Global Change Impact Studies Centre (GCISC)

(A Body Corporate established under the GCISC Act 2013)

Performance Report 2019-20

Global Change Impact Studies Centre (GCISC) was first established as a development project in April 2002, with the mandate to undertake research on climate change and its impacts and potential remedies. Subsequently, GCISC's status was formalized through the passage of the GCISC Act 2013 by the Parliament (notified vide Gazette of Pakistan on 26 March 2013 as Act No. XVII of 2013). The Act defines GCISC as a body corporate governed by an independent Board of Governors (BoG), which is chaired by the Federal Minister in-charge of the concerned Ministry dealing with the subject of climate change.

1. Mission Statement

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. Main Functions

Under the GCISC Act, the Centre 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. Ongoing Research Activities

I. Climatology & Environment Section

The key research activities of Climatology & Environment Section revolve around following themes:

- Assessment of past climatic changes;
- Development of future climate projections for Pakistan by employing state-of-the-art high resolution Climate Models;
- Scientific Investigation and Prediction of Climatic Extremes by using modeling as well as statistical techniques;
- Simulation modeling to study monsoon dynamics and its associated impacts;
- Intra seasonal to inter decadal climate predictions;
- Development & Updating of GHG Inventory of Pakistan for Energy & Industrial Processes Sectors;

II. Water Resources & Glaciology Section

- Climate change analysis for the high elevation Karakoram region;
- Analysis of early 21st century changes in Kabul Basin Hydro-glaciology;
- Spatio-temporal assessment of climate change impacts on the UIB-cryosphere and variability of flows based on high resolution climate model data;
- Analysis of climate impact on the frequency and intensity of hydrological extreme events;
- Plausible Adaptation strategies to ensure country's water security under the umbrella of Climate change and Water policies.

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 watesectors.

4. Achievements and Progress of GCISC:

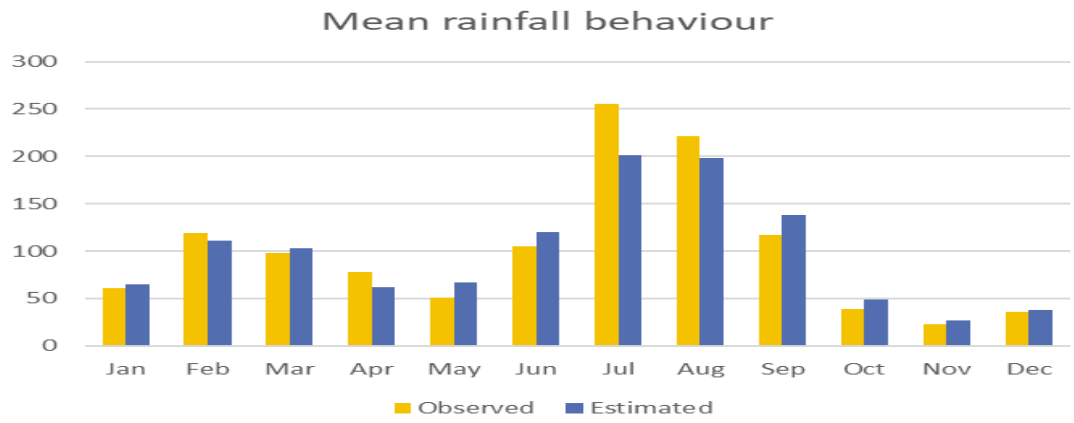
During the year, GCISC made significant contribution to the international scientific literature in the field of climate change and its associated impacts, and provided tangible inputs in a no. of research projects. It also organized a no. of workshops/seminars for information dissemination and awareness. The following is a summary of the accomplishments in 2019-20:

- Publication of key research findings in scientific journals = 24
- Contribution towards technical reports = 6
- Contributions in research projects = 6
- Organization of scientific activities/workshops/seminars for information dissemination and awareness = 4
- Effort on capacity building of GCISC young scientists through academic and specialized trainings and participation in conferences, workshops etc at International level (Nos) = 19
- Effort on capacity building of GCISC young scientists through academic and specialized trainings and participation in conferences, workshops etc at National Level (Nos) = 115
- Provision of training to university students across Pakistan in the field of climate change through summer internship program = 20
- GCISC experts delivered lectures as resource persons and imparted trainings to the researchers of various organizations = 51
- Muhammad Arif Goheer, Principal Scientific Officer/ Head- Agriculture and Coordination elected as Chair in UNFCCC's Consultative Group of Experts(CGE).
- Contributions to Pakistan's 1st Biennial Update Report to be submitted to UNFCCC.
- Two scientists from GCISC are contributing as Lead Author for IPCC 6th Assessment Report.
- One GCISC scientist contributed as "Reviewer" to the GEO report on Cities.

