Climate Change Scenarios in Pakistan

A CASE STUDY OF THAR

SINDH

Research and Development Foundation

Climate Change Adaptation Project in Tharparker

RDF Research and Development Foundation

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A CASE STUDY OF THAR

SINDH

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1 PREFACE

Pakistan faces a number of significant environmental challenges, particularly due to the degradation of natural resources. The geographical diversity of Pakistan is reflected in its considerable climate variability. In the north, the Himalayas and northern highlands experience cool conditions and precipitation levels can average around 1500 mm per year. In the southern low lying plains and the coastal zone, the climate is considerably hotter and drier, with rainfall in some locations being less than 100 mm per year. Climate change is altering these conditions. Mean annual temperatures in Pakistan increased by 0.57°C in the 20th century; and this warming trend has accelerated in recent years.

Concurrently, mean annual precipitation levels increased by 25 percent between 1901 and 2000 for all of Pakistan. However, rainfall in the southern arid plains and along the coast has decreased by 10 to 15 percent since 1960, while wetter areas in the north have received more precipitation than the national mean. In addition, precipitation intensity has increased in most areas over the past few decades. These trends are projected to continue into the future.

The Thar region of Pakistan is one of the most vulnerable regions, both socially and environmentally. The Thar Desert is definitely going to get hotter, and rainfall conditions are unlikely to improve in any meaningful capacity.

This study is part of RDF's series of practical guidance documents and toolkits being developed to support the adaptation to climate change in Thar. The study was commissioned to Pakistan Meteorological Department by RDF under its climate change adaptation program being implemented in Taluka Chachro, District Tharparker Sindh. The Program is being implemented with the support of Kindernothilfe (KNH) and funding by the German Federal Ministry for Economic Cooperation and Development (BMZ).

The study has focused on indicative and expected range of rainfall and temperature changes in next three decades in Thar. The presented scenarios indicate that the global warming may accompany much larger climatic changes and their adverse impacts in the coming decades.

RDF hopes that climate scenario study would provide important information about the possible future climate in Thar region. This information can be used to address the potential adverse impacts of climate change in a way that promotes climate resilient development.

Research & Development Foundation
Hyderabad

2 MESSAGE FROM BMZ

One of the many challenges Pakistan is facing is its increasing vulnerability to climate change. Scientific studies such as this one, are needed as a basis for developing adaption strategies to climate change in general and water scarcity in particular. I therefore applaud the authors for this study which sheds light on the Thar desert in Sindh province.

The German Government is assisting Pakistan to adapt to climate change through a number of projects since the beginning of the bilateral development cooperation in 1961.

One of the priority areas of Pakistan-German Development Cooperation is renewable energy and energy efficiency. There is great potential for the use of hydropower that allows for the sustainable production of much needed energy supply and which contributes to reducing greenhouse gases at the same time.

Renewable energy is one side of the coin called "combating climate change". The other side ist improving energy efficiency, which is another priority area of our cooperation. Inefficient energy distribution and use impedes competition and the development of manufacturing industry. In cooperation with the private sector and the Ministry of Commerce, experts financed by Germany are endeavoring to identify savings potential and to determine what specific measures could be taken to increase efficiency. As this study shows water scarcity is likely to increase in regions such as the Thar desert. Therefore the efficient use of water by industry, households and agriculture is extremely important.

Around 20 per cent of the water used worldwide is consumed by industry and the demand is rising continuously. As Pakistan's economy is growing, industrial wastewater cannot be fed untreated into surface waters or groundwater. Protecting scarce groundwater resources is therefore extremely important. Germany supports Pakistan in order to help enterprises and farms to use water efficiently, to develop treatment facilities and introduce water-conserving production methods.

Without water there can be no harvest. Irrigated agriculture accounts for more than 70 per cent of global water consumption. However, large amounts of water are often lost as a result of unsuitable cultivation and irrigation techniques and inefficient systems. Therefore the German government supports the development of water management systems in Pakistan which aims to conserve natural resources and bring lasting improvements to people's living conditions.

Finally, Germany is supporting Pakistan in taking action to conserve biodiversity and protect its forests. The purpose of these measures is both to protect scarce national resources and protect against disasters, especially floods, and the protection of water catchment areas.

Dr. Stefan Oswald
Head of Division Afghanistan / Pakistan
German Federal Ministry for Economic Cooperation and Development

MESSAGE FROM
Kindernothilfe (KNH) Germany

Since the 1970s, Kindernothilfe and its partners in Pakistan have been working together to improve the lives of poor people and to strengthen the capacities of communities – all with the intention of enhancing living conditions. The measures taken were and are designed to align with the needs of the most vulnerable groups of the population. The focus of KNH will always be on the specific situation, the rights and capabilities but also the vulnerability of children.

In the course of their joint work in Pakistan, KNH and its partners have become aware of the necessity to take ecological and environmental issues more and more into account. Over the years the occurrence and the impacts of natural hazards such as floods and droughts seem to have changed – sometimes for the better, often for the worse. Particularly ecologically frail areas like the Thar Desert are susceptible to devastation by natural disasters caused or reinforced by climate change. Therefore, regional or local authorities and people living in these regions will have to learn more about the possible impact of climate change on their environment and how to deal with it. Scientific data is crucial in order to predict natural hazards and to enable the communities in the most disaster-prone areas of Pakistan to better prepare for such events, thus strengthening the resilience of the local population.

Especially children will have to cope with a deteriorating or changing environment since the actual impact of climate change will show in the future. Hence for the children of today it will not suffice to rely purely on the techniques and knowledge of their forbearers to sustainably use natural resources and to mitigate natural hazards when they are grown. Educating the young generation about the effects of climate change on the ecosystem based on scientific findings will be essential to prepare them adequately for the future. It is imperative, nevertheless, to contextualize scientific data regarding climate. Such data may be used in a meaningful way if it connects with the knowledge and experience of the people in a given area. The indigenous understanding of local context and established skills of how to cope best with the hardships of living and working in a fragile ecological environment are not only relevant for the local population. That expertise might be the basis of and a resource for the development of new strategies to adapt to the challenges of a changing climate.

Using an established scientific model of climate change the authors of the present study predict that until 2040, the mean temperature in the two examined communities Chhor and Mithi of the Thar Desert will rise and that rainfall will stay unpredictable; the annual amount of precipitation is even estimated to decrease in the 2030s. Hanif and Hassan conclude that the already existing water scarcity in the Thar Desert will be exacerbated – not only by the effects of climate change but also by factors related to overpopulation, e. g. an unsustainable use of water and other natural resources. People living in the area will have to find new strategies of adaptation in order to ensure the availability of water and thereby also their livelihoods. In the long run their options of land use may be more and more restricted by the changing climatic conditions which might force them to change their way of life and their sources of livelihood.

One of the expected results of the joint six year project of RDF, BMZ and KNH will be the development of a shared understanding of the causes and process of climate change and of how it will affect the project communities. This study has been realized as one of the first steps in this process. Its findings will go a long way towards helping project partners and communities to integrate scientific research and traditional knowledge in their joint endeavor to rise to the challenge of climate change and to protect lives and livelihoods.

Veronika Schwanz
Head of Department
Department for Project Development, Sector Affairs and Evaluation
Kindernothilfe (KNH) Germany

Due to increasing concentrations of Green House Gas (GHG) in the atmosphere as caused by burning of fossil fuels for industrial use, land use change and population pressures, the global average temperature has increased by about 0.6°C. The future change in global average temperature is very likely from 2 – 4.5°C by the end of 21st century (IPCC 2007). In South Asia, average annual temperature could rise to a maximum in between 3.5 – 5.8°C by the end of 21st century because the region falls in arid and semi-arid zone (IPCC 2001). The global warming has altered the global and regional climates of different parts of the world. The resultant climate change effects will therefore be more pronounced in the South Asia region including Pakistan. The increase in temperature will be associated with changes in rainfall patterns and will impact (positively and negatively) various socio-economic sectors e.g., water, agriculture, health, forestry, biodiversity and human health. In Pakistan most of these impacts are already showing their signs especially since 1990.

