Global Climate-Change Impact Studies Centre (GCISC)

(A Body Corporate established under the GCISC Act 2013)

YEAR BOOK (2022-23)

(in pursuance of Rule 25 of Rules of Business 1973)

1. INTRODUCTION

The Global Climate-Change Impact Studies Centre (GCISC) was initially established as a developmental initiative in April 2002, with the mission to conduct research on climate change, its impacts, and potential solutions. Later, GCISC's status was formalized with the enactment of the GCISC Act 2013 by the Parliament, officially recognized through the Gazette of Pakistan on March 26, 2013, as Act No. XVII of 2013. According to the Act, GCISC is designated as a corporate entity governed by a Board of Governors (BoG), presided over by the Federal Minister responsible for the relevant Ministry overseeing climate change matters.

The Centre is mandated to undertake scientific investigations of the phenomenon of climate change at regional and sub-regional levels and study its impact on various sectors of socio-economic development in order to prepare the country to meet threats to its water resources, agriculture, ecology, energy, health, bio-diversity etc.

2. ROLES & FUNCTIONS

GCISC, under the act, is tasked with three functions, namely research, capacity building, and outreach and awareness:

a. **Research**: the research program is driven by national policy goals, namely protecting people against the impacts of climate change, promoting economic growth and sustainable development in a climate-constrained future, and honoring Pakistan's international commitments. To these ends, research is organized in three groups:

   - **Climatology and Environment**: using climate system models to predict future climate behavior in Pakistan, including monsoons, temperature, precipitation, and climate extremes.
   - ***Water Resources* and Glaciology**: using glacio-hydrological and water models to assess future behavior of glaciers, aggregate and seasonal flows in the Indus River System, and changes in the hydrological extremes across the country.

- ***Agriculture, Forestry & Land Use:*** use of crop simulation models to predict the impact of projected changes in temperature, precipitation, and water availability on agriculture and food security of the country and to assess the impacts on Forestry, Land Use.

b. **Capacity building**: imparting technical and communication skills to GCISC staff as well as students and climate scientists at other national research organizations and universities.

c. **Dissemination of research findings**: to the scientific community, planners, policymakers, and to the public at large, in order to raise awareness of climate change among policymakers as well as the citizenry.

3. ACTIVITIES

RESEARCH

The key research activities of the Research Sections revolve around following themes:

I. Climatology & Environment Section

The Climatology & Environment Section research areas focus on key aspects of climate variability and change, which can be summarized as follows:

- To assess historical climate trends over Pakistan and its regions;
- Climate profiling of Pakistan based on IPCC future climate scenarios (RCPs, SSPs etc.);
- To generate up-to-date information on changes in near to long term climate extremes and to study associated impacts;
- Study variations in summer monsoon patterns for impact assessments;
- High resolution climate information for future urban climate issues
- Intra seasonal to inter decadal climate predictions;
- Integrated modeling of air pollution and greenhouse gas emissions;
- Development & updating of GHG inventory of Pakistan for energy & industrial processes sectors;

II. Water Resources & Glaciology Section

- Application of Machine Learning and Artificial Intelligence (AI) techniques to model Indus River System (IRS) flows;
- Climate change analysis for the high-elevation Hindukush-Karakoram-Himalaya (HKH) region;

- Application of different hydrological and cryospheric models to assess the water availability and variability (quantitatively) in space and time in the Indus River System (IRS) under the latest socio-economic and climate projections;
- Analysis of climate impact on the frequency and intensity of hydrological extreme events at seasonal and sub-seasonal scales;
- Drought prediction in the Indus Basin as a climate adaptation strategy;
- Plausible Adaptation strategies in line with national Climate change and Water policies to ensure the country's water security;
- Research dissemination (International and national scientific journals and books, newspaper articles, policy briefs, etc.);
- Capacity building, awareness raising and collaboration among National and International institutions, researchers and academicians
- Identification of location and time-specific climate extremes (dry and warm) for related impacts on water availability and variability from different sources (surface water and groundwater)

III. Agriculture, Forestry and Land Use Section

- Assess impacts of projected climate change on productivity of key agricultural crops in different climatic zones using crop models;
- Assess impacts on related areas, including productivity of forestry, grasslands, rangelands and fragile ecosystems (i.e., mountains, wetlands, coasts, and arid areas); livestock; and land degradation and deforestation, insect-pest infestation dynamics;
- Assess food security in the face of future climate change and especially under reduced availability of irrigation water;
- Devise adaptation measures, including smart agriculture;
- Studies on water, food, energy nexus;
- Updating GHG emissions from agriculture, forestry and land use and waste sectors.
- Research dissemination (International and national science journals and books, newspaper articles and policy briefs etc.)
- Capacity building and awareness raising

4. GOALS & TARGETS

Throughout the year, GCISC made notable advancements in the international scientific literature concerning climate change and its associated effects, while also offering substantial inputs to various research projects. Additionally, the organization conducted several workshops and seminars aimed at disseminating information and raising awareness on pertinent issues:

The following is a summary of the accomplishments in 2022-23:

- Publication of key research findings in scientific journals = 22
- Contribution towards technical reports = 12
- Organization of scientific activities/workshops/seminars for information dissemination and awareness = 12
- Scientific contributions/ presentations and effort on capacity building of GCISC young scientists through academic and specialized trainings and participation in online conferences, workshops etc. at International level (Nos) = 23
- Effort on capacity building of GCISC young scientists through academic and specialized trainings and participation in conferences, workshops etc at National Level (Nos) = 80
- Scientific Contribution Presentation in National Conferences and Workshops = 43
- Provision of training to university students across Pakistan in the field of climate change through internship program = 30
- Responses to NA/Senate starred questions and provided inputs (presentations/ briefs) for NA Standing Committee on Climate Change on the aspects of Climate Change = 10
- Muhammad Arif Goheer, Principal Scientific Officer/ Head- Agriculture and Coordination contributed to UNFCCC's Consultative Group of Experts (CGE) activities.
- Contributions to Pakistan's 1st Biennial Update Report submitted to UNFCCC in 2022.
- GCISC provided technical inputs in the preparation of National Adaptation Plan
- GCISC has been awarded contract by Ministry of Climate Change (MoCC) to contribute in various chapters of Third National Communication (TNC).
- Development of MRV platform for GHG Inventories & MRE platform for Adaptation tracking in Agriculture (Pilot basis).
- One Water Section Scientist is working as a Co-PI in "Flash Floods Harnessing for the Prosperity of Arid and Resource-stressed Neglected Agro-based Communities (ProNAC)" approved by Higher Education Commission (HEC) in National Research Program for Universities (NRPU) (Ongoing).
- Global Climate-Change Impact Studies Centre (GCISC) is leading a project on Climate Risk Assessments under GIZ's Strengthening Adaptation and Resilience (SAR) Programme. Water section taking the lead as Expert Working Group Coordinator to perform Climate Risk Assessment (CRA) related to the Water Sector.

5. ACHIEVEMENTS & SALIENT RESEARCH FINDINGS

A) Research

a. State of Climate, State of the Basins Report- Afghanistan–Pakistan Shared Waters:

Climate change is a major threat in all the shared river basins in South Asia owing to the huge populations they sustain and the complex regional dynamics. This chapter summarizes the available knowledge related to changing climate trends in three Afghan–Pakistani transboundary river basins: the Kabul, Kurram and Gomal. A key finding indicates a consistent rise in temperature over the last 30 years. By the end of the 21st century, temperatures may rise by an additional 3–4°C under RCP1 4.5 and 5–6°C under RCP 8.5, relative to 2020 levels. The potential impact of temperature rise is compounded by considerable uncertainty associated with the current and future behaviour of precipitation in the three basins. The findings in this chapter will help practitioners and policymakers visualize the nature and scope of likely climate challenges in the three basins.

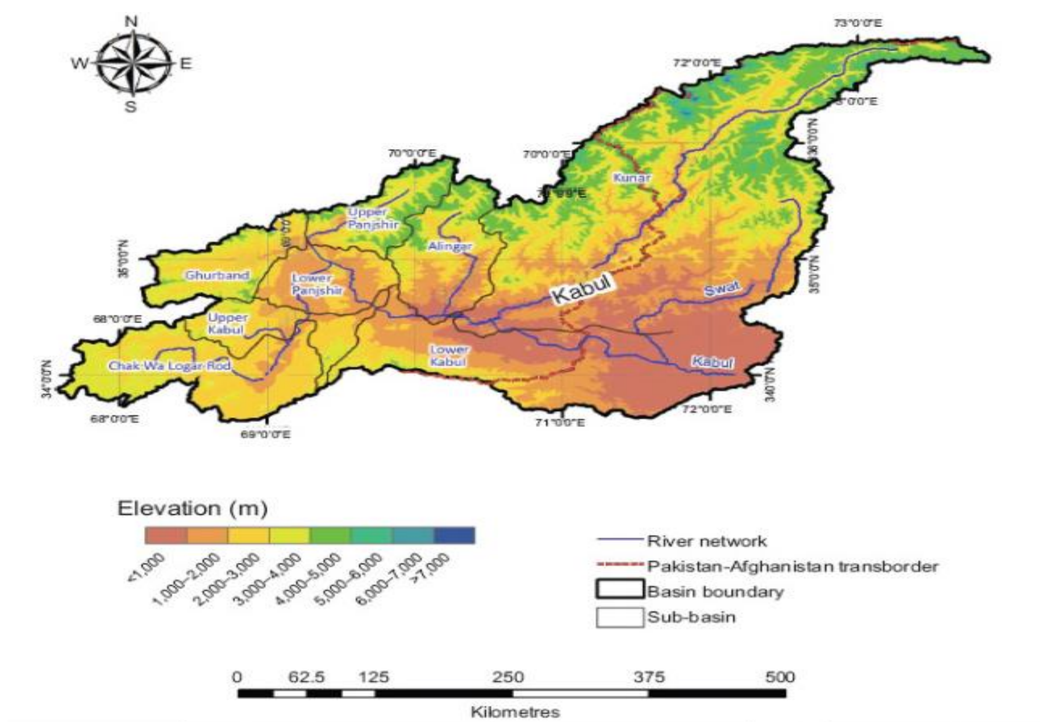


Figure 1: *The Kabul river basin, glaciated and non-glaciated sub-basins.*

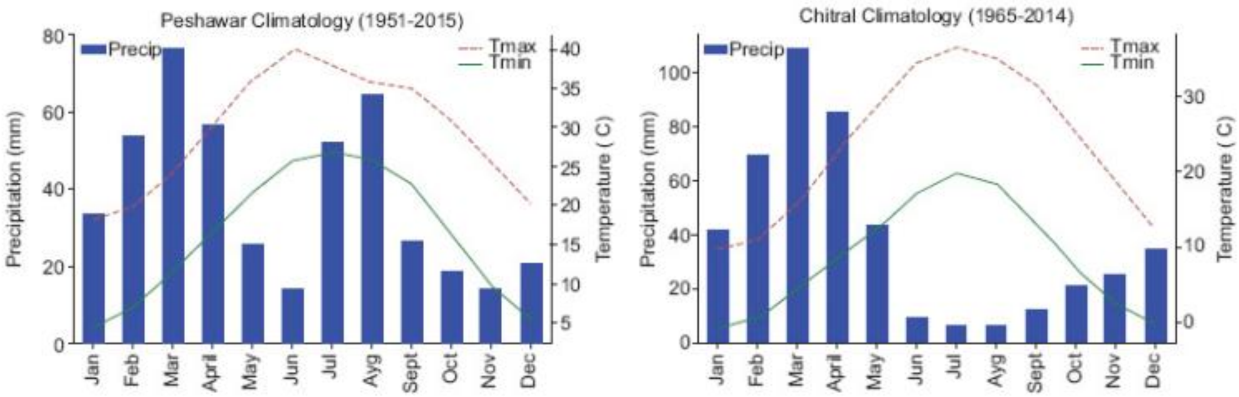


Figure 2: *Monthly variation in temperature and precipitation at Peshawar and Chitral in the Kabul River basin*

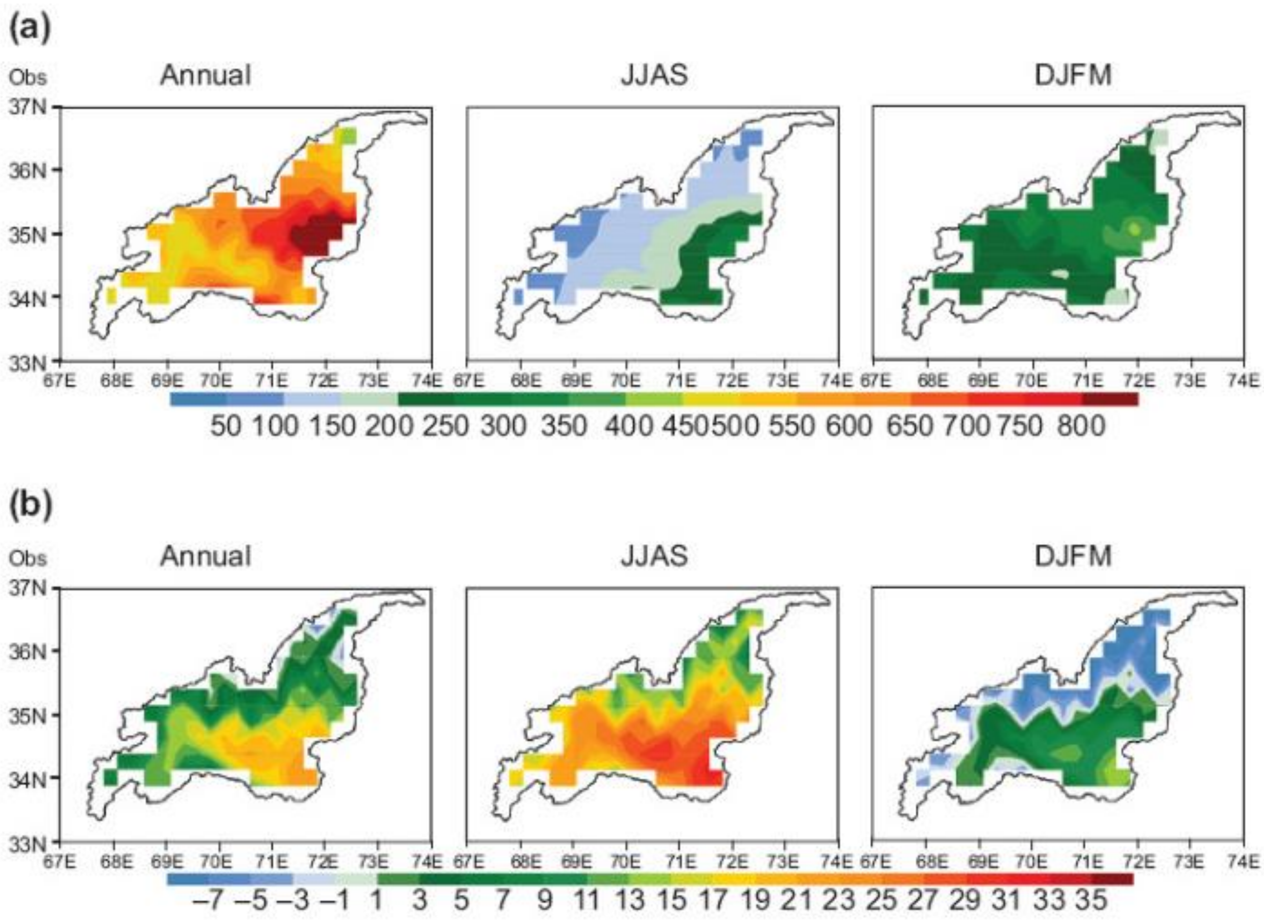


Figure 3: *(a) Mean precipitation (mm) 1975–2005; (b) Mean temperature (°C) 1975–2005. (Adapted from Bokhari et al., 2018)*

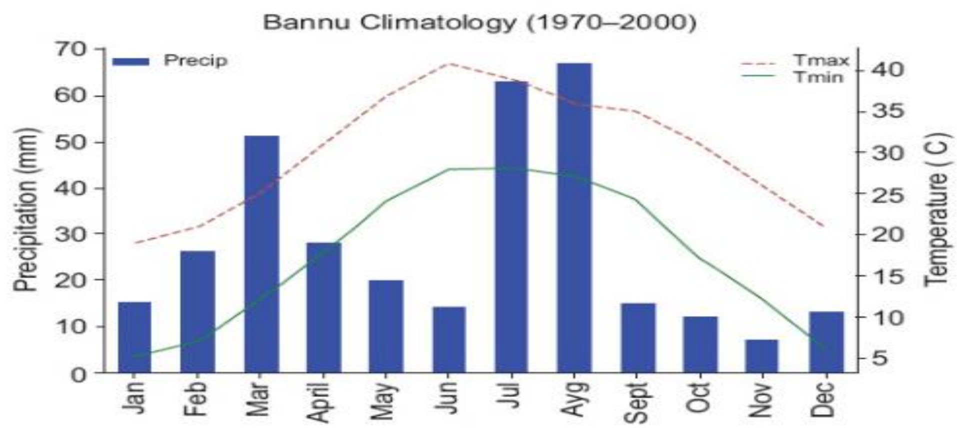


Figure 4: *Monthly variation in temperature and precipitation at Bannu in the Kurram river basin*

b. Hydrologic Interpretation of Machine Learning Models for 10-daily streamflow simulation in Climate sensitive Upper Indus Catchments:

Machine learning for hydrologic modeling has seen significant development and has been suggested as a valuable augmentation to physical hydrological modeling, especially in data scarce catchments. In Pakistan, surface water flows predominantly originate from the transboundary Upper Indus sub-catchments of Chenab, Jhelum, Indus and Kabul rivers. These are high elevation data scarce catchments and generated streamflows are highly seasonal and prone to climate change. Given the catchment characteristics, there is utmost need to develop machine learning models that are hydrologically robust. Thus, the current study besides evaluating the potential of three machine learning models for streamflow simulation also focused on the hydrologic interpretation of machine learning models using SHapley Additive exPlananations(SHAP).XGBOOST, RandomForest and Classification and Regression Trees(CART) were evaluated. All of these models performed well and range of R 2 and Nash Efficiency for all three models lies between 0.65 to 0.90. Our study's most crucial contribution is SHapley Additive exPlananations (SHAP) method which gives extensive insights into the influence of each variable on simulated streamflow. SHAP analysis highlighted the significance of minimum temperature in high elevation zones for both Indus and Chenab catchment where streamflows are dominated by snow and glacier melt. We strongly believe that the findings of this study will promote the use of SHAP analysis for streamflow forecasting in data scarce and high elevation catchments in Pakistan.

