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Climate Change: A Review of the Current Trends and Major Environmental Effects

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Abstract: Among the many environmental issues that the earth is facing today, such as, population growth, increasing resource demand, unsustainable development and environmental pollution, climate change has been increasingly recognized as the most significant problem associated with changes in atmosphere being faced by humankind. Climatic changes have been occurring as a result of the warming of the globe, due to the accelerated release of greenhouse gases, principally carbon dioxide (CO_2), methane and nitrous oxide into the atmosphere from anthropogenic activities. The resulting impacts from deviations in the global climatic patterns are multiple and wide ranging. Changes in surface and ocean temperatures, cloud density, extreme weather events, glaciers melting and rise in the sea level, water quality and crop management practices have been widely attributed to both short-term and long-term changes in the climate. This review involves a critical discussion on climate change, its natural and anthropogenic causes, trends in climatic variables and its direct and indirect impact on glacier’s melting, weather events, hydrology and water quality, forest resources, agriculture production and biodiversity with particular focus on South Asia and Pakistan.

Key words: Climate change, Climate variables, Anthropogenic sources, Environmental impacts, Pakistan.

INTRODUCTION

The earth’s climate has warmed and cooled for millions of years, as observed from the historical temperature data of earth surface and oceans (Solomon, 2007). This natural warming and cooling of the climate is mainly the result of natural processes such as variation in solar irradiance, change in the Earth’s axial tilt, changes in the continent drifting and volcanic activity (Kondratyev and Cracknell, 1998; Rodo and Comin, 2003). However, the abrupt increase in earth’s mean temperature since the beginning of the 20th century, especially after the inception of industrial revolution led the scientists to relate the man-made emissions of carbon dioxide (CO_2) and other greenhouse gases for being the principal cause of contemporary climatic changes. This human-induced increase in temperature and the resulting climate change is either directly or indirectly causing the rising of sea levels around the world, frequent and uneven precipitation distribution, flash flooding, prolonged droughts, glacial melting, tropical cyclones, hurricanes, severe dust storms, dry and cold spells, have altered the availability of water and its quality, impacted the plants and land use pattern and many other environmental impacts (Alam and Rabbani, 2007) (Fig. 1). Changes in cloud cover, precipitation, soil moisture and atmospheric circulation are the main factors responsible for much of the rising trend differential globally and cause frequent heat waves, droughts, extreme precipitation events and related impacts, such as, wildfires, heat stress, vegetation changes and sea-level rise (Braganza *et al.*, 2004; Dai and Trenberth, 1999; Przybylak, 2000).

Observed global trends and contemporary status: Understanding of the past and future climate patterns is achieved by scientists, mainly using observations and theoretical models to match past climate data, make future projections, and link the causes and effects to the climate change. Temperature, ice cores, floral and faunal records, glacial and pre-glacial processes, oxygen isotopes and other sediment analyses, and sea level records are used globally to interpret the climate change. Mann and Jones (2003) showed the mean surface temperature over the past two millennia and reported that the warmth in late 20th century was unprecedented and attributed to the anthropogenic forcing of climate (Thorne *et al*.,

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2003). Since the late 19th century, average global surface temperatures have been recorded with an increase of approximately 0.6°C ± 0.2 (95% confidence interval). In the 20th century, an increase in temperature has been noted in two periods, from 1910 to1945 and 1976 to date (Jones, 2001). The warming rate from 1976 (0.17 °C/decade) was slightly higher, as compared to the period between 1910 and 1945 (Solomon, 2007). However, future forecasted increase in temperature is expected in the order of 1.4 °C to 5.8 °C over 21st century, if the current rate of greenhouse gases (GHG) emissions continues (Folland *et al*., 1999). On the other hand, changes in climate are already being observed with the last 60 years as the warmest in the past 1000 years (Wassmann and Dobermann, 2007). The most recent warming period is faster over land as compared to ocean's warming (Christy *et al.*, 2000).

