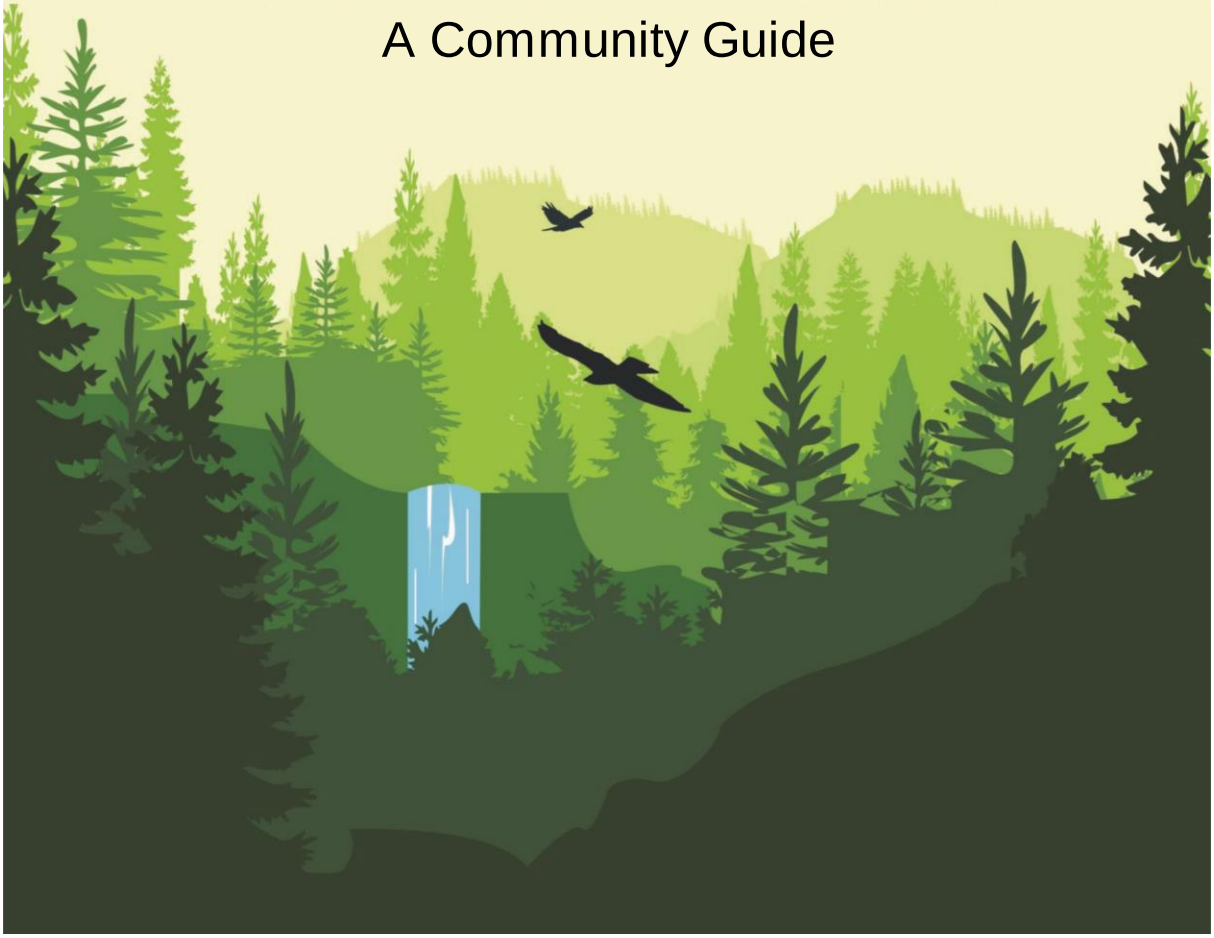
Ministry of Climate Change
Government of Pakistan

REDD+ Pakistan

CLIMATE CHANGE
AND
ROLE OF FORESTS

A Community Guide



DISCLAIMER

Pakistan Forest Institute makes its best effort to provide accurate and complete information while developing this document.

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Contents

ABBREVIATIONS

ACS	Additional Chief Secretary
ADP	Annual Development Plan
AJK	Azad Jammu Kashmir
AR4	Fourth Assessment Report of IPCC
AR5	Fifth Assessment Report of IPCC
BTTP	Billion Tree Tsunami Project
CBA	Cost-Benefit Analysis
CBO	Community Based Organisation
CITES	Convention on International Trade in Endangered Species
CO_2	Carbon Dioxide
COP	Conference of Parties
CPEC	China Pakistan Economic Corridor
EIA	Environmental Impact Assessment
EPA	Environment Protection Agency
ESMF	Environmental and Social Management Framework
FAO	Food and Agriculture Organization of the United Nations
FATA	Federally Administered Tribal Area
FCPF	Forest Carbon Partnership Facility
FGRM	Feedback and Grievance Redress Mechanism
FLEG	Forest Law Enforcement and Governance (under WB PROFOR)
FLEGT	Forest Law Enforcement, Governance and Trade (under EU)
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
GB	Gilgit-Baltistan
GEF	Global Environment Facility
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
AR4	Fourth Assessment Report
AR5	Fifth Assessment Report

PREFACE

Government of Pakistan signed Cancun Agreement in 2010 and took several measures for implementation at the national, provincial and district levels. Reducing Emissions form Deforestation and Forest Degradation (REDD+) process was initiated by Ministry of Climate Change, Government of Pakistan in 2010 with consultative workshops and awareness raising.

In 2013, Pakistan was selected as a REDD+ Country Participant in the Forest Carbon Partnership Facility (FCPF) of the World Bank. The participant Committee of the FCPF through its Resolution PC/16/2013/8 decided to allocate grant funding to Pakistan to enable it to move ahead with preparation for readiness. Pakistan received a grant of US $ 3.8 million during June 2015 under REDD+ Readiness Preparation Proposal (RPP). Under R-PP Pakistan is working on four main components i.e. (i) REDD+ Policy Analysis, (ii) REDD+ Technical Preparation, (iii) Readiness Management Arrangements and (iv) Designing and Testing REDD+ Payments for Environmental Services.

- The Pakistan Forest Institute, Peshawar Pakistan was awarded a study by the National REDD+ Office, Ministry of Climate Change for "Designing REDD+ Payment for Environmental Services" in the two selected ecosystems of the country in 2018. One of the main components of this consultancy was to prepare awareness raising material on Climate Change and Role of Forests: A Community Guide. This document is designed to educate and build the capacities of the forest communities of Pakistan about climate change and the role of forests.

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Ministry of Climate Change

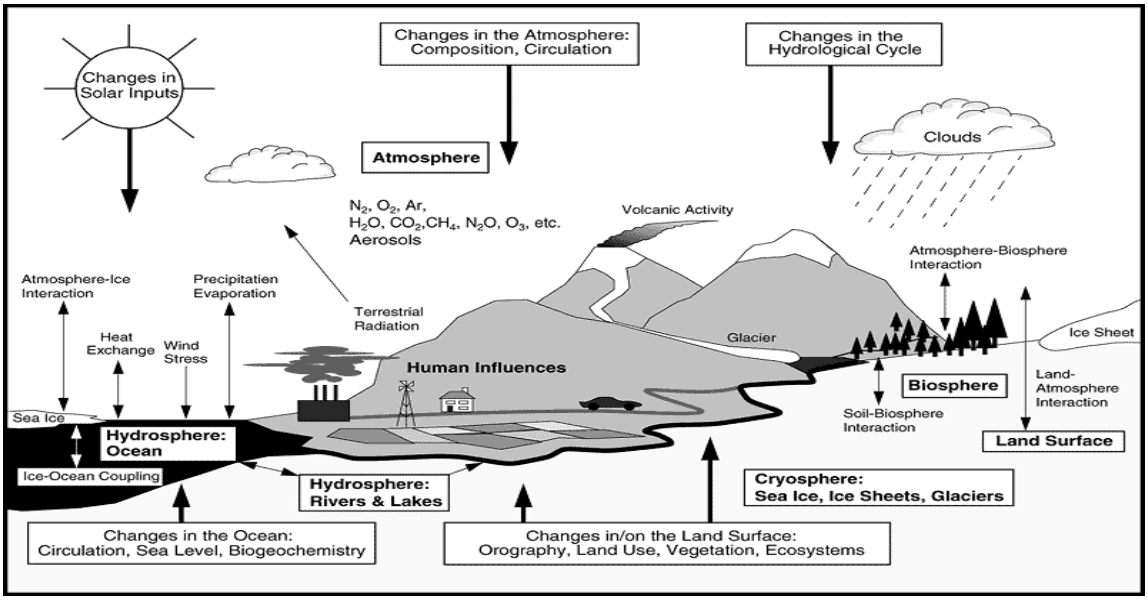
Chapter 1

EARTH'S CLIMATE SYSTEM AND CLIMATE CHANGE

1.1 Introduction

General weather conditions over a long period of time (usually 30 years) in an area are described as climate. Besides, the condition of the atmosphere over a short period of time (hours or days) at a particular place is defined as weather such as the state of heat, cloudiness, wetness, dryness, sunshine, wind and precipitation.

Climate helps us decide what clothes to buy and weather helps us decide what clothes to wear each day (Twain, 2017). Climatic conditions define various ecosystems and habitats around the world. Species and ecosystems respond to changing climatic conditions by adapting, migrating or shrinking population size. Climate and life have reciprocating relationship; climatic factors sustain life and living organisms regulate climate system under normal state of affairs. However, peculiar human activities (i.e. industrialization) are disturbing climate system and ecosystem balance leading to climate change. This climate system is driven by sun. Figure 1 demonstrates the interaction of key components of climate system.



Source: *IPCC (2001)*

Figure 1. Demonstration of the components of the Earth's climate system (bold), processes and connections (thin arrows) and some aspects that can change (bold arrows).

The climate of the Earth is a complex system comprising of five key components:

- Atmosphere (Gases)
- Biosphere (Vegetation)
- Cryosphere (Snow)
- Hydrosphere (Water)
- Lithosphere (Land)

1.1.1 What is Climate Change?

During last few decades, the two words "climate change" have become popular and captured attention of scientists. In simple words, climate change means a change that takes place in the normal climate of a region. The change in climatic patterns happening over many years is termed as climate change. This can be a change in a quantity and frequency of rainfall in a region. Or it can be a change in typical temperature of an area for a month or season. Or it might be a change in venue of rain and snowfall. Scientists across the globe have observed an increasing trend in the normal temperature of the Earth, this is called Global Warming. The global climate is not just warming but also resulting in a variety of severe weather incidents.

