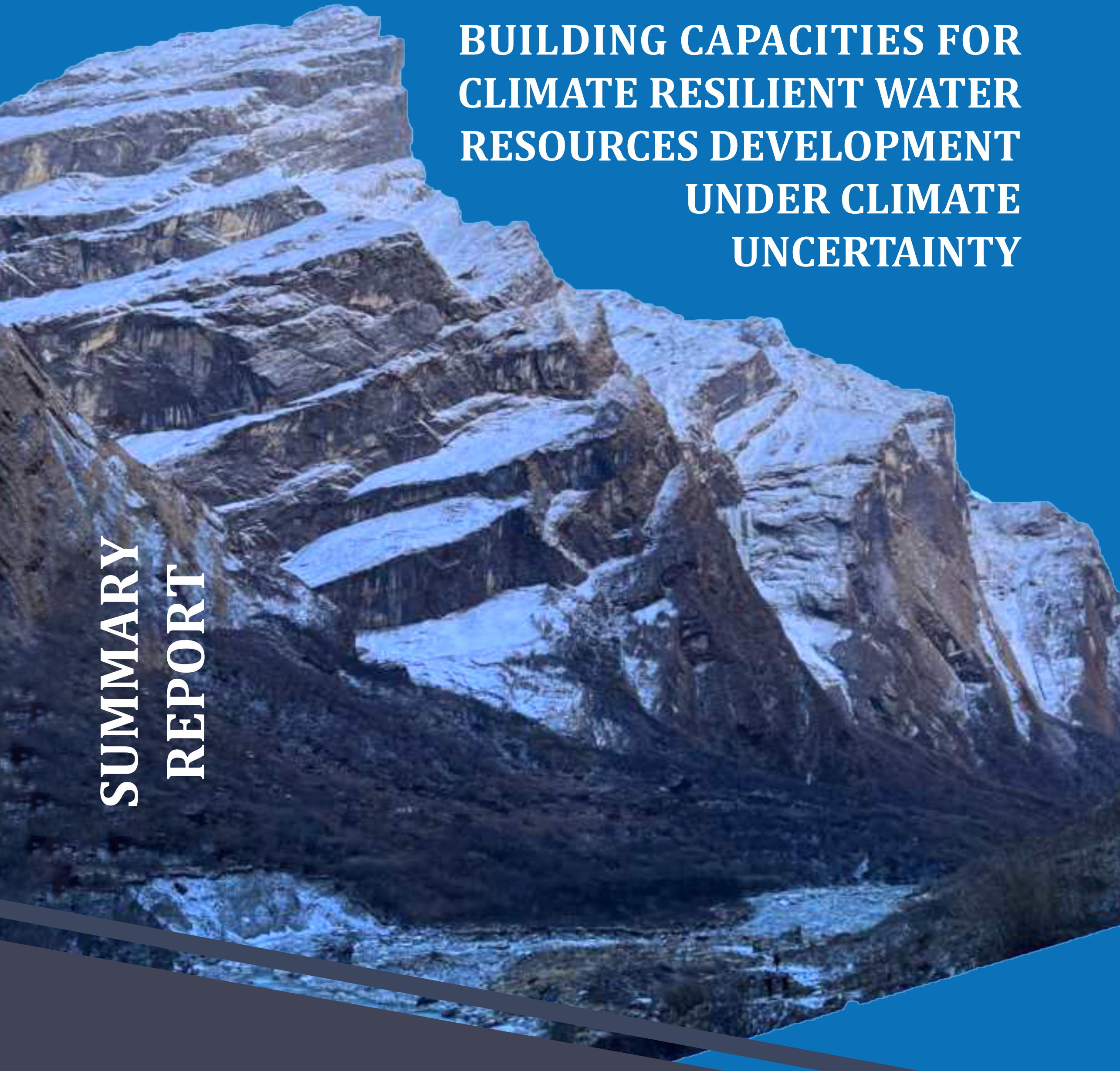
BUILDING CAPACITIES FOR CLIMATE RESILIENT WATER RESOURCES DEVELOPMENT UNDER CLIMATE UNCERTAINTY



SUMMARY REPORT

NEPAL DEVELOPMENT RESEARCH INSTITUTE (NDRI)
TRIBHUVAN UNIVERSITY
ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH (APN)

October 2024

NDRI नेपाल विकास अनुसन्धान प्रतिष्ठान Nepal Development Research Institute

APN ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

Cover Photo Location: Annapurna Base Camp Trek Route

Cover Photo Credit: Ms. Sophiya Shrestha, NDRI

Project Name: Building capacities for climate resilient water resources development under climate uncertainty (CBA2022-04SY-Shrestha)

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Location: Mt Grivola, Italy

A. Brief Project Overview

The project – '**Building capacities for climate resilient water resources development under climate uncertainty**' was conducted to bridge the challenges in adapting to climate change in water resources and developing resilience in developing countries include the inadequacy of systematic climate risk assessment (CRA) skills and knowledge for practical implementation. The project was carried out by Nepal Development Research Institute (NDRI) and Tribhuvan University (Department of Meteorology, Tri-Chandra Multiple Campus), Nepal. The project was supported by Asia-Pacific Network for Global Change Research (APN) under the reference number - CBA2022-04SY-Shrestha.

Major objective of the project was to facilitate climate risk assessment (CRA) for water resources practitioners. Specific objectives were:

(a) To facilitate CRA through upgrade of existing WECCS-Gen tool with climate downscaling capabilities;

(b) To build capacity of WR practitioners (national and international) on conducting CRA, using upgraded state-of-the-art tool, into their professional practices;

(c) To promote CRA into existing practices at organisational and national level

This project facilitated climate risk assessment process by upgrading the existing "WEather generator and Climate Change Scenario Generator" (termed as WECCS-Gen). The tool was initially developed by NDRI and this project allowed to upgrade this tool with climate downscaling capabilities commonly known as Bias Correction and Spatial Disaggregation. This tool provides a platform for the user to perform pre-processing of the climate data like generation of climate scenarios, downscaling of the global circulation models results as per spatial scale required by the user which is a necessary step for climate risk assessment.

In addition, the workshop- 'Capacity Building Workshop on Climate Risk Assessment for Water Resources Management' was conducted on 5-8th February, 2024 in Lalitpur, Nepal in on order to build capacity of water resources practitioners at national and international level. Participants were provided a comprehensive detail on methodology and tools for climate risk assessment followed by the on-session practice exercises. Besides, this project also provided support for Fulbright Specialist Program - Science, Technology, Engineering, and Mathematics (STEM) Education and Research workshop.

The workshop aimed at enhancing the skills and knowledge of the STEM students providing insights into ways to perform world-class research. In order to promote and build awareness about the climate risk assessment (CRA) to the decision makers in water resources sector, the dissemination workshop at national level was organised in 15th March 2024.

The project also emphasized on building the capacity of the young researchers hence thereby supporting the research assistants and young enthusiastic water research practitioners /students. The latter group (total 4 in number) was provided with the research grant in order to develop case study with regards to climate risk assessment.

B. Experiences of NDRI in Climate Risk Assessment

One of the key working themes of Nepal Development Research Institute (NDRI) is climate and water. NDRI has always prioritized researches and projects that focuses on climate change impacts, adaptation and resilience. NDRI has activities providing the research outputs with an aim to aid the policy process of the country thorough achieving the climate resiliency. Since, persistent efforts of NDRI towards the policy process of the country for two decades has also been recognized by the Policy Research Institute of the Government of Nepal in the form of 'Neeti Sammaan 2081' in September 2024. Brief experiences of NDRI towards the climate risk assessment, adaptation and resiliency are discussed in this section.

In 2011, NDRI conducted the community-based flood damage assessment for historical flood and future floods in the lower West Rapti Basin in Nepal under the project- "Assessment of Flood and Inundations under the Effect of Climate Change in Lower West Rapti River Basin in Nepal". In the project, the integration of the modelling works and socio-economic approach to estimate the damages under future projects under the impact of climate change was achieved. Estimates for household damages, agricultural damages and business damages due to flooding were done under 2007-flood event and climate change scenario utilizing high-resolution MRI-AGCM outputs. Its details can be found in Perera et al (2015) (https://doi.org/10.1007/s11069-014-1339-5). Damage assessment for floods under climate scenarios was core of the project.

Similarly, NDRI carried out the assessment of flood risks in the context of climate change incorporating socio-economic vulnerability in the Koshi River

Basin in the eastern Nepal in 2012-2013 under the project – "Disaster risk reduction and climate change adaptation in Koshi River Basin, Nepal". Besides, the project was also focused on contributing to policy formulation process and awareness building and training of new generation of researchers on advanced technology and tools. Major research findings and its contribution can be found in Devkota and Gyawali (2015) (https://doi.org/10.1016/j.ejrh.2015.06.023) and Seidler et al (2018) (https://doi.org/10.1016/j.ijdrr.2018.04.023).

One of the key research projects by NDRI was on the application of the Climate Risk Assessment in the hydroelectricity sector in Nepal because (a) it is one of the first projects that carried out the comprehensive climate risk assessment of the whole hydropower sector of Nepal and (b) the importance of the hydro-energy in terms of National interest for sustainable and renewable energy. Under the project – 'Adaptation to Climate Change in the Hydroelectricity Sector in Nepal' in 2015/2016 (NDRI et al., 2016), the study focused on the evidence on vulnerability of the hydroelectricity-sector to climate change based on the climate risk assessment. Bottom-up climate risk assessment was adopted for the study (**Figure 1**). In the process, the first version of the Weather Generator and Climate Change Scenario Generator tool (WECCS-Gen tool) was also developed in MATLAB. Project also featured the integrated model development and identification of viable adaptation options that enhance resilience for the hydropower sector in Nepal. It also addressed the challenges of mainstreaming adaptation in the sector and worked on to build capacity and help enable adaptation action amongst policy makers and the private sector. Key findings of the research include – (a) the greatest impacts of climate change are likely to be increased climate-induced hazards, such as sediment load, extreme floods and geo-hazard; (b) adaptation pathways can help address the challenges associated with adapting the hydro sector (c) adaptation needs to be designed to the specific context, hydro plant and vulnerability; (d) focus on low-regret options and (e) important role of the institutional context for mainstreaming climate change into future sector development plans and policies. The researches of the work were shared in different forums notably on the UNESCO-forum on "Adaptation in an age of uncertainty: tools for climate-resilient water management approaches" (https://www.unesco.org/en/articles/adaptation-age-uncertainty-tools-climate-resilient-water-management-approaches).

