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Snowmelt Runoff Investigation in Tosh Nala using Snowmelt Runoff Model (SRM)

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Keywords: snow melt runoff model (SRM), MODIS, SCA, rainfall contribution area (RCA).

I. Introduction

Glacier and snow cover area play an important role in hydrology of glacierised basin (Verbunt, M.et al., 2003). Snow plays a key role in the hydrologic cycle. Snow cover area is a fundamental parameter in the hydrologic cycle and climatology of the earth. Mountainous snow cover exists in many regions on earth and this snow cover can regulate climate cycle, global temperature, water cycle, monsoon intensity of inland areas and so on. In the Himalayas, the glaciers cover approximately 34,660 sq. km(Yongping, S. H. E. N et al. 2004) area and this is one of the largest concentrations of glacier-stored water outside the Polar Regions. Melt water from these glaciers forms an important source of run-off into the NorthIndian Rivers (perennial rivers of North India) during critical summer months. Himalayan glacier fed rivers supply water to one third of the world's population. Himalaya glaciers feed many significant rivers of Asia ensuring a year-round water supply to hundreds of millions of people in the Indian subcontinent and china (Taylor, 2005).These glacier, which release an estimated 8.6 million (Krishna, Akhouri Pramod.et al. 2011) cubic meter of water annually, have nourished seven great river of Asia – Ganga, Indus, Brahmaputra, Salween, Mekong, Yangtze and Huang ho.

In hydrology, snowmelt is surface runoff produced from melting snow. The snow melting caused by higher temperature accompanied with precipitation. Runoff from the glaciered basin is energy dependent, while that from a non- glaciered basin precipitation depend. Thus precipitation in glaciered basin is not directly converted into runoff, but rather is transformed and stored as ice and produce runoff during warm period. In western Himalayas, the temperature is lesser due to higher altitude and as a consequence the snowline in the western Himalaya is at a lower altitude than the eastern Himalaya. As distance from the sea is greater, both annual and diurnal range of temperature is greater in the western Himalayas. So it receives lesser precipitation than eastern Himalayas Anil Bose et al (2013). As in western Himalayas, the snowmelt commences in March, the snow line starts receding upwards and by the end of June to an altitude of 4,500m VajjaHari Prasad, et al. (2006). Changes in climate have rapidly impact on entire earth and also Himalayan glaciers. These glaciers are more sensitive due to changes the climate. According to NSIDC report, over the last 25 years, Gangotri glacier has retreated more than 850 meters (930 yards), with a recession of 76 meters (83 yards) from 1996 to 1999 alone. These process need detailed investigation and developed different model for estimating snowmelt runoff.

For snowmelt runoff modelling, two approaches are accessible i.e. energy balance approach and degree day method. The energy balance method needs more parameter. The degree day method are more applicable and needs less parameter. In this research used degree day method for estimation snowmelt runoff. The snowmelt runoff model (SRM) also referred to in the literature as the "Martinec Model" which is designed to simulate and forecast daily stream flow in mountain

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basin where snow melt is a major model; the main component is estimation of snow melt. SRM is designed to simulate and forecast daily stream flow in mountainous basins where snowmelt is a major runoff factor. Most recently, it has also been used to evaluate the effect of a changing climate on seasonal snow cover and runoff (Rango et al. 2008). For snowmelt runoff modelling, the two pragmatic approaches are accessible. They are energy balance approach and degree day method. In comparison to the energy balance approach, degree day approach is more practicable and needs minimum parameters for simulating snow & glacier melt runoff. It is widely used due to its being less complicated. The energy exchange at snowpack surface can be explained by four major components. They are shortwave radiation exchange and heat exchange, convective heat transfer and adventives heat transfer. These radiations exchange and heat transfer can be estimated if information on various parameters as cloud covers, albedo, wind, cloud temperature and dew point temperature are known Anderson et al. (1976). Information on these parameters is normally not available; therefore, degree-day approach is used for this study. Precipitation and temperature are the major factors for generating runoff in mountainous regions which are covered with snow and glaciers. More than 80% of applications of SRM have been performed by independent users. SRM also successfully underwent tests by the World Meteorological Organization (WMO) with regard to runoff simulation (WMO 1986). The snow cover area of a basin has a very important role to play in hydrological and climatological behavior (Baral and Gupta,1997). SRM can be applied in mountain basins of almost any size (so far from 0.76 to 917,444 km2) and any elevation range. A model run starts with a known or estimated discharge value and can proceed for an unlimited number of days, as long as the input variables - temperature, precipitation and snow covered area - are provided. As a test, a 10-year period was computed without reference to measured discharges (Martinec & Rango, 1986).

The present paper described the snowmelt process in a selected basin of Tosh Nala. The applied method includes the integration of remote sensing and geographic information system (GIS) and numerical modeling technique. Data measured in-situ, like show properties, precipitation, temperature etc, were used for the parameterization of the SRM model to calculate the contribution of snowmelt and rainfall of the basin for the year of 2006-2010. The snow covered area and its depletion with time were determined using satellite image. The general objective of this study is to simulate the daily snowmelt runoff in snowmelt season for the study area. Another objective of this paper is Simulation of river flows on daily basis in a summer season (21 March -10 July) and determining the contribution of snowmelt to the rivers.