The change in the past climate is directly related to human activities. Humans are responsible for production of greenhouse gases and modifying composition of the atmosphere (UNFCCC, 2012). Human activities largely the industrial development and fossil fuel consumption by vehicles add greenhouse gases in the air. These gases largely include carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Ozone (O_3), Chlorofluorocarbons (CFCs) and Hydro-fluorocarbons (HCFCs).

Greenhouse gases contribute to the warming of our atmosphere because they have the capability to absorb infrared spectrum of sunlight. Once these gases are produced in the atmosphere, these remain stuck in the atmosphere for hundreds of years (WIRED, 2018).

1.2 Evidence: Past and Present

There is enormous evidence that the Earth's climate is changing. The scientific studies indicated that over the past century mean temperatures of the atmosphere and oceans have increased. The proof of climatic change includes:

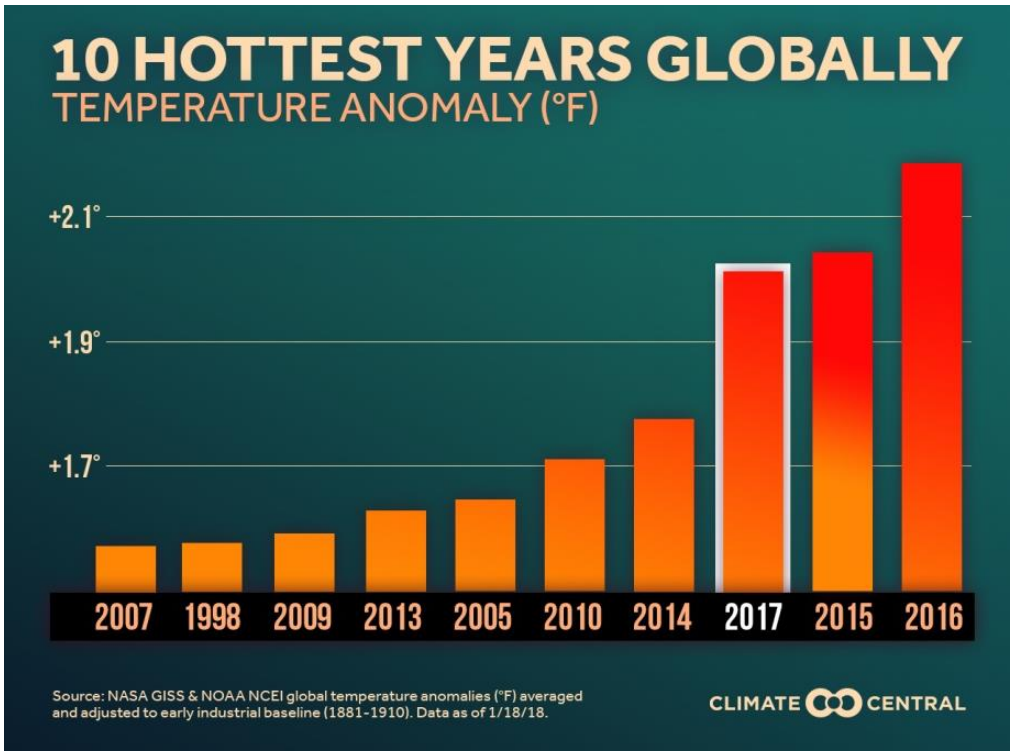
- Measurement of land temperature (historical records)
- Changes in the point of time and duration of lakes and rivers melting and freezing
- Decline in the extent of snow cover in Northern Hemisphere
- Reduction in glaciers cover
- Lengthy growth periods of plants
- Variations in stored heat in the oceans
- Alteration in intensity and frequency of droughts and floods

The biological changes observed comprised of:

- Adjustments in the natural extent of animal and plant species existence and distribution
- Adjustment in timing of life cycle events such as flowering, leaf-, unwrapping, bird relocation and egg-laying for some species (MOE NZ, 2018)

Increase in Global Temperature

Since the late 19th century, the increased greenhouse gas concentrations in the atmosphere have raised the Earth temperature by ~2ºF (1.1ºC) as shown in Figure 2. Climatic records indicated the last 17 years as the warmest years in the century. The warmest year in the Earth history was 2016 and eight months from January through September, were the warmest in the history with the exclusion of June (NOAA, 2018a; GISTEMP, 2018; NASA, 2017; Jones *et al*., 2012).



Source: *Climate Central (2018)*

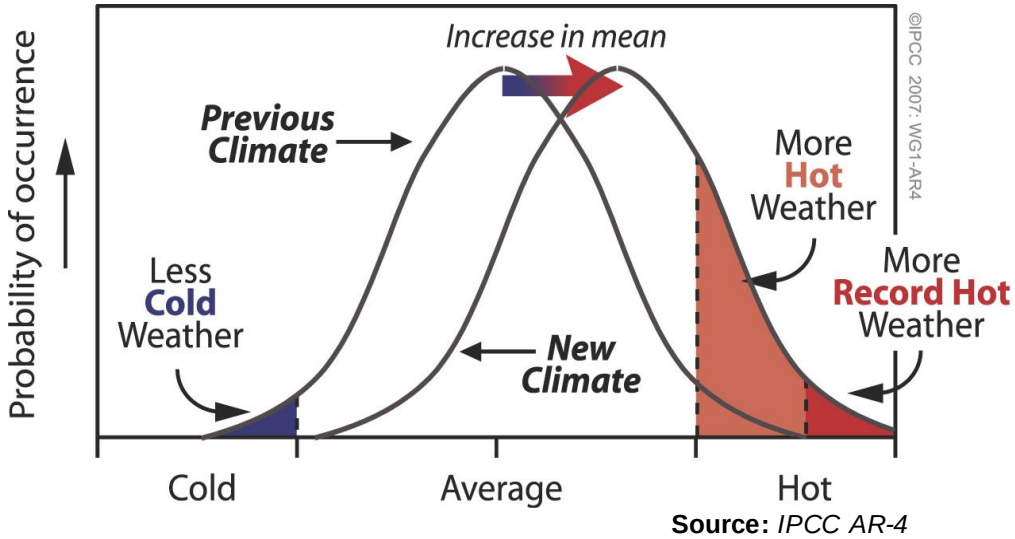
Figure 2. The historical records of ten hottest years of the Earth

Extreme Events

An upsurge in the intensity and occurrence of extreme weather occasions is one of the most visible consequences of global warming. IPCC's fifth assessment report (AR5) mentioned with high confidence that since ~1950, variations in extreme climate and weather have been detected. The frequency of occurrence of warm days and nights has risen whereas cold days and nights have lessened internationally. The occurrence of heat waves is greater than before in large parts of three continents e.g. Asia, Australia and Europe. There are many regions in the world where precipitation intensity has increased whereas decline in precipitation frequency has observed. The intensity of extreme weather events has tremendously increased in Europe and North America.

A minor increase in average temperature indicates to large changes in severe weather events. Large changes in weather happen when minor changes in the averages of many key climatic variables take place. A small change in the average

mean of temperature distribution, precipitation or other climate variables can result in substantial changes in the rate of recurrence and intensity of extreme events. Climate change modifies the probabilities for severe weather events as shown in Figure 3.



Source: *IPCC AR-4*

Figure 3. Demonstration of the effects on extreme temperatures with the increase in mean temperature for a normal distribution

The variations in the weather conditions can be illustrated with a bell type curve as shown in Figure 3. This means normal weather is very common while extreme weather is rare. While events close to normal occur regularly are shown in the broad centre of the curve. Further away from normal, a sudden decrease in the occurrence of the events, in the smoother ends of the curve can be seen. For instance, entire curve moves toward hotter high temperatures by a small increase in temperature. The rarest and most extreme heat events become even more severe and much more frequent. The similar theory applies for precipitation: lesser and medium intensity rains are being substituted by more heavy rains.

Threats to Human Health Due to Severe Weather

The extreme temperatures and fluctuations in precipitation as well as intensifying drought conditions have been increasing across the globe. Some evidence given below:

i. In July 2014, around 1.2 million people had to abandon their homes in China as 60 rivers started overflowing out of the banks.
ii. After an unusual dry summer, many wildfires fumed throughout the Pacific Northwest in North America, burning thousands of acres, making air smoky and raining ash around the region.
iii. During summer 2017, about 1200 people died due to floods across South Asia. United Nation reported that 41 million have been directly affected by floods and land sliding in India, Bangladesh and Nepal.
iv. About a thousand people died in Sierra Leone (a country in Western Africa) during August 2017 as a consequence of floods and land sliding.

v. Recently in Australia, a town has broken the past records of the highest temperature in the country. Birds Ville (Queensland, Australia) hit 42.5ºC on September 27, 2017.
vi. In, South Africa (Cape Town), sever famine is due to low water quantity in reservoirs. Different measures have been taken for storage of water in the city.
vii. Twenty two people were killed in Central America as Hurricane Nate settled over the region, hitting Nicaragua and Costa Rica particularly hard. Nate reached after two weeks of continual rain, causing mud slides and floods.

Ocean Acidification

Humans have triggered carbon dioxide emissions into the atmosphere since the start of the industrial uprising, the acidity of surface ocean waters has become greater than before by ~30% due to more carbon dioxide absorbed in the oceans. The quantity of CO_2 absorbed by the upper layer of the oceans is rising by two billion tons every year (Sabine *et al*., 2004; NOAA, 2018b).

Rise in Ocean Temperature

Our Earth is a water world. Five oceans of this planet cover ~71% of the Earth surface (World Atlas, 2018). Moreover, oceans contain ~97% of all the water on the Earth. In fact, the ocean controls whatever happens with our climate. Oceans absorb heat energy and disperse it more evenly around the Earth. Main role of the ocean is to take in CO_2. Oceans have more capacity to absorb heat compared to the atmosphere. About 80-90% of sun's heat is going to oceans (NASA, 2018b). The ocean acts like a sponge and absorb excess heat from the atmosphere. The upper few meters of the ocean stocks heat equal to Earth's entire atmosphere. Thus, as the Earth warms up, the ocean absorbs most of the extra energy. Therefore, if the ocean becomes overly warm, the animals and plants living inside the ocean either acclimatize or die.