A. Salient Research Findings:

a) Variability and Predictability of Summer Monsoon Rainfall over Pakistan

Devising effective strategies to ensure sustainable development in Pakistan requires that monsoon rainfall be predicted on inter-annual time scale. One study was performed focusing on prediction of inter & intra-annual variability of monsoonal rainfall over Pakistan. Observed and estimated rainfall also feature a close agreement, except for a few extremely wet years Fig 1. It is concluded that intra-annual predictability is dependent on monthly rainfall variability, as high variability in rainfall affects the model's predictability skills. This study is useful for policy making and associated planning purposes, as the intra and inter-annual variability of monsoon rainfall has huge impact on the socio-economic sectors and enhanced predictability of rainfall can help in better planning of water resource management for agricultural sector. Agriculture contributes around one quarter to Pakistan GDP and is tied up with the annual cycle of rainfall variability. Hence, the model proposed in this study provides a step forward in solving the problem of medium to long term rainfall predictability.



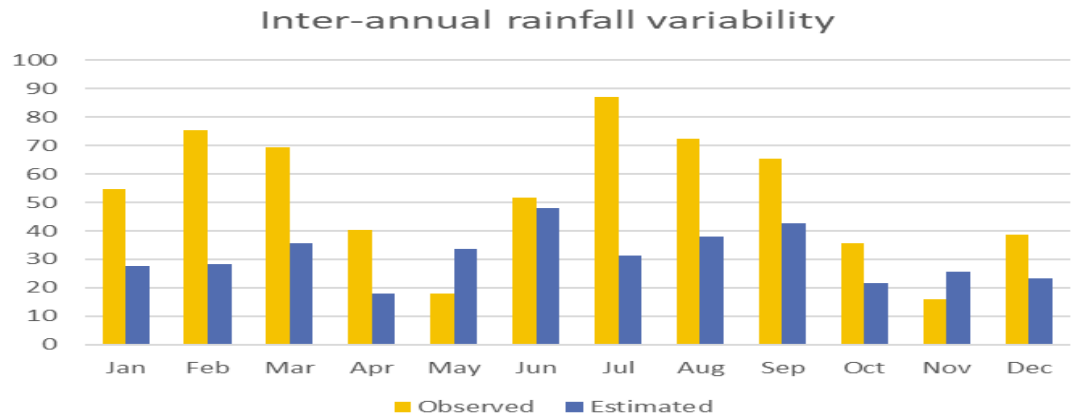


Fig. 1: Mean and inter annual rainfall behavior over monsoon dominated region of Pakistan.

b) Joint Effect of East Asia-Pacific and Eurasian Teleconnections on the Summer Precipitation in North Asia.

The research has been performed on relationship between global teleconnection patterns (e.g., ENSO, IOD and NAO, etc.) on monsoon system. It has been observed that ENSO and the Indian Ocean Dipole (IOD, also known as the Indian Niño) have pronounced global and regional circulation effects that in turn modify the global monsoon system, especially, the Asian and African monsoons. The IOD-ENSO relationship at different timescales is temporally non-uniform, which is important to understand the monsoon phenomenon in order to evaluate its socioeconomic impacts.

C) **Identifying hotspots cities vulnerable to climate change in Pakistan under CMIP5 climate projections.**

The hotspots cities vulnerable to climate change in Pakistan under CMIP5 climate projections have been identified in one study carried out this year. Hotspot cities where extreme climate, that is, the hottest, dryer and wetter, exists were also identified. Hyderabad will likely become the hottest city of Pakistan by end century with the highest average temperature reaching 29.9°C under RCP4.5 and 32.0°C under RCP8.5 followed by Jacobabad, Bahawalnagar, and Bahawalpur. Most of the hottest cities are detected in areas on the southern side of Pakistan. On the other hand, the wettest cities, Murree, Balakot and Muzaffarabad, are located in the monsoon region. Dry conditions are likely to be prevalent in Dalbandin followed by Khanpur and Jacobabad under both RCPs.

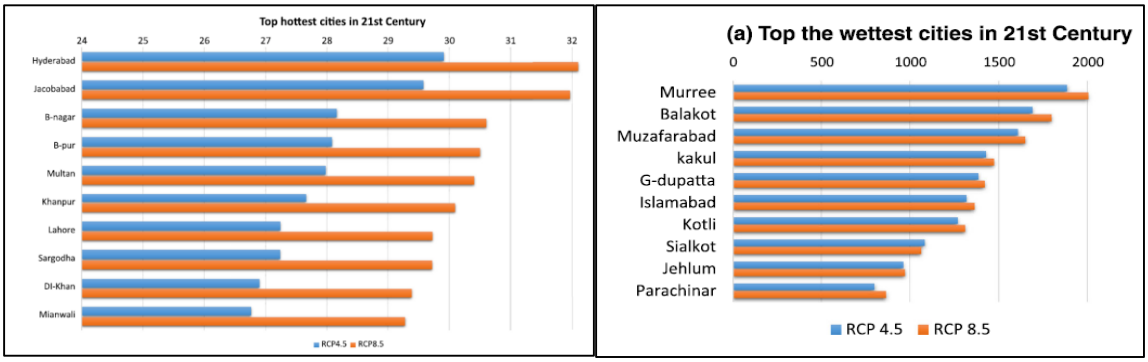


Fig. 2: Top hottest and wettest cities of Pakistan in 21st Century under RCP4.5 and 8.5

d) **Assessment of climate extremes in future projections downscaled by multiple statistical downscaling methods over Pakistan.**