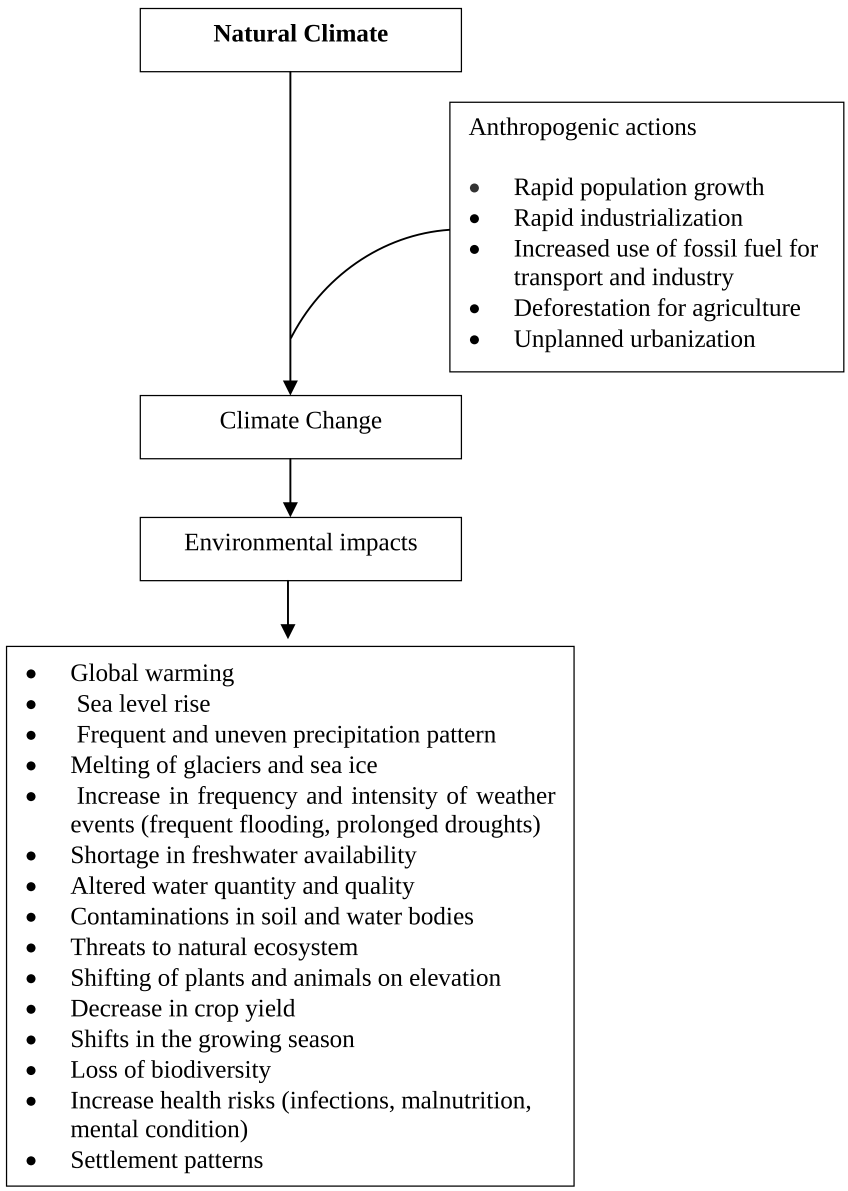

Fig 1: Climate change, causative anthropogenic actions and major environmental effects.

Since the start of the global mean temperature record from 1856, the decade between 2000-2010 has been recorded the warmest (Jones and Moberg, 2003). The data of the global temperature from December, 2004, through November, 2005, show that 2005 was the warmest year, followed by 2010, 2007 2003, 2002, 1998, 1997 (Solomon, 2007). The year 2005 shows a clear global warming trend of the last several decades by equaling the record warmth of 1998, without the occurrence of El Nino, which, in 1998, added extra heat from the ocean to the earth's surface (Hansen *et al.*, 2010). Similarly, recent findings from Global Climatologically Record from Climate Data Centre and National Oceanic and Atmospheric Administration (NOAA) and NASA showed that 2010 equaled 2005 as the earth warmest year on record over the last 131 years (instrumented monitoring stations date back to 1880). According to NOAA (2010), since 1876, there has been an increase in mean November and December temperatures by 2°C and 1.5°C, respectively. Mean humidity in December has also been increasing since 1950. Other studies, relevant to increasing temperature trend in the world as well as in the South Asia, are illustrated in Table 1.

Table 1: Significant temperature trend around the world.

Region/ Country	Significant trend	Source
Global	0.5 °C/100 years	(Easterling *et al*., 1997)
Global	0.3 °C/10 years in 54 years data	(Vose *et al.*, 2005)
Pakistan	0.5 °C to 1°C increase	(Muhammed *et al*., 2004)
Pakistan	0.133 °C/10 years (1976-2005)	(Shah, 2008)
Pakistan	0.64 °C increase from 1901-2007	(Afzaal *et al.*, 2009)
Himalayan region	Maximum temperature is more than minimum temperature	(Bhutiyani *et al*., 2010)
Eastern Himalayas	0.02 °C/Annum from 1977 to 2000	(Shrestha and Devkota, 2010)
Northeast Himalayas	+1.0 °C during winter and 1.1 °C during autumn over the last century	(Dash *et al*., 2007)
Turkey	1.1 °C/50 years	(Kadioğlu, 1997)
Bangladesh	0.61°C from 1961-1990.	(Islam *et al.*, 2008)
India	0.4 °C/100 years	(Kumar *et al.*, 1994)
India	0.25°C/decade	(Dash and Hunt, 2007)
Nepal	0.06 °C/17 years	(Shrestha *et al*., 1999)
Nepal	0.04 °C/30years	(Shrestha, 2005)
Bhutan	0.5 °C from 1985-2002	(Tsering, 2003)
South eastern China	0.6 °C/Annum	(Zhou *et al*., 2001)
Japan	Increasing incidences of daily maximum temperature >35°C, decrease in extremely low temperature	(Kawahara and Yamazaki, 1999)
West China	0.01-0.04 °C/year in 41 years	(Yunling and Yiping, 2005)
South-East Asia	Increase in hot days and warm nights and decrease in cold days and nights between 1961 and 1998	(Cruz *et al*., 2007; Manton *et al*., 2001; Tran *et al.*, 2005)

CAUSES OF CLIMATE CHANGE

The present warming of the globe that causes climate change is chiefly attributed to changes in the concentrations of various gases in the atmosphere, which affect the earth radiation balance including carbon dioxide (CO_2), methane (CH_4), ozone (O_3), nitrogen oxides (N_2O) and chlorofluorocarbons (CFCs). These gases are called greenhouse gases (GHG) as they trap heat in the atmosphere just as greenhouses used to grow plants trap sunlight to raise the heat inside. Sources of greenhouse gases in the atmosphere are mainly the combustion of fossil fuels (oil and natural gas) for industry and transport, rapid industrialization, fast growing population, deforestation for agriculture, unplanned urbanization and infrastructure developments. The level of these GHGs has been rising (Fig. 2) and the net result is a gradual increase in global warming (McCarthy, 2001). According to McCarthy (2001), the greenhouse effect, due to these gases, has been intensifying since the later part of the 20th century and global climate will remain warmer in the next decades of the 21st century (Karl *et al*., 2006; Trenberth, 1999). Particularly responsible is CO_2, whose level in the atmosphere has amplified, due to increase in use of fossil fuels. On the other hand, the destruction of natural vegetation has prevented the environment from restoring the balance.

