperature. Hyderabad has no change in the mean maximum temperature, but the mean minimum temperature has an increasing tendency, and has been rising since 1984. During 1984-2001, temperature has risen about 0.27%, annual temperature is also changing. Lahore had a declining trend during 1947-58 and from 1958 to 1984 no change was observed. After 1984 an increasing trend was observed in mean maximum temperature. In Lahore the temperature is rising slowly, with a rate of 1% per 50 years. The mean maximum- minimum temperature of Multan has not been changing for a long time. Temperature in Rawalpindi was decreasing in mean maximum and minimum during 1947-71, after which an increasing trend is observed. Bahawalpur has a significant rising trend. During 1976-2001 there was about 0.73% increase in the mean maximum temperature. It may rise up to 2.1% till 2025. Peshawar had a decreasing trend in the mean maximum temperature during 1973-1983. For the last two decades, the temperature of Peshawar has been rising fast. During the last 50 years, there has been a 0.4% increase in the temperature of Peshawar city.

Quetta, Zhob, Dalbadin and Panjgoor show have notable increases in mean maximum and minimum temperatures. In Quetta, from 1982 to 2001 the mean maximum temperature increased by 0.7%. The mean maximum temperature of Zhob increased by 0.3% during the last three decades. Dalbadin's temperature rose by 1.6% during the last two decades. In Jhelum temperature has been increasing regularly since 1980. The linear trend during the entire data period 1947-2000 shows a change in temperature at 5% per 50 year thus validating the claim that the surface temperature of Pakistan is rising. (Sajjad, 2004)

Rainfall Importance

As rainfall is one of the most significant and noticeable of all atmospheric processes and essential for survival of all plants and animals, it has received much attention from planners in different fields. Rainfall has an important position in the evaluation of climatic water balance of a region. (Anandeshwari, 1995:53)

Monsoon

Monsoon movement is most marked over the a vast area from Pakistan to Japan. The Himalayan mountains play a major role in the development of the Asia monsoon (Pant and Kummar, 1997: 32). Changes in monsoon rainfall in the region occur frequently.

Spatial and sequential variations of monsoon observed, being a reliable source of water not only for Pakistan but for the entire region, to have manifold impacts on the economy of the countries. Even economic planning, particularly that of natural resources is dependent on monsoon rainfall. It has a seasonal fulcrum-like situation i.e. occurrence of flood in one part and drought in other part. A Major part of the total annual rainfall in major parts of the country is attributed to the summer monsoon (Pant and Kumar, 1997:14) The major rainfall season of Pakistan is the summer monsoon season. The mean summer monsoon rainfall of Pakistan is 13.3 cm which accounts for about 58.5% of the annual rainfall, based on data for the period 1901-1990. (Chaudry, 1994). The Western disturbance during the winter gives little, but vital, precipitation in the form of rainfall and snow.

Latif And Tariq, (2006: 11), while discussing the Indus Irrigation System of Pakistan discuss the importance of rainfall, as a source of water. However, the rain is variable and insufficient for crop growth. A large portion of the rainfall (about 70%), floods the area or flows into the sea without serving any use and often causing misery to the villages and towns. The Plains of Sindh get more rainfall during July-August with a declining trend from

coastal to Central Sindh. Southern Punjab and northern Sindh are areas of low rainfall having 152 mm as an annual average. The areas above the Salt Range get a higher annual average of 635 mm, including districts of Jhelum, Rawalpindi, Attock and Mianwali. The water in Indus Plains and Peshawar Valley is 26 MAF (31.82BCM) but its contribution to the crops is about 6MAF (7.34BCM) in the irrigated areas. Khan (1988) states the average rainfall range from 10mm to 1000 mm. He estimates the runoff losses from cultivated portion of rainfall area equal nearly 6MAF (7.34BCM). If water loss from rangelands and forest region is added then this loss rises to 18MAF (22.03BCM) approximately. If 25% of this loss is conserved and stored i.e. 4.5 MAF (5.5BCM), it can further be managed for proper utilization in agriculture and power sector for a visible change in barani backward areas, on social, economic and agricultural bases.