In the ocean, animals inhale oxygen and exhale carbon dioxide. Similar to land plants, ocean plants absorb carbon dioxide and release oxygen. The ocean is enormous at extracting up CO_2 from the air. Oceans absorb about one fourth of the CO_2 that humans produce by burning fossil fuels such as coal, natural gas and petroleum products (NASA, 2018b).

However, the water becomes more acidic when the ocean absorbs greater amount of CO_2. Generally, alkaline pH (~8) of marine water is essential for survival of marine animals. The animals may not be able to develop strong shells if the water is too acidic. Corals (marine invertebrates) can also be affected due to this imbalance. Unfortunately, most of the excessive atmospheric heat has been absorbed within the upper ~700 meters (~2,300 feet) of ocean indicating a warming of 0.302 of since 1969 (Levitus *et al*., 2009).

Shrinking of Ice Sheets

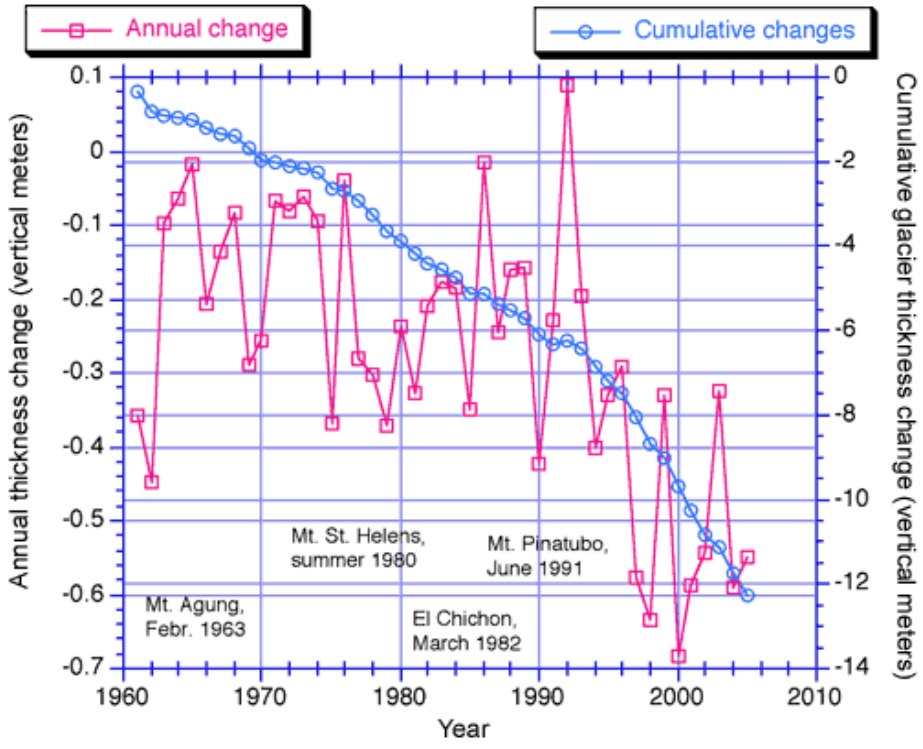
The mass of ice sheets have reduced in the world's largest island, Greenland (a country between the Arctic and Atlantic oceans) and Antarctic (polar region around the Earth's South Pole). A study by NASA for a period of 2002-06 indicated that

Greenland has reduced 150 to 250 cubic Kilometres of ice every year whereas Antarctica has lost annually ~152 cubic kilometres of ice during 2002-05 (NASA, 2007).

Glacial Melting

Glaciers are declining almost all over the world including in the Alps (in Europe the highest and most extensive mountain range), Himalayas, Andes (longest main land mountain range in the world beside the western edge of South America), Rockies (most important mountain range in western North America), Alaska USA and Africa. During last few decades both the magnitude and depth of Arctic sea ice has dropped quickly. Glaciers provide clues about the effects of global warming because of their sensitivity to temperature variability. The detection of 5,000 year old ice man that was preserved in European Alps glaciers astonished scientists around the world in 1991. Glaciers all over the World (with few exceptions) have retreated at exceptional rates during the last century. Some ice covers, glaciers, and ice shelves have vanished altogether. Some are disappearing so rapidly that they may disappear within few decades (Roe *et al*. 2017).

Average annual and cumulative glacier thickness changes overtime measured in vertical meters for a time span of 1961 to 2005 are shown in Figure 4. Glacier mass balance can also be affected by explosive volcanic eruptions, which contribute dust to the stratosphere and cool the Earth's climate. Four important eruptions with global impacts are shown in Figure 4. These are generally linked with episodes of increased mass due to dropped temperature.



Source: *NSIDC (2017)*

Figure 4. Global glacier thickness changes overtime

Glacier Retreat Occurs In the Karakorum Region

An exemption to the global trend of glacier departure happens in the Karakoram region of the western Himalaya known as the Karakoram irregularity, glaciers in this region are steady or even prolonged over the previous 150 years. The description for this uncommon trend may be regional weather conditions. Other Himalayan glaciers have experienced reduced snowfall and obtain most of their precipitation during the monsoon seasons during summer.

IPCC's Fourth Assessment Report released in 2007 indicated that Himalayan glaciers will probably melt as soon as year 2035. UNESCO also reported the catastrophic retreat of Himalayan glaciers up to 2035. Scientific investigations revealed that many Himalayan glaciers are disappearing at a fast pace, and above 80% of the glaciers in western China have left over during past decades. Most of the precipitation in Karakoram is being received from non-monsoonal winter-storms and the region mostly remains cool and dry during the summer time (Bagla, 2009; Fitzpatrick *et al*., 2010; Kapnick *et al*., 2014; NSIDC, 2017).

1.3 Causes of Climate Change

The temperature of the Earth hinges on the balance between how much energy from the sun arriving and leaving the Earth system. When incoming energy from the sun is more absorbed by the Earth system it starts warming. Earth avoids warming when the sun's energy is returned back into space. Earth becomes cool when absorbed energy is released back into space.

1.3.1 The Greenhouse Effect

What is Greenhouse?

A greenhouse is a chamber made of see-through glass. The walls and roof of this chamber is made of glass. Sunlight goes in through glass and warms up the inside environment. However, the heat energy inside the chamber cannot get away. Therefore, inside temperature of glass chamber is always higher than the outside and remains warm during winter season. This simple technique is very useful for growing summer vegetables and flowers during winter.

Mechanism of Greenhouse Effect

Earth's atmosphere acts like a greenhouse. Greenhouse gases in the atmosphere play a role of roof of the greenhouse. The surface of the Earth warms up during the day time with the availability of solar radiations. Whereas the surface of Earth cools down at night and releases the heat back into the air. However, some heat is locked by the greenhouse gases in the atmosphere. This process makes possible the life on the Earth. If there is no natural greenhouse effect, the average surface temperature would be very low (below freezing point of water) about -18ºC rather than the 15ºC on average found today. However, human activities, primarily the burning of fossil fuels, use of synthetic fertilizers, industrial processes and clearing of forests have greatly intensified the natural greenhouse effect triggering global warming.

The most plentiful gases in the atmosphere, nitrogen (78% of the atmosphere) and oxygen (21%) have no influence on greenhouse effect. Instead, the greenhouse effect comes from molecules that are more complex and less common. Water vapour is the extremely crucial greenhouse gas, and carbon dioxide is the second most important one. Ozone, methane, nitrous oxide and several other gases present in the atmosphere in lesser amounts also enhance the greenhouse effect. In the humid equatorial regions (areas near equator), where there is so much water vapours in the air that the greenhouse effect is very large, adding a small additional amount of CO_2 or water vapour has only a small direct impact on downward infrared radiation. However, in the cold dry Polar Regions (areas near North and South Pole), the effect of a small increase in CO_2 concentration or water vapour is much greater. The same is factual for the upper atmosphere where a small increase in water vapour has a larger influence on the greenhouse effect than the same change in water vapour would have close to the surface. Numerous components of the climate system, especially biosphere and hydrosphere, control atmospheric concentrations of greenhouse gases. A key example of this phenomenon is photosynthesis in plants.

Thousands years old climatic data collected by scientists were not readily available, researchers analysed glacier lengths, ice cores, tree rings, pollen remains and ocean sediments to obtain. This data displays that the climate system fluctuates naturally over time. Overall, natural causes explained climate changes earlier to the industrial uprising in the 1700s, such as natural changes in greenhouse gas concentrations, solar radiations and volcanic eruptions.

Scientific investigations specified that recent climate changes are not due to natural causes alone. However, scientists concluded with high confidence that human activities are the leading cause of global warming. The mechanism of global warming through greenhouse gases and its effect are shown in Figure 5.

Greenhouse Effect: Key Cause of Warming

Greenhouse gases act like an over-blanket; they retain heat near the surface of the Earth and avert the loss to the space. Earth surface absorbs shortwave solar radiations and discharges some of the energy back into the atmosphere in the form of infrared radiations. Greenhouse gases like water vapours (H_2O), carbon dioxide and methane absorb some of the reflecting infrared radiations. In this way, making the Earth warmer than it would otherwise be.

Greenhouse Effect: Customary Role

Over the past hundreds of years, carbon dioxide concentration fluctuated in sequence with the glacial cycles. During warm periods (inter-glacial**)**, carbon dioxide levels were greater whereas during cool periods (glacial), carbon dioxide levels were lesser. The cooling or heating of Earth's surface and oceans have the potential to modify natural sinks and sources of greenhouse gases and consequently altering their concentrations in the atmosphere. These varying levels are assumed to have a positive feedback, intensifying the temperature variations due to long-term shifts in the Earth's orbit.

Greenhouse Effect: Recent Role

Human activities have played a substantial role in climate change by enhancing greenhouse gases concentrations in the atmosphere since the industrial revolution began around year 1750. The concentrations of these gases have amplified the greenhouse effect leading to elevated earth temperature. These emissions especially from the burning of fossil fuels are the primary human activity intensifying the rate of climate change.