The study assesses climate extremes in future projections downscaled by multiple statistical downscaling methods over Pakistan. In case of temperature, the results indicate a projected increase in frequencies and magnitudes for warm extremes, while it is decreasing for cold

extremes in the 21st century (fig. 2). The corresponding trends of maximum and minimum temperature extremes are greater than the mean temperature trend; where the frequency and magnitude of minimum temperature extremes is higher than maximum temperature extremes over Pakistan particularly over North in last half of the 21st century for both RCPs. In the case of precipitation extremes, most of the sub-regions across Pakistan show a higher increase in total annual precipitation and intense precipitation events. However, numbers of consecutive dry days (CDD) are increasing while consecutive wet days (CWD) are decreasing which can give rise to drought conditions particularly in Sindh.

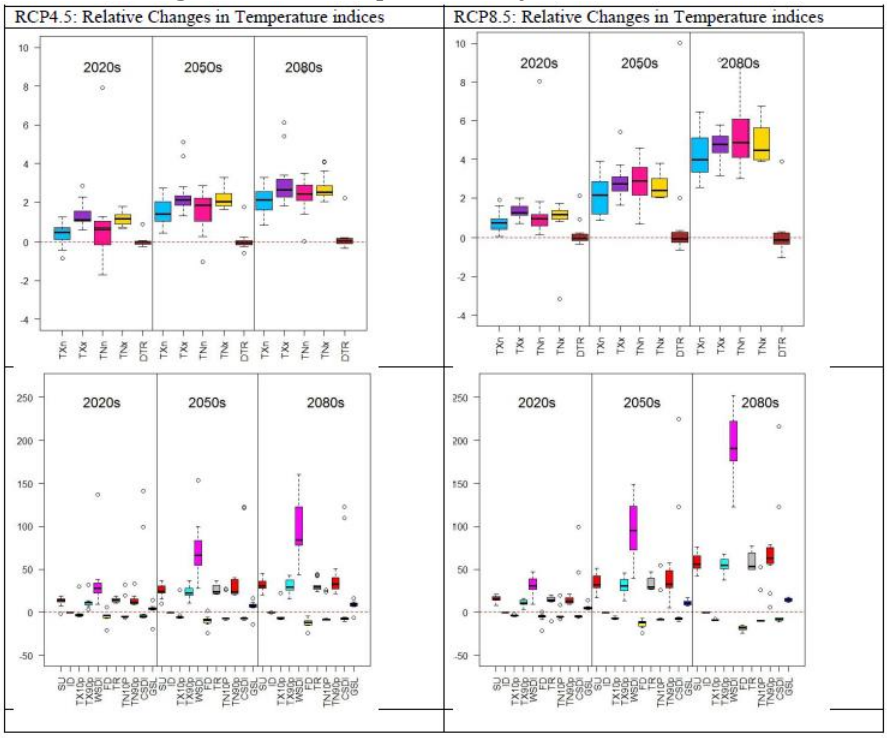


Fig. 3: Relative changes in maximum and minimum temperature-related extreme indices by projections from GCMs for RCP4.5 and RCP8.5 over Pakistan

e) Drought monitoring and prediction in climate vulnerable Pakistan: Integrating hydrologic and meteorological perspectives

In Pakistan, surface water flows predominantly originate from the transboundary Upper Indus sub-catchments of Chenab, Jhelum, Indus and Kabul rivers. Hence, impact of droughts manifested through water deficits in these catchments are strongly felt by downstream users. Use of different drought indicators is limited in Pakistan's operational drought monitoring system. This study aims to explore the relationship between meteorological and hydrological droughts in the Upper Indus catchments of Pakistan using the Standard Precipitation and Evaporation Index (SPEI) and the Standard Streamflow Index (SSI). Since there are no previous studies for the Indus that compare different distributions for SSI computation, we compare five distributions to adequately compute SSI values at catchment

outlets. Our most crucial contribution in this study is analysis of seasonal cross-correlations and lagged cross correlations between SSI and SPEI for the above-mentioned four catchments. The cross-correlation analysis shows strong lagged (with up to 2 lag months) cross-correlations between SPEI and SSI for Chenab, Jhelum and Kabul catchments in early Kharif months. These correlations may be used in operational drought monitoring and forecasting systems, and also in reservoir planning and operations (for Mangla resrvoir in Jhelum) in drought conditions. We strongly believe that the findings of this study can be used in future to collectively explore hydrological and meteorological drought perspectives in Pakistan and to successfully incorporate multiple indicators into operational drought management.