Pakistan is a land of great topographic contrasts and therefore the climate of the country has large spatial and temporal variations. The northern and western mountain ranges in the country add to the wide variation in the climate of places located in the same latitudinal belts. Most of the areas of Pakistan are very sensitive to the changes in both temperature and precipitation. Some of the regions of the country, particularly the southern provinces are extremely vulnerable to droughts and heat stresses. Mean annual rainfall and temperature distribution is shown in Fig 1 and Fig 2 respectively.

Climate change has become a considerable international political issue during recent years. Pakistan is also vulnerable to the consequences of climate change. The global mean surface air temperature is the most commonly used indicator of climate change. Several studies have detected the human influence on temperature trends (Houghton et al., 2001; Njau, 2007). The precipitation may also be an equally important component of global climate change, but the reasons for precipitation change are more complicated than those for temperature by human activity. Due to the discontinuous nature of precipitation and the non-availability of long-term global precipitation data of rain gauges, it is difficult to find the human finger prints on precipitation. Many attempts have been made to examine the precipitation changes and trends for different regions of the world. Very few studies are available for global precipitation changes because it is a most challenging task to measure the global precipitation. More recently Zhang et al. (2007) have detected the anthropogenic impact on global precipitation which is the best work so far. Floods and droughts are the most important weather events affecting Pakistan during the recent decades. In Pakistan, there is a general perception of this change in the frequency of occurrence of these weather events.

Fig 1:
Mean annual rainfall distribution

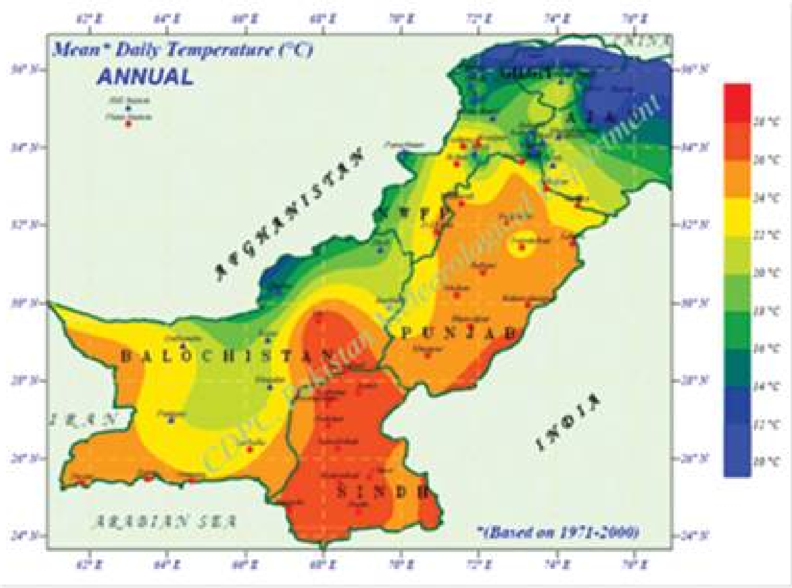


Fig 2:
Mean annual temperature distribution

Temperatures and rainfall have direct application to agricultural production and other aspects such as water resources. Investigations into changes and trend in the temperatures and rainfall are essential for a country such as Pakistan whose economy is dependent on agricultural production. Crop failure, due to extreme temperatures and the deficient and excess rains have become very critical to the country. Wheat is the staple food of the people in Pakistan, grown over an area of 8.18 million hectares and about one third of the total area under wheat falls in rain-fed areas where deficient seasonal rains may cause crop failure (Khaliq et al., 1999). Farmers in Pakistan typically rely on wheat as their main crop for subsistence. Therefore, it is important to monitor closely the temperature and rainfall variation across the country on monthly, seasonal and decadal time scales. Pakistan receives over 60% of the mean annual rainfall during the summer monsoon season (June–September), and about 75% of the mean monsoon seasonal rainfall during July and August which are the peak rainy months of the season. Monsoon is the major rainy season of Pakistan, and therefore is critical for agriculture, industry, drinking water, energy and human health.

Some of the studies revealed that no significant changes have observed in the seasonal temperatures and rainfall over the southern Pakistan. However, the spatial rainfall trends showed that some specific areas of southern Pakistan have significant decreasing trends (Hanif et al., 2013). These areas of southern Pakistan, including the Thar Desert, are extremely vulnerable to droughts. Such features of declining precipitation and increasing temperatures are most significant and alarming for these areas. More care is therefore needed in further development projects in these areas that the encroachment of desert conditions may be averted. The declining rainfall trend may not be permanent but the environmental degradation is likely to be aggravated, which in turn may be responsible for further shortfall in total annual rainfall in future. The areas extremely vulnerable to drought are rapidly developing areas of the country over the last few years due to some mega projects across the country. These areas may suffer from severe water shortage in the future due to the current trend of decreasing rainfall, and therefore more care is needed for these areas. The reasons of significant changes in temperatures and rainfall of Pakistan, either due to global climate or forced by anthropogenic activities, have not been examined in detail so far. The purpose of this work is just to understand and identify the most vulnerable areas, and then it may be easy to convince the communities and the policy makers to adopt the measures for the specific vulnerable areas to mitigate the potential effects of rapidly changing climate. The computed temperature and rainfall scenarios in this work may be helpful in this regard.

Due to great topographic contrasts, temperature and rainfall over Pakistan have large spatial variability and therefore some of the regions of the country are extremely vulnerable to floods and droughts. The region of southern Pakistan is hot and arid, the annual average rainfall in eastern parts of Sindh (study area) is less than 200 mm. The province of Sindh receives only 20% of the annual rains, and this region is highly vulnerable to drought. Thar is the study area which is located along eastern border of Sindh covering a wide area of the province. The winter rainfall in the study area is almost negligible. The area receives only monsoon rains from June to September. The Thar Desert has an extreme type of climate. In summer it is very hot in the day while the nights are cooler. In winter the days are warmer and the nights are very chilly. It is because the sand gets heated up fast in the day and cools down quickly at night. The desert is almost dry and it receives very little rainfall. Sometimes it does not rain for years together resulting severe drought as observed during 1999-2001. It is because the rain laden monsoon winds coming from the Arabian Sea pass over this desert without giving any precipitation. There are no high hills which may force the monsoons currents to cause rain. The Aravali ranges which are parallel to the direction of these winds do not stand as a barrier. The monsoon winds which come from the Bay of Bengal loose almost all the moisture by the time they reach here. As a result this part remains dry and has no rains. It has turned this fertile land into a barren desert. There are no rivers and the only local river 'Loni' which flows through this land remains dry for most of the time and ends up in sand.

In some places where water from under the ground comes up to the surface there are date palm trees. The life of the people in the desert region is very hard. The population is very thin and the villages are situated at quite long distances from one another. There are a few towns in the Thar Desert.

