Potential of Climatic Extremes over Sindh in an Overly Carbonized Future Scenario

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Climate of Sindh

The province of Sindh is situated in a subtropical region; it is hot in the summer and cold in winter. Temperatures frequently rise above 46 °C between May and August, and the minimum average temperature of 2 °C occurs during December and January. The annual rainfall averages about seven inches, falling mainly during July and August. The south-westerly monsoon wind pattern prevail from mid-February till the end of October, whereas the cool northerly wind blows during the winter months from November to January.

Sindh lies between the two monsoons — the southwest monsoon from the Indian Ocean and the northeast or retreating monsoon, deflected towards it by the Himalayan Mountains— and escapes the influence of both. The average rainfall in Sindh is only 150–180 mm per year. The region's scarcity of rainfall is compensated by the inundation of the Indus twice a year, caused by the spring and summer melting of Himalayan snow and by rainfall in the monsoon season. These natural patterns have recently changed somewhat with regulatory infrastructure on the Indus River.

1.1 Climate hazard indicators over Sindh:

Over the past, Sindh has seen catastrophes based on the following extreme indicators

1. Heat waves
2. Ratio of wet over dry days
3. Warm days and nights
4. Consecutive wet days
5. Hill torrents and floods
6. Droughts

1.2 Data and methodology:

a) Climatic Data

For the assessment of extreme climate indices, observation, simulation and projection level data of Pakistan Meteorological Department (PMD) and the NASA Earth Exchange Global Daily Downscaled Climate Projections (NEXGDDP) were engaged for the period of 1971-2050. Historical data of the NEXGDDP was bias corrected with in-situ data of PMD using the quantile mapping approach which removed systematic biases in the model output and regenerated the data at high resolution of 25 km of horizontal scale. A high carbon forced Representative Concentration Pathway (RCP) was used for projections which prognosticated the CO2 levels to reach 500 parts per million (or 20 giga tonnes of carbon) and reside in to the atmosphere by 2050.

b) Methodology used for climate indices

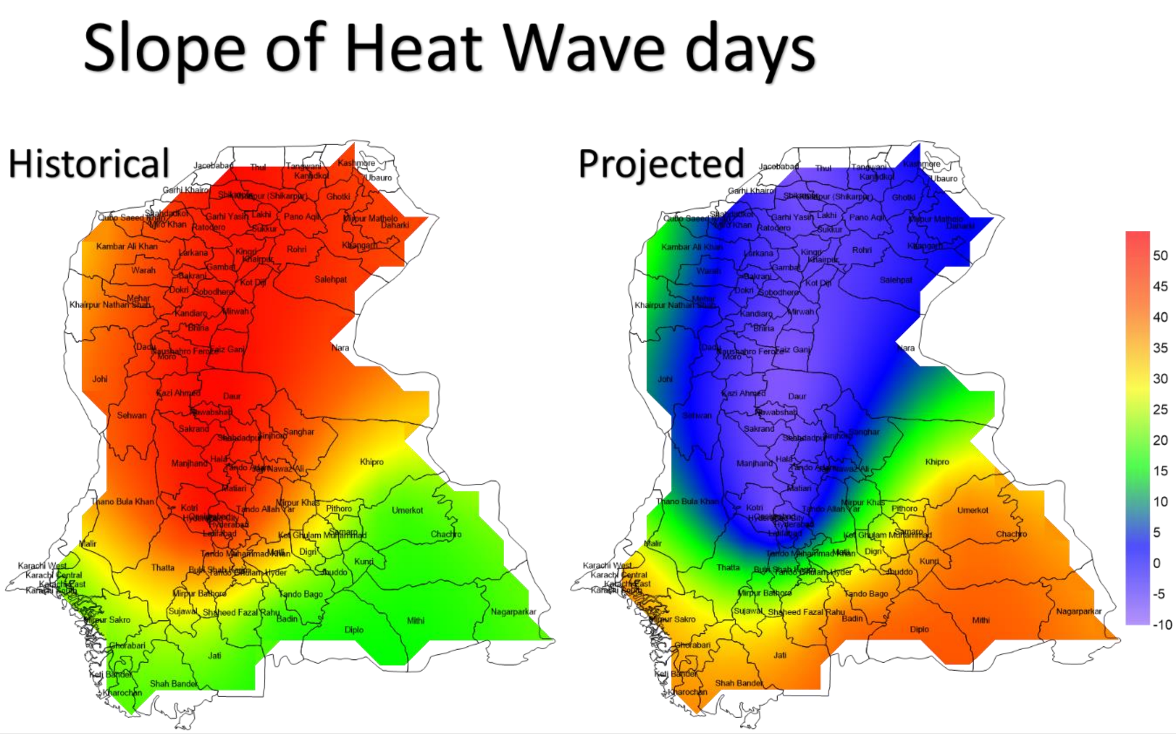
For the detection of extreme climate, methodology based on Expert Team on Climate Change Detection and Indices (ETCCDI) proposed by World Meteorological Organization (WMO) was used. The ETCCDI is used as standard operating procedure by WMO member countries for detection of extreme climate and as decision support systems for guidance of policy makers. The current analysis has deployed these indices and calibrated them to detect provincial scale anomalies in several climate related analytics describes as follows:

Sr. No.	Index Name	Description	Definition	Unit
1	Heat wave	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when Tmax >90th percentile	Days
2	Ratio of wet over dry days	Annual rainfall intensity	Fraction of number of wet days (when total Precip >= 1.0 mm)	Days

3	Ratio of warm days	Annual fraction of warm days	Percentage of days when Tmax >90th percentile	%
4	Ratio of warm nights	Annual fraction of warm nights	Percentage of days when Tmin >90th percentile	%
5	Consecutive wet days	Annual longest wet spells	Maximum annual number of consecutive wet days (when Precip >= 1.0 mm)	Days

1.3 Projection of heat wave days

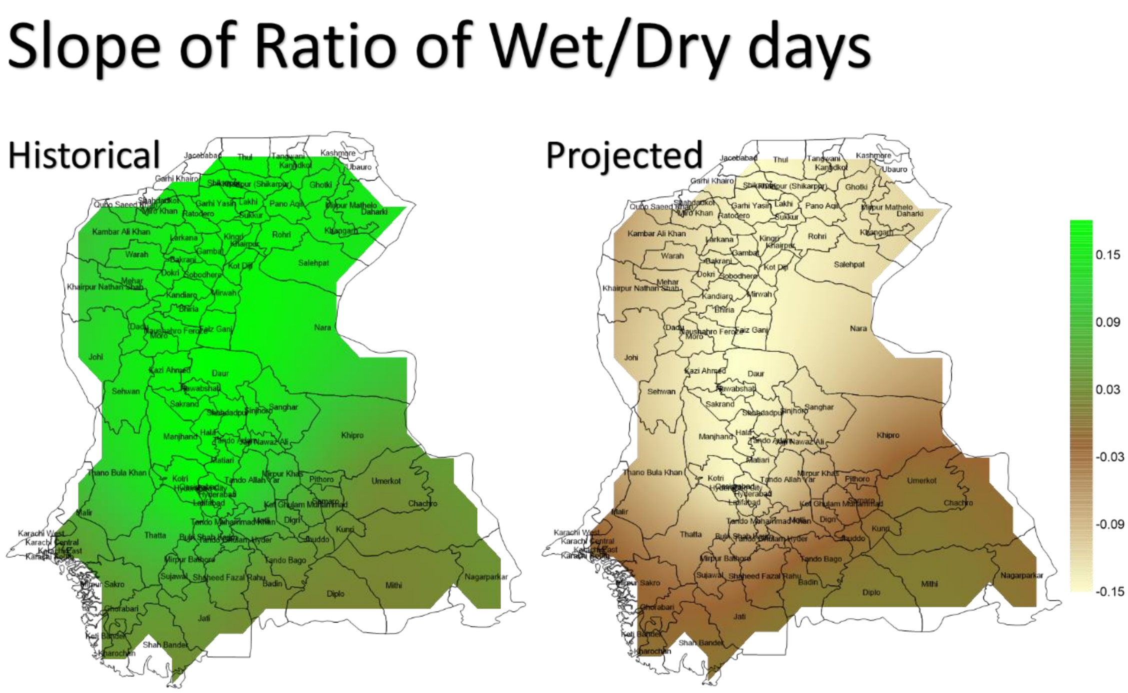
Over recent past, heatwaves have become eminent in the Sindh province. The heatwave episode of 2015 gulped more than 2000 lives in the Karachi city. With increasing urbanization and fossil fuel consumption, the carbon emissions of the province are susceptible to increase. The coal based power generation projects recently commissioned in Sindh for operations have special tendencies to add significant amounts of greenhouse gases in to the atmosphere. Retention of such gases have the capacity to