The combined use of the Standard Precipitation Evaporation Index (SPEI) and the Standard Streamflow Index (SSI) was investigated to analyze their capability in monitoring and early detection of droughts in the four key upper catchments of the Indus Basin of Pakistan, i.e., Chenab, Jhelum, Indus and Kabul. Our combined indicator based drought analysis shows that both SPEI and SSI are able to identify historical hydrological droughts and streamflow deficits at the outlets of these catchments. Moreover, a brief analysis of two key drought characteristics, duration and severity, shows that there is a high correlation between drought duration and severity. Moreover, empirical distribution plots of drought duration were also analyzed and visual coherence between SPEI-based and SSI-based drought duration statistics (and respective empirical distributions) was also observed.

Since a key purpose of this study was to analyze coherences between SPEI and SSI, in order to unearth new insights for improvement of existing Drought Early Warning Systems (DEWS), we also analyzed cross-correlations and lagged cross-relations between SPEI and SSI. When seasonality was not considered, weak cross-correlations were observed between SPEI and SSI for all catchments. In order to incorporate seasonality into our analysis, we also computed monthly cross-correlations between SPEI and SSI. Strong cross-correlations (i.e., $r > 0{:}7$) were observed for Chenab, Kabul and Jhelum catchments, especially in late winter and early spring months.

f) Under predicted climate change: Distribution and ecological niche modelling of six native tree species in Gilgit-Baltistan, Pakistan

This study presents the tree species distribution and habitat suitability maps in Gilgit-Baltistan, Pakistan at 1 km spatial resolution. This study is based on bioclimatic and topographical variables and 440 samples of six native trees species: *Abies pindrow*, *Betula utilis, Cedrus deodara, Picea smithiana, Pinus wallichiana,* and *Quercus ilex. Data is* collected through field survey. Exclusively for each tree species, a multicollinearity test was performed among 24 independent or environment variables (21 bioclimatic and 3 topographic). The highly correlated independent variables ($r \geq 0.9$, Pearson correlation coefficient) were eliminated from the independent variables list. In this study, we employed the Maximum Entropy (MaxEnt) model to produce current (2015–2016) as well as RCP4.5 and RCP8.5

climate-change scenarios by 2050 for tree species spatial distribution results. The jackknife test was carried out to depict the importance of variables with the highest gain and it was observed that overall elevation, precipitation, and temperature are the factors with the highest gain. The results of the MaxEnt model for each tree species were satisfactory with ROC (receiver operating characteristic) AUC (area under the curve) curve training and testing values greater than 0.9 and 0.84 respectively. Based on 10-percentile training presence threshold-dependent values, the overall accuracy of True Skill Statistics (TSS) was more than 80%. The maximum area coverage of all tree species existed under "inadmissible natural surroundings (0–0.2 probability)" and least area fell under "exceptionally appropriate environment (0.6–0.7 probability)" to "profoundly reasonable living space (0.7–1.0 probability)". A tree species diversity map prepared through equal weighted average overlay analysis, using all six developed tree species probability outputs. The field observation might possess certain limitations because it was difficult for the field crew to access the areas with rough terrain, long distances, harsh weather conditions, and locations of forest in steep, narrow valleys. Overall, this study contributes to enlarge tree species distribution research datasets applicability in Pakistan and over the Hindu Kush Himalayan (HKH) mountains region. It may also provide interesting insight, which could be used for the habitat corridor suitability modelling of endangered species, and ground intervention to protect and expand tree species distributions.

g) Emission profile of Pakistan's agriculture: past trends and future projections

Reducing greenhouse gas (GHG) emissions is a global concern after Paris Agreement (PA). Identifcation of GHG emission sources and accurate and precise estimation of the corresponding emissions is the frst step to meet reduction targets under PA. Increasing share of agricultural emissions in the global concentration has raised concerns on this sector. Now, reducing agricultural emissions without compromising food security is a real challenge. The present study was aimed to provide the current emission profle of Pakistan's agriculture, historical emission trends and future projections under agricultural growth scenarios according to prescribed guidelines of Intergovernmental Panel on Climate Change (IPCC) for national GHGs inventory development. In this study, GHG emissions were estimated using United Nations Framework Convention on Climate Change (UNFCCC) Non-Annex-I Inventory Software (NAIIS), version 1.3.2 as per prescribed Revised 1996 IPCC Guidelines. In these emission estimations, tier-1 approach (which employs default emission factors) was used in accordance with national circumstances and data availability in the country. The emissions baseline was projected for 2030 under business as usual (BAU), food security (FS) and enhanced consumption pattern (ECP) scenarios. Agriculture sector emitted 174.6 million tons (Mt) of carbon dioxide equivalent (CO2-equivalent) emissions, of which 89.8 Mt is methane (CH4) and 83.7 Mt is nitrous oxide (N2O). Carbon monoxide (CO) emissions were found to be 1.07 Mt of CO2-equivalent. Emission from agricultural soils constituted 45.5% of

the total agricultural emissions followed by 45.1% from enteric fermentation and 6.5% from livestock manure management. The rest of 1.7% of the emissions were from rice cultivation followed by 1.1% from burning of crop residue.