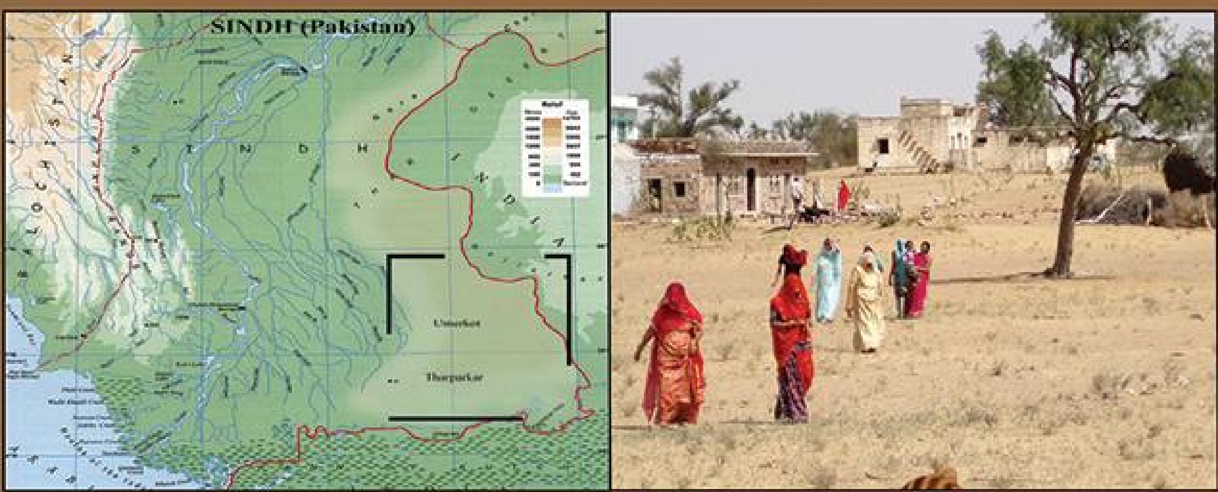


Fig 3: Study area of Thar (Sindh)

CLIMATE OF CHHOR

Chhor is a town of District Umerkot, located at lat 25.5°N and long 69.5°E. Umerkot district is ranked number two at the provincial level (46.2% people lives under the poverty line) covering an area of 5,608 square kilometers with population density of 118.2 people per square kilometer. Irrigated land, brick-line, labour, rain-fed cultivation and livestock are the main livelihoods of the district. Wheat, cotton, sugarcane, red chilies, bajra, guwar, moong, moth & seamus are the main crops sowed in western parts of the district. The climate of Chhor is hot and dry. The average minimum, maximum and the mean temperatures are displayed in Fig 4. Chhor receives less than 200 mm annual rainfall. The mean monthly rainfall of the town is displayed in Fig 5.

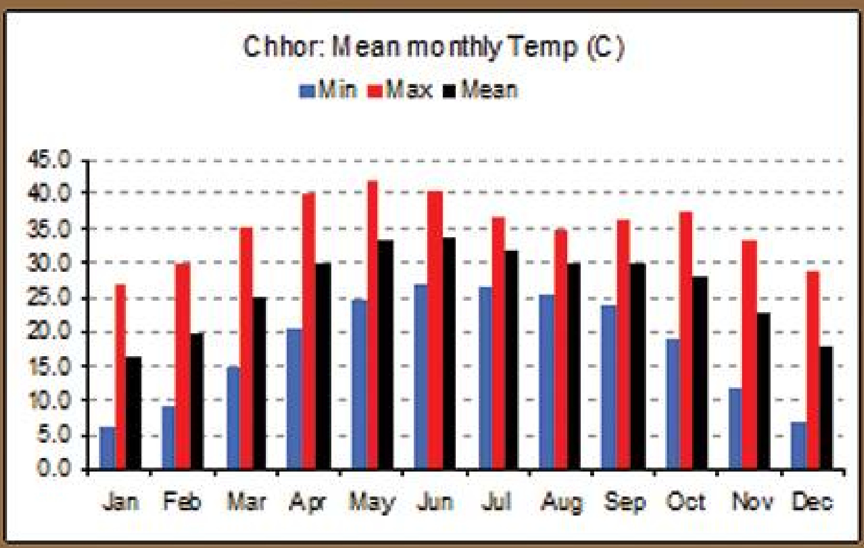


Fig 4: Mean monthly temperatures of Chhor (Sindh)

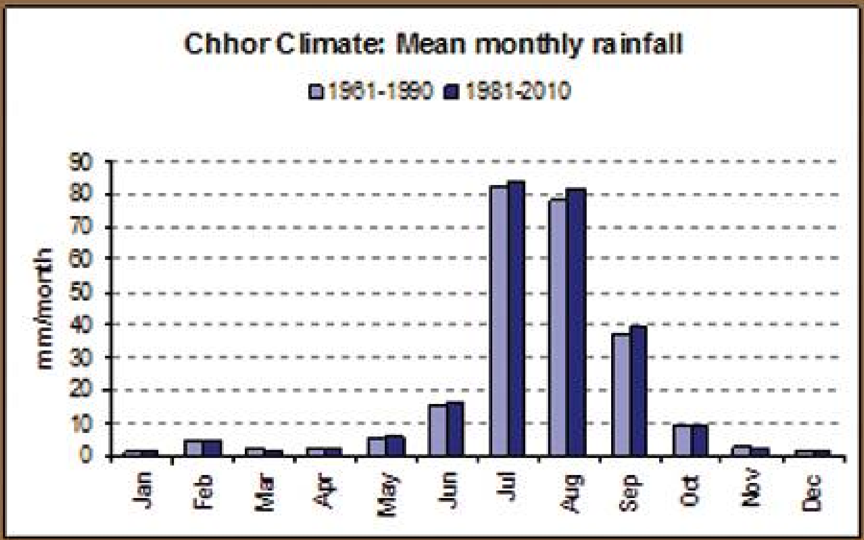


Fig 5: Mean monthly rainfall of Chhor (Sindh)

CLIMATE OF MITHI

Mithi is located in the the south of Thar Desert in the district of Tharparkar at lat 24.5°N and long 70.0°E. Tharparkar is one of the largest districts of Pakistan which is spread over 19639 square kilometres. Tharparkar is not connected with an irrigation system and it depends on monsoon rainfall for farming and sprawling pastures which feed its livestock and inhabited people. The whole area is a semi-desert arid that lacks many facilities with people there having to live without basic utilities such like food, health and proper shelter. Tharparkar also happens to be a home to wildlife and biodiversity. However, the area is hammered by climate change and desertification. The climate of Mithi is also hot and dry but mostly humid during monsoon season. The mean monthly temperatures and the rainfall of the town are displayed in Fig 10 and Fig 11 respectively.

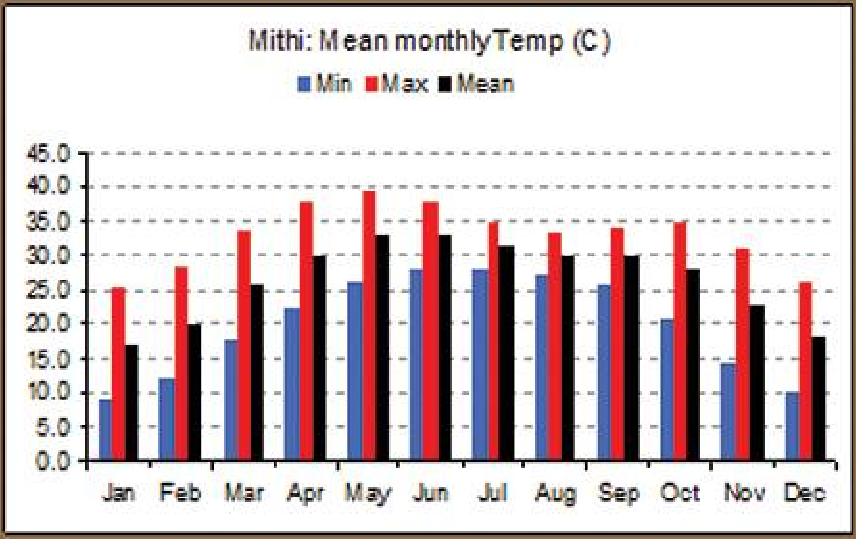


Fig 10: Mean monthly temperatures of Mithi (Sindh)

