
ABSTRACT

THESIS SUBMITTED FOR THE DEGREE OF
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in
GEOGRAPHY
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Enrolment No: 295185

2015
Hydrological studies in Sirsa Basin of Satluj River, Himachal Pradesh using Remote Sensing and GIS

ABSTRACT

Hydrological studies include assessment of quantity and quality of hydrologic components and its response to changes in environment that control its processes. As hydrologic processes are interconnected, any change in environmental conditions will affect whole hydrologic behaviour. In recent times, anthropogenic interference has aggravated water related problems like, flood, drought, water scarcity, contamination of water, sediment load etc. worldwide. The critical situations are manifested due to alteration of land use practice, climate change, soil erosion, population explosion, huge uptake of fresh water. The disruption in global hydrological cycle has caused a concern and debate among hydrologists, geographers, planners and resource managers on the manner in which the water resources are fast depleting and the means of conserving water for sustainable use in future. The present study investigates the temporal land cover changes and climate variability, and their impact on the hydrological response of Sirsa River Basin, western Himalaya, India.

Hydrologic modelling is the process of investigation of interrelationship among climate, soil, surface characteristics and water through mathematical abstractions. It essentially facilitates simulation of hydrologic components and its variations resulting from dynamics in certain environmental condition. Hydrologic models incorporate various parameters to miniature real world processes through algorithms. Therefore, calibration of model parameters is essential to adjust parameters so that model could predict close to real phenomena. For realistic simulation, a large number of datasets are needed in distributed hydrologic models. Constraining in application of hydrologic models is commonly arising in a developing county, like India where most of the basins are ungauged. This study has attempted to calibrate a semi-distributed model, Soil and Water Analysis Tool (SWAT) with satellite based evapotranspiration data for Sirsa River, an ungauged tributary basin of Satluj River.

Any hydrologic model needs a wide range of input dataset, varies with complexity, processes and parameters involved in the model. The basic data needed for hydrologic modelling are topographic data, soil data and hydro-meteorological data. The reliability and availability of hydro-meteorological data at desired spatial and temporal scale is a major concern in hydrologic
modelling. Past studies were mainly focused for most of the developed countries where spatial and temporal data are available. Even, the study of ungauged catchments through hydrologic modelling are conducted mainly in the various European countries, Australia and USA. The most popular method of hydrologic simulation of ungauged catchment is regionalization approach, in which model parameters are transferred to ungauged basin from a donor catchment (gauged river basin) based on their physio-climatic similarity. But, if a gauged basin with similar physio-climatic characteristics cannot be availed for any ungauged basin, how can a physically based model be applied for an ungauged basin? To address this problem, satellite based remote sensing data have been used in this study to simulate hydrologic components and its response to land use change and climate variability through hydrologic modelling in geospatial environment. The present study is more relevant and significant for developing countries, especially in data scarce region.

The present research work is carried out for a river basin that has been affected by the growing industrial development in Solan district of Himachal Pradesh. The study aims to: a) understand the nature, characteristics and hydrologic response of the basin, b) spatial and temporal analysis of historical land cover changes (1989–2009) and climatic variability (1983–2008), c) individual effect of change in each land cover class and climate variability on hydrologic components like, surface flow, baseflow, lateral flow, streamflow, percolation and evapotranspiration etc., and d) combined and relative influence of land cover change and climate variability on streamflow.

For this study Survey of India Toposheets (53 A/12, 53 A/16, 53 B/9 and 53 B/13) is used as base map for the study. For topographic data, Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER GDEM) of 1 arc-second resolution is used. A soil map is acquired from National Bureau of Soil Survey and Land Use Planning (NBSS & LUP). LANDSAT TM & ETM+ Images (1989, 1999 & 2009) are used to extract land cover information. In absence of long term in-situ meteorological data, gridded raster climatic data of NCEP/NCAR Global Reanalysis Products of Global Meteorological Forcing Dataset for Land Surface Modelling (ds314) is used in this study for the period of 1980 – 2008. The meteorological parameters used for the study are minimum and maximum temperature, precipitation, solar radiation, wind speed and relative humidity. The Moderate Resolution Imaging Spectroradiometer (MODIS) evapotranspiration data product (MOD16A2) was used to calibrate the hydrologic model for the period of 2004 – 2008. Erdas imagine 9.2 is used for the image processing, while ArcGIS 9.3 is used for geospatial analysis. Arc SWAT 2.3.3 (2005) is considered
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for hydrologic modelling in ArcGIS interface. Programming language Python 2.7 is used for various purposes. The charts, maps and diagrams were prepared in MS Excel, OriginPro 8 and ArcGIS 9.3