II. Study Area

Tosh Nala is located on Kullu district at Himanchal Pradesh. The basin has total area including glacier is 375.46 square kilometer, with elevation ranging from 2163m to 6443m at mean sea level. Kullu is bounded on the north and east by Lahul and Spiti, on the south east by Kinnaur on the south by Simla. This catchment meets with the Parbati basin and finally becomes part of the Beas River at Bhuntar. Location map of the basin is given in Figure 1 and basin characteristics is given in Table 1.

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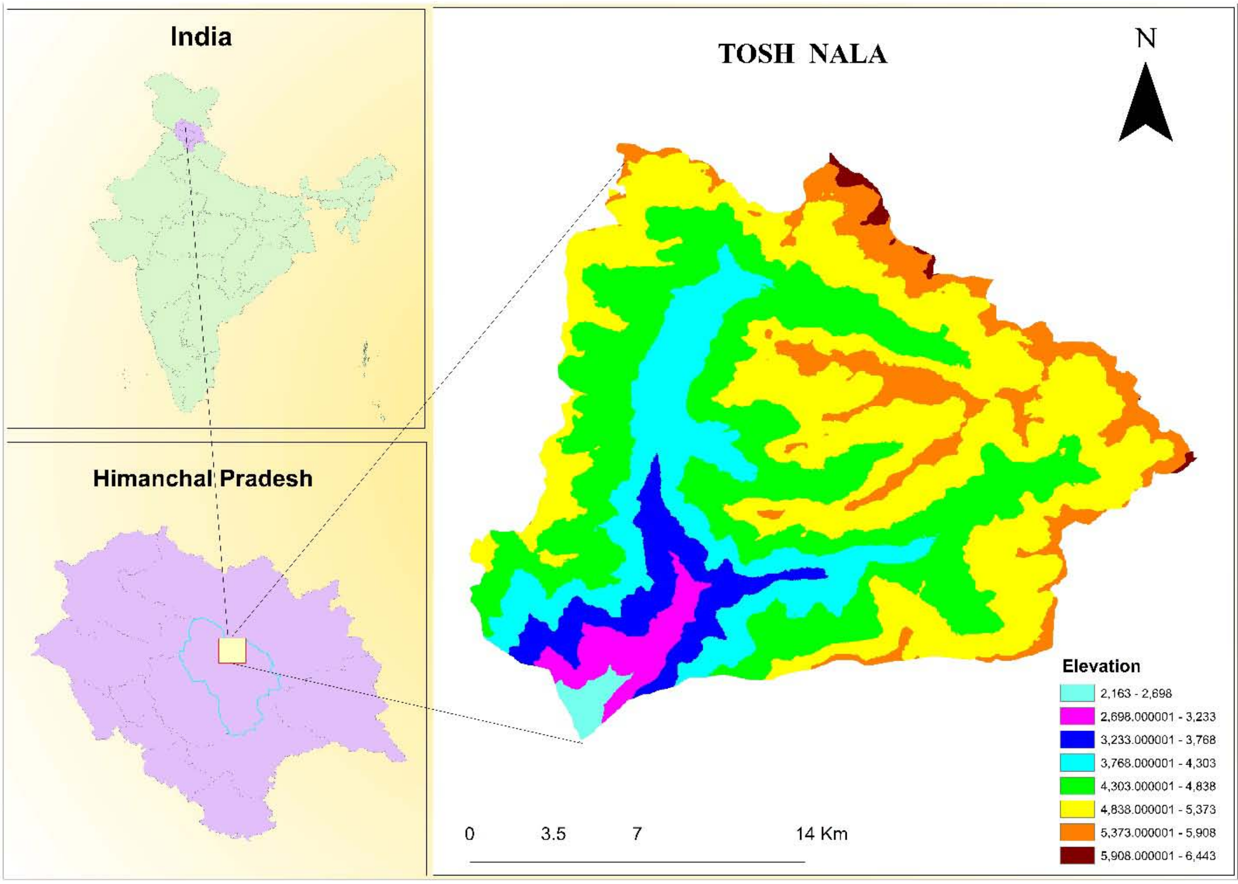


Figure 1: Location map of the Basin

Table 1: Mean hypsometric elevation and area for different elevation zone

Zone	Elevation range(m)	Mean hypsometric elevation(m)	Area(km^2)
Zone 1	2163-2698	2493	3.470323
Zone 2	2698-3233	3003	11.48433
Zone 3	3233-3768	3522	21.49467
Zone 4	3768-4303	4074	51.67062
Zone 5	4303-4838	4588	115.8388
Zone 6	4838-5373	5101	132.0446
Zone 7	5373-5908	5522	37.39416
Zone 8	5908-6443	6059	2.057855

III. Materials and Methods

a) Data Requirements for SRM Model

i. Satellite Datasets

For the Snowmelt runoff modelling, need a fixed and limited data i.e. Meteorological and Satellite data. Meteorological data such as Temperature and Precipitation data. MODIS (Moderate Resolution Imagining Spectroradiometer) is the 36-channel spectroradiometer on board AQUA satellite from NASA's Earth Observation System(http://nsidc.org/cgibin/snowi/search.p1). The MODIS/AQUA snow cover 8 Day Global 500m grid (MYD10A2) selected for this study comprises of data fields for snow cover extents over an 8 day repetitive period with approximately 500m spatial resolution entirely covering the Tosh Nala catchment. The catchment is delineated using the ASTER (Advanced Space borne Thermal Emission and

Reflection Radiometer) Digital elevation model downloaded from the USGS (U.S. Geological Survey). For detailed analysis of the cryosphere distribution over the study area, eight different elevation zones were extracted from the DEM. Table 1 shows the information about the satellite datasets used in this study such as product, spatial resolution, number of images and source.

