SIMULATING HYDROLOGICAL RESPONSE OF SNOW AND GLACIER MELT AND ESTIMAING FLOOD PEAK DISCHARGE IN SWAT RIVER BASIN, PAKISTAN

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ABSTRACT

Pakistan is a flood prone country and undergo flood almost every year. In this research Swat River Basin which originates from the foothills of Hindu Kush mountain range has been studied. Havoc caused by frequent flooding and flash flooding because of narrow flood plain and concentrated residential and commercial activities into flood plain is a major issue of this basin. Structure countermeasures are very poor, therefore this research has been carried out to strengthen the non-structural measures of flood early warning system. In the past no hydrological model in which snow and glacier melt have been addressed, used for simulation of hydrological response for flood forecasting. Therefore the applicability of Integrated Flood Analysis System (IFAS) snow model, based on the degree day approach and Moderate Resolution Imaging Spectroradiometer (MODIS) snow data for flood forecasting was evaluated and improved. The simulated snowmelt runoff was reliable for 2005, but for 2007&13 years of validation, the model results were unsatisfactory. The model was validated after fixing the bug of IFAS import function of minimum temperature. Based on the snow cover and the average temperature of the grid, the rainfall has been separated from precipitation as snow is recorded as rain. The lack of the sufficient number of rain gauge stations is a major factor of disruption of hydrological study of the basin, in order to address this issue, corrected GSMaP rainfall has been used for rainfall runoff, as a result the model gave simulated discharges best fit to observed one with Nash-Sutcliffe Coefficients 0.71, 0.42 & 0.63 respectively for 2005, 2007 & 2013 and Correlation Coefficient 0.84, 0.68 & 0.91 respectively. After developing the model, IFAS snow model is easily applicable model for flood forecasting.

Keywords: IFAS, Degree Day Approach, Bifurcation of Precipitation, Bias Correction of Satellite Rainfall

INTRODUCTION

The northern Pakistan is considered as home of snow and glacier after Polar Regions, received heavy snowfall in winter playing a dynamic role in water budget (Muhammad Umar et al., 2015). Snow and glacier melt runoff contribute about 80 % to Indus river discharge (Young & Hewitt, 1990). Although snow and ice are great water resources, when melt abruptly, a flood occurs. Pakistan is a flood prone country and undergoes from medium to high level flood almost every year. Mainly floods in Pakistan are caused by heavy concentrated rainfall during summer monsoon season, augmented by snow and glacier melt in Upper Indus Basin (UIB) Rivers. Both poor structural and non- structural countermeasures cause flooding in. The main objectives of this research are

- Investigation of the applicability of Degree Day Model of IFAS and MODIS snow data for reliable flood forecasting.
- Estimation of snowmelt and glacier melt runoff contribution to total river discharge.
- Investigation of the applicability of satellite rainfall data for reliable flood forecasting.

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In this research Swat River Basin is selected as study area. The location of the study area is shown in Fig.01. Th PMD observatories & Water and power Development Authority (WAPDA) stream gauge station used in this research has been shown in table I & II.

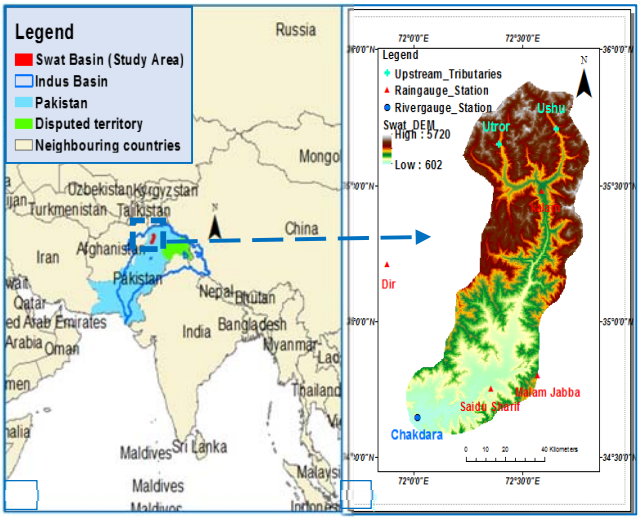

Fig. 1: Location of study area inside the Indus Basin

Table I: PMD observatories used in study area

Station Name	Latitude (°N)	Longitude (◦E)	Elevation (m)
Saidu Sharif	34°45′00″	72°21′18″	950
Kalam	35°28′42″	72°35′19″	2000
Malam Jaba	34°47′59″	72°34′11″	2450
Dir	35°12′36″	71°52′48″	1400

Table II: WAPDA steam gauge s used in study area

Station Name	Latitude (°N)	Longitude (◦E)	Elevation (m)
Chakdara	34°38′40″	72°01′30″	676

THEORY AND METHODOLOGY

IFAS Model

Two layer tank model was used for this study. The configuration of two layer tank model is given in table III, below.

Table III: Model configuration

Model	Function
Surface Tank Model	Infiltration to unsaturated layer, surface runoff, surface storage, evapotranspiration, rapid intermediate outflow
Aquifer Tank Model	Outflow from aquifer, aquifer loss
River Tank Model	River course discharge

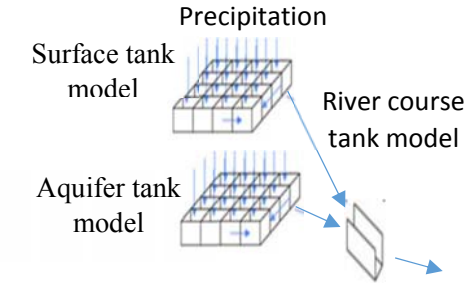

Fig. 2: Schematic representation of Two layer tank model

Degree Day Model:

By using this approach snow and glacier melt can be estimated, regardless of location and elevation of snow and glacier cover area (Hagg et. al., 2007). Snowmelt is a function of temperature lapse rate, degree day factor and critical temperature (Archer, 2003). First temperature is estimated at each grid cell by the equation

$$T_{est(i,j)} = T_{obs} + dE * \left(-\frac{dT}{dE}\right) \quad \text{..... (1)}$$

Where $T_{est(i,j)}$ is average estimated temperature in each grid, T_{obs} is average observed temperature of the station, dE is the difference of elevation of grid from nearest station and (- dT/dE) is the temperature lapse rate (TLR). The snowmelt can be calculated at each grid cell by the equation

$$Snowmelt_{(i,j)} = Snow\_Count_{(i,j)} * (T_{est(i,j)} - T_{cri}) * DDF \quad \text{..... (2)}$$

Where T_{cri} is critical temperature for melting snow and DDF is degree day factor.