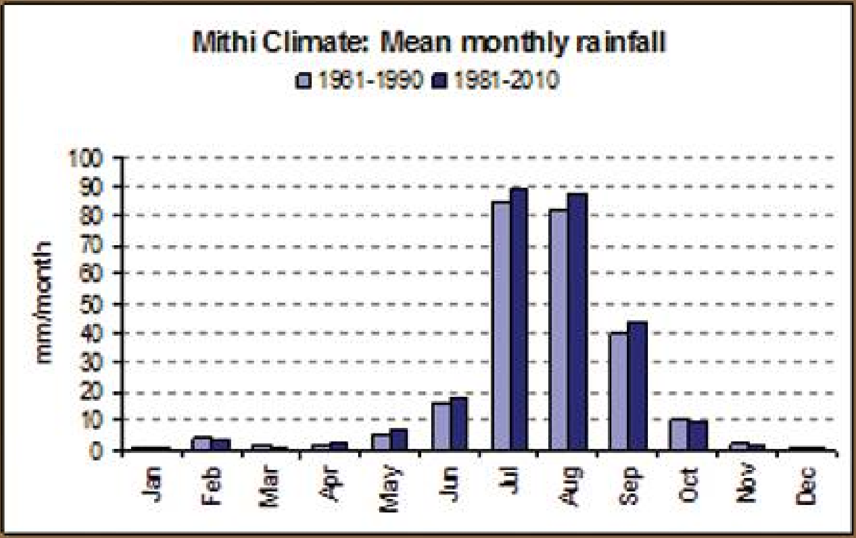


Fig 11: Mean monthly rainfall of Mithi (Sindh)

9 CLIMATE SCENARIOS AND THE METHOD

A climate scenario is a plausible representation of future climate that has been constructed for explicit use in investigating the potential impacts of anthropogenic climate change. Climate scenarios often make use of climate projections (descriptions of the modeled response of the climate system to scenarios of greenhouse gas and aerosol concentrations), by manipulating model outputs and combining them with observed climate data. The science of climate scenario development acts as an important bridge from the climate science to the science of impact, adaptation and vulnerability assessment.

All IPCC reports have already mentioned the very likely scenarios of temperatures, rainfall and the extreme weather events in the South Asian region including Pakistan. Almost same global models have been used to develop the temperatures and rainfall scenarios for the study area. Useful information about possible future climates and their impacts has been obtained using various scenario construction methods.

Scenario construction techniques can be usefully contrasted according to the sources of uncertainty that they address and those that they ignore (Rupa Kumar et al., 2006). These techniques, however, do not always provide consistent results. For example, simple methods based on direct GCM (Global Coupled Models) changes often represent model-to-model differences in simulated climate change, but do not address the uncertainty associated with how these changes are expressed at fine spatial scales. With regionalization approaches, the reverse is often true. A number of methods have emerged to assist with the quantification and communication of uncertainty in climate scenarios. The major and very commonly used approach is use of multi-model method to minimize the uncertainties and model biases. Same approach has been used to develop the climate scenarios for two stations in the study area (Chhor and Mithi). The available data of five global models have been used to compute the next three decades climate scenarios. The statistical downscaling approach was used to convert the low resolution data into high resolution scale. The possible available climate data of Pakistan Meteorological Department of two stations have been used as a base line. The temperature and rainfall scenarios of two stations, Chhor and Mithi, have been developed in the present work. The results are discussed in next section.

CLIMATE SCENARIOS OF CHHOR

The climatic scenarios for temperature and precipitation for Chhor are discussed in this section.

TEMPERATURE SCENARIOS OF CHHOR

The projected seasonal and annual average, minimum and maximum temperatures in next three decades for Chhor are given in Table 1. The projections indicate that annual temperature of the study area is increasing gradually and an average expected increase in 2040 would be 1.76°C. The projected seasonal scenarios indicate that the NIGHTS during the winter season are likely to become warm and the DAYS during the summer are expected to become hotter. The projected annual and seasonal minimum and maximum temperatures are also displayed in Fig 6 and Fig 7. The projected winter temperatures indicate that the season is getting warm and the winter span would be in reduction.

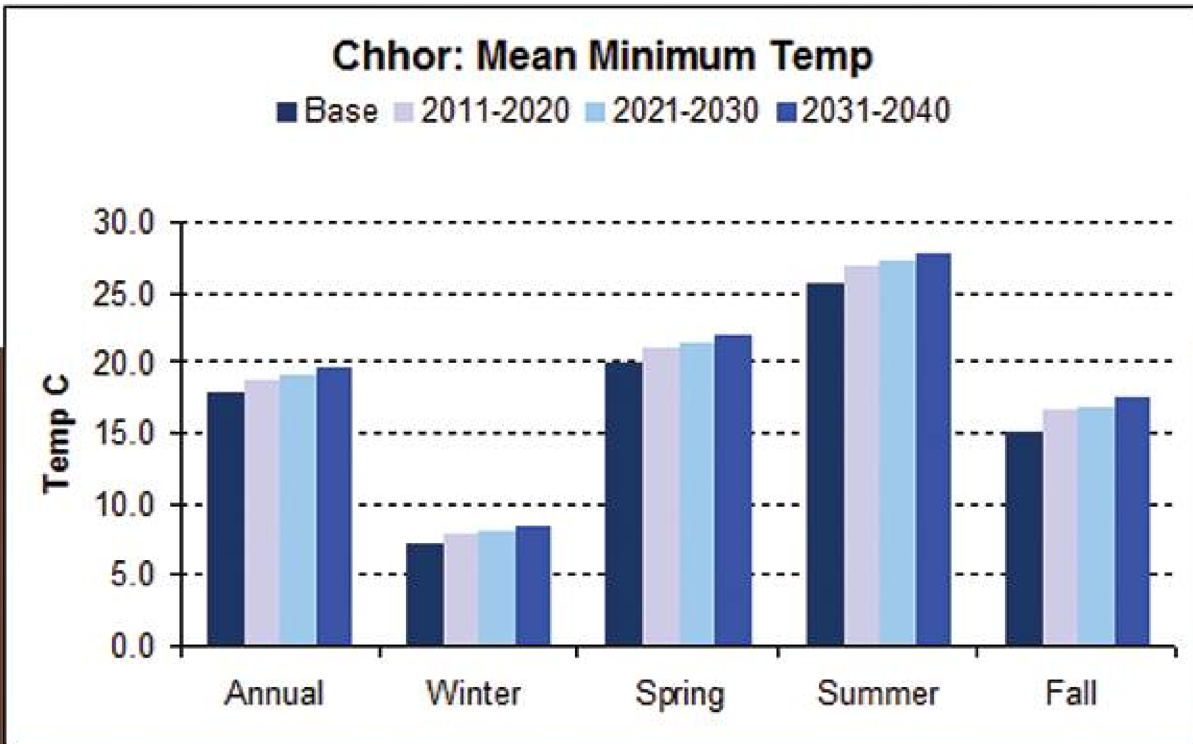
CHHOR Temperature	Base	Projected	% change From	Projected	% change from	% change from	Projected	% change from	% change from
	1981-2010	2011-2020	Base	2021-2030	Base	2011-2020	2031-2040	Base	2021-2030
Annual									
Average	26.57	27.60	3.87	27.95	5.19	1.27	28.38	6.79	1.52
Minimum	17.92	18.90	5.49	19.20	7.16	1.59	19.65	9.67	2.34
Maximum	35.23	36.30	3.05	36.70	4.19	1.10	37.2	5.61	1.36
Winter									
Average	17.90	18.83	5.17	19.20	7.26	1.99	19.70	10.06	2.60
Minimum	7.27	7.95	9.40	8.25	13.53	3.77	8.55	17.66	3.64
Maximum	28.53	29.75	4.26	30.15	5.67	1.34	30.85	8.12	2.32
Spring									
Average	29.58	30.68	3.71	31.01	4.82	1.08	31.6	6.82	1.90
Minimum	20.03	21.15	5.57	21.45	7.07	1.42	21.95	9.57	2.33
Maximum	39.13	40.20	2.73	40.60	3.75	1.00	41.2	5.28	1.48
Summer									
Average	31.40	33.22	5.80	33.55	6.85	0.99	34.10	8.60	1.64
Minimum	25.65	26.90	4.87	27.20	6.04	1.12	27.75	8.19	2.02
Maximum	37.15	39.50	6.33	39.90	7.40	1.01	40.45	8.88	1.38
Fall									
Average	25.40	26.70	5.12	27.10	6.69	1.50	27.75	9.25	2.40
Minimum	15.25	16.70	9.51	17.00	11.48	1.80	17.55	15.08	3.24
Maximum	35.55	36.70	3.23	37.10	4.36	1.09	37.9	6.61	2.16