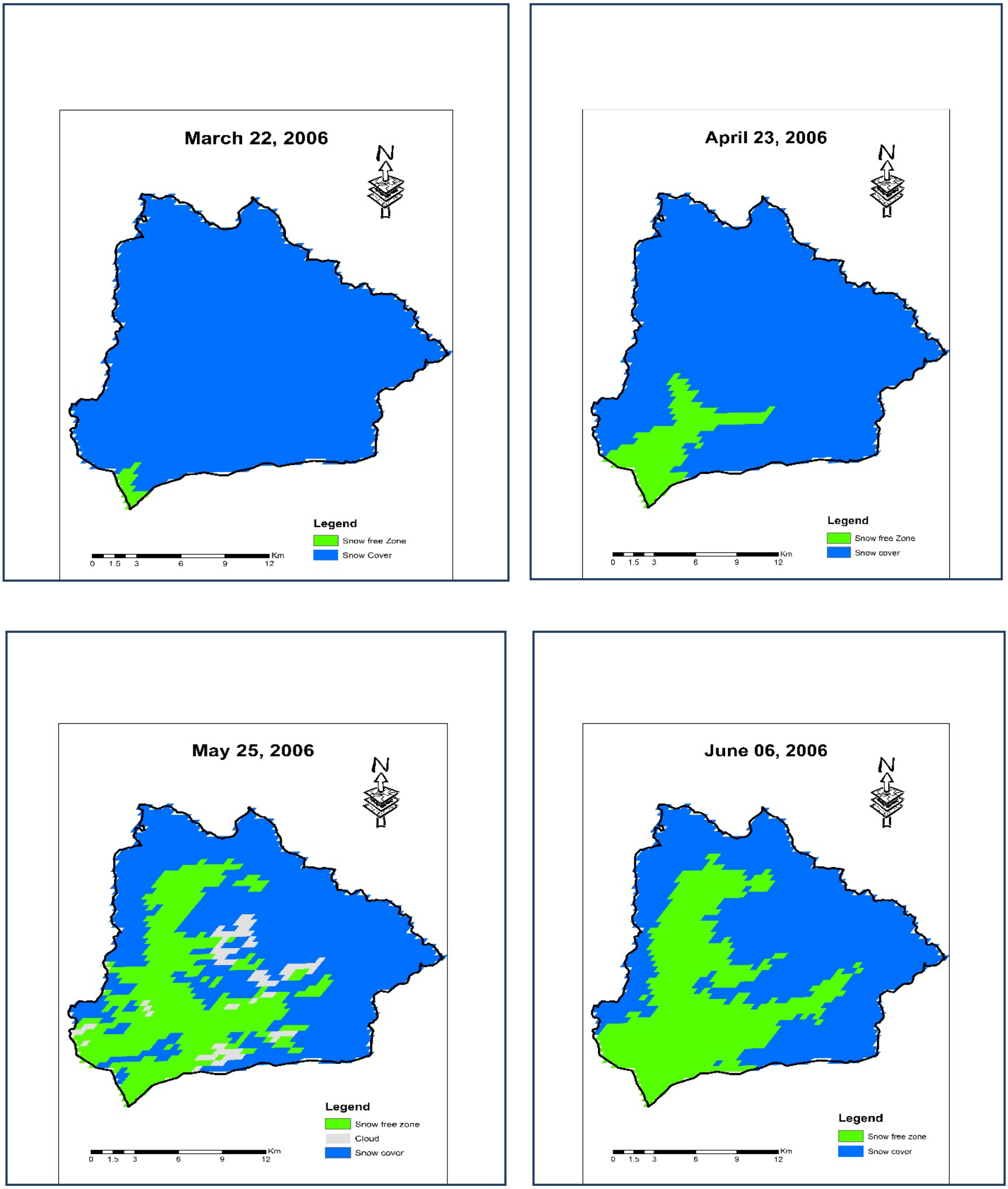


Figure 2: MODIS (MYD10A2) satellite images presenting the snow cover area for each month (summer season) in the Tosh Nala in the year 2006

Table 3: Description of Satellite data

DATA	Spatial Resolution	No. of Images	Source
MODIS (MYD10A2)	500m	70	NASA (National Snow and Ice Data Center Distribution Active Archive Center)
ASTER (DEM)	30m	—	USGS (US-Geological Survey)

ii. *Meteorological Data*

Meteorological data including temperature and precipitation are very important variables for estimation of runoff in snow and glacier covered area. When air temperature is raise, atmospheric water vapours fall into earth surface. Meteorological data have been taken from IISc. Bangluru. Maximum and minimum air temperatures and precipitation data from 2006 to 2010 available in daily format.