Karl and Trenberth (1999) described that human induced actions are the dominant factors in recent global warming and if climate mitigation measures are not adopted at the right time, situation will become the worst in near future. For this purpose, the international response to mitigate climate change has been organized under United Nations Framework Convention on Climate Change (UN/FCCC), and in 1997, the first protocol for quantitative GHG emission reduction targets was signed (FCCC, 1997). The Intergovernmental Panel on Climate Change (IPCC) scientifically studied and assessed all aspects of global climate system and its interaction with atmosphere, land surfaces, oceans, glaciers, sea ice and ecosystem. The findings of these IPCC assessments have been arranged in authoritative reports in 1990, 1995, 2001 and 2007, and these reports are the primary source of the scientific information.

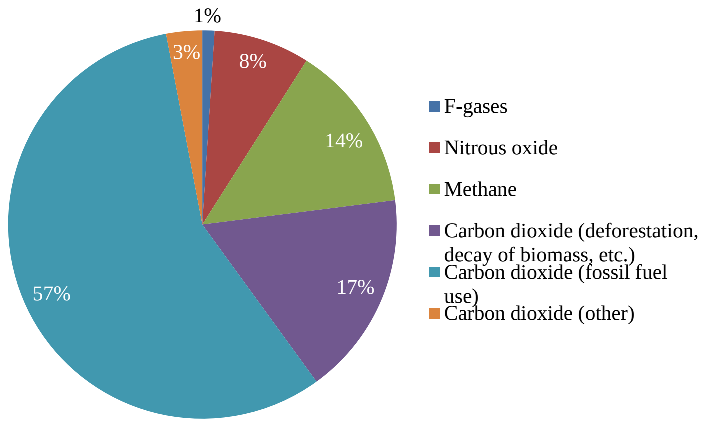

Fig 2: GHG and their increase level in percentage (Source: Solomon (2007); based on global emissions from 2004).

Global trend in GHG emissions: IPCC in its 1st report mentioned that the emission of GHGs is increasing and does not remain stable, due to increased energy consumption as a result of population growth and industrialization, especially in the developing countries. Further, significant increase in GHG level is expected, particularly, as developing countries became more industrialized. Based on present warming trends, World Energy Outlook (2010) report predicted a 53% increase in global energy demand by 2030, with 70% of that coming from developing countries that will subsequently result in further rise in temperature (Birol, 2010). Recent research revealed that these temperature trends are actually much higher than those thought previously. From the period of pre-industrial to the present era, the concentrations of GHGs are increasing by approximately 2.5 ppm per year. It is estimated that, if the world's GHG emissions remain at a level of 550 ppm at a minimum, there is a 63% chance the dangerous limit of 2 °C temperature increase will be exceeded till 2100 (Meinshausen *et al.*, 2009; Solomon, 2007; Stern *et al.*, 2006).

Changes in the concentration of GHGs, which occur both naturally and as a result of human activities, also influence Earth's climate. GHG emissions are increasing faster in developing countries as compared to the developed countries. According to the US government forecast, from 2003 to 2030, global emissions of CO_2 will rise up to 75% mainly from the fossil fuel burning in the developing countries. Though, United States is the world leading emitter of CO_2, countries, like China and India, will very soon surpass its limit that is only one-fourth and one-fourteenth, respectively, the level of America's per capita emissions. Member states of the European Union (EU) are trying to cut their greenhouse emissions, however, the same report reveals that GHG emissions from the US have increased by 15.8% from 1990 to 2004 (Rogge *et al.*, 2006).

Role of urban regions: Being home to more than three billion people, the cities are a major source of GHG. According to Re (2004), up to 80% of global GHGs are estimated to originate from urban areas. For instance, an increase in transport, the use of electricity for space heating and/or cooling, lighting and domestic appliances and industrial processes directly emit heat into the urban areas. At the same time, the increased surface roughness in cities hinders wind speeds, convective heat loss and evapo-transpiration, which can reduce air quality. China and India alone have more than a quarter of the world's urban population and the world's largest urban populations. Currently, about half of the world's population is living in urban areas. Even in Africa, which has long been considered a rural continent, close to 40% of the population is living in cities. Urbanization rate increases on an average 2% globally but it is higher in many developing countries. However, despite their lower levels of urbanization, less developed regions have more than double the numbers of urban dwellers than the more developed (2.3 billion vs. 0.9 billion). In Asia, windstorms and floods between 1996 and 2005 caused over 70,000 deaths and economic loss of around $190 billion, a large part of which could be attributed to the lack of adequate infrastructure (Dodman, 2009; Satterthwaite, 2008).

In addition, climate record of the globe is also affected by urbanization. Uncertainty in climate trends, particularly temperature trends, is revealed by the differences in observed temperature and the diurnal temperature range for large urban areas, smaller urban areas, and rural areas in China and Japan. In both these countries, the large urban areas are warmer than the smaller urban and rural areas.

Similarly, the diurnal temperature range (DTR) in large urban areas is smallest, as compared to the smaller urban areas and rural areas. A number of studies have examined the impact of urbanization in the climate record and arrived at the following conclusions. Approximately 0.1 °C warming is of the observed 0.6 °C since the late 1800s in the global temperature time series, due to urban warming (Easterling *et al*., 1997; Jones, 1994). Statistical data show that in the last century, global industrial growth enhanced nearly 50% with fourfold increase in the world population (Table 2).

Nearly 50% of the land pattern is changed due to human actions while the burning of fossil fuels has increased the concentration of CO_2 to a level that was not found in the last 4.2 million years (Hansen *et al*., 2008).

Table 2: Global proportion of the urban population increase.

Year	Urban population (Million)	Proportion (%)
1900	220	13
1950	732	29
2005	3200	49
2030	4900	60

Source: UN Population Division, 2010.