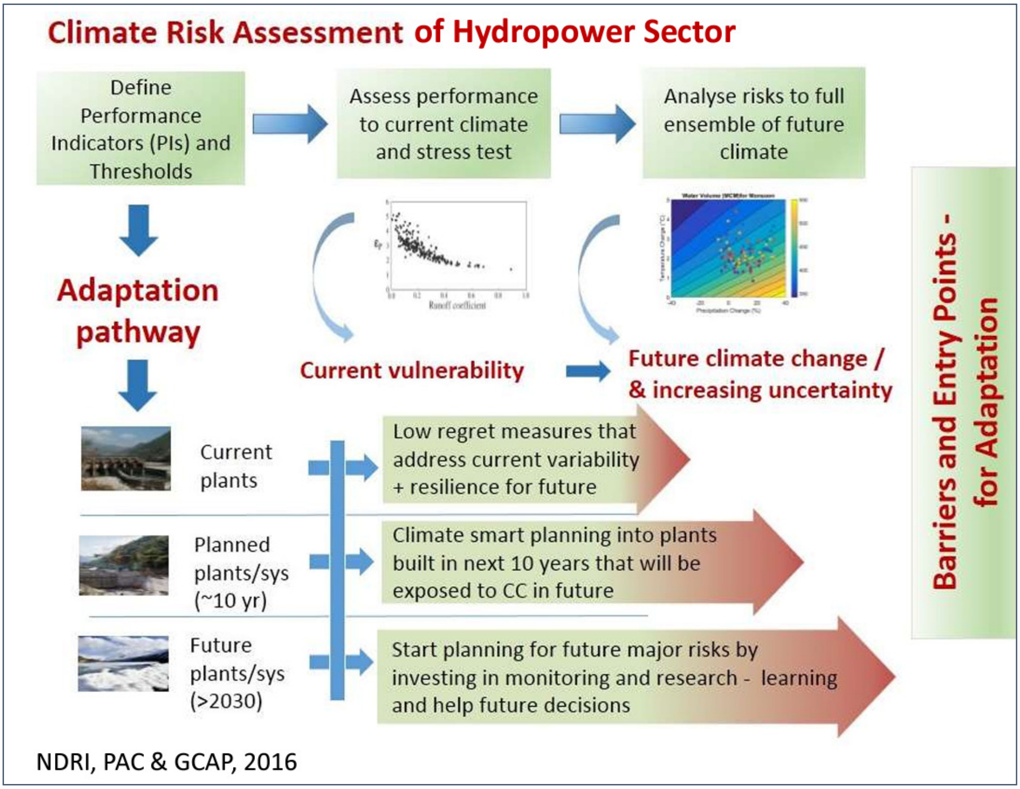


Figure 1: Climate risk assessment and adaptation pathways for hydro-electricity sector in Nepal

Developing the culture of the Climate Risk Assessment in Nepal has been the focus of NDRI and its activities. And to promote it, it needs tools and awareness. In this context, NDRI decided to develop the tools needed to conduct the CRA. So, as part of NDRI inhouse research project, the new version of the desktop application on Weather Generator for Climate Risk Assessment was developed in 2019, which became the background for the improving the tool under the support of APN. The current project – 'Building capacities for climate-resilient water resources development under climate uncertainty' which is supported by the Asia-Pacific Network builds on this background by upgrading this user-friendly tool to facilitate Climate Risk Assessment (CRA) process in more comprehensive way.

In further research related to climate risk assessment, NDRI participated as a consortium of GCRF's funded "Tomorrow's Cities" project for "multi-hazard risk-informed planning and decision-making - Climate Change Analysis and

Impacts on Flood Hazards/Risks in Kathmandu Valley for flood risk" in 2021. The aim was to support evidence for climate resilient city and decision process. The study carried out the flood hazard assessment for the future climate scenarios based on the National Adaptation Plan for Nepal; and simulated the flood hazard in the Kathmandu Valley. The inundation pattern due to floods simulated for rainfall of 100-year return period for future period in the study was similar to inundation for the observed rainfall records of late September 2024. This highlights the importance of the research work for the climate resilient development. Refer to the Shrestha et al (2023)and Kathmandu city is no exception. Rainfall events are projected to become more intense and frequent in a warm and wet future, and they pose a major challenge to the sustainable development of Kathmandu city. This paper analyses historical extreme rainfall patterns across the city and uses these as the basis for future projections in combination with a range of General Circulation Models. Future projections of extreme rainfall are then fed into the numerical flood model HAIL-CAESAR (Lisflood for more details (https://doi.org/10.1016/j.ijdrr.2023.103997). The application of the framework for the flood hazard assessment in climate change has also been implemented in the Rapti, Nablus, Cox's Bazaar and Chattogram cities project under the project.

NDRI has further applied the climate risk assessment for the project – 'Climate resilient guideline for hydropower and its application in the Narayani Basin' (NDRI, 2024). Aim of the project was to study the hazards under different climate change scenarios on hydropower development; vulnerability and risk assessment of the above-mentioned hazards on hydropower development in context of climate change, analyze impact of climate change on runoff with respect to hydropower production; and develop Guidelines for Climate Resilient Hydropower in Nepal with supplementary guidance and recommendations on equitable economic benefits and trade-offs to secure sustainable hydropower development. Recommendations to the current hydropower development guidance were made in the research and the document is under-process of review for publication.

Recognizing the importance of climate change adaptation measures, Nepal has developed a National Adaptation Programme of Action (NAPA), and it has made a promising start in developing Local Adaptation Plan of Action (LAPA) along with other disaster management and/or climate resilience policies at local level to implement the national adaptation priorities. However, the mainstreaming of Ecosystem based Adaptation (EbA) measures in those policies are limited despite of notable success of EbA measures in Nepal. In addition, the role of women in climate change adaptation is often restricted to participation in events while their leadership role is suppressed. Hence, NDRI has recently focused on “softer” approach to climate change adaptation through EbA. In the project, ‘Mitigating flood risks through women's leadership in EbA interventions’, funded by Global EbA Fund/IUCN, the focus is on integration of gender-responsive EbA measures into disaster management and/or climate change policies for flood risk management. An accompanying Gender Equality, Disability, and Social Inclusion (GEDSI) action plan for the watershed will be co-created to promote the role of women in EbA design, construction, monitoring, and maintenance. The project will also facilitate capacity building of local government and communities to adopt EbA approaches to mitigate flood risks at the watershed level.

Economics of climate change is key to successful climate change initiatives. NDRI is currently carrying out the ECONOGENESIS research project along with international partners with an aim to provide new analysis of the economics of climate change, the costs of adaptation, and bankable adaptation finance projects, including new knowledge on gender, equality and social inclusion (GESI) effects.

In summary, NDRI has dedicated itself through continued efforts of producing the evidence-based outputs and aiding the policy process of Nepal for climate adaptation and resiliency in different sectors.

C. Brief Description of the Weather Generator and Climate Change Scenario Generator for Climate Risk Assessment (WECCS-Gen) Tool

Weather Generator and Climate Change Scenario Generator for Climate Risk Assessment (WECCS-Gen) Tool is a tool to facilitate Climate Risk Assessment (CRA) process. Screenshot of the tool is shown in **Figure 2**. This tool allows for

(a) Generation of multiple climate realizations using k-nearest neighbour (k-NN) based multisite multivariate weather generator. In this approach, users can change parameters like mean, standard deviation of the simulated time series (of historical observation) and create user-defined climate realization. This can be used for the climate stress test in climate risk assessment and serves as a part of the bottom-up method.

(b) Bias correction and Spatial Disaggregation (BCSD) for statistical downscaling of future climate projections. In this approach, users can bias-correct and downscale the Global Circulation Model (GCM) based on the observation data. This is normally used for the climate impact studies where the driver is GCM as main source of climate data. The method is based research by Wood et al (2004) and Thrasher et al (2022); and this serves for the top-down approach.

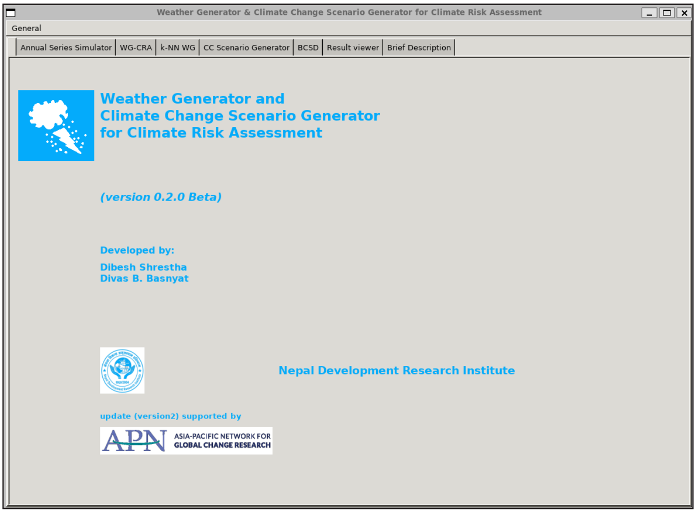


Figure 2: Landing screenshot of WECCS-Gen Tool

Why do we need this tool?

At present and in future, climate resiliency in water resources infrastructures is largely needed for sustainable development by addressing uncertainties and future climate risks. This requires a thorough climate risk assessment of water resources projects. And there are two basic frameworks for conducting climate risk assessment.

The first one, a bottom-up, context-based CRA can serve as a decision support tool for WR development under uncertainty (Ray and Brown, 2015). Uncertainties of GCM projections and thus conclusions derived from them lack systematic risk analysis (Ray et al., 2018). Therefore, bottom-up or system-driven approaches like Decision Tree Framework (Ray and Brown, 2015), CRIDA (Mendoza et al., 2018) and Hydropower Sector Climate Resilience Guide (IHA, 2019) are adopted. These frameworks identify performance indicators of the hydro-system through stakeholders' consultation and run climate stress test to expose vulnerability and risk (Ray et al., 2018).This allows the decision-makers to adopt adaptive and resilience design of water resources infrastructures. Key step in the bottom-up climate risk assessment is to generate multiple realisations of the key climate variables (precipitation, temperature) and then generate the climate vulnerability domain of the selected performance indicator under scrutiny or test, for instance, streamflow, dry energy under various climatic realisations. This requires generation of multiple climate realizations. It allows for altering the parameters like mean, coefficient of variation and transition probabilities of current climate and generate wide possible range of future scenarios (Steinschneider and Brown, 2013)multisite daily weather generator is presented for use in decision-centric vulnerability assessments under climate change. The tool is envisioned to be useful for a wide range of socioeconomic and biophysical systems sensitive to different aspects of climate variability and change. The proposed stochastic model has several components, including (1. In this aspect, the first part of the tool - 'k-nearest neighbor (k-NN) based multisite multivariate weather generator' becomes a handy tool to aid in climate stress test and CRA. This aspect in WECCS-Gen tool is based on paper by Apipattanavis et al (2007) and Steinschneider and Brown (2013)multisite daily weather generator is presented for use in decision-centric vulnerability assessments under climate change. The tool is envisioned to be useful for a wide range of socioeconomic and biophysical systems sensitive to different aspects of climate variability and change. The proposed stochastic model has several components, including (1.