galvanize and trigger increased number of heatwave days in the future. As may be seen in the warm spell duration analysis, the number of heatwave days have increased by up to 54 days in the centrally focused regions of the Sindh province. However in the projected period the trigger is moderate in the central but significantly high along the coastally enacted regions. This also include the Karachi city, the Mithi, and the Nagarparkar where an additional 35-40 days are augmented in the heat wave days under a high end emission scenario. However, the historically vulnerable region of the central Sindh – even with the high end emissions – would experience an up to 10 days relief in the heatwave days in the future by 2050. Oceanic saturation of CO_2 will become the reason for enhanced CO_2 concentration along the coastal regimes that would further aggravate the number heatwave days in the future. Monsoonal winds are susceptible to carry additional CO_2 from the ocean and divert it towards the coastal peripherals of the province.

1.4 Projection of rainy days

The annual number of rainy days in the Sindh province have increased in the upper regions over the course of historical period. The ratio of annual wet to dry days is higher than 0.15 which means that 15 % additional rainy days have occurred in the upper regions of Sindh along the historical period. However, this ratio

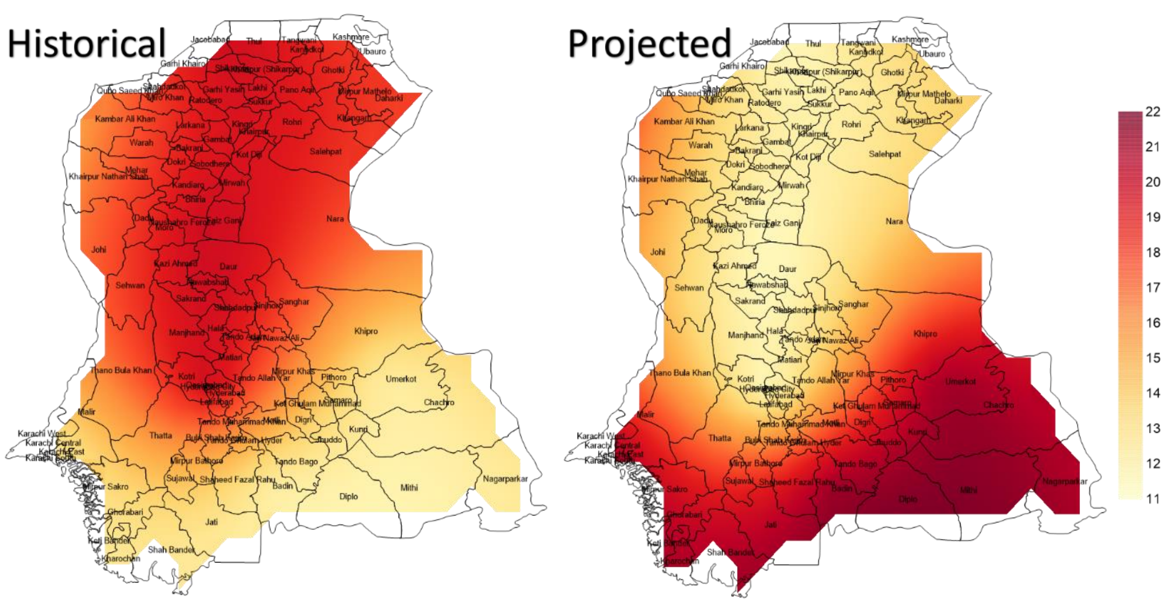


significantly drops to negative value in the projected period which means that 15 % of the rainy days are suspected to be curtailed down under the high end emissions scenario. Nevertheless it is important to be noted that the attenuation of the number of rainy days does not necessary imply the reduction in total amount of rain. Future projections of total precipitation, on the contrary, are prognosticating increased amount of precipitation which means that the more rain will fall in smaller number of days, or in other words rain intensity will increase over Sindh in the future.