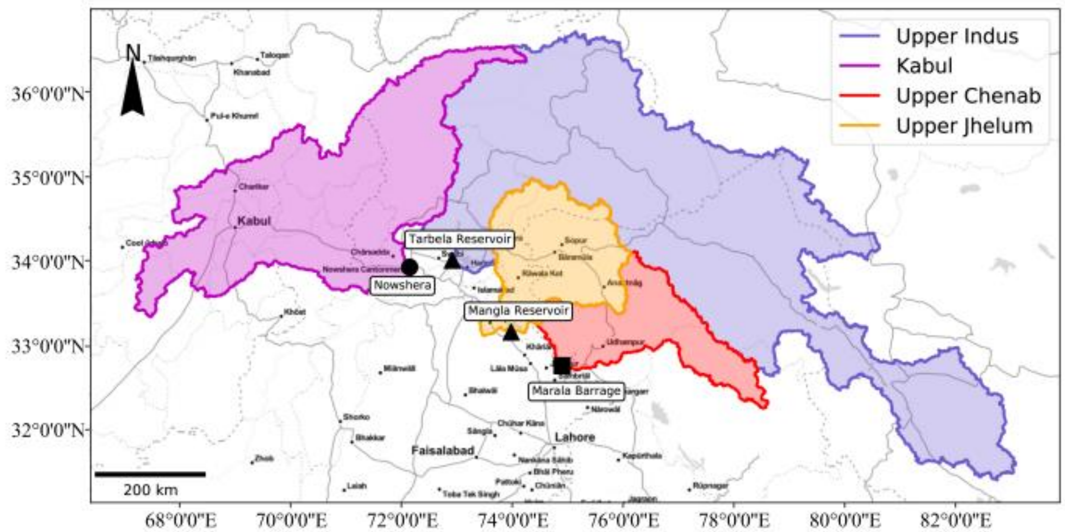


Figure 5: *Overview of study area for meteorological and hydrological analysis, that includes the four western river catchments of the Upper Indus Basin Chenab and Upper Jhelum, and the studied streamflow stations at respective catchment outlets, i.e. Nowshera, Tarbela, Mangla and Marala (Akhtar et al. 2020)*

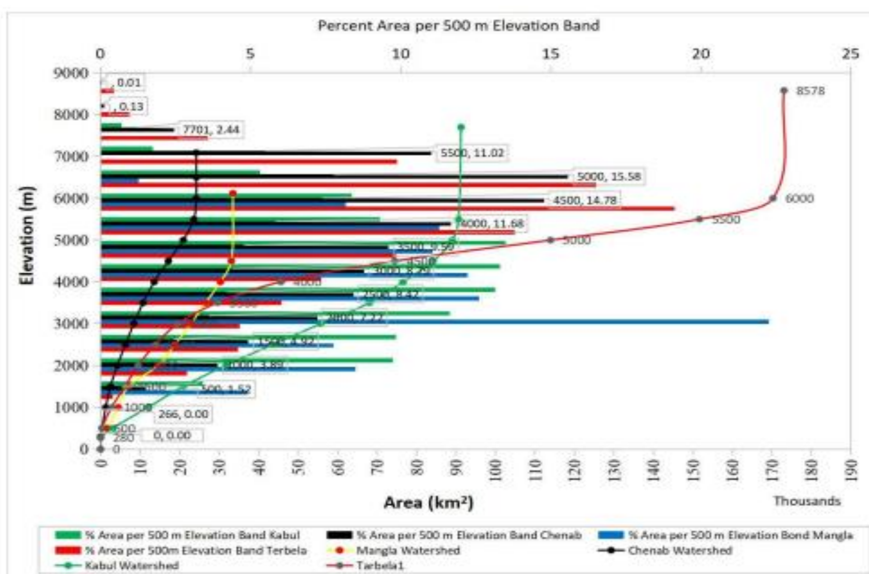


Figure 6: *Hypsometric curve of the study watershed at four catchments namely: Indus at Tarbela, Jhelum at Mangla, Chenab at Marala and Kabul at Nowshera*

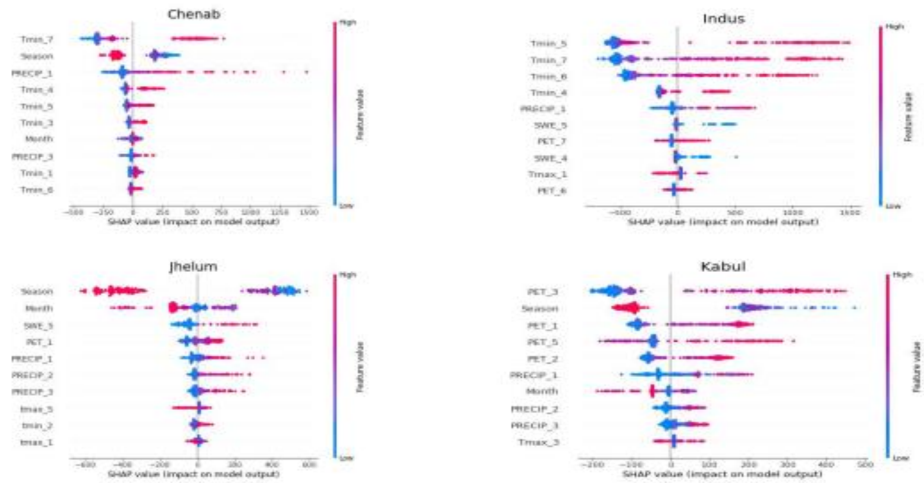


Figure 7: *SHAP summary plot. Each dot corresponds to a sample, and its x position shows the impact a predictor variable has on the simulated streamflow for Random Forest Model testing period 2005-2014*

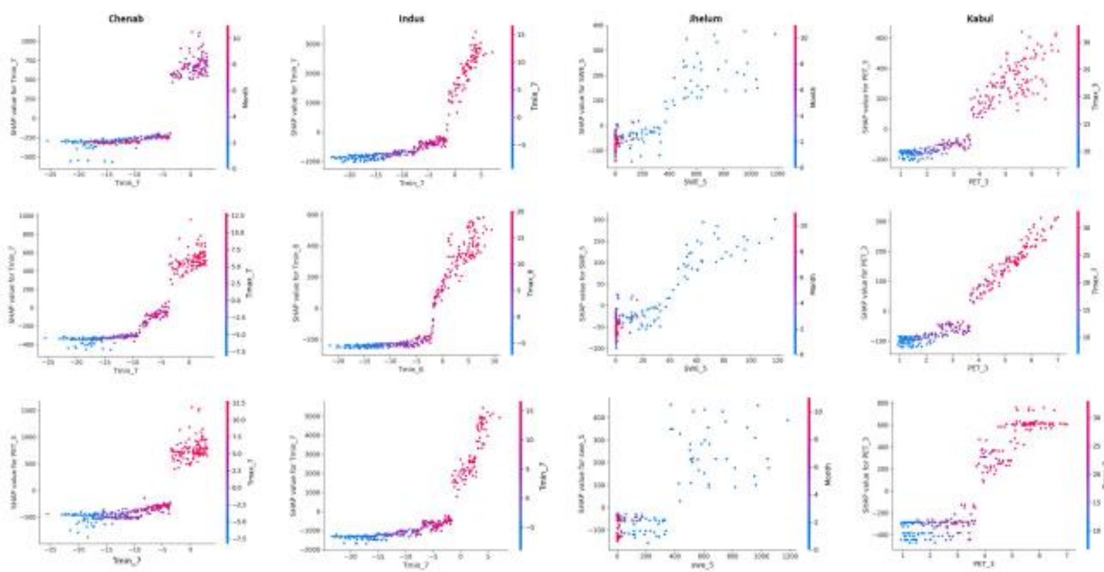


Figure 8: *SHAP dependence plots for XGBBoost (First Row), RandomForest(Second Row) and CART (Third Row). The variables are plotted against the SHAP values. Each dot corresponds to a sample*

c. Climate-induced shifts in irrigation water demand and supply during sensitive crop growth phases in South Asia:

This study investigated the shifts in irrigation water demand and supply of the major staple and water-intensive crops (wheat and rice) in the Indus, Ganges and Brahmaputra (IGB) river basins of South Asia under the combined impacts of climate change and socio-economic development during the period 1981–2100. It explores irrigation water usage during climate-sensitive crop growth phases (i.e. vegetative and reproductive which required ~ 60% of the total seasonal (sowing to harvest) water demand), which is supposed to be crucial for long-term integrated crop water management. A hydrology vegetation model Lund Potsdam Jena Managed Land is forced with an ensemble of eight downscaled (5 arc-min) global climate model's using the RCP (Representative concentration path- ways) -SSP (Shared socio-economic pathways) framework, i.e. RCP4.5-SSP1 and RCP8.5- SSP3. To investigate phase-specific crop water projections, trend analysis is performed. It shows a significant ($p<0.001$) increase in irrigation water demand during the vegetative phase of wheat (6 mm) and reproductive phase of rice (26 mm) and a decrease dur- ing the reproductive phase of wheat (13 mm) and vegetative phase of rice (11 mm) in selected study sites. The large decrease in projected irrigation demand for wheat can be explained by a shortening of the growing season length as a result of rising temperatures and increased precipitation. Whereas, an increase in irrigation demand for rice is a combined effect of higher temperatures and less precipitation during the reproductive phase in the region. At the same time, irrigation supply by surface water and groundwater is likely to change in future due to warmer and drier growing periods, causing a significant increase in groundwater irrigation, mainly for rice. Our major research findings show the importance of crop water assessments during the sensitive crop growth phases of wheat and rice which vary in space and time. Including crop phase-specific, climate impact assessments of regional and global projection will help improve the region's existing crop-water management strategies and adaptation practices.

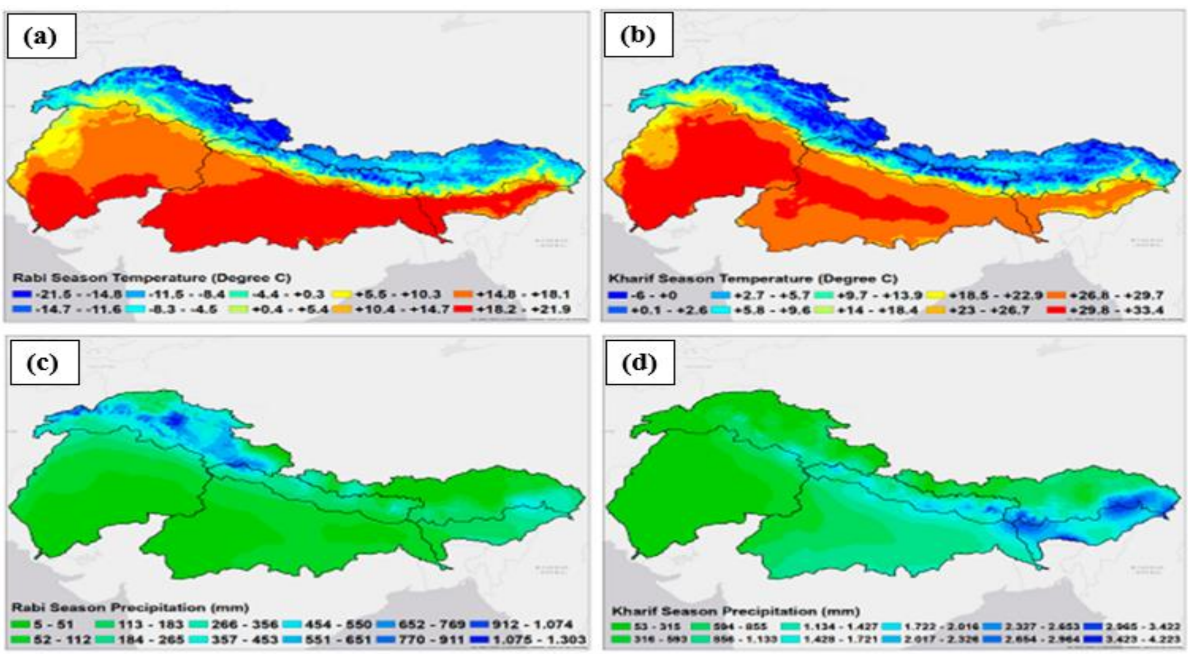


Figure 9: *S1 30 years mean temperature (◦ C) of wheat in rabi season (a), rice in kharif season (b), 30 years mean of season total precipitation (mm) of wheat in rabi season (c), and 30 years mean of season total precipitation (mm) of rice in kharif season (d) during 1981–2010 over whole IGB river basins. Climate data (i.e., temperature and precipitations) at 5 arc-min spatial resolutions has been acquired from HI-AWARE data archive, particularly developed for the IGB river basins* (Lutz & Immerzeel, 2016)

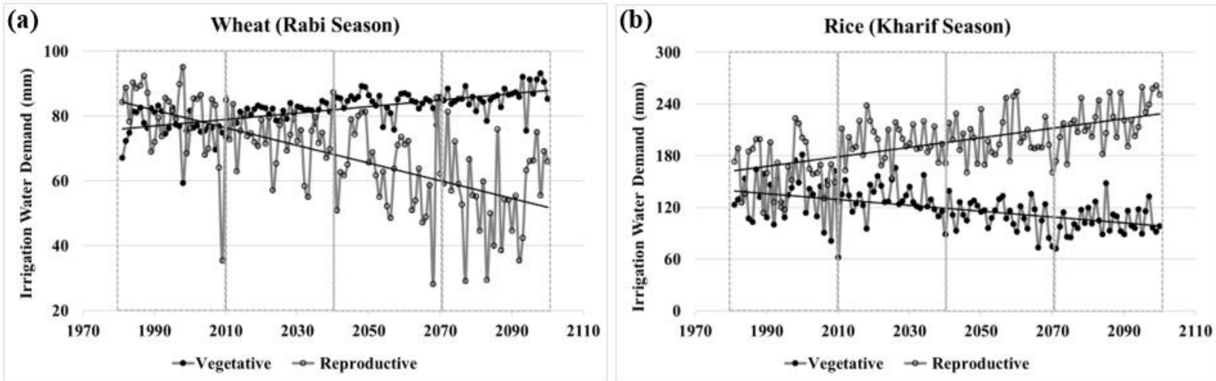


Figure 10: *Inter-annual variations and trends of irrigation water demand (mm) of wheat (a) and rice (b) during the vegetative and reproductive crop growth phases for the period 1981-2100 for Punjab Pakistan.*

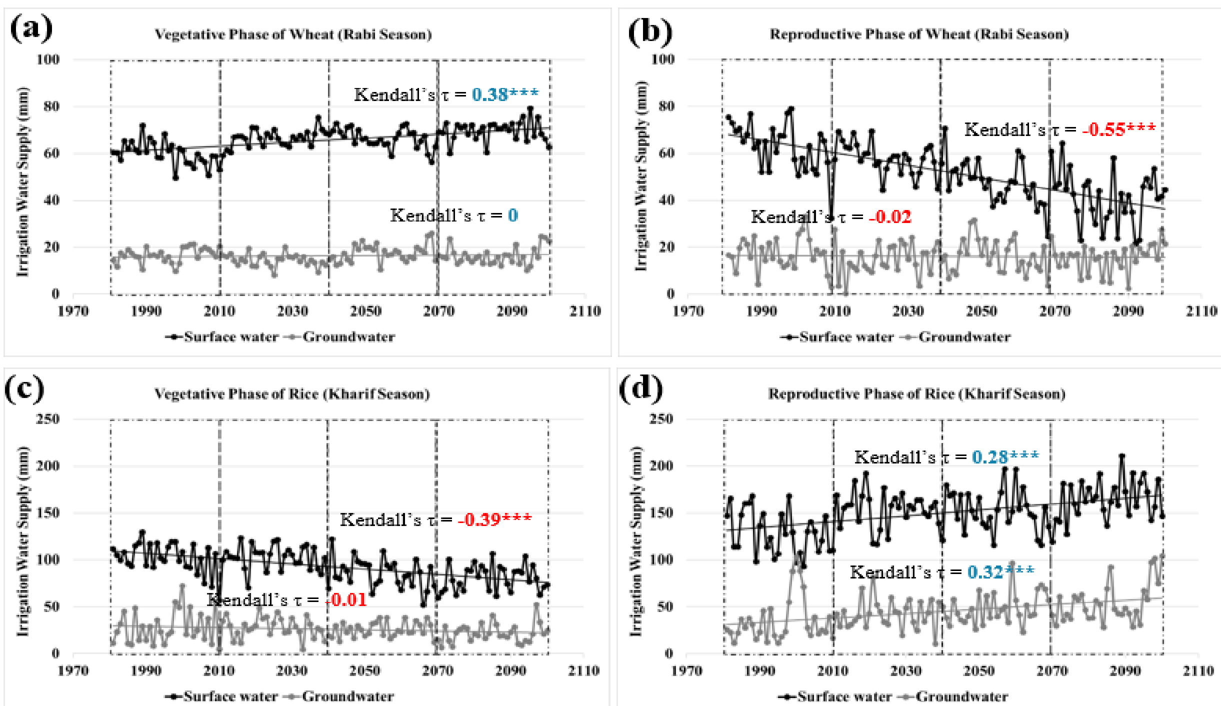


Figure 11: *S3 Inter-annual variations and trends (presented as Tau value where blue color show increasing trend and red as decreasing) of irrigation supply (mm) by sources (surface water and groundwater) during the vegetative (a, c) and reproductive (b, d) phases of wheat (a-b) and rice (c-d) for the period 1981-2100 for Punjab Pakistan simulated by LPJmL using the ensemble mean of four GCM's of RCP4.5-SSP1 emission scenario*

d. Mid-century change analysis of temperature and precipitation maxima in the Swat River Basin, Pakistan:

This study analyzes trends in historical (1989–2018) and projected (2041–2060) temperature and precipitation maxima in the Swat River Basin, Pakistan. This basin has a history of climate-related disasters that directly affected livelihood and personal safety in local communities and are becoming more intense and more frequent due to changing climate. Major economic sources of this basin are agriculture and tourism, both highly sensitive to extreme climate events. Therefore, it is very important to assess future trends in extremes of temperature and precipitation. Non-parametric tests were employed for currently acquired data, while future projections were assessed using the statistical downscaling model (SDSM) with CanESM2 GCM under three scenarios: representative concentration pathways (RCPs) of 2.6, 4.5, and 8.5. The R2 value between monthly observed and simulated temperatures varied from 0.82 to 0.91 and 0.92 to 0.96 for training and confirmation periods, respectively. For areal precipitation, an R2 value of 0.49 was noted for calibration and 0.35 for validation. Observed temperatures showed a decreasing trend at all stations except Saidu Sharif, but the differences were not significant. Precipitation showed an increasing trend at two stations, Kalam and Malam Jabba, and a decreasing trend at two other stations, Dir and Saidu Sharif. A >2°C rise was noted for the annual projected maximum temperature (2041–2060) at areal and Dir, while Kalam, Malam Jabba, and Saidu Sharif showed a 1°C rise. For precipitation, an approximately 12% increase in annual maximum (areal) and seasonal precipitation (summer and autumn) was seen under all scenarios except RCP 4.5 in which there was a 20% and 32% increase in summer and autumn, respectively. The performance of SDSM in simulating maximum temperature and precipitation was satisfactory.

