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RELIEF ANALYSIS OF SOLANI WATERSHEAD USING REMOTE SENSING AND GIS TECHONOLOGY

Dr. B. R. Thakur
Praveen Kumar Thakur
V. Hari Prasad
S. P. Agarwal

Abstract

The present study is aimed at analyzing the relief characteristics of Solani watershed using ASTER image (Dec. 2003) and Survey of India toposheets with combination of geospatial techniques. In the present study, an endeavor has been made to study quantitatively the relief characteristics of Solani watershed in terms of absolute relief, relative relief, dissection index, hypsometry and landscape profiles. These attributes of relief have been analysed while dividing the digital elevation model (DEM) of 30m spatial resolution and grids of 2 km2. The spatial variations in absolute relief, relative relief and dissection index have been shown with the help of maps. The hypsometric curves have been computed and prepared based on sliced DEM at an interval of 50m height above mean sea level. The study reveals that more than two-third of the watershed comes under the category of < 500m height. The areas of high relative relief coincide with areas of high absolute relief. The plains and valley flats support low dissection index, while gorges, scarps and steeply sloping divides and highs and crests of divides support moderate dissection index in Solani watershed. The study indicates that as the elevation increases beyond 850m, the areal coverage decreases in the watershed. The hypsometric integral computed for Solani watershed is as high as 82.50 per cent which indicates its youth or inequilibrium stage. The superimposed and composite profiles portray both the sharpness of relief features in the northern part and flatness of valley bottoms in the southern part of watershed. The slope analysis reveals that about 16.10 per cent of study area has nearly level slope. The area lying in very steep slope category accounts for about 12.60 per cent of total watershed.

Introduction

Relief of earth surface is the product of a complexity of morpho-climatic processes. The term relief refers to the relative vertical inequality of land surface collectively or terrain-wise variations of the earth –configuration. Differences in elevation lead to variations in relief and other morphometric attributes which include absolute relief, relative relief, dissection index, slope, drainage frequency and drainage density etc. (Singh and Sinha, 1996). These parameters help in delimiting and classifying the morpho units of any terrain. Different processes of denudation

acting upon varying environmental conditions have helped to carve out the varying relief structure. The relief characteristics of various basins and sub- basins have been studied using conventional methods in earlier studies. Such studies lack time effectiveness of data for a large drainage network over a whole river basin. Remote sensing technology provides a unique data set for studying the geomorphometry of any watershed (Agarwal, 1998). Remotely sensed data can be utilized for obtaining information concerned with the quantitative description of drainage basins and channel network (Astaras, 1985). Drainage and relief characteristics express stage of development, distribution pattern of the landforms, texture of the surface material and water resources (Singh, et al, 1985). It seems justified to give more weightage to the mathematical symbolization of landform characteristics, for mere descriptive assessment of landform may not be helpful in adopting similar scale of observation in other areas (Asthana, 1967).

In quantitative geography, the employment of precise data concerning landforms is essential for basic research into the laws governing relief development, for elaborate mathematical models, and for practical applications such as forecasting discharge, and the regional modeling of hydrological features (Zavoianu, 1985). Gardiner (1982) has underlined that numerical analysis of form characteristics is potentially a most important approach to study the geomorphometry. Since, it affords quantitative information on large-scale fluvial landforms, which make up the vast majority of earth configuration (quoted in Singh and Singh. 1997).

Thus, the numerical study of landforms refereed to as morphometry which deals with the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its landforms is of utmost significance (Upendran, et al. 1998; Singh and Singh, 1997; Agrawal, 1972). The area, altitude, volume, slope, profile and texture are the main aspects examined in the quantitative study of relief.

The morphometric approach used in the present study is useful for examining varied characteristics of drainage basins, which include erosion surfaces, nature of erosion, formation of slopes and direct and indirect evidence for genesis and evolution of certain landforms (Kharkwal, 1968). There are several published studies, which deal with landform analysis (Horton 1948; Strahler, 1952). Most of them are dependent on the degree of accuracy of depiction of drainage networks obtained from maps (Morisawa, 1957, quoted in Astaras, 1985). Only a few studies in the last 30-35 years have specifically used geomatics for studying the relief characteristics. However, such a study on relief analysis using these modern techniques has not been undertaken in Solani watershed so far.

