Practices for management of climate change adaptation plans in decision support systems engaged by stakeholder agencies of Pakistan

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Abstract

Pakistan is a highly vulnerable country in the world of climate change. The Global Climate Risk Index has placed Pakistan on the fifth spot on the list of countries most vulnerable to climate change in its annual report for 2020. This study attempts to cover major aspects of how Pakistan currently mitigate climate change impacts; what are the opportunities and challenges with respect to the current weather and climatic conditions. It also attempts to address future prospects of magnitude and risks associated with the climate change narrative over Pakistan. To reach this goal, we deployed a five step approach of semi-systematic analysis and used data from published literature on mitigation and adaptation efforts that are either being carried out, or are being planned for future implementation in Pakistan. Results revealed that average low (minimum) temperature, average high (maximum) temperature of summer season, prevailing wind patterns, average rainfall, dry times, wet times, frost, hail, snow, extreme temperature, extreme wind, heavy rain, drought, snow storms and earthquakes have been widely investigated for reporting and research of climate and weather effects over Pakistan. Results further revealed that future impacts of climate were mainly attributed to climatic changes, its magnitudes, its effects and its timeframe of occurrence, by most of the cited literature in this study. In its coherence, results also showed that although impacts on socio-economic businesses render vulnerability to the country's assets, yet potential opportunities among the impacts offsets likelihood of some risks in the future. Based on our richly sourced literature, the results also proposed a framework for adaptation rules of business for combatting heat waves, floods and wind storms over Pakistan. A final corollary of this research study establishes that key uncertainties, information gaps, impacts on our production system, cost and benefit ratio, and our priorities in addressing such narratives should be the major components of any long term planning and monitoring programme proposals for Pakistan. In its lieu, a brief and effective monitoring and evaluation programme for droughts, floods, high temperature and winds is proposed. With the accomplishment of this research we believe that our proposed potential risk management plan can help policy makers to adopt suitable plan to protect Pakistan from climate change impacts on different priorities. The study is further deemed to provide recommendations to the policy makers in Government of Pakistan to make a policy plan which would be effective for longer periods of times.

Keywords: Climate Change, Adaptation Plan, Pakistan, Policy Making

Introduction

Pakistan is one of the most vulnerable countries due to climate change. The country is extremely susceptible to climate change because of its lower adaptive capacity. With its arid geography and scarcity of resources, country is widely exposed to the impacts of climate change. The country has been suffering from increased severity and occurrence of meteorological hazards including floods, dry periods, extreme temperatures and water shortages (Naz et al., 2019).

Effects of climate change in the country:

In Pakistan, climate change have wide-ranging impacts, such as reduced agricultural productivity, increased variability in water availability, increased coastal erosion, sea water incursion and increased frequency of extreme climatic events. Climate change has increased variability of monsoons - the likely impact of receding Himalayan glaciers on the Indus river system, has

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decreased capacity of water reservoirs, has reduced hydropower during drought years, and has increased frequency and intensity of extreme events including floods and droughts.

Impacts on our production system:

Pakistan has been ranked globally in the top ten countries most affected by climate change in the past 20 years owing to its geographical location. According to the Global Climate Risk Index annual report for 2020, Pakistan has lost 0.53 percent per unit GDP, suffered economic losses worth US$ 3792.52 million and witnessed 152 extreme weather events from 1999 to 2018. Akin to this, Asian Development Bank (ADB) analysis shows that the socioeconomic costs of environmental degradation are considerable with climate adaptation needs ranging between $7 billion and $14 billion per year (MOCC, 2020).

Ways in vision to manage impacts:

The government being cognizant of the situation is taking measures at policy, management and operational levels to mitigate the adverse effects of climate change in the country. The Government has launched the Eco-system Restoration Initiative (ESRI) for facilitating the transition towards environmentally resilient Pakistan by mainstreaming adaptation and mitigation through ecologically targeted initiatives. These include afforestation, biodiversity conservation, enhancing policy environment consistent with the objectives of Pakistan's Nationally Determined Contribution (NDC) and attaining Land Degradation Neutrality (LDN). The objective of this initiative is to establish an independent, transparent and comprehensive financial mechanism in Pakistan called "Eco-system Restoration Fund (ESRF)" to finance the projects and programmes (UNDP).

We usually react to a disaster once it has happened, instead of preparing ourselves beforehand. The proactive approach of preparedness and foresightedness will save much time, money and lives. Making climate change a priority in the development agenda is the right way to do. Climate change will influence every area of human and economic development and needs to be taken into account at every level. To address these pressing issues, practices for management of climate change adaptation plans in decision support systems engaged by stakeholder agencies of Pakistan are therefore reviewed in this paper.

Methodology

Temperatures, rainfall, storm intensity and sea levels are all expected to change in future. Changes in climate can offer benefits but can also lead to increased frequency and intensity of weather-related natural disasters. This risk needs to be managed – for instance by locating infrastructure away from high flood risk areas, planting drought tolerant species or building resilient infrastructures for high wind speeds. This is known as climate change adaptation. Planning ahead can help maximize benefits and minimize costs. Some adaptation decisions require a number of actions while others are quite straightforward, requiring few changes.

Pakistan needs communities that are prepared for climate change and hazards that come with it. Urban environments are particularly vulnerable to extreme weather and flooding events. Our methodology is designed to provide guidance and decision tools that can be used by urban council staff and policy makers to reduce potential harm caused by these projected changes.

A climate change adaptation toolbox can be helpful in finding out about the changing climate, what it might mean for our business, organization or community and what we can do about it. We can assess our current climate resilience and plan for future change by working through a series of steps.

Since engagements of stakeholder agencies in combatting climate change are diverse, they hinder a full systematic review process. Therefore a different strategy was adopted that described how engagement of the stakeholders in climate risk management has progressed over time. Hence, to address narratives in

management of climate change adaptation plans in decision support systems, a semi-systematic review approach is employed. This type of analysis rendered itself useful for detecting theoretical perspectives and common issues within the current scope of the study (Snyder, 2019). It further enabled us to map an effective monitoring and evaluation programme, synthesize available state of knowledge, create an agenda for further planning, to provide an overview over a timeline for climate risk management practices in Pakistan.

The following flow of methodology is expected to help city, district, regional and central government identify opportunities and reduce the impacts of climate change. The method follows a science-based risk assessment process and demonstrates methods of identifying adaptation options and evaluating their benefits. The method builds on frequently referred existing climate change guidance material.

Step 0

In step zero of this study, we mapped current climate change hazards using Cressman Interpolated High Resolution Gauge-based Gridded Observations (CIHGGO) over the domain of Pakistan (Burhan et al., 2019). We deployed the famously known Expert Team on Sector–specific Climate Indices (ET–SCI) method for determination of relevant indicators for the period of 1980-2018 (Please see Burhan et al., 2021 for details). The purpose of this exercise was to validate claims in our cited literature and to establish ground for improvement in potential risk management in Pakistan.

Step 1

We first identified how the agencies in Pakistan currently manage climate risk. Afterwards, scanning of information relevant to local climate, weather and environment was done. This rendered it feasible to record how climate and weather affected the country over national scale. It further enabled to identify any critical thresholds where the impacts of climate and weather exceeded. Moreover, we listed what further information is needed and whether there is any information gaps/limits.

Step 2

In step 2 we found out the expected changes in Pakistan's climate in coming decades, e.g. 2050 and 2090. We further identified what assets/elements of the country could be affected by climate change. We considered any critical thresholds that could affect the assets e.g. 100 mm of rain could lead to dam breaking; a temperature of -2°C could lead to frost sensitive crops dying. Afterwards we assessed the risk (likelihood and consequence) of each climate change effect and used a risk measure to estimate the risk (low, low-medium, medium, medium-high or high). Following the climate risks assessed in this step we noted how organizations could potentially manage those risks.

Step 3

In step 3 we discovered possible ways to adapt to the pre-assessed climate change risks identified in the Step 2. There were a few ways we could use to incorporate adaptation into our rules of business in Pakistan. For instance we found that, research or training, as well as actions such as changing land-use practices could potentially suppress impact of associated climate change risks via adaptation. We then established our timeline for when we needed to act (or not to act) to priorities our actions. To address that, we identified current weather or climate related issues Pakistan has had been facing. To prioritize our adaptation actions, we familiarized ourselves with how soon (or how likely) we could expect climate risks to exceed any critical thresholds. In addition, we also probed in to the timeframe it could take to plan and implement solutions by considering pathways for adapting over time. We then deduced how to reduce risk by modifying regular maintenance - taking climate change into account. That enabled us to incorporate climate considerations into long lived decisions, such as re-modelling of rules of business in Pakistan.

In subsequent process of evaluation, we compared the costs of acting with the impacts we avoid (or the income we might realize) to estimate the benefits of acting. It rendered us to think about the level of adaptation we wanted, as well as the potential for under- or over-adapting in the future. We also

considered which of our adaptation options are on national priority currently, based on weighing the level of risk, as well as the cost of acting vs. the avoided impacts. Finally, at the end of the step 3, we used our responses from our pre-analyzed working steps to develop our climate change adaptation implementation plan for our priority actions.

Step 4

In this final step, we analyzed our key climate uncertainties and information gaps in detail. We thereafter developed an effective monitoring and evaluation plan and also included information within the existing measurement systems. Our monitoring plan described how the review could feed back into policymaker's decisions, show changes in risks (including opportunities) and options and monitor sources for new information on climate change.

This approach provided a framework and resources to help us develop our risk management plan and adaptation strategy.

Results

How Climate and Weather Presently Affects Us: Current Climate

Average low (minimum) temperature

The temperature of northern areas of Pakistan is low (Figure 1). The coldest place in Pakistan is Gilgit Baltistan, where in winters the average temperature remains below -20 °C (PMD, 2021). Skardu has lowest temperatures where they drop to below −10 °C during December-to-January. Winter is the time best for tourists to visit and local restaurants to get benefits (Baltistan Times, 2021).These areas are best for the growth of fruits which can only grow at low temperature e.g. peach, apricot, seed cheery, strawberries etc. (Rasul et al. 2015).