Table 1: Annual and Seasonal Temperature Scenarios of Chhor

CLIMATE SCENARIOS OF CHHOR

TEMPERATURE SCENARIOS OF CHHOR

Fig 6: Minimum Temp Scenarios of Chhor for next three decades



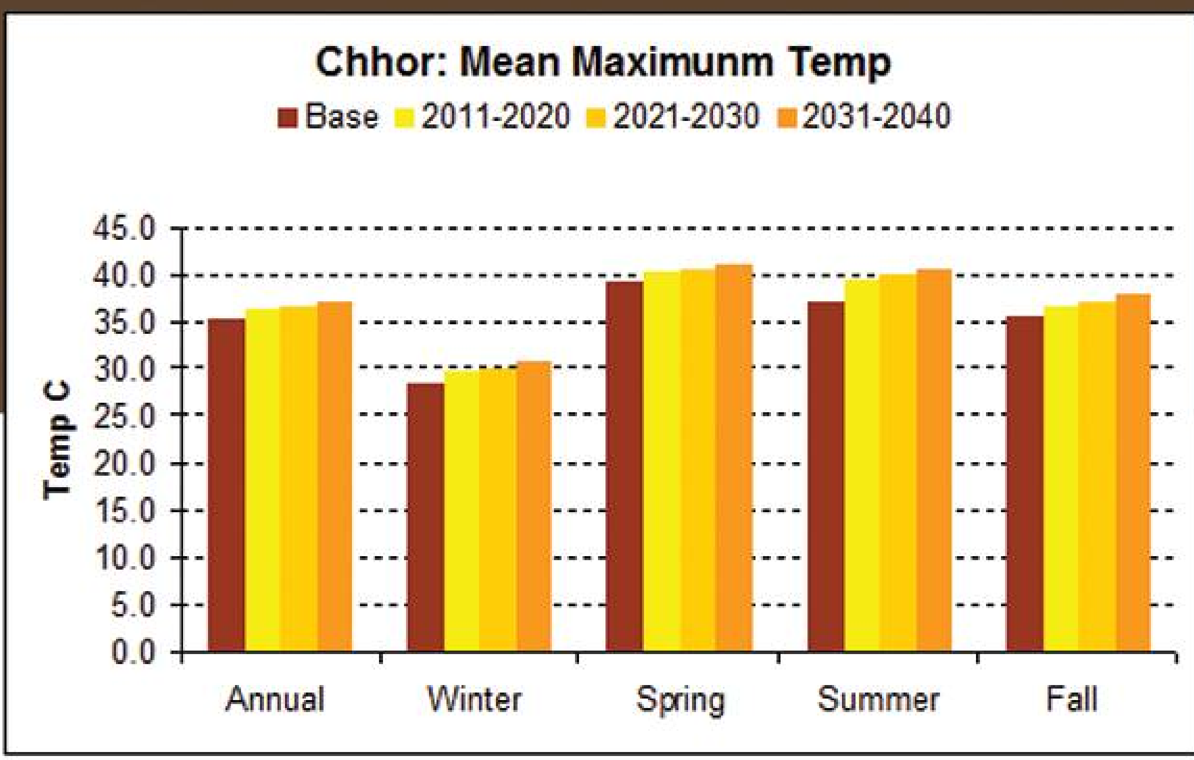


Fig 7: Maximum Temp Scenarios of Chhor for next three decades

CLIMATE SCENARIOS OF CHHOR

RAINFALL SCENARIOS OF CHHOR

In several studies it is mentioned that annual rainfall in the study area has increased during recent few decades. The projected seasonal and annual average rainfall for next three decades for Chhor is shown in Table 2 and displayed in Fig 8 and Fig 9. The projected scenarios indicate that monsoonal and annual rainfall would continue to increase gradually till 2030 but expected to decrease after that. The negligible winter rainfall of the study area is already decreasing and the projected amount is also indicating decreasing trend.

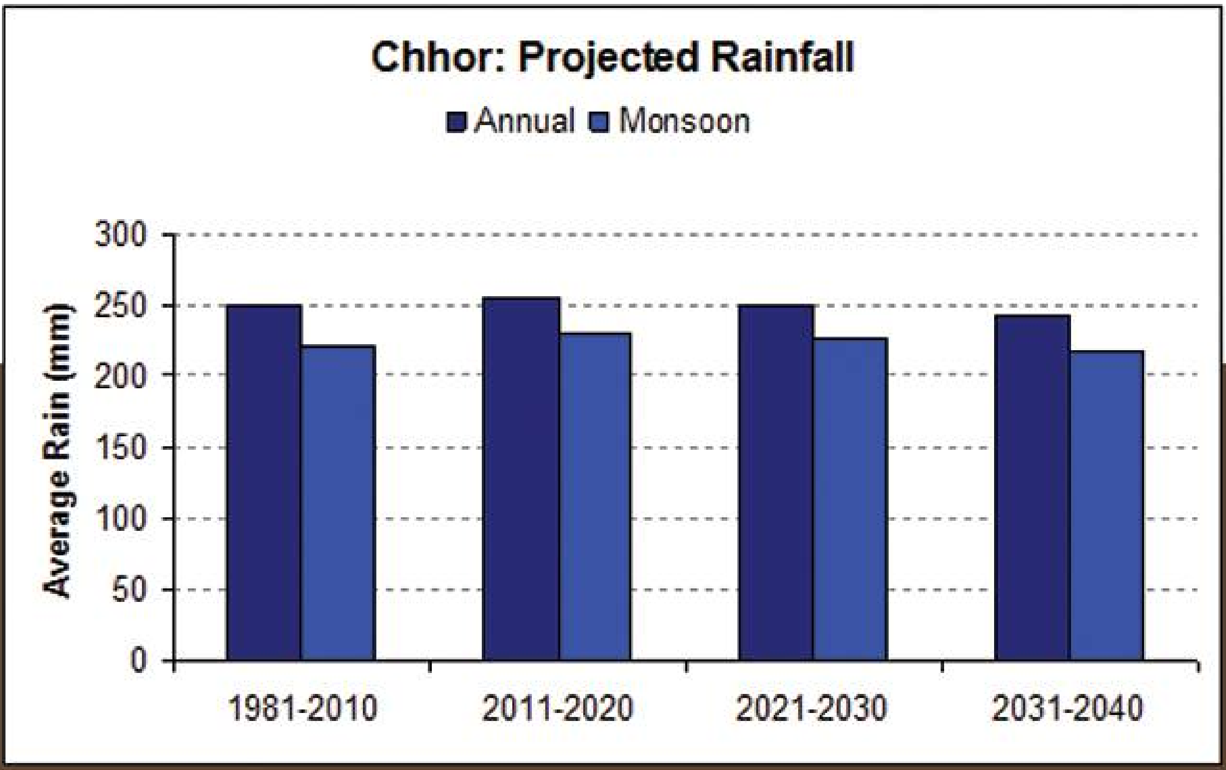
Rainfall (mm)	Base	Projected	% change From	Projected	% change from	% change from	Projected	% change from	% change from
	1981-2010	2011-2020	Base	2021-2030	Base	2011-2020	2031-2040	Base	2021-2030
Annual									
Average	249.5	255.6	2.44	251.1	0.64	-1.76	243.4	-2.44	-3.07
Summer (JJAS)									
Average	222.2	230.7	3.83	226.7	2.03	-1.73	218.20	-1.80	-3.75
Winter (DJF)									
Average	6.2	6.0	-3.23	5.8	-6.45	-3.33	5.50	-11.29	-5.17
Spring (MAM)									
Average	9.9	10.3	4.04	10.1	2.02	-1.94	9.70	-2.02	-3.96