SOI toposheets and DEM are used to prepare various morphometric parameters, as described in literature review. The morphometric analysis of topographic and drainage parameters, and their correlation helped to analyze basin hydro-geomorphic characteristics and geomorphic evolution. Maximum-likelihood based supervised classification technique is adopted for preparation of LULC maps in Erdas imagine 9.2 tool. Accuracy assessment and change detection of LULCs at basin and sub-basin level is conducted with the help of Erdas imagine 9.2. The variation in climatic components is experimented through trend analysis and other statistical analysis. The NCEP/NCAR Global Reanalysis meteorological data is processed and extracted using Python 2.7. MODIS ET data is processed and extracted in Arc GIS 9.3 environment. All the input parameters of SWAT model are prepared and arranged as guided in SWAT manual (Neitsch et al., 2005). After initial SWAT run, sensitivity analysis and manual calibration is performed. The calibration process is conducted by ‘trial-error’ method with the help of MODIS ET. After getting satisfactory performance of the model simulation, the model is finally run for three climatic period (1983 – 1992, 1993 – 2002 and 2003 – 2008) in three LULC conditions (1989, 1999 and 2009) at annual and monthly time steps. The simulated results are analyzed to understand long term hydrologic scenario, and the response of hydrologic components to LULC change and climate variability.

This thesis is organized in seven chapters as outlined below:

1. **Chapter 1: Introduction**

   This is an introductory chapter wherein the conceptual background, statement of problem, research questions, objectives, justification of the study, literature review, methodology and organisation of the thesis are discussed.

2. **Chapter 2: Geographical Settings of the Study**

   The second chapter gives an overview of the study area that includes topographic characteristics (relief and landforms), geology, drainage, climate, soil, vegetation, and population.

3. **Chapter 3: Morphometric analysis: A perspective of drainage basin evolution and basin hydrologic response**

   This chapter is devoted to the analysis of the hydro-geomorphic characteristic and basin evolution through the use of various morphometric techniques of relief and slope aspects and
drainage characteristics at the basin and sub-basin scale. The correlation analysis to understand
the nature and degree of correlation among various morphometric parameters has also been
carried out.

4. **Chapter 4: Land use/land cover change and climate variability**

Fourth chapter discusses the pattern of Land use/ Land cover and the changes that have
occurred in the three decades(1989-2009) at the basin and sub basin scale in the study basin. The
trend analysis of climatic data has also been done to understand the nature of variations
annually, seasonally and monthly.

5. **Chapter 5: Hydrologic Modelling with SWAT Model: Component, Input Data and
Model Setup**

The fifth chapter mainly describes the basics of hydrologic modelling. It includes the
description of various types of hydrologic models, criteria and reasons for selection of SWAT
model in the present study; the components of SWAT model, input data preparation and setup of
the model. The techniques of sensitivity analysis, calibration and validation and model
performance evaluation have also been discussed.

6. **Chapter 6: Hydrologic simulations and its response to LUCC and climate variability**

The sixth chapter elaborately discusses the results of the estimation of various hydrologic
variables for three LULC and three meteorological scenarios and impact of LULC change and
climate variability on hydrologic regime. At the outset the performance of the SWAT model is
assessed through sensitivity analysis, calibration and validation. In the next step the long term
actual hydrologic scenario of the basin and sub-basins is discussed through annual, seasonal and
monthly analysis. Finally, the annual, monthly and seasonal response of hydrologic components
to land use/ land cover change (LUCC) and climate variability is analyzed at the basin and sub-
basin scale. The effect of individual LULC on water balance components and the combined and
relative effect of LUCC and climate variability has also been analysed to identify their relative
influence on hydrologic regime.

7. **Chapter 7: Conclusions and recommendations**

The last chapter summarizes the entire thesis work, highlights the major findings and
draws conclusions from the study. It also contains recommendations in light of the findings and
outlines the limitations and future scope of the present research work. The chapter also seeks to
answer the questions raised in the beginning of the thesis.
The major findings of the work are summarized below:

- In the basin, forest cover and barren land have decreased, and agricultural land and built-up area have increased appreciably.
- For ungauged basin, satellite-based ET data can be used satisfactorily for calibration of hydrologic model parameters.
- On an average, annual value of streamflow and aquifer recharge showed decreasing trend with time in the Sirsa basin.
- From 1989 to 2009 LULC, contribution to total SURQ increased from BU and AGRI by 17.21% and 12.97%, respectively. Baseflow increased maximally from AGRI by 17.2%, DA_RCHG decreased maximally from decrease in DF and OF by more than 12% from each.
- Correlation and estimation of effect of individual LULC to hydrologic response is more effective to understand hydrologic response to LUCC. It could be used to predict future hydrologic scenario.
- From 1989 to 2009, LULC scenario showed positive influence on streamflow.
- Rainfall variability is primarily responsible for decrease in streamflow component and aquifer recharge.
- From 1989 to 2009, average annual stream flow has decreased by 58.86 mm of which 98.24 mm negative change and 39.38 mm positive change accounted from climate variability and LULC change, respectively.
- The study basin will face serious water crisis in near future.