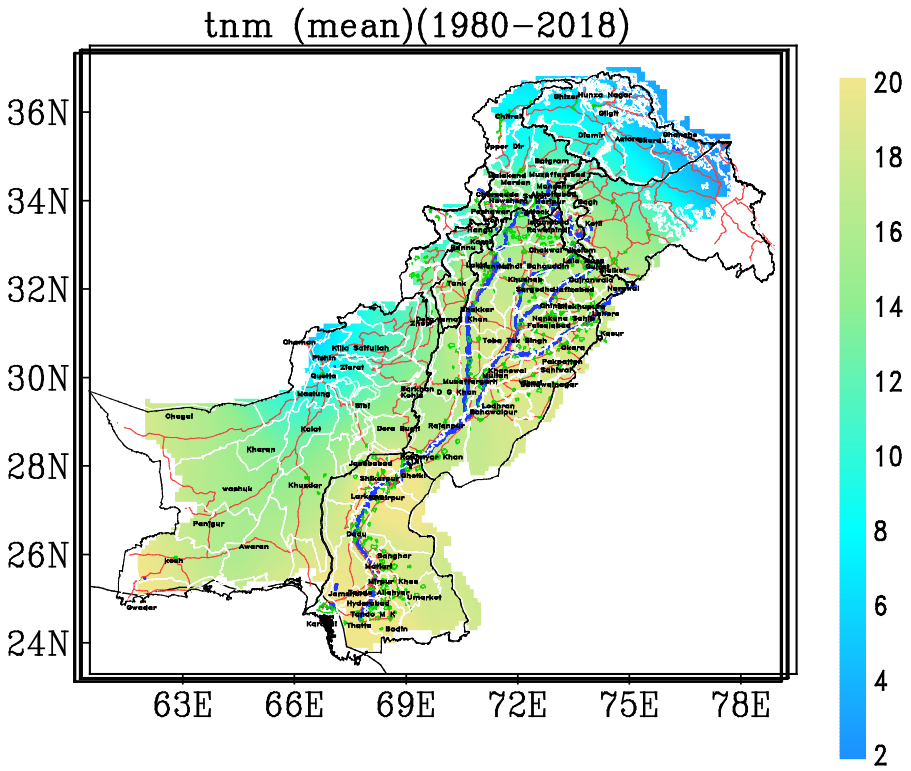

Figure 1: Long term mean of minimum temperature over Pakistan. Sourced from CIHGGO by Burhan et al., (2019).

Around 20 percent people in Azad Kashmir, Gilgit-Baltistan move to south to escape harsh weather (Saeed, 2020). The extreme cold weather in Gilgit-Baltistan poses several problems to locals. Households rely on wood stoves to stay warm. The high price of firewood in the region poses a threat to the livelihood of residents.

Average high (maximum) temperature- summer

Many regions of Pakistan have got enormous solar energy potential - Baluchistan being at the top. Currently in practice, solar radiations are being converted into solar energy to cope with the energy shortage in Pakistan (Ayaz et al. 2020). Larkana, Shikarpur and Jacobabad are suitable for growing rice, matter, rape, mustard and safflower due to high temperature in these areas (Agriculture supply and prices department, Government of Sindh, 2020).

South Punjab and Sindh host the hottest cities in Pakistan - crossing temperatures of 50°C (Figure 2). The situation is made worse by the fact that blackouts are common and only few have air conditioning to combat the blistering heat. The province has also witnessed a spike in cases of heat-related illnesses (Panaji, 2021). Higher temperatures can result in high evaporation in plants leading them towards dehydration - e.g. tomatoes, get into trouble when temperature exceeds 35 °C (Dyer, 2021).

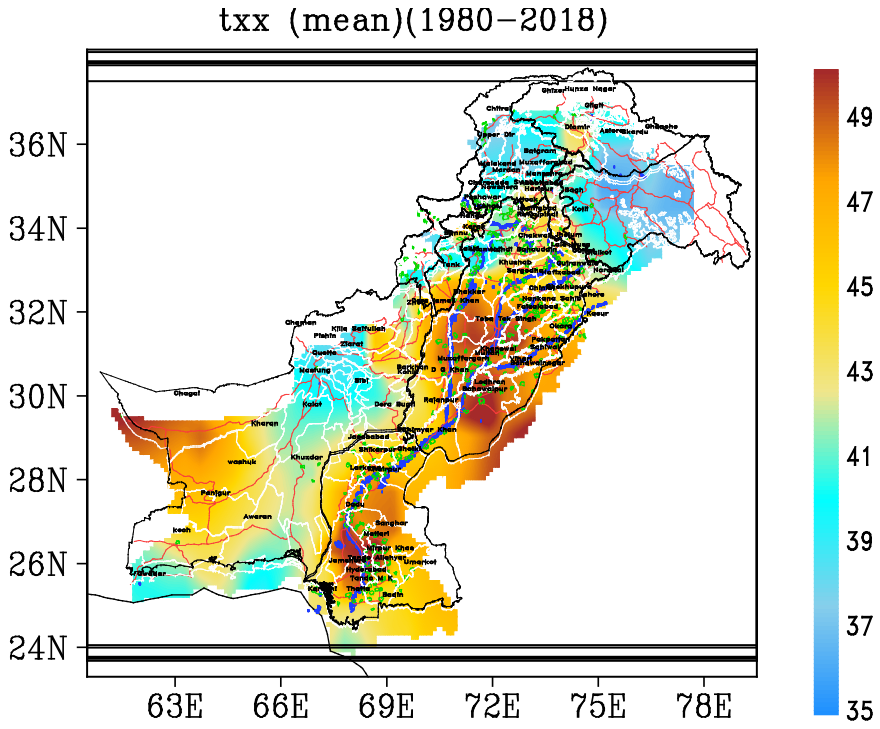

Figure 2: Long term mean of annual warmest day temperature over Pakistan. Sourced from CIHGGO by Burhan et al., (2019).

Prevailing wind

Westerly winds in Pakistan bring rains which are beneficial for rain-fed areas in Punjab and KP, as scattered rains of light to medium intensity benefits the standing wheat crop (DAWN, 2016).

The rain due to westerly winds causes a drop in the mercury level due to cold winds, and gas shortage for Punjab residents can intensify further as heating requirements will lead to an increase

in demand. The plains of Punjab face intensifies fog following rainfall, due to additional moisture in the soil and increased humidity in the air (DAWN, 2016).

Wind directions differ across seasons in Pakistan. Research on wind patterns and storms of Pakistan are under study across the world. Pakistan can make collaborations with those developed countries who have developed infrastructure for research in order to predict wind storms and related disasters.

Average rainfall

Rains in Pakistan are not only used for water needs of plants in agricultural sector but also to kill the insects by physical beating. Monsoon is generally a blessing as it reduces water shortage and provides ample water to dams for generation of electricity which in-turn can improve power shortage crisis in the country (Ali et al. 2016). Not only agriculture but other sectors of economy are also dependent, directly or indirectly, on monsoon rainfall to a great extent. Hence, accurate prediction and analysis of trends in monsoon rainfall is imperative for informed decision-making and management of water resources and agriculture. Monsoon gratifies crops in rain-fed agricultural areas, recharges groundwater reservoirs and replenishes surface water resources for hydropower generation in the country (Ali, 2019). Areas with ample annual precipitation in any form provide drought relief in Pakistan (Figure 3). Precipitation that enters soil recharges groundwater, which in turn sustains vegetation and feeds streams during periods of no rain. A single soaking rain provides lasting relief from drought conditions (USGS, n.d.).

Monsoon rains and flood create havoc in different parts of the flood-affected areas leaving thousands of families affected. Large number of houses destroy, thousands of acres of ready to harvest crops and fruits orchards ruins and link roads and bridges sweep away. Due to a compromised drainage system, widespread monsoon rains cast a negative impact on crops and affect yield. When monsoon hits Pakistan, a large outbreak of diseases are also reported in different parts of the country.

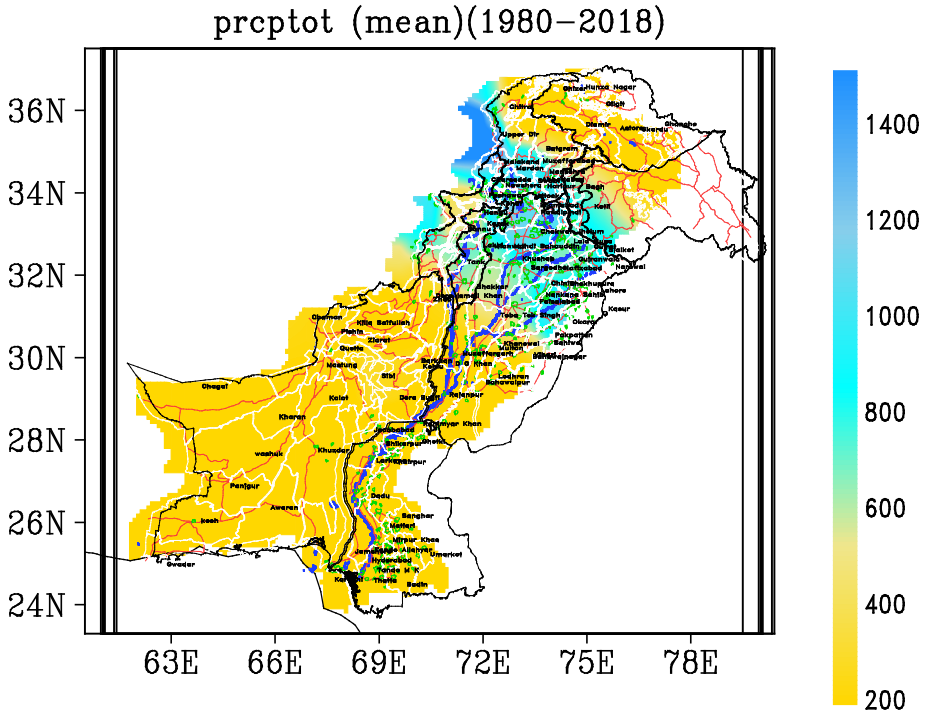

Figure 3: Long term mean of annual total precipitation over Pakistan. Sourced from CIHGGO by Burhan et al., (2019).

Dry times

During the dry season there is an opportunity to plant drought resistant olive trees, to sell fruit and oil and generate income, thereby increasing resilience of the local community (Khan, 2019). Drought tolerant wheat verities have been introduced in rain fed areas (Shaikh et al. 2016). Farming in dry season if well implemented and well planned would allow for all year round farming and is capable of dampening national poverty. One major way of meeting demands of food for increasing population is by dry season farming. Currently, there are over 400,000 farmers from 19 states of the country involved in this practice however, unwavering increase in importation of food products shows that there's still a need for an increased number of dry season farmers. Dry season farming has been used to cultivate crops like cotton, rice, tomatoes, vegetables and maize. This type of farming improves food availability and ensures better pricing all year long (Ndidi, 2019).

Low humidity or dry winds that occur in Pakistan causes health issues like skin dryness, itchiness in the throat, parched lips, dryness in eyes, bleeding from the nose, headache, lethargy and difficulty in breathing (Humayun, 2021). Ali, (2018) claims that dry season causes drought like condition which can also be verified via conditions over Sindh and Baluchistan in Figure 4. It also adds to acute shortage of fodder for livestock (Khan, 2019).