Objectives and Research Questions

The present study aims at analyzing the following set of objectives and investigate research questions related to them:

- to describe and discuss quantitatively the relief properties of Solani watershed;
- to study the relationship among the relief properties of Solani watershed and to examine that how these properties are associated with each other and
- to evaluate the denudational level of Solani watershed through the creation of profiles, hypsometric curves, hypsometric integrals and mapping the terrain. And also to investigate the relative picture of valley slope and geomorphic stage of development of Solani watershed.

Data Base and Methodology

The present study is based on Terra Satellite ASTER MX data (14 bands) acquired on March 17, 2003 namely FCC of the bands 1, 2 and 3N of 15 m spatial resolution for visual analysis of the landforms. The Survey of India toposheets Nos.53 F/15; 53F/16; 53G/13; 53J/3; 53J/4 of scale 1:50,000 and 53/F; 53/G; 53/J of scale 1:2, 50,000 as collateral data have also employed. The satellite data was geometrically rectified with respect to the Survey of India toposheets of 1:50,000 scale. An epipolar stereopair using 3N channel as left image and 3B as right image was created in ILWIS software. Subsequently, to delineate the watershed boundary, anaglyphic visualization (3-D, seen stereoscopically through anaglyph spectacles) was employed. The database was generated using ERDAS 8.7, Arc GIS and MS office. The relief characteristics have been studied with reference to absolute relief, relative relief, dissection index, hypsometry and landscape profiles. These attributes of relief properties have been analysed by dividing the DEM of 30m spatial resolution and grids of 2 km2. Superimposed profiles have been drawn at an interval of 2 km2 grids. The spatial variations in absolute relief, relative relief and dissection index have been shown with the help of maps. All the hypsometric curves have been computed and prepared based on sliced DEM at an interval of 50m height above mean sea level. The percentage hypsometric curve has been drawn by involving two ratios; relative height (h/H) and relative area (a/A). Where, "h" is the height of the contour above the base of the watershed concerned and "H" is the total height of the same watershed plotted on the ordinate and "a" is the area enclosed by corresponding "h" and "A" represents the total watershed area plotted on abscissa. The slope of Solani watershed has been calculated in per cent as per the technical guidelines on Integrated Mission for Sustainable Development particularly devised for watershed characterization and management studies. Thus, slope analysis has been done by using a scheme advanced by National Remote Sensing Agency (1995).

Study Area

The Solani watershed covering an area of about 532.40 sq km with 119.51 km perimeter is located between 29052'45. 53"to 30016'16. 72"N latitude and 77043'58. 45" to 78000'05. 93"E longitude (Fig.1). Solani River is a moderate size right bank tributary of the river Ganga. It originates from the northeast part (Siwalik hill, 787 m) of Saharanpur district near the Kaluwala pass (30015'59.36"N latitude and 78053'16.83"E longitude). The river flows essentially from SW to SE for 60.18km and joins the Ganga river in Jansath tehsil of Muzaffarnagar district (U.P.). About three-fourth of study area lies in Uttrakhand state.

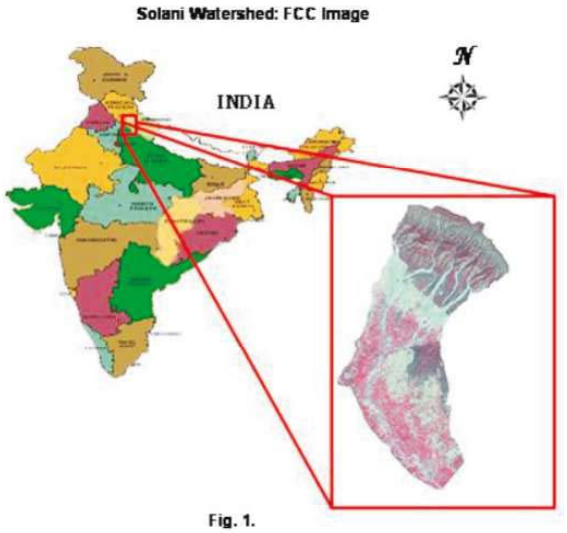

Fig. 1.