ENVIRONMENTAL IMPACTS

Rise in Sea level: Melting ice and thermal expansion of oceans are the key factors for sea level rise. Global observations at different locations reveal that an increase in global temperature is considerably causing seawater to expand and sea level to rise. Rise in sea levels was observed during the 20th century around the northern and southern Pacific Ocean, Indian Ocean and Caribbean Sea, however, the rise is not geographically uniform like warming of the land surface (UN-OHRILLS, 2009; Cruz *et al*., 2007). In the years 1961 and 2003, global sea level rose at an average rate of 1.8 mm per year, however, the rate was faster (about 3.1 mm per year) during 1993 to 2003 (Solomon, 2007; WMO, 2010). According to the IPCC 4th assessment projection, a mean of 0.4 m rise by the end of the Century excluding future changes in glacier melt are projected. In India and Pakistan, the current rise in sea level is reported to be about 1 mm per year since 1960. Bangladesh is particularly vulnerable with estimates of sea-level rise varying from 0.30 to 1.5 m by 2050 under alternative scenarios (Broactus, 1993). In addition, according to Nicholls and Misdorp (1993) about 13 million to 94 million people living near the coast are at an increased risk of flooding if sea level rises up-to 40 cm. Sea level rise may cause flash flooding, increase the salinity of inland waters, inundate low lying areas, drown wetlands and coastal marshes and erode beaches. Coastal areas of China, India, Bangladesh, Africa and the small islands (96%) are especially susceptible to increasing salinity of their water resources (UNEP, 2007). In addition, rising sea levels will also lead to salt water contamination of groundwater supplies, threatening the quality and quantity of freshwater supply. Since 1990, the IPCC has documented such changes as an evidence of global warming.

Melting of Arctic ice: Numerous studies have shown that Arctic summer ice is melting at an alarming rate than ever before due to the global warming. In a study, Stroeve *et al.* (2007) found that four out of five lowest years of sea ice coverage have occurred since 2002. A similar study on the decline of Arctic summer sea ice melt was done by Overpeck *et al.* (2005). They predicted that Arctic could be completely free of summer sea ice well before the end of this century. Records of past ice-sheet melting indicate that the rate of future melting and the related sea-level rise could be faster than the last century. Otto-Bliesner *et al.* (2006) reported that during the last interglacial period, approximately 130,000 to 127,000 years ago, sea level was 4 to 6 meters higher than today. Climate models project that the high northern latitudes will remain warmer than they were during the last interglacial period. Temperatures in the late 21st century would be warm enough to melt at least large portions of Greenland and West Antarctica. Millions of people would be vulnerable to flooding and displacement from the resulting rise of sea level, and the economic loss associated with coastal inundation. However, it is not just the ice system that is changing the changes in the permafrost or the permanently frozen ground also reflects a warming trend in the Arctic. Recent study of the National Centre for Atmospheric Research's Community Climate System Model (2006) projects that under GHG scenarios; there will be up to 80% decline in permafrost by the end of the 21st century (Collins *et al*., 2006).

Glaciers melting/retreating: Melting or advancing of inland glaciers is also occurring and would affect the land use patterns around the glacier. For instance, agriculture lands or herding near the glaciers, alter the habitat of animals and plants that have become adapted to surviving closer to the glacier (FAO, 2004). De Haen (2008) reported that large scale melting of mountain glaciers is occurring at the fastest rate.

Meanwhile, Kaser *et al.* (2004) reported that increased air temperature leads to govern the glacial melting in a direct manner in Kilimanjaro. The effect of global warming on the mountainous areas is most visible from the shrinkage of glaciers and reduction in reduced snow cover duration (Barry, 2001). There is some disagreement among the scientists that all glaciers of Himalaya-Karakorum-Hindukush region are retreating. According to the World Glacier Monitoring Service (2002), most of the world's mountain glaciers have been shrinking for the last 30 years, including the greater Himalayan and might disappear by 2035, as shown in Table 3 (Chaudhry and Rasul, 2007; Hasnain, 1999; Mastny, 2000; Rees and Collins, 2004; Shrestha, 2005).

Table 3: Observed rates of glacial retreat in different parts of the Himalayas.

Glacier and Region	Rate of retreat (m/yr)
Kashmir and Himachal (India)	
Barashigri, Chandan Basin of Eastern Lahul	44
Stock, Ladakh	6
Tajiwas Nar, Sindh basin of Kashmir	5
Fanfstang, Bhara basin of western Lahul	12
Garhwal (India)	
Trisul, Nanda Devi sanctuary	10
Betharti, Nanda Devi sanctuary	8
East Kamet	5
Gangotri, Bhagirathi Basin	15
Santopanth – Bhagirathi glaciers complex, Alaknanda	12
Kumaun (India)	
Milam, Gouri Ganga basin	13.5
Poting, Gouri Ganga basin	5
Shankalapa, Gouri Ganga basin	23
Sikkim (India)	
TistaKhangse, Tista Basin	8
Nepal	
Shorong region	2.7–2.3 (1978–1989)*
Khumbu region, 7 clean-type glaciers	30–60 (1998–2004)* 2.0–3.4 (1970s–1989)*
Exceptional rate in Nepal	71
Bhutan	
Luggye glacier	** 160

* Mean for the period, **This glacier is in contact with a large glacial lake

Source: (Bajracharya *et al.*, 2007; Fujita *et al.*, 1998; Mukhophadayay, 2006; Shrestha and Aryal, 2011)

Uneven precipitation pattern: Like the rising trend of global temperature in 21st century, no clear evidence with regard to a long-term change in the global precipitation has been found (Allen and Ingram, 2002; Karl and Trenberth, 2003; McCarthy, 2001). Recent studies show a rising trend of only 9 mm, which is approximately 0.98% per decade for 20th century (New *et al.*, 2001). However, the above mentioned increase has been observed over high latitude areas and tropical oceans with a decrease over tropical lands (Bosilovich *et al.*, 2005; Kumar *et al.*, 2004; New *et al.*, 2001). It is obvious that climate warming leads to increased moisture-holding capacity of air and cause changes in the characteristics of precipitation events, including their frequency, intensity, amount and duration (Karl and Knight, 1998; Trenberth, 1999; Treydte *et al.*, 2006). Other evidence for increasing precipitation rates are shown in Table 4.