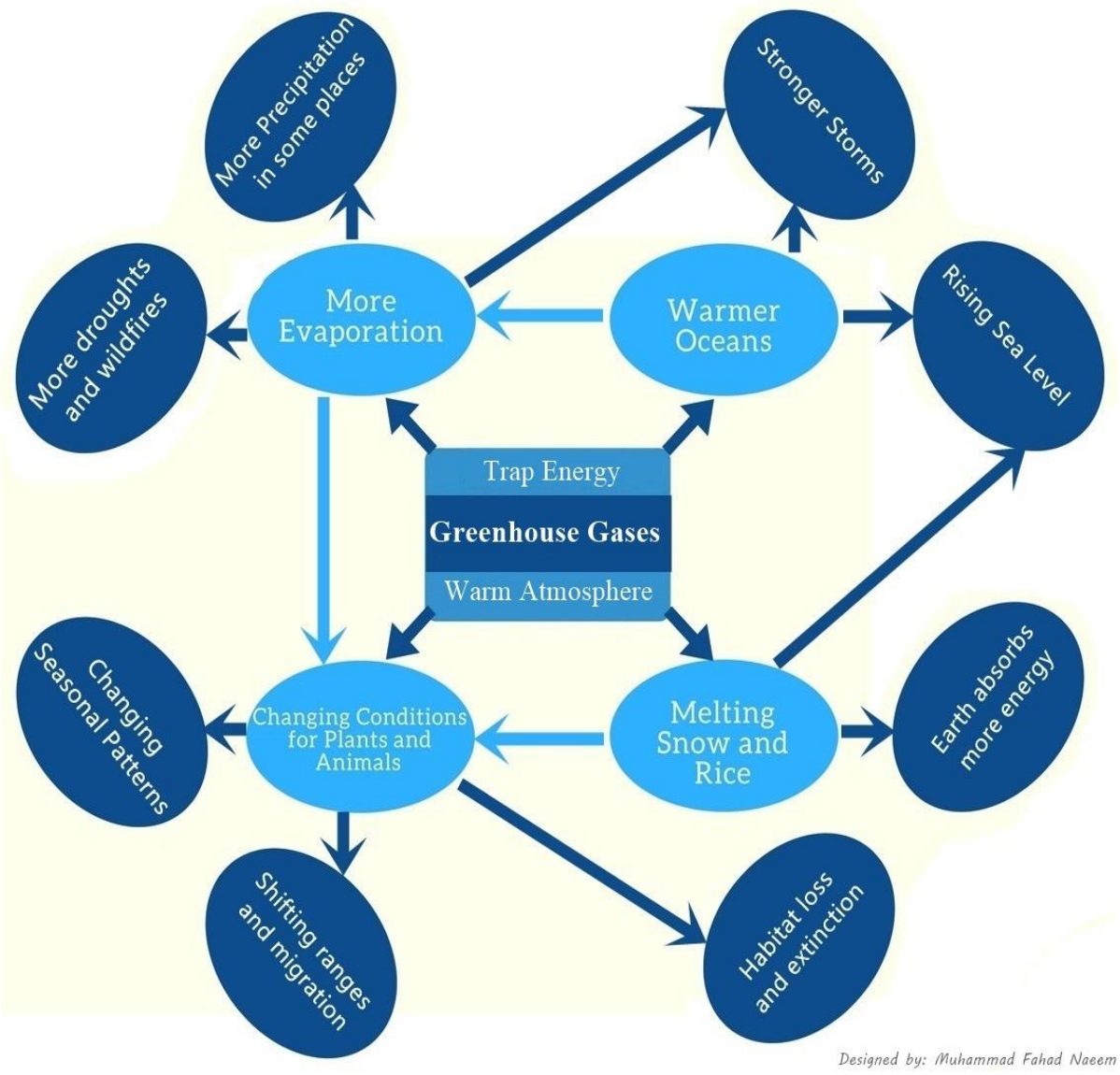
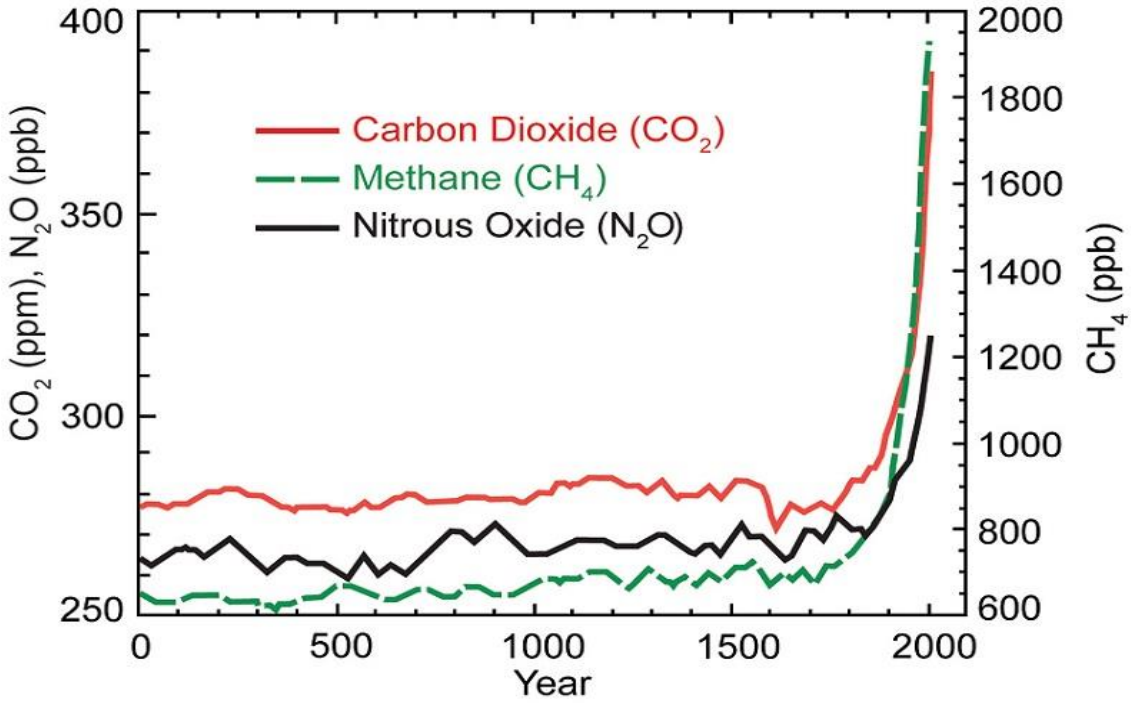


Figure 5. Diagrammatic presentation of association between greenhouse gases, global warming and consequences.



Source: *IPCC (2007)*

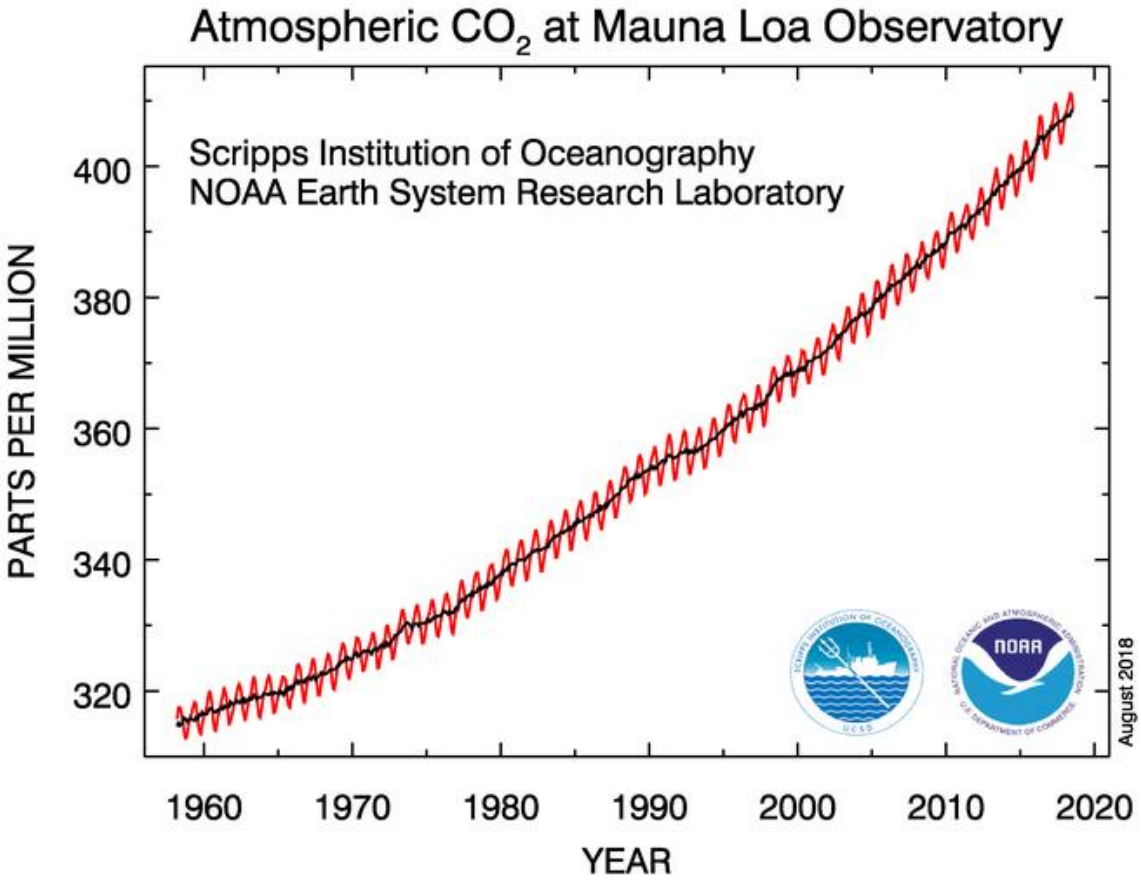
Figure 6. The trend of atmospheric greenhouse gas concentrations over the last 2,000 years. (ppb/ppm: parts per billion or million)

1.3.2 Greenhouse Gases: Source, Status and Trends

The concentrations of greenhouse gases in the atmosphere are increasing globally. Figure 6 demonstrating trend of global greenhouse gas concentrations during last 2000 years. The sources and contributions of greenhouse gases in climate change are discussed below:

- **Carbon dioxide (CO_2)**

The most important greenhouse gas that has a remarkable contribution in recent climate change is carbon dioxide. Naturally, CO_2 is discharged through plant and animal respiration and volcanic eruptions. Since pre-industrial era, atmospheric CO_2 concentrations have increased by more than 40%, from ~280 to >405 ppm in 18th century and in 2018, respectively (NASA, 2018a). First time in human history, the monthly mean concentration of CO_2 at Mauna Loa, USA now exceeds 400 ppm.



Source: *NOAA, ESRI)*

Figure 7. The trend of atmospheric carbon dioxide concentration at an observatory in USA

The atmospheric concentration of carbon dioxide has risen from pre-industrial levels of 280 ppm to over 401 ppm in 2016 as shown in Figure 7. Since 1959 alone CO_2 concentration has risen by more than 85 ppm. Globally, volcanic eruptions produced large amounts of CO_2 in the ancient times. United States Geological Survey (USGS) accounts that volcanoes now release less than 135 times as much CO_2 as human activities each year. Presently, human activities discharge over 30 billion tons of CO_2 each year into the atmosphere.