The second framework for climate risk assessment is top-down approach which is traditional approach. This is also climate model (like General Circulation Model) driven approach. It is common practice to use the climate models using ensemble (e.g. Whetton et al (2012)an expanding number of potentially relevant climate model results, and a desire amongst many users to limit the number of future climate scenarios in their assessments. While it may be attractive to select a small number of climate models based on their ability to replicate current climate, there is no robust method for doing this. We outline and illustrate a method that addresses this challenge in a different way. The range of plausible future climates simulated by climate models is classified into a small set of Representative Climate Futures (RCFs) or envelope approach (e.g Lutz et al (2016)) to address uncertainties. Climate model projections are then treated using climate downscaling (like Wood et al (2004)) and bias correction (like quantile mapping in Gudmundsson et al (2012)) procedures to reduce biases and contextualise it to local conditions. These are widely used in national and international context, like in the National Adaptation Plan of Nepal (MoFE, 2019), The Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) and many others. In order to facilitate top-down approach, **Bias correction and Spatial Disaggregation (BCSD)** has been integrated into the WECCS-tool. This aspect is based on papers by Wood et al (2002) and Thrasher et al (2022). Given the technical complexities involved in either simulating climate realizations or downscaling, this WECCS-Gen tool provides a and accessible platform to WR practitioners to facilitate CRA using either of the approaches.

Usages of this tool:

1. Generation of synthetic dataset in case of limited observed data
2. Generation of climatic data enforced with future climate change conditions
3. Climate stress test and climate risk assessment of water resources system
4. Statistical downscaling of the future climate projections

Basic steps used in generating climate data using weather generator with this tool:

1. Generation of annual series using ARMA process
2. Conditioned in annual series, generation of daily weather series using k-NN based multisite multivariate weather generator
3. Enforcement of long-term shifts in climate means and distributions using quantile mapping techniques

Basic steps used in statistical downscaling with this tool:

1. Bias correction of climate variables using quantile mapping techniques
2. Spatial disaggregation that merges the observed spatial climatology with the relative changes simulated by climate models

This tool was initially developed in 2019 by Water and Climate Program, Nepal Development Research Institute (NDRI). Upgrade of this WECCS-Gen tool was carried out following the integration of the Bias Correction and Spatial Disaggregation (BCSD) component. The upgrade of the tool was done with the financial support from Asia-Pacific Network for Global Change Research (APN) in 2022-2023. It can be downloaded from https://github.com/np-ndri-org/WG_CRA_tool or https://ndri.org.np/program/project/weather-generator-and-climate-change-scenario-generator-for-climate-risk-assessment .

D. Concise Illustration of the Materials and Presentations made during the Capacity Building Workshop

Introduction: A four-day capacity building workshop on Climate Risk Assessment for water resources management was jointly organized by Nepal Development Research Institute (NDRI) and Tribhuvan University (TU) from 5-8 February 2024 in Lalitpur, Nepal. This capacity-building workshop, targeted at early career water resources researchers and practitioners, was a part of the project "Building Capacities for Climate Resilient Water Resources Development under Climate Uncertainty" funded by the Asia-Pacific Network for Global Change Research (APN). The primary objective of this training workshop was to equip water and climate researchers and practitioners with the skills and knowledge to conduct effective CRA.

Twenty-seven individuals from notable national and international organizations actively participated in this workshop. Notably, among these participants, five individuals represented foreign countries: Bhutan, Bangladesh, India, Sri Lanka, and the Philippines. Various governmental organizations from Nepal were represented in the workshop including the Ministry of Energy, Water Resources and Irrigation (MoEWRI), Department of Water Resources and Irrigation (DWRI), Department of Hydrology and Meteorology (DHM), and Water and Energy Commission Secretariat (WECS). Additionally, esteemed educational institutions such as TU - Nepal, Purbanchal University (PU) - Nepal, the Asian Institute of Technology - Thailand, the Central University of Rajasthan - India, and the Royal University of Bhutan were represented. Non-governmental research organizations, including the Centre for Policy Dialogue (CPD) in Bangladesh, The Small Earth Nepal (SEN), Centre of Research for Environment, Energy, and Water (CREEW) as well as various private and public organizations, also participated in the workshop.

Brief summary of presentations / materials made during the workshop

1. Climate Vulnerability and Resilience of Water Resources in Mountainous Regions (Presented by Dr. Dhiraj Pradhananga)

The presentation focused on the importance of the climate change in the Himalayas covering the range of aspects from climatic extremes, water stresses to the glacial changes. Education and training initiatives (Capacity Building), developing projects, partnerships, and research initiatives (Research) and continued collaboration and knowledge sharing for sustainable mountain water management (Awareness) is a key to climate resiliency.

2. Climate Risk Assessment of Water Resources /Hydropower Projects (Presented by Dr. Divas B. Basnyat)

The presentation highlighted on climate uncertainty and resilience, climate risk assessment approach and key messages from the past studies done by NDRI. Climate uncertainty is about the future climate and current climate models presents wide range of changes which leads to different impacts for different changes whereas resiliency of any system lies in robustness and flexibility of the system to those changes. Figure 3 shows the CRA framework used by NDRI 2024. There are two approaches for climate risk assessment – top-down approach and bottom-up approach. Bottom-up approach focuses on what matters. From the past NDRI studies, (A) the greatest impact of climate change is from increased climate induced hazards, higher than from changes in water availability; (B) current climate and hydrological variability is a major challenge for Nepal's water resources and hydropower sectors; (C) future climate change is highly uncertain and what is needed is robustness-based approach emphasizing preparedness for a range of possible futures (Climate Resilience) and (D) invest to learn: monitoring, research and pilots, to improve future decisions and planning. Mitigation aspect of climate risk management is also necessary for sustainable water resources management.

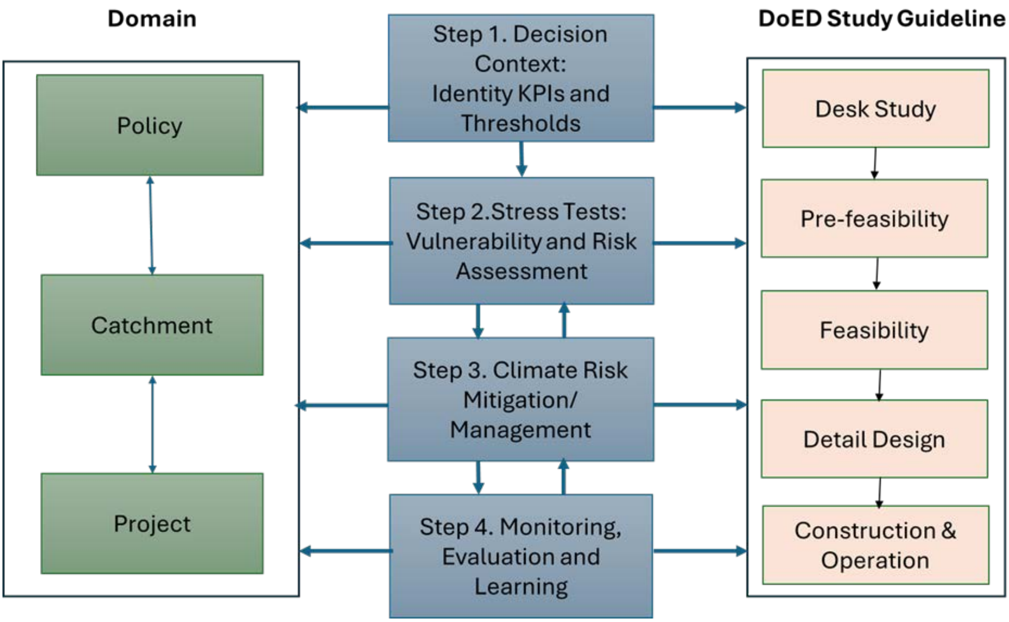


Figure 3: Climate Change Risk Assessment and Resilience Framework for Hydropower (NDRI, 2024)

3. Climate Change: Background and Terminologies (Presented by Divya Laxmi Subedi)

In this presentation, the foundational aspects of climate change and its associated extremes were discussed. The topic covered basic concepts and terminologies in CRA including climate change, climate extremes, climate models including General Circulation Models (GCMs) and Regional Climate Models (RCMs), Coupled Model Intercomparison Project (CMIP), Representative Concentration Pathways (RCMs), and Shared Socioeconomic Pathways (SSPs) (Example **Figure 4**). The participants practice the downloading of climate data from two portals: Copernicus Climate Data Store and World Climate Research Programme.

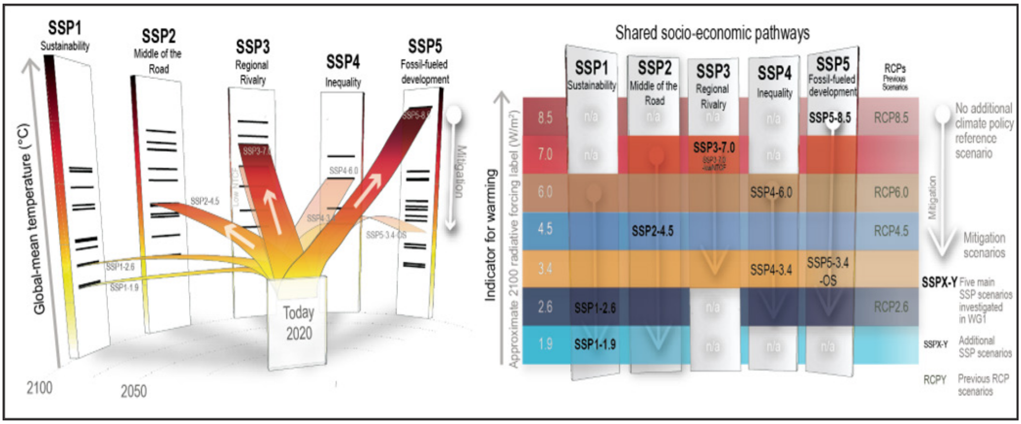


Figure 4: Shared socio-economic pathways (Source: IPCC (2022))

4. Climate Change Analysis Fundamentals for Climate Risk Assessments (Presented by Dibesh Shrestha)

Basics concepts that are needed to conduct climate change analysis and climate risk assessment were discussed (Figure 5) . The important input are climate data and their attributes. Climate data sources for future are basically global circulation models, regional climate models; and user-generated climate realizations. Climate data attributes are variables, models (sources), scenarios, spatial and temporal resolution, time scale, data type and geo-references; and these attributes affect the processing and handling of climate data. Climate data analysis include, but not limited to, data quality checking climatic changes and projections, climate extremes (in terms of indices), trends , frequency analysis (stationary, non-stationary), bias correction and downscaling, climate scenario generations. The tools for anlaysis and visualization range from MS

Excel to programming in Python or R. all these are needed for the climate impact analysis like integrated modelling, climate risk assessment.