Table 4: Significant rainfall trend all over the world.

Significant trend	Country/Region	Source
Upward	Japan	(Iwashima *et al.*, 1993)
Upward	Australia	(Suppiah, 2004)
Upward	South Africa	(Mason *et al.*, 1999)
Upward	China	(Zhai and Pan, 2003; Zhai *et al.*, 2005)
Downward trend in June, July and September and upward in August	India	(Guhathakurta and Rajeevan, 2008)
Upward trend in high latitude and downward in lower latitude	Whole Globe	(Zhang *et al.*, 2007)
Downward trend in coastal and hyper arid plains and upward in northern areas	Pakistan	(Solomon, 2007)
Upward	Himalayan region	(Chaudhry and Rasul, 2007)
Upward	Bangladesh	(Shahid, 2010)

Extreme weather events: The largest impacts of global warming mainly come from the incidence of the extreme weather events, such as heavy rainfall, severe storms, heat waves and droughts (Glasby, 2002). Extreme cold waves and record snowfalls were observed during winter season of 2009/2010 in Europe and U.S. In 2008, severe prolonged drought hit several states of the South America, such as, Argentina, Uruguay, Paraguay and southern Brazil, causing severe damage to agriculture, livestock and water resources. For most parts of the South America, it was observed as one of the driest years on record. Heavy rainfall in 2010 in China contributed to floods and landslides along with devastating mud/rockslide in the northwest of the country. Similarly, extreme precipitation events in West Africa have been observed in 2010, with the worst flooding in 50 years (WMO, 2010). However, by their very nature, extreme events are hard to study and predict precisely because they are relatively rare and can be influenced by local factors, such as, terrain and snow pack. Unfortunately, the increase in heavy rains would not necessarily make more water available for hydropower or irrigation because natural and engineered reservoirs are greatly affected by severe storms. Moreover, both the Northwest and the Gulf Coast would also see an increase in the number of dry days (Diffenbaugh *et al.*, 2005). In a Special Report (Nakicenovic and Swart, 2000), it is estimated that on Emission Scenarios (SRES), that 120 million to 1.2 billion people will experience an increased water stress by 2020s, and by 2050s, the number will increase to 185 to 981 million people. New evidence on recent trends, particularly, on the increasing tendency in the intensity and frequency of extreme weather events are more evident in Asia in the 21st century. For instance, a decline in summer precipitation was observed over the central parts of the arid and semi-arid Asia leading to the expansion of deserts and periodic severe water stress conditions. Increased rainfall intensity, particularly during the summer, monsoon could increase flood prone areas in temperate and tropical Asia. In South-East Asia, extreme weather events associated with El-Nino were reported to be more frequent and intense in the past 20 years.

Significantly, longer heat wave duration has been observed in many countries of Asia, as indicated by pronounced warming trends and several cases of severe heat waves (Cruz *et al*., 2007; Ryoo *et al.*, 2004; Tran *et al*., 2005). Generally, the frequency of occurrence of more intense rainfall events in many parts of Asia has increased, causing severe floods, landslides, and debris and mud flows, while the number of rainy days and total annual amount of precipitation has decreased (Gruza and Rankova, 2004; Rosenzweig *et al*., 2007; Shrestha *et al*., 2000; Zhai and Pan, 2003). However, there are reports that the frequency of extreme rainfall in some countries has shown a decreasing tendency (Adams *et al*., 1997; Kanae *et al*., 2004; Manton *et al*., 2001).

Increasing frequency and intensity of droughts in many parts of Asia are attributed, mainly to a rise in temperature, particularly, during summer and drier months of the year (Batima *et al.*, 2005; Gruza and Rankova, 2004; Lal, 2003; Natsagdorj *et al.*, 2005). A study, conducted by Lal (2003), indicates that the frequency and intensity of tropical cyclones originating from the Pacific Ocean have increased over the last few decades, while, cyclones originating from the Bay of Bengal and Arabian Sea have been noted to decrease since 1970, however, their intensity has increased. In both cases, the damage caused by intense cyclones has risen significantly in the affected countries, particularly, India, China, Philippines, Japan, Vietnam and Cambodia, Iran, Bangladesh and Tibetan Plateau (ABI, 2005; Jose, 2001). About 80% of Bangladesh is prone to floods and every year, at least one-third of the country's territory is affected (Chowdhury, 2000). Recently, abnormal weather behavior caused extreme events in Pakistan. About 40% of the people are highly prone to frequent multiple disasters with variations in rainfall patterns, storms, floods and drought (McElhinney, 2011). Beside these, weather related disasters hit the countries regularly like cyclones, hurricanes (Katrina and Nargis), heat waves, super floods, droughts and intense rainfall. According to the Annual Disaster Statistical Review (2007) report, Pakistan loses nearly $4.5 billion annually due to environmental disasters (Scheuren *et al*., 2007).