In Pakistan, northern Indian, Nepal, Bhutan and Bangladesh, the winter westerlies dominate at surface level and also at high altitudes. The reasonably significant regional climatic characteristics of northern Pakistan and north western India depend on these western disturbances. Winter westerlies bring appreciable amounts of rain to a narrow belt of N.W.F.P and Punjab in addition to Peshawar vale. (The Cambridge Encyclopedia of South Asian Countries, 1989: 16-18)

Pakistan is a thickly populated country in the world's most populated region, South Asia. As most of the country is arid and semi arid, so climatic change would affect different fields of the life. There are several instances of rainfall departure in different years having extreme weather conditions, causing floods to draughts. (Parthasarthy and Kothwale, 1995: 113)

In July 2007, over 6000 villages were hit by floods in Sindh and Baluchistan, due to unexpected rains 350 people died, and Rs. 8.427 billion worth of damage was caused in the agriculture sector (Dawn 14th July 2007). In 2010, floods have paralyzed all

areas of life. Every 5th person in Pakistan is affected by this natural disaster. Estimates of damages sustained are still underway. According to one estimate, standing crops on 2.1 million hectares land were destroyed, 0.3 million cattle and 1.2 million sheep & goat died. At the same time 13,042 water courses were damaged. According to the estimate a loss of more than 5 billion dollars is expected (The Daily Jang, Lahore, 22 November 2010)

Climate and Deserts

Climatic differences and human activities are among the different factors which support desertification. While desertification may take place in any climatic zone, dry and hot climatic regions are more prone to this phenomenon developing. As this is where degeneration of land, water and other resources takes place. Pakistan has 79.6 million hectares of land in total. Estimates show that the major part, 85% (i.e. 70 million hectares) fall under semi-arid and arid climate; 41 million hectares are desert land with an extra-arid climate. The main deserts are Thar, Cholistan, Thal and Chagi-Kharan. (Akram, et al, 1995: 1-11) The vast Area of the Cholistan desert (26,000 Km²) depends on rain as main source of water. Ground water is mainly saline. Annual rain varies 100mm to 250mm. The mean annual temperature of the area is about 27.5°C. The Thar Desert, covering 30% of the total Sindh area, (43,276 Km), has an arid climate with an average rainfall of 200-300mm mostly during monsoon season. The mean maximum and mean minimum annual temperatures are 35.5°C and 20.5°C respectively. Water is a scarce commodity in the Thar Desert: humans and livestock both depend on wells and ponds. The Thal desert, (23000 Km²), is in Punjab about 50% of the Thal falls in an arid to very arid region (rainfall is less than 200 mm) where as the remaining half falls in the semi-arid zone (rain fall is 200-500 mm). About one third of the Thal desert has irrigation facilities. The Chagi-Kharan desert is located in Balochistan. The climate of the desert is dry the mean annual rainfall is 127 mm. The maximum rainfall occurs during January – March. The mean annual maximum and minimum

temperatures are 29.8°C and 16.6° C respectively. In deserts, rainwater harvesting can be operated by suitable catchments for domestic uses, livestock and to sustain wildlife, forestation and crops.

Variance in Climate

Abnormality to cool water of the eastern tropical Pacific Ocean occurs every few years, as these normally cool waters of the eastern tropical Pacific become uncommonly warm in a phenomenon called El Nino. During the El Nino years the weather pattern of the world is disturbed: flooding rains can strike one part of the globe, while unusual drought may occur in other parts of the world. (Water Encyclopedia, 2005: 43-44) Every few years, due to the warmer surface of Pacific Ocean, a severe effect on the weather in many parts of the world is recorded. (Oxford Advanced Learner's Dictionary, 2005)

During El Nino years, anomalous warm and fresh surface water is carried hundreds of kilometers further south. The sea surfaces high temperature persists for over a year. El Nino is also known to be associated with climatic uncertainties in distant areas of the world. The Southern Oscillation is an atmospheric counterpart to El-Nino. Atmospheric and oceanic circulations play an important role in climate change (Berlage, 1957: 152). During 1997, the sea surface temperatures in tropical Pacific were 5°C (9°F) higher than the routine temperatures. These weather phenomena have been occurring for thousands of years.

The El-Nino and Southern Oscillation (ENSO) are highly interactive. Many climatic implications due to ENSO in tropical, extra tropical and many remote areas are documented, although causes of the ENSO mechanism's development are not well-understood.

A Cold sea surface temperature anomaly is La Nina The phenomenon of cooling of the water in the central and eastern

Pacific that happen every few years and affect the weather in many parts of the world is described as La Nina. (Oxford Advanced Learner's Dictionary, 2005)

Climate Change

Effect on Water Resources

The crisis due to the development of Water resources may have resulted partly due to climate change and partly due to mismanagement of the water resources by the concerned authorities. Global warming, ozone depletion, loss of tropical forests and marine life is believed to be dangerous just like a nuclear danger. The depletion of the ozone layer is raising temperatures in different parts of the world. This in turn would cause a severe drought in the hotter areas of the world as evaporation would enhance due to additional heat. Thus, the hot arid areas would become ultra arid. (Mastoor, 2008: 95-102) Peterson and Klepper (2003) state that the climate changes will affect precipitation which in turn will affect water resources and the demand for water. Scientists were of the point of view that weather change would not exert a major affect on the hydrological cycle. However, small changes in climate in recent years reveal a significant affect on the water resources in some parts of the world. The major cause of weather changes is the sun, although other factors include man-induced effects, increasing green-house gases, aerosols and geographical events, like volcanic activity.