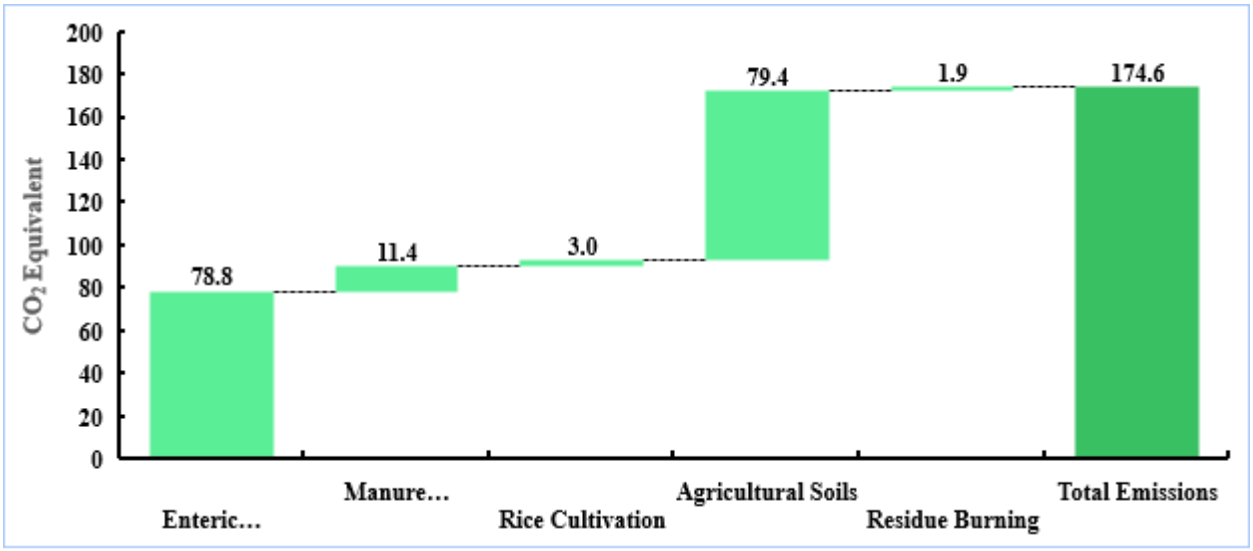


Figure 4: Sub-sectoral emissions from agriculture sector (Mt of CO_2-equivalent)

Historical emission trends showed that the agricultural emissions grew from 71.6 to 174.6 Mt of CO2-equivalent from 1994 to 2015, a 143.8% increase over the period of 21 years. Emissions baseline projections were found to be 271.9, 314.3 and 362.9 Mt tons of CO2-equivalent under BAU, FS and ECP scenarios, respectively (Fig.5) .

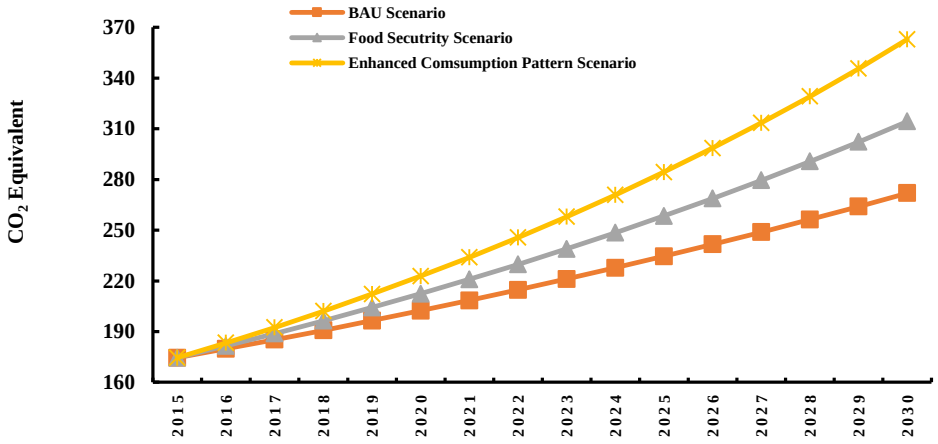


Figure 5: Overall agricultural emissions under BAU, FS and ECP Scenarios

h) Mapping and Monitoring of Glacier Lake Outburst Flood (GLOF) Using Geospatial Modeling Approach of Darkut Valley, Pakistan