Severe rainfall events: According to US global change research, the warmer temperatures are likely to increase evaporation from land surfaces and cause severe rain events. Increased rain events are responsible for an increase in surface runoff. An increase in precipitation of 1-5% per decade in the mid/high latitudes of the Northern Hemisphere, has also been observed during 20th century (IPCC, 2001). An analysis of heavy rainfall events indicates a probability of over 90% that a 2-4% increase in frequency has occurred during the past 50 years in the Northern Hemisphere (IPCC, 2001). Liu *et al.* (2005) analyzed heavy precipitation events in China during 1960-2000. Although a total rainy days trend was observed negative. For India, Ryoo *et al*. (2004) found about two thirds of increasing trend for precipitation extremes during a study period from 1910 to 2000 and also observed some regions with significant increase and decrease across India. Brunetti *et al.* (2001) investigated the precipitation pattern (intensity and extreme events) for about seven stations located in the north-eastern Italy for the period 1998-1920. They found a negative trend in the number of wet days associated with an increase in the number of heavy rainfall events to total precipitation.

Floods and prolonged droughts: According to climatologists, temporal and spatial variability in extreme weather events like both floods and droughts have increased. In South Africa, Latin America, the Mediterranean, and some parts of South Asia, an increase in temperature may also induce a prolonged drought which along with anthropogenic factors cause deforestation, weathering and soil erosion (UNEP, 2007). More intense and longer droughts have been observed since 1970s, particularly, in tropical and subtropical regions (IPCC, 2001). One effect of the rising temperatures that are expected in the next century is that the atmosphere's capacity to hold moisture will go up. For every 1°C increase in temperature, the water-holding capacity of the atmosphere rises 7%. The increased moisture in the atmosphere will lead to more intense precipitation events – even when the annual total amount of precipitation is slightly reduced. These changes in precipitation patterns are shown in Table 5. Over the past century, Eastern North America has gotten wetter, while Southern America and the Mediterranean have become drier. In the 21st century, the North eastern U.S. is expected to receive more precipitation, while the Southwest is expected to become even drier (Hall *et al.*, 2008). Similarly, unpredictable rainfall has been noted in Northern Europe, some parts of North, South and Central Asia. Cruz *et al*. (2007) reported that most of the regions of Asia like Eastern and the Southern parts will receive summer as well as intense winter precipitation with a greater probability in the intense precipitation frequency. In the northern part of Indian Ocean, the annual rainfall is likely to increase in winter season (December, January, and February), and around the Maldives in summer season (June- August), while the same decrease may occur in Mauritius in the same months of summer (IPCC, 2007). According to the IPCC (2001) report, it is estimated that although total rainfall increase may be smaller (1.0 - 3.4%) but its intensity will be slightly larger (Allen and Ingram, 2002). Recent studies, based on climate models and past observational records, predict a future increase in droughts in the south of Europe as a result of increased evapo-transpiration and a relatively slow decrease of rainfall and precipitation frequency (Kostopoulou and Jones, 2005; Vicente-Serrano and Cuadrat-Prats, 2007). IPCC (2001) report, about 0.3% average decrease in rainfall per decade for the subtropical land areas as opposed to tropical lands with 0.3% increase per decade (Houghton *et al.*, 2001). Similarly, many parts of Europe and East Asia showed a positive trend in the annual maximum consecutive days having rainfall below 1.0 mm and a negative trend in the number of rainy days during 1950-1995 (Kiktev *et al.*, 2003). The results of Kiktev *et al*. (2003) were found relevant with the research conducted on the Mediterranean areas by Trigo, Davies, and Bigg (2000) and Alpert *et al*. (2002) during 1951-1995. Their findings focused on the Mediterranean areas, indicate a larger frequency of drought periods, with associated impacts on agriculture, water resources and socio-economic activities. Decreasing trends in annual mean rainfall are observed in Russia, North-East and North China, coastal belts and most parts of North-East India, Indonesia, Philippines and some areas in Japan. Annual mean rainfall exhibits an increasing trend in Western China, South-Eastern coast of China, Arabian Peninsula, Bangladesh and along the western coasts of the Philippines (Solomon, 2007). Liu *et al*. (2005) analyzed heavy precipitation events in China during (1960-2000). They found only 2% increase in the total precipitation and 5% increase in total extreme precipitation events at 95% confidence interval.

Threats to biodiversity: According to (Hanski, 2005; Loh, 2002), there has been a loss of 37% in biodiversity globally from 1970 to 2000. This study, concluded climate change as one of the main driving forces for the decline in biodiversity. Documented extinction rates for the last 400 years through geological time scale include 58 mammals and 115 birds (Groombridge, 1992; Institute, 1995). Cruz *et al*. (2007) reported that in Asia, approximately 50% of the region's total biodiversity is at threat and is becoming almost extinct due to change in temperature. He estimated that in China, 105 to 1522 plant species and 5 to 77 vertebrates and in Indo-Burma about 133 to 2,835 plants and 10 to 213 vertebrates would be extinct by the end of the century.

Forest resources: Warming of the globe has also influenced the forest resources and altered biomass production and its quality. Warming may considerably affect plants carbon nitrogen ratio, biomass production, yields, root morphology, shoots morphology, soil nutrients uptake etc. High CO_2 level in the atmosphere may affect plant responses to different limiting factors including water, light, nutrient availability. For instance, a mild change may result in vegetation stress, rapid plant loss and desertification in certain circumstances (McDowell *et al*., 2008). In non-temperate climates, climatic warming may enhance the ability of present day forests to withstand these changes (Table 6). According to Siddiqui *et al.* (1999), a change of 3 °C can lead to an elevation shift of forests of about 500 m, and even though species have the ability to adapt warming since the last Ice Age about 10,000 years ago, the predicted change (2.5 °C for a doubling of CO_2) is very high and will exceed their rate of "migration" to keep up. A rate of change of 0.01 °C is a threshold value for survival of many species (Siddiqui *et al*., 1999).

Impact on crop yield: Short and long term climate change is also leading to changes in crop yield and crop management practices and techniques. Temperature variations greatly affect albedo, soil quality and humidity variations (Bonan, 2002).