Climate changes would affect precipitation and run-off. Due to a rise in temperature, evaporation would be enhanced which in turn increase precipitation to balance the moisture as water vapour would not stay in atmosphere more than ten days. These changes would further enhance spring glacier melting on the one hand, and on the other, in mountainous areas rain fall would increase the snow fall. At the same time, the snowfall period be shortened with an increase in runoff. The areas with lower

moisture in the soil, due to enhanced evaporation would be converted to more dry regions. Hence drought occurrence would increase in these arid and ultra-arid areas. In the arid and semi arid regions of the world even smaller changes in climate would affect water supply enormously. (Khan and Imtiaz, 2002: 13-14)

Wrapping up

The Kyoto Protocol is an international agreement adopted in December 1997 in Japan. The protocol sets binding targets for developed countries for addressing global warming. The countries are required to specifically reduce greenhouse gas emissions.

In the future global warming poses a threat to the survival of mankind. During the coming decades, frequent extreme climate would be observed. Kofi Annan, then UN Secretary General, on 15th November 2006, addressed Climate Change Conference in Nairobi:

“Climate change is not just an environmental issue, as too many people still believe. It is and all encompassing threat. It is a threat to health, since a warmer world is one in which infectious disease such as malaria and yellow fever will spread further and faster. It could imperil the world’s food supply, as rising temperatures and prolonged drought render fertile areas unfit for grazing or crops. It could endanger the very ground on which nearly half the world population live coastal cities such as Lagos or Cape Town, which face inundation from sea levels rising as a result of melting icecaps and glaciers.” (Annan, 2006)

Flood waters and spring waters development may contribute to 40BCM (32.64MAF) as additional use in a water-scarce environment with variable precipitation. Still, hill torrents have a 23 BCM (18.76MAF) potential in all the four provinces of Pakistan. Small dams, rechargeable dams and delay action dams can play better role in changing climate. Overuse of water in agriculture is one of the major problems in Pakistan. The

productivity of water in Pakistan is counted as one of the lowest in the world.

CICERO (2000) projects 0.9°C increase in temperature by 2020, by 2050 it would double, 1.8° C. The CSIRO9 model predicts 17% increase in wet summer spell in South Asia. (Wigley and Jones, 1985:149-152) showed that a little change in precipitation could affect water supplies considerably.

The Sea level rise may affect 1000km long coastline of the country. The National Institute of Oceanography (NIO) shows 1.1mm/year sea level rise along the coast, compatible with global sea level rise. Impacts on the Indus Deltaic by climate change and water development are expected both ways, positive and negative. High inundation of coastal areas is expected. The rise in Sea level will cause the penetration of salt-water further upstream and inland. Cyclone intensity and frequency has been on the rise since 1992.

The actual requirement of crop water is ignored by farmers. It aggravates prevailing scarcity of water but this also increases water logging and salinity. This has led to reduction of crop yield overall to 25% but Sind yield has fallen to 40% to 60%. Sustainable groundwater management is essential. Use of waste water for agriculture, estimated 4.5BCM (3.67MAF)/year must be used for augmenting the water resources. (Mirza and Ahmad Eds, 2005:206-224)

Important socio-economic impacts on local, regional and national scale have been observed due to variation in summer monsoon. Rainfall affects all parts of society. Fast melting of the Himalayan Mountain glaciers would reduce river flows in the long run. Although in near future surplus water may be available due to glacier melt. As the country is arid to semiarid any significant change in climate can disturb the highly populated society. Serious consideration to evaluate different type of researches already

available to combat the water crisis aggravated due to climate change. No doubt climate change is global worry but we also need to make efforts for alleviation of impact of these change sufferings. On the other hand implementation of different solutions to save our economy and agriculture is certain. Multipurpose storages should be developed at the topmost priority. A Colossal campaign at public level for the consensus of construction of controversial dams and canal network should be initiated without any delay. As the precipitation pattern is going to change promptly, glacier melt flow is going to be substituted by excessive rainfall. This also demands to change cropping pattern along with cropping substitution. This is not the mere impact of climate change on water: rather it is a question for survival of the Pakistan. Let all of us join hands in this struggle.

