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ASSESSING THE IMPACT OF GEOMORPHOLOGY AND LAND COVER ON SURFACE RUNOFF OF A WATERSHED

Shakeel Ahmad Bhat and Shakil Ahmad Romshoo
Dept. of Geology and Geophysics, University of Kashmir, Hazratbal, Srinagar, Kashmir (India)-190006

ABSTRACT

Land cover and geomorphological characteristics of a basin represent physical and morphological attributes that have a direct bearing on the hydrologic regime, annual water production, flood volumes and soil erosion. The current study was conducted in a watershed upstream of the Rembiara River, a main tributary of the Jehlum basin. In this study, a variety of data including multi-temporal satellite images, digital elevation model, soil map, topographic maps, hydro-meteorological data and various other thematic data from various sources were used as data sources. LANDSAT ETM (2001) and MSS (1976) were used to extract the land cover information of the area. Digital elevation model at 20 m resolution was generated in a GIS environment. The 25 years time series of meteorological data was analyzed for SWAT model input to simulate the surface runoff in the watershed. Results indicate that there is an increase in the runoff from 1976 to 2001 as a result of change in the land cover in the study area. The runoff was 79.905 mm during the year 1976 and it increased to 91.042 mm in the 2001. These results reveal that hydrological processes have got disturbed during last 25 years in this high altitude watershed. Detailed Morphometric analyses have been carried out using 20-meter resolution Digital Elevation Model. The analyses of the morphometric parameters indicate that the watershed is prone to flooding in the event of any high intensity rainfall event. The morphometry and the hydrological model provide valuable insight into the hydrological response of the ungauged watershed and can be a very useful watershed prioritization.

Key words: - SWAT model, DEM, Morphometry, Drainage density, runoff, Taudem

INTRODUCTION

Geomorphological, land cover and climatic characteristics of a basin govern its hydrological response to a considerable extent. Geomorphological characteristics of a basin represent physical and morphological attributes that are employed in synthesizing its hydrological response (Bhaskaran *et al.*, 2002, Miller, 1953,) These attributes have direct effects on the hydrological regime, annual water production, flood volumes, soil erosion and vegetation cover (Chalam, 1996, Muley, 2002). Also, recently due to anthropogenic influences, most of the basin has undergone land use and land cover changes. The land use/ land cover changes within the basin can have significant impact on runoff characteristics (Sharma 1999, Dilip *et al.*, 2000). Hence, linking the geomorphologic parameters with the hydrologic characteristics of the basin can lead to a simple and useful procedure to simulate the hydrologic behavior of various basins, particularly the ungauged ones (Longbein, 1947). The current study was conducted in the upstream of Rembiara River that drains whole Pulwama district of the J&K state. The catchment is experiencing recurrent floods during the last few decades and therefore it is important to study the influences of land cover, Morphometry and other hydro-Geomorphological processes on the flood characteristics of the basin. In this study, a variety of data including multi-temporal satellite images, digital elevation model (DEM), soil map, standard 1:50000 scale topographic maps, hydro-meteorological data and various other thematic maps obtained from various sources have been used as data sources. LANDSAT ETM (2001) and LANDSAT MSS (1976) geometrically corrected satellite images were used to identify the land use/ cover and its change during the last 25 years. Digital elevation models at 20 m resolution, from 1: 50000 scale topographic maps were generated using contour information at 20m intervals. Digital elevation model was used to generate elevation, aspect and slope information of the watershed. Mapwindow, Arcview, Taudem and self-developed programs have been used to generate stream network. A detailed Morphometric Analysis has been carried out using the 20m resolution Digital Elevation Model (Tarboton *et al.,* 1991, Tarboton, 2003, Nag, 1998). The SWAT model was used to simulate the surface runoff from this watershed. (Arnold *et al.*, 1994).

