GIS Framework to Evaluate Impact of Climate Change on Water Resources

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Objectives of the Study

- To Develop portal to assess the impact of climate change on water resources
- Identify Hotspots
- Identify Adaptation & Coping strategies
Changes in hydrological phenomenon is complicated by the conjoined effects of:

- Climate variability over both short and longer term time scales.
- Water Engineering and Management.

\[ Q = P - E + \Delta S \]

The primary forcing function, \( \Delta CO_2 \), alters \( Et \) directly, whilst the secondary forcing function, the \( \Delta T \), enhances both \( Es \) and \( Ew \) and simultaneously, through changes in atmospheric pressure belts, alters precipitation patterns and consequently, \( \Delta S \). These changes have important hydrological repercussions which need to be evaluated through model studies.
Analyzing for Impact of climate change on Water Resources

- Global climate changes will have major effects on precipitations, evapotranspiration and runoff.

- Primary interest to water planners.

- Understanding of hydrological response of river basin under changed climatic conditions:
  - Help to solving potential water resources problems associated with flood, droughts etc.
This framework uses the distributed hydrological modelling (SWAT) to quantify the impact of climate change on the water resources.

The impact of climate change on the particular drainage area can be visualized through this Web Interface (http://gisserver.civil.iitd.ac.in/natcom).

In this case the HadRM3 baseline scenario (BL) and GHG Scenario A1B, A2 & B2 are incorporated.
Generation of Indirect Information through simulation
Soil & Water Assessment Tool (SWAT MODEL)

Features

- Physically based Distributed model
- Continuous time model (long term yield model)
- Uses readily available data
- Suitable for long term impact studies
Hydrological Modelling of Indus Basin (SWAT Model)
Model Set Up

The SWAT hydrological model set up for Indus basin

- The model requires climatic data pertaining to the precipitation, maximum temperature, minimum temperature, solar radiation, wind speed and relative humidity

- The model has an inbuilt weather generator which can be used for predicting the daily values of all these variables, provided certain long term weather statistics are available

- Using IMD girded data
  - Rainfall data (0.5° X 0.5°) - 1971-2005
  - Temperature data (1° X 1°) - 1969-2005
HadRM3 (RCM-PRECIS model) control and future GHG climate scenarios

- In the present study control (1961-1990) and two future GHG scenarios A2 (2071-2100) and B2 (2071-2100) is used to capture the range of uncertainties associated with driving forces and emissions

- Digital Elevation Model (DEM) – Shuttle Radar Topography Mission (SRTM) 90m
- Land Use Layer: Global Land Cover Facility (one km grid cell size)
- Soil Layer : FAO Digital Soil Map (scale of 1:5,000,000)

Different Threshold
- Catchment
- Sub-Catchment
- Watershed
Location of model calibration and validation
Model Calibration and Validation Satluj Sub-catchment at a monthly time scale

Calibration

Validation
Physical Database Design of the Spatial databases

Hydro Geodatabase Datasets

Hydro Data Model

- Landuse & Soil Dataset
- Hydrography Dataset
- Drainage Dataset
- Administrative Dataset
- Socio-Economic Dataset
- TS/Data Tables
- Raster datasets
Model Base to Hydro Geodatabase

- In Geospatial integration HIS is constructed which contains a central Geodatabase and the simulation models required for the analysis.

- The output of a model simulation are imported into the central Geodatabase.

- Hydro data model was design to support SWAT model output (Viz. Suboutput, Reachoutput).
- SWAT Model was run on desktop

- Monthly and Daily model results of Subbasin & Reach where upload to Hydro geodatabase (Central Geodatabase)
Geospatial integration of Hydro geodatabase with SWAT model
Interface Designed and Developed for connecting SWAT model output

- A large amount of information shall be generated indirectly by using various kinds of models ranging from hydrological; hydraulic to environmental model that can form the model base to be attached to the framework (simulated output of the SWAT model is incorporated into the Hydro Geodatabase).

- Integrating SWAT model output with this framework provides a simple but powerful mechanism to understand the spatial variability of water quantity and quality variables within the context of the drainage system.

- The recent concerns of vulnerability on account of climate change and safe adaptation options are also in the realm of modelling.

- It can address the issue of evaluating the change in water availability under anthropogenic changes.

- Provide sufficient information on hydrologic and environmental sustainability of the drainage system that can be used for planning, management and evaluation process.
Identifying the area of interest

Facility to identify the area of interest
Accessing the hydrological model output for sub-areas

**Basinwise Model Results**

- **Select Basin:** Satluj 106
- **Select Catchment:** Beas 10601
- **Select Subcatchment:** BEAS 1060110
- **Select Watershed:**
- **Select Parameter:** Water Balance
- **Select Period:** (Start-End) 1980 – 1980

**Model Results**

<table>
<thead>
<tr>
<th>Virgin Condition</th>
<th>BL Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run with IMD Grid Data</td>
<td></td>
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<tr>
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<td>HadRM3 GHG Scenario (A2)</td>
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<tr>
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<tr>
<td>A1B Baseline Scenario (1961-90)</td>
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<tr>
<td>A1B Mid Century Scenario (2021-50)</td>
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<td>A1B End Century Scenario (2071-98)</td>
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**Water Balance: BEAS 1060110**

IMD Grind data Virgin Condition

![Graph showing water balance: rainfall, water yield, evapotranspiration, ground water](image-url)
Discharge at the outlet of Beas 1060110 Sub-catchment
Framework also provides the option to store and view the water quality parameter from the SWAT model output.
Analyzing for Impact of Climate Change on Water Resources

Understanding of hydrological response of a river basin under changed climatic conditions will help in solving potential water resource problems associated with floods, droughts and availability of water for agriculture, industry, hydro-power generation and for domestic and industrial use.