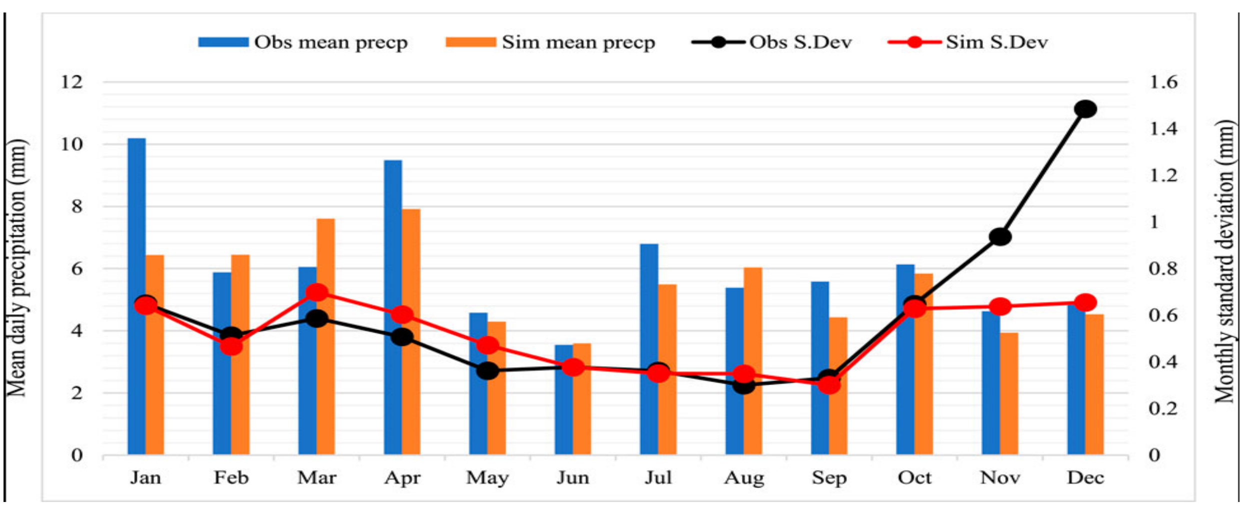


Figure 12: *SDSM calibration of observed and simulated areal precipitation characteristics.*

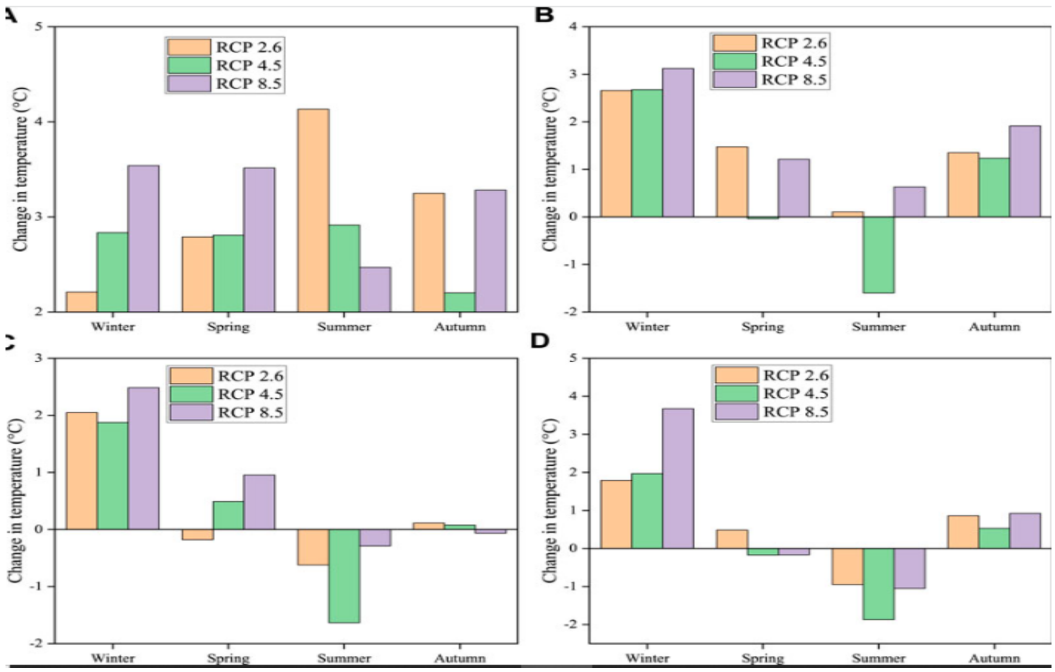


Figure 13: *Changes in maximum seasonal temperatures of Dir* ***(A)****, Kalam* ***(B)****, Malam Jabba* ***(C),*** *and Saidu Sharif* ***(D)****.*

e. The Coincidence of Climate Extremes with Sensitive Crop Growth Phases: Projected Impact on Sustainable Crop Water Use and Crop Yield in the IGB River Basins:

Increased climate variability and extremes are unequivocal with unprecedented impacts on water resources and agriculture production systems. However, little is known about the impacts of climate extremes at the intra-seasonal level which remained largely unexplored. We investigated the coincidence of climate extremes with sensitive crop growth phases of wheat and rice in the Indus, Ganges and Brahmaputra (IGB) river basins of South Asia. We also quantified the related impacts on irrigation water demand (IWD), gross primary production (GPP) and crop yields (CY) simulated by a hydrological-vegetation model (LPJmL) during 1981-2100 using RCP4.5-SSP1 and RCP8.5-SSP3 framework. The climate extremes revealed a higher frequency and intensity during crop growth phases with significant increasing trends in future. Diverse changes in IWD, GPP and CY are projected in future under the influence of crop phase-specific extremes. The crop phase-specific changes in the IWD of wheat and rice will intensify in the future. More than 50% of the change in future wheat irrigation is caused by warm and dry extremes during the ripening phase. Whereas, increase in IWD for rice is mainly associated with warm extremes only. The crop phase-specific GPP shows a decreasing trend in future for both wheat and rice in the Western part of IGB with the largest decrease during the reproductive phase of wheat (up to 36 %) and vegetative phase of rice (> 20%). This decrease is clearly reflected in seasonal yields i.e., both wheat (20%) and rice (12%) showed a decrease in future linked with warm and dry extremes. However, in the Eastern part of IGB, the GPP will mostly increase in future during the three crop phases of wheat and rice. These results can be used to help develop efficient adaptation strategies considering seasonal changes and sensitive crop phases for sustained food and water security in South Asia.

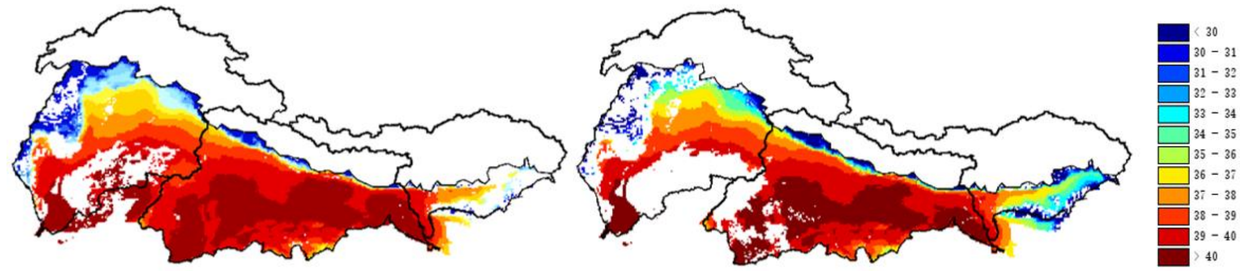


Figure 14: *Spatial distribution of P99 (^0C) over the irrigated areas of wheat (a) and rice (b) during base line period (1981-2010) in the IGB river basins.*

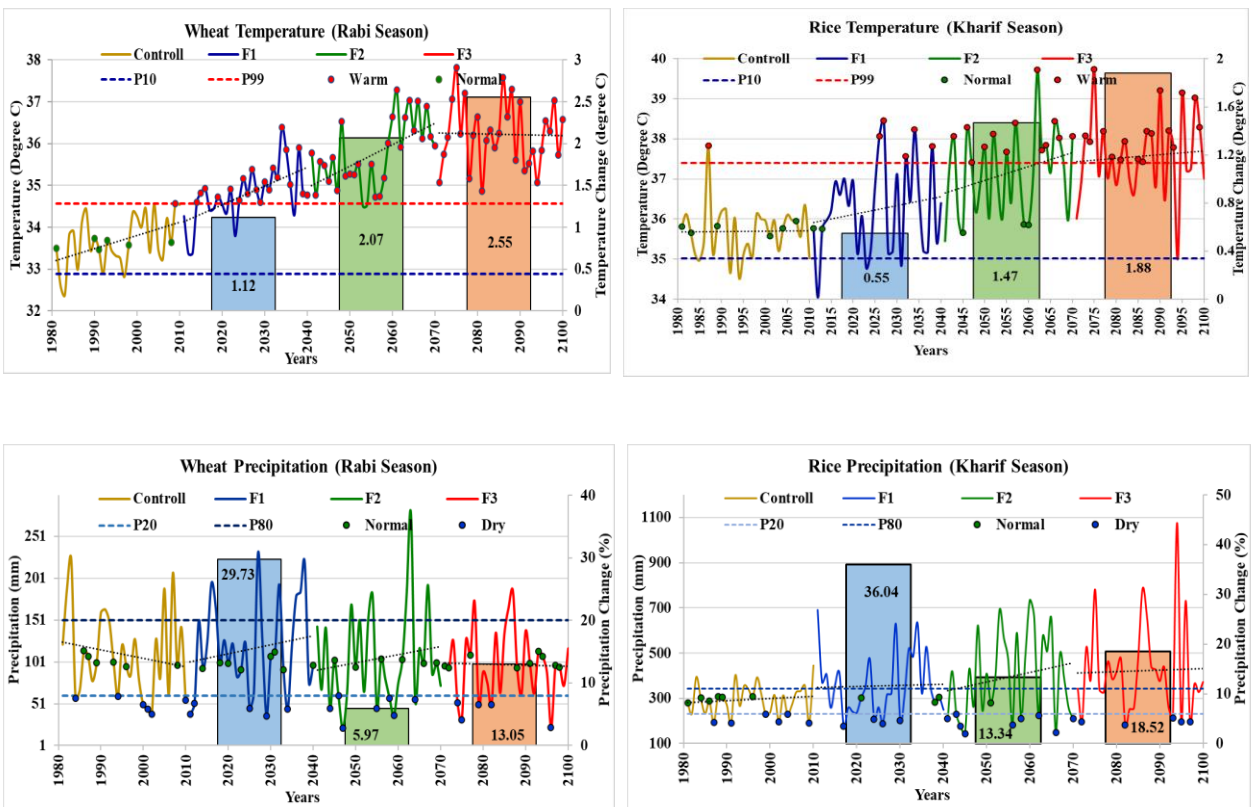


Figure 15: *3a-b: Warm and dry extremes estimated using temperatures data (^0C) at seasonal (sowing to harvest) scales of wheat (rabi season) and rice (kharif season) for the Punjab Pakistan during the period 1981-2100 using the ensemble mean of four GCM's of RCP4.5-SSP1 emission scenarios. Dotted lines show the upper and lower bounds of temperature extremes estimated at 99^{th} (red) and 10^{th} (blue) percentiles. Future changes in temperature (^0C) (colored bars in each panel) are estimated for three scenario periods i.e., F1 (2011-2040), F2 (2041-2070) and F3 (2071-2100) w.r.t base line period (1980-2010).*

f. Climate Projections over Pakistan using Bias Corrected CMIP6 model Data at a higher Spatio-temporal scale for planned adaptations and informed policy decisions:

The assessment and quantification of future climate projections at higher Spatio-temporal scales in Pakistan is vital for food security-related adaptation. In this study, daily bias-corrected climate data of 13 individual General Circulation Models (GCM's) from CMIP6 (Climate Model Intercomparison Project Phase 6) project was chosen for future changes in seasonal climate data in the two major wheat and rice-producing provinces of Pakistan. The climatic research unit (CRU TS4.03) dataset was used to compare and analyze the CMIP6 models' performance. We have estimated the climate projections uncertainty range of 13 CMIP6 models and Multimodel Ensemble Mean (MMEM) under two emission scenarios i.e., SSP245 and SSP585 scenarios for the historical period 1951-2100. Moreover, MMEM data was further used to estimate the season and location-specific climate patterns/ trends and variations in the future under different climate scenarios. The Mann-Kendall trend test and Sen's slope method were adopted to estimate the spatial and temporal trends in the climate data. The selected model ensemble from CMIP6 has a very robust capability to reflect on the spatial and temporal diversity of climate parameters over the main crop producing provinces in Pakistan. These results provide a basis for developing a better understanding of crop and region specific adaptation measures for an agriculture dependent country like Pakistan.

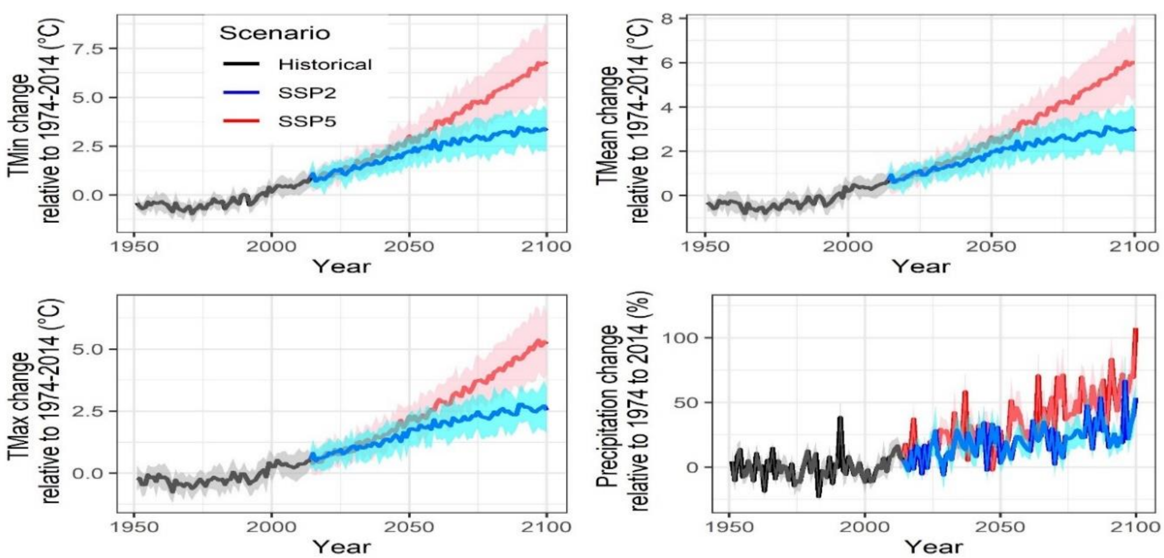


Figure 16: *shows the long term trends, inter-annual variations and uncertainty range of the 13 GCM's CMIP6 models data along with multi-model ensemble mean (MMEM). The climate data of temperature and precipitation has been plotted at annual scale over whole Pakistan using two selected emission scenarios for period (1951 -2100). The MMEM data is plotted with the dark lines (i.e., black during control period (1974 -2014) and blue (SSP245) and red (SSP585) line for future period (2020 – 2100).*

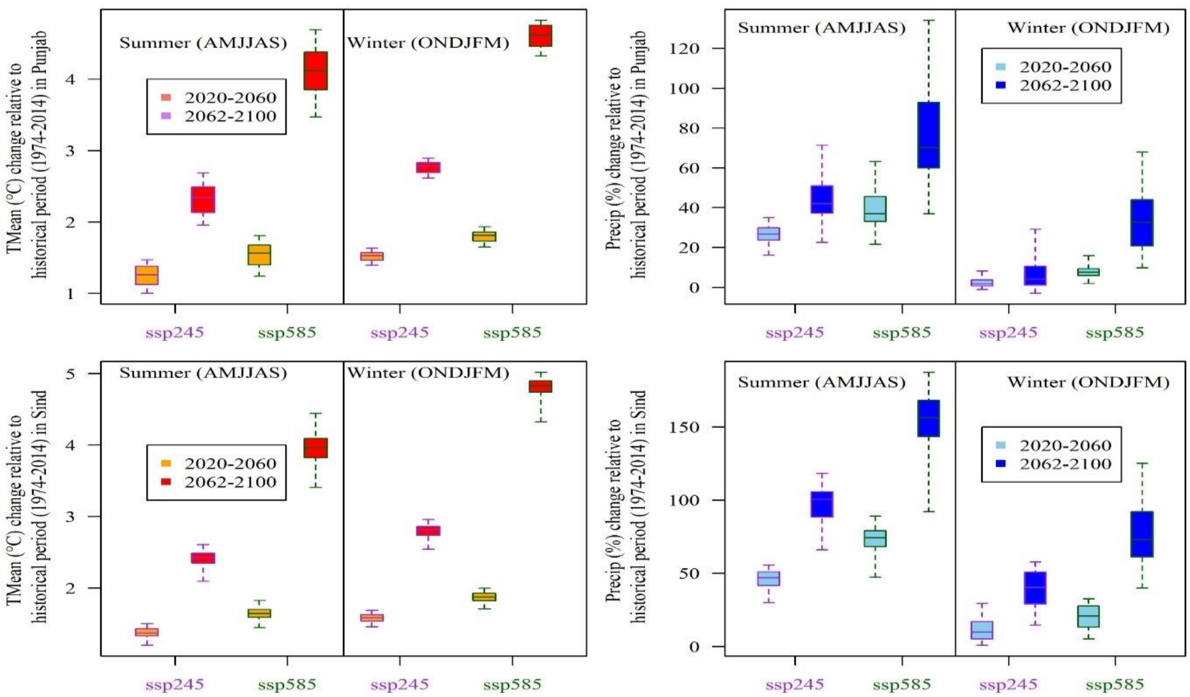


Figure 17: *Box and whisker plots for projected changes in seasonal temperature and precipitation over Punjab and Sindh provinces of Pakistan under two emission scenarios i.e., SSP245 and SSP585. The boxes show the interquartile range, horizontal lines represent the median and the whiskers show the maximum/minimum value of the lower/upper quartile.*

g. Optimized irrigation scheduling as an adaptation option to support Wheat production in the Indo-Gangetic Plain (IGP) of South Asia:

Increased climate variability and growing populations in the Indo-Gangetic Plain (IGP) of South Asia exacerbate pressures on existing natural resources. In the IGP, agriculture is the primary source of livelihood and is responsible for ~ 90% of total freshwater consumption. Water availability and demand in the region are highly variable within and between the years, posing threats to sustained water use for food production. To address this concern, we investigated supplemental irrigation as an adaptation strategy by determining the effects of optimal irrigation scheduling, including quantity and time, during critical crop growth stages of wheat using the Crop Kites concept. Crop kites investigate the relationship between water use and yield, showing that this can change substantially between locations and years. This study explores the potential of increasing water productivity in irrigated fields with supplemental irrigation. Specifically, we investigate the potential of maximally reducing irrigation while minimally reducing yield. This analysis assumes perfect information on the best irrigation schedule a priori, estimating an upper limit on the yield potential and water savings of investing in supplemental irrigation practices and infrastructure. Additionally, we focus on the added benefits of supplemental irrigation regarding irrigation water productivity. The hydrology and vegetation model, Lund Potsdam Jena managed Land (LPJmL), is used to simulate crop yields of 16 rainfed crops with 20,000 different irrigation schedules in India at 30 arcminute resolution (around 50 km at the equator) under two irrigation scenarios. Our modelling results show that the same total irrigation amount distributed differently can produce significantly different outcomes. For example, in our study, the Crop kite for a specific location but for a different year showed 60% of the previous maximum, with a slight increase in water use. Our results of crop water productivity under the prioritizing irrigation water productivity scenario show that by using 4% of the total irrigation water, we maintain 56% of the full irrigation harvest. Furthermore, our other statistical analysis results under maximizing irrigation water productivity show that by using 23% of the irrigation water, 84% of the full irrigation harvest is maintained. Our study outcomes suggest that an optimal distribution of supplemental irrigation is a promising adaptation measure to help increase water productivity and yields and buffer climatic variability with limited water availability.