1.5 Projection of warm days

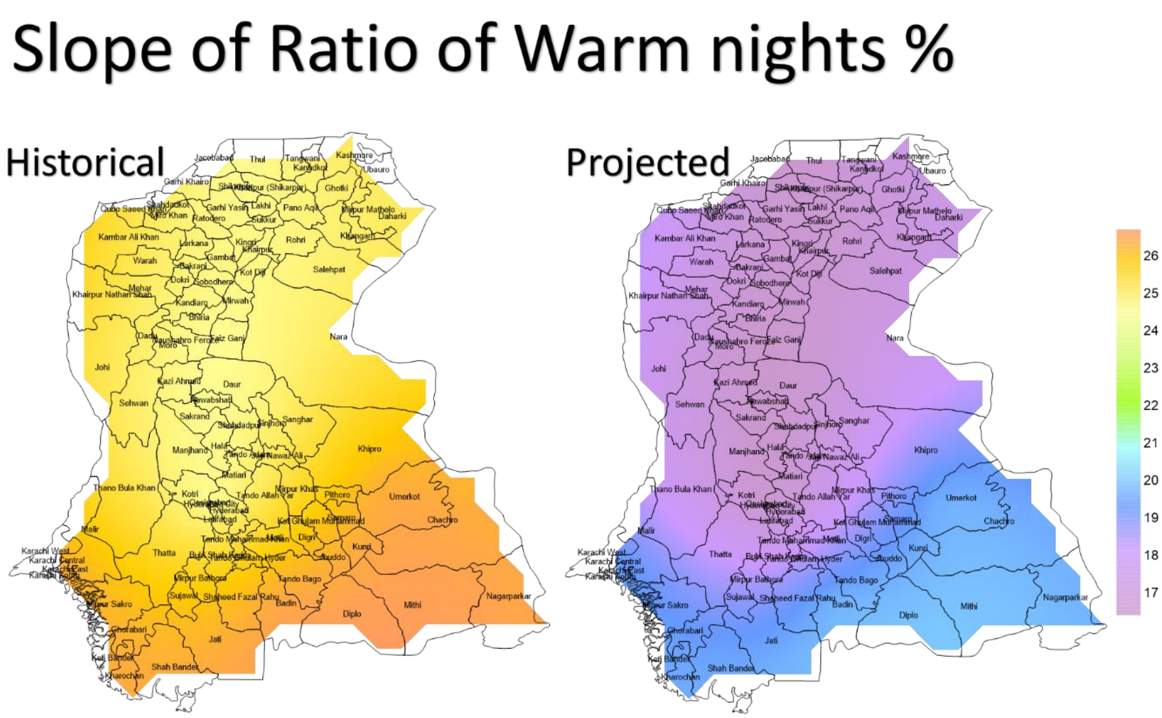
Historical patterns of warm days were concentrated to the upper side of the province. However, as seen in the analysis, the projected concentration is towards the southern side with desert regions being most susceptible to aggravate. Over the course of next 30 years, the percentage of warm days are projected to increase by up to 22 % which would imply significant migratory responses and an amplified energy use for air conditioning in the carbonized future of Sindh.