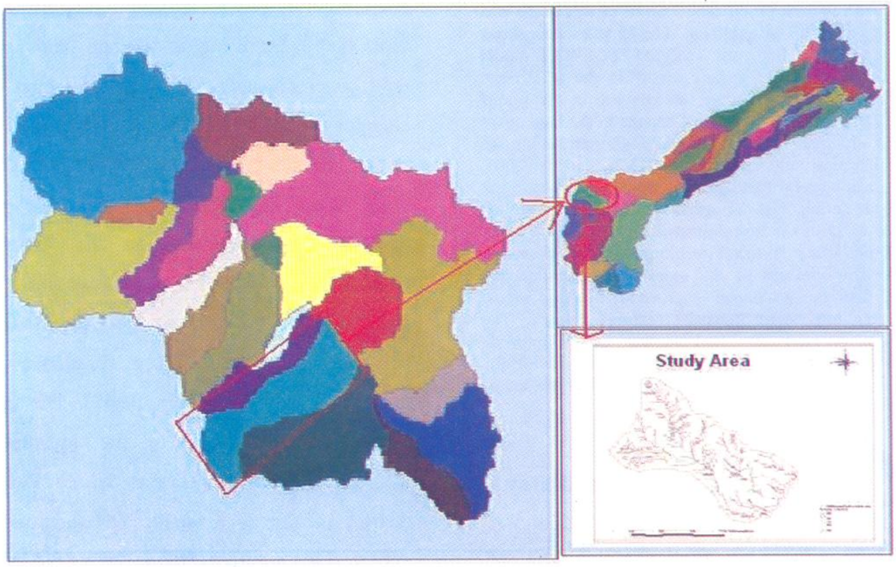

Fig. 1. Shows Location of study area

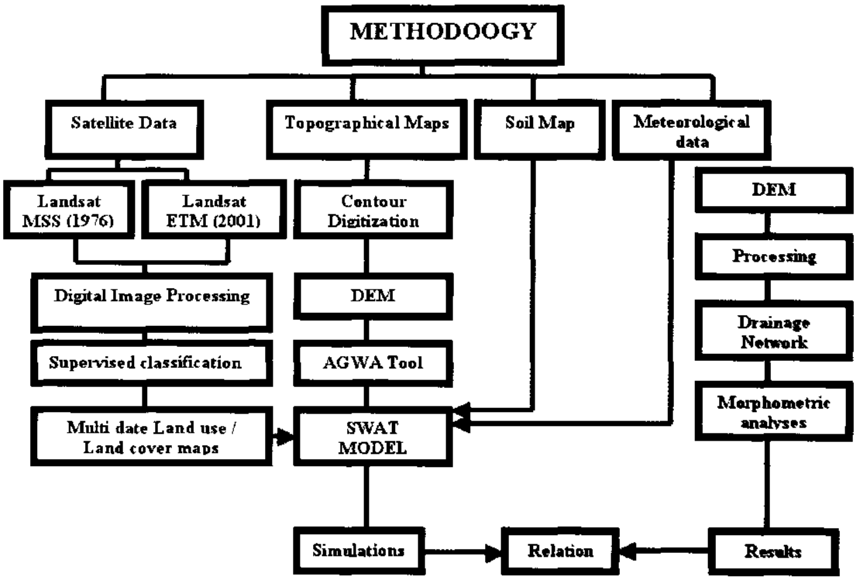

Fig. 2. Flow chart showing the research

STUDY AREA

A watershed of Rembiara catchment of Jehlum basin, located between longitude 74°32, and 74°33 E, and Latitude 33°39 and 33°40 N, has been selected for detailed Hydro-geomorphologic analysis and to see the impact of change in land cover on surface runoff using hydrological modeling. the areal extent of the watershed spreads over 12.49 Km. (Fig. I)

DATA SOURCES

In the study, a variety of data including satellite images of LANDSAT ETM, 2001 and MSS 1976, Digital Elevation Model (DEM), soil map, and standard 1:50000 scale SOI topographic maps, hydro-meteorological data of 25 years and various thematic maps obtained from various sources have been used as data sources together with ground truth.

DATA ANALYSIS

The detailed methodology employed for assessing the impact of land use/land cover change on the surface hydrology is illustrated at Fig. II. The following paragraphs broadly elucidate the steps involved in the data analysis for simulating the hydrological regime of the watershed.

Land Use/Land Cover

To generate the multi-date land use and land cover maps of the study area from two date satellite data, different image processing techniques were used. These include data pre-processing and post-processing image analysis. Supervised classification techniques based on maximum likelihood algorithms were used to extract land cover information from the satellite data.

Generation of Digital Elevation Model

For generating DEM, the topographic maps at 1:50,000 scales with 20m and 40m contour interval, of the study area were used for DEM generation. The maps were digitally registered by using an image-to-map registration algorithm. 48 Ground control points (GCPs) common to scanned images and the topographic maps were registered to sub-pixel accuracy using third order polynomial transformation. Every contour was digitized by line theme and with every digitized contour; an associate elevation attribute was added. After digitizing all contours of the study area the data was translated into e00 format. This e00 format was then imported to arc interchange format to create a continuous raster surface by interpolating the line elevation values. Using Surface generation tool, the 20m resolution DEM of the study area was generated using interpolation techniques.