- **Methane (CH_4)**

Methane is the primary component of natural gas (Sui gas in Pakistan), a common fuel source. Natural and human activities both produce methane. Natural wetlands, forests, crop production, livestock farming and fossil fuel extraction and transport release CH_4. Presently, Methane concentration is at the highest in the history of the Earth. The concentration of CH_4 increased unexpectedly during 20th century due to the human activities and its concentration are now more than double of pre-industrial levels. However, due to increasing awareness and introduction of environmental friendly technologies, its rate of increase has reduced greatly in recent decades.

- **Nitrous Oxide (N_2O)**

Nitrous oxide is another greenhouse gas that is produced through both natural and human actions, primarily during agricultural and industrial activities, natural biological processes and burning of fuel and solid waste. The concentrations of N_2O have increased around 20% since the industrial uprising. A rapid increase was observed in the concentration of N_2O in the last decade of 20^{th} century.

- **Additional Greenhouse Gases**

Water vapour is the most plentiful greenhouse gas irrespective of having a short atmospheric lifetime also the most significant in terms of its contribution to the natural greenhouse effect. Some anthropogenic activities have control over regional water vapour levels. Globally, surface temperature drives the concentration of water vapours by influencing evaporation process. Thus, humans don't have direct control over global concentration of water vapour.

Another important and powerful greenhouse gas is tropospheric ozone (O_3) but it has a short atmospheric lifetime. Ozone is produced through the chemical reaction of nitrogen oxides and volatile organic compounds from automobile engines, power generation plants, and other chemical manufacturing processes in the occurrence of sunlight. In addition to its role in greenhouse effect, it also affects human health e.g. respiratory problems as well as damage to agriculture crops and ecosystems.

Chlorofluorocarbons (CFCs) hydro-chlorofluorocarbons, hydro-fluorocarbons, per-fluorocarbons, and sulphur-hexa fluorides are Fluorinated gases. These powerful greenhouse gases are produced from a variety of industrial processes. Fluorinated gases are frequently used in coolants, fire extinguishers, solvents and pesticides. These gases are produced in minor quantities but have long atmospheric lifetime and have potential to disturb the climate for a long time i.e. centuries (US EPA, 2017).

1.3.3 Land-use Change and Albedo

Land-use and land-cover are important components of global climate system. Scientists believe that changes in land-use may have critical local, regional and global climatic consequences in addition to change in the atmospheric composition due to increasing greenhouse gases. Incident solar radiations on earth surface are either reflected or absorbed. The reflection or absorption of light is influenced by the type of surface and atmosphere. The surfaces that are light in colour e.g. fresh snow and clouds have a tendency to reflect most sunlight whereas surfaces which are darker in colour e.g. forests, ocean and soil have the tendency to absorb more sunlight. Figure 8 demonstrating albedo of different surfaces.

Albedo is defined as the portion of light that is reflected by a surface. This is also considered as reflectivity index of an object or surface. Either it is measured on a scale of 0-1 (0: no reflection & 1: all reflected) or expressed in percentage. Overall albedo of the Earth's surface is around 30%, meaning that the amount of sunlight that reaches the planet is absorbed around 70%.

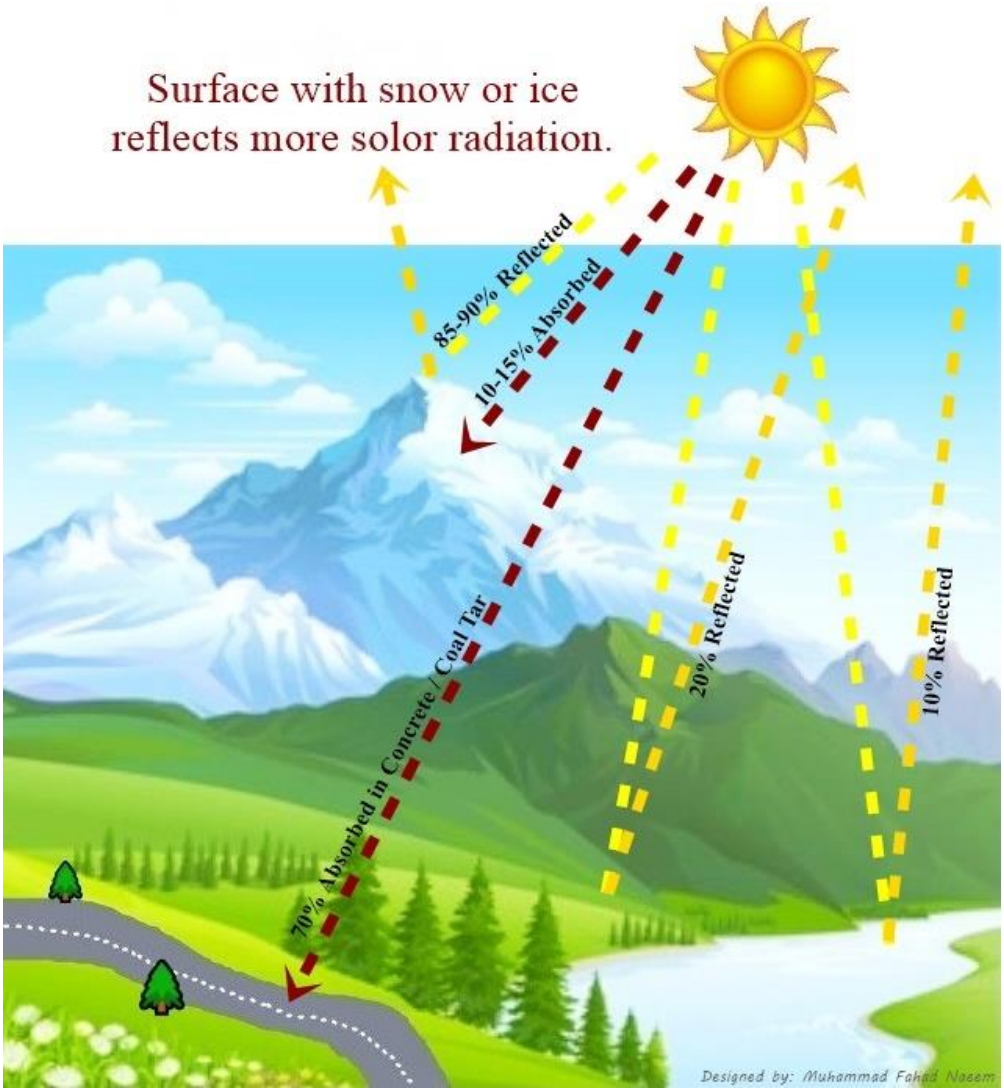


Figure 8. Demonstration of albedo effect of different surfaces

1.4 Impacts of Climate Change on Important Sectors

i. Agriculture

Agriculture produces food, the most critical human need exceedingly dependent on climate. Hence, changing climate will critically affect global food supplies, particularly in the less developed countries. This global change will possibly shift cropping zones by hundred kilometres with 1°C increase in temperature. The productivity of agriculture crops will likely increase in some parts of the world whereas exceedingly decrease in others parts. The rising temperature and carbon dioxide concentration can increase crop yields subject to adequate water and optimum nutrient availability. However, climate change has complicated effects that can trigger more severe impacts than predicted. For example, around 20% of the world's croplands depend on irrigation, but produces ~40% of global crop production. Therefore, a reduction in water supply will result in reduced food production in irrigated areas. Furthermore, as crops are stressed by changing conditions they

become more susceptible to pest and disease attacks. Scientific studies reported that the net effect of changing climate on global agriculture is likely to be negative. However, certain regions and crops will get benefit but most will not (SSSOA, 2018).

ii. Land Use Change and Forests

The distribution of species around the world is mainly the function of climate defined by temperatures and precipitation. Each forest community has naturally allocated best climatic range suitable for its abundance. A changing climate may inflame potential threats to forests, such as drought, pest and disease attack, wildfires and urbanization. This global change has potential to alter the species composition as well as distribution of grasslands. Therefore, species that currently exist only on mountain tops may disappear as the climate warms since they have no room for further shifting to higher altitudes. Finally, the impacts of climate change on forests would likely be highest in the higher latitudes, where more warming is anticipated (Sedjo, 1998). Increasing forest area (land use change to forest) has a considerable potential for neutralizing the effect of greenhouse gas emissions.

iii. Energy

Increasing temperature and changing precipitation patterns will likely increase energy demand in the future. In a warmer climate, energy requirement for air conditioning would increase whereas efficiency of electricity production plants will reduce because these plants use water for cooling. Climate change is expected to disturb both demand and supply of energy. The International Energy Agency reported that world energy demand is increasing slowly than in the past although still rising by 30% by 2040. Global oil demand will reach by 10 million barrels per day to reach 105 by 2040. The share of renewable energy resources is growing due to increasing awareness about sustainability and climate change. The increasing frequency of extreme events under climate change will enhance maintenance and operational cost energy infrastructure as well as distribution system. Climate risk assessment/screening should be conducted before the execution of new energy sector projects. The negative impacts of climate change on energy sector may be diminished due to increasing efficiency of equipment's /appliances and development of alternate energy resources.

iv. Industrial Processes

Generally, industrialization is considered as the main cause of climate change but its consequence on industrial processes have rarely been considered or discussed. Climate change will have an impact on both raw material supplies and processes. Generally, higher temperatures negatively influence manufacturing processes, a $1^{O}C$ increase in temperature decrease the output by 2% (Sudarshan and Tewari, 2014).

Chapter 2

FORESTS: OUR LIFE LINE

2.1 Introduction

Forests are essential for life on the Earth. Forests are characterized as land of more than 0.5 hectares with tree crown cover of more than 10% and the trees should be able to reach a minimum height of 5 meters at maturity (FAO, 2000). Forest can be of "closed formations" where tree crop is multi story and undergrowth cover a high proportion of the ground; or an "open forest formations" with continuous vegetation cover in which tree crown cover exceeds 10%. Young natural forests and all man-made forests (plantations) established which have yet to reach a crown density of 10% or tree height of 5 m are also considered forest.