Slope of Ratio of Warm days %



1.6 Projection of warm nights

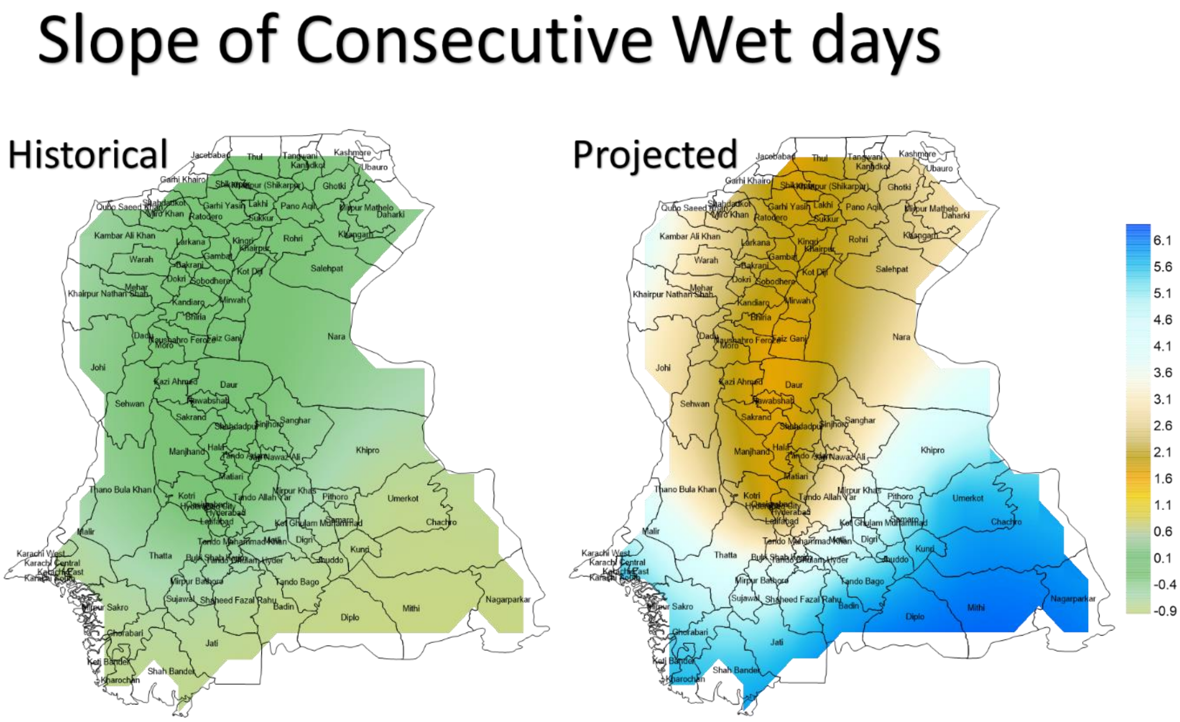
Warm nights bring devastation for crop phenology, especially when milder night time temperatures are desired. The Sindh province is a major Rice/wheat/cotton basket which, in addition to sustain its provincial food and textile security, also exports significantly and adds up to the economic wheel of the country. Historical analysis of the warm night’s index suggest an increase of up to 27 % over the Sindh province. Moreover they are projected to additionally grow by up to 21 % in the projected periods. This calls for serious interventions in permitting and commissioning genetically modified crops for increased tolerance and resilience in prognosticated warmed up future climate of the Sindh province.



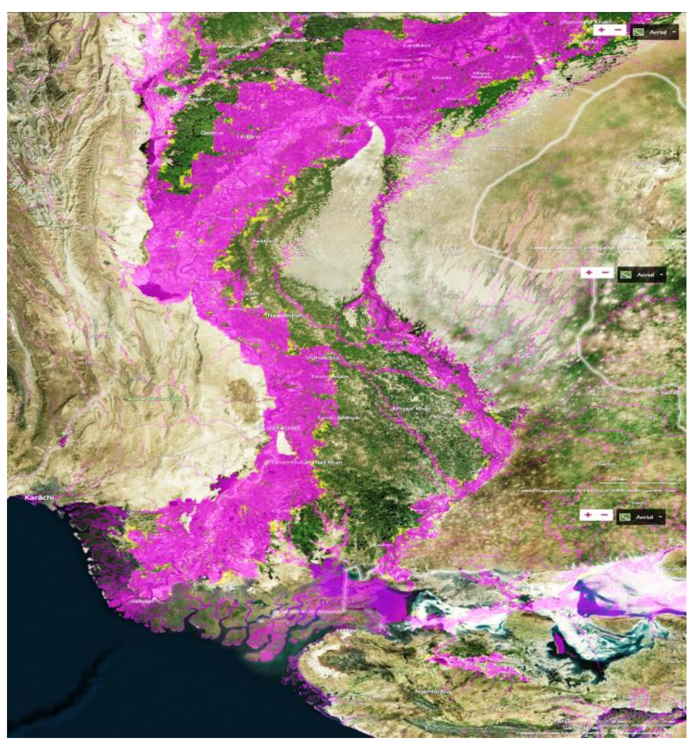
1.7 Projection of consecutive wet days

Consecutive wet days are triggers for flood emergence. Although historically the number of consecutive wet days have remained unvaried, yet the over-carbonized future projections suggest addition of more than 6 days over the southern peripherals of the Sindh province. Recent devastation of floods in the

Karachi city and in the croplands of the province are thus attributed to beginning of a carbon forced environment which has the potential to trigger significant amount of flood water to seep in to the province in the future projections.