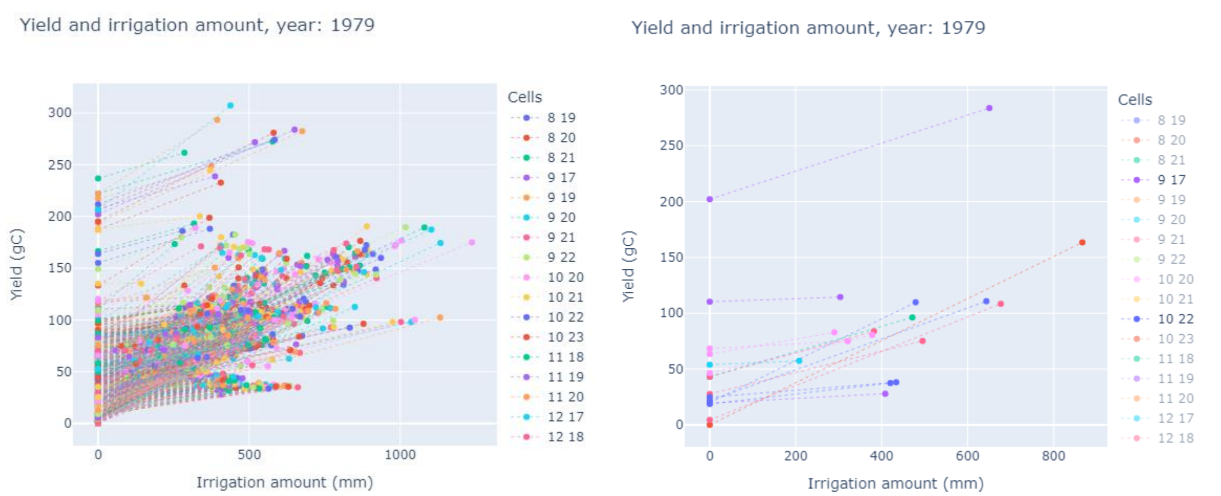


Figure 18: *Total Yield and irrigation for wheat for each 30-arcminute cell across India in 1979*

Figure shows the total wheat yield (gC/m^2) and total irrigation amount only for rainfed and fully irrigated wheat for each 30-arcminute cell across India in 1979. The right figure presents a subset of the complete collection of simulated cells on the left. These figures show the diverse range of yield.

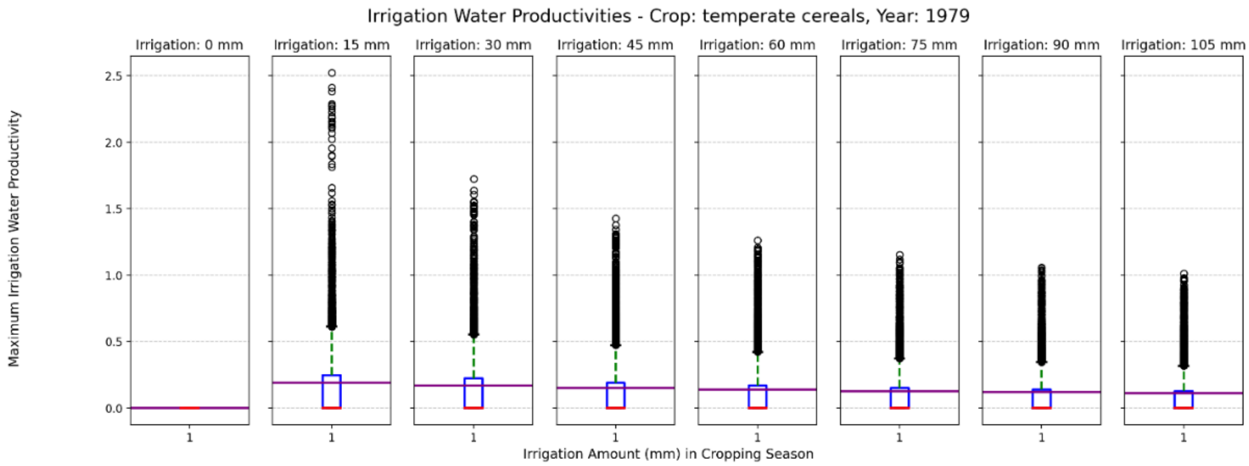


Figure 19: *Box Whisker plots of Maximum irrigation water productivity of wheat over whole study area for 1979*

h. Sediment Load Forecasting of Gobindsagar Reservoir using Machine Learning Techniques:

With ever advancing computer technology in machine learning, sediment load prediction inside the reservoirs has been computed using various artificially intelligent techniques. The sediment load in the catchment region of Gobindsagar reservoir of India is forecasted in this study utilizing the data collected for years 1971–2003 using several models of intelligent algorithms. Firstly, multi-layered perceptron artificial neural network (MLP-ANN), basic recurrent neural network (RNN), and other RNN based models including long-short term memory (LSTM), and gated recurrent unit (GRU) are implemented to validate and predict the sediment load inside the reservoir. The proposed machine learning models are validated for Gobindsagar reservoir using three influencing factors on yearly basis [rainfall (R_a), water inflow (I_w), and the storage capacity (C_r)]. The results demonstrate that the suggested MLP-ANN, RNN, LSTM, and GRU models produce better results with maximum errors reduced from 24.6% to 8.05%, 7.52%, 1.77%, and 0.05% respectively. For future prediction of the sediment load for next 22 years, the influencing factors were first predicted for next 22 years using ETS forecasting model with the help of data collected for 33 years. Additionally, it was noted that each prediction's error was lower than that of the reference model. Furthermore, it was concluded that the GRU model predicts better results than the reference model and its alternatives. Secondly, by comparing the prediction precision of all the machine learning models established in this study, it can be evidently shown that the LSTM and GRU models were superior to the MLP-ANN and RNN models. It is also observed that among all, the GRU took the best precision due to the highest R of 0.9654 and VAF of 91.7689%, and the lowest MAE of 0.7777, RMSE of 1.1522 and MAPE of 0.3786%. The superiority of GRU can also be ensured from Taylor's diagram. Lastly, Garson's algorithm and Olden's algorithm for MLP-ANN, as well as the perturbation method for RNN, LSTM, and GRU models, are used to test the sensitivity analysis of each influencing factor in sediment load forecasting. The sediment load was discovered to be most sensitive to the annual rainfall.

Figure 20A depicts the comparison of actual volume of sediments deposited inside the Gobindsagar reservoir with reference neural network model and proposed machine learning models using tested data from year 1971 to year 1999 while in Figure 20B it can be seen that the relative errors estimated using GRU model are lying between -0.5% and 0.5% inside the grey rectangle and showing the better results as compared to the other models. Figure 21A, B, and C depict the three yearly forecasted influencing factors for the Gobindsagar reservoir: rainfall, inflow of water, and storage capacity.

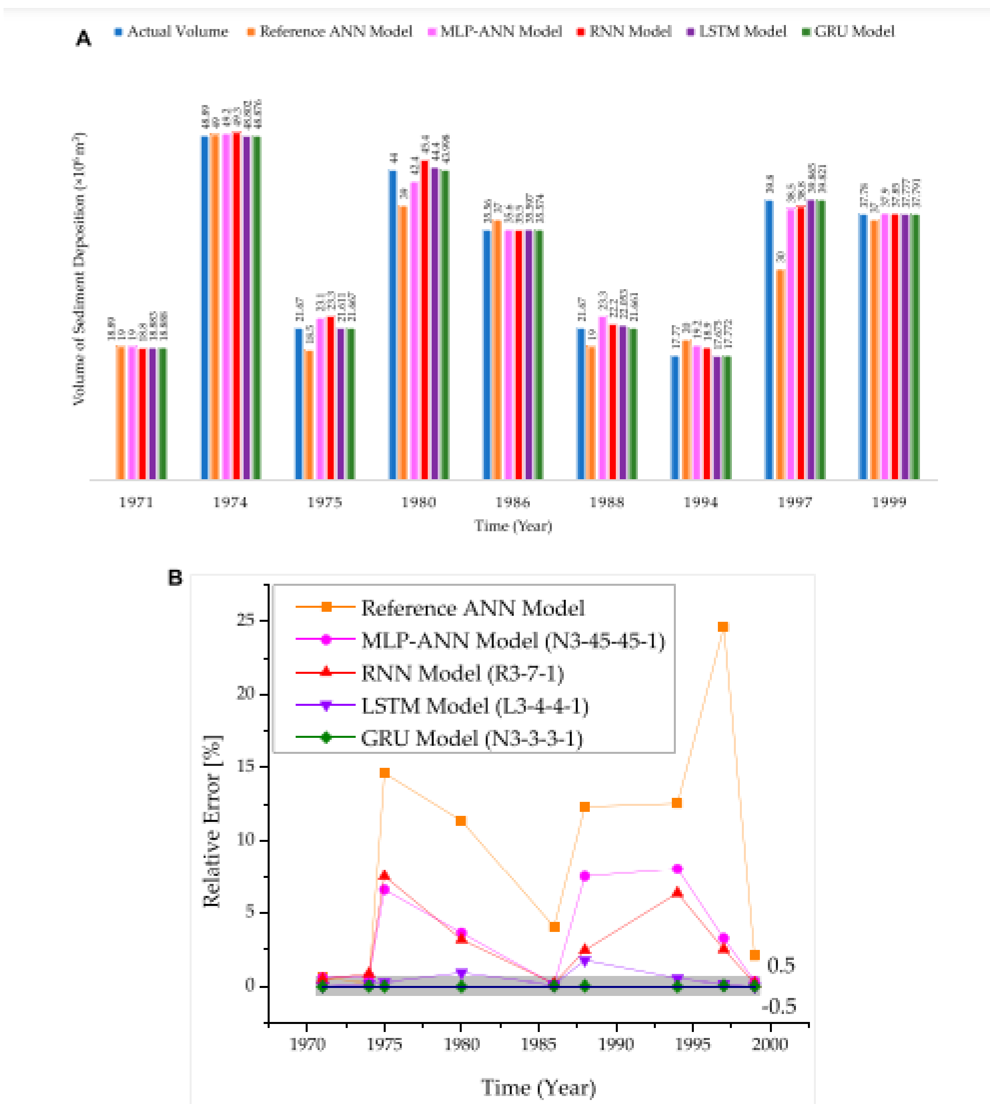


Figure 20: *(A). Comparison of actual volume of sediments retained inside the Gobindsagar reservoir with reference ANN model and proposed machine learning models using tested data from year 1971 to year 1999, (B). Reduction in relative error of proposed machine learning models in comparison with the reference model.*

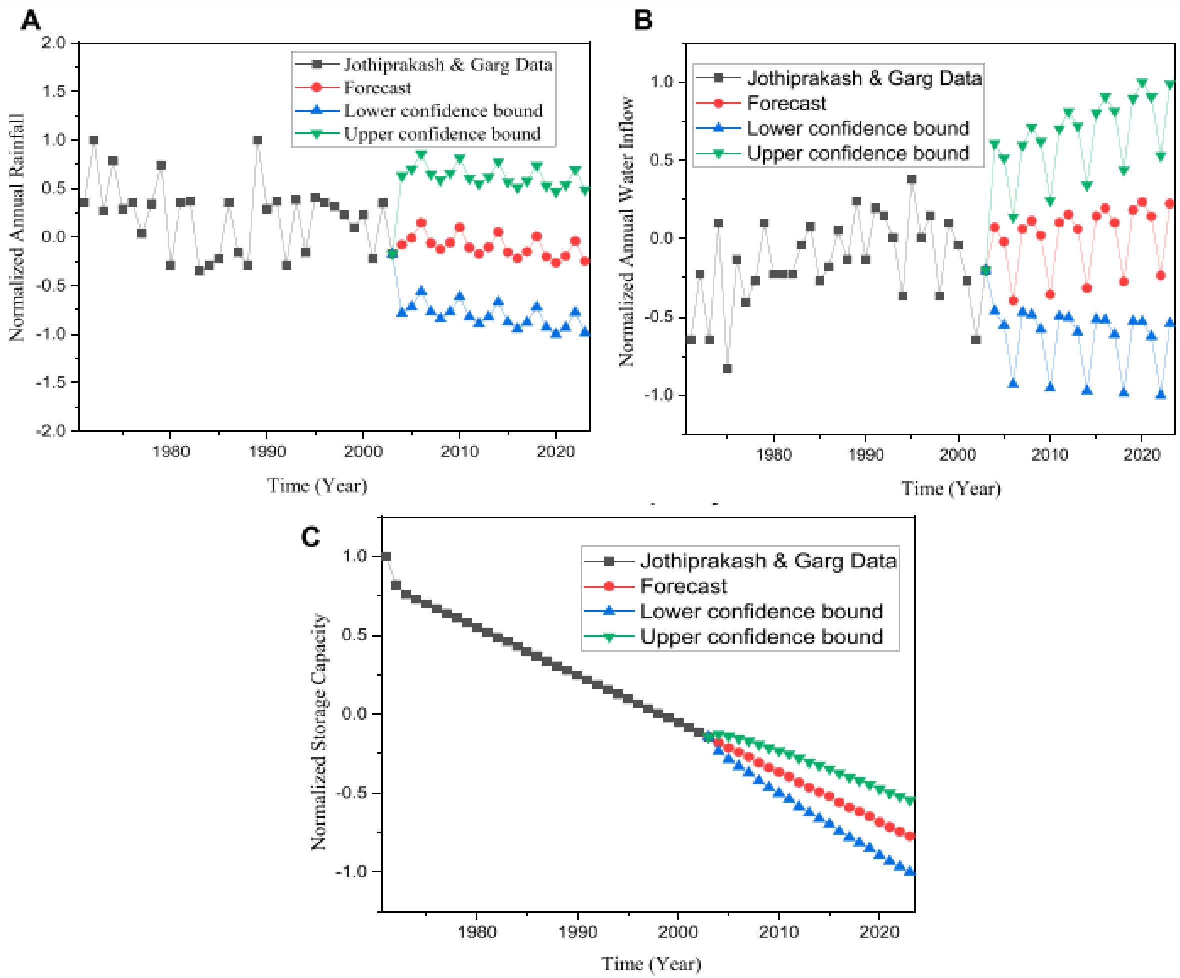


Figure 21: *Forecasted input parameters for the Gobindsagar reservoir including (A) normalized rainfall; (B) normalized inflow of water and (C) normalized storage capacity.*

i. Spatiotemporal Characterization of Meteorological Drought in Saudi Arabia:

The drought phenomenon is a natural disaster that occurs due to a lack of water supply and harms the growth and production of crops and other agriculture and socio-economic activities along with the ecosystem. Lack of precipitation for a longer period is the main cause of the drought. The Kingdom of Saudi Arabia (KSA) lies in a water-stressed region with high rainfall inter-annual variability and is highly vulnerable to recurring droughts. There are several indices/methods to measure droughts but the Standardized Precipitation Index (SPI) is the widely used index because of its simplicity. The analysis showed negative (decreasing) SPI trends in all the drought years starting at the end of the 20th century and continuing till 2012. There are no or very rare extreme wets in the country within the data while there are many severe and extreme droughts (highest SPI =3.87, and lowest SPI =-

5.38). Percentiles mapping 90th (10th) and 95th (5th) for upper (lower) bounds of SPI help policymakers manage the adaptive measures to overcome the consequences of drought based on different levels of uncertainty represented by these percentiles.

Figure 22 (the last-row left image). represents the 32nd percentile which exhibits that most of the country is observing mild droughts while some parts are also observing mild wets such as the southern part Riyadh region (Wadi ad Dawasir), Asir, Madina, and Hail regions. Figure 22 (the last-row right image) represents the 68th percentile which exhibits that the whole country is exhibiting mild wets. It means more intense drought events happened in different years throughout the KSA which can also happen in the near and far future as well based on the trends of SPI values.

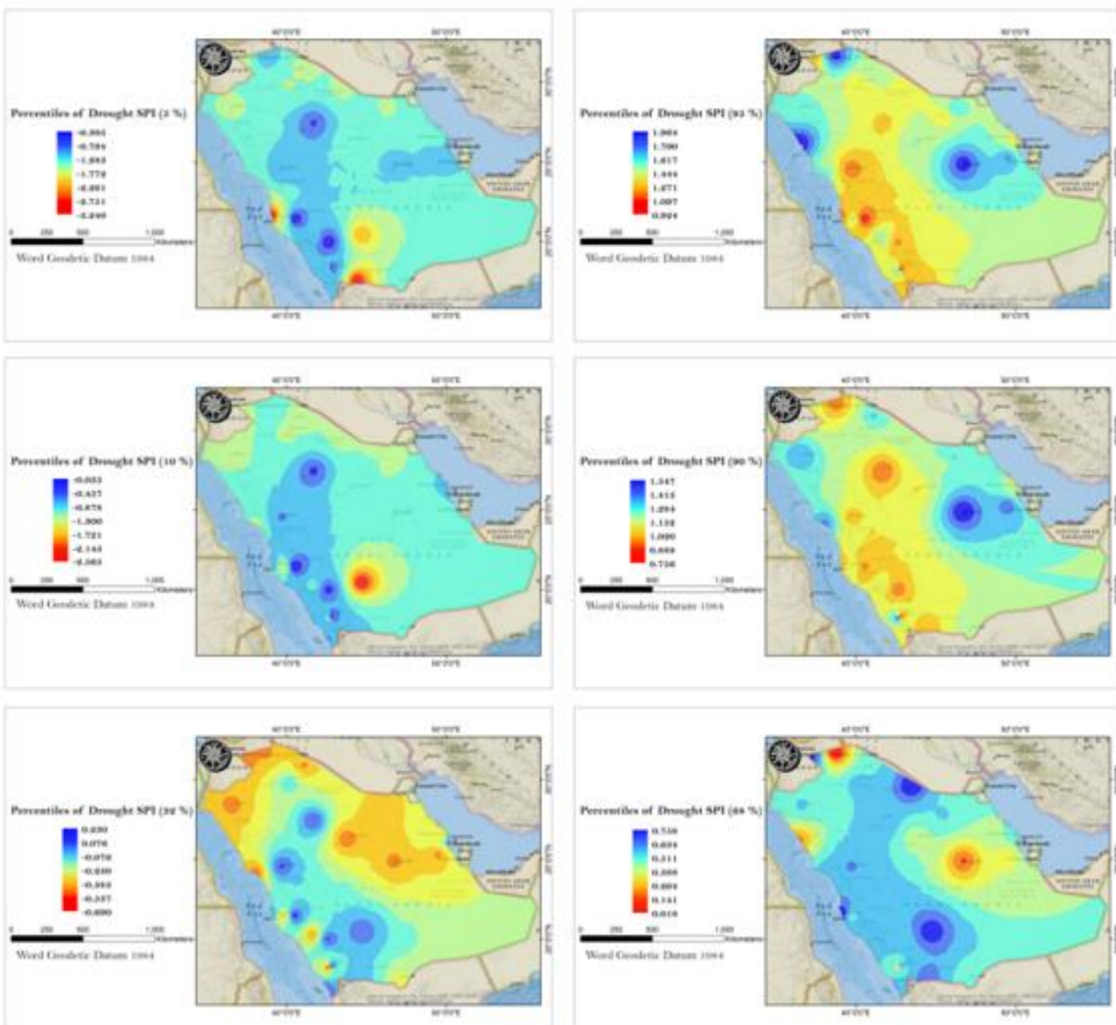


Figure 22: *Percentile mapping: First row 5th Percentile values (left), and 95th Percentile values (right), middle row: 10th Percentile values (left) and 90th Percentile values (right), last row: 32th Percentile values (left) and 68th Percentile values (right).*

j. Simulation of the meltwater under different climate change scenarios in a poorly gauged snow and glacier-fed Chitral River catchment (Hindukush region)

Seasonal and annual water supplies of the rivers originating in the Hindukush-Karakoram-Himalaya (HKH) region of Pakistan are important to manage the Indus basin irrigation system for better agricultural production and its dependent agrarian economy. In this study, we simulated the current and future snowmelt runoff in a poorly gauged river basin of the Hindukush region under Representative Concentration Pathways (RCP) climate change scenarios. Snowmelt Runoff Model (SRM) furnished with satellite snow cover maps and hydro-meteorological data were used to simulate the daily river discharge for the period 2000–2005. The results indicated that SRM has effectually simulated the runoff in Chitral River with Nash-Sutcliffe model efficiency coefficient of 0.85 (0.84) and 0.88 (0.83) in the basin-wide (zone-wise) application during the calibration and validation periods, respectively. The results obtained under future climate change scenario showed ~14–19% increase in mean summer discharge under three mid-21st century RCP (2.6, 4.5 and 8.5) scenarios. While an increase of ~13–37% is expected under late-21st century RCP scenarios. This study can help water resource managers to plan and manage peak discharges from the Chitral River Basin in the future and can thus prevent major losses due to floods in the area.