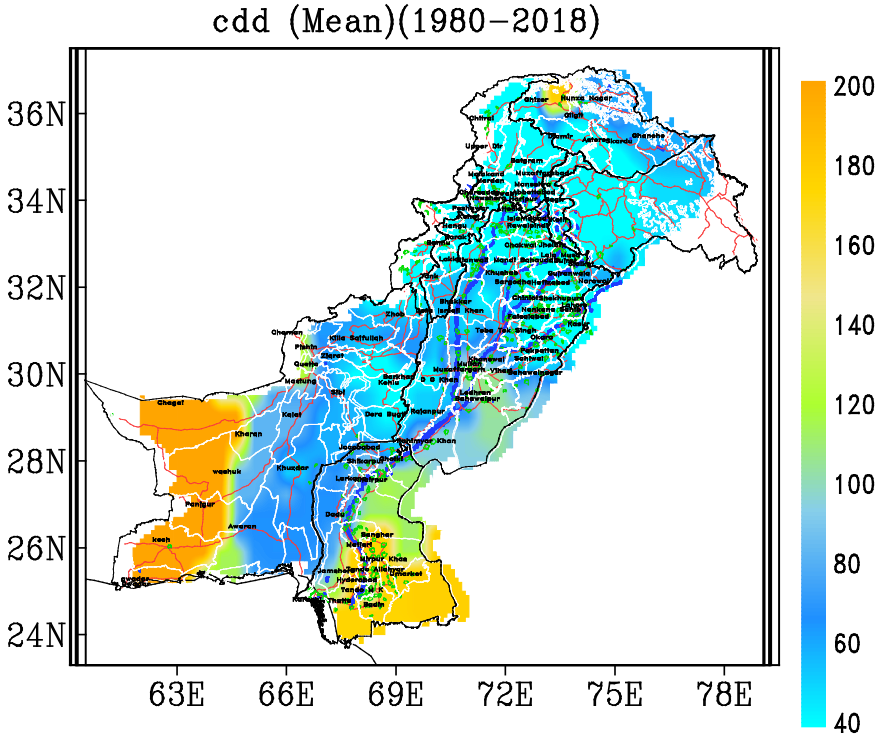

Figure 4: Long term mean of consecutive dry days over Pakistan. Sourced from CIHGGO by Burhan et al., (2019).

Wet times

Rain water infiltrates in to ground and attributes to ground water table rise that is useful for irrigation purposes. Rain is very helpful in keeping dew balance in atmosphere which balances temperature on the Earth (Davis, 2021). Rainfall in any form will provide some drought relief. Water that enters soil recharges groundwater, which in turn sustains vegetation and feeds streams during periods of no rain.

Heavy monsoon season can cause fatal flooding across Pakistan (Figure 5). An example may be taken from 2020 floods where more than 200,000 homes were either damaged or destroyed. More than 2 million people across Sindh Province were affected by monsoon rains that year, with 68,000 residents displaced in relief camps. The government also reported that nearly one million acres of crops were also destroyed by the flooding. Fields of cotton, vegetables, onions, tomatoes, and sugarcane were reportedly affected (NASA, 2020).

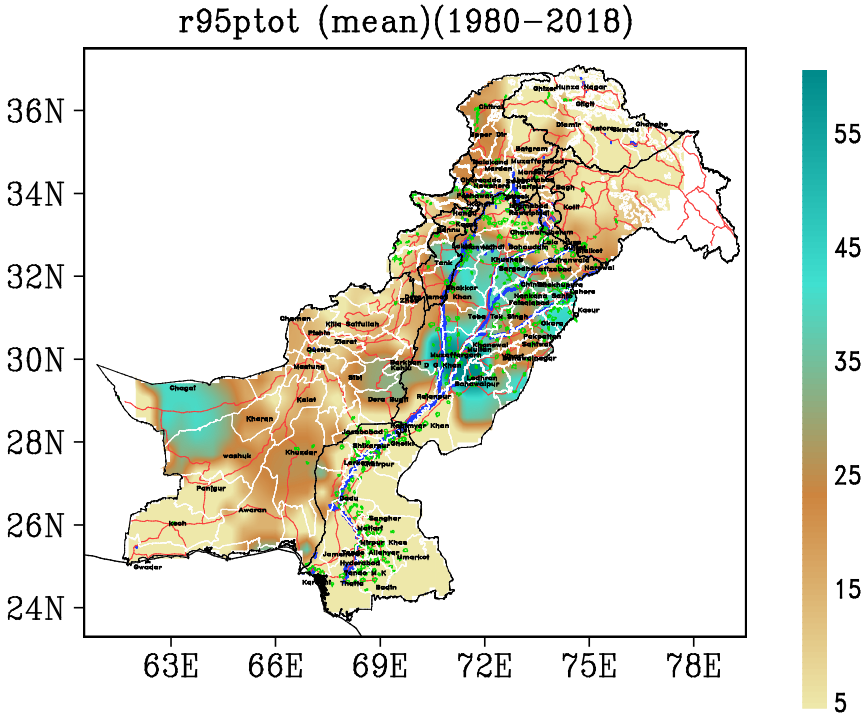

Figure 5: Long term mean of percent contribution from very wet days over Pakistan. Sourced from CIHGGO by Burhan et al., (2019).

Frost, hail and snow

Deciduous fruit trees benefit from winter chilling, and cold snaps turn starches to sugar in crops such as parsnips, improving their flavor. Frosts can also disrupt pest and disease cycles, and improve soil structure – when moisture within soil freezes, it expands, and splits open soil particles. Some fruits varieties require a high level of winter chill to enable good bud break in spring (Wrigglesworth, 2015).

After the hail has melted, it has the same effects on the environment as rain water. Melted hail soaks into ground and replenishes lakes, rivers, streams and other water reservoirs. It can also sustain plant, animal and human life (Greener, 2012).

Seasonal snow is an important part of Earth's climate system. Snow cover helps regulate temperature of the Earth's surface, and once that snow melts, the melt-water helps fill rivers and reservoirs in many regions of the world including Pakistan. (NSIDC, 2020). One major benefit of a good snow cover is snow functions as an excellent insulator of the soil. Without snow, very cold temperatures can freeze the soil deeper and deeper. This could lead to damage of root systems of trees and shrubs. The insulation effect of snow also helps protect perennials, bulbs, ground covers, and strawberry plantings from alternating freezing and thawing cycles. Without snow, milder temperatures and the sun could warm the soil surface, leading to damage from soil heaving, which

can break roots and dry out plant parts. Snow also helps conserve soil moisture over winter (Janssen, n.d.).

Flowering wheat, triticale, podding canola, and field peas are some of the most sensitive crops to frost. Black frost occurs when temperature drops below zero but surrounding air is dry (e.g. drought conditions). Ice cannot form on plant surface and water between cells freezes quickly and forms large crystals. These large crystals "pop" holes in the cells causing permanent damage. Once thawed, plant parts affected immediately look floppy, spongy and discolored (Grey, 2014). Freezing temperatures can damage corn seedlings, particularly if the temperature drops to or below -2 °C. Seedlings with soft and dark-colored growing points are likely to get affected. Under favorable weather, a new leaf should develop and appear 3 to 4 days after the frost (Dekalb, 2020).

Depending on severity of a storm, property may get damaged by hail. Sizable hail can injure. Birds, livestock and other animals are unable to seek proper shelter during this kind of weather. Hail damage has been known to be harmful to trees, plants, crops and flower beds. Even small pieces of hail combined with strong winds can be damaging to vegetation such as lettuce, cabbage and spinach. This can leave farmers who rely on this type of produce as one of their main sources of income to become financially devastated (Greener, 2012).

Snow is very reflective, and long-term exposure to snowy expanses can cause snow blindness, which is like a sunburn to the eyes. Consequently, people who live and work in snow regions need to protect their eyes (NSIDC, 2020). When snow and ice accumulate, it can become heavy and cause building damage or water damage. Snow and ice can collapse roofs, especially on older buildings. Older buildings have a greater risk of corrosion, which can weaken its structural integrity. Newer buildings that have roofs made of light-weight metal, roofs that are flat, or roofs that do not have a lot of supports are more likely to give-in under the pressure of excess snow and ice (Polygon, 2019). Also, one of the biggest challenges to rescue and relief operations is access - as heavy snowfall blocks roads. Frozen water pipes are the leading cause of property damage from snowy weather.

Extreme temperature

In a span of less than 10 days, the 2015 heatwave in Karachi affected 65,000 people (Government of Sindh, 2015; Khan 2018). Heat illnesses include: heat edema (swelling of hands, feet, and ankles), heat rash, heat cramps (muscle cramps), heat fainting, heat exhaustion and heat stroke. Extreme heat can keep everyone at risk from heat illnesses (Saleem et al., 2018). When soil temperature rises above an optimum threshold, plant water and nutrient uptake weakens and hence attributes to damage to plant components. Extreme air temperature coupled with extreme soil temperature can cause varying degrees of damage to different parts of plants (Irmak, 2016).

Heat waves tend to persist over major cities of Pakistan (Figure 6). Heat waves result in pollution, chronic water shortages and climatic changes (Saleem et al., 2018). A coordinated action is needed to prepare for the rising threat and forecast system needs to be strengthened that can alert administrative authorities to implement advance mitigation plans. Along with that, excessive trees should be planted and energy from other key sources must be availed to overcome energy crisis (Saleem et al., 2018).

Extreme wind

During extreme storms, both wind-driven changes in water levels and intense precipitation can contribute to flooding. Particularly on low-lying coastal plains, storm-driven flooding can cover large areas, resulting in major damage (Corbett et al., 2020). Dust storm reduces visibility and prompts power outages in parts of Sindh and causes transportation disruption (PMD, 2021).

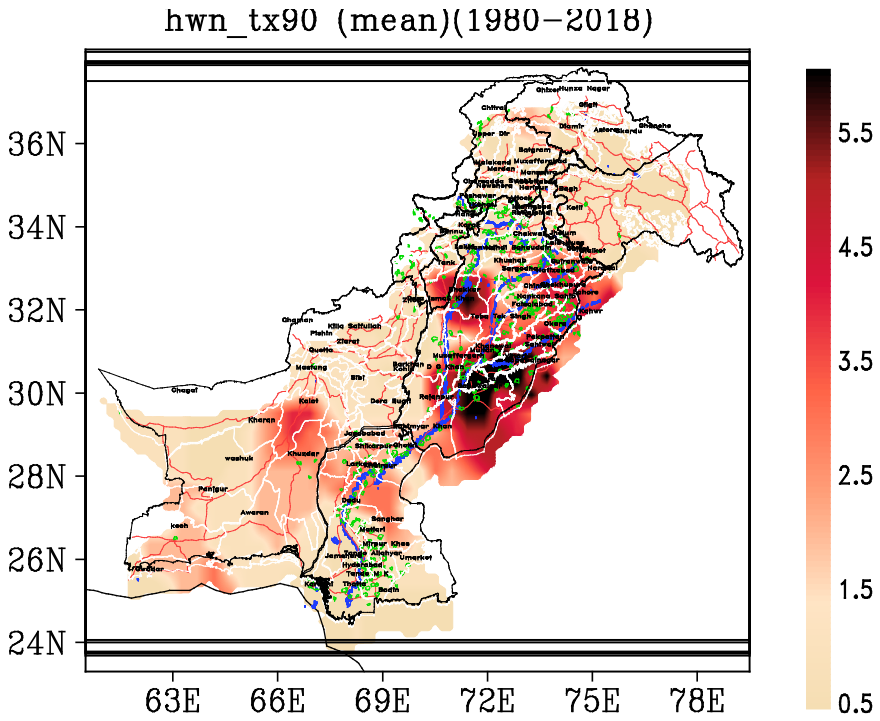

Figure 6: Long term mean of annual number of heat waves across Pakistan. Sourced from CIHGGO by Burhan et al., (2019)**.**

Wind is a renewable energy source. Using wind to produce energy has fewer effects on the environment than many other energy sources. Wind turbines also reduce amount of electricity generation from fossil fuels, which results in lower total air pollution and carbon dioxide emissions (EIA, 2020; NASA 2021). Wind is also a major factor in determining weather and climate. Wind carries heat, moisture, pollutants, and pollen to new areas. The sun heats the land more quickly than the water (National Geographic 2012).