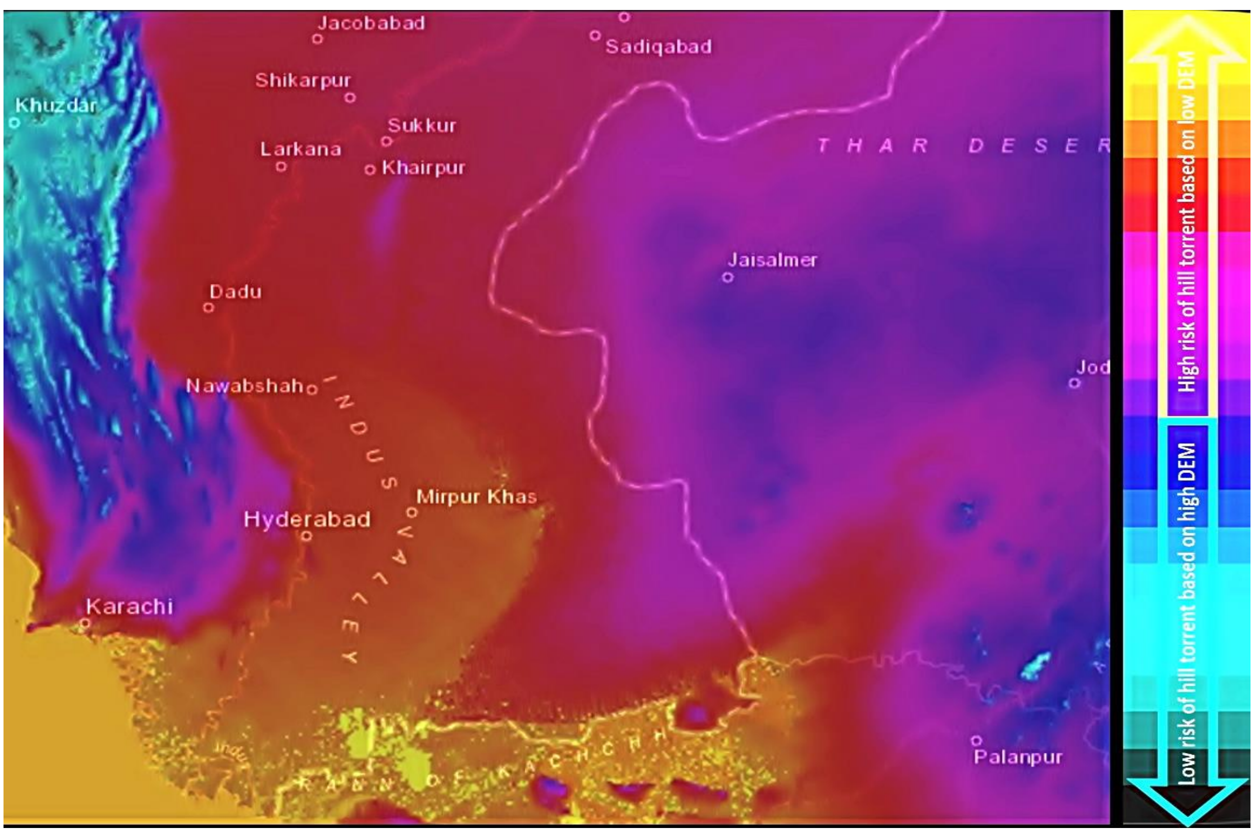


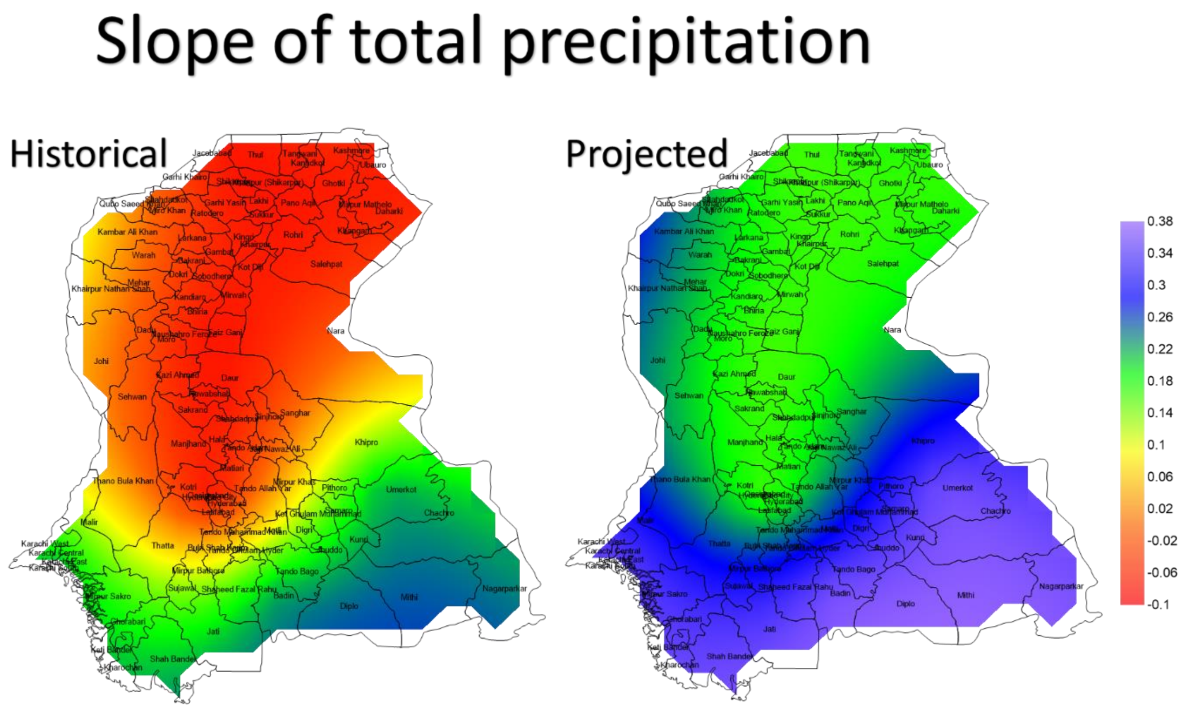
1.8 Risk of floods Flood is one of the costliest natural hazards in the world, yet most flood loss is both predictable and preventable. The analysed inundation map over Sindh allows us see the flood exposure for community locations along its potential course. The pink highlighted locations in a 100-year flood zone have at least a 1 percent chance of experiencing a flood each year. Flood protection resources like dikes are recommended the structural engineers can take to protect livelihood sites.



1.9 Risk of hill torrent

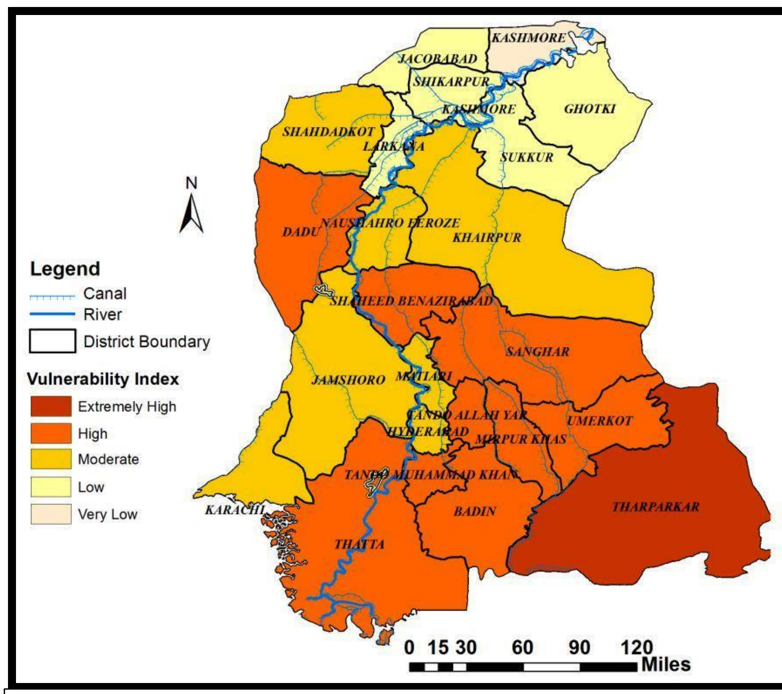
Based on natural valley-like structure of the Sindh province, districts of the province are at high risk of receiving hill torrents from either sides. The depression of terrain of the province from the western side is nearly 8000 feet and that from the eastern side is nearly 1800 feet. Any major extreme rainfall event can trigger waterways in which water can drain from the mountains and hit the localities and infrastructure in its way with enormous speed. Although, slope of total precipitation has decreased along the historical period, yet the projections show significantly higher slopes towards the upper and central regimes of the Sindh province. The western peripherals of the Sindh adjacent to the foothills of the rocky Baluchistan are projected to experience increased amount of precipitation under the high end emission scenario. This, coupled with increase in consecutive wet days are liable to bring hill torrents to the downhill communities of the province.