Climate change and human activities have resulted in the receding of glaciers throughout the world including Pakistan. Glacier lake outburst floods (GLOFs) are amongst the most common climate-change-induced hazards in northern Pakistan. In the present study, GLOF mapping and modelling was carried out using remote sensing and geographical information system techniques coupled with ground-truthing. The study aimed to assess and analyze the dynamics of glacial lakes and to develop a model of possible GLOFs using RS and GIS technology coupled with HEC-RAS and field assessments and surveys. The objectives of the study were (a) to analyze temporal changes in the glacial lake using time series (1991–2015) RS data (Landsat) and (b) to develop GLOF scenarios and identify downstream inundation zones. The depth of the lake was estimated to be 81 m and the volume of the lake was calculated using a digital terrain model and extracted as 9.79 × 106 m^3. The glacial lake extent has increased from 0.045 to 0.154 km^2 in the last two decades. Two GLOF scenarios (peak and extreme flood) were developed on an existing volume of water in the study. There are 14 households exposed to medium flood and 10 to low flood risk while one helipad and one school are also in the low flood zone in the first scenario (i.e. peak flood) based on 87.84 m^3. s^{-1} of water (Table Below). The second scenario (i.e. extreme flood) was executed on 3,128 m^3. s^{-1} of water, in which 14 households are at high flood risk, eight at medium and 35 in a low flood zone, as well as one school, a helipad and a community stockpile which are exposed to low flood (Table Below). The outcomes of the study will help in the development of risk management plans, preparedness strategies and risk reduction from GLOF hazard.

Table: Elements at Risk of Peak (P) and Extreme (E) GLOF

Settlement	Facilities Name	High (P)	High (E)	Medium (E)	Medium (E)	Low (P)	Low (E)
Darkut	Helipad	0	0	0	0	1	1
	House	0	14	14	8	10	35
	School	0	0	0	0	1	1
	Stockpile	**0**	0	0	0	0	1
Total		**0**	**14**	**14**	**8**	**12**	**38**

I) Monitoring Agricultural Drought Using Geospatial Techniques; A Case Study of Thal Region of Punjab, Pakistan

Thal region of Punjab experiences often dry weather conditions with extreme variability in rainfall at spatiotemporal scale during Rabi cropping season. The current study assesses the impacts of agriculture drought on wheat crop for 2000-15. The main objectives of the study were: (i) To develop drought risk map based on meteorological (SPI) and vegetation indices for selected period (dry and wet period over Thal region); (ii) To develop relationship between meteorological and vegetation indices to shows the impacts of meteorological variable (SPI and rainfall) on wheat crop yield in Thal region for selected period and (iii) to

develop a combined drought risk map. The results indicate that the wheat Rabi cropping seasons of the years 2000–02 experienced extreme agricultural drought, with a spatial difference in severity level caused low and poor yield, while the years 2011 and 2014 were almost normal among all the years leaving varied impacts on wheat yield. The combined agricultural risk map (Figure6) generated by integrating the agricultural and meteorological droughts severity maps indicate that total Thal area can be classified into slight, moderate and no drought covering 28.12%, 12.76%, and 59.12% respectively of the total area.

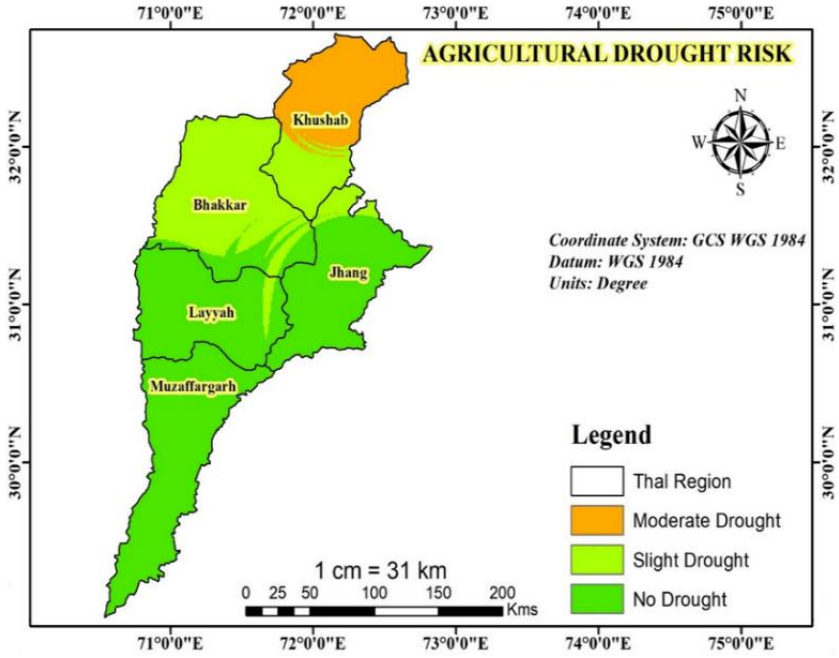


Figure 6: Overall Agricultural Drought Map

j) Growth and Yield Response of Turnip to Different Deficit Irrigation Levels and Sowing Dates under the Agro-Ecologocial Conditions of Khyber Pakhtuankhwa