Monthly water balance components for BL scenario for Beas 1060110 Sub-catchment
The user can ascertain the variation in the hydrological regime of the drainage area between different scenarios.

**Basinwise Model Results (SWAT)**

**Model Results: BEAS 1060110**

- Virgin Condition
- BL Condition

Select Parameter: Water Balance

- Run with IMD Grid Data (1971-2005)
- HadRM3 Baseline (BL) (1961-1990)
- HadRM3 GHG Scenario (A2) (2071-2100)
- HadRM3 GHG Scenario (B2) (2071-2100)
- A1B Baseline Scenario (1961-1990)
- A1B Mid Century Scenario (2021-2050)
- A1B End Century Scenario (2071-2098)

Select Period: (Start-End) 2075

Show Graph  Show Table

**Water Balance: BEAS 1060110**

HadRM3 GHG Scenario (A2) Virgin Condition

**Monthly water balance components for A2 scenario for Beas 1060110 Sub-catchment**
Vulnerability Assessment

- Vulnerability is defined as the degree to which a system is susceptible to or unable to cope with adverse effects of climate change including climate variability and extremes (IPCC, 2001)

Drought Analysis

- Central and State Government Departments use drought indices to assess and respond to drought

- Soil Moisture Deficit Index (SMDI) & Evapotranspiration Deficit Index (ETDI) has been developed (Narasimhan & Srinivasan, 2005) to monitor drought severity using SWAT model output to incorporate the spatial variability

- SMDI & ETDI formulation has employed in this framework
Template Analyzing Drought Severity

Drought Analysis

Select Basin: Satluj 106
Select Catchment: Beas 10601
Select SubCatchment: BEAS 1060110
Select Watershed:

Select Period: (Start-End)
2075  2075

- SMDI (Soil Moisture Deficit Index)
- ETDI (EvapoTranspiration Deficit Index)

Graph Type: Line

Drought Analysis
HadRM3 GHG Scenario-A2 (BEAS 1060110)

Soil Moisture Deficit Index

Time Line in weeks (* Values range from -4 to +4 represents dry to wet conditions.)
Vulnerability Assessment

Flood Analysis

- Flood analysis has been carried out using the daily outflow discharge taken for each drainage area from the SWAT output.

- These values are used to draw the **Flow Duration Curve**.

- It is a plot of discharge against the percentage of time the flow was equalled or exceeded.

- **Flood Frequency Analysis** - Gumbel’s distribution (Gumbel, 1941).
Interface displaying Flow Duration Curve for Control scenario

### Flood Analysis: BEAS 1060110

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- Flow Duration Curve
- Gumbel's Distribution Method

[Show Graph] [Show Table]

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**Flow Duration Curve**

SubCatchment: BEAS 1060110

![Flow Duration Curve Graph](image)
Flood Frequency Analysis

Template displaying Gumbel’s Distribution for BL scenario

Flood Analysis: BEAS 1060110

- Virgin Condition
- BL Condition

- Run with IMD Grid Data (1971-2005)
- HadRM3 Baseline (BL) (1961-1990)
- HadRM3 GHG Scenario (A2) (2071-2100)
- HadRM3 GHG Scenario (B2) (2071-2100)
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- Flow Duration Curve
- Gumbel’s Distribution Method

Show Graph  Show Table

Gumbel's Distribution Method
SubCatchment: BEAS 1060110

Discharge in Cumecs

Recurrence Interval T years

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
0 5000 10000 15000 20000
Interface to present results of various Climate Change Scenario analyses

- The three basic hydrological components namely precipitation, water yield and actual evapotranspiration are the ones that have been tracked to reflect the climate change impacts.

- The analysis has been made on these components with respect to mean annual as well as mean monthly values for control and GHG scenarios.

- These analyses help the user and the water manager to understand the change in hydrological behaviour of the drainage area with respect to climate change scenarios.
Average Annual Water Balance Components for IMD and for Control and GHG Scenarios
Average Monthly Precipitation for IMD, Control and GHG Scenario

- Average Monthly ET for IMD, Control and GHG Scenario
- Average Monthly Water Yield for IMD, Control and GHG Scenario
Template of Monthly change (%) in PCP with respect to Control for GHG Scenario.

- Monthly change (%) in ET with respect to Control for GHG Scenario.
- Monthly change (%) in Water Yield with respect to Control for GHG Scenario.
The framework has also incorporated the option to present model result with respect to multiple drainage area and multiple scenarios for the users who need to compare these for better understanding.
Multi Scenario Selection
Conclusions

- The present framework can serve as an important tool for water resources management by integrating water resources related information on a common geospatial platform.

- This information can contribute to long-term improvement in water resources decision making by providing more timely and comprehensive access to water resources data.

- Furthermore, it can also serve as a ready input for hydrological modelling which, in turn, generates scenarios for evaluating the impact of anthropogenic as well as climate changes on water resources. Thereby help in taking various adaptation strategies.
Thank YOU