1.10 Risk of Drought

Southern districts of Sindh are more vulnerable to droughts than the northern districts of Sindh. The Tharparkar district is highly dependent on monsoon rainfall and extremely vulnerable to drought (once every three years). The districts of Thatta, Badin, Tando Muhammad Khan, Tando Allahyar, Dadu, Mirpur Khas, Umerkot, Sanghar, and Shaheed Benazirabad are highly vulnerable to drought as well. The western and eastern parts of Sindh districts (where no canal or river network is present) and the Kohistan region are also highly vulnerable to drought.



Drought hazard map showing the vulnerability index of each district of Sindh

1.11 Conclusion and recommendations

Pakistan is an emerging economy whose operations – even its pledges to COP21 – would be highly based on fossil fuel energy systems. Sindh's thar coal project and such others under the CPEC will continue to develop Pakistan's economic strength in the future. However, such economic development would not come without a cost – the cost of increase of CO2 in ambient environment which will trigger extreme events like heat waves, floods, hill torrents etc. with even higher frequencies. The need of the hour is to strengthen mitigation and adaptation capacities under following proposed outlines.

- *For heat waves:*

More emergency responses by overhauling and declaring dispensary units as hospitals for compensating higher number of patients in the future. For mitigating impacts, green rooftops and green side walks in future urban planning are proposed.

- *For rain intensity:*

Rooftop rainwater harvesters are proposed to prevent impacts of rain intensity in the future building design. Moreover, to mitigate impacts, indirect forcing of carbon in to the atmosphere may be reduced by shifting to clean energy alternatives, since carbon saturation in the atmosphere is majorly responsible for cloudbursts and intense rains.

- *For warm days and nights:*

Greener urbanized infrastructure, balanced land use and land cover, and usage of natural gas as a cleaner alternative to coal and oil based energy requirements could mitigate impacts of warmer day time temperatures in the future.

- *For consecutive heavy spells:*

Although mitigation to this index has remained vague, adaptive measure could involve getting an emergency checklist of actions to take when flood is imminent. Knowing what to do after flooding has occurred is non-trivial. Safeguarding of facilities with a detailed Flood Emergency Response

Plan (FERP) is also recommended. The plan can act as a guide to prevent or minimize water damage along the crops and livelihood areas, should flood ever present a threat.

- *For Drought management:*

In the light of these above mentioned resutls in para 1.9 , it is highly recommended that the water resource managers and diasters managers may develop contigency plans to minimize the drought impacts in future over these areas.

1.12 Few Research articles contributed by PMD scientists on Climate Change issues

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- Pasha, M., Ali, A., & Waheed, A. 2015. Sindh drought 2014—Pakistan: was it a natural or a man-made disaster. *Am J Soc Sci Res*, *1*(1), 16-20. http://files.aiscience.org/journal/article/html/70330001.html
- Evaluation_of_Past_and_Projected_Climate_Change_in_Pakistan_Region_Based_on_GCM20_and_RegCM43_Outputs. https://www.researchgate.net/publication/326683941
- PDF_based_seasonal_changes_in_AgMERRA_observations_and_GCM20_and_RegCM43_projections_over_Pakistan_Region. https://www.researchgate.net/publication/330080782
- Observed_Simulated_and_Projected_Extreme_Climate_Indices_over_Pakistan. https://www.researchgate.net/publication/326684144
- URBAN_HEAT_ISLAND_IN_CHANGING_CLIMATE_A_CASE_STUDY_OF_KARACHI_HEAT_WAVE_2015. https://www.researchgate.net/publication/335421402