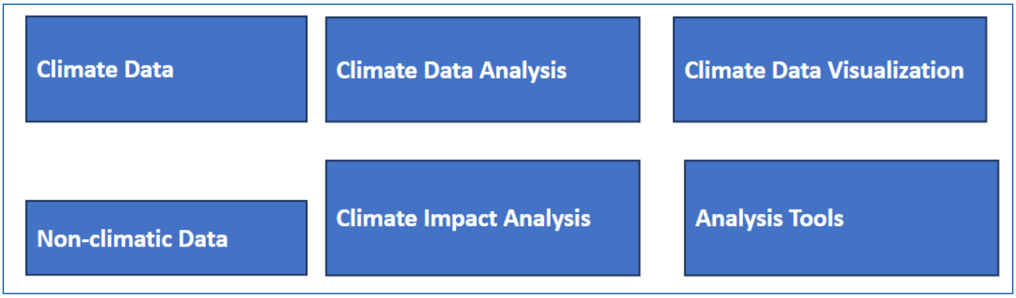


Figure 5: Different components needed for the climate impact analysis

5. Weather Generator and Climate Change Scenario Generator for Climate Risk Assessment (WECCS-Gen) Tool (Presented by Dibesh Shrestha)

WECCS-Gen is a tool aiming to support climate risk assessments of water resources system and is designed to produce inputs for climate stress test, climate scenario generation and bias correction and downscaling of the climate projections.

a. Concepts of k-nearest neighbour weather generation (Apipattanavis et al (2007) and Steinschneider and Brown (2013))

1. Simulation the annual precipitation series with ARMA process
2. Closest k nearest neighbour is searched from historical annual time series using Euclidean distance metric
3. k-NNs are sorted in ascending order based on distance metrics and they are given weights such probability of sampling them with replacement is given by the weights. Sampled with replacement.
4. Daily data of weather variables (Eg: precipitation, temperature) are arranged year wise corresponding to each of the samples in order.
5. Daily time-series formed in step (3) are used to estimate parameters for daily weather generator and new time series is formed. This is carried out for each of the year.
6. Define precipitation stations as dry (S = 0), wet (S = 1) and extremely wet (S = 2) and get transition probabilities.
7. For a user defined window of size N days (eg- 15 days – if the day is 8th Jan , then it consists all the days from 1st Jan to 15th Jan for

all the years in the series), assuming that the precipitation state for previous day, say t-1, is known, the precipitation state for given day, t, is given by the transition probability.

8. Once the states for day t-1 and t, [S_(t-1) S_t], are known, we search and arrange all the days in moving window with states [S_(t-1) S_t]
9. search the k-nearest neighbour to X(t-1) in X(S_(t-1)) using Euclidean distance metrics.
10. k- nearest neighbors are arranged in ascending order according to values of distance
11. Based on the sampled weather variables set on the X(t-1) in states on X(t-1), the weather variables in the successive day X(t) is selected.
12. The process is repeated to generate for all the days.

b. Concepts of climate change scenario generation

For precipitation: (1) For given month m, the precipitation series is fitted by gamma distribution with shape parameter (α) and scale parameter (β). This is reference distribution. The relation between the mean (μ) and standard deviation (σ) between these parameters are $\mu = \alpha\beta$ and $\sigma = \alpha\beta^2$. (2) Change in mean or Coefficient of Variation or both as climate change scenario are introduced. Then, new parameters are computed defining new gamma distribution. This new distribution is distribution for climate change scenario. This is target distribution. (3) Now precipitation value from reference distribution is mapped to target distribution such that they have equi-probability in both distributions. The corresponding value from target distribution is the new value in climate change scenario.

For temperature: For enforcing climate change scenario for other variables than precipitation, additive factor was used as in Steinschneider and Brown (2013). For a given month m, we add constant value of temperature to all data in that month.

6. Data Sources (Presented by Dibesh Shrestha)

Data sources that are needed for climate changes studies or climate impact analysis are presented (Table 1) . Sources for climate data, water resources data, soil-land-agriculture, and digital elevations are discussed.

Table 1: Example of sources of climate data

Net Radiation	NASA	https://neo.gsfc.nasa.gov/view.php?datasetId=CERES_NETFLUX_M
WATER VAPOR	NASA	https://neo.gsfc.nasa.gov/view.php?datasetId=MYDAL2_M_SKY_WV
High resolution climate dataset - ICIMOD (Precipitation and temperature)	ICIMOD	https://rds.icimod.org/Home/Data?group=30
CHIRPS Precipitation and TRMM	Climate Hahard Centre	https://data.chc.ucsb.edu/products/CHIRPS-2.0/
APHRODITE: Asian Precipitation	Hirosaki University, Japan	http://aphrodite.st.hirosaki-u.ac.jp/products.html
GPM-IMERG precipitation	NASA	https://disc.gsfc.nasa.gov/datasets/GPM_3IMERGHH_06/summary
GsMAP precipitation	JAXA	https://gportal.jaxa.jp/gpr/
ERA5 - Various variables see remarks)	ECMWF	https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=overview
GPCC Global Precipitation Climatology Centre (v2020, v2018 etc)	DWD	https://opendata.dwd.de/climate_environment/GPCC/html/download_gate.html
Climatic Research Unit gridded Time Series (CRU)	Natural Environment Research Council	https://crudata.uea.ac.uk/cru/data/hrg/
MSWEP		http://www.gloh2o.org/mswep/
Global Meteorological Forcing Dataset (GMFD) for Land Surface Modeling	Princeton University	http://hydrology.princeton.edu/data.pgf.php
CMIP5 (Raw)	ESGF Portal	https://esgf-node.llnl.gov/projects/cmip5/
CMIP6 (Raw)	ESGF Portal	https://esgf-node.llnl.gov/projects/cmip6/
CMIP6 (RAS)	ECMWF	https://cds.climate.copernicus.eu/cdsapp#!/dataset/projections-cmip6?tab=overview
CMIP6 (Downscaled- Global) - NEX-GDDP-CMIP6	NASA	https://www.nccs.nasa.gov/services/data-collections/land-based-products/nex-gddp-cmip6
CMIP6 (Downscaled- Global) - WorldClim	WorldClim	https://worldclim.org/data/cmip6/cmip6climate.html
Climate Classification (KÖPPEN-GEIGER)	Climate Change and Infectious Diseases	http://koeppen-geiger.vu-wien.ac.at/present.htm
Earth Wind Map	windy	https://www.windy.com/?26.894,80.815,4,i:pressure

7. Global Circulation Model (GCM) selection for climate studies (Presented by Dibesh Shrestha)

There are different methods available for GCM selection for impact studies. One of the cooom method of selection, particularly in Nepal, is the approach followed by MoFE (2019) – 'Climate Change Scenarios for Nepal', which has been adopted for National Adaptation Plan (NAP) and 'Vulnerability and Risk Assessment and Identifying Adaptation Options in the Water Resources and Energy in Nepal, MoFE 2021'. It is a three-step method - (1) Selection based on projected changes in future (ΔP and ΔT) (Figure 6) (2) Selection based on projected extremes on precipitation and temperature (R95pTOT, CDD, WSDI and CSDI) and (3) Selection based on fidelity of model to represent historical climate. Climate scenarios like SSP2 4.5 and SSP5 8.5 can be considered. NDRI has used this approach for GCM selection for CMIP6 SSP2 4.5 and SSP5 8.5 for 'Climate resilient guideline for hydropower and its application in the Narayani Basin'.

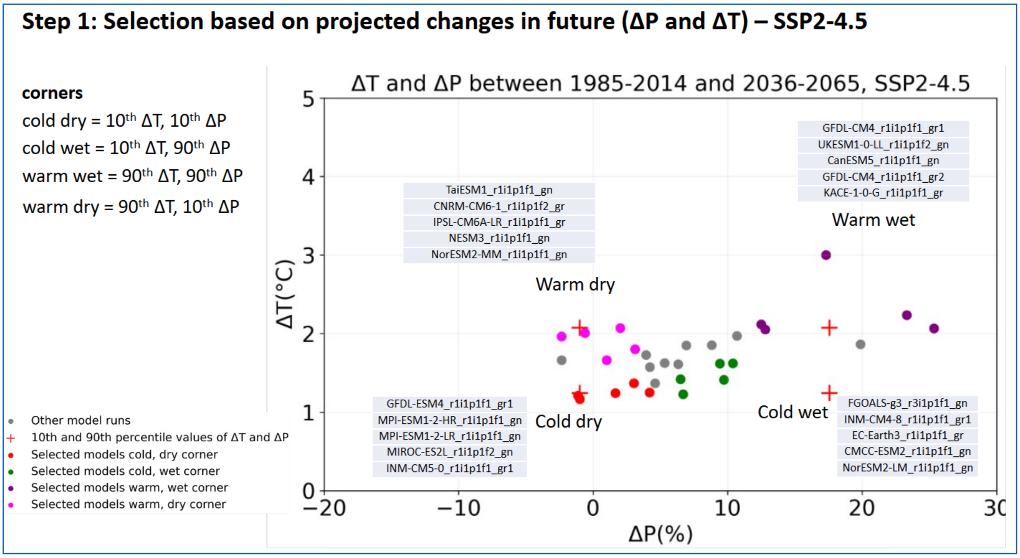


Figure 6: Step 1 of GCM selection based on future changes in temperature and precipitation (Source: NDRI (2024))

8. Bias correction and spatial disaggregation (BCSD) (Presented by Dibesh Shrestha)

BCSD method is commonly used as top-down approach in climate impact studies. It also has been implement in WECCS-Gen tool. It is based on concepts of Bias correction and Spatial Disaggregation by Thrasher et al (2022).

Bias correction: Quantile Mapping

Spatial disaggregation (Figure 7) : At first, the observation climatology (mean of the values over the historical period for each day of the year). Smoothened version was produced using the Fast Fourier Transform (FFT) preserving the third harmonics as described in Thrasher et al (2022). The daily climatology is then regridded (interpolated at the GCM resolution). Multiplicative or additive factors are computed. In case of the variables like precipitation, the multiplication factors are computed by dividing the GCM values at each time step (day) by the daily observed climatology for given day of the year. In case of the variables like temperature, the additive factors are computed by subtracting daily observed climatology from the GCM values. Factors or residual fields which are computed at the GCM resolution are then interpolated back into the observation resolution. Finally, spatially disaggregated future projection are obtained by multiplying or addition of the factors at observation scale with the daily observation climatology.