Table 2: Annual and Seasonal Rainfall Scenarios of Chhor

CLIMATE SCENARIOS OF CHHOR

RAINFALL SCENARIOS OF CHHOR

Fig 8: Annual and monsoon rainfall scenarios for Chhor



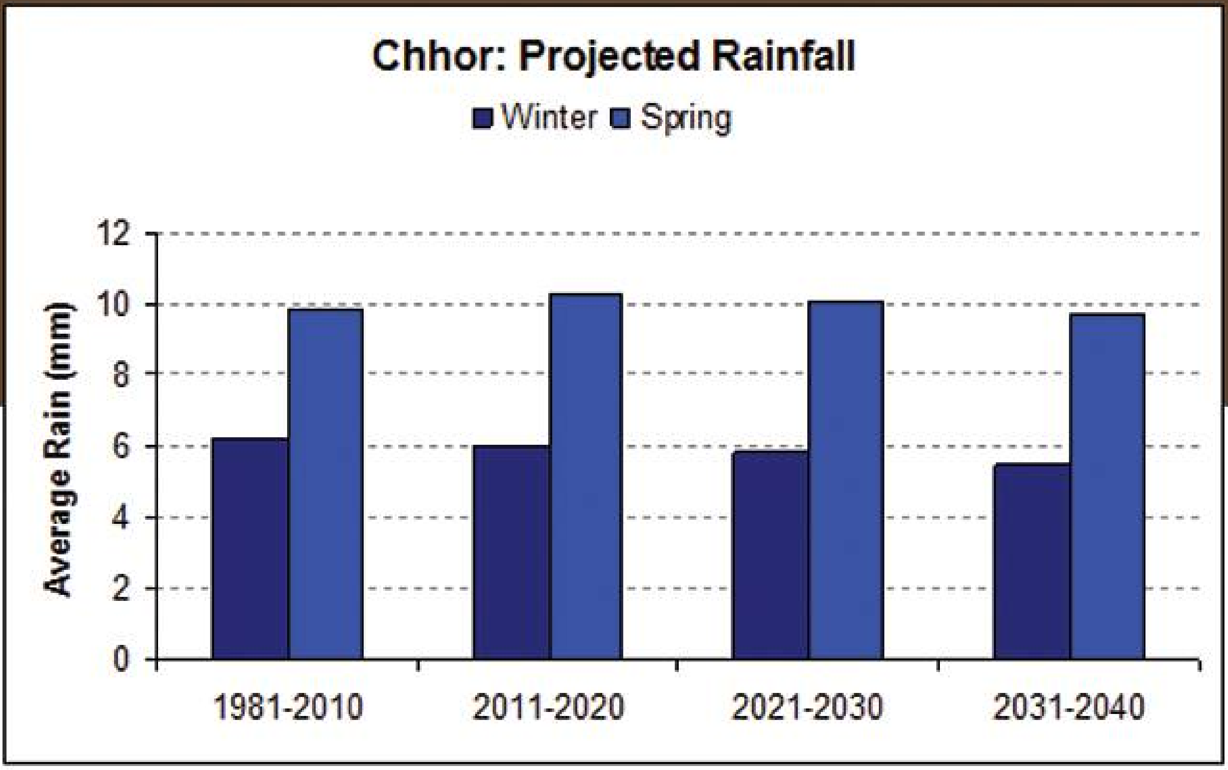


Fig 9: Winter and Spring rainfall scenarios for Chhor

CLIMATE SCENARIOS OF MITHI

The climatic scenarios for temperature and precipitation for Mithi are discussed in this section.

TEMPERATURE SCENARIOS OF MITHI

The projected seasonal and annual average, minimum and maximum temperatures in next three decades for Mithi are given in Table 3 and also displayed in Fig 12 and Fig 13. The projections indicate that annual temperature of the study area is increasing gradually and an average expected increase in 2040 would be 1.75°C. The projected seasonal scenarios indicate that the NIGHTS during the winter season are likely to become warm and the DAYS during the summer are expected to become hotter. Like Chhor, the winter season in Mithi is also becoming warm with the passage of time as shown by the projected temperatures.

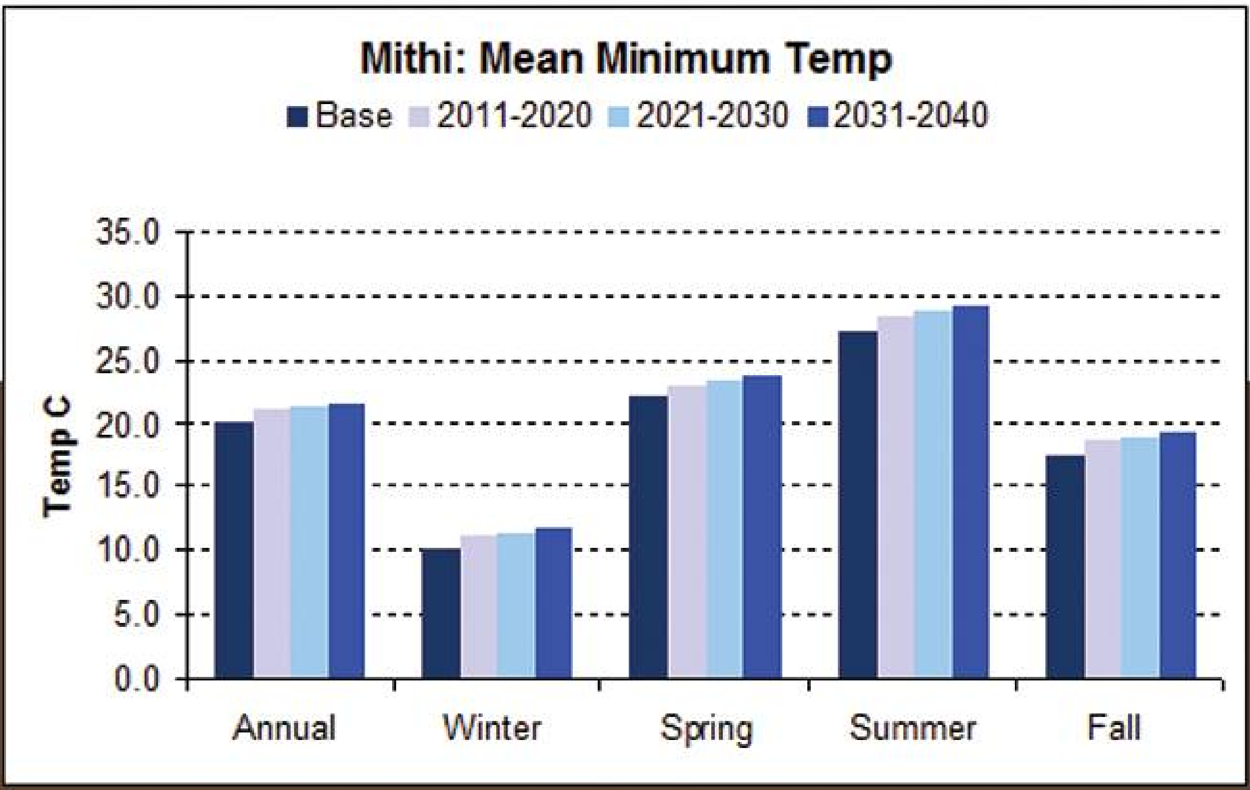
MITHI Temperature	Base	Projected	% change From	Projected	% change from	% change from	Projected	% change from	% change from
	1981-2010	2011-2020	Base	2021-2030	Base	2011-2020	2031-2040	Base	2021-2030
Annual									
Average	26.60	27.72	4.19	28.10	5.62	1.37	28.35	6.56	0.89
Minimum	20.08	21.10	5.11	21.40	6.60	1.42	21.55	7.35	0.70
Maximum	33.13	34.35	3.67	34.75	4.88	1.16	35.15	6.09	1.15
Winter									
Average	18.33	19.83	8.16	20.18	10.07	1.77	20.70	12.91	2.58
Minimum	10.23	11.25	9.93	11.55	12.87	2.67	11.85	15.80	2.60
Maximum	26.43	28.40	7.44	28.80	8.95	1.41	29.55	11.79	2.60
Spring									
Average	29.57	30.80	4.17	31.15	5.36	1.14	31.73	7.32	1.86
Minimum	22.10	22.95	3.85	23.25	5.20	1.31	23.8	7.69	2.37
Maximum	37.03	38.65	4.37	39.05	5.45	1.03	39.65	7.07	1.54
Summer									
Average	31.14	32.63	4.79	32.95	5.82	0.98	33.88	8.81	2.82
Minimum	27.23	28.40	4.32	28.70	5.42	1.06	29.2	7.25	1.74
Maximum	35.05	36.85	5.14	37.25	6.28	1.09	38.55	9.99	3.49
Fall									
Average	25.33	26.70	5.43	27.10	7.01	1.50	27.75	9.58	2.40
Minimum	17.50	18.70	6.86	19.00	8.57	1.60	19.4	10.86	2.11
Maximum	33.15	34.70	4.68	35.10	5.88	1.15	36.12	8.96	2.91