RESULTS AND DISCUSSIONS

Absolute Relief

Absolute relief refers to the maximum

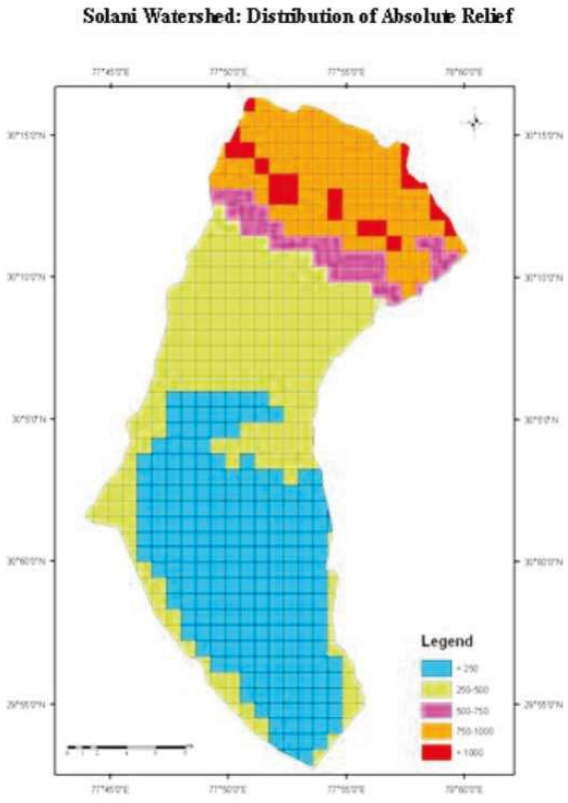

Fig. 2

elevation of any morphological area, including the existence of erosion surfaces. The values, of absolute relief range from a minimum of 164 m near Roorkee in the southern part to a maximum of 1144.54 m in Kaluwala reserved forest near the confluence of Andheri Rao and Bangori Rao streams located in Siwalik.

The spatial distribution of absolute relief categories (Table 1 and Fig.2) is enumerated as under:

i) Areas of Low Absolute Relief (< 250 metres):

Covering about little less than one-third (31.69 per cent) of the watershed this category of relief is observed in the alluvium tract along the valley bottom and in the southern part of Solani watershed. A certain pockets in the western part, except Chuttmalpur area also dot the low relief areas.

ii) Areas of Moderately Low Absolute Relief (250 -500 metres):

This category of relief comprising a large area of about 38.81 per cent includes the Biharigarh and its surrounding areas of the study area. It lies in the zone between lower Siwalik in the northern part and alluvium plains in the south.

iii) Areas of Moderate Absolute Relief (500 – 750 metres):

This category constitutes about 6.57 per cent of total watershed which is represented by lower Siwalik ranges covering upper Mohand and some area of Raja National Park. It is also observed in the form of detached summits in the extreme northeastern part of the study area.

iv) Areas of Moderately High Absolute Relief (750 – 1000 metres):

Embracing about one- fifth of the total watershed, this elevation range is concentrated in the northern part which includes a large part

Table 1
Solani Watershed: Distribution of Absolute Relief

Range of Elevation(m)	Area (km^2)	Area (%)	Grid Frequency	Grid Frequency (%)	Explanation
< 250	168.70	31.69	214	34.97	Low
250 - 500	206.41	38.81	237	38.72	Moderately
500 - 750	34.97	6.57	35	5.72	Moderate
750 - 1000	99.89	18.76	103	16.83	Moderately
> 1000	22.23	4.17	23	3.76	High
Total	532.40	100.00	612	100.00	

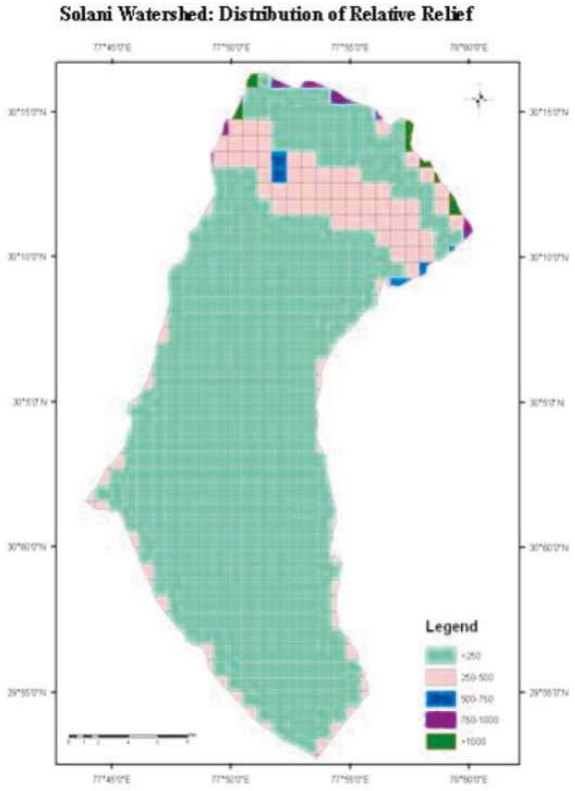

Fig. 3

of the middle Siwalik range of the study area.