iii. *Description of the SRM Model*

The Snowmelt Runoff Model (SRM) is a conceptual, deterministic degree–day (temperature index method) model used to simulate and forecast daily rainfall and snowmelt runoff in mountainous regions. It can be usefully applied for the estimation of the consequences of climate change on snow cover and runoff from the alteration of the percentage of snow cover and temperature. SRM was designed by Martinec (1975) for small basins in Europe. The availability of remote sensing snow cover data provides flexibility to apply this model in large basins. The SRM has been applied in the Ganges River Basin, which has an area of 917,444 km2 and elevations up to 8,840 m (Martinec et al. 2007). This model has been used successfully in more than a hundred catchments located in different regions of the world. SRM was effectively tested by the World Meteorological Organization (WMO) for daily stream flows simulation (WMO 1986) and moderately to simulate the circumstances of real-time runoff predictions (WMO 1992). Initially, the user must provide a known or gauge stream flow value as the initial condition, and then it can be run according to the length of input data set variables, such as precipitation, temperature, and snow-covered area (SCA). Furthermore, the model requires a number of basin physical characteristics such as the basin area, zone area (in the case of zone-wise application) and the hypsometric (area–elevation) curve. The main Equation, on which the algorithm of the model is based, computes the water generated from rainfall and snowmelt, overlaid on the computed recession flow and converts this into daily stream flow from the catchment.

$$Qn+1 = [Csn \cdot an\ (Tn + \Delta\ Tn)\ Sn + CrnPn]A*10000/86400\ (1-kn+1) + Qn\ kn+1$$

Where

Q = average daily discharge [m^3s^{-1}]

c = runoff coefficient expressing the losses as a ratio (runoff/precipitation), with Cs referring to snowmelt and Cr to rain

a = degree-day factor [cm °C^{-1} d^{-1}] indicating the snowmelt depth resulting from 1 degree-day

T = number of degree-days [°C d]

Δ T = the adjustment by temperature lapse rate when extrapolating the temperature from the station to the average hypsometric elevation of the basin or zone [°C d]

S = ratio of the snow covered area to the total area

P = precipitation contributing to runoff [cm]. A preselected threshold temperature, TCRIT, determines whether this contribution is rainfall and immediate. If precipitation is determined by TCRIT to be new snow, it is kept on storage over the hitherto snow free area until melting conditions occur.

A = area of the basin or zone [km^2]

k = recession coefficient indicating the decline of discharge in a period without snowmelt or rainfall

k = Qm+1/Qm (m, m + 1 are the sequence of days during a true recession flow period).

n = sequence of days during the discharge computation period. Equation is written for a time lag between the daily temperature cycle and the resulting discharge cycle of 18 hours. In this case, the number of degree-days measured on the nth day corresponds to the discharge on the n + 1 day. Various lag times can be introduced by a subroutine.

10000/86400= conversion from $cm \cdot km^2\ d^{-1}$ to $m^3\ s^{-1}$

b) Input Parameters

i. *Runoff Coefficient*

Runoff coefficient accounts the runoff losses, i.e. the difference between the available water volume (snowmelt + rainfall) and the outflow from the basin. The runoff coefficient is different for snow and rain. The SRM model can accept separate runoff coefficient for snow and rain. Runoff coefficient takes care of such losses. Runoff coefficient can vary throughout the year due to changing soil moisture, vegetation and snowpack condition. For this present study, runoff coefficient used ranging from 0.6 to 0.8 (Kulkurni,2002).

ii. *Degree-day factor*

The degree day factor used to obtain snowmelt depth. The degree-day factor converts the number of degree –days into the daily snowmelt depth as follows;

$$M = aT$$

Where

M=Daily snowmelt Depth (cm)

a= Degree day factor (cm C d)

T=Number of degree Days (Cd)

Normally, calculation of melt factor (a) need to density of snow and density of water. So these type of absence of data, in this study used standard value of the degree day factor which is 0.5cm C d (Kulkarni, 2002) for summer season.

iii. *Temperature lapse rate*

Temperature decrease with the increase in altitude above mean sea level with a certain rate called temperature lapse rate. Since temperature variation is major factor for melting of snow/ice at high mountain peaks, so lapse rate is an important parameter in hydrological model such as SRM to determine the temperature variation with elevation. The lapse rate can be predetermined from historical data if temperature stations at different altitudes are available. Otherwise it must be evaluated by analogy from other basins or with regard to climatic conditions. The temperature lapse rate is the change in temperature with altitude. It is used to adjust temperature measured at the basin reference elevation to each zones hypsometric mean elevation. In this present study was used a lapse rate of 0.65°C per 100m.

iv. *Critical Temperature*

The critical temperature is pre-selected value of temperature which determines whether the precipitation event is rain or snow. In Win SRM, the critical temperature is used only in the snow melt season in order to decide whether precipitation is immediately contributes to runoff (if rain), or having delayed contribution (if snow). Model keeps the newly fallen snow in storage until it is melted on subsequent warm days. Generally, critical temperature is kept higher than the freezing point and diminished to 0 °C. Critical temperature was used in this study is 0 to 2^{0}C.