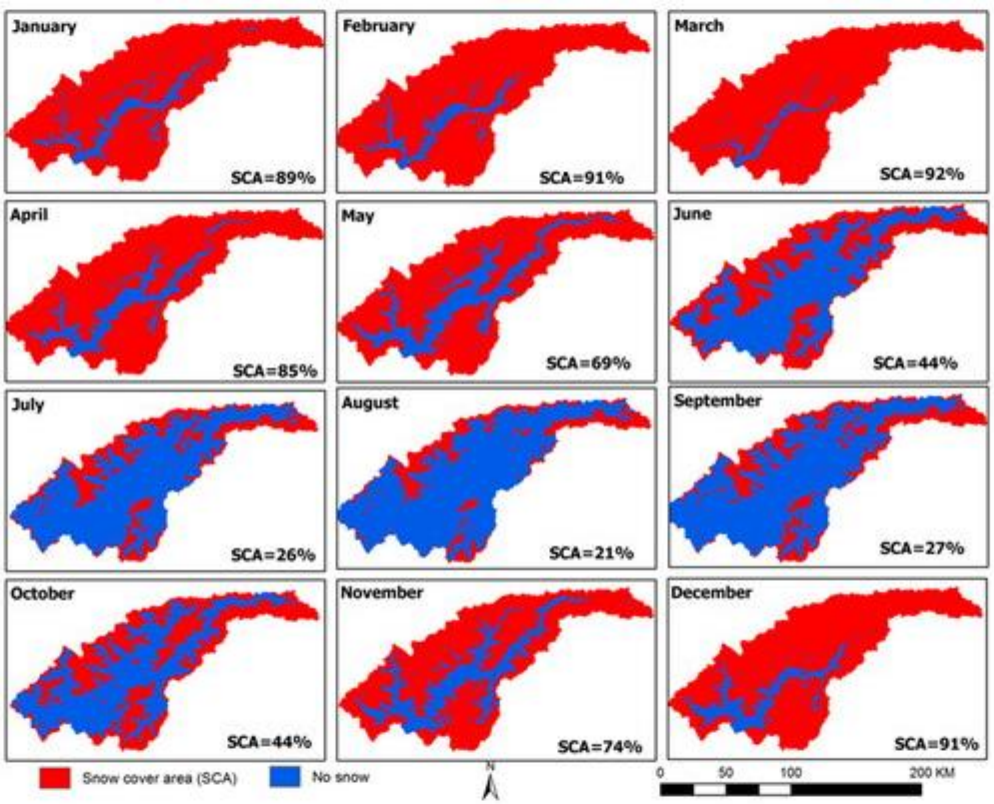


Figure 23: *Spatial extent of mean monthly snow cover area (SCA) estimated from the MODIS data period of 2000–2005 for the Chitral basin.*

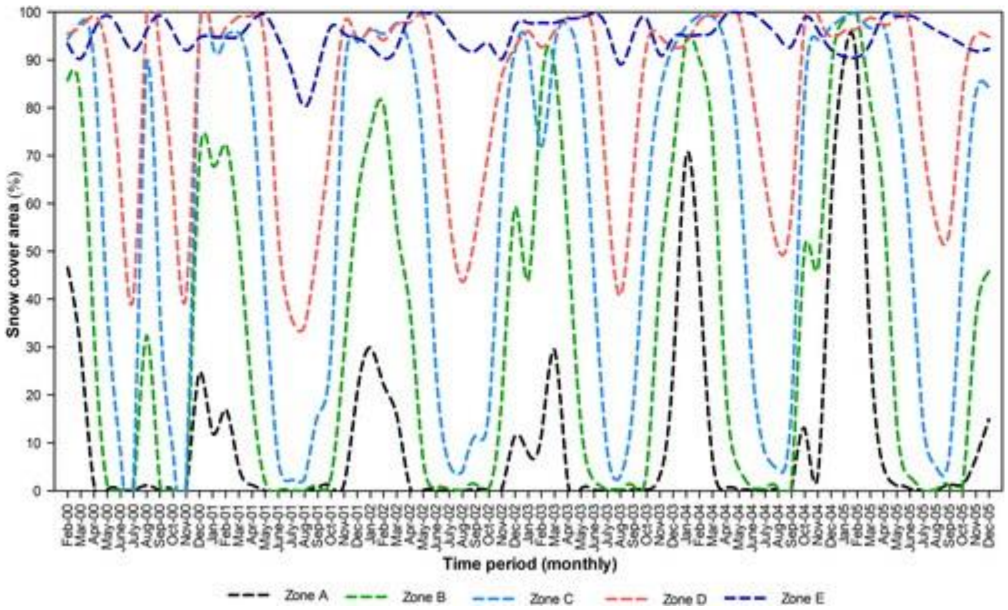


Figure 24*: Mean monthly snow cover distribution (zone-wise) in the Chitral River basin over a period of 2000–2005.*

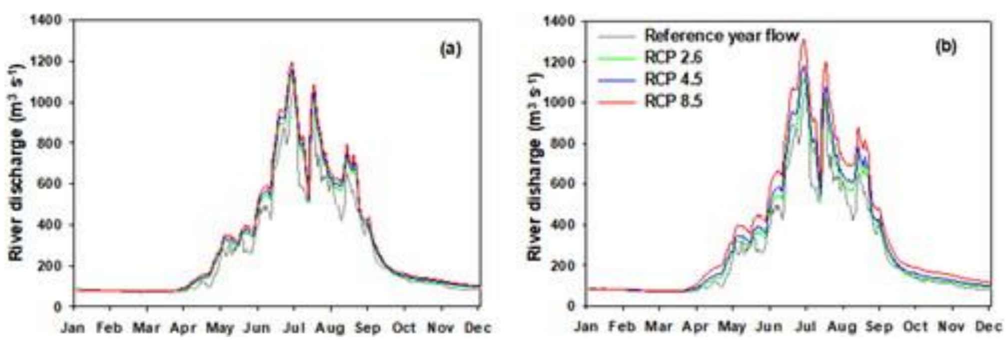


Figure 25: *(a) Simulation of the Chitral River discharge under RCP 2.6, 4.5 and 8.5 climate change scenarios for the (a) mid-21st century, and the (b) late-21st century.*

k. Assessing drought and its impacts on wheat yield using remotely sensed observations in rainfed Potohar region of Pakistan:

Drought is a serious threat to agriculture particularly of rainfed regions like Potohar region of Pakistan. Wheat, staple food crop of this region is mostly affected by drought, thereby impacting food security of the region. Effective drought monitoring and its impacts on wheat production have therefore been the key concerns of the farmers and policy makers in order to plan for any upcoming food crises in the region. A proactive drought management approach is needed in this regard. This study aims to assist the decision-making process for drought monitoring and yield predictions, as it informs drought assessment and its impacts on crop yield using drought and vegetation indices along with climate and crop yield data. This research quantifies recurrent drought events for Rubi (wheat crop) season (November-April) from 2000 to 2018 in the Potohar region using indices such as; Standardized Precipitation Index (SPI), Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI) and Soil Adjusted Vegetation Index (SAVI) along with climatic parameters i.e., mean temperature, rainfall and soil moisture. Results show a strong positive correlation of wheat yield with rainfall (r = 0.97) and soil moisture (r = 0.88), while a strong negative correlation with temperature (r = -0.98). Three moderate (2000-01, 2001-02, 2009-10) and two weak (2011-12, 2017-18) drought events are identified using SPI, whereas two more drought events (2007-08 and 2016-17) are noticed when vegetation indices are used. Looking at Oceanic Niño Index (ONI), no definite pattern relating to ongoing La Nina or El-Nino conditions during the specific drought years is observed for the Potohar region. Artificial Neural Network (ANN), a multilayer perception (MLP) model is applied afterwards to see the individual impact of each study parameter on wheat yield. Soil moisture is found to impact yield by 100 %, temperature as 74 %, rainfall as 61 % and then rest of the indices. The findings of this study not only provide a scientific base for future studies on drought indicators, but assert that a cumulative approach is needed for effective drought management at national level.

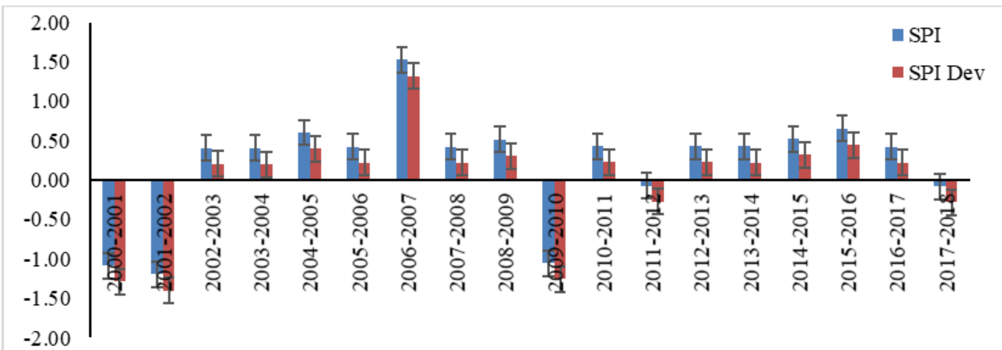


Figure 26: *6-month SPI and SPI Deviation in the Potohar region during Rubi season from 2000-2018*

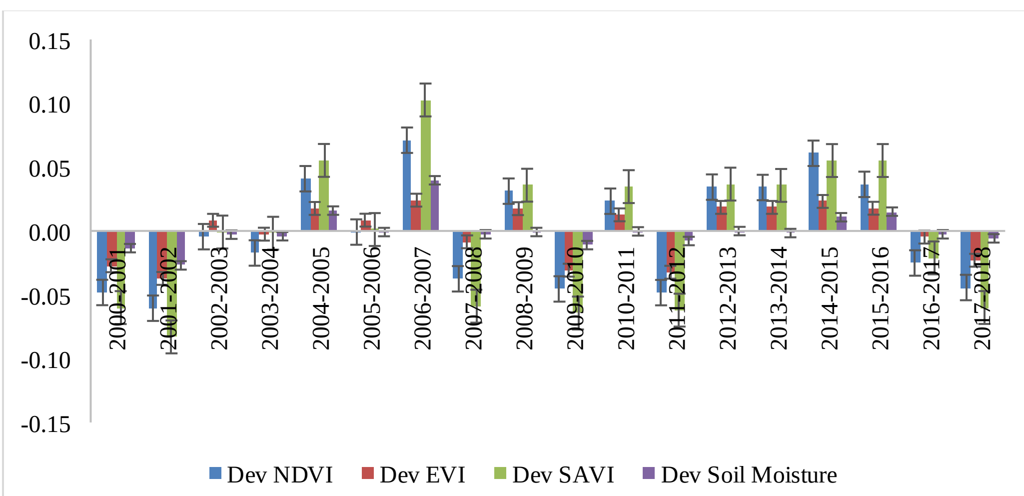


Figure 27: *Deviation of NDVI, EVI, SAVI and soil moisture in the Potohar region during Rubi season from 2000-2018*

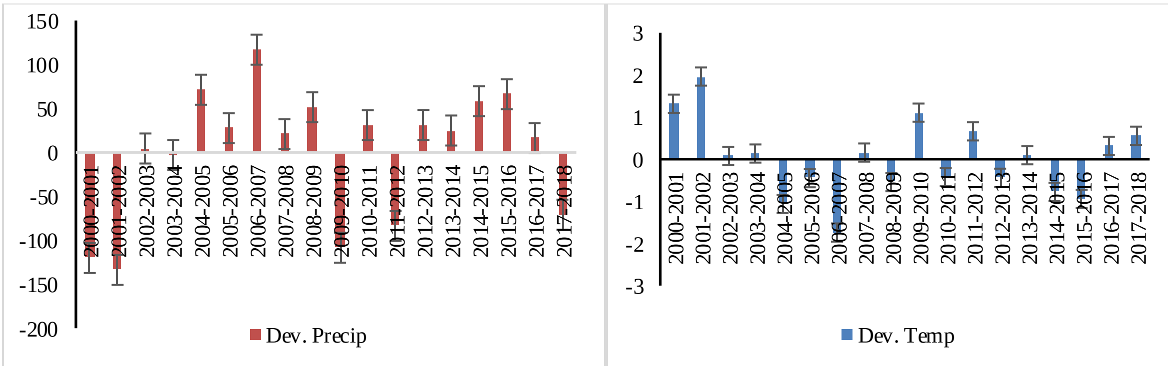


Figure 28: *Deviations of (a) Rainfall (in mm) and (b) Mean surface temperature (°C) in the Potohar region during Rubi season from 2000-2018*

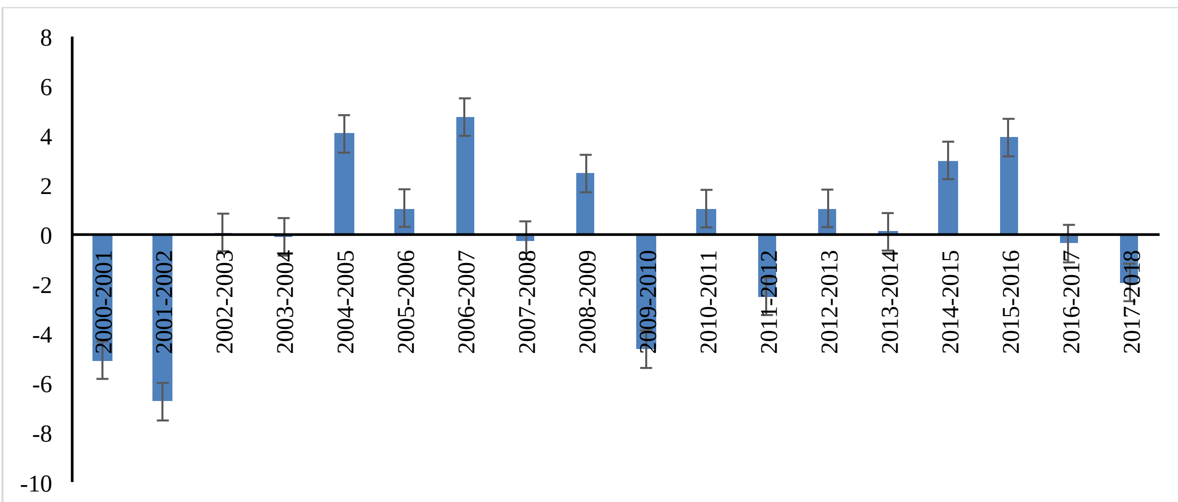
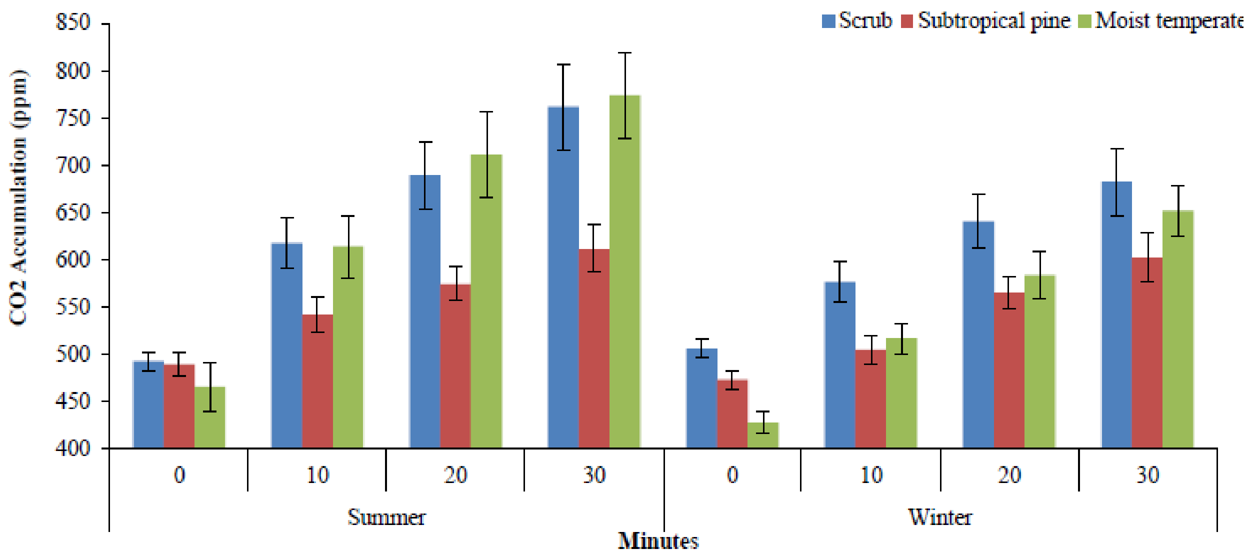


Figure 29: *Yield deviation (Maund/ha) in the Potohar region during Rubi season from 2000-2018*

l. Spatio-temporal dynamics of greenhouse gas emissions from soils in forest ecosystems of Pakistan

Intergovernmental Panel on Climate Change (IPCC) in its sixth assessment report (AR-6) has documented that the atmosphere, ocean, and land have been warmed at an unprecedented rate as per history of last 2000 years. Greenhouse gas (GHG) emissions from agriculture and forest soils account for 24% of the total global emissions. Soil processes directly contribute to climate change through the production and consumption of carbon dioxide (CO2), methane (CH4) and nitrous Oxide (N2O). Because of huge spatial and temporal variability in the soil-atmosphere exchange of GHGs, the measurement of prevailing concentrations and prediction are still difficult. Under different forest types, soil responds in a dissimilar fashion under varying climatic conditions.