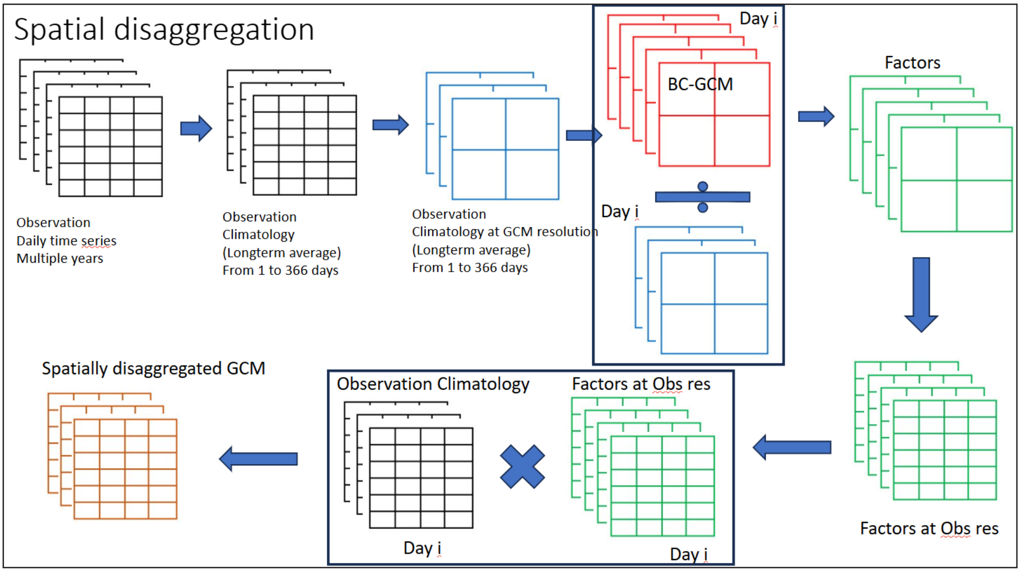


Figure 7: Simplified diagram for concept of spatial disaggregation

9. Hands-on Session on Climate Data Operator (CDO) (Instructed by Girish R. Lamsal)

It covered:

i Brief introduction of Linux and Climate Data Operator

ii Installation

iii Exploration of the climate data file using CDO, example – sinfo commands etc.

iv Extraction and processing of the file with commands for variable extraction, slicing (along time, latitude, longitude), changing units, extracting tabular data, defining grids.

v Clipping and extracting reduced (min/max/average/weighted average) time-series form netcdf file with shapefile using pyscissor

10. Hands-on session on bias correction using quantile mapping (Instructed by Dibesh Shrestha)

Quantile mapping is commonly used method to correct the biases in rainfall magnitude in GCMs during the historical period (reference period). In the empirical quantile mapping method, probability distribution of rainfall of GCMs is mapping with the probability distribution of the observed rainfall (Figure 8) . Details are provided in Gudmundsson et al (2012).

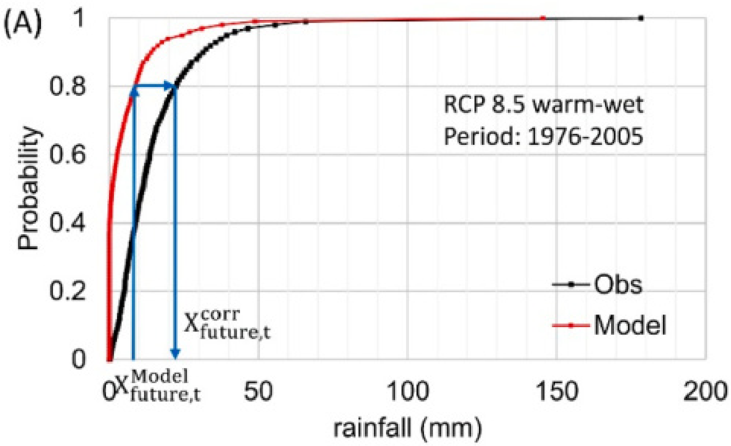


Figure 8: Empirical cumulative distribution for quantile mapping (Source: Shrestha et al (2023)and Kathmandu city is no exception. Rainfall events are projected to become more intense and frequent in a warm and wet future, and they pose a major challenge to the sustainable development of Kathmandu city. This paper analyses historical extreme rainfall patterns across the city and uses these as the basis for future projections in combination with a range of General Circulation Models. Future projections of extreme rainfall are then fed into the numerical flood model HAIL-CAESAR (Lisflood)

The hands-on session covered – (a) Exploration of the python code for quantile mapping (b) Data preparation and (c) quantile mapping and (d) analysis of results

11. Hands-on generating climate realizations using WECCS-Gen tool

a. Installation of the WECCS-Gen tool

WECCS-Gen tool is designed to operate on the Linux platform. Therefore, the users needs to install the Ubuntu WSL and MobaXterm to run the WECCS-Gen tool. Brief instructions to install the WECCS-Gen tool is provided as follows:

i. Install Ubunutu WSL, MobaXterm in Windows.
ii. Install miniconda.
iii. Create new environment (ex. spyder-env) and install Spyder (IDE).
iv. Install spyder, numpy, scipy, pandas, matplotlib, sympy, cython, statsmodel, xesmf, dask netCDF4, matplotlib, cartopy, CDO (python version), xrft, wxpython
v. Please download the WECCS-Gen tool (CODES - both version and technical documentation) from https://github.com/np-ndri-org/WG_

CRA_tool or https://ndri.org.np/program/project/weather-generator-and-climate-change-scenario-generator-for-climate-risk-assessment .

vi. Install Weather Generator module (wg) for Climate Risk Assessment
    a. For this copy the downloaded WECCS-Gen tool from step 5 to working directory (any) extract the zip files.
    b. Change directory for the ubuntu to "working directory/WG_CRA/CODES/WGEN" by:
    c. $ cd 'working directory/WG_CRA/CODES/WGEN'
    d. Install module for weather generator with (make sure you have spyder-env activated step B):
    e. $ python setup.py install --user

vii. Activate the conda environment (eg. spyder-env) in MobaXterm platform (using Ubuntu WSL) and run WG_CRA2.py code. WECCS-Gen tool is then ready to use.

b. Generating climate realizations from observed series

Generating the climate realizations from the observed series uses the following steps. This can be done in 'WG-CRA' tab.

i. Generation of the simulated annual series using ARMA method or any other methods.
ii. It requires the observed annual series, and corresponding multisite precipitation and temperature data.
iii. Users need to define the model parameters like number of resamples(default =20), number of precipitation states (dry, wet and extremely wet), wet threshold (to separate precipitation and non-precipitation), extreme threshold (in fraction – to separate extremely wet from wet state), moving windows size (default =15), and weights assigning method (general method is equal) to variables.
iv. User can provide the initial precipitation state.
v. Then, user can simulate to obtain new multisite series generated using k-NN method.

Screenshot of the tool to generate climate realizations from observed series is shown in **Figure 9**.

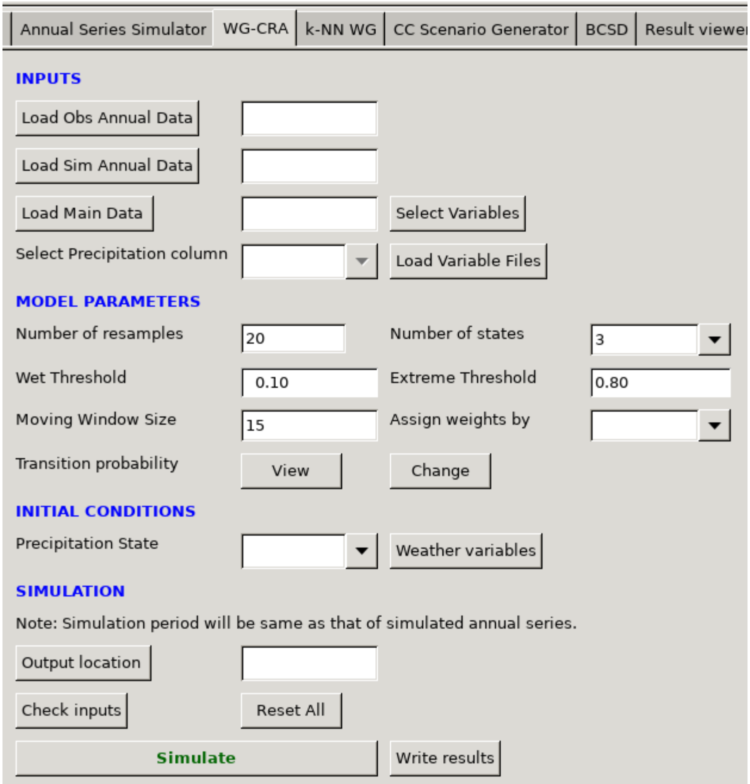


Figure 9: Snapshot of the WG-CRA page to generate climate realization

c. Enforcing climate change to climate scenarios

Enforcing climate change (for example change in mean or standard deviation) to precipitation is carried using quantile mapping method (screenshot is shown in Figure 10) . This can be done in 'CC Scenario Generator' tab. Steps are described as follows:

i. Data (annual and multisite) are loaded.
ii. Define the wet-threshold.
iii. In the 'CC PARAMETERS' section, the users can define the amount of changes they want to introduce to the simulated series (Example +0.10 (+10%) in mean). Users can change the mean and standard deviation for precipitation. For temperature, simple addition / subtraction is carried out.

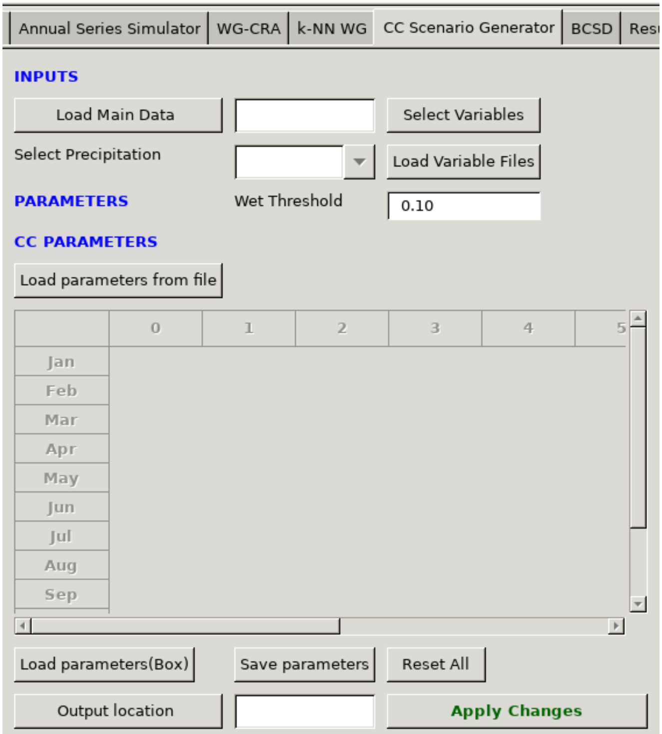


Figure 10: Snapshot of the CC Scenario Generator page to enforce climate scenario

d. Bias correction and Spatial Downscaling

Bias correction and spatial downscaling can be done in 'BCSD' tab (screenshot shown in Figure 11) in the tool with following steps:

i. Users provide the observation data, hindcast data and model data (all in netcdf format and in same coordinate system with same naming conventions.)
ii. Select variable (like precipitation, temperature) to be corrected and downscaled.
iii. Select the rain threshold.
iv. Select regrid engine (python-cdo / XE regridder), regrid method (Nearest Neighbor/ Bilinear / Conservative) and method (Multiplicative for precipitation and Additive for other variables as required).
v. The first step of bias correction is to convert the observation into the model scale and second is to apply quantile mapping.
vi. In spatial disaggregation, at first the observation climatology is

processes and then interpolated to model resolution. Secondly, factors are processed followed by the interpolation of factors back to the observation resolution. Then, the factors is applied to the observation to observation climatology to receive spatially disaggregated data.