Soil Map

The coarse resolution existing soil map of the area was improved with the help of the satellite image of Landsat ETM 2001 using on screen digitization techniques. Accordingly, soil map was refined as per the requirement of the SWAT model used to simulated the hydrological response.

Meteorological Data

A time series of hydro-meteorological data, collected from various Deportments of the J&K state, was formatted for analysis as per the requirements of the SWAT model. The data was used for calculating minimum, maximum, average, standard deviation, probabilities of dryness and wetness, kurtosis, skewness etc of the hydro-meteorological parameters for simulating the hydrologic response.

Morphometric Analyses.

Detailed Morphometric analyses have been carried out at 20-meter resolution Digital Elevation Model using Taudem software and self developed programs. In the present study, the geospatial analysis for the ger eration of morphometric parameters namely stream order, stream length, mean stream length, stream length ratio, bifurcation ratio, mean bifurcation ratio, relief ratio, drainage density, stream frequency, drainage texture, form factor, circularity ratio, elongation ratio, length of overland flow, basin length, shape factor, compactness coefficient, texture ratio etc was carried out using high resolution DEM.

RESULTS AND DISCUSSIONS

Land use / land cover mapping: -

The multi- date land use/ land cover maps have been prepared using the methodology described above. The major land cover classes found in the area include exposed rock surfaces, shrubby lands and pastures. The area under each class is shown in Table-I. From the change detection analysis, it is estimated that in the year 1976, the watershed was having 7.23 Km^2 areas under exposed rock surfaces followed by 3.83 Km^2 under shrubby lands and 2.72 Km^2 under pastures, while as in the year 2001, analysis shows that exposed rock surfaces occupies 8.60 Km^2, shrubby lands covered 4.77 Km^2 and pastures having area of 0.21 Km^2. Over all, the results show that there is increase in the exposed rock surfaces and decrease in other two classes, it may be due over grazing or any adverse anthropogenic and/or natural phenomena.

Hydrologic Response:

SWAT is a river-basin, or watershed-scale model developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields on large, complex watersheds with varying soils, land use, and management conditions over long periods of time (Arnold *et al.*, 1994). The model combines empirical and physically based equations, uses readily available inputs, and enables users to study long-term impacts. SWAT is defined by eight major components: hydrology, weather, erosion and sedimentation, soil temperature, plant growth, nutrients, pesticides and land management. The schematic operation of the model is shown in the Fig. III.

Table I: Shows the Land use/Land cover Information in the Study area in 1976 and 2001

S. No	Class Nmae	Area km^2	Area %
	Land cover 2001		
01	Exposed Rock Surface	7.6	60.85
02	Shrubby Lands	4.68	37.47
03	Pasture	0.21	1.68
	Land cover 1976		
01	Exposed Rock Surface	6.23	49.88
02	Shrubby Lands	3.54	28.34
03	Pasture	2.72	21.78

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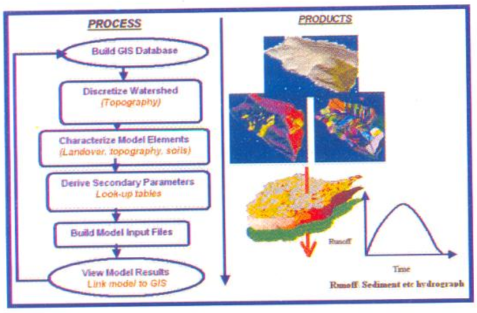

Fig. 3. **Conceptual Operation of the SWAT model**

The model was run for two years (1976 and 2001) simulating the impact of land use and land cover on hydrologic response using constant soil data and meteorological data The various input data for the model have been generated as per the requirement of the model. The various input geo-spatial data generated for the model are shown in Fig IV to X. The model simulations show an increase in the surface runoff as a result of change in the land use and land cover between 1976 and 2001 data.