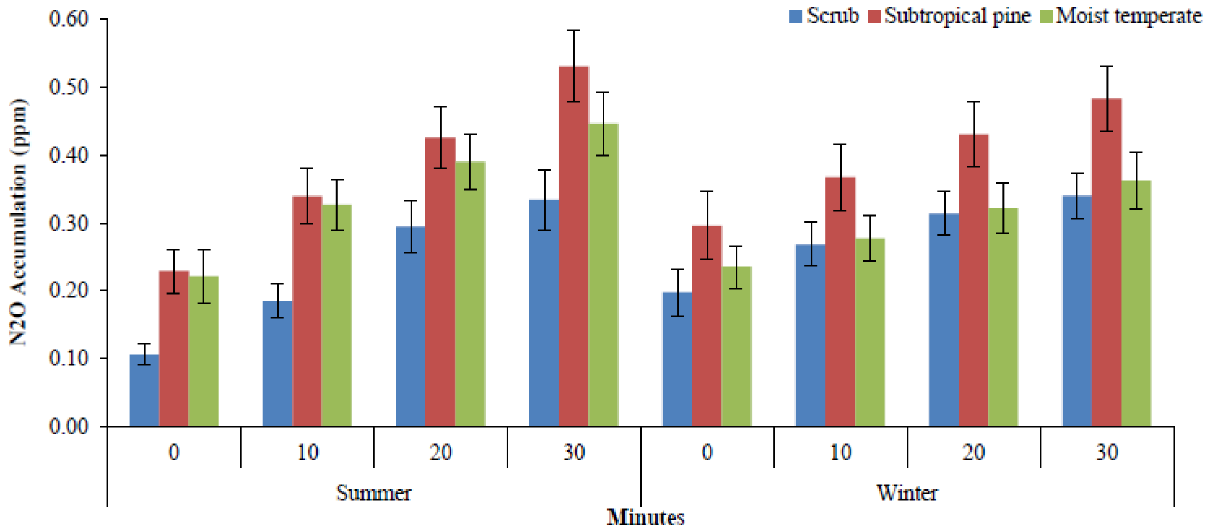
This research endeavor was pursued to estimate GHG accumulations from soil under scrub, subtropical pine and moist temperate forests. This study is of unique scientific efforts and features in which empirical data of the soil GHG emissions was gathered based on field observations. The present study apprehended forest diversity and temporal variations using a static chamber and photoacoustic spectroscopy to estimate GHG accumulations from soil. Seasonal variations strongly influenced CO2 emissions in three forest types (Fig. 30), while N2O accumulation was not influenced by seasonal variations.



- Error bars are indicating Standard Error

Figure 30: *Carbon dioxide accumulation by season from soils of three forest types*

In the winter season, the GHG accumulation decreased due to reduced microbial and root respiration. Methane was not detected in any of the forest types investigated in this study. Our results showed that soil under moist temperate forests produced more CO2 in summer as compared to that in the other forest types. The subtropical chir pine forest has the highest N2O accumulation in both summer and winter seasons. The outcomes of the research will be useful for developing national GHG inventory as well as Forest Reference Emission Levels (FREL) for REDD+ implementation under the Paris Agreement. Further, the data produced in this study may be helpful in carbon trading under Kyoto Protocol. The present approximations of GHGs will aid in predicting the future climate trends.



- Error bars are indicating Standard Error

Figure 31: *Nitrous Oxide accumulation by season from soils of three forest types*

m. GIS-based spatio-temporal assessment of forest cover change and carbon sequestrations of District Abbottabad, Pakistan

Forest plays an important role in the climate of a country and ecosystem's balance. During the last decade, District Abbottabad of Pakistan has gone through extensive land-use changes due to accelerated development, urbanization, and agriculture. This study examines the change in forest cover due to environmental factors with the help of satellite images (Landsat, Sentinel) and their classification through supervised classification, as well as the application of change detection technique after classification using geographical information system (GIS) over the last three decades (1986–2019). The land-use transition matrix was calculated from the year 1986 to 2019. The result shows an overall increase of 3.17%, 17.24%, and 7.24% in the forest, vegetation, and build-up areas, respectively; whereas water-bodies and others (barren land) has decreased significantly by 0.69% and 26.96% respectively (Figure 32). Figure 33 presents the temporal pattern of various LULC for the period of 1986 – 2019. Results revealed that carbon sequestration increase as the year passes due to afforestation in the study area. From 1986 to 2004 carbon sequestration decreased by 12.93%, while in 2002 – 2014 carbon sequestration increased by 19.54% between 2014 – 2019. Figure 34 shows the trend of total wood volume, Dry matter biomass, total carbon, carbon dioxide during 1986 – 2019 for Abbottabad District.

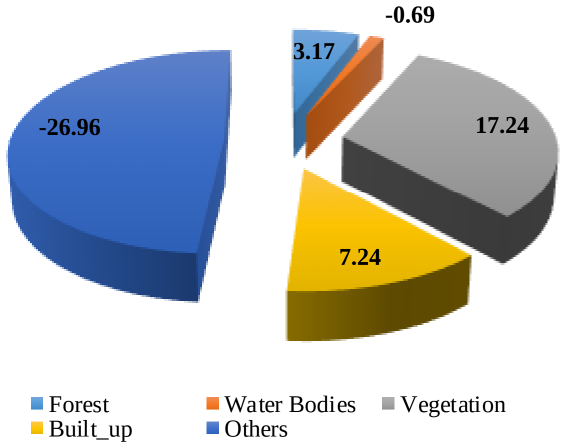


Figure 32: *Net percentage Change in Land Use Land Cover (1986 – 2019)*

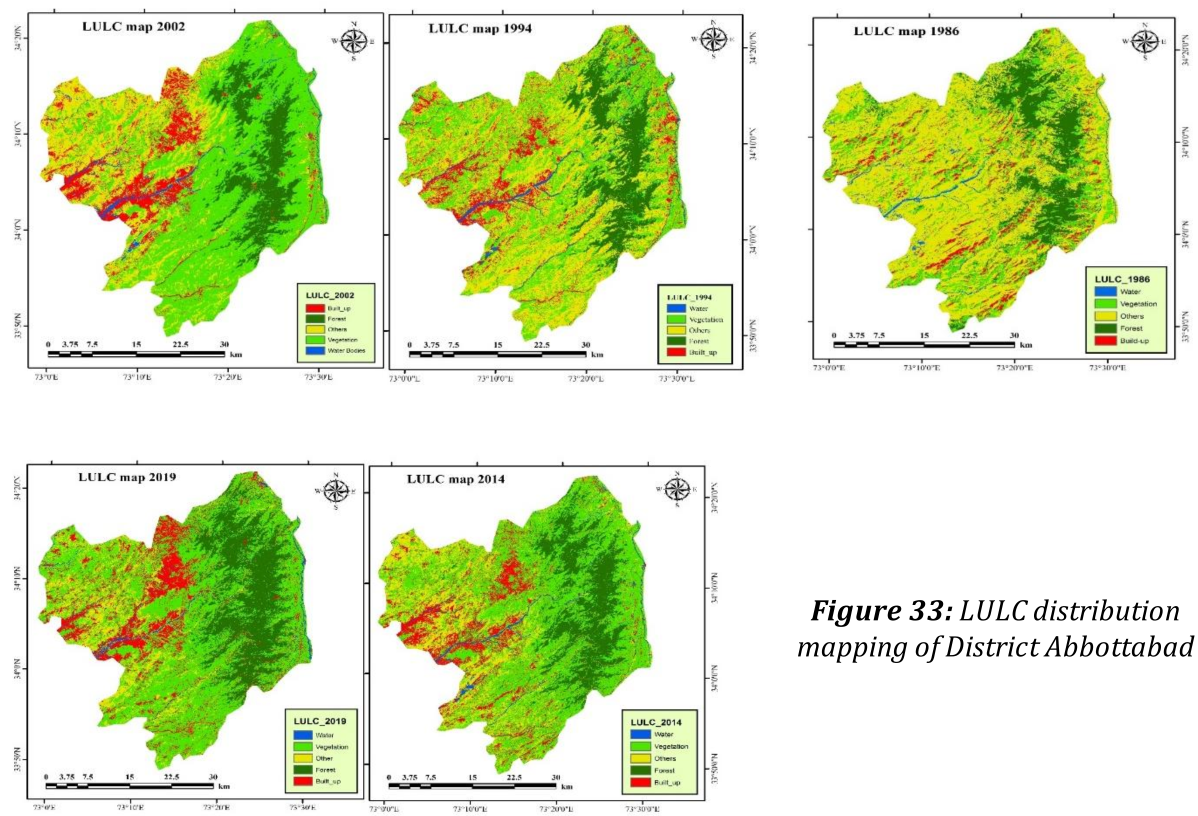


Figure 33: *LULC distribution mapping of District Abbottabad*

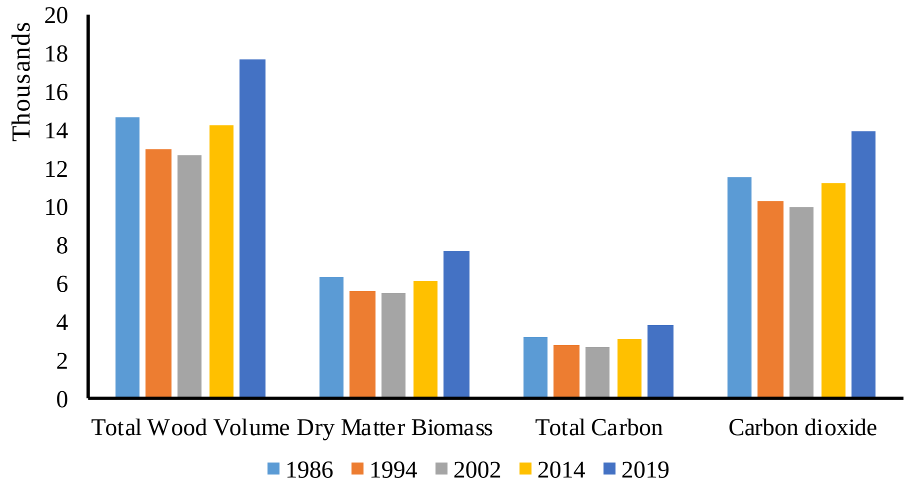


Figure 34: *Trend of total wood volume, Dry matter biomass, total carbon, carbon dioxide during 1986 – 2019 for Abbottabad District*

n. Assessment of change in forests land, carbon stock and carbon emissions of KPK, Pakistan for past three decades using geospatial techniques

Reducing emissions from deforestation and forest degradation is a mechanism to cut down GHG emissions and protect the threatened forest ecosystems. Pakistan is suffering from high forest degradation and deforestation rates, but recent plantations under BTTAP have created a significant impact. This study was designed to identify the LULC changes, forest sequestration and emissions from forest degradation in the forest hub districts (Malakand, Mardan, Lower Dir and Upper Dir) of KPK, Pakistan using Landsat imageries. LULC changes were analyzed from 1990 to 2020. In addition, the amount of carbon sequestration and emissions from forest degradation were also calculated. Results of the analysis showed forest area reduction from 1990 to 2009, followed by a sharp increase in the next decade (2010–2020) by 56% (Table 1). Around 836 km^2 of land was found to be covered with forests during BTTAP. The net change was a 32% increase in forest land over three decades. Figure 35 below summarized total carbon sequestration (tons) potential and emissions due to deforestation over the time period in the study area. The study offers important information which environment managers and decision-makers can utilize to encourage the plantation of trees and save existing forests in the country to combat climate change.

Table 1: Net change in classes over the years (1990 - 2020)

Category	**Change (km^2)**	**% Change**
Forest land	565.55	32.17
Agricultural land	-937.75	-44.45
Water Bodies	-28.83	-63.89
Settlement	1493.77	86.95
Others	-1092.48	-47.33
Note: -ive sign shows decreasing trend		

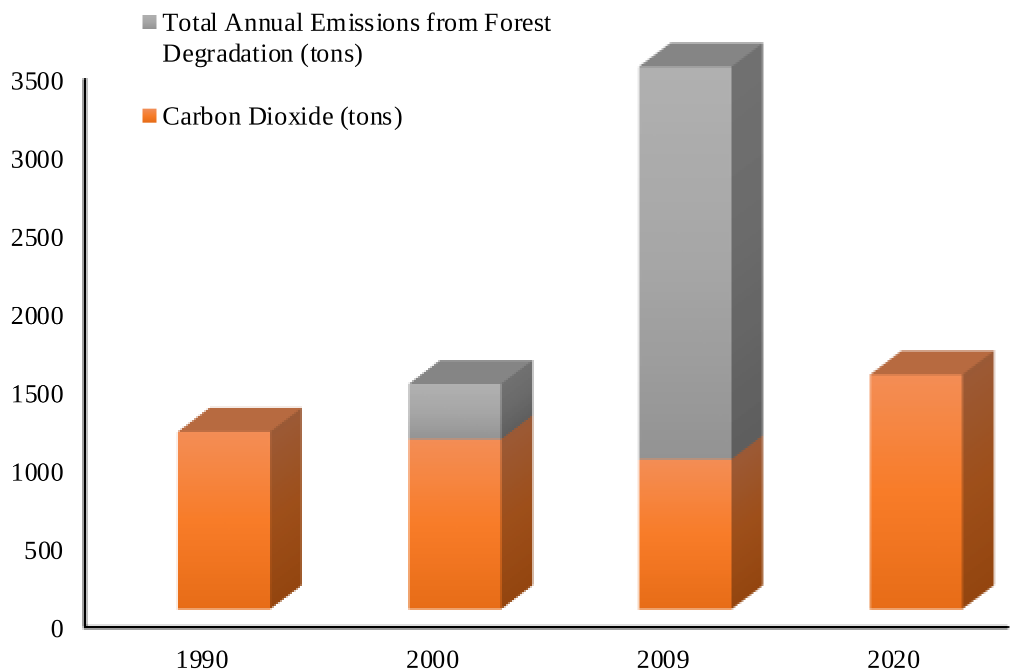
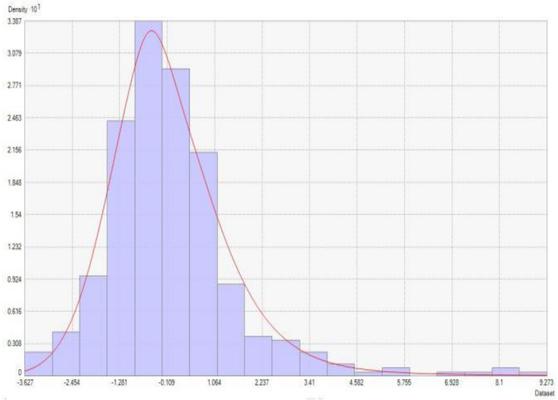


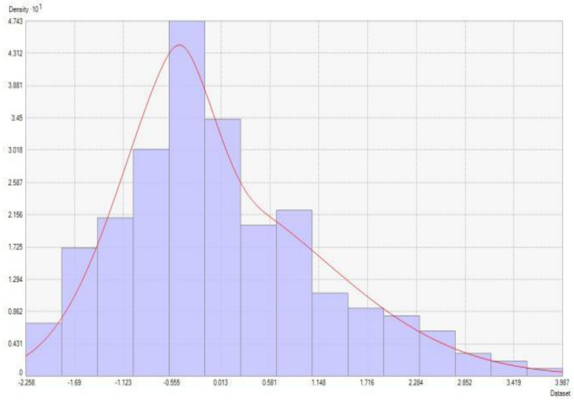
Figure 35: *Carbon Stock Assessment and total annual emissions from forest degradation*

o. Geostatistical investigation of groundwater quality zones for its applications in irrigated agriculture areas of Punjab (Pakistan):

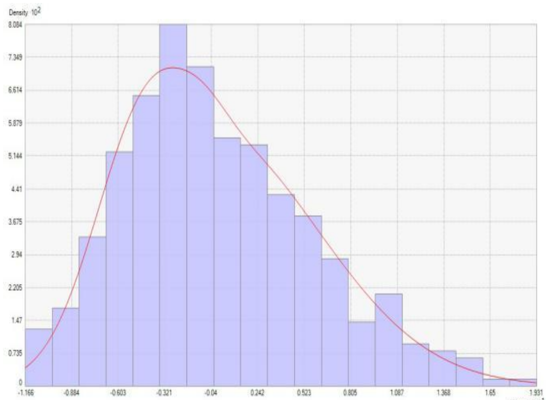
The farmer's income and crop yield are greatly affected in Punjab, Pakistan due to poor quality groundwater. To observe, monitor and categorized groundwater quality, this research study was carried out in Faisalabad (FSD) and Toba-Tek Singh (TTS) districts of Punjab, Pakistan to check its suitability for irrigation with three major parameters (i.e. EC, SAR, and RSC). Geo-statistical water quality analysis was carried out using the GS+ and ArcGIS includes three basic components normalized histograms, semivariograph, and Kriging. The cross-validation techniques were used to determine the accuracy. A hydro-economic model was applied to observe the impact of groundwater quality on crop yield and farmers' income. It was found that the percent area under a good groundwater quality zone in FSD was about 25% fewer than TTS. In FSD, the majority area of the aquifer was under marginal (50-55%) to poor (39-44%) quality groundwater zones and salinity and sodicity are major threats depicted by EC and RSC, respectively. In TTS district, salinity was the only major risk to groundwater quality as about 45% area was under poor quality zone. The overall aquifer's area under about good (~33%), marginal (~29%) and poor (~38%) quality groundwater zone. It was found that the impact of the monsoon season was found not considerable on the groundwater quality of both districts. Comparing the economic models in two districts using the different quality water it was found that the BCR (Benefit Cost Ratio) was recorded 2.31, 2.13 and 1.73 in FSD district while in TTS district the BCR was 2.35, 2.09 and 1.58 for good, marginal and poor quality zone, respectively. The results of the research recommend that monitoring and mapping of groundwater s are necessary for proper management of groundwater resources leads to reduce economic losses and increased crop yield.