Due to complex origins of extreme winds, there are great knowledge gaps about their variations and associated mechanisms, which makes their prediction very challenging (Amir, 2020). Good land-based wind sites are often located in remote locations, far from cities where electricity is needed. (energy.gov n.d.).

Heavy rain

Flood takes only few hours to destroy but takes years to restore flooded area to back to its normal. (Ismail 2021). Floods usually generate when ample rain falls over a period of consecutive days. Heavy monsoon season can cause dangerous flooding across Pakistan (NASA, 2020). The Pakistan Meteorological Department (PMD) reported heavy rains in late August in other parts of the Sindh province, in 2020. More than 2 million people across Sindh were affected by monsoon rains that year, with 68,000 residents displaced in relief camps (PMD, 2020). Nearly one million acres of crops were also reportedly destroyed by the flooding. Heavy rains lashed several cities inundating streets and crippling life across Punjab (The NEWS, 2020). In long term, Punjab specifically bears conditions where more than 270 mm of rain normally pours down in a set of any 5 consecutive days as per historical trends (Figure 7).

Small floods are very important to health of a river and land around it. They nurture life in and around rivers. Fish, wildlife and plants that live in or along a river, or floodplain, often need floods to survive and reproduce. Areas that receive heavy rainfall can take advantage of the flood

generated extra water by harvesting it. Using rainwater for showering, toilet flushing and crop irrigation conserves public supply of purified potable water (Ather, 2020).

Water is one of the most valuable resources on Earth. Rainwater fills reservoirs that supply drinking water, provide a habitat for fish to live, and nourishes soil with water necessary for vegetation (Tolbert, 2017). Multiple resources have confirmed that air gets cleaner after heavy rainfall. The reason for this being that as raindrops fall through the atmosphere, they have the ability to attract hundreds of particles of pollutants like dander, soot, sulphates and bacteria before hitting the ground (krivolenkov, 2019).

There is a bad drainage system in Pakistan. Main drains are always vulnerable to siltation as the surface runoff deposits large amounts of silt. City managers across Pakistan have largely failed to cater to its drainage needs. This simply means that, while housing societies, concrete boulevards, flyovers, underpasses, high-rises and signal-free corridors have popped up all over the country, green spaces and urban tree canopy has had to bear the brunt of these developments. Vast population increase and lack of investment in sewers in dense cities like Karachi pose challenge to manage floods (Hasan 2020).

Drought

The drought that is yet to show its full face has already had a sizable impact on the economy of the country. The State Bank of Pakistan has noted that floods and droughts have either completely damaged crops or have affected their production as well as associated processes of dependent sectors that have impacted borrowers' ability to pay their debts. As Pakistan is an agriculture based economy, major industries owe their production to the agricultural output which has been significantly reduced due to increased frequency and intensity of droughts that has resulted in increasing the country's dependence on imports and thus has adversely affected the "Balance of Trade" of the country. Another major setback of the drought is the reduction in the country's ability to produce hydroelectricity due to lack of water. To remedy this, additional furnace oil has to be imported for the production of thermal electricity that further dwindles foreign exchange reserves. Not too long ago, it had attempted to cause an additional loss of nearly $ 1.2 billion to the country (UNHC Drought Report Pakistan, 2001).

Pakistan has developed various schemes to combat impacts of climate change. A government project in Sindh Pakistan is helping farmers in drought hit areas to harvest rainwater using small dams. The schemes boosts sustainability; enables the farmers to earn more from their land - increasing their income by more than 60% in total. Under such schemes, several Reverse Osmosis (RO) desalination and filtration plants were installed by Pak Oasis, with the help of Sindh Government (Durrani, 2018). National Drought Monitoring Centre in Pakistan serve the nation in order to forecast and manage droughts. The main objective of National Drought Monitoring Centre is to serve as a hub for the collection, consolidation and analysis of drought related data from all possible related sources in the country. It also issues monthly drought bulletins and moisture stresses in different regions of the country based on various indices. This center advises the government agencies on drought related matters including drought declaration. It further conducts research in drought related issues and has developed statistical models for improving drought reduction (NDMC, PMD n.d.).

Under rehabilitation efforts for 2018-2019 drought, UNOCHA mobilized USD 10 million and launched its internal funding tool i.e. CERF. Furthermore, USD 1 million was also secured under Pakistan Humanitarian Pool Fund (PHPF). Additionally, Care International and Islamic Relief succeeded to access this pool fund to respond in the drought affected areas. UN FAO has also endeavored to access its internal funds of USD 500,000 to support the drought operations. The Governments of China, Germany, Japan, Kuwait, Norway, Saudi Arabia, South Korea, Turkey, the United Arab Emirates, the United Kingdom and the United States of America, ECHO, UNDP,

UNHCR, UNICEF, FAO, WFP, OCHA and other NGOs also have a history of participation in relief activities in the drought-stricken areas.

The strongest long-term effects that come from severe droughts include export of local industries with high dependence on electricity supply since length of drought is negatively associated with export of industries with high reliance on water supply (Ladyaeva, 2018). During severe drought conditions, there is scarcity of nutritional food and potable water, which leads to the spread of disease. Recent droughts in Pakistan, caused by less than average and erratic rainfall and long dry spell has led to out-migration of rural population to barrage areas to seek food, water, and gainful employment (International Federation of Red Cross and Red Crescent Societies, 2019). Long-term drought escalates the damages caused to plants, ecosystems, and wildlife. In the agricultural sector, sustained drought can result in complete crop and forage failure and livestock sell-offs. Drought conditions can increase wildfire intensity and severity (National Integrated Drought Information System). Livestock sector has also been affected very adversely by the drought. The impact of drought on food prices is severe - especially under categories of staple food items such as maize. This affects mostly poor households which spend relatively large portions of their income on food - as much as 34% of their total income. Also, lower agricultural production affects food supplies. (International Federation of Red Cross and Red Crescent Societies, Pakistan). Economic impacts of droughts include farmers who lose money because drought devastated their crops or ranchers who may have to spend more money to feed their animals. Economic impacts can be both direct, such as decreases in dairy production, and indirect, as seen by increases in the price of cheese. (NOAA, NCEI).

The existing system of monitoring drought and its impacts on various sectors is weak. There is a need to develop a policy for access to information related to drought and water management. Such information databases themselves are limited at present. A similar situation exists at the regional level. Farmers are not aware of actual crop water requirements, and irrigation-scheduling practices are still largely based on the amount of water available with a farmer and the situation of a farm. Farmers tend to over irrigate to cover unlevelled fields. Efforts are needed to help farmers in efficient conveyance and application of pumped groundwater. Water-management technologies are hardly tested and adapted in drought-prone areas. Due to excessive exploitation of groundwater coupled with successive drought, water table in different parts of Sindh and especially in Baluchistan have considerably declined. Communities should be directly involved in campaign of recharging aquifers and in conjunctive use and management of surface water and groundwater resources. Efficient irrigation methods, farm layout, balanced use of fertilizer and pesticides, and integrated nutrient management remain limited and are key factors underlying low productivity in Sindh and Baluchistan provinces. Presently, there is no comprehensive drought-mitigation infrastructure and strategy at federal and provincial levels. Institutional arrangements and their capacities are inadequate at the federal and the provincial levels to effectively launch early warning systems, preparedness and contingency plans, and rehabilitation measures, while such arrangements are non-existent at district level. This justifies a regional initiative to evaluate the existing institutional setups and mechanisms for drought mitigation and build an effective structure and mechanism, which can be adopted by the countries of the region. A collaborative effort is needed in the region with the active involvement of The International Water Management Institute (IWMI). For formulation and implementation of the National Drought Policy, there is a need to establish an apex organization for planning, coordination and monitoring of the policy interventions at the federal level (Ahmed et al. 2020).

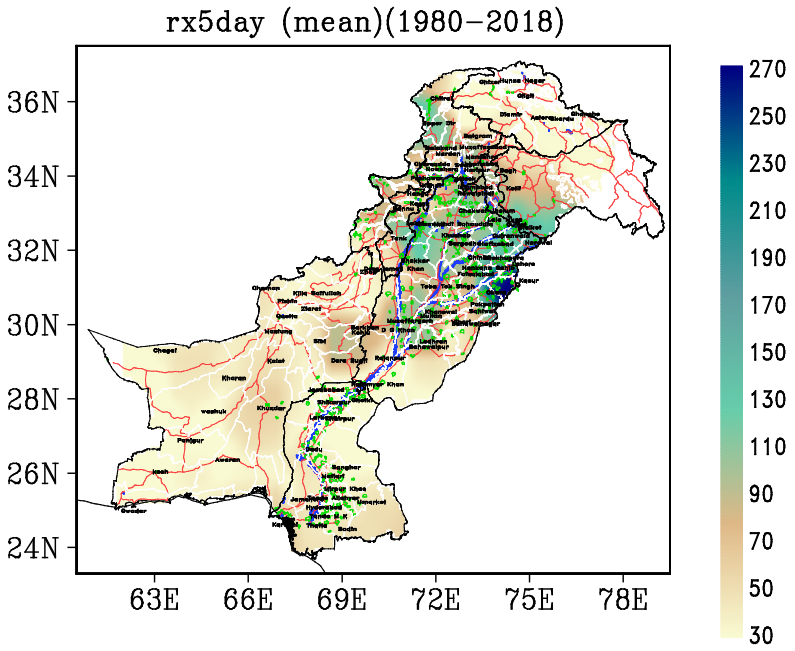

Figure 7: Long term mean of maximum amount of rain that falls in five consecutive days across Pakistan. Sourced from CIHGGO by Burhan et al., (2019).