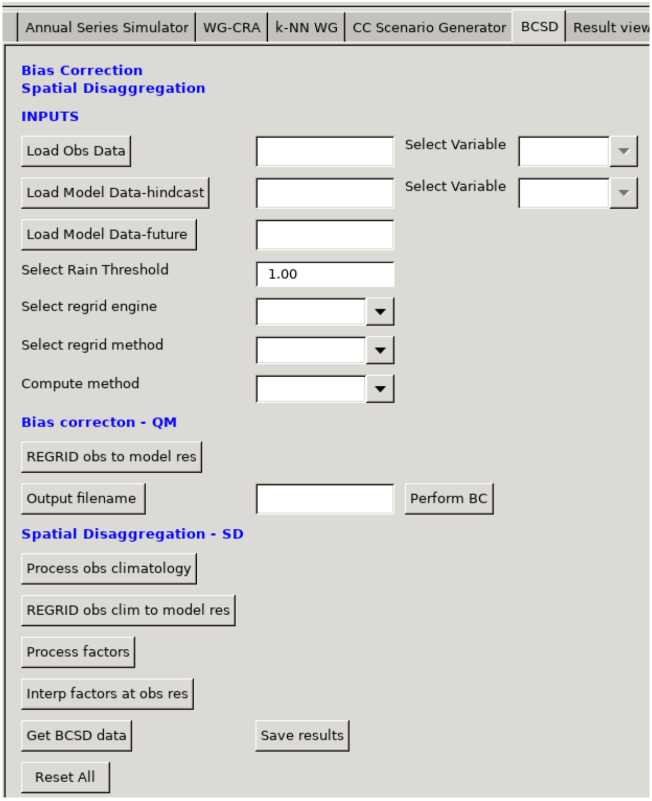


Figure 11: Snapshot of the BCSD page to bias correction and spatial disaggregation

12. Introduction to APN and Climate Challenges in South Asia (Presented by Dr. Madan Lal Shrestha)

The presentation provided an in-depth introduction to the Asia-Pacific Network for Global Change Research (APN), emphasizing its critical role in supporting climate research and fostering sustainable development throughout the Asia-Pacific region (Example Figure 12). Established in 1996, APN enables climate-focused initiatives tailored to address unique global change issues in the Asia-Pacific. APN's mission is anchored in four strategic pillars - the Regional

Research pillar, Capacity Development, Science-Policy Linkages and Community Engagement. Through these resources, funding, and active collaboration, APN remains deeply committed to advancing climate science and promoting resilience across the Asia-Pacific region.

The presentation spotlighted priority topics for South Asia, aligned with the region's heightened climate vulnerabilities. Key areas of focus include climate adaptation and loss and damage, which address the intensifying risks of extreme weather events and the pressing need for adaptive solutions. The presentation also covered future greenhouse gas emissions and decarbonization pathways as essential elements for meeting global carbon neutrality goals, along with integrated urban waste management to support sustainable city planning. Water security was highlighted as a critical challenge given increasing climate variability, and ecosystem resilience and ecosystem-based adaptation were also emphasized, underscoring the importance of biodiversity conservation and nature-based solutions.

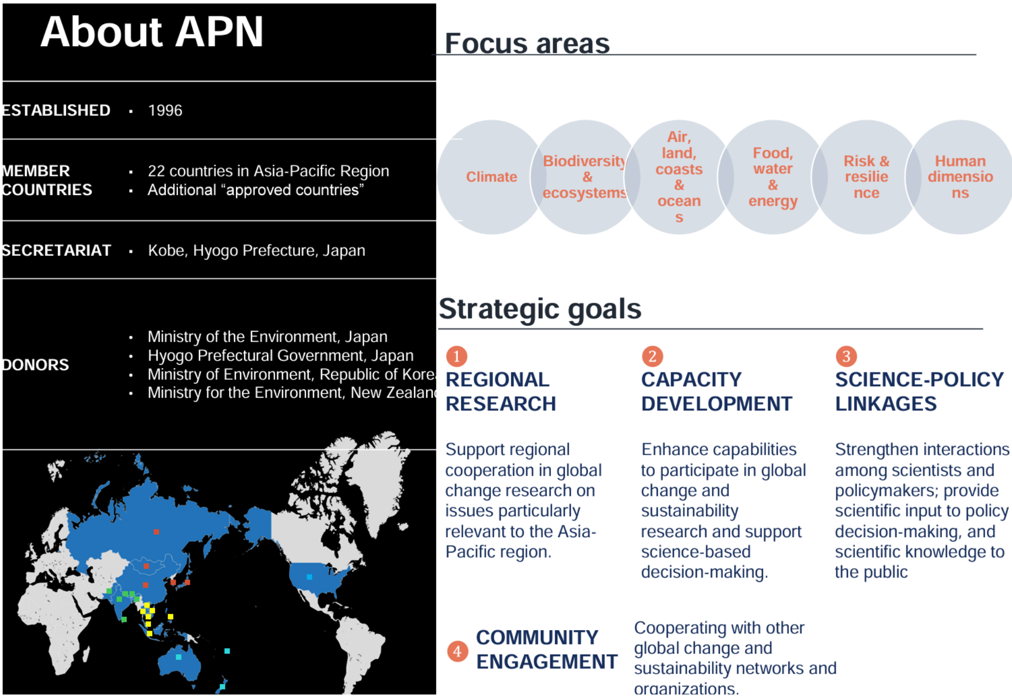


Figure 12: Introduction of the Asia-Pacific Network for Global Change Research (APN) (Source: Shrestha (2024))

13. Climate Resilience in Hydropower

a. Introduction and Background (Presented by Girish R. Lamsal)

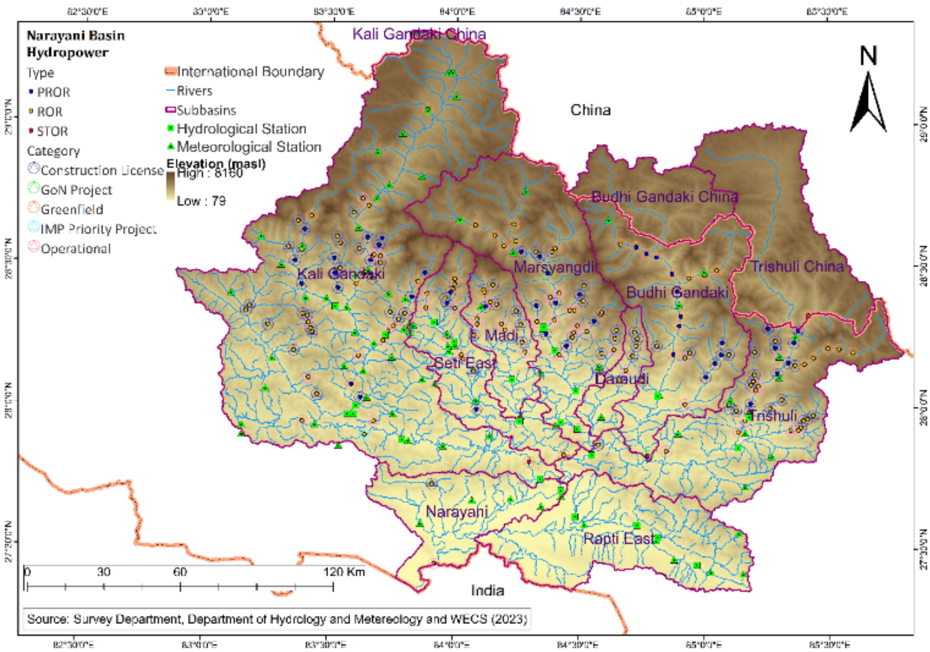


Figure 13: Narayani River Basin (NRB), showing potential and current hydropower location (Source: NDRI (2024))

In the face of rapidly changing climate dynamics, hydropower projects are increasingly vulnerable to climate-induced hazards. The Narayani River Basin (NRB), a critical hydropower region in Nepal, exemplifies the challenges and opportunities for building resilience into hydropower infrastructure. Covering over 36,500 km², the NRB's geography and high-altitude features make it highly susceptible to shifts in water availability, sedimentation, and extreme weather events (Figure 13) . This knowledge product synthesizes findings from recent climate impact assessments, vulnerability analyses, and financial stress testing to propose a comprehensive framework for resilience-oriented hydropower management, with a particular focus on Run-of-River (RoR) and Peak Run-of-River (PRoR) hydropower projects.

b. Climate Change Impacts on Water Resources (Presented by Girish R. Lamsal)

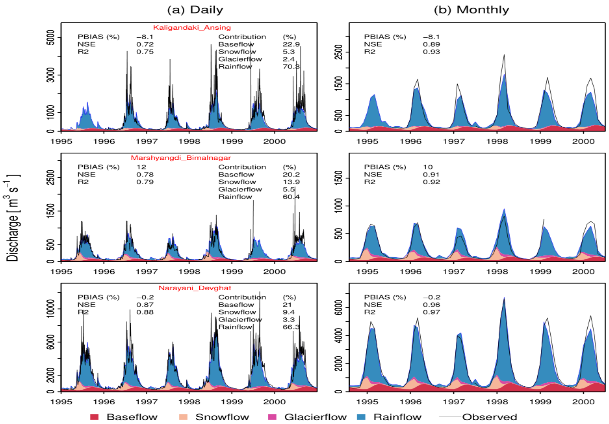


Figure 14: Historical hydrology at Narayani Devghat (Source: NDRI (2024))

The NRB's water resources are closely modeled using the SPHY (Spatial Processes in Hydrology) framework, which simulates critical processes such as snowmelt, glacier runoff, and rainfall-runoff. Figure 14 shows different flow components of Narayani River. This model leverages high-resolution data from sources like HiHydroSoil and ESA CCI, as well as climate projections from CMIP6, providing both daily and seasonal flow projections under a 5 km² resolution for the period 1985 to 2100.