Crop yield at mid to high latitudes may increase for low level change in temperature, but will decline at higher level change in temperature. Bruce *et al*.

(1999) studied impact of global climate change on agriculture yield and noticed that direct impact of the increase in temperature causes a shortening or elongation of growing season, change in duration and intensity of precipitation, water and soil quality, and extreme weather events, while indirect impacts may result in excessive rate of soil erosion. Seshu and Cady (1984) estimated a decrease in crop yield of 0.71 tons/ha, 0.42 tons/ha and 0.04 tons/ha with a temperature increase from 18 °C to 19 °C, 22 °C to 23 °C and 27 °C to 28 °C, respectively. According to Pakistan Agricultural Research Council (2003) Report, temperature increase in winter months (December to March) have negative impacts on the big grain crops, sugarcane and fruits (Shah, 2008). Moreover, the production volume and quality have also been adversely affected because of changes in reproductive periods (Spring/late winter season), irrigation water requirements and its supply, altering soil characteristics, and increasing the risk of pests and diseases (TFCC, 2010). Beside the adverse effects of climate change, some of them are likely to be beneficial. In middle to high latitudes, there may be an increase in agricultural productivity, depending on crop type, growing season, changes in temperature regimes and the seasonality of precipitation (Breshears *et al.*, 2008; Lucier *et al*., 2009; Perry *et al.*, 1990; Rosenzweig *et al*., 2007; Watson *et al.*, 1998). In these areas, temperature increase can enhance crop growth by allowing earlier planting of crops in the spring, faster maturation, earlier harvesting and carbon sequestration potential (Rosenzweig and Hillel, 1995). All these phenological changes were observed in oak (Bauer *et al*., 2010), apple and pears (Blanke and Kunz, 2009) and a range of 29 Mediterranean species (Gordo and Sanz, 2010).

Table 5: Severe rainfall events and flood & drought episodes in different countries.

Region	Event	Reference
Pakistan	Super flood in 2010 after heavy monsoon rainfall in over eighty years. An estimated 2000 people died and over 700,000 houses were damaged or destroyed. Worst drought hitting the country during the period 1998-2001	Faisal *et al.*, 2013.
South Asia	50% of droughts associated with El Niño; consecutive droughts in 1999 and 2000 in Pakistan and N-W India led to sharp decline in water tables; consecutive droughts between 2000 and 2002 caused crop failures, mass starvation and affected ~11 million people in Orissa; droughts in N-E India during summer monsoon of 2006	Lal, 2003; Webster *et al*., 1998.
South Asia	Serious and recurrent floods in Bangladesh, Nepal and north-east states of India during 2002, 2003 and 2004; a record 944 mm of rainfall in Mumbai, India on 26th to 27th July. Floods in Surat, Barmer and in Srinagar during summer monsoon season of 2006; 17 May 2003 floods in southern province of Sri Lanka were triggered by 730 mm rain	Francis and Gadgil, 2010.
China	Increase in area affected by drought has exceeded 6.7 Mha since 2000 in Beijing, Hebei Province, Shanxi Province, Inner Mongolia and North China; increase in dust storm affected area	Chen *et al.*, 2005; Zhou *et al*., 2001.
China	Floods in Changjiang river in past decade; more frequent floods in North-East China since 1990s; more intense summer rains in East China; severe flood in 1999; seven-fold increase in frequency of floods since 1950s	Zhai and Pan, 2003; Zhai *et al*., 1999; Zhai *et al*., 2005.
Russia	Increase in heavy rains in western Russia and decrease in Siberia; increase in number of days with more than 10 mm rain; 50 to 70% increase in surface runoff in Siberia	Gruza and Rankova, 2004; Izrael and Anokhin, 2001; Ruosteenoja *et al.*, 2003.
Russia	Decreasing rain and increasing temperature by over 1°C causing droughts; 27 major droughts in 20th century have been reported	Golubev and Dronin, 2003; Izrael and Sirotenko, 2003.
Japan	Increasing frequency of extreme rains in past 100 years attributed to frontal systems and typhoons; serious flood in 2004 due to heavy rains brought by 10 typhoons; increase in maximum rainfall during 1961 to 2000 based on records from 120 stations	Kajiwara *et al.*, 2003; Kawahara and Yamazaki, 1999.
South-East Asia	Increased occurrence of extreme rains causing flash floods in Vietnam; landslides and floods in 1990 and 2004 in the Philippines, and floods in Cambodia in 2000	Cruz *et al*., 2007; Food and Organization, 2004; Tran *et al*., 2005.
Mongolia	Increase in frequency and intensity of droughts in recent years; droughts in 1999 to 2002 affected 70% of grassland and killed 12 million livestock	Batima, 2003; Natsagdorj *et al*., 2005.

Source: IPCC, 2007.

Table 6: Different types of forest and potential impact of climate change.

Forest type	Effect	Region	Reference
Alpine forest	Mean annual temperature increase of 1-1.5 °C over the last 100 years	Australian and Swiss Alps	Grabherr *et al.*, 2009.
Alpine forest	Summer drought stress	Yellowstone National Park, USA	Romme and Turner, 1991.
Riverian wetlands	Mean July temperature increase almost 4 °C	Mississippi River, USA	Janzen, 1994.
Coastal mangroves	Sea level rise up to 9-12cm per century. In 1980, 3.6 million hectares of mangroves have been lost, equivalent to a 20% global reduction	Pacific, Indian and Atlantic oceans	Hamilton, 2008; Smith and Buddemeier, 1992.
Temperate forest	Wildfire and prolonged droughts	UK and USA	Clinton *et al.*, 1993; Nilsson and Pitt, 2013.
Arctic alpine	Winter temperature increase upto 4 °C or more	Norway	Holten, 1993.
Rainforest	Deforestation and fires degraded upto 55% Amazon rainforest	Amazon	Aragao *et al*., 2008; Nepstad *et al.*, 2008.
Tropical rainforest	Deforestation, high CO_2 saturation level	Africa, Asia, Pacific and the tropical countries of Latin America, Amazon	Clark *et al.*, 2003; Feeley *et al.*, 2007; Hamilton, 2008; Malhi *et al.*, 2008; Mayle and Power, 2008.