Earthquake

On 8 October 2005, a devastating magnitude-7.6 earthquake struck the Kashmir region in the Himalaya. It left 3 million people homeless. The earthquake caused thousands of landslides that buried entire villages. The 2005 Kashmir quake broke all the way to the Earth's surface. Huge scars ran along the surface of the fault for 75 kilometres and in some places, the ground moved more than 7 meters. The earthquake was shallow, and therefore produced more focused, intense damage. The less distance seismic waves travel, the less energy they lose (Kathyrn, 2016). Direct damage caused by the earthquake was estimated at approximately Rs. 135.1 billion (US$2.3 billion), (Asian Development Bankl and World Bank 2005). No disaster management organization currently exists to handle a relief operation on such a large scale, and the existing infrastructure is either very poor or totally destroyed. Given the inaccessibility of earthquake-affected areas and that fact that road links will always be difficult, helipads and landing strips are needed in quake-prone areas, along with enhanced radar communication for aircraft (Khan, 2006).

Data on earthquakes are very useful to scientists because they provide a picture of what's going on underground. This can make oil and gas extraction more efficient, and allows scientists to monitor the progress of water during geothermal energy extraction. They also tell them what is happening in the structure of the earth, for example, magma chambers, and allow scientists to monitor volcanoes and the threat of eruption. Earthquakes also tell them about internal structure of the Earth (Chester n.d.). An earthquake can push land further up, thus may help vegetation flourish. It also loosens and churns the soil, allowing nutrients and minerals to be deposited evenly, creating a very fertile soil (Soumo, 2016).

To enhance its resilience to natural disasters and sustain inclusive growth, Pakistan will need to assess seismic vulnerabilities, identify high-risk structures, and implement comprehensive seismic risk management programs (Kim et al, 2020). Pakistan geologically overlaps both the Eurasian and Indian tectonic plates. Hence this region is prone to violent earthquakes, as the two tectonic plates collide.

Future Climate Effects

Expected climate changes, magnitudes, effects and timeframe

Projected temperature rise in Pakistan is significantly higher than the global average. The IPCC projects a global average temperature increase of 3.7°C by 2081–2100 under the highest emissions pathway (RCP8.5) whilst the model ensemble projects an average increase of 4.9°C for Pakistan in the same scenario. The projected rise in annual maximum temperatures is estimated at 5.24°C (The World Bank Group, 2021). Pakistan frequently faces increases in average temperatures significantly above the global average. There is a positive change in mean temperature of 2.7°C under RCP 4.5 scenario and 8.3 °C under RCP 8.5 scenario till the end of this Century (Ikram et al, 2016).

Pakistan experiences strong bursts of westerly's and deep vertically integrated moisture flux convergence (VIMT) over the Arabian Sea and along the Himalaya mountains. Summertime near surface wind speed projections for Indian sub-continent based on 7 best climate models, for RCP8.5 scenarios, has been calculated to show a mean increase by ~ 10–15% on the eastern coast (Eastern Ghats), ~ 1–2% on the western coasts (Western Ghats), ~ 1–5% decrease in the Indo-Gangetic Basin and ~ 3% decrease in the Gangetic West Bengal and adjoining Bangladesh (Shaha et al, 2017).

On the precipitation occurrences, RCP4.5 has been reported to show an increase of 4 mm/day in annual mean precipitation with a shift in maxima toward the north-eastern part of the country until 2050. After 2050, the precipitation pattern is reported to shift toward northwest until the end of the 21st century with the same magnitude and wet situation in the southern region. The RCP 8.5 reportedly shows 2-3mm/day precipitation (Pakistan's Climate Change Portal, 2020). Significant decrease in precipitation trend of -0.54 mm/day under RCP 4.5 scenario for the time period 2011 to 2100 is also reported. Under the RCP 8.5 scenario, literature suggest significant increase in precipitation of up to 0.9 mm/day during the first half of and a negative trend during the next half the 21st century. Summer precipitation reportedly show an overall decreasing trend with a significant decrease of up to -1.8 mm/day from 2051-2100 under the RCP4.5 scenario whereas, the RCP 8.5 show an increasing trend of 1.3 mm/day during the first half and a decreasing trend of -0.7 mm/day during the second half of the century (Ikram et al, 2016).

Accelerated ice melting may lead to an increased risk of floods and hazards related to glaciers (e.g., glacial lake outburst floods, icefalls, and crevasses) in the following decades. By the end of the 21st century (2071-2100), snowfall is expected to decrease significantly, reducing the contribution of glacial melt, and therefore, total water availability across the whole Indus Basin (Habib, Z. 2021). An increase in the number of people affected by flooding is also projected, with a likely increase of around 5 million people exposed to extreme river floods by 2035–2044, and a potential increase of around 1 million annually exposed to coastal flooding by 2070–2100 (World Bank Group, 2021). By 2050, the increased melting may result in landslides, heavy flooding, dam bursts and soil erosion. After the glaciers have melted away, drought and famine will follow (Bhutto, 2020).

As per reports, Pakistan could "run dry" by 2025 as its water shortage is reaching an alarming level. Pakistan is on its way to becoming the most water-stressed country in the region by the year 2040 (Baloch, 2018). Pakistan could face mass droughts by 2025 as water level nears 'absolute scarcity' (THE NATION, 2018). The International Monetary Fund (IMF) has ranked Pakistan 3rd in the world among countries which are facing water shortage. It is estimated that by 2025 the country will have very little clean water (Zhang et al, 2020). It is predicted that Pakistan's average temperatures will increase by 2-3 °C by 2045, according to Global Circulation Models (GCMs) outputs, and similar regional level models project temperature increases of up to 1.5 °C by 2020s and up to 2.8 degree Celsius by 2050s. It is also predicted that intensity and severity of droughts is going to increase, along with the variability in monsoon rains (Durrani, 2018).

Impacts on socio-economic businesses

Vulnerable assets and elements

At high temperature, grains of wheat do not gain proper size and weight rather are shriveled; hence result is a reduced yield. Due to global warming, temperatures are expected to increase over the present limits at a variable rate. Simultaneously, water demand of the crops will also increase. Increased temperature will affect physiological processes necessary for crop growth and development of crops and ultimately crop yields are most likely to drop over the present level (Rasul et al, n.d.). Due to rise in temperature, the Himalayan glaciers (75%) are melting, and may virtually disappear by 2035 (Ali, et al, 2017). Sustained projected higher temperatures in Peshawar are likely to cause traffic related rutting and softening of BRT road paved surfaces and at temperatures of 50°C may even result in the softening and spread of liquid asphalt (London M25, 2013 and 2003, BBC). Very hot temperatures in Peshawar can also cause thermal expansion of joints of bridges and underpasses in concrete infrastructures (BRT CRVA, 2017).

In future storm could reach the strength of a major hurricane, with winds well over 100 mph, in addition to a serious storm surge, or rise in ocean water above normally dry land, and pockets of flooding rainfall inland. Reportedly, the storm could threaten Karachi - Pakistan's largest city and home to some 15 million people (Cappucci, 2021). The immediate effects of strong winds, high rainfall and storm surges have potential to result in buildings and bridges be destroyed and roads and railways be damaged. Under influence of such storms, power cables and telephone lines come down, crops are ruined, and water and sewage supplies are affected. Coastal habitats like beaches and mangroves can be damaged by storm surge floods (BBC, 2021). Sand and dust storms have many negative impacts on the agricultural sector including: reducing crop yields by burial of seedlings under sand deposits, the loss of plant tissue and reduced photosynthetic activity as a result of sandblasting, delaying plant development, increasing end-of-season drought risk, causing injury and reduced productivity of livestock, increasing soil erosion and accelerating processes of land degradation and desertification, filling up irrigation canals with sediments, covering transportation routes, affecting water quality of rivers and streams, and affecting air quality (Stefanski, 2016). Intense future wind storms, though may be rare, can cause increased threat to stability of sign boards, tall structures, lighting fixtures along BRT route and particularly at the elevated terminal stations (BRT CRVA, 2017).

Root loss occurs when excess water reduces oxygen in soil. A plant cannot grow without healthy roots. Extreme summer rain can leach nitrogen out of the soil; nitrogen is vital for photosynthesis (Hubbard et al. 2019). Heavy rainfall can lead to numerous hazards including flooding, including risk to human life, damage to buildings and infrastructure, and loss of crops and livestock. Landslides, which can threaten human life, disrupt transport and communications, and cause damage to buildings and infrastructure (Yang Yang n.d). Although Peshawar future precipitation projections are indicating a decrease in total annual rainfall, but extreme precipitation events can overload the urban storm drainage systems particularly at the indicated hotspot locations along BRT route causing inundation, damage to roads and underground tunnels, due to flooding (BRT CRVA, 2017).

Melting glaciers at reported scales can initially result in greater river flows by 2050-60, thereby increasing risks of heavier floods, bigger landslides, excessive soil erosion, dam busts and silting of reservoirs. Global warming due to greenhouse gas (GHG) emissions can result in higher air and ocean temperatures. Warmer oceans mean more evaporation from the oceans, and warmer air means more moisture holding capacity of the air – resulting in bigger and heavier clouds, and bigger and heavier precipitation (rains and snow fall) events (Abbas and Hussain, 2019). Increases in precipitation may exceed capacity of drainage and flood control infrastructures. This may further

exacerbate road deterioration and damage structures and vehicles in Karachi BRT (Climate Change Assessment of BRT Karachi, 2018).

During severe drought conditions, there is scarcity of nutritional food and potable water, which has potential to lead to spread of disease. Prolonged period of drought can badly affect food production systems and hence health of community members (IFRC, 2019). Declining underground water level in Quetta and the lingering water crisis may affect implementation of the China-Pakistan Economic Corridor project.

To sum up, energy, transport and agriculture are the major vulnerable assets and elements that remain responsible for impacts on our socio-economic businesses (Figure 8).