Definitions of forest by international organization:

- United Nations Framework Convention on Climate Change defines forest as "A minimum area of land of 0.05–1.0 ha with tree crown cover of more than 10–30% with trees with the potential to reach a minimum height of 2–5 m at maturity in situ" (UNFCCC, 2002).
- United Nations Convention on Biological Diversity: "A land area of more than 0.5 ha, with a tree canopy cover of more than 10%, which is not primarily under agriculture or other specific non-forest land use" (UN-CBD, 2010).
- United Nations Convention to Combat Desertification: "Dense canopy with multi-layered structure including large trees in the upper story" (UN-CCD, 2000).
- International Union of Forest Research Organizations: "A land area with a minimum 10% tree crown coverage (or equivalent stocking level), or formerly having such tree cover and that is being naturally or artificially regenerated or that is being afforested" (Schuck *et al*., 2002).

Generally, forest consists of two components: abiotic (non-living) and biotic (living). Abiotic component comprises of heat, light, soil, minerals, rocks and water. Biotic component consist of trees, shrubs, herbaceous plants, grasses, mosses, algae, fungi, mammals, insects, birds, reptiles, amphibians, and soil microorganisms.

Globally, 300 million people live in forests and about 1.6 billion depend on them for their livelihoods (WWF, 2018). Forests are the habitat for a vast variety of plant and animal species, many of which are still not identified.

2.2 Why Forests are Critical for Life

Forests provide a vast range of goods and services to humans including food, medicine, water, wood and most critical oxygen for breathing. Forests regulate many natural processes such as hydrological cycle, carbon cycle and global climate system. The ecosystem supporting humans can collapse without forests.

Forests provide a number of benefits which are fundamental for human and animal life. Key advantages of forests are summarized here:

Provide Oxygen for Breathing

The basic requirement for human and animal life is oxygen. Forests produce oxygen for breathing and consume carbon dioxide released by living things a result of respiration. Generally, a mature tree has the potential to provide oxygen for ~2 people and can absorb carbon dioxide at a rate of 48 lbs. per year (McAliney, 1993). Phytoplankton's (ocean plants) are more productive by providing half of Earth's oxygen, but forests are a key source of clean and oxygen rich air.

Offer Animal Habitat

Eighty percent biodiversity of the Earth and about half of the identified species of the globe live in forests. Biodiversity is rich in tropical rain forests such as amazon forest in South America. Every species on the Earth has an important role to play, microbes and earth worms improve soil fertility and structure, flies and birds spread seeds and pollens and animals for example wolves and cats keep hungry herbivores under control.

Offer Human Habitat

About 300 million people live in forests worldwide. Many millions live adjacent to forest but urban forests make sustainable cities. The farmhouses, away from urban area and nearby forest are preferred options for residence in this recent era of advancement.

Provide Cool and Clean Environment

Forests maintain balance in climate of the region and clean the environment vital for human well-being. Trees and soils help regulate atmospheric temperatures through evapotranspiration. Trees also help to remove air pollutants. Trees capture sunlight for photosynthesis and provide shade to underneath. Urban trees reduce need for air conditioning by providing shade to buildings. Trees help in dealing with rising temperature by absorbing CO_2 that cause global warming. Forests absorb 2.6 billion tonnes of CO_2, about one-third of the released globally from the burning of fossil fuels. Plants store carbon in biomass and wood for long time which helps in climate change mitigation.

Help in Rain Formation

Trees take water from the soil and release it into the atmosphere by the process of evapotranspiration. The water vapours saturate the atmosphere, condense and develop rain. After oceans, forests are considered the most efficient sources of precipitation. The Amazon forests in America create conditions that promote rainfall in the whole region.

Protect From Floods

Forests also serve as a watershed, water in rivers and lakes ultimately come from forests. Tree roots create space between soil particles that help the soil in absorbing more runoff water, reducing soil loss and other damages by reducing the intensity of flow. Due to this, chance of flooding is significantly reduced. Trees also act as barriers to flood water. Furthermore, forests prevent soil erosion and reduce sedimentation in rivers and dams.

Recharge Aquifers

Aquifers are underground bodies containing water. Ground water is extracted from these water bodies through boring or making wells. These aquifers are shrinking and water table going down due to excessive pumping and less recharge by rain water. Forests are like massive sponge, holding runoff rather than allowing it to pass through. The Infiltration water that passes through tree roots trickles down into aquifers, replacing groundwater supplies that are important for drinking, sanitation and irrigation.

Prevent Winds

Heavy winds cause serious damages to agriculture farmers by harming their crops and eroding fertile soil. High winds cause accidents on highways and motorways. Block of trees serve as a windbreak, providing a defence for agriculture crops and roads. In addition, slow and less wind promotes cross pollination.

Phytoremediation

Phytoremediation is the efficient use of plants to remove, clean or restrain environmental contaminants in soil and water through the natural biological, chemical or physical activities. Forests help in phytoremediation to clean out certain pollutants. Trees either isolate the toxins away or degrade them to less hazardous form. This is a very useful technique in which trees absorb sewage/contaminated water. Various agriculture and forest crops can be grown on contaminated water and soil. However, especial care should be taken for eatable fruit and vegetables. Below photo showing cabbage field growing close to a zinc smelter in Silesia, Poland. Due to smelt activities lead concentration was highly increased in the soil and then absorbed by crops in the surrounding areas.

(Photo: IETU; **Source**: UNEP (2018)

Purify Air

Forests play an essential role in purifying the air. Trees clean up air on larger scale and not just absorb CO_2 but an extensive range of pollutants, including carbon monoxide, sulfur dioxide nitrogen dioxide surface level ozone. *Adiantum* fern is principal air purifier for indoor, with the highest capacity per leaf area.

Adiantum fern; **Source**: Google Images

Control Noise Pollution

Forests are natural noise barriers and reduce noise pollution. Forests act as absorbent of sound waves. The silencing effect is largely due to swirling leaves. For the purpose of noise abatement trees should be planted according to the scientifically designed layout. In this way, trees can reduce noise by ~50% as caught by human ear.

Feed Animals and Humans

Forests are direct source of food for humans, domesticated (livestock) and non-domesticated (wild) animals including fish and birds. Not only forests provide fruits, nuts and seeds but they also provide enabling environment to produce other eatables from mushrooms and berries to hunting animals like deer, rabbits, houbara bustard and fish. Organic honey is also a product of forest.

Source: *Google Images*

Source of Natural Medicine

Forests are source of diverse range of natural medicines and organic chemicals. For, example, the drug theophylline extracted from tea plant (*Camellia sinensis*) and cocoa tree (*Theobroma cacao*) widely used for respiratory diseases such as chronic obstructive pulmonary disease (COPD) and asthma. A chemical in eastern red cedar needles has been found effective against Methicillin-resistant Staphylococcus Aureus (MRSA) infection which is caused by a type of bacteria that is resistant to a wide range of antibiotics used to treat ordinary staphylococcus infections. About 80% of all known herbal medicines for cancer come from forests.

Source of Renewable Material

Forests are source of renewable materials to make everything, from writing paper and furniture to building and clothing. The use of renewable material is crucial for sustainable development and climate change mitigation. Wood is still a unique material for building construction and furniture even after the advancement of technology. Synthetically produced materials don't match the wood characteristics.

Source of Aesthetic Gratification and Natural Beauty

Forests are the rich source of aesthetic gratification for humans. This role of forest is an important social function of forests during the period of stress and depression. Natural scenic beauty is the most evident and emerging sector of eco-tourism forests offer. They inspire humans and provide places for recreation and relaxation. A combination of shade, green vegetation and coolness has great advantages for human life.

2.3 What are threats to forests?

Forests currently cover about 30% of the world's landmass. Forests are lungs of the Earth and are being declined at faster rates. The key causes of deforestation include wildfires, clearing for agriculture, unmanageable logging for timber, and degradation due to global warming.

Deforestation is of two types namely: gradual and rapid. Gradual is caused due to change in climatic conditions e.g. rise in temperature. While rapid deforestation happens while clearing for different purposes such as urban development or agriculture.

Current rate of global deforestation is 18.7 million acres per annum. About half of the world's tropical forests have disappeared to date (FAO, 2015). This extraordinary change in forest cover is the biggest threat to stakeholders as well as local flora and fauna. If current situation goes on reduction of 170 million hectares of forest globally is expected till 2030. Illegal cutting of trees is the key cause of

deforestation in third world countries. Wildfires are also a serious threat to forests. These fires destroy millions of hectares of forest annually around the globe. A drastic change in structure and composition of forests is the result of fires; this alteration provides suitable conditions to invasive species which in turn puts pressure on indigenous species. The use of wood as a traditional fuel is responsible for half of the illegal cutting of forests. Due to ever increasing population the demand for food is growing rapidly. Growing demand and price of agriculture products have motivated land owners to convert their lands from forest to agriculture. Urbanization is also a serious threat to forests in terms of land use change and construction material.

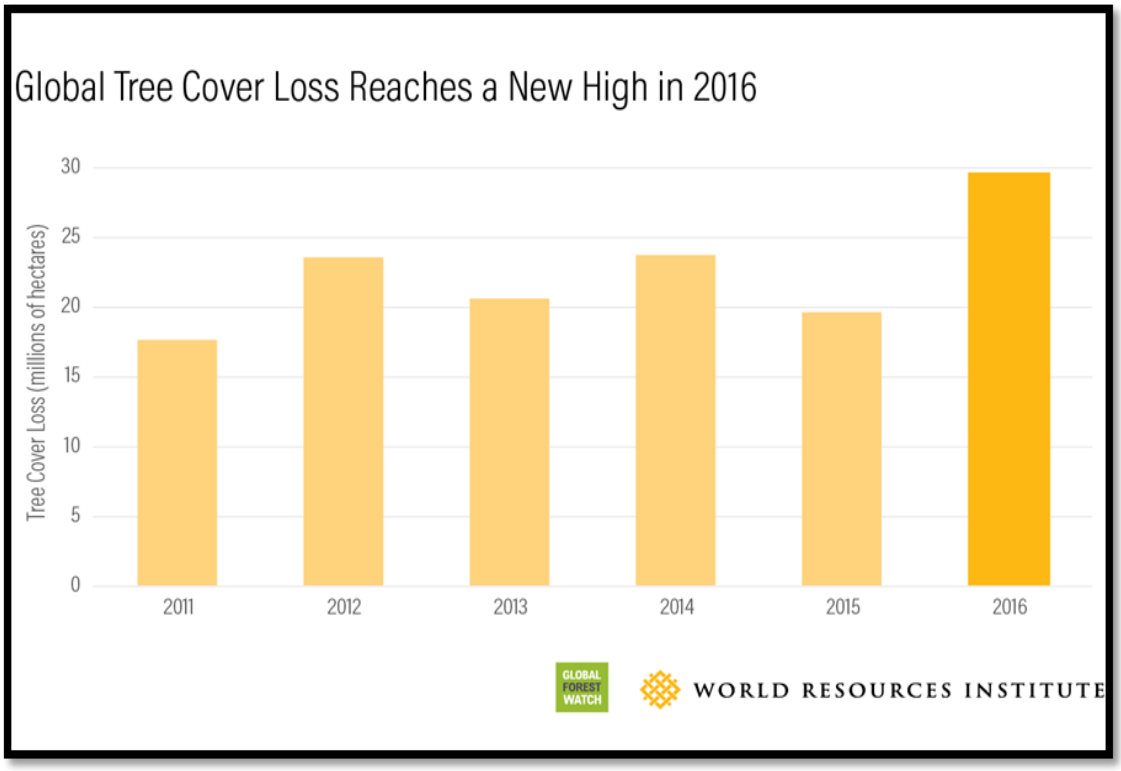


Figure 9: Global deforestation rates

2.4 Effects of deforestation

Amplified Greenhouse Gas Concentration

Forests are sink and source of carbon. According to an estimate, deforestation adds 17% of total greenhouse gas emissions and weakens the role of forest as carbon sink.