If Tm >=2^{0}C, so all precipitation is rain, if Tm<= 0^{0}C, all precipitation is snow. If Tm <= 2^{0}C and Tm >=0^{0}C, so precipitation will be considered as a mixture of rain and snow (Charbonneau, 1981).

v. *Rainfall contribution area, RCA*

Rainfall contribution area helps to determine whether the rainfall induced runoff is added to snowmelt induced runoff only from the snow-free area or from the entire zone area. For *RCA* = 0, it is assumed that rain falling on the snowpack early in the snowmelt season is retained by the snow which is usually dry and deep, and rainfall contributes to runoff only from the snow-free area. At some later stage, the snow cover becomes ripe (*RCA* = 1) and if rain falls on this snow cover, it is assumed that the same amount of water is released from the snowpack so that rain from the entire zone area contributes to runoff.RCA equals to 0 or 1 or combination of 0 and 1 were tried in this study.

vi. *Recession Coefficient, k*

The recession coefficient is an important parameter of SRM since (1-*k*) is the proportion of the daily melt water production which immediately appears in the runoff. Analysis of historical discharge data is usually a good way to determine "*k*". It varies from 0.73 to 1 for Tosh watershed.

IV. Methodology

In the SRM model used some type of variables and parameters. After to do the project, necessary to understand these variables and parameters and its analysis. The main step of the research are as;

- Analysis of metrological data such as temperature data and precipitation data from the station located inside and outside the study area and calculating model parameters for SRM such as temperature lapse rate.
- Using ASTER DEM (Digital elevation model), the study area divided into different elevation zones, the interval between each zone is 500 meter. The study area is divided into different elevation zones because in the mountains basin, every elevation zones has different air temperature, so the present study used different elevation zone recommended through SRM.
- The physical characteristics of the basin are necessary for the determination of the model parameter such as extrapolation of temperature data for different zones.
- Computation of zonal degree day from temperature lapse rate, mean hypsometric elevation and altitude of metrological station for adjusting the temperature for each zone.
- Computation of degree day from temperature data. This is used in the model for the calculation of daily snowmelt depth.
- The SRM model require the monitoring snow cover in the selected basin. A series of image from MODIS (MYD10A2) (AQUA platform) sensor is to be used for monitoring the snow cover extent.
- Analysis on the snow cover image, during summer season, in this section analysis about how much area are changes in the summer season with understand through satellite images and graphs.

- Simulation of the runoff using SRM model. The following variables are needed such as daily data of precipitation, daily data of temperature, snow cover area. The model parameter such as degree day factor, runoff coefficient for snow, runoff coefficient for rain, temperature lapse rate, critical temperature, rainfall contributing area, recession coefficient. In this present study some parameter are directly taken from standard value and some parameter are calculate through basin parameter.
- Analysis about the changes in different year for the discharge from the basin for instance how much water flow from the basin in year of 2006, 2007,2008,2009,2010.

V. Result

In this study, the snowmelt runoff model which is based on degree day method was used to simulate daily discharge from Tosh Nala, Himanchal Pradesh. The simulation period from 2006 to 2010 and each year simulation period from 21 March to 10 July (summer season). The basin was divided into 8 elevation zones. The SRM model input snow cover only in decimal (fraction) of zonal snow which was derived from the area of snow cover divided from total area of the basin. In this current study used MODIS daily 8 day data and the middle days snow cover data obtained from periodical snow cover method. In this periodical snow cover method linear interpolation method. The critical temperature was considered 2^0 C, degree day factor was used 0.5 (*Anil V. Kulkurni et al, 2002*). Cs and Cr was also considered 0.6 and 0.7 (*Anil V. Kulkurni et al, 2002*) respectively.

The model suggest stream runoff in summer as average an each year 20 to 40 m^3/s for Tosh Nala. The simulated discharge flow ranged from 3.93 m^3/s to 68.93 m^3/s. in each year. The stream flow start with low from March and starting from July, it went too high.

Table 4: Snow cover pattern for 2006-2010

Year	Maximum SCA (%)	Minimum SCA (%)
2006	97.36 (22, March)	54.59 (07, April)
2007	97.90 (22, March)	56.58 (25, May)
2008	96.95 (14,April)	43.01 (09, June)
2009	94.30 (07, April)	71.66 (01, May)
2010	93.48 (22, March)	57.68 (02, June)

From the table 1, the snow cover in the Tosh Watershed is maximum in 2006 i.e. 97.36 % on 22-03-06 and lowest is 54.59 % on 07-04-2006 and the same data in 2010 the highest snow cover is 93.48% and lowest is 57.68 %. For this study area, the highest snow cover are found in the year of 2006, 2007, 2008, 2009, 2010 are 97.36 %, 97.9 %, 96.95 %, 94.30 %, 93.48 % respectively, minimum snow cover for tosh watershed are respectively; 54.59 %, 56.58 %, 43.01 %, 71.66 %, and 57.68%.

a) *Discharge data analysis*

The snowmelt runoff model simulate the discharge from the Tosh Nala during the snowmelt season (21 March to 10 July) from 2006 to 2010. The result of average discharge data in the year of 2006, 2007,2008,2009,2010 are 20.50m^3/s, 25.35m^3/s, 23.86m^3/s, 28.57m^3/s, 40.029m^3/s respectively. According to the result the process of snowmelt runoff going on ascending order to year by year.