References

- Akram.M.Abdullah; M, Khan et al (1995) Rehabilitation of Cholistan Desertified Lands for Sustainable Production In: Proceedings of the Sixth All Pakistan Geographical Conference, 26-29 Dec 1993, at Department of Geography Islamic University, Bahawalpur,
- Anandeshwari (1995) 'Indian Climatology' A.P.H Publishing Corporation News Delhi.
- Berlarge, H.P.(1957) "Fluctuation of the General Atmospheric Circulation of More Than One Year: Their Nature And Prognostic Value" ,K.Ned. Meteol.Inst. Meded verh, 69, In: Pant G. B and Kumar K. Rupa, 1997. 'Climate of South Asia', John Wiley and Sons Publishers, England PP 46.
- Chaudry Q.Z, (1994) 'Pakistan summer monsoon rainfall association with global and regional circulation feature

and seasonal prediction' Proceedings of the International Variability and Prediction. Trieste, Italy May 9-13, 1994.

Daily *Jhang* Lahore 22nd November 2010.

Dawn 14th July 2010.

IPCC (007) 'Climate Change 2007: The Physical Science Basis', Summary for Policy Makers, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel (IPCC) on Climate Change, February 2007. <http://www.ipcc.ch>.

Jacobson, Mark Z., (2002). 'Atmospheric Pollution', Cambridge University Press.

Khan Hameed Ahmad . and Ahmad Imtiaz . (2002) 'Water the Global Picture' In: Water and New Technologies, Global Change Impact Studies Centre, Islamabad.

Kheli Tahir (1997) 'Encyclopedia of European and Asian Regional Geology', Eds (Eldridge M Moores and Rhodes W. Fairbridge, Chapman and Hall, U.K..

Annan Kofi (2006)'Frightening Lack of Leadership on Climate Change', the UN Secretary General Kofi Annan's address to the Climate Change Conference, Nairobi , 15th November 2006, Secretary General SG/ SM/10739 ENV/DEV/904, Department of Public Information, News and Media Division, United Nations, New York.

Latif M. and Tariq A.(2006) 'Indus Basin Irrigation System Of Pakistan: A Food Engine 'Centre of Excellence In Water Resources,UET, Lahore.

- Mastoor Maryam (2008) 'Environmental Degradation : Focus On Water Scarcity In South Asia' Regional Studies, Vol XXVII, No. 1, Winter 2008-09.
- Mirza and Ahmad Eds (2005) Climate Change and Water Resources in South Asia.
- Mustafa, Malik Qasim (2007) 'Climate Change: No Longer A Distant Reality' Strategic Studies, Quarterly Journal of the Institute of Strategic Studies Islamabad.
- Oxford Advanced Learner's Dictionary (2005)
- Pant G. B and Kumar K. Rupa, 1997. 'Climate of South Asia', John Wiley and Sons Publishers, England
- Parry, Martin and Timothy Crator 1998, 'Climate impact and Adaptation Assessment', Earth scans publication, London In Sajjad Hussain Sajjad. 2004, 'Climatic Changes and its Impacts on South Asia' M. Phil Thesis (Unpublished) CSAS Punjab University Lahore.
- Parthasarthy, B, Monot, A.A. and Kothwale D.R. 1995. Monthly and Seasonal Rainfall Series for All-India Homogenous Regions and Metrological Sub-Division: 1871-1994. Research Report No. PR-065 Indian Institute of Tropical Meteorology, Pune.
- Peterson and Klepper, op. cit; UNESCO (2003); 'Water for People Water for Lives' The United Nations World Water Development Report, UNESCO Publishing, Berghen Book, Barcelona.
- Riaz Muhammad (2002) 'Meteorological Aspects of Drought and Water Resources.' National Symposium on Drought and Water Resources in Pakistan, 18th March 2002, CEWRE, Lahore]

Ruddiman William F. (2008) "Earth's climate, past and Future", W.H. Freeman and company, New York.

Sahi Aoun(2011) <http://www.thennews.com.pk/> July 22,2011

Sajjad Hussain Sajjad. 2004, 'Climatic Changes and its Impacts on South Asia' M. Phil Thesis (Unpublished) CSAS Punjab University, Lahore

Sethi Huma Naz (2007), 'The Environment of Pakistan', Peak Publishing London 2nd revised edition

The Cambridge Encyclopedia (1989) of South Asian Countries The Cambridge Encyclopedia (1989) of South Asian Countries.

Vivekanada Janani (2011) <http://www.chinadialogue.net/article> July 21,2011

Wigley, T. M. L. and Jones, P. D (1985) Influences of Precipitation Changes and Direct CO₂ Effects on Stream Flow. Nature 314.

Water Encyclopedia, vol 4 (2005) J.H. Lehr and Jack Keeley Eds, John Wiley and Sons Inc, New Jersey.