Loss of Species

Native species are under threat due to deforestation. The direct loss of species is caused by land clearing process. Habitat destruction is the ultimate result of this land clearing process depriving the wildlife species from food and breeding process. An approximate loss of 137 species per day which is equal to 50,000 species per annum is happening around the globe.

Flooding and Erosion

Forests protect water catchments and make possible clean supply of water on sustained basis. Heavy floods become more devastating due to lack of vegetation-cover results in soil erosion which removes the fertile layer of soil into the rivers.

2.5 Role of Forests in climate change

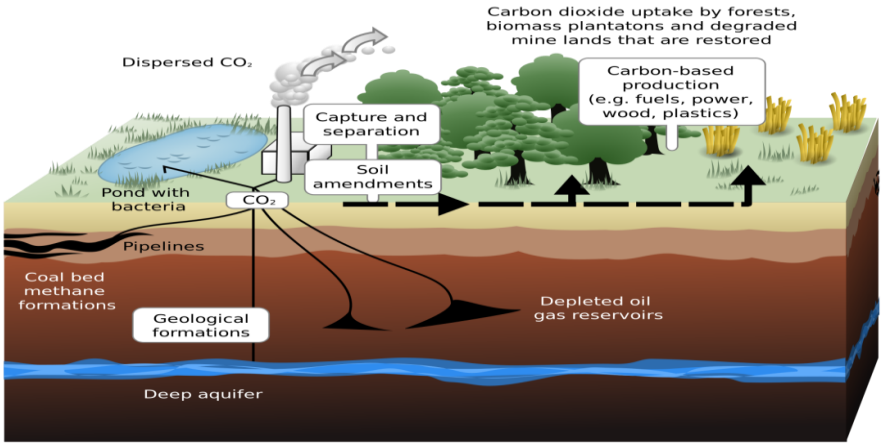
2.5.1 Mitigation

Forests are fundamental for life and regulate our climate system. Sustainable management of forests improve the readiness of communities by providing environmental, economic and social services such as food, fodder, fibre, wood and shelter along with employment. The emerging concept of Reducing Emissions from Deforestation and Forest Degradation (REDD+) forests contribute to sustainable development by reducing carbon-emissions and increasing carbon sinks in the forests.

Mitigation is the attempt to prevent human triggered changes and their progressive effects on climate system of the Earth. The ultimate purpose of mitigation is to decrease the rising level of greenhouse gases in the atmosphere for reducing the upcoming climatic changes. Mitigation works for minimizing the emissions of greenhouse gases. The motivating option for mitigating greenhouse gas emissions is carbon dioxide capture and storage.

Sequestration

Capturing and storing of atmospheric CO_2 in soil for longer period is called carbon sequestration. Previously, the carbon dioxide emissions and their uptake level were in balance. But next to anthropogenic activities such as fossil fuel burning, the CO_2 capture mechanisms are inadequate to uptake the increasing volume of CO_2 in the atmosphere. There are three possible methods to restore carbon such as: carbon sequestration by ocean, soil and deep rocks (Figure 10).



Source: *Ahmad et al. (2015)*

Figure 10. Demonstration of carbon sequestration on the Earth

IPCC working group 1 reported a widespread list of CO_2 removal methods:

1. Improved terrestrial carbon sequestration through afforestation, reforestation and soil carbon management
2. Increased ocean carbon sequestration by ocean impregnation
3. Increased weathering through the use of crushed silicates to soil or the ocean
4. Biological or chemical capturing with geological storage by direct air capture

Terrestrial Carbon Sequestration

This sequestration method is achieved by topsoil and forest management methods. Organic carbon sequestration is also recognized as terrestrial carbon sequestration. These approaches are supportive in catching and storing of atmospheric CO_2 in the profound hard rocks of the soil. The CO_2 in photosynthesis process is captured and returns some of its amount back in the air by respiration.

The carbon is transferred from plant to soil after the decay of plants. The animals consume plants, after their death, the bodies decompose and release carbon to soil. Biochar and soil organic matter are two main forms of carbon storage in soil. Approximately 0.2-1 billion tons of carbon is stored by biochar yearly in the world (Ahmad *et al*., 2015). Carbon is also sequestered in soil by alteration in crops, as it increases the organic matter in topsoil. New plantations enhance the biological carbon sequestration. This can be also be achieved by re-establishing fresh grasslands, or decreasing the CO_2 release by chimneys to screen smoke in industries. Reduced ploughing practices in farming and well-ordered wild fire can also be used for biological carbon sequestration.

How Land And Forests Sequester Carbon For Mitigation?

Climate change can be mitigated by confining carbon in the terrestrial portion. Several methods involved include afforestation, urban tree planting, re-establishing of peatlands, and altering harvest field to stable pastures. Integration of trees with crops and livestock (silvo-pasture) can also be an active source to sequester carbon. Furthermore, these tactics are compatible with sustainable forest management as well as climate-smart agriculture (use of perennials, low till or no-till practices, good fertilizer and feed management, and soil fertility techniques).

In 2015 at Paris, all members of United Nations Framework Convention on Climate Change agreed that the future global warming should be limited to below 2.0 °C. For this purpose, scientific studies suggest that achieving this target would require annual global emissions of greenhouse gases in 2050 reduced by 30-50% compared to 1990 levels. UN encourages promoting use of cleaner technologies and renewable energy sources. In global efforts to deal with climate change, all countries are needed to reduce greenhouse gas productions, fossil fuel consumption per capita and timber harvesting.

2.5.2 Adaptation

Climate change adaptation helps to deal with consequences of climate change that cannot be escaped. It develops resilience and capacity in people and system to deal with risks from climate impacts. Adaptation comprises of strategies and steps to

be taken gradually over time for transformation with swift change. Adaptation is a collective duty of all individuals in different roles e.g. a community, an organization and institute. Conclusively, it is a way to reduce negative consequences of the wide range of climate change impacts. Forests provide essential services to humans as well as maintain climate balance. Scientific investigation confirms that climate change is already affecting forest and will have increasing effects on them in the future under the scenario of climate change.

Sustainable forest management leads to successful adaptation of forest to changing climate. Development of new varieties of tree-species tolerant to climatic change is the most important approach for adaptation but is a long-term task. Other adaptation choices in forestry are afforestation, economical management and reduction in deforestation, with vast differences in their relative significance across regions (IPCC, 2014). Few examples of some adaptation practices are described below:

In semi-arid and arid regions, a variety of local methods has been developed to harvest and conserve water resources in traditional silvo-pastoral agroforestry. India is promoting short rotation species and silviculture treatments to strengthen the resilience of forests to climate change.

Promoting poly-culture and suppressing mono-culture: mix of species should be preferred to avoid failure of single species against extreme weather conditions and pest disease outbreak. Mono to poly-culture transformation in forestry is to adopt mixture of species and age classes in a forest.

It is worth mentioning that local knowledge gained by experience is being wiped out and not transforming to next generation. Efforts should be made to document this informal knowledge because it is vital for climate change adaptation as well as other purposes. Reforestation, the insurance of existing forests and convenient changes in the composition of tree population could settle nearby water balance, ensure protection of soils against erosion and raise biodiversity, consequently reinforcing flexibility. Forestry is a long-term business; the consistency in policies and strategies is the key to success. The management actions taken for adaptation, such as the prevention of wildfires, could also assist in the mitigation of climate change.

Chapter 3

PAKISTAN'S CLIMATE: ROLE OF FORESTS

Historical state of Pakistan's climate is vital to describe for better understanding of present and future trends in the climate of Pakistan.

Pakistan has a unique combination of various physiographic conditions including permafrost and alpine regions, temperate, topical and sub-tropical ecosystems, and coastal areas. The country comprised of eleven distinct climatic zones, ranging from areas characterized by mild, moist winter and hot, dry summer in the north to semi-arid and arid zones in the west (FAO, 2004). Ten agro-ecological zones of Pakistan indicate its rich ecological diversity (IPCC, 2014). Most parts of Pakistan receive insufficient rainfall, with the exception of the Northern regions, where monsoons fetch about 200 mm per month from July to September. Rainfall frequency and amounts are highly variable during the year leading to floods and droughts. Frequent, short, dry and wet spells bring about floods and drought in the country. About half drought spells are associated with El Niño events and cause significant damage to crops and livelihoods showing the way to starvation in Pakistan.

Pakistan is situated at Tropic of Cancer (latitudes 25° and 36° N). Generally, climate is continental characterized by extreme variations of temperature, both seasonally and daily. The mean temperature during June remains on average 38 °C in the plain areas; however, sometime exceeds 47°C. The intensity of dry and hot weather is gone down sometimes by storms that reduce the temperature for a short period of time. Daily variations in temperature range between 11-17^{o}C. Winters are cold, with lowest mean temperature of 4°C during January in Punjab province. However, temperature falls below zero in northern areas as well as parts of Baluchistan. The cool and dry winter is experienced during the months of December to February, whereas hot and dry conditions are observed from March to June. The months of July to September are relatively humid due to monsoon rains. Northern highlands including Himalayas annually receive 1500 mm precipitation on average and experience cool conditions. Southern plains and coastal areas are relatively hotter and drier with annual rainfall ranging from 100-500 mm per year.