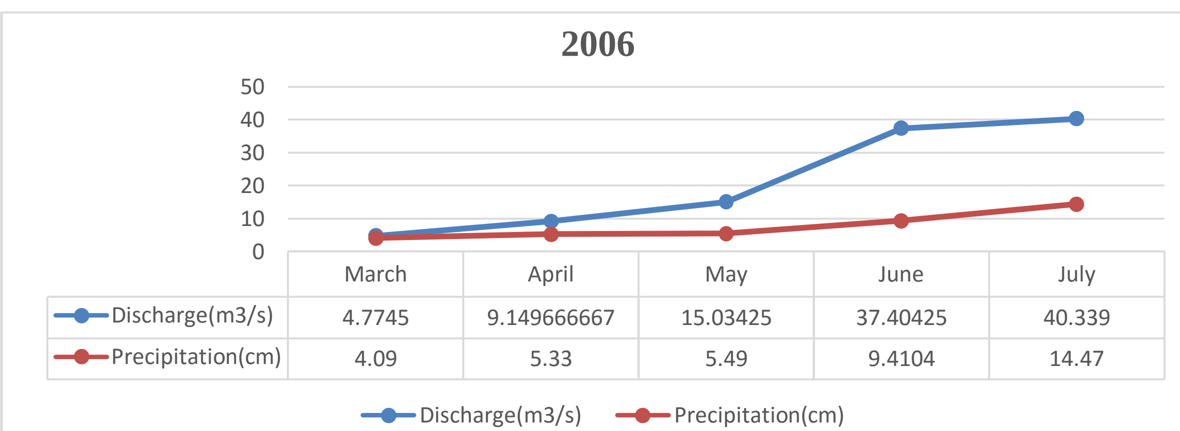


Figure 3: Compares the monthly precipitation and monthly discharge

It means the stream flow at Tosh Nala gradually exceed due to the snowmelt runoff, but in the year of 2010 that has occur highest stream flow from this basin because of in this year occurs highest precipitation comparison among other previous year. During this summer season the precipitation appears to be more influencing factor than temperature because in this season the precipitation has almost high. Above the figure based on data 2006. As shown in the figure, monthly average discharge in m^3/s and monthly rainfall in cm. The discharge is change rapidly in the month of May and June of the year of 2006 because of in these month precipitation range between 5cm to 14.47cm and after these day the temperature is increased.

The simulated discharge of the Tosh Nala basin, below the following figure are represented the simulated discharge from 2006 to 2010.