v) Areas of High Absolute Relief (>1000 metres):

Covering about 4.17 per cent area this category of relief is concentrated in certain pockets of Solani watershed. It is characterized by steep slope and many vertical escarpments.

Relative Relief

The term relative relief means the difference between the highest and the lowest point in a unit. In other words, it is defined as the amount of variation of height in a unit area with respect to its local base level.

The study indicates that relative relief varies from 410 m to 1075 m with average value of 178.43 m. The values of relative relief (Table 2 & Fig.3) have been classified into following five groups:

i) Areas of Extremely Low Relative Relief (Less than 250m):

This category constitutes about three-fourth of total area. It characterizes almost whole southern and few pockets in the middle part of watershed.

ii) Areas of Low Relative Relief (250–500m):

This category occupies one-fifth area immediately surrounding the low relative relief. It mainly covers the lower Siwalik areas and some patches in the northeastern parts of the watershed.

iii) Areas of Moderate Relative Relief (500–750m):

This category accounting for about 1.24 per cent is found in detached patches in lower Siwalik ranges.

iv) Areas of Moderately High Relative Relief (750–1000m):

This category comprises a small area of 2.58 per cent concentrated in the area of upper

Table 2
Solani Watershed: Distribution of Relative Relief

Sl No.	Relative Relief Category(m)	Area (km^2)	Area (%)	Grid Frequency	Grid Frequency (%)	Explanation
1	<250	407.05	76.46	461	75.33	Extremely Low
2	250 – 500	96.18	18.06	121	19.77	Lower
3	500 – 750	6.59	1.24	7	1.14	Moderate
4	750 – 1000	13.73	2.58	14	2.29	Moderately High
5	> 1000	8.85	1.66	9	1.47	High
6	Total	532.40	100.00	612	100.00	

Table 3
Solani Watershed: Distribution of Dissection Index

Sr. No	Dissection Index Category	Area (km^2)	Area (%)	Grid Frequency	Grid Frequency (%)	Explanation
1	Less than 0.35	407.18	76.48	467	76.31	Low Dissection
2	0.35-0.70	49.76	9.35	50	8.17	Intermediate Dissection
3	Above 0.70	75.46	14.17	95	15.52	High Dissection
4	Total	532.40	100.00	612	100.00	

Siwalik and some grids partaking ridge of the study area.

v) Areas of High Relative Relief (>1000m):

Covering merely 1.66 per cent area, this category of relative relief is observed in some patches partaking upper and middle portions of Siwalik ranges of watershed.

It is evident from present study that areas of high relative relief coincide with areas of high absolute relief.