Pakistan's exposure to climate change threats has been demonstrated by drought periods (e.g. 1999-2002) and floods (e. g. 2010). Low plains of Sindh and Baluchistan provinces are exposed to cyclones in the past decades (PMD, 2015). Typical climatic conditions have been changed in the recent past due to climate change. A rise of 0.6^{o}C in mean annual temperature has been observed during the past century. Overall, annual precipitation has increased by 25% during 1901-2000 for whole of Pakistan. Average precipitation in the arid and coastal areas of Pakistan has decreased by -10 to -15% whereas an increase has been noticed in Northern areas of Pakistan since 1960. The frequency of heavy rainfall in Pakistan has also increased. An annual rise of 1.2 mm in sea level has been recorded during past few decades.

Unusual heavy rainfall during 2010 monsoon caused flooding in almost one-fifth of the Pakistan. Recent climatic data indicated increased winter precipitation over the Himalayan region in the last 40 years suggesting that the glaciers in the

Indus valley region may be expanding. The number of cold nights has decreased by -10 days per year whereas the number of hot days and nights have increased by 20 days and 23 days per year respectively (World Bank, 2012; IPCC, 2014).

3.1 Recent Indication of Climate Change in Pakistan

World Metrological Organization reported, "A peak of 50.2°C was measured in Nawabshah, Sindh Province, in the southeast of Pakistan on 30th April 2018" (WMO, 2018). This was the highest recorded temperature in the history of the Earth. On the other, unusual snowfall was recorded on 20th April 2018 in Murree and Nathia Gali. (PMD, 2018). Desertification is converting green areas into barren lands e.g. Sulaiman range in south western Pakistan, most catchments are eroded and lost vegetation cover exposing to bed rock (UNDP, 2011). Warm air has the capacity to hold bigger amounts of water. Meanwhile due to higher evaporation, storms and other extreme weather events have become more common in Pakistan.

3.2 Pakistan's Climate: Future Scenario

Pakistan is among the seven most vulnerable countries of the world in long-term climate risk index (Eckstein *et al*., 2017). Global rise of ~40 cm in sea level will also be realized in Arabian Sea expected by the end of 21st century. The coastal areas of Pakistan are vulnerable to the cyclones. Most part of the country is expected to face drought conditions under the scenarios of climate change. The frequency and intensity of floods are expected to be increased. Warming is expected to be more rapid in the south and coastal areas with an average increase of 1.4-3.7 °C by the end of 2060. Generally, warming will be more in the winter compared to the summer. On average, rainfall would increase during January to June and decrease during July to September.

Overall, temperature rise in Pakistan would be more than the expected global average increase. The projected increase in temperature is higher in northern region of the country (AJK & KPK) than in the southern region. This is also expected that rise in temperature during winter will be more than in summer. The incidences of extreme events (i.e. heat waves, heavy rains and cyclones) are expected to be increased (Eckstein *et al*., 2017).

A joint study was carried out by Global Change Impact Studies Center (GCISC) and Pakistan Meteorological Department (PMD) in 2007 for developing future climate change scenarios for Pakistan. This joint study reported significant temperature changes in the future across the region. An increasing tendency in minimum and maximum temperature was observed. A larger part of land area expected to be under substantial alteration in the minimum temperature (5°C) than the maximum temperature. Percentile based spatial change demonstrated that the daily minimum temperature will be raised compared to the increase of daily maximum temperature during summer whereas in winter the change in maximum threshold temperature is high.

3.3 State of Pakistan's Forests

Pakistan has 4.5 million hectares of forests, which makes 5 percent of the total land area of the country. Around half of the Pakistan's forest comprises coniferous

and scrub forest in the northern hills and low mountains. Pakistan is forest poor country with only 0.05 ha. per capita forest area against a global average of 1.0 ha (FAO, 2002). Pakistan per capita forest area will be less than the reported based on the latest census of 2017 indicating population of more than 200 millions. However, recent initiatives of federal and provincial governments like Green Pakistan and Billion Tree Tsunami Afforestation Project are expected to improve forest's situation in Pakistan.

3.4 Role of forests in mitigation and adaptation to climate change in important sectors of Pakistan

I. Agriculture

Agriculture sector is the back bone of Pakistan's economy and provides livelihood to most population of the country. Agriculture sector is one of the most significant victims of climate change. The outcomes of climate change such as droughts, floods, storms, extreme weather events and pest and disease outbursts directly affect agriculture.

This sector is the second highest contributor (43%) of GHG emissions in Pakistan and has lot of potential in mitigation such as enhancing the carbon saving in soil and reduction of emissions from crop fields. Improved varieties of crops and better farm management practices can help in mitigation. Livestock and fertilizer management to decrease methane releases, improved nitrogen fertilizer application methods to decrease nitrous oxide releases are important ways to reduce GHG emissions from agriculture sector. The use of green manure as organic fertilizer and agriculture residues as bioenergy can contribute enormously in mitigation efforts.

Adaptation includes changes in management practices from agricultural perspective. The most common strategies for agricultural adaptation are the usage of crop varieties that have adaptive capacity or developed for certain conditions such as drought resistance, less sensitive to temperature fluctuations, modified sowing time, saving soil humidity through suitable cultural techniques and enhancing water system effectiveness. Adaptation strategies practiced to adapt climatic change should consider traditional crops/varieties because those are less expensive, simpler to acquire and are able to withstand climatic pressures than new hybrid varieties. A study of households in China demonstrated that they still use local varieties of rice and maize which are better adjusted to dry seasons. Empirical data from Guangxi province China demonstrated that while most of modern hybrids varieties were lost in the dry season in 2010, most locally developed varieties survived (Nelson *et al*., 2012).

Agro-forestry/farm-forestry incorporate the blend of trees, livestock and crops that balance GHG emissions, makes a durable soil cover against erosion, reduces damaging risk from flooding, enhances storage of carbon and expands overall profitability (Buttoud *et al*., 2013).

II. Land Use Change and Forestry

The connection between land use and climate is not so simple. First, traditional land use practices, affects the global GHG concentration. Second, while land use change is an important driver of climate change, a changing climate can lead to changes in land use and land cover. Farmers may shift from their traditional

crops to crops that will have higher economic return under changing climatic conditions. Or forest land may be converted to agriculture land due to higher economic returns.

Overall share of this sector GHG inventory of Pakistan is about 2%. However, forests are sinks of carbon and have greater potential of carbon sequestration. The establishment of new forests where no previous forest was observed and rehabilitation of degraded forests are major options to be implemented. Forests can also be a principal source of renewable energy substituting fossil fuel use. Biofuels have high potential to decrease carbon emissions compared to fossil fuels. The carbon emissions from fossil fuel burning are an addition to carbon pool and it remains in the system for millions of years.

III. Energy

This sector is on the top contributor (46%) of GHG emissions of Pakistan. This sector has also enormous potential for mitigation. Significant decrease in greenhouse gas emissions is required which demands for state-of-the-art technologies and low carbon fuels. Promoting use of LED and fluorescent lighting, decreases energy quantity essential to achieve the equivalent brightness compared to using traditional light bulbs. LEDs are the most efficient energy technology. Energy star, a volunteer organization for energy efficiency declared that LEDs use ~25% of the energy and last up to 25 times longer than the traditional luminous bulbs they replace. Furthermore, LEDs last 8 to 25 times longer than traditional halogen bulbs. LED lamps utilize about 10% of the energy as incandescent lamp needs (Energy, 2016). In addition, use of efficient appliances e.g. inverter air-conditioner, smart water heater and stove can reduce use of energy and consequently reduction of GHG emissions. Forests have a twofold role in energy sector: first as a source of bioenergy and second as an insulator of temperature. Urban forests and trees act as a shield against warming and reducing air conditioning needs.

IV. Industrial Processes

The contribution of industrial sector in national GHG inventory of Pakistan is ~5%. Globally, GHG emissions from industrial sector are increasing (IPCC, 2014). However, current rate of growth of Pakistan's industrial sector emissions is relatively slower than in the past. That may indicate a slow economic growth or use of advance technology in industry.

According to IPCC's latest report, the energy intensity of this sector can be reduced to 25% by adopting best practices. The major mitigation potential in industry lies in reducing CO_2 emissions from fossil fuel use. Forests are the principal source of value added low carbon fuel. Packages Limited, a famous pulp and paper mill of Pakistan has converted its factory on renewable and environment friendly fuel. Adaptation of efficient technology for industrial processes and preference to renewable materials can help in climate change mitigation.

V. Waste

The potential for climate change mitigation in the waste management sector is substantial. It can contribute appreciably to national greenhouse gas (GHG) mitigation goals. Although the share of waste sector in Pakistan is low but with high rate of urbanization it is expected to grow in the future. Phytoremediation, use of

trees to treat waste (solid & liquid), has tremendous potential to convert waste as well as mitigation.

3.5 Role of community in improving forest resource

The involvement of local community is essential in improving forest resources. The increasing population pressures and resource use conflicts make it more critical to be adopted. Local stakeholders provide effective solutions for conservation and improvement of natural forests. When communities work together with local stakeholders best results can be achieved. The involvement of communities in forest management develops a mutually beneficial relationship. A sense of ownership motivates communities to conserve and improve as well as securing livelihood that leads to sustainable forest management.

In underdeveloped countries, people are highly dependent on subsistence needs such as food, forage and fuel wood. Local communities have been sustainably managing forest resources and on-farm trees based on traditional knowledge over long periods of time. Women are the integral part of forest community. It has been observed that communities are successfully managing nurseries and planting trees where women are taking lead. Communities can be advantageous in improving forest recourses in following ways:

1. Community involvement in forest management motivates people and leads to understanding threats and right solutions.
2. Long term community involvement in management makes them self-sufficient and ultimately improves forest conditions.
3. The decision at local level improves efficiency of human resource as well as productivity of forest resources.
4. Conflicts among forest stake holders are common but can be successfully resolved if community takes ownership.
5. Communities living inside or adjacent to forest improve water harvesting and conservation.

The concepts of decentralization and devolution of powers at local level have gained the attention of policy makers due to successful implementation in many countries world. Community forestry has successfully restored Nepal's forests and provided sustainable livelihood to local communities. In Pakistan community forestry programme initiated by AKRSP (Agha Khan Rural Support Programme) has also demonstrated significant success in Gilgat.

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