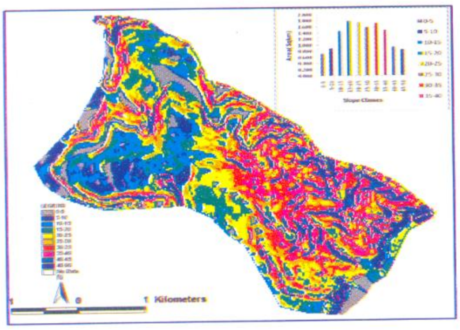

Fig .4. Slope map of the study area

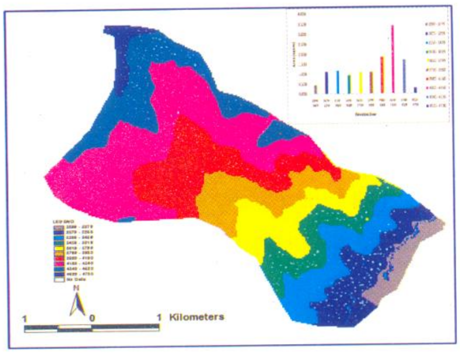

Fig .5 Elevation Zones of the study area

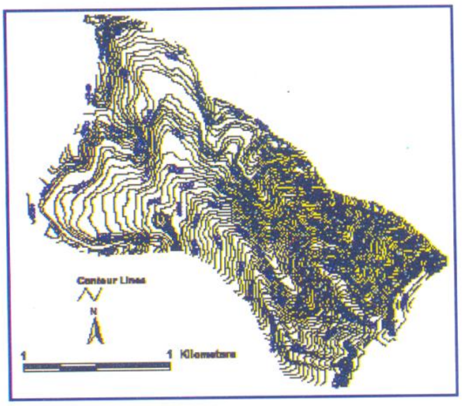

Fig .6. Contour map of the study area

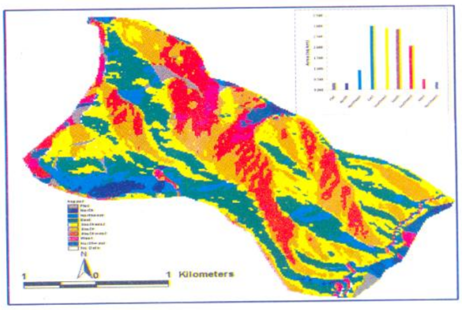

Fig .7 Elevation Zones of the study area

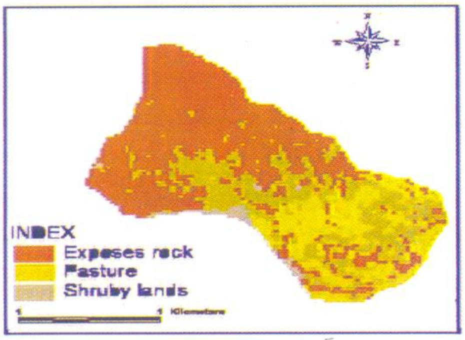

Fig. 8. Land cover of the study area (19976)

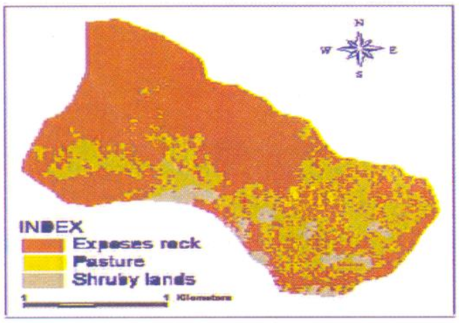

Fig. 9. Land cover of the study area (2001)

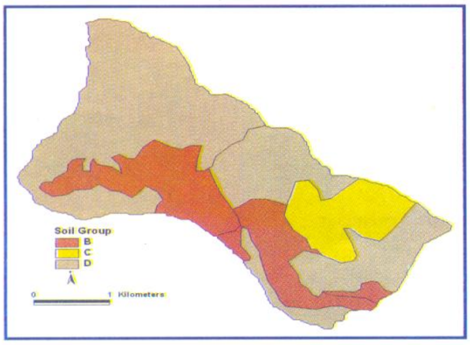

Fig. 10. Soil map of the study area

Morphometric analyses

Morphometric analyses have been carried out at 20m resolution DEM using 3 order threshold and the Strahler ordering (Strahler, 1964) scheme was followed to obtain the ordering scheme of the study area. A self-developed program has been used to obtain various morphometric parameters (Table. III). The drainage network pattern that the terrain exhibits ranges from dentritic to sub-denritic dr (Fig. XI). Stream length, mean stream length, stream length Ratio and bifurcation ratio show variations from order to order (Table IV). The stream frequency (30.89 km/km^2) show positive relation with the drainage density (7.7 km/km^2). Form factor (0.33), Elongation Ratio (0.65) and Circulatory Ratio (0.36), as shown in Table-V, reveals that the watershed resembles more or less elongated in shape. All the morphometric parameters (Table-IV and Table-V) indicate that this watershed can have high runoff during heavy rain spells and also run off will take very less time to reach to outlet during precipitation event and can cause serious floods in the down stream portion of the catchment. The drainage density indicates resistant, impermeable subs-urface material, mountainous relief and high runoff during the precipitation period. This would reflect in early peak discharge and result in flash floods. Length of overland flow also reveals that the runoff takes less time to reach to the outlet.