Due to climate change, irrigated agriculture take place under water-scarce conditions, at present and more so in the future. Inadequate water supply for irrigation will be the usual rather than the exception, and irrigation management will shift from emphasizing production per unit area towards maximizing the production per unit of water consumed. This field experiment was carried out to assess growth and yield responses of turnip to different deficit irrigation levels and sowing dates at Research Farm situated at The University of Agriculture, Peshawar. The purpose of the study was to determine the effect of different irrigation levels and sowing dates on the growth and yield parameters of turnip. The study reported that delay in sowing have significantly reduced the turnip yields. Similarly, even a 10% reduction in full irrigation have significant effect on the productivity. The study necessaies the need of early sowing in the month of November with full irrigation levels.

k) Modeling and Monitoring Wheat Crop Yield Using Geospatial Techniques: A Case Study of Potohar Region, Pakistan

In countries like Pakistan, whose economy greatly depends on agriculture and predominantly crop production, the estimation of crop yield before harvesting is very important. The objective of the study is to evaluate the possibility of MODIS derived vegetation indices using GIS & RS to estimate pre-harvest wheat yield in the Potohar region, Pakistan. Results interpret that overall the percentage average difference between the actual and predicted yield was within -1.986%. The average % difference between actual yield and predicated yield for Rawalpindi, Jhelum, Chakwal, and Attock are -0.46, -4627, -0.741 and -2.116 respectively. Average RMSE and MAE values ranged from 34.28 to 76.50 kg/ha and 108.09 to 129.99 kg/ha respectively. The MBE vale ranged from 7.20 to 62.80 kg/ha. The results concluded that accurate wheat yield predication can be made almost two months before harvesting using geospatial techniques along with the statistical modeling approach.

l) GIS Based Spatio-temporal assessment of forest cover change and carbon sequestration

Forest plays a significant role in the ecosystem's balance and climate of a country. During the last decade, District Abbottabad of Pakistan has gone through extensive land-use changes due to accelerated development, urbanization and agriculture. This study highlights the forest cover change due to environmental factors using satellite imageries (Landsat, Sentinel), and classifying them via supervised classification and finally applying the post-classification change detection technique in GIS over the past three decades (1986-2019). The result shows an overall significant 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% (Figure 7). This study also assists in assessment of carbon stock incline from the forest cover over the period of the study mentioned above. Carbon sequestration between 1986 – 2019 was increased by 17.19%.

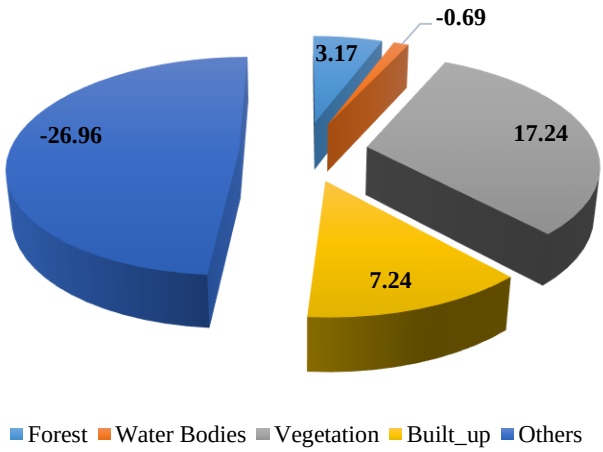


Figure 7: LULC net % change (1986 – 2019)

n) Pakistan's First Biennial Update Report (BUR1)

Ministry of Climate Change is implementing Project on 'Preparation of Pakistan First Biennial Update Report (BUR1) under United Nations Framework Convention on Climate Change (UNFCCC), with financial support from Global Environment Facility (GEF) through United Nations Environment.

GCISC has been assigned to contribute to the chapters on Greenhouse Gas Inventory, National Circumstances, Information on domestic Measurement, Reporting & Verification and Information of Technical support needs and provided and Gender and Climate Change.

The work is in progress. Muhammad Arif Goheer, Head-Agriculture & Coordination is coordinating this effort with MoCC on behalf of GCISC.

o) Preparation of National GHG-Inventory (2017-18)

Last Greenhouse Gas Inventory (2014-15) was prepared by GCISC in 2017. New inventory for the year 2017-18 has been planned to be prepared as per part of BUR1 and Revised NDCs.