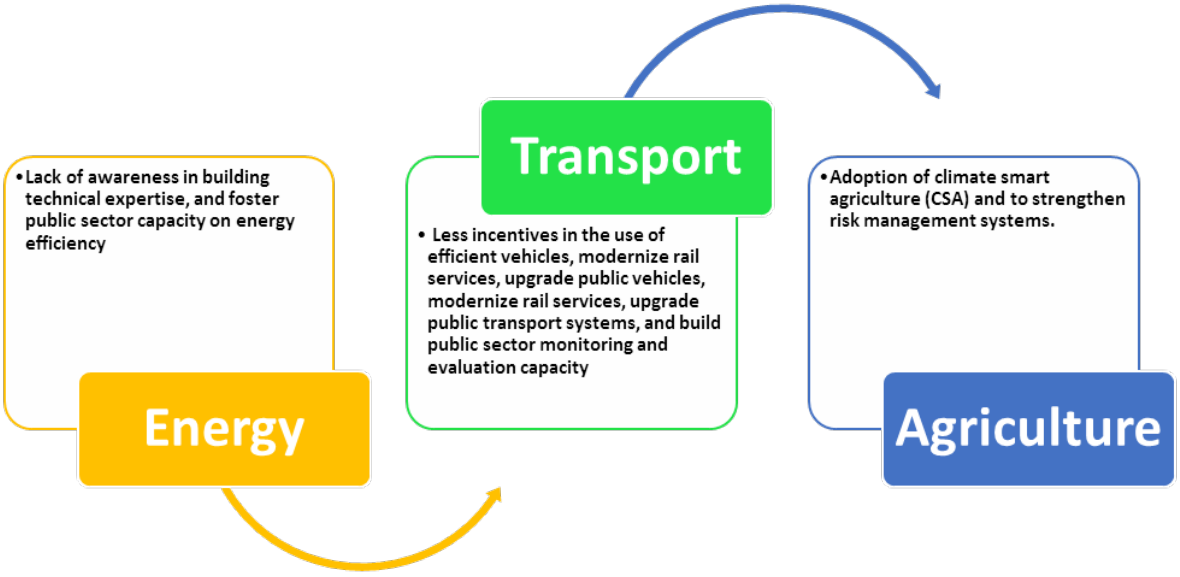

Figure 8: Major vulnerable assets and elements and their deficiencies.

Potential opportunities among the impacts

Pakistan aims to develop 9700 MW by 2030 (AEDB, 2009). Market for wind energy in Pakistan is expected to grow at more than 5% in the forecast period of 2020-2025. The Government of Pakistan is aiming to achieve 6% of its electricity generation from renewables by 2030; with solar and wind going to be the major markets in the coming years. With 11 separate wind projects approved by AEDB, comprising a collective capacity of 560 MW, a rapid growth in the wind market of Pakistan is expected in the future.

Reconstruction projects give a chance to "build back better" - making sure rebuilt buildings are more resilient to whatever flooding may come in the future (TNH, 2016). Heavy, persistent rain would have been a challenge for Pakistanis under any circumstance. Human activities, however, probably made them worse than nature alone could have.

Vegetation naturally reduces the risk of flooding by soaking up precipitation, so almost every time humans remove trees, shrubs, and plants from the landscape, they increase the risk of floods. Decades of deforestation in Pakistan, particularly in the Swat Valley, have left the landscape less able to absorb moisture (Scott, 2010). Heavy rainfalls will help in boosting the growth of Kharif crops namely rice, maize, cotton and Rainwater flowed through catchment areas into dams and

water reservoirs. It had helped in accumulating a favorable amount of water to cater the needs for future sugarcane (Noor, 2020).

After facing several floods in the past few years Pakistan is building disaster-proof houses (Welt hunger hilfe 2018). Floods nourish riverine forests which are home to important wildlife species. Flood waters also provide spawning sites for several fish species. Additionally flood waters recharge groundwater aquifers and add nutrients to soils improving fertility. Floods also feed wetlands which provide an important habitat for many resident and migratory waterfowl species in addition to several aquatic species (Ali, 2015).

Rise in temperature could well enhance crop growth and faster maturation that allow earlier planting and earlier harvesting of the winter crops (Saif 2017). Various transgenic have been developed with improved thermo-tolerance having potential benefits for inducing heat tolerance in food crops (Kaushal, 2016).

Risks involved

Likelihood of risks

Very likely to occur

A study reported that Pakistan will experience around 12 heat wave events annually by 2030, 20 such events by 2060 and 26 events by 2090 (Suzman, 2019). Future trend of annual heat accumulation, in 2030 reportedly increased by 17%, 26%, and 32%, for 2060 the trends were reportedly increased by 54%, 49%, and 86% and for 2090, up to 62%, 75%, and 140% for RCP-4.5, RCP-6.0, and RCP-8.5, respectively (Nasim et al. 2018). Intense heat waves in Pakistan are likely to occur in the southwest (Khan et al. 2018). Frequency of heat waves in Pakistan are projected to increase up to 12 events per year while the duration is projected to increase up to 100 days in a year during 2060 to 2099 for the highest emission scenario (Khan et al. 2020). The DJF season projected higher increase in temperature in the northern (3.8℃ 5.1℃ and 6.5℃), followed by central regions (3.8℃, 4.9℃ and 6.4℃) under SSP245, SSP370 and SSP585 scenarios, respectively. The central region is likely to record significant increase in JJA (3.0℃, 4.4℃ and 5.4℃) mean temperature in far future under the given SSP scenarios. The southern regions are projected to possible rise in far future JJA temperatures by 2.7 ℃, 3.3 ℃ and 4.3 ℃, under SSP245, SSP370 and SSP585, respectively (Karim et al. 2021). In Jhelum basin, intensity and frequency of warm temperature extremes are likely to be higher and the intensity and frequency of cold temperature extremes are likely to be lower in the future (Mahmood et al. 2014).

Due to presence of a huge water body, Mangla dam, district Mirpur experiences frequent and strong winds. Strong gusts of winds has a history of sweeping through Islamabad, Rawalpindi. Central Punjab (Mirpur District Disaster Risk Management Plan, 2017). Most parts of Khyber Pakhtunkhwa have recorded dry winds blowing at a speed of 70-100 kilometres per hour. Low pressure system causes the winds in surroundings areas, especially in the north, to rush to this region and beyond producing gusty, dry winds (THE NEWS, 2021).

There is a high probability of heavy precipitation events mostly confined in the north east region of the country. The increase precipitation over Monsoon belt is up to 4 mm/day.

Multi-day flood events are projected to increase with a faster rate in the future than the single day events, which can have strong implications for agriculture and infrastructure (Ali et al. 2019). Potentially damaging urban floods are expected to occur at least once in Pakistan in the next 10 years (GFDRR, n.d.).

Likely to occur

Increase in the number of heat wave events towards the end of the century are also likely to happen in the provinces of Baluchistan and Sindh, however increase in heat waves is most pronounced over the Punjab plains. In the period between 2076-2100, the increase in the number of heat wave becomes more than 75 over Punjab, implying an average increase of 3 events per year as compared to control period.

The moderate drought is likely to occur in different areas of Baluchistan such as Chaghi, Gwadar, Harnai, Ketch, Kharan, Mastung, Noshki, Panjgur, Kalat, Quetta, and Washik in near future (The Express Tribune, 2021). Drought can be expected to occur in district Mirpur due to the extensive de-vegetation and low rainfall (Mirpur District Disaster Risk Management Plan, 2017).

Less likely to occur

The northern areas, which are characterized by low temperatures due to their higher topographic extent, have not achieved a high temperature of 45°C. They are less likely to have heat waves of such magnitude (Saeed and Suleri, 2015). Intense wind storms are not very common in Peshawar and climate projection are also not indicating any increase in frequency of such wind storms by 2070 (Climate Risk and Vulnerability Assessment, 2017). The decrease in precipitation is up to 2 mm/day over southern parts of the country (Ikram et al. 2016). However, there are no areas of Pakistan, where drought is less likely to occur.

Consequences of risks

Summer time heat waves are most likely to increase over northern areas of the country which hosts reservoirs of snow and glacier, which may result in events like glacial lake outburst flood and snow/ice melt flooding. The increase in winter time heat waves may affect negatively on the wheat production, which in turn can distress the overall food productivity and livelihoods of the country (Saeed et al, 2017). Heat waves are most devastating when those occur in highly populated southeast region (Khan et al, 2018). Faisalabad, Rawalpindi, Multan, Gujranwala, Sargodha, and Sialkot are all located in this region, which are more susceptible to the negative impact of heat waves. Most of the hottest cities are detected in areas on the southern side of Pakistan (Ali et al. 2020).

There appears to be a strong association between rainfall and the occurrence of mass- movement, especially landslides and debris-flows, which could lead to an increased frequency and severity of river blockage and subsequent landslides in Northern areas of Pakistan. An increase in summer rainfall could lead to an increased potential for summer flooding from intense summer-storms. There has been a marked increase over the twentieth century in the annual 1-day maximum rainfall from 10 to 28 mm at Gilgit and from 12 to 30 mm at Skardu. An overall increase in precipitation; if repeated at higher altitudes would lead to greater nourishment and vigor of glaciers. An increase in the number of people affected by flooding is projected, with a likely increase of around 5 million people exposed to extreme river floods by 2035–2044, and a potential increase of around 1 million annually exposed to coastal flooding by 2070–2100. Projections suggest yield declines in many key food and cash crops, including cotton, wheat, sugarcane, maize, and rice. One million people can face coastal flooding annually by the period 2070–2100 (Awan, n.d.).

No person in Pakistan, whether from the north with its more than 5,000 glaciers, or from the south with its 'hyper deserts,' will be immune to water scarcity (Neil Buhne, UN humanitarian coordinator for Pakistan, 2018). Due to consistent deficiency of rainfall moderate drought has been further intensified into severe drought, especially in the south-western Balochistan and south-eastern Sindh. Drought conditions may further affect the agriculture and live stocks (The Express Tribune,

2021). Increase in temperature expected in future will negatively affect agro-climatic conditions in Balochistan and Sindh; continuous drier conditions in Balochistan and Sindh may increase water requirements for the standing crops and orchards. Moderate drought will likely occur in Balochistan such as Chaghi, Gwadar, Harnai, Ketch, Kharan, Mastung, Noshki, Panjgur, Kalat, Quetta, and Washik in near future (The Express Tribune, 2021). Drought has dragged life of majority of people to below subsistence level, has reduced income generating opportunities, has negatively affected food security and has increased indices of poverty in Tharparkar district of Sindh (Memon et al, 2018).

What Actions Should We Take

Incorporating adaptation into our lives and businesses

For heat waves

i. Developing a comprehensive long-term plan to reduce the heat threat. This include cool roofs, cool pavements and road surfaces. Green roofs and walls improve urban vegetation share.

ii. Developing a heat wave response plan.

iii. To reduce health impacts, mass awareness campaigns are needed to build perception and improve adaptation to heat waves. There is a need to develop training programs to educate and train masses to achieve ultimate objectives of adaptation to heat waves. Policy aimed at increasing force of health workers will also yield expected results of adaptation to heat waves. Increased income of households would enable individuals to invest in adaptation measures as well as improving individual health. Incentives in financial and other forms can work to overcome this challenge. Drinking plenty of water even when not feeling thirsty. Avoiding drinks that include caffeine. Eating light meals and avoiding too much salt. Drinking plenty of water even when not feeling thirsty. Wearing loose-fitted, lightweight, and light-colored clothes that cover most of the skin. Wearing a scarf or a wide-brimmed hat to protect the face. Avoiding strenuous work and take frequent breaks when working during the hottest part of the day (DAWN, 2021).

iv. In order to protect plants from extreme heat, shade cloth or protective row cover can be used. Watering plants early in the morning and evening can also protect them from the effects of heat wave. (Seaman 2019).