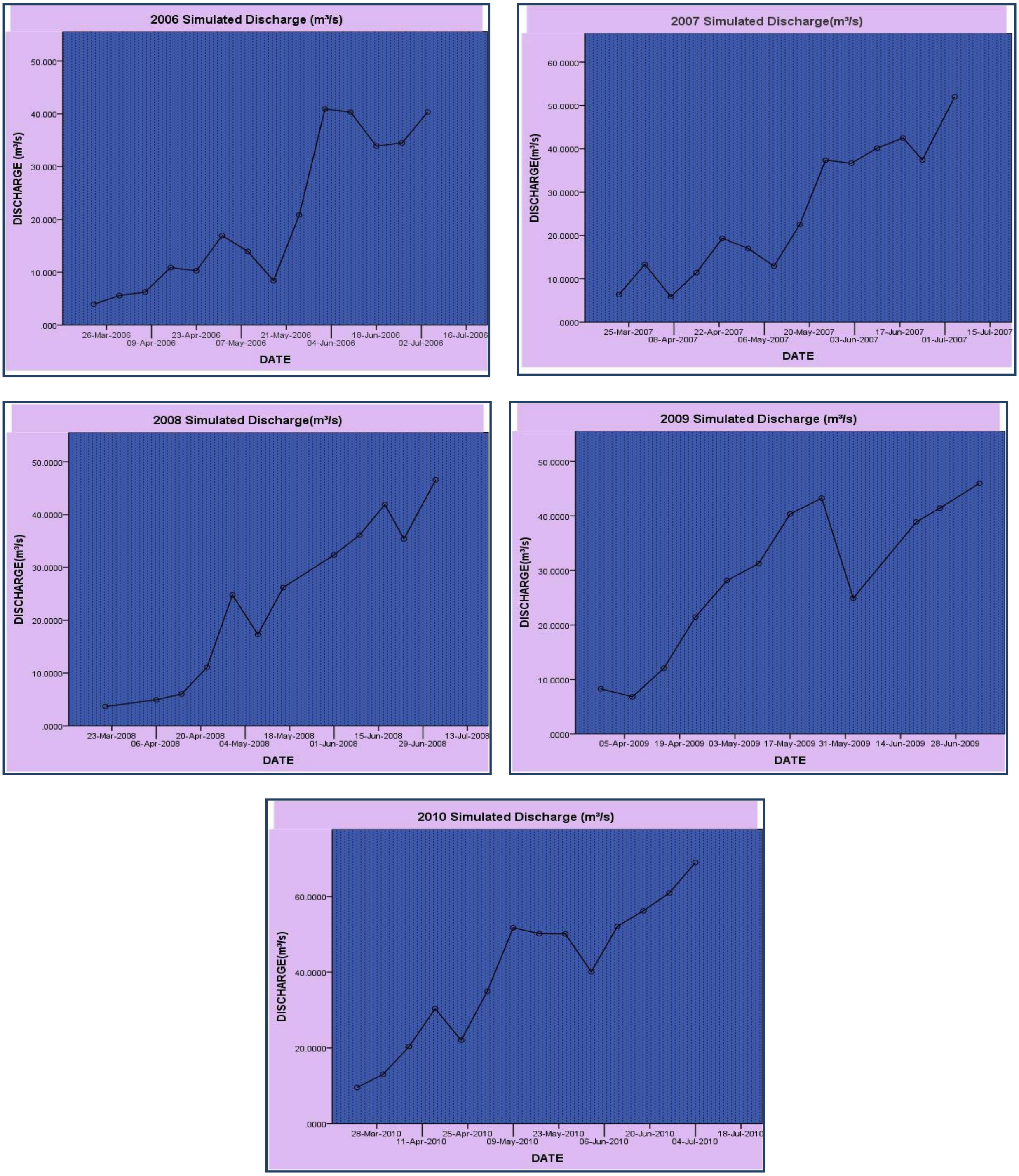


Figure 4: Simulated discharge from Tosh Nala

b) Contribution of snowmelt in runoff

Distinction between rain and snow is important in snowmelt runoff model because the contribution of rain to runoff can be see immediately. As the melting season (March to July) able snow cover gets depleted and it start limiting the snowmelt runoff more than the temperature snowmelt contributing to the runoff is usually delayed. In this study area the precipitation input may be underestimated because of the precipitation station is in lower altitude. During this summer period most of seasonal snow cover (Zone 1 to zone 3) at lower to medium elevation is melted and the snow melt runoff mainly comes from snow cover at the high elevation (zone 4 to zone 6) and zone 7 and zone 8 are the glaciered area. So from these two zones are released too less discharge. Below the figure () represent the melt depth and contribute runoff, also represent from elevation zone 4 to zone 6, contribution of snow melt in the stream runoff is higher compared with the direct rainfall and zone 1 to zone 3 contribution of direct rainfall in the stream runoff is higher compared with the snowmelt.

The snowmelt contribute increased from May due to the increases in the temperature of the basin. There is a definite response in simulated snowmelt runoff to seasonal snow cover change i.e. an increasing discharge is associated with a decreases of snow cover.

c) Comparison between snow cover depletion curve and average temperature

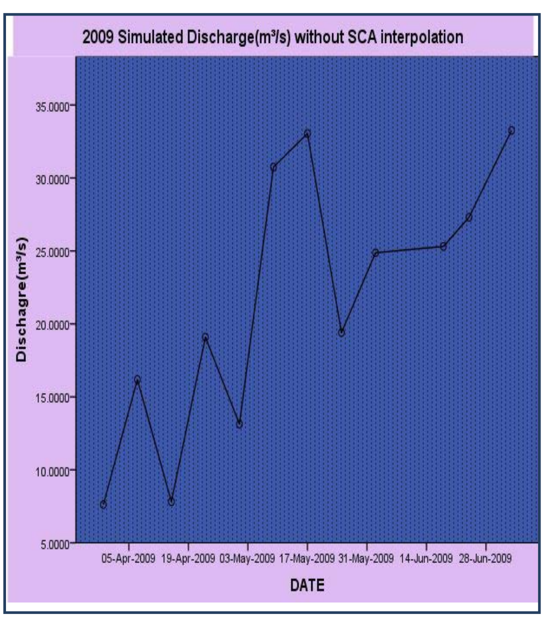
In this present study, was used MODIS aqua 8 day snow cover data and daily 8 day snow cover data were interpolated by the method of linear interpolation for obtaining the middle days of these snow cover. In this section represent the relation between zonal snow cover (%) and extrapolated temperature by the lapse rate. Below in this table shown the average snow cover (%) in each zone for each month (summer season) and average temperature for each zone of the year of 2010.

Table 7: Monthly average SCA% and average temperature of the year of 2010

Months	Avg. SCA (%) (Zone 1)	Avg. SCA (%) (Zone 2)	Avg. SCA (%) (Zone 3)	Avg. SCA (%) (Zone 4)	Average SCA (%) (Zone 5)	Avg. SCA (%) (Zone 6)	Avg. SCA (%) (Zone 7)	Avg. SCA (%) (Zone 8)	Avg. Tem. (^{o}C)
March	0.155	0.888	2.528	12.21	29.52	33.23	8.802	0.455	20.74
April	0.211	0.721	1.675	10.75	29.89	34.32	9.36	0.435	20.35
May	0.197	0.868	2.01	9.25	29.23	33.95	9.169	0.451	23.11
June	0.084	0.199	0.511	4.71	26.24	29.22	7.66	0.368	23.43
July	0	0	0	0	25.945	27.48	7.355	0.3	25.53

VI. Sensitivity Analysis

The snowmelt runoff model is sensitive to its parameter but it is mainly more sensitive to input variables i.e. snow cover, temperature data and precipitation. It is also more sensitive to temperature lapse rate. However degree day factor and runoff coefficient for snow should not be ignored for the best result. Before interpolation for the snow cover depletion curve used the MODIS daily 8 day snow cover data for the model. It means for this study area has only snow cover data available are interval between 8 days. For the SRM model needs to daily fraction of snow cover for input.