Source: (Markham, 1996)

Increased duration of wild fire: Studies have shown that in North Asia, an increase of 1 °C in average temperature may increase the duration of wild fire season by 30 times (Cruz *et al*., 2007), which may cause various adverse consequences on key forest ecosystem functions, including structure and composition of soil, outbreaks of pest, loss of biodiversity, species habitat quality and prevalence of diseases. Wildfires in the western United States have been recorded increasingly over the past few decades, but the extent of these changes had never been analyzed until recently. Westerling and Bryant (2008) found that a four time increase in the number of western wildfires and 6.5 times as much area burned in 2003, as compared to 1987, has been recorded. The wildfire of 1987 was recorded to be devastating more than that of 1970. The length of wildfire season was observed 78 days. The average burn duration for large wildfire was observed to vary 7.5 to 37.1 days over the same time period. They concluded that wildfire in United States is primarily due to changes in climate that specifically increases in spring and summer temperatures and earlier spring snowmelt.

Water supply and quality: Changing climate has been widely recognized to significantly impact the availability of water, as well as the quality and quantity of water. Reduced rainfall and increasing temperatures may further lead to reduce the availability of water supply including smaller flows in springs, rivers and underground levels. An increasing trend in temperature and its association with precipitation can induce stress in hydrological cycle, resulting in dryer and wetter rainy seasons, and subsequently enhance the risks of more extreme flash floods and droughts. Melting glaciers will increase flood risk during the rain season, and reduce the dry-season water supplies to one-sixths of the world's population (Heinberg, 2013).

Many of the world's countries are already struggling for the availability of fresh water supply for drinking, municipal, agricultural and industrial purposes (Table 7). Irrigation demand, industrial pollution and sewerage will put pressure on existing water resources and all these will be significantly intensified by climate change. According to the World Bank (2006) report, Pakistan is among 17 countries that are already facing water shortage and is among the 36 countries where there is a serious threat of food crisis.

Table 7: Per capita water-availability in different countries (m^3).

Country	1955	1990	2025
China	4,597	2,427	1,818
Mexico	11,396	4,226	2,597
Philippines	13,507	5,173	3,072
Iraq	18,441	6,029	2,356
USA	14,934	9,913	7,695
Pakistan	2,490	1,672	837

Source: (Engelman and LeRoy, 1993).

The quality of existing water supplies will also become a further concern in some regions of the globe. Water acquires most of its geochemical and biochemical properties during its cycling from clouds to rivers, through the biosphere, soils and geological layers. Changes in the amount or pattern of precipitation will change the route and residence time of water in the watershed, thereby affecting its quality. As a result, regardless of quantity, water could become unsuitable as a resource, if newly-acquired qualities make it unfit for the intended use (IPCC, 2007). For example, in areas with relatively high water tables, or under intensive irrigation, increased evaporation due to higher temperatures will raise the concentration of dissolved salts in water. Further, increased flooding may raise water tables to the point where agrochemicals and industrial wastes from soil may leach into the groundwater supply. Likewise, higher ocean levels will lead to salt water intrusion in coastal groundwater supplies, threatening the quality and quantity of freshwater access to large proportions of populations.

Economic and human losses: Over the last 30 years, South Asia has experienced more than 65,000 deaths and about a billion people have been affected by floods and landslides. This accounts for around 33% of all flood events in Asia. In 1998, the floods in India and Bangladesh caused over 2,600 deaths, displaced 25 million people, and caused an estimated US$ 3.4 billion of economic damage. In 2007, floods in India, Nepal, and Bangladesh caused more than 3,400 deaths, affected 30 million people, and caused an estimated US$ 5 billion of economic damage. The impact of floods can only rise as the population in floodplains grows and the value of infrastructure increases (Bajracharya *et al.*, 2008).

Health risk: Occurrence of extreme events, like outbreaks of flood, prolonged droughts, changes in surface temperature, decreasing water availability, intense rainfall, tropical cyclones and unexpected cold and heat waves, have been considered the widespread cause of diarrhoea and other infectious diseases, like cholera, Hepatitis, dengue fever, in South Asian countries, like India, China and Bangladesh (Ebi *et al.*, 2006; Haines *et al.*, 2000; Hajat *et al*., 2005; Shah, 2008; Takahashi *et al.*, 2007). According to a study by Adams *et al*. (1997), there are annually about 1200 deaths, due to cold and hot weather. Similarly, lower rainfall trend and other changes affect the agriculture, particularly, its interruption in food storage and supplies in sudden, acute events. Children in Africa born in drought years, for example, are significantly more likely to be malnourished or stunted. In Kenya, children are 50% more likely to be malnourished, and in Niger, 72% more likely to be stunted (Watkins, 2007). When children are malnourished, their vulnerability to infection is greatly increased and a vicious cycle results (Lechtig and Doyle, 1996). A chronically malnourished three or four year-old child may be at a permanent disadvantage, becoming both physically and mentally stunted (Grantham-McGregor *et al*., 2007).

CONCLUSION

Review of climate trends and different scenarios at global level revealed that climate change poses significant risks and vulnerabilities to environment in terms of certainty, urgency, and severity of impact, as well as the importance of the resources being affected. It is, however, essential to continue scientific research not only to further ascertain climate change but also on aspects of timing, frequency and intensity of the projected and perceived threats so as to be able to predict and mitigate hazardous events before they strike.

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