For floods

i. Managing aquifer recharge in the riverine corridor, combined with improved irrigation efficiencies, can literally make Pakistan secure in the event of longest conceivable droughts (Abbas and Hussain, 2019).

For wind storms

i. Cyclone monitoring generally allows a warning period of 2–3 days, and the most common way of alerting remote communities to potential threat in this case is to send alerts to district government officials, or more commonly armed forces or security agency personnel; or to notify them in person. Officials can travel by boat or by road to inform communities and to support evacuation plans.

ii. Local NGOs can develop deep roots and an extensive network in the coastal areas of Sindh and Baluchistan. These NGOs have much of the required local knowledge and access to remote areas; however, such organizations are dependent on donor funding, which usually comes in post-disaster situations. If a disaster occurs, NGOs with a local presence – for example, Plan Pakistan, HANDS, the Indus Resource Centre (IRC) and Association for Humanitarian Development (AHD), among many others – work with international

coordination groups such as UNOCHA and with local and provincial governments at least until the first phase. Such an example was seen during cyclones Gonu, Phet, and cyclone Keila in 2011 for recovery.

Long-Term Planning and Monitoring

Costs and benefits:

1. Water Sanitation and Hygiene: Every $1 invested in water and sanitation provides a $4 economic return from lower health costs (water.org).
2. Ten Billion Tree Tsunami Programme (TBTTP): Although the Programme, in its Phase-I has the total cost of Rs. 125.1843 billion, yet it is not only helping restore ailing ecosystems and improve natural capital, it is also supporting livelihoods. The project is expected to create jobs for almost 85,000 daily wagers. In addition, Pakistan's protected areas initiative will create almost 7000 long term jobs (UNEP, 2021).
3. Scaling-up of Glacial Lake Outburst Flood (GLOF) risk reduction in Northern Pakistan: With total project investment of USD 37.5 million, 29.2 million beneficiaries took returns from early warning systems and disaster risk management (Figure 9).

Priorities:

An effective nationally determined contribution from Pakistan is presented in Figure 10. Pakistan's climate change concerns which needs to be solved on priority basis are increased variability of monsoons, the likely impact of receding Himalayan glaciers on the Indus river system, decreased capacity of water reservoirs, reduced hydropower during drought years, and extreme events including floods and droughts. Other potential climate change induced impacts include severe water stress, food insecurity due to decreasing agricultural and livestock production, more prevalent pests and weeds, degradation of ecosystems, biodiversity loss and northward shifting of some biomes. Also, combatting temperatures and precipitation related challenges is also a priority since they can affect composition, distribution and productivity of mangroves and contribute to salt stress (UNDP). A proposed and prioritized national mitigation and adaptation plan is presented in Figure 11. Based on intended acceleration in climate and development, a national action plan is described in Figure 12.

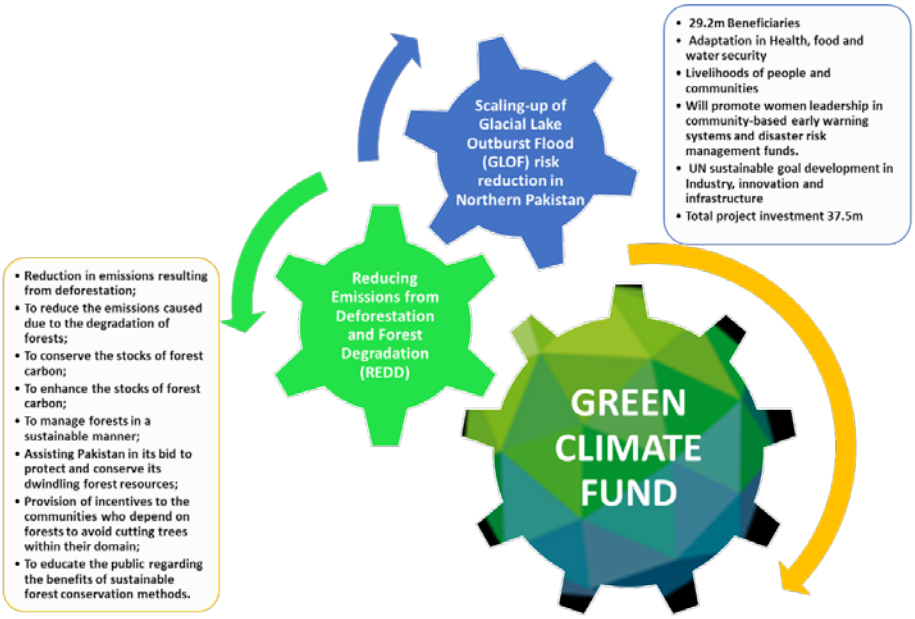

Figure 9: Cost benefit analysis of two major projects in Pakistan

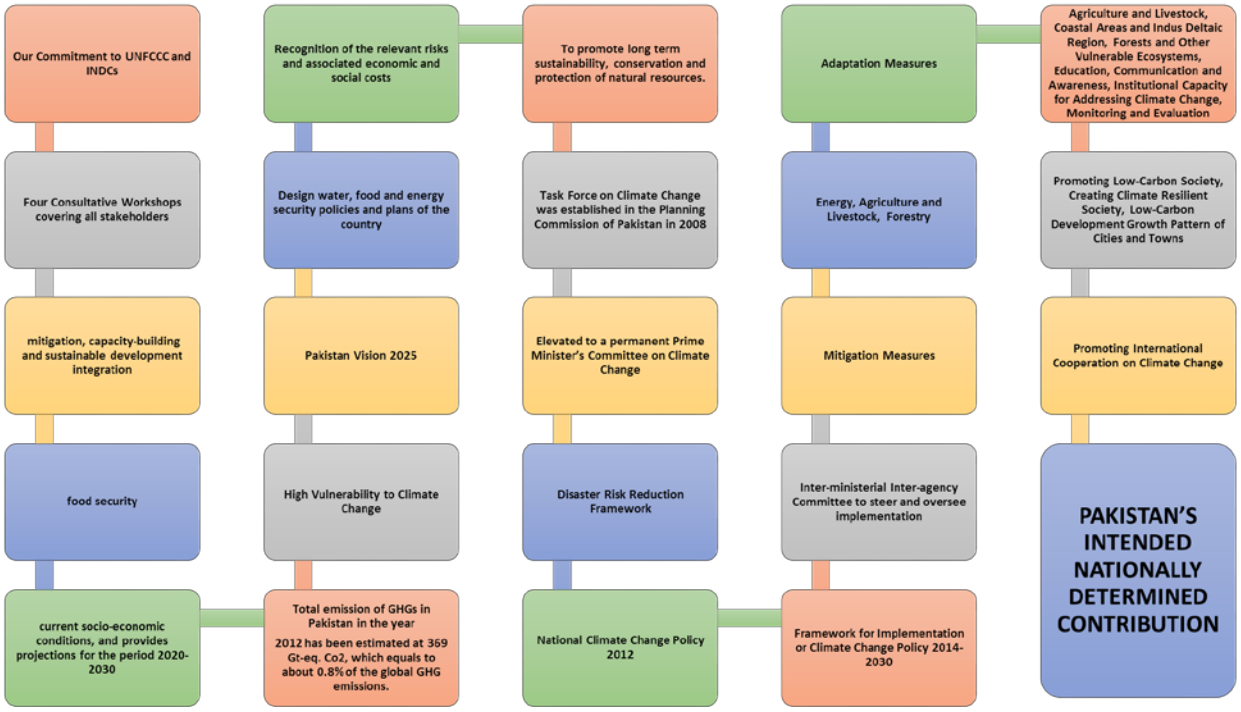

Figure 10: Pakistan's intended nationally determined contribution (PAK-INDC)

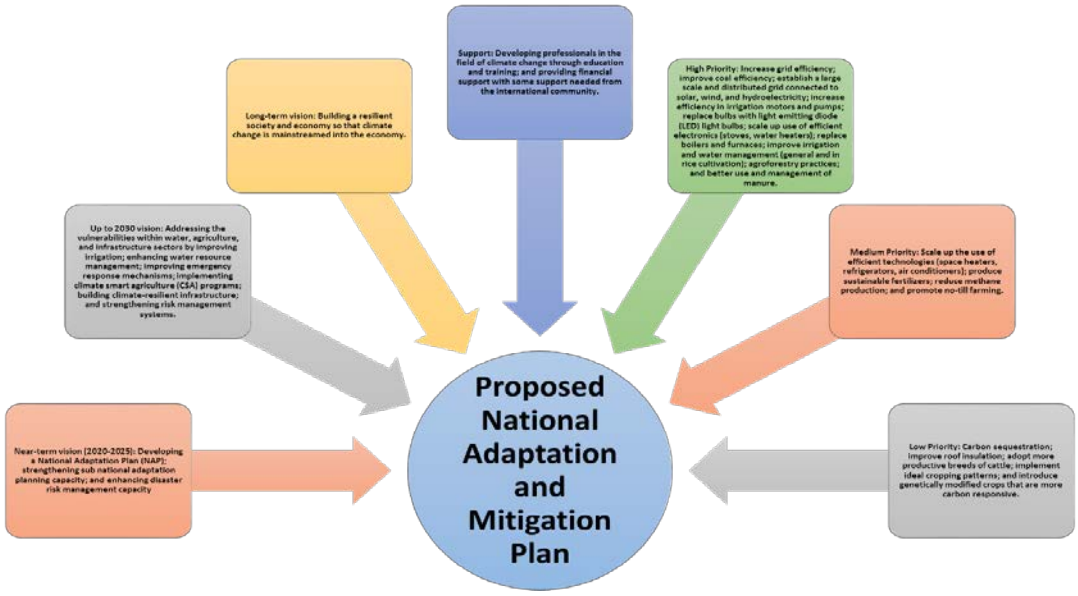

Figure 9: A proposed national adaptation and mitigation plan with prioritized engagements.