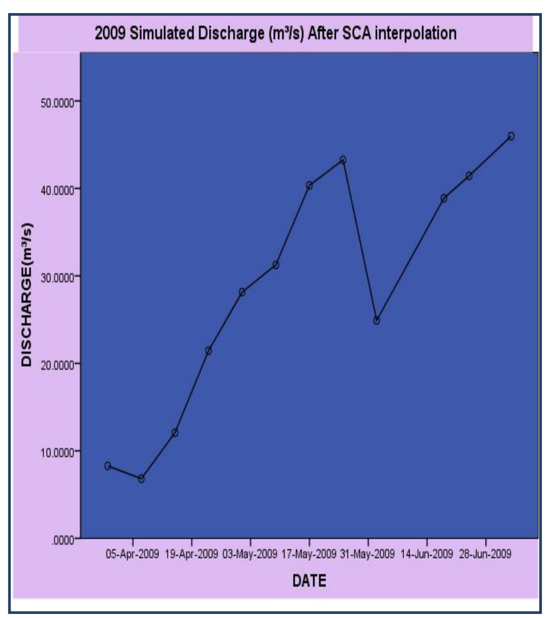


Figure 5: Difference between without SCA interpolation discharge and after SCA interpolation resulted discharge

In this section discuss about the how the snow cover is sensitive to SRM model. For instance for the year of 2007, the discharge data graph is too distorted. It means the discharge curve went on zig- zag shape and then after interpolation of the snow cover the discharge curve is keep regular. Below the figure we can see the clear difference between without interpolation of snow cover resulted discharge curve and after interpolation of snow cover resulted discharge curve.

a) *Sensitivity for rain and snow runoff coefficient*

The acceptable range for the rain runoff coefficient are the same as the snow runoff coefficient but the result of the rain runoff coefficient test differ substantially from the test on the snow runoff coefficient. At the start of the snow melt season, losses are usually very small because they are limited to evaporation from the snow surface, especially at high elevation. In the next stage when some soil becomes exposed and vegetation grows, more losses must be expected due to evapotranspiration and interception. Towards the end of the snow melt season, direct channel flow from remaining snowfields and glacier may prevail in some basins, which leads to a decrease of losses and to an increase of runoff coefficient. In this study, when put the Cr is 0 and Cs is 0.7 runoff volume was changed by 30% and when put the value of Cs is 0 and Cr is 0.7, the runoff volume was changed by 55% (went down). When put the value of snow runoff coefficient and rain runoff coefficient is 0, the resulted volume and discharge went fell down.

So the snowmelt runoff model (SRM) has more effect on the output (sensitive). According to this study temperature lapse rate, runoff coefficient for snow, runoff coefficient for rain, and snow depletion curve are too sensitive for this model.

b) *Assessment of Result Accuracy*

The SRM computer program includes a graphical display of the computed hydrology and of the measured runoff. A visual inspection shows at the first glance whether the simulation is successful or not but this research we have not measured discharge data. So checking of the accuracy of the simulation compared the result adopted (Kulkarni et. al, 2002, snow and glacier melt runoff model to estimate hydropower potential).

Table 8: comparison between (Kulkarni et. al, 2002) and simulated data

Referenced Data		Simulated Data				
Season	2002	2006	2007	2008	2009	2010
Autumn	16.49					
Winter	5.30					
Summer	21.08	20.50	25.35	23.86	28.57	40.029
Monsoon	49.13					

VII. Conclusion

Snowmelt runoff modelling at Tosh Nala is done through remote sensing data and metrological data using degree day method. Parameter such as melt factor, runoff coefficient, critical temperature, temperature lapse rate, recession coefficient and variable such as snow cover, daily temperature, daily precipitation.

During summer season high elevated catchment in this study area, two higher zone are glaciered area, which is not change according to months and almost of six zones are covered with snow in starting of summer season and then gradually melting months to months. Temperature and precipitation are found major factor in contributing runoff. Temperature data suggest that the melting season start from March to starting of the July.

Result have represent that:

- The SRM model is a suitable tool to calculate runoff from snow using metrological data and remote sensing derived snow cover maps.
- Satellite data accompanied with GIS method can be used to define the snow cover area and define the elevation zone. ASTER has been very useful in getting the basin boundary and in the snow cover estimation in different elevation zone of 500m interval.
- The SRM model is more sensitive to temperature lapse rate, runoff coefficient and snow cover depletion curve.
- The stream flow discharge is exceeds gradually year by year i.e. 2006 to 2010, the discharge is 20.50, 25.35, 23.86. 28.57, 40.029 m^3/s respectively.
- MODIS snow cover data is the most useful in this study because it is provided direct snow cover data for the study area. We have no need to any classification.

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