Table 3: Annual and Seasonal Temperature Scenarios of Mithi

CLIMATE SCENARIOS OF MITHI

TEMPERATURE SCENARIOS OF MITHI

Fig 12: Minimum Temp Scenarios of Mithi for next three decades



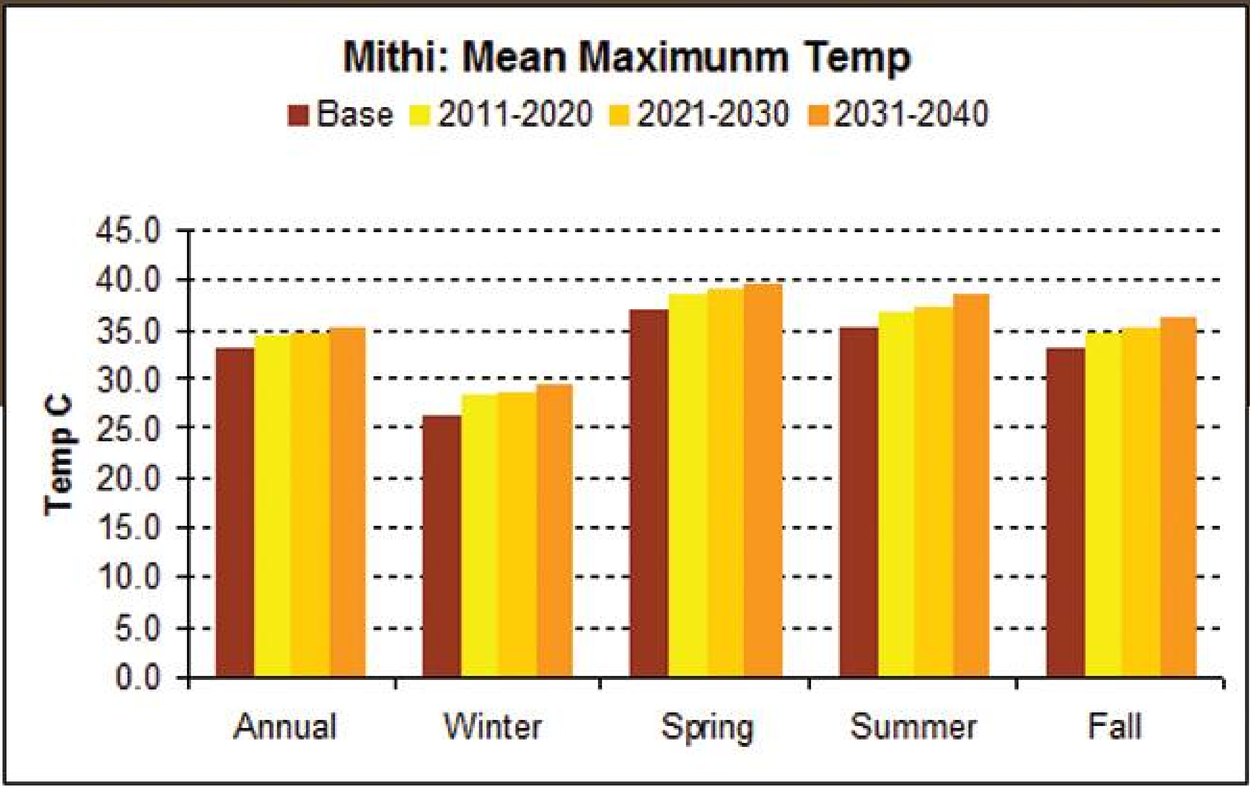


Fig 13: Maximum Temp Scenarios of Mithi for next three decades

CLIMATE SCENARIOS OF MITHI

RAINFALL SCENARIOS OF MITHI

The projected seasonal and annual average rainfall for Mithi is shown in Table 4 and displayed in Fig 14 and Fig 15. The projected scenarios indicate that seasonal and annual rainfall is likely to continue to increase gradually till 2030 but expected to decrease after that except of winter rainfall. The winter rainfall of the study area is already negligible and the winter season is expected to become drier with passage of time.