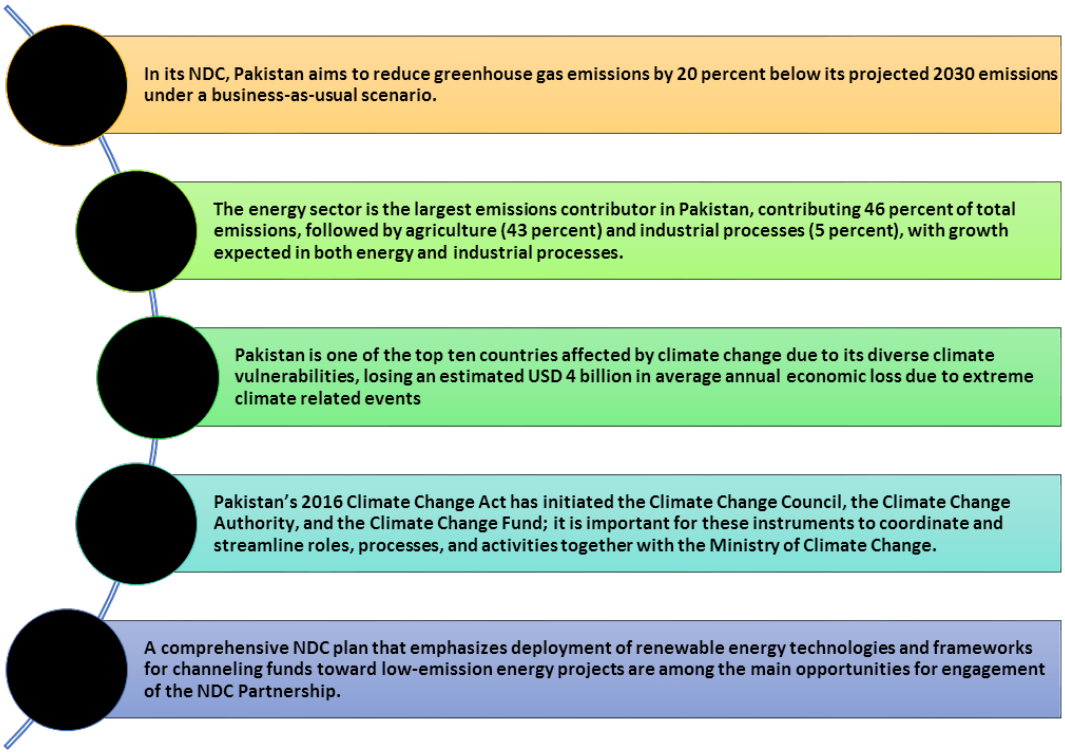

Figure 10: Acceleration in climate and development action.

Effective monitoring and evaluation programme

Drought

Water-supply projects can also be implemented for drought mitigation, with a view to strengthen drought preparedness. Activities such as water-use planning, rain-water harvesting, runoff collection using surface and underground structures, improved management of channels and wells, exploration of additional water resources through drilling and dam construction, can be implemented as a part of a drought-mitigation plan. A drought-mitigation plan should have the following three primary components:-

1. Monitoring and early-warning system.
2. Risk and impact-assessment and mitigation.
3. Post-disaster need (Sheikh, n.d.).

Floods

It is recommended that for effective and sustainable flood management, the Government of Pakistan needs to: (i) Improve and approve flood policy and laws along with their effective implementation. (ii) Integrate flood management that includes flood prevention, preparedness, mitigation and vulnerability reduction into national development policy, plan and program. (iii) Strengthen flood institutions, interagency coordination, mechanisms and capacities at national and local level. (iv) Continue to improve technical capability to forecast and warn against all sources of flooding. (v) Develop and implement a national adaptation plan to deal with climate change impacts. For this purpose, the Government of Pakistan should provide adequate financial resources to the stakeholder agencies and should also invest in capacity development of climate professionals. (vi) Develop and implement extensive community awareness raising programs to inform the community about flood hazards and preparedness for floods (Aslam, 2018).

High Temperature

To combat high temperature risks, the Government of Pakistan can undertake urgent reforestation and afforestation programmes on mountain slopes. Northern areas have suffered severe deforestation due to a lack of access to electricity and natural gas. The Billion-tree Tsunami campaign is a good start but needs to be scaled up in the long-term. The communities and the general public also need to be engaged in mass plantation drives across the country. Devise and implement a waste management strategy for mountainous areas. Since mountain communities have nowhere to dispose of their waste, they end up either throwing it in the rivers, burning the waste in open air (which contributes to black carbon deposition on glaciers and accelerates their melting) or burying it underground (which resurfaces in the event of a natural disaster and adds to existing risks). Proper waste disposal systems and awareness (especially for tourists) can help mitigate greenhouse gas emissions, air pollution and disaster risk. Also the Government can restrict diesel vehicles in the mountains, since an increasing number of tourists visiting the scenic mountains in the north opt for using diesel (the most inefficient fuel) in their four-wheelers. The particulate matter emitted by the incomplete burning of fuels at such high altitudes directly contributes to the rapid melting of glaciers, thereby accelerating climate change and worsening the health of people. The Government can also switch to renewable energy sources on larger scales. We have massive potential for solar energy in Thar and hydropower in the north which can provide clean, cost-effective and uninterrupted energy, at least for residential uses. The Government should also acknowledge that Pakistan has faced diverse climate challenges in different geographical and cultural contexts. For example, the climate impacts in Chitral will be vastly different from the impacts faced by Sindh. Therefore, there is a need to ideate solutions keeping in mind the context and diversity. Under these solutions, the Government can deploy a proactive approach rather than a reactionary one.

Winds

The research on wind patterns and storms of Pakistan are under study across the world. Pakistan can make collaborations with those developed countries who have developed infrastructure for research in order to predict wind storms and related disasters.

Conclusion

To combat impacts of climate change, efforts are urgently required, but it is also important to recognise that the onus for change is not completely on the government. We, as aware citizens, need to demand action on these issues and work closely with Governmental and non-Governmental institutions to ensure that these measures get implemented. It is time to shun passivity and take an active part in climate advocacy (DAWN, 2019).

High Target Risks

Heat waves can cause great discomfort to people (Suzman, 2019). Heat waves over northern areas of Pakistan - which hosts reservoirs of snow and glacier - may result in events like glacial lake outburst flood and snow/ice melt flooding (Saeed et al, 2017). Temperature increases are likely to place strain on urban dwellers and outdoor labourers, with increased risk of heat-related sickness likely under all emissions pathways (Bronkhorst and Bhandari 2021). Hyderabad will likely become the hottest city of Pakistan by end century with the highest average temperature reaching 29.9ºC under RCP4.5 and 32.0ºC under RCP8.5 followed by Jacobabad, Bahawalnagar and Bahawalpur (Ali et al. 2020).

Pakistan is also likely to experience frequent occurrence of severe cyclones and storm surges due to rising atmospheric and sea temperatures. These events, accompanied by rising sea levels, could threaten coastal cities such as Karachi, Thatta and Badin. High risk near coastal areas, and coastal infrastructure will be especially affected. Key assets like Gwader Port and the Coastal Highway could need extra

protection (Islam et al, 2011). Literature also claims that there is more than a 20% chance of potentially-damaging wind speeds in Pakistan in the next 10 years (Think Hazard).

Heavy monsoon rains in northern Pakistan cause devastating impact across the entire Indus river basin (Oxley and Marcus, 2010). As heavy rainfall over consecutive days can create flood conditions, RX5day is usually defined as a potential flood risk index (Frich et al., 2002). On review of this index over Pakistan, it was found that RX5day was increasing for near future and decreasing for far future under RCP 4.5 and this decrease was also significant over some grid points of the country. Whereas for RCP 8.5 it was decreasing in near future and significantly increasing (90% confidence level) in far future over the country - particularly over the north east side. The average increase of this index went up to 117.50 mm by the end of this century under RCP 8.5 which indicated increase in floods over monsoon dominating regions of the country (Rehman et al, n.d.). Events of sparse but heavy precipitation in typically mountainous valleys in the north and desert in the south were found to be catastrophic, in Pakistan (Hunt, 2018).

Pakistan - which is already prone to flooding - could observe almost a doubling in high-end flood risk, with 11 million people at risk of floods by 2040 (DAWN, 2018). Flooding was projected, with a likely increase of around 5 million people exposed to extreme river floods by 2035–2044, and a potential increase of around 1 million annually exposed to coastal flooding by 2070–2100 (Awan, n.d.). Damages incurred via torrential rainfall were found widespread over Pakistan (Khan, 2020). Risk associated with drought, economic, social and environmental degradation costs and losses associated with the drought were found very high in Baluchistan and Sindh.

Climate Risks and Timeframe

Pakistan Council of Research in Water Resources (PCRWR) announced that by 2025, there will be very little or no clean water available in the country due to which approximately 60 million people are at risk of being affected by high concentrations of arsenic in drinking water (Nabi et al, 2019). Significant population segments are likely to be marooned / isolated due to storm surge wave and ensuing heavy rains. High winds are likely to cause widespread damage and take a heavy human toll. Blockage of storm water drains is likely to accentuate the post cyclone flooding impact. Relief operations are likely to be seriously undermined due to flooding of essential communication infrastructure. Break down of essential services like electricity and water will accentuate the humanitarian impact of the disaster. Absence of shelters, evacuation plans and poor state of emergency response services makes coastal cities increasingly vulnerable to cyclones (NDMA, 2008). There is more than a 20% chance of potentially-damaging earthquake shaking in Pakistan in the next 50 years.

Potential Risk Management

To cope with and mitigate the adverse effects of climate change, there is a need for development of heat- and drought-resistant high-yielding varieties to ensure food security in the country (Ali et al. 2017). Managing aquifer recharge in the riverine corridor, combined with improved irrigation efficiencies, can literally make Pakistan secure in the event of longest conceivable droughts (Abbas and Hussain, 2019). Managing river systems can help Pakistan manage floods, can deal with droughts and can create engines for a green economy. Management of riverine corridors and active flood plains is the key to managing large and frequent floods. With proper management of wetlands and forests in Pakistan, it could hold and recharge between 30 to 50 MAF of water during a flood (Abbas and Hussain, 2019). Magnitude of the challenge associated with seismicity is daunting; there are clear, tangible actions that can be taken to reduce seismic risks in Pakistan, with a focus on both soft and hard interventions. First, structural innovations, such as retrofits can enhance resilience of existing public infrastructure, especially schools and hospitals in vulnerable areas. Second, these risk reduction investments can be complemented with measures that enhance capacities for emergency communication, information management, and response. Third, all buildings, not just priority public

buildings, can be made more resilient by better enforcing building codes and land-use regulations (World Bank, 2020).

Uncertainty/ Additional Resources Needed

There is a difficulty to predict and mitigate climatic impacts due to lack of precise information on many related issues (Ahmad et al. 2004). Despite a number of measures including legislative frameworks, structural infrastructure and flood management institutions in Pakistan, flood disasters are likely to challenge and overpass these arrangements (Khan, 2019). Cyclones are most prevalent in the coastal areas - which are not highly developed areas of Pakistan. They do not have proper facility of early warning systems. Facilities of mobile, fax and internet is also very low. In order to send early warning signals to the local community district government have to send their representatives through vehicles or boats which take long time and people have less time to cope with the emergency situation. So, the effectiveness of early warning system is very low in Pakistan. More facilities and training should be provided by government in these areas. Earthquakes is the most devastating natural disaster with a high rate of wide spread destruction. Earthquake induce ground shaking plays a key role in excessive ground deformation and infrastructure damage, and in triggering secondary hazards such as landslides, flooding, tsunamis, fire and liquefaction. The magnitude of prevailing earthquake induced risk needs detailed earthquake hazard assessment. Need of the hour is to design earthquake resistant structures; implement the seismic building codes and aware public to adopt for earthquake risks in the future (Shafique and Khan, 2015).

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