CONCLUSION

The present study reveals that the land cover changes in the study area has disturbed the hydrological regime resulting in an increase in the surface runoff and can be the main reason for flooding in the down stream areas. Further, all the morphometric parameters analyzed in the study indicate that the runoff from the watershed will be quite high and take very less time to reach to outlet during precipitation event. The hydro-geomorphological analysis using DEM and SWAT model provided valuable insight into the hydrological response of this ungauged watershed of the Rambiara river. The study has a potential to be replicated in other ungauged and inaccessible watersheds of the Jhelum basin to plan and prioritize for their management.

Table 2: Shows the model simulated runoff estimates for 1976 and 2001

Runoff (mm) (1976 land cover)	Runoff (mm) (2001 land cover)
79.90	91.04

Table 3: Shows the equations used for computing different morphometric parameters

S.No	Parameters	Formulae
01	Stream order	Hierarchal rank (Strahler method)
02	Stream length(Lu)	Length of streams (order wise)
03	Mean stream length(Lsm)	Lsm=Lu/Nu Where Lu= total length of order' u' Nu= total streams segments of the order 'u'
04	Stream length ratio (Rl)	Lu/Lu-1
05	Bifurcation ratio	Rb=Nu/Nu+
06	Mean Bifurcation ratio (Rbm)	Rbm=Average of Rb of all orders
07	Drainage density(Dd)	Dd=TL/A TL=total length of all orders A=area of watershed
08	Stream frequency (Fs)	Fs= Nu/A
09	Form Factor (Rf)	Rf = A/lb Lb = Square of basin length
10	Circularity Ratio (Rc)	Rc = 4* Pi * A/P2 Pi= 3.14, p = peremeter
11	Elongation ratio (Re)	$Re=1.128A^{0.5}/Lb$
12	Length of over land flow	Lo = 1/2Dd
13	Elipticity Index(E)	$E= \Pi L^2/ A$
14	Basin Length(lb)	$Lb=1.312A^{0.568}$
15	Shape factor(Sf)	$Rf=(Lb)^2/A$
16	Compactness coefficient	$Cc= 0.2821P/A^{0.5}$

Table 4: Shows the stream order-wise morphometric parameters

Area	Perimeter	Lb	Stream Order	Order wise streams	Total Streams	Lu (km)	T. Length	Lsm	Rl	Rb
12.49	17.99	5.41	1	63	78	16.02	33.89	0.25	0.49	5.73
			2	11		7.92		0.72	0.58	3.67
			3	3		4.57		1.52	1.18	3
			4	1		5.38		5.38	-	-

Table 5: Shows the watershed-wise morphometric parameters

Rbm	Dd	Fs	Re	Rf	Rc	Lg	Ei	Cc	Max E	Min E
4.31	7.7	30.89	0.65	0.33	0.36	0.06	9.54	1.05	4700	2900

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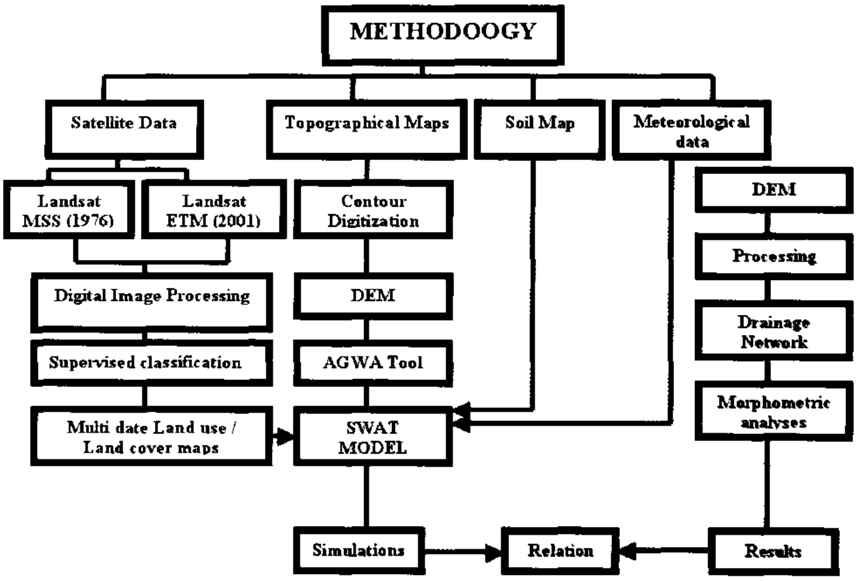

Fig. 2. Flow chart showing the research

STUDY AREA

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