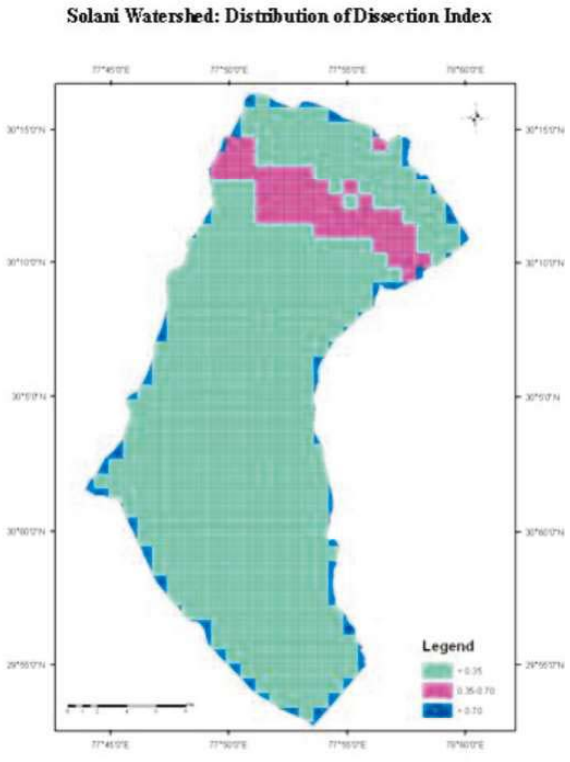

Fig. 4

Dissection Index

The finer elements of terrain can not be revealed solely by an analysis of absolute and relative relief. Hence, a study of dissection index has gained more significance in the analysis of landforms. It may be defined as the ratio between relative relief and absolute relief. The values of dissection index may differ from 0.00 (complete absence of dissection) to 1.00 (vertical cliff at sea level). Table 3 and Fig.4 reveal the values of dissection index which has been summarized into following three categories:

Areas of Low Dissection Index (Less Than 0.35):

Low dissection index constitutes 76.48 per cent area of the watershed. It broadly covers the areas of Roorkee, Sakrauda and Biharigarh, comprising almost whole alluvium plain tract except some fringe areas. Interestingly, the upper Siwalik region of the study area except some northern portion has lower dissection index. It shows that hills with a comparatively flat bottom possess lower dissection index. It manifests their comparatively mature stage of development in comparison to other valleys of the terrain. The term 'mature' should not be applied strictly here in relation to the Himalayan topography which itself is the youngest mountain chain of the world.

Areas of Intermediate Dissection Index (0.35-0.70):

This category accounts for one- tenth area of the watershed mainly confined to lower Siwalik hills in the form of about 3-4 km wide east–west marked zone except some exceptions.

Areas of High Dissection Index (Above 0.70):

Typical of rugged and undulating terrains characterizing gorges and scarps constitutes about 14.17 per cent of total watershed. Such a high dissection index is observed in upper Siwalik areas bordering the watershed boundary.

The distributional pattern of dissection index reveals that plains and valley flats support low dissection index, gorges, scarps and steeply sloping divides have high dissection index and crests of divides have moderate dissection index in Solani watershed.

Hypsometry

Hypsometry is a measurement of interrelationship between altitude and area. It is one of the quantitative techniques to interpret terrain characteristics.

Area Elevation Curve

It is used to indicate the proportion of area lying at various height categories in percentage. The graph reveals that about 12 per cent of total area has an elevation of about less than 200 m, about 38 per cent area falls in 200-250 m elevation. The study indicates that as the elevation increases beyond 850m, the areal coverage decreases in the watershed (Fig.5). It is evident from the fact that only 4.00 per cent of Solani watershed falls in higher altitudes.

Percentage Hypsometric Curve

The percentage hypsometric curve drawn shows distinctive difference both in sinuosity of form and in proportionate area below the curve; here termed as hypsometric integral (Strahler, 1952, quoted in Singh, S. B. 1979). Hypsometric integral computed for Solani watershed indicates the watershed is passing through the young stage. Only 17.50 per cent area of the watershed has been eroded. The hypsometric integral computed for Solani watershed is as high as 82.50 per cent (Fig. 6). The nearness of the watershed to the Himalayan ranges which are the youngest mountains in the world also supports this observation that Solani watershed is in its youth or inequilibrium stage.

Landscape Profiles

The digital elevation model does not portray a complete picture of the terrain. Therefore, different landscape profiles are drawn to get a clear idea of the surface configuration. The landscape profiles of the