(a) Electrical Conductivity (EC) Pre-Monsoon

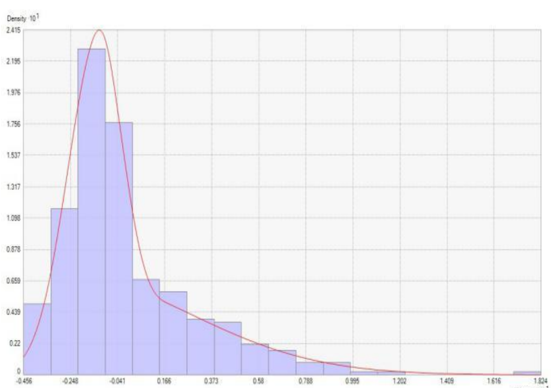


(b) Electrical Conductivity (EC) Post-Monsoon

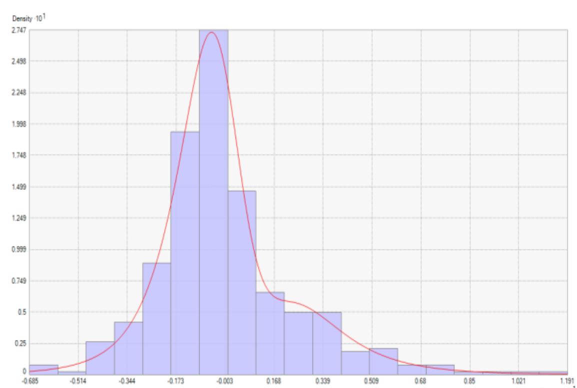


(c) Sodium Adsorption Ratio (SAR) Pre-Monsoon

(d) Sodium Adsorption Ratio (SAR) Post-Monsoon

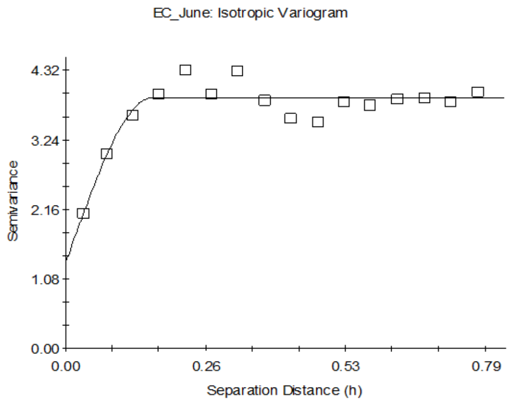


(e) Residual Sodium Carbonate (RSC) Pre-Monsoon

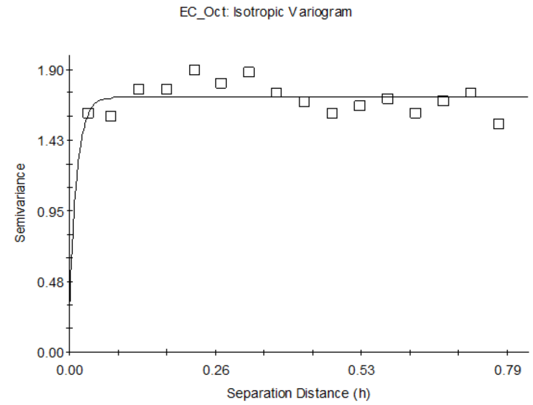


(f) Residual Sodium Carbonate (RSC) Post-Monsoon

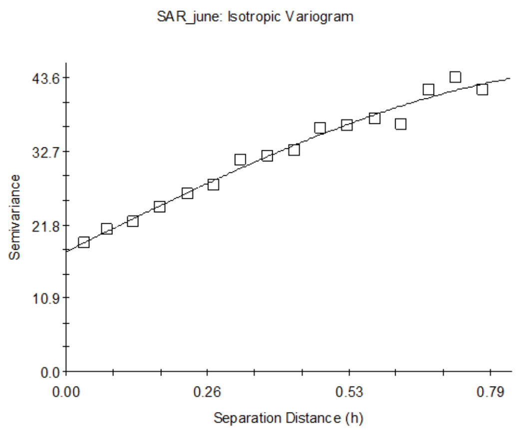
Figure 36: *Normalized histograms of water quality parameters for irrigation*



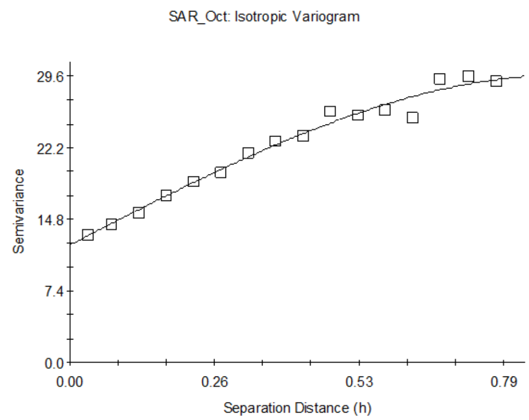
(a) Electrical Conductivity (EC) Pre-Monsoon



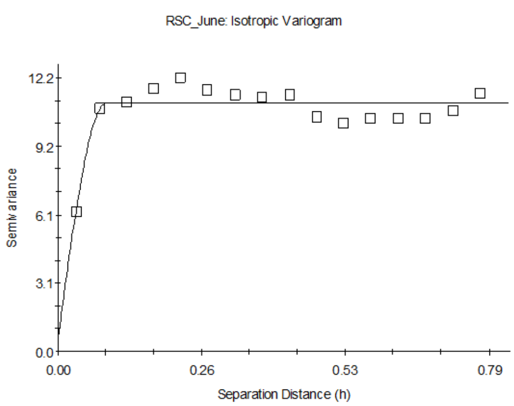
(b) Electrical Conductivity (EC) Post-Monsoon



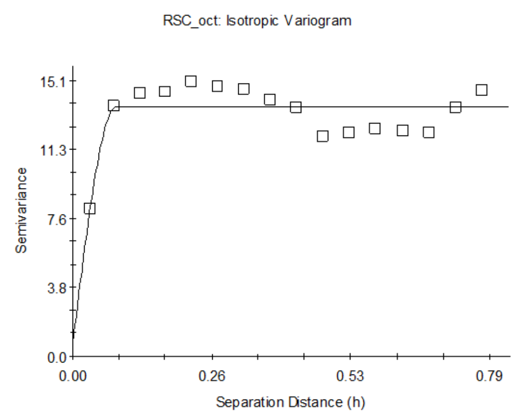
(c) Sodium Adsorption Ratio (SAR) Pre-Monsoon



(d) Sodium Adsorption Ratio (SAR) Post-Monsoon

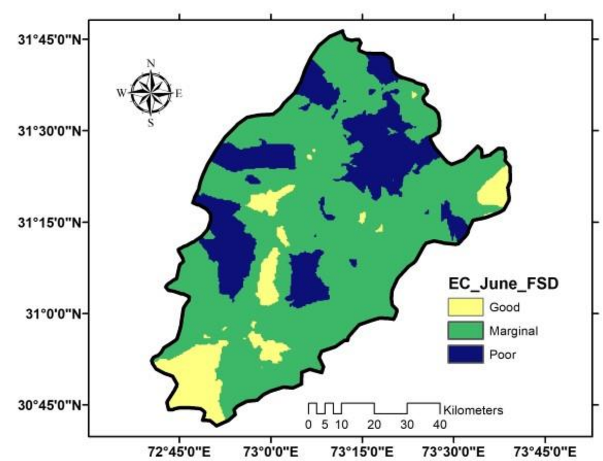


(e) Residual Sodium Carbonate (RSC) Pre-Monsoon

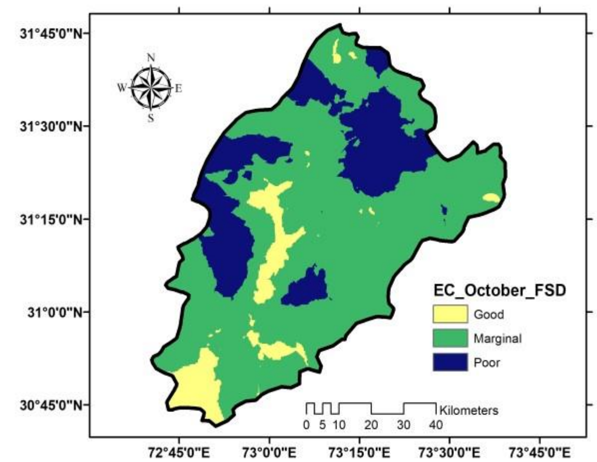


(f) Residual Sodium Carbonate (RSC) Post-Monsoon

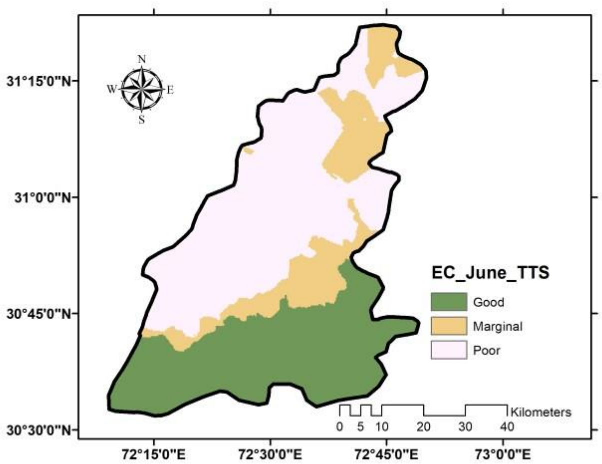
Figure 37: *Best fit experimental semivariogram model of water quality parameters for irrigation*



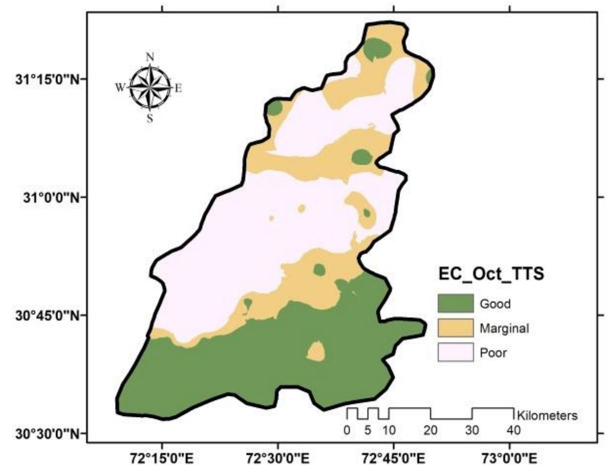
(a) Faisalabad district (Pre-monsoon)



(b) Faisalabad district (Post-monsoon)

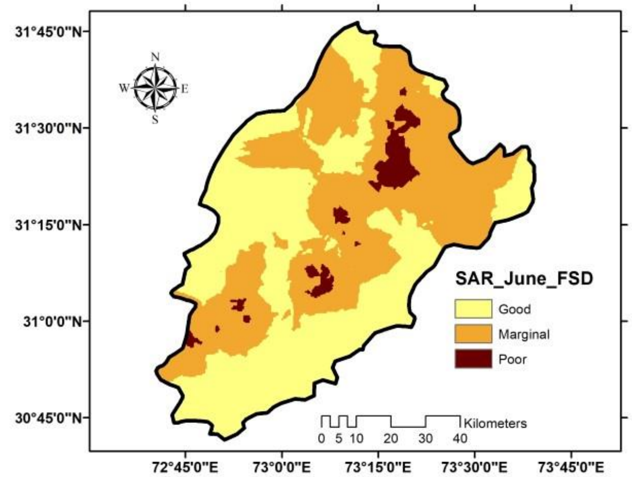


(c) Toba-Tek Singh district (Pre-monsoon)

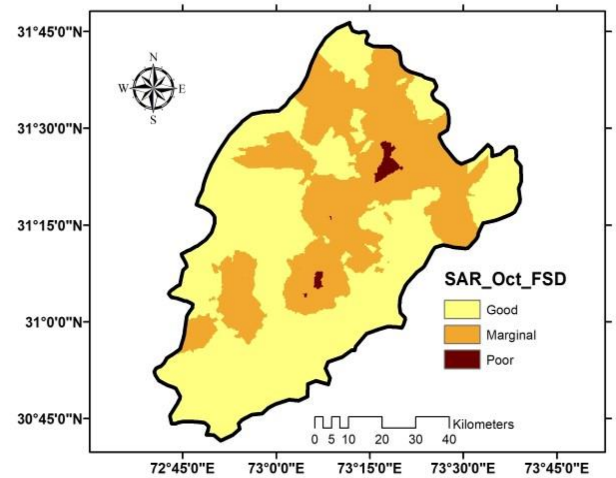


(d) Toba-Tek Singh district (Post-monsoon)

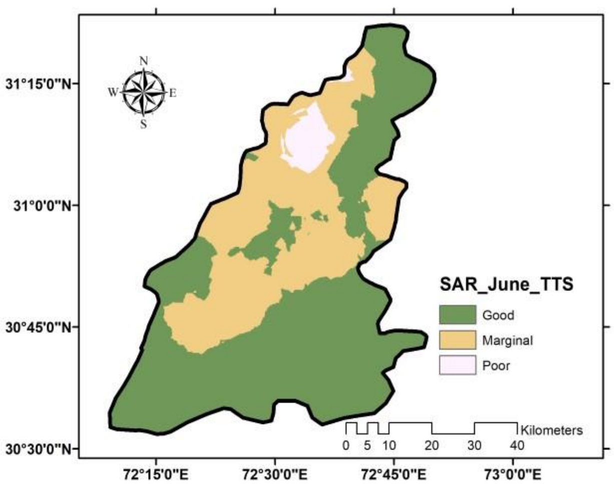
Figure 38: *Spatial variation of electrical conductivity*



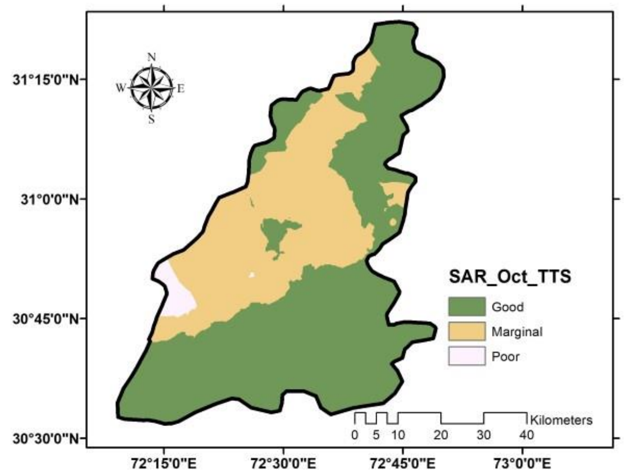
(a) Faisalabad district (Pre-monsoon)



(b) Faisalabad district (Post-monsoon)

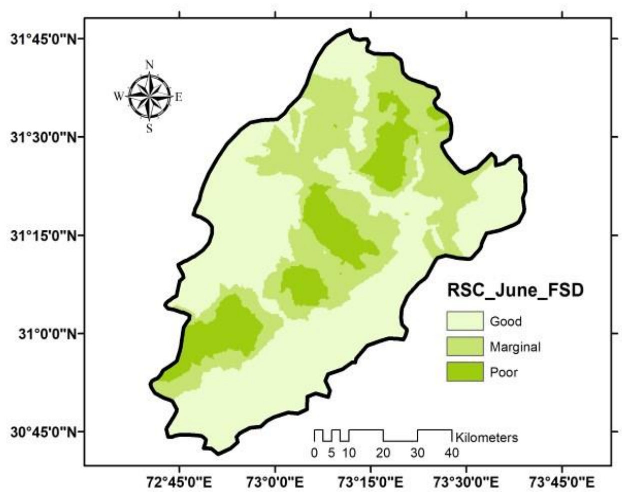


(c) Toba-Tek Singh district (Pre-monsoon)

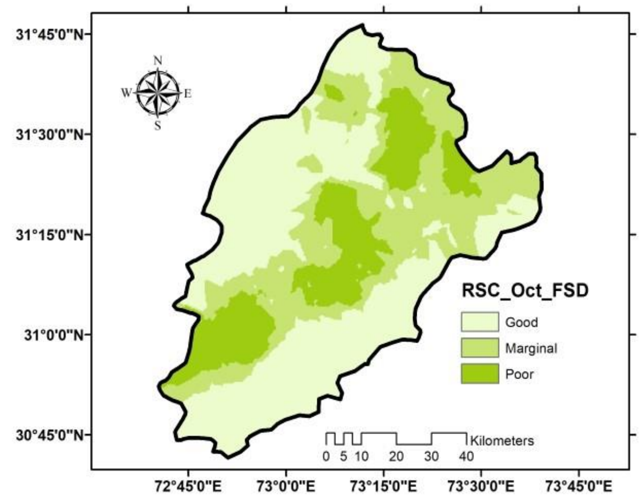


(d) Toba-Tek Singh district (Post-monsoon)

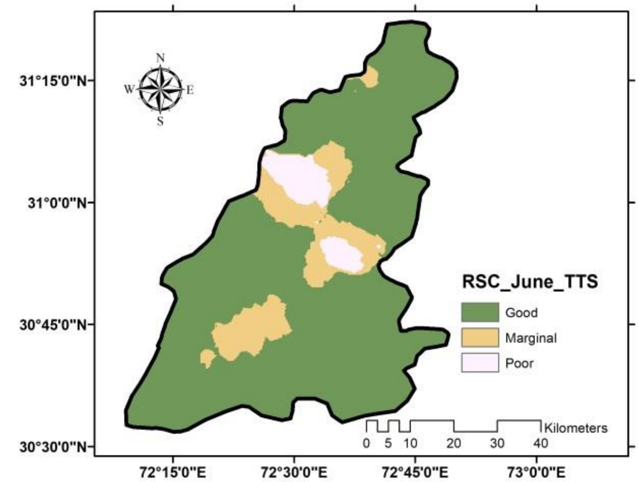
Figure 39: *Spatial variation of sodium adsorption ratio (SAR)*



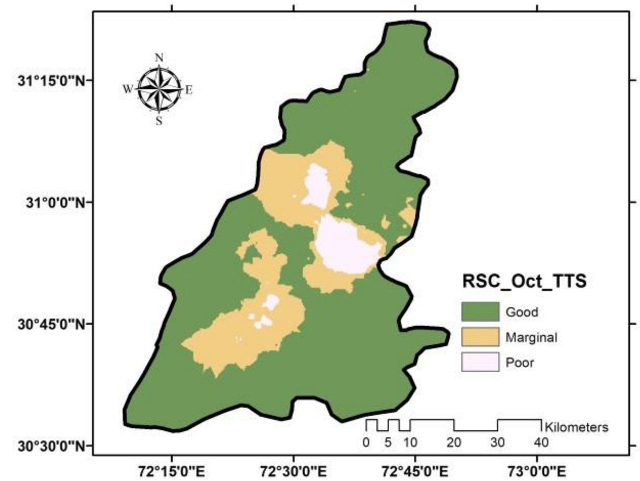
(a) Faisalabad district (Pre-monsoon)



(b) Faisalabad district (Post-monsoon)

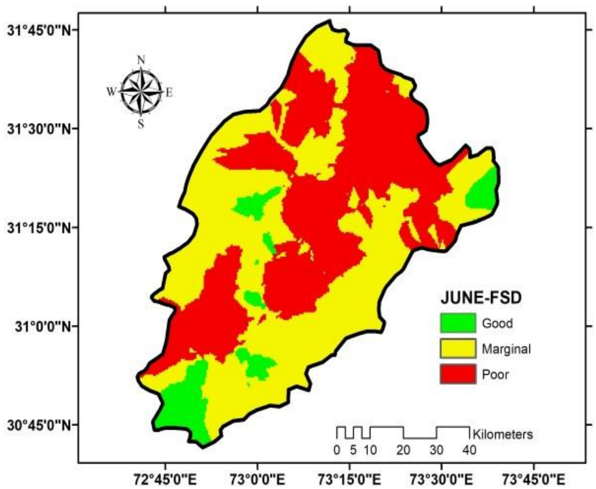


(c) Toba-Tek Singh district (Pre-monsoon)