The work on the Inventory has been started and the data on the following sectors has been collected from various Government institutions:

- Energy
- Transport
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry & Other Land Use (AFOLU)

- Waste

The inventory is being prepared using first time the IPCC 2006 Guidelines and standardized QA/QC procedures.

p) Revision of Nationally Determined Contributions (NDC)

Pakistan submitted its 1st NDC in November 2016 which commits to reduce up to 20% of its 2030 projected GHG emissions, subject to the availability of international support.

Under the PA, countries revise their NDCs every five years to cut GHG emissions to limit Earth's temperature rise and implement solutions to adapt to the effects of climate change.

The updating of NDCs presents countries with significant opportunities to align their climate and development agendas to promote sustainable growth, but also presents challenges in reinventing policies and operations and mobilizing enough investment.

In August 2019, Pakistan submitted CAEP application to NDCP for NDC revision desiring support for a no. of activities including;

- Greenhouse Gas Inventory and its projections, capacitating for consistent and credible reporting with updated emission factors;
- Mapping of Pakistan's vulnerabilities in key sectors of economy and strengthening resilience;
- Assessment of adaptation needs, mitigation potentials
- Economic valuation of cc impacts and development of marginal abatement cost curves,
- Analysis and estimation for emission from refrigerant gases,
- Carbon market mechanism, etc

Ministry of Climate Change has declared GCISC as the Secretariat for the NDC Revision and Muhammad Arif Goheer, Head-Agriculture & Coordination will serve as the Coordinator of the Secretariat. The Secretariat will liaise with other organizations and development partners to collect the information required for the revised version of NDC in the light of activities pitched in CAEP application.

q) Collaborative Climate Change Related Research Studies

GCISC is pursuing collaborative climate change related studies with various Universities and Research institutions on the aspects of (a) future scenarios in Pakistan for different degrees of global warming (i.e., 1.5 degrees, 2 degrees, 3 degrees, etc.); (b) Action on Pakistan's INDC's consistent with national goals and objectives; (c) disaster management under the impact of climate change; (d) climate finance; and (e) from climate policy to implementation. In the context above, forty studies (40) with nineteen (19) institutes have been carried out.

B. Capacity Building:

Capacity building is an important component of GCISC's activities. Climate change still is an evolving science. The new concepts, tools and methodologies for impact assessment emerge quite frequently. Capacitate the Centre's researchers as well as other institutions with upcoming technologies and skills is imperative for quality research and action.

During 2019-20, the Centre's scientists participated in a number of national/ international training workshops and acquired new skills ranging from climate science, climate modeling, seasonal forecasting, early warning systems, drought monitoring and assessments, hydrological, crop simulation and water management modeling, water surface runoff analysis, water-food-energy nexus, to earth observation systems, space technology and RS/GIS tools. In some the workshops GCISC's scientists also contributed as resources persons. The acquired skills are being used for the ongoing and planned research activities at the Centre.

Given the complex and evolving nature of the climate change subject, the international mentorship of the Centre's scientists is very much essential. To fill this gap, the Centre has declared some world renowned scientists, majority of them are Pakistani expatriates, as Senior Fellows. GCISC's researchers are engaged with in various research studies.

Twenty (20) students from 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 attended GCISC as Interns for a period of 2-3 months. The Centre's researchers provided them orientation lectures on climate science, modeling and other analytical skills and supervised them for various studies assigned to them by their university teachers.

The Centre is also organizing a series of lectures called as 'Friday Seminar' in which GCISC's own as well as researchers from other institutions deliver lectures on the latest ongoing research and present studies on the aspects of climate sciences, sectoral impacts and response strategies. During 2019-20, Eighteen(18) seminars were organized at GCISC.

C. Mass Awareness / Media Appearance:

The Centre's scientists published several news articles in the leading national newspapers on the various aspects of climate science and its associated impacts on water, agriculture, and forestry. In a Live Radio Programme "Raabta", GCISC's scientist discussed the issues of climate vulnerabilities to agriculture sector and how the ordinary farmers can adapt to

minimize the risks and increase resilience. Scientists also provided interviews and responses on the ongoing issues of glacier melting, locust havoc, wheat crisis, effective irrigation water management and other allied issues pertaining to climate change.

D. Inputs for parliamentary Business

GCISC, being the research arm of the Ministry of Climate Change is frequently engaged for providing technical inputs on climate change, impacts and response strategies for parliamentary business. In this regard GCISC provide answers to National Assembly and Senate questions and also contributes to the proceedings of the standing committees on the concerns of climate change. During 2019-20, GCISC provided responses to five (5) NA/Senate starred questions and provided inputs (presentations/ briefs) for NA Standing Committee on Climate Change on the aspects of Climate Change, Agriculture and food security. GCISC also provided technical inputs to various reports and submitted responses to various queries reading Joint and Inter Ministerial coordination meetings and memorandums etc.