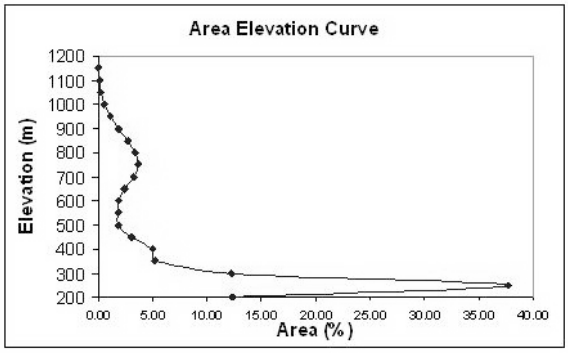

Fig. 5

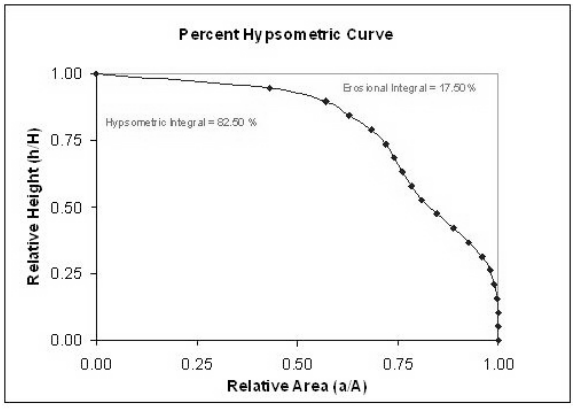

Fig. 6

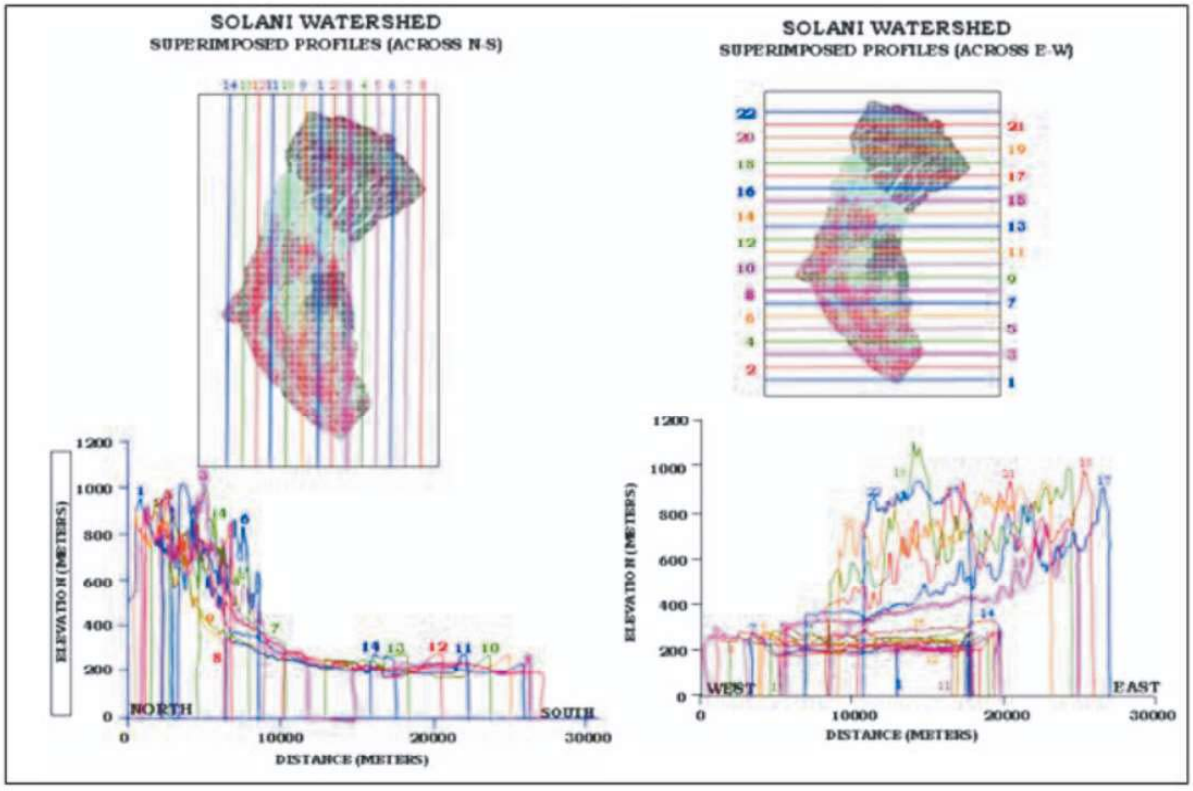

Fig. 7

study area have been drawn along east -west and north-south lines at regular intervals.

a) Superimposed Profiles

Superimposed profiles are constructed on the basis of serial profiles. Serial profiles are superimposed on each other at a fixed scale and axis. It is noted that superimposed profiles, more or less, confirm the results obtained by the analysis of relief and hypsometric curves. The summits of lower and middle Siwalik ranges, scarps, valley plains and undulating terrain like features can be easily identified on the superimposed profiles (Fig. 7). These profiles also show the clustering forms of hill tops in the northwest portion of the watershed. The degree of dissection, indicating the vertical difference between the hill tops of Siwalik ranges and the valley bottoms or alluvial plains are also clearly noted on these profiles.

b) Composite Profile

Composite profile portrays the actual bird's view of any area. The Fig .8 showing the composite profiles drawn across and along the streams clearly reveal the dominance of skyline or higher elements of relief in the northern part of the watershed.