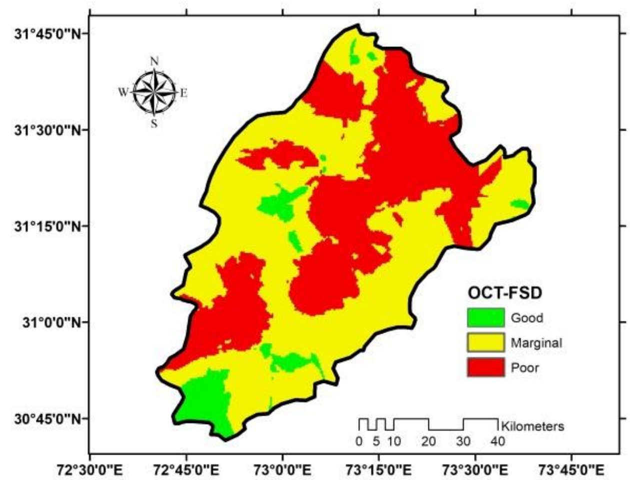


(d) Toba-Tek Singh district (Post-monsoon)

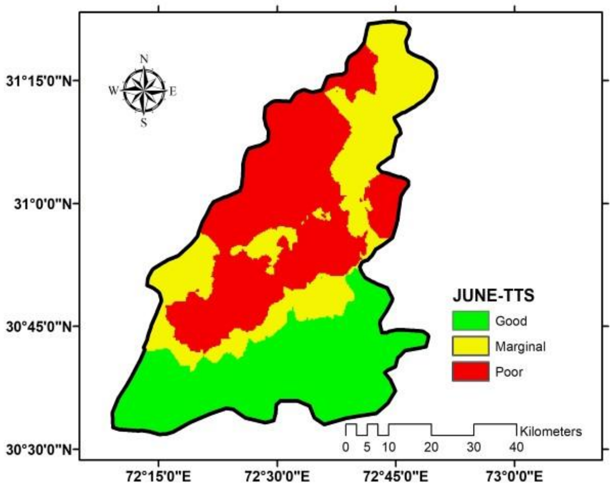
Figure 40: *Spatial variation of residual sodium carbonate (RSC)*



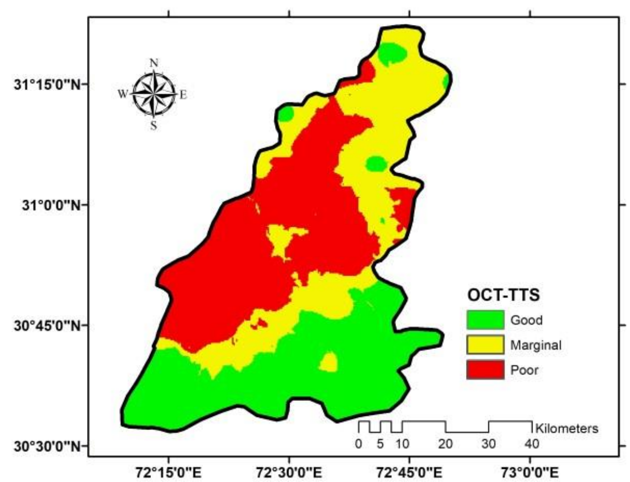
(a) Faisalabad district (Pre-monsoon)



(b) Faisalabad district (Post-monsoon)



(c) Toba-Tek Singh district (Pre-monsoon)



(d) Toba-Tek Singh district (Post-monsoon)

Figure 41: *Spatial variation of overall water quality for irrigation*

p. Improving decision support system in identifying vulnerability rating and prioritizing the best interventions for sustainable watersheds in Pakistan, Nepal, and Sri Lanka

Quantification of watershed vulnerability rating and prioritization of the best watershed management intervention is always a challenge for multidisciplinary experts in developing consensus. Consequently, the lack of a decision support system (DSS) negatively affects the adoption of promising interventions leading to reduced watershed communities' resilience to climate change. Therefore, a DSS has been developed to integrate local multi-disciplinary knowledge in identifying the watershed vulnerability ratings and prioritizing the best site-specific watershed management interventions. The DSS developed was applied to selected watersheds using 25 local experts in Pakistan, Nepal, and Sri Lanka. Results showed that DSS is conveniently applicable and effective in developing consensus among multidisciplinary experts. The DSS recommended that the best interventions for the selected watersheds should primarily reduce the existing accelerated land and water degradation through engineering and biological actions. These actions may include controlling the rainwater run-off losses through appropriate harvesting systems and their subsequent efficient utilization for improving food security, climate change resilience and livelihood of vulnerable watershed communities. The DSS developed can be helpful in developing local adaptation plans and strengthening the policy support for promoting sustainable watersheds in Pakistan, Nepal, and Sri Lanka. However, the system needs further refinement through the incorporation of the design, specifications and costing of the interventions and making the data acquisition and analysis automatic using an online electronic system for quicker results and appropriate resource allocation for stimulated adoption.

q. Climate change and spatio-temporal trend analysis of climate extremes in the homogeneous climatic zones of Pakistan during 1962-2019:

Climate extremes, such as heat waves, droughts, extreme rainfall can lead to harvest failures, flooding and consequently threaten the food security worldwide. Improving our understanding about climate extremes can mitigate the worst impacts of climate change and extremes. The objective of this study is to investigate the changes in climate and climate extremes by considering two time slices (i.e., 1962–1990 and 1991–2019) in all climate zones of Pakistan by utilizing observed data from 54 meteorological stations. Different statistical methods and techniques were applied on observed station data to assess changes in temperature, precipitation and spatio-temporal trends of climatic extremes over Pakistan from 1962 to 2019. The results showed increasing precipitation (DJF) and decreasing maximum and minimum temperatures (JJA) at the meteorological stations located in the Karakoram region during 1962–1990. The decadal analysis, on the other hand, showed a decrease in precipitation during 1991–2019 and an increase in temperature (maximum and minimum) during 2010–2019, which is consistent with the recently observed slight mass loss of glaciers related to the Karakoram Anomaly. These changes are highly significant at 5% level of significance at most of the stations. In case of temperature extremes, summer days (SU25) increased except in zone 4, TX10p (cold days) decreased across the country during 1962–1990, except for zones 1 and 2. TX90p (warm days) increased between 1991–2019, with the exception of zone 5, and decreased during 1962–1990, with the exception of zones 2 and 5. The spatio-temporal trend of consecutive dry days (CDD) indicated a rising tendency from 1991 to 2019, with the exception of zone 4, which showed a decreasing trend. PRCPTOT (annual total wet-day precipitation), R10 (number of heavy precipitation days), R20 (number of very heavy precipitation days), and R25mm (very heavy precipitation days) increased (decreased) considerably in the North Pakistan during 1962–1990 (1991–2019).

r. Co-benefits of air pollution control and climate change mitigation strategies in Pakistan:

In this recent investigation, an insightful examination of prevailing policies in Pakistan has unearthed inadequacies in addressing the nation's escalating air quality crisis. Under the projections of a business-as-usual scenario, the costs associated with air pollution control are expected to soar to a staggering €12 billion or 1.4% of GDP by the year 2050. Despite this substantial financial investment, only modest reductions in SO2, NOx, and PM2.5 emissions are anticipated. In stark contrast, the study introduces the Sustainable Development Scenario, incorporating forward-thinking strategies that promise a paradigm shift. This innovative approach is projected to yield a remarkable 76-88% reduction in emissions, concurrently diminishing control costs by 23%. Additionally, it is anticipated to prevent 24% of total PM 2.5 attributable deaths, making substantial strides towards achieving multiple Sustainable Development Goals. Furthermore, this visionary scenario is poised to curtail greenhouse gas (GHG) emissions by 53% compared to the business-as-usual scenario by the year 2050.

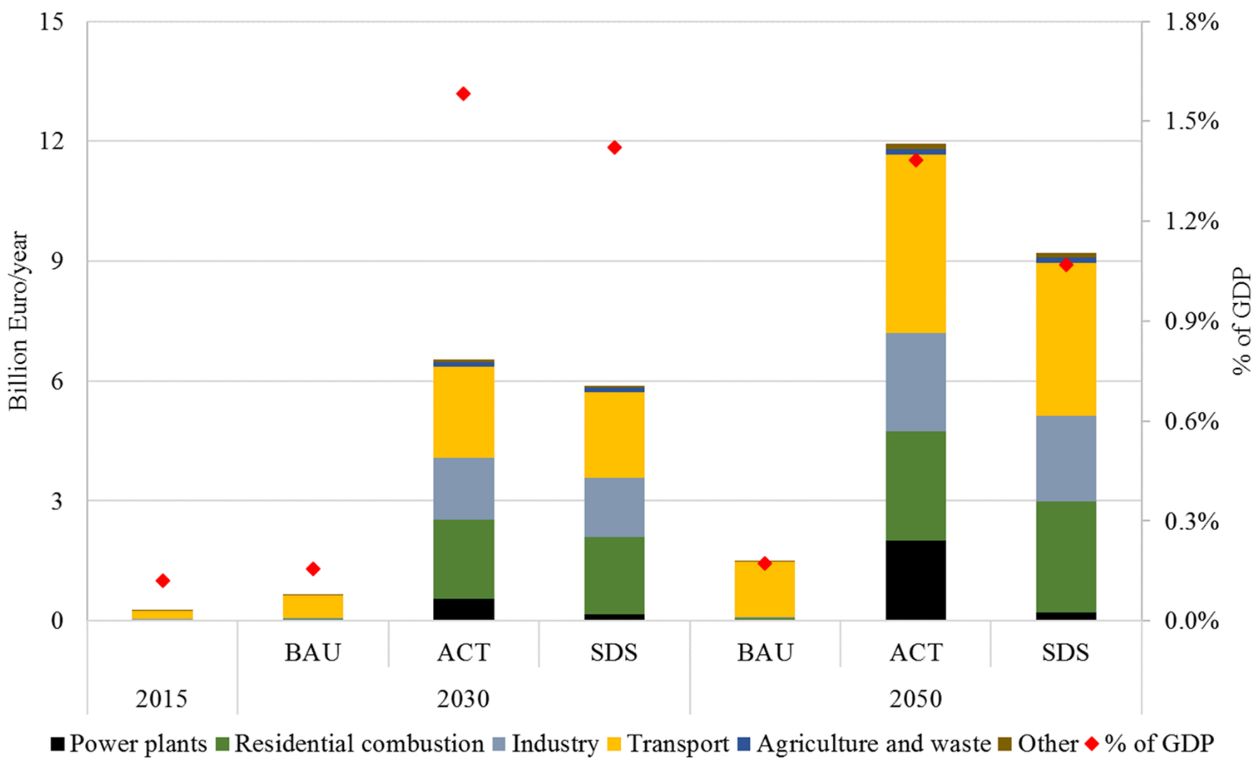


Figure 42: *Air pollutant emission control costs for the various scenarios.*

Foreseeing an annual population growth rate of 2.02% until 2030, followed by a slightly slower rate of 1.22%, Pakistan is poised for a substantial 72% surge in population by 2050, relative to 2015 figures. This demographic surge underscores the urgent need for sustainable development strategies to accommodate and uplift an expanding populace. Simultaneously, the per capita Gross Domestic Product

(GDP) is expected to witness an annual increase of approximately 2%, culminating in a nearly fourfold rise in total GDP by 2050—a testament to Pakistan's economic resilience and potential. To facilitate and sustain this robust growth, the study envisions a profound shift in energy consumption patterns. This envisages an augmentation in coal utilization for power generation, aligning with the overarching objective of ensuring affordable and accessible electricity. This shift is anticipated to propel a threefold surge in primary energy demand from 2015 to 2050. In this dynamic energy landscape, biomass usage is expected to remain relatively stable, serving as a cost-effective energy source for rural households. Conversely, coal consumption is slated to undergo a remarkable 18-fold surge, while renewable energies such as wind, solar, and hydropower are anticipated to witness a six-fold increase. Nuclear energy, with its potential for sustainable power generation, is projected to experience a fivefold rise. Additionally, the utilization of oil and gas is expected to surge by factors of 1.9 and 2.6, respectively.

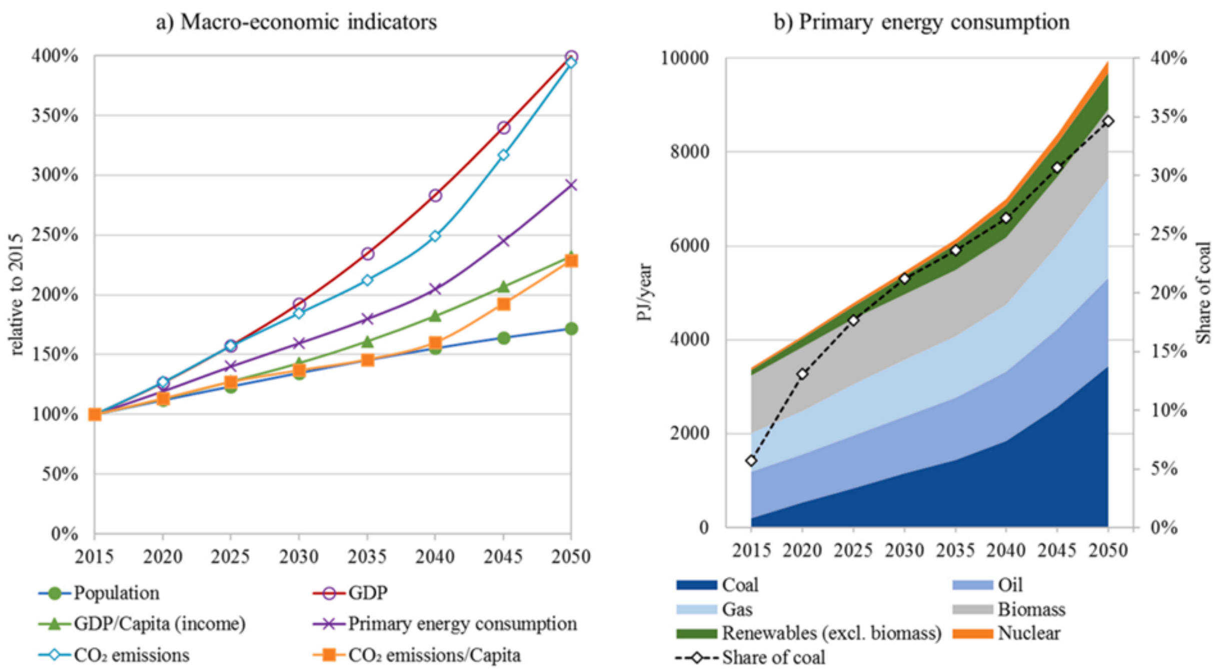


Figure 43: *Assumed baseline trends, of a) macroeconomic indicators relative to the year 2015 and b) primary energy consumption in PJ per year.*

s. Ocean–atmosphere circulation coherences associated with temperature increase in Pakistan:

In recent decades, temperature variations have significantly affected the ecosystem and human livelihood in Pakistan. This study focuses on identification of the associations between regional temperature change and global teleconnections, i.e. North Atlantic Oscillation (NAO), El Niño–Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO) etc. This paper computes the temperature changes in Pakistan and its homogenous climatic regions during 1960–2020. It is found that the temperature in Pakistan has increased significantly at 0.23 ◦ C dec−1 in the last 62 years, which is also higher than the global average increase. This increase is more evident in region in spring at 0.63 and 0.43 ◦ C dec−1 followed by summer and autumn. Temperature changes in Pakistan and its sub-regions are mainly associated with higher mean significant coherences. Overall, temperature changes are significantly influenced by multiple interactions of global teleconnections, and these combinations indicate that the integrated influence of teleconnections can better explain the regional temperature changes. The modulation effect of teleconnection patterns has been observed on the temperature changes over Pakistan.

B. Capacity Building:

Capacity building constitutes a crucial element of GCISC's endeavors, given the continuous evolution of climate science. Given the frequent emergence of novel concepts, tools, and methodologies for impact assessment, it is essential to equip the Center's researchers and other institutions with the latest technologies and skills to ensure high-quality research and effective action.

Throughout 2022-23, scientists at the Center actively participated in numerous national and international training workshops, acquiring expertise in a broad spectrum of areas, including climate science, climate modeling, seasonal forecasting, early warning systems, drought monitoring and assessment, hydrological modeling, crop simulation, water management, water surface runoff analysis, water-food-energy nexus, earth observation systems, space technology, and remote sensing/geographic information systems (RS/GIS) tools. These newly acquired skills are being effectively utilized in both ongoing and planned research endeavors at the Center. Additionally, GCISC's scientists contributed as resource persons in workshops and seminars organized by various entities.

Furthermore, thirty students from prominent institutions such as the National University of Science and Technology (NUST), Islamabad, Bahria University, Islamabad, PMAS-Arid Agriculture University Rawalpindi, University of Agriculture, Faisalabad, and University of Engineering & Technology (UET) Peshawar participated in internships at GCISC for periods ranging from 2 to 3 months. During their tenure, the Center's researchers provided them with orientation lectures on climate science, modeling, and other analytical skills. These interns were supervised by GCISC researchers and assigned various studies by their university teachers and GCISC mentors, enabling them to gain practical experience and contribute to ongoing research initiatives.

C. Mass Awareness / Media Appearance:

The scientists at the Center disseminated numerous articles across prominent national newspapers, covering diverse facets of climate science and its implications for water resources, agriculture, and forestry. Additionally, these experts engaged in interviews and offered insights into pressing matters such as heatwaves, glacier retreat, monsoon disruptions, food insecurity, challenges in wheat production, efficient irrigation practices, and other related concerns linked to climate change.

D. Inputs for parliamentary Business

The GCISC, serving as the research division under the Ministry of Climate Change, regularly offers expert insights on climate change, its effects, and potential mitigation measures to support parliamentary activities. This includes furnishing answers to inquiries from the National Assembly and Senate and actively participating in the discussions of standing committees addressing climate change issues.

E. Administrative Matters

GCISC Act (Amendments) 2023 after completion of procedure by the Federal Government, finally, GCISC Act amendments passed by the Parliament and President of Pakistan. The Act amendments after publishing in the Gazette of Pakistan, received in GCISC vide MoCC & EC Council & Coord Section's U. O. No. 2-12-2015-N.A dated 22.May.2023. GCISC name has been changed and the major amendments are mentioned below:

a) **<u>Change in the Name of Centre</u>: for the words "Global Change" wherever occurring, the words "Global Climate-Change" shall be substituted. However, the acronym of 'GCISC' will remain the same. *Global Climate-Change Impact Studies Centre (GCISC)***

b) <u>Additions of Members in Board of Governors</u>**:**

   i. Chairman HEC
   ii. Secretary, Ministry of Foreign Affairs
   iii. Chairman NDMA
   iv. Two eminent representatives from Civil Society

c) <u>Expansion of Term Technical Experts</u>**:** The term technical expert nominated by respective provincial Governments as members of Board of Governors, shall be expanded to read, "Technical Expert or Scientist".

d) <u>Bifurcation of the Ministries / Divisions</u> Secretaries of the Divisions to which business of the ministries stands allocated.

e) <u>Replacement of the words 'Federal Government' with appropriate authorities</u> in the light of Cabinet Division's instructions the word 'Federal Government' replaced with appropriate authorities.