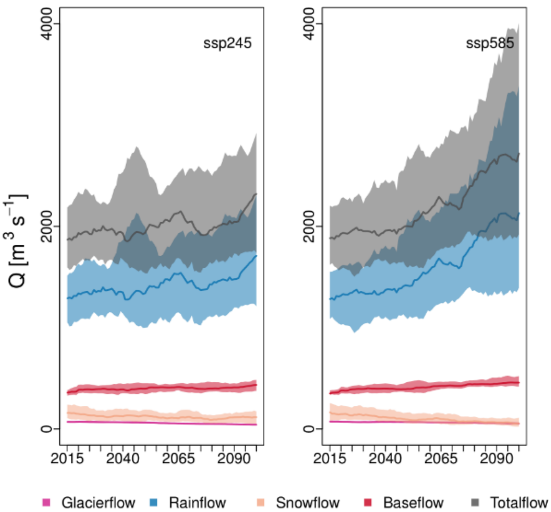


Figure 15: Variability (minimum and maximum) of the flow contributors at Narayani Devghat (Source: NDRI (2024))

Future climate scenarios under SSP2-4.5 and SSP5-8.5 are used to model mid-century (2036–2065) and end-of-century (2071–2100) impacts on water flows. Results indicate that projected temperature and precipitation variations could drastically alter seasonal flows and the frequency of extreme events, impacting the dependability of discharge and peak flows critical for Run-of-River (RoR) and Peak RoR projects (Figure 15). Seasonal shifts show a significant increase in runoff from glaciers and rain during warmer months, while extreme flow events under these SSP scenarios suggest that more frequent and intense peak flows will challenge existing infrastructure, requiring comprehensive flood management measures to ensure operational continuity.

c. Vulnerability and Hazard Assessment for Hydropower Projects (Presented by Rupesh Baniya and Sunita Magar)

The NRB hydropower infrastructure is exposed to various natural hazards, including Glacial Lake Outburst Floods (GLOFs) (Figure 16), permafrost thawing (Figure 18) , landslide susceptibility (Figure 17), and sediment load increases. Utilizing ICIMOD's GLOF inventory, this document identifies high-risk glacial lakes such as Langtang and Thulagi, which pose a significant threat to downstream hydropower projects. These lakes, vulnerable to climate-induced temperature increases and seismic activity, could lead to catastrophic outbursts impacting the Marsyangdi and Trishuli river basins.

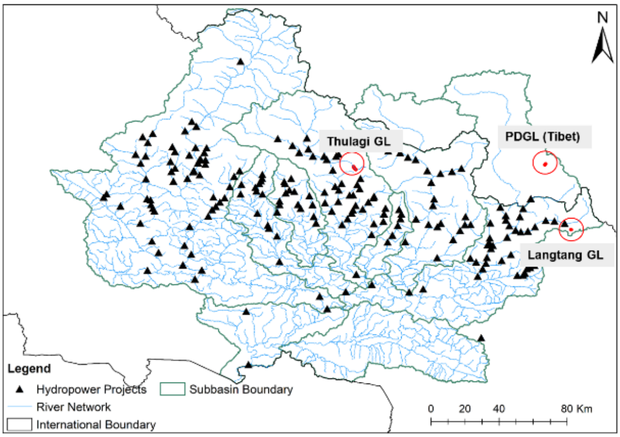


Figure 16: ICIMOD Glacial Lakes and PDGL Inventory (Source: Bajracharya et al (2020))

Alongside GLOF risks, permafrost degradation presents a growing hazard, especially in areas close to permafrost zones where even minimal warming could destabilize terrain.

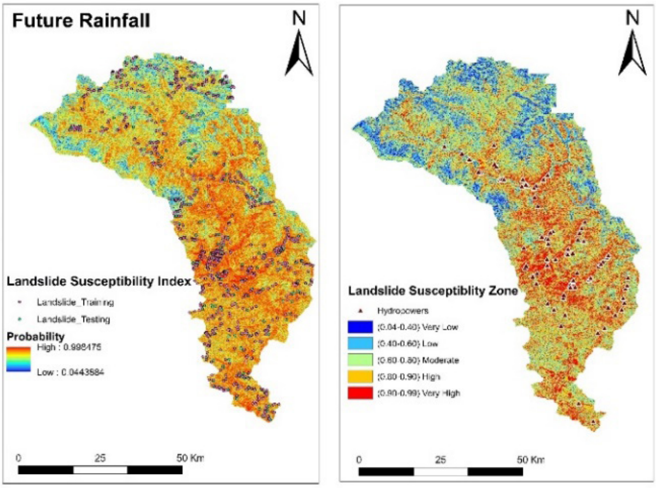


Figure 17: Landslide susceptibility map for Marsyangdi basin for future rainfall scenario (Source: NDRI (2024))

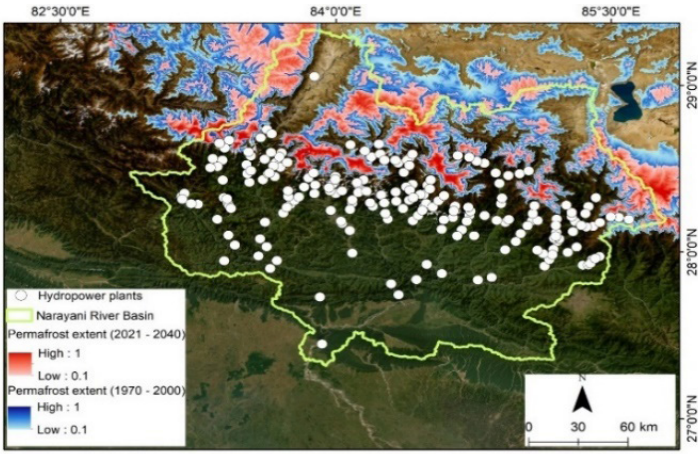


Figure 18: Permafrost distribution maps (above 10%) for Narayani River Basin for the years 1970–2000 and 2021–2040 shown in background (Source: NDRI (2024))

Landslide susceptibility mapping, validated with a high AUC (Area Under Curve) score in the Marsyangdi Basin, shows that climate-induced intense rainfall events increase the likelihood of landslides, particularly under RX5day extreme precipitation projections. Seasonal sediment load also poses operational challenges, with projections indicating increased sediment inflow during high runoff months, affecting plant efficiency and lifespan. Flood frequency

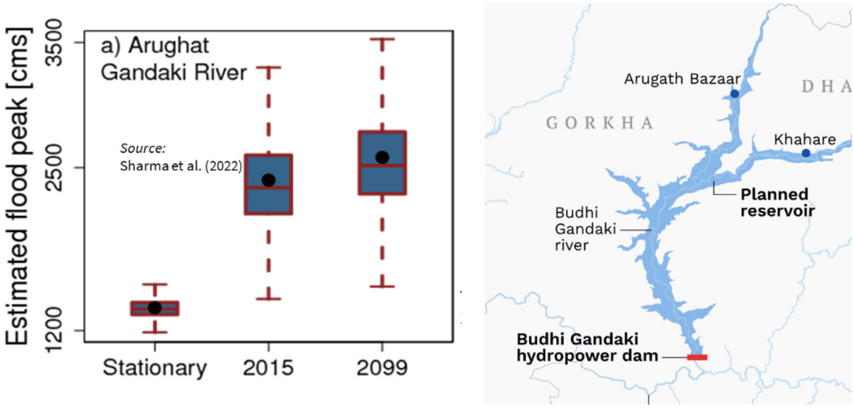


Figure 19: Stationary and Non-Stationary flood analysis for Arughat (Source: NDRI (2024))

analysis using Generalized Extreme Value (GEV) models reveals that previously rare events, such as 100-year and 1000-year floods, may occur with greater regularity, further necessitating improved non-stationary flood management protocols to adapt to the altered hydrological patterns (Figure 19).

d. Financial Analysis, Risk Assessment, and Climate Stress Testing (Presented by Saroj Bhattarai)

The financial analysis framework focuses on optimizing discharge and capacity for hydropower under both historical (HH) and climate-change-adjusted (CCH) conditions. By calculating optimal design discharge (QoHH, QoCCH), this methodology determines the capacity for storage, RoR, and PRoR projects to balance costs and operational performance (Figure 20).

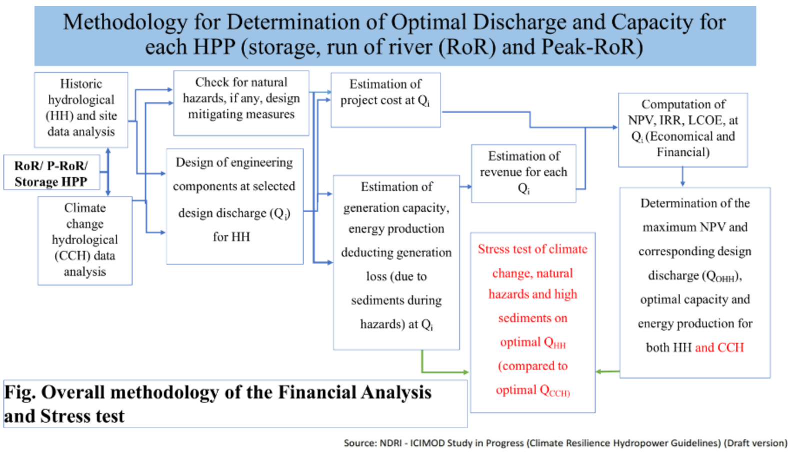
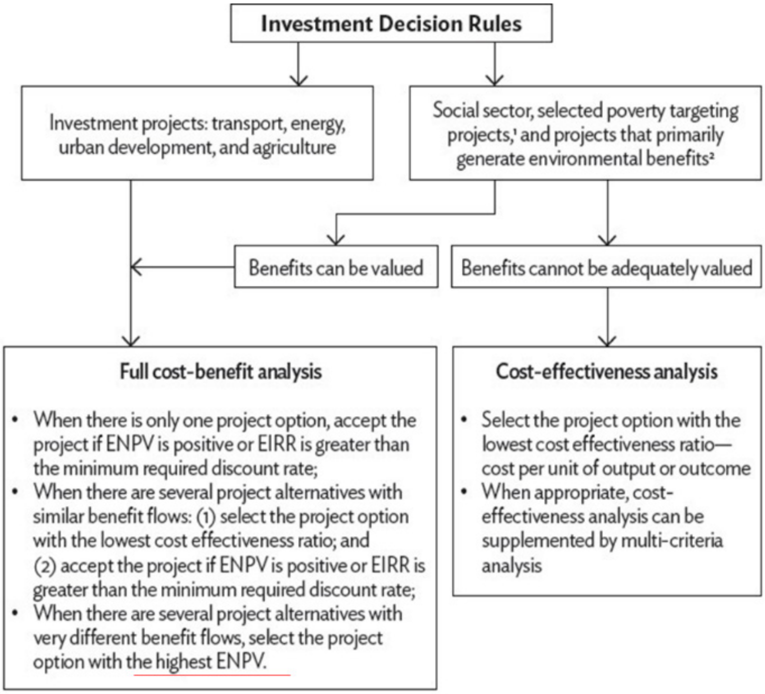


Figure 20: Methodology for determination of optimal discharge and capacity for HPP (Source: NDRI (2024))

To assess the financial resilience of these projects, the framework evaluates key indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), and Levelized Cost of Electricity (LCOE) under varied financial scenarios. Sensitivity analyses are performed on CAPEX, discount rates, and Power Purchase Agreement (PPA) rates, with findings showing that CAPEX increases by up to 50%, and PPA rate variations significantly influence project viability. Additionally, climate change stress tests measure operational impacts under high sediment loads and extreme climate events, illustrating potential risks to generation capacity and profitability. This analysis reinforces the need for adaptive design in hydropower infrastructure, such as PRoR systems with flexible operational modes, enhanced spillway capacity, and efficient sediment-handling mechanisms to reduce downtime and maintenance costs due to sediment and debris.

e. Translating Hazard Insights to Project Management and Adaptive Design (Presented by Prof. Dr. Hari Pandit)

Insights from climate risk and hazard analysis highlight key design and management strategies essential for hydropower resilience. Structural adaptations include spillway expansions, additional sediment handling infrastructure, and improved debris control systems to address the heightened sediment loads and flow variability. Operational adaptations such as reservoir flushing, strategic gate operations, and maintenance scheduling during low-flow seasons can mitigate sediment impacts on revenue. The economic rationale for these measures is supported through a cost-benefit analysis that compares the costs of climate adaptation interventions with the projected savings from reduced operational outages and extended asset life. Adaptive strategies at the basin level, such as GLOF early warning systems, erosion control, and community disaster risk management, are also essential to safeguard hydropower infrastructure and surrounding communities under changing environmental conditions.