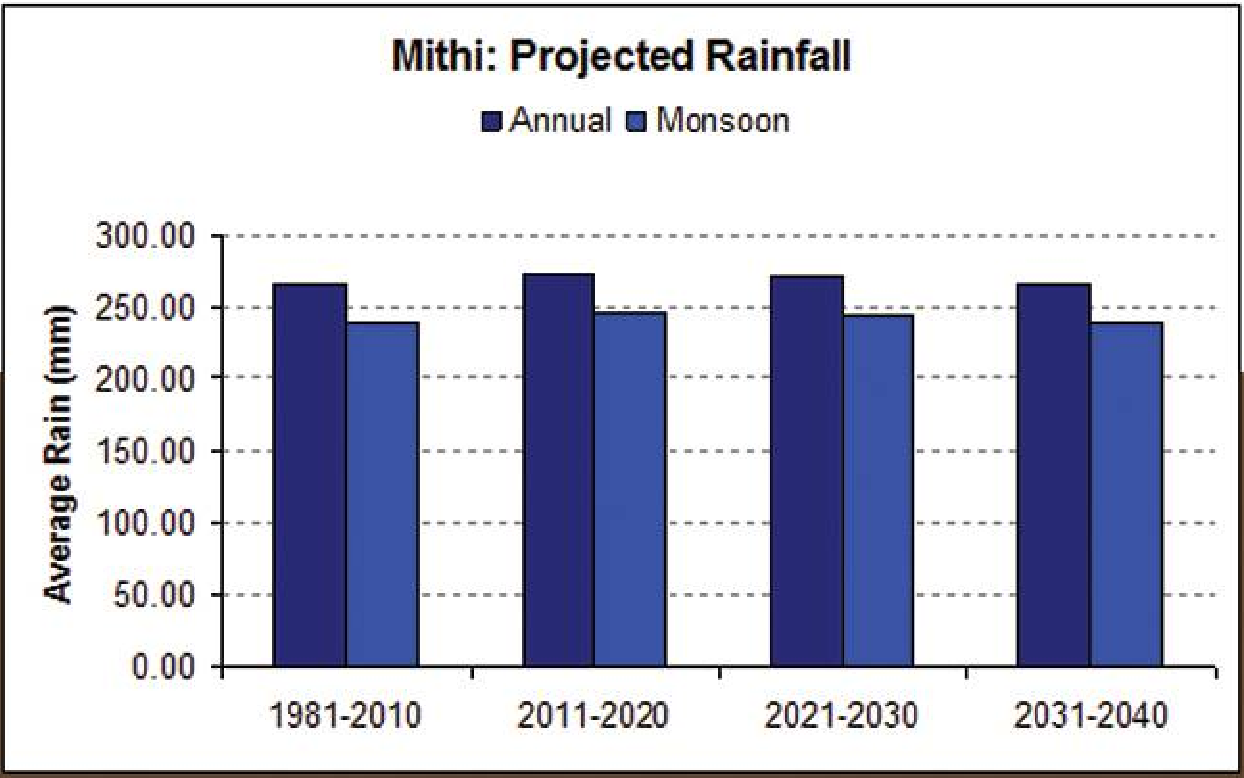
Rainfall (mm)	Base	Projected	% change From	Projected	% change from	% change from	Projected	% change from	% change from
	1981-2010	2011-2020	Base	2021-2030	Base	2011-2020	2031-2040	Base	2021-2030
Annual									
Average	266.60	274.1	2.81	271.4	1.80	-0.99	266.7	0.04	-1.73
Summer (JJAS)									
Average	239.0	247.2	3.43	244.8	2.43	-0.97	240.50	0.63	-1.76
Winter (DJF)									
Average	5.9	5.7	-3.39	5.4	-8.47	-5.26	5.10	-13.56	-5.56
Spring (MAM)									
Average	10.2	10.5	2.94	10.3	0.98	-1.90	10.00	-1.96	-2.91

Table 2: Annual and Seasonal Rainfall Scenarios of Chhor

CLIMATE SCENARIOS OF MITHI

RAINFALL SCENARIOS OF MITHI

Fig 14: Annual and monsoon rainfall scenarios for Mithi



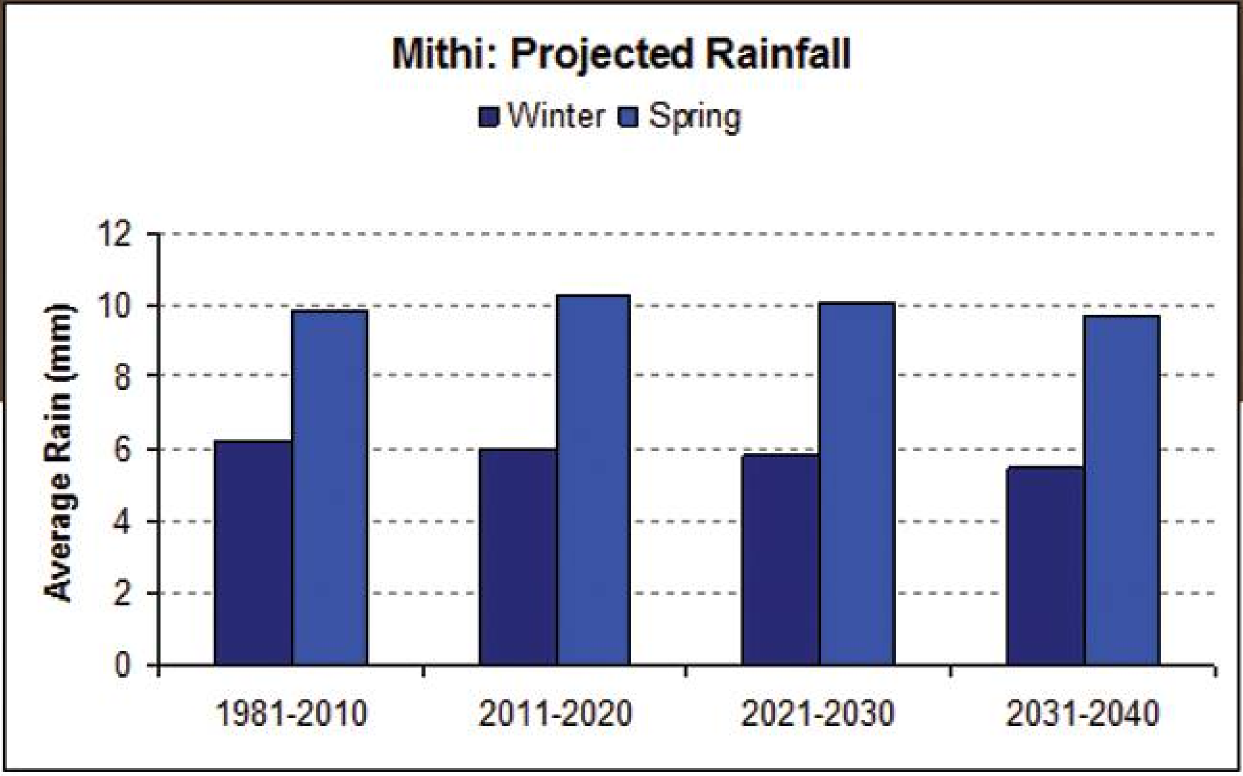


Fig 15: Winter and Spring rainfall scenarios for Mithi

CONCLUSION AND RECOMMENDATION

The present work includes only the basic aspects of the simulation results which are indicative of expected range of rainfall and temperature changes in next three decades. The presented scenarios in this work indicate that the global warming may accompany much larger climatic changes and their adverse impacts in the coming decades. The most commonly considered indicator of climate change is the increasing surface air temperature that causes an increase in evaporation/evapotranspiration and generally higher levels of atmospheric water vapors, resulting changes in the seasonal rainfall patterns.
The Thar area of Pakistan is one of the most vulnerable regions, both socially and environmentally. The Thar Desert is almost definitely going to get hotter, and rainfall conditions are unlikely to improve in any meaningful capacity: they're probably going to remain as wildly variable as they are now. The Thar region exhibits some of Pakistan's lowest indicators on measures of education, employment diversification and social mobility, all of which are key factors for promoting resilience. Often, poverty leads to vulnerability because it limits adaptation.

Climate change poses further risks in its interaction with other environmental problems. The IPCC reports also indicate the combination of overpopulation and climate change in Pakistan could potentially decrease the amount of water available per person, leading to intense water shortages. Such changes would be especially potent in the Thar Desert, where water is scarce enough as it is. Thar is the world's most densely populated desert ecosystem, it already endures heavy resource stress, with increasingly dire situations of overgrazing and groundwater exploitation. Climate change exacerbates existing problems, especially depletion of groundwater. Farmers who use tube wells are less likely to perceive or expect changes in rainfall, and they are less likely to implement certain adaptive practices, suggesting that groundwater irrigation serves as a potentially unsustainable crutch against climatic adversity.

The local communities in the Thar region should adopt many traditional and sustainable practices that foster resilience, such as rainwater harvesting, agricultural diversification, animal husbandry, and conservation of forests to deal with the climatic variability. By continuing and improving these practices, the residents of the Thar can efficiently adapt to future changes. As farming becomes more difficult, villagers will need to seek alternatives to agriculture as a source of livelihood. Otherwise, the life in the Thar, in the long run, cannot be truly sustainable. The climate scenarios presented in this report may be a broad examination of climate change vulnerability in the Thar region. Because the climate change adds an extra challenge to an already difficult way of life, but timely and appropriate adaptation measures can soften the blow. The present work makes a substantial contribution towards developing local adaptation strategies in the study area which is very likely to be severely affected by climate change in the near future. The scenarios presented in this work are very useful for impact assessments of various sectors.

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