EIRR = economic internal rate of return, ENPV = economic net present value.

[1] Such as rural roads and rural electrification.

[2] Such as pollution control, protection of the ecosystem, flood control, control of deforestation, and disaster risk management.

Source: ADB Economic Research and Regional Cooperation Department.

Figure 21: Investment decision rules (Source: NDRI (2024))

f. Conclusion and Recommendations for Future Research (Presented by Prof. Dr. Hari Pandit)

In conclusion, climate resilience is integral to sustaining hydropower production in vulnerable river basins like the NRB. Adaptive infrastructure design, robust financial planning, and policy integration are foundational to climate-proofing hydropower projects. Future research should prioritize advanced sediment prediction models using machine learning, real-time glacial lake monitoring, and scenario-based planning to improve risk quantification. Developing region-specific financing models and insurance options to cover climate-induced losses could further promote sustainable hydropower investment (Figure 21) . Overall, this framework provides a strategic roadmap for adapting hydropower to climate change, ensuring continued energy security and economic viability for Nepal and the broader region.

E. Learning Experiences on the Capacity Building Workshop

'Capacity Building Workshop on Climate Risk Assessment for Water Resources Management' was conducted on 5-8th February, 2024 in Lalitpur, Nepal in on order to build capacity of water resources practitioners at national and international level. Participants in the capacity building workshop included the water practitioners, students and researchers from different sectors in water resources. This created diversity in the how they perceive the climate change impacts on their own working sector. Few participants often used and applied climate data but lacked knowledge on CRA process, while some were more focused on the out results of the whole CRA processes. Many participants were in mid-line between these two aspects. Therefore, the workshop was able to at least provide overarching concepts on the flow of the climate information from data sources to the generation of the outputs of the CRA process; which is to say the use of future climate data to get on what will be its impacts on water sector (note, the example was carried out for the hydropower sector) and this is actually the essence of CRA process.

One of the important aspects of the capacity building workshop was to develop on the illustration provided in the workshop into practice. Though limited in what can be achieved in a single workshop due to time constraint, professional experiences shared in the workshop provided lots of avenues to explore the application of CRA. One of the examples can be the learning obtained by the student participants from the hydropower professionals about the practical situation where climate projects are used for computing expected energy changes in future. Similar experiences were shared on irrigation or disaster management sectors.

Development of the case studies for selected participants of the workshop was another step to develop on the knowledge and skills provided in the workshop. Following the workshop, four participants were provided financial support to develop the case study based on their own filed of expertise. Similarly, the follow-up session was also carried out to the selected young researchers who were more interested in the using the tools.

Focus of the workshop was on usage of the WECCS-Gen tool. In the workshop, one of the challenges faced by the participants was the software environment due to their limited exposure to the software environment, particular the Linux environment. Linux environment is one of major environment used in application of climate science, and therefore, the WECSS-Gen tool was also based on the Linux environment because some of the libraries used for the tool are only exclusive to Linux. Many of the participants were unfamiliar to the Linux environment, and therefore knowledge on how to use the basic of Linux for working with climate data provided most of the participants with new approach to climate data. Knowing the software like Climate Data Operator (CDO) and with how much ease it can handle the large volume of data (which climate data normally is), many of the participants were elated and enthusiastic to learn more about it.

Learning Linux, python and WECCS-Gen tool application was clearly necessary part in the workshop. Simultaneously, this also highlights one of key gap on the usage of the climate data by the water practitioners. Most of them were unfamiliar with the different methods and tools to process the climate data in efficient way. This actually limits the usage of the future climate data and its application. Allowing the participants to know better about nature, exploration and application of climate data in different environment in the workshop will surely help fill one of gap in climate risk assessment.

Hands on training on the WECCS-Gen tool provided the participants to gather and consolidate the knowledge of importance of climate data in climate risk assessment. Furthermore, application of the results from WECCS-Gen tool in hydrological model to generate the streamflow with and without climate change scenarios provided participants to explore the impacts of climate change. Not only, it highlighted the application, but the focus was also on the information flow from climate to hydrological model and then further to the hydro-economic modelling, thus highlighting the process of CRA.

The workshop focused on the climate risk assessment with an example of the hydropower sector in Nepal. Majority of the examples were based on the study conducted by NDRI of the development of policy for hydropower sector in Nepal. Therefore, the importance of the local context in the hydropower development was discussed. These constitute various components of risk namely hazard, exposure and vulnerability at the local context of Nepal and hydropower sector. Not only the risk is dependent of climate change, but also it is governed by other additional factors like policy, governance, market etc. Hands-on exercise done on economic analysis of hydropower in the context of climate change was valuable to highlight this aspect, where, participants can do exercise on their own by changing various parameters.

Photo A: Group photo of Capacity Building Workshop participants

Photo B: Ongoing hands-on exercise during the session

F. Summary of Dissemination Workshop of the Project

NDRI in collaboration with Tribhuvan University (TU), organized a dissemination workshop on March 15, 2024 (Friday) as part of the project. The workshop aimed to disseminate the project's findings, highlight key activities conducted throughout the project duration, and promote Climate Risk Assessment (CRA) at the national level.

The workshop had notable participation from various governmental entities, including the Water and Energy Commission Secretariat (WECS), the Department of Electricity Development (DoED), and the Department of Water Resources and Irrigation (DWRI). Academic and research institutions were also well represented, with attendees from the Institute of Engineering (IOE), Tribhuvan University (TU), Practical Action Nepal, Hydro Lab, and Jalsrot Vikas Sanstha (JVS). Additionally, notable associations such as the Independent Power Producers Association Nepal (IPPAN), Small Earth Nepal (SEN), and the Society of Hydrologists and Meteorologists (SOHAM) enriched the discussions with their valuable insights and expertise.

The dissemination workshop was targeted to policymakers. One of the points of discussion was the sustainability of the updated WECCS-Gen tool citing that many of the tools in the past have failed to sustain. Regular updates and relevance of the tool in the CRA process in the policy can provide adoption of tool in the future. Also, another point of discussion was the limited recognition of the climate-related considerations in the current frameworks and practices. The need for potential collaboration with various relevant government and consulting organizations as well as educational institutions was highlighted to enhance the CRA initiatives and tools like the WECSS-Gen tool. Such collaborations would increase the acceptability of the WECCS-Gen tool and facilitate its incorporation into policy frameworks. Emphasis was provided on the potential of the CRA tools to be integrated into community practices. One of the limitations of Local Disaster and Climate Resilience Framework Guidelines is a lack of focus on CRA aspects. If these guidelines were to recommend the use practice of the CRA method, it could significantly promote its application at the local level.

Photo C: Group photo of dissemination workshop participants

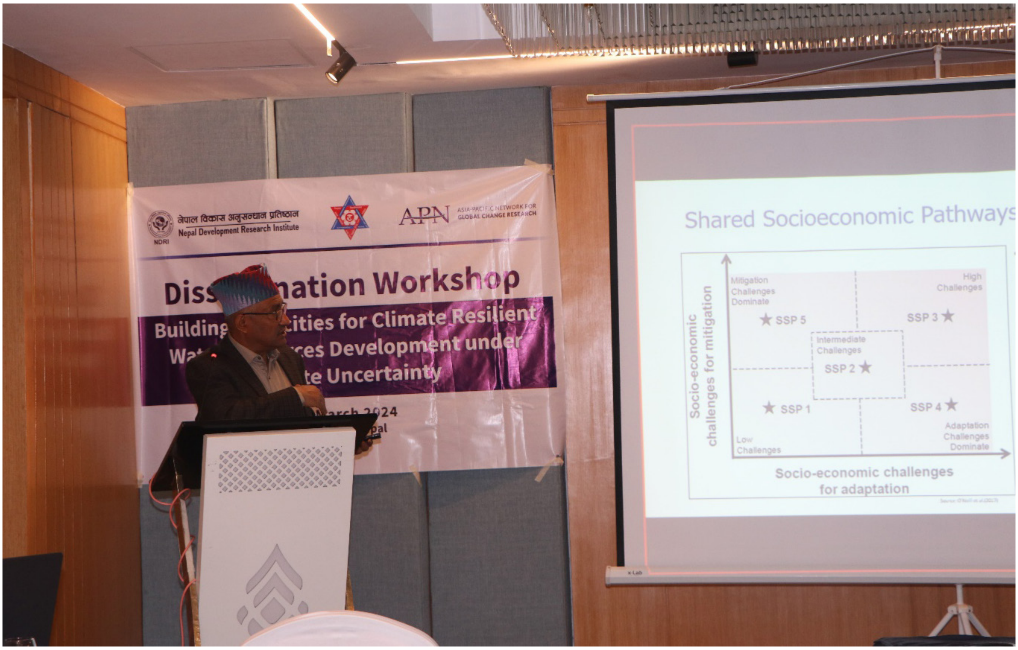


Photo D: Dr. Divas B. Basnyat presenting about Climate Risk Assessment

G. Summary of Workshop - 'STEM Education and Research: Building New Generations'

The Small Earth Nepal (SEN) in collaboration with the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Fulbright Specialist Program, Asia-Pacific Network for Global Change Research (APN) and Nepal Development Research Institute (NDRI) and Tribhuvan University (TU) designed a 10-day workshop to enhance the skills and knowledge of the students of Science, Technology, Engineering, and Mathematics (STEM) further providing insights into ways to perform world-class research which commenced on 18th February at the United Nations House, Lalitpur.

The STEM education component of the Fulbright Specialist Program yielded several valuable lessons. The personalized mentorship provided through the SRA was instrumental in empowering participants and fostering their research skills. The hands-on approach of the SRA, emphasizing practical research projects, was highly effective in engaging participants and reinforcing learning. The program facilitated networking among participants and with the Fulbright Specialist, creating valuable connections for future collaborations.

The Fulbright Specialist's presence offered a unique opportunity for cultural exchange and exposure to different perspectives on STEM education and research. The program's focus on building capacity and inspiring participants has the potential to create a lasting impact on STEM education and research in Nepal.

Based on these lessons, future STEM initiatives in Nepal could benefit from expanding mentorship programs, strengthening research infrastructure, promoting STEM careers, and fostering international collaboration. By incorporating these recommendations, Nepal can continue to build a strong foundation for STEM education and research, empowering its youth and contributing to its overall development.

Photo E: Group photo of STEM workshop participants

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