Slope Analysis

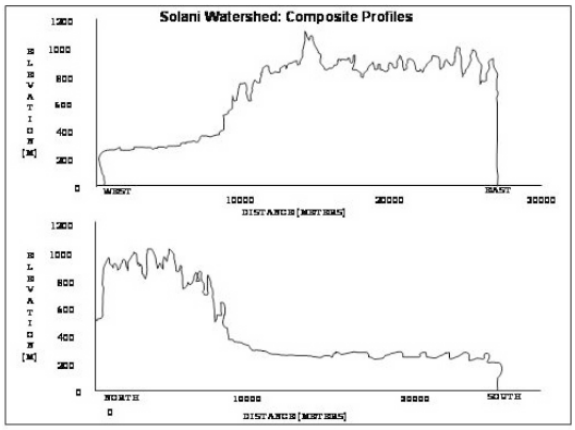

Fig. 8

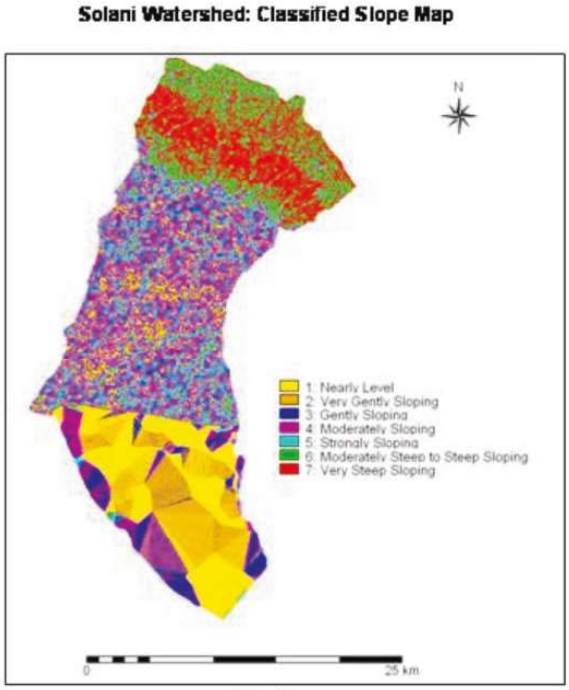

Fig. 9

One of the most important attributes of morphometric elements is the slope or the inclination of the terrain. The slope scale has been grouped into following 7 classes ranging from below 1 to > 35 per cent (Table 4 and Fig. 9).

Spatial Distribution of Slope Categories:

i) Nearly Level Surface (0-1 Per cent): This category occupies about 16.10 per cent of total study area. Its major concentration is found in the southern and central parts of the region including Roorkee, Chhutmalpur, Biharigarh, Sakrauda etc.

ii) Very Gentle Slope (1-3 Per cent): This category of slope occupying highest i.e. more than one-fifth of the area is found in upper alluvial plains in a distinguished zone.

iii) Gentle Slope (3-5 Per cent): The area observed in gently slope category is about 12.79 per cent mainly found in the vicinity of very gentle and moderately steep slope.

iv) Moderate Slope (5-10 Per cent): Moderately sloping topography is found in Sakrauda reserved forest area, along the roads and river beds in the plains. Its major concentration is found in certain pockets in Siwalik hills of the watershed.

v) Strong Slope (10-15 Per cent): This category of slope covers about 7.24 per cent of the area found in certain specific areas in alluvial plains. Its concentration is more in hills than the plains.

vi) Moderately Steep to Steep Slope (15-35 Per cent): Occupying about more than one-tenth of area. This category of slope is mainly observed in hills except some linear strips of river beds in the plains.

vii) Very Steep Slope (> 35 Per cent): The study brings out that about 12.68 per cent of the area has steep escarpments and cliffs largely found in lower Siwalik range. However, some areas could also be traced in upper Siwalik

Table 4
Solani Watershed: Distribution of Slope

Slope Category (%)	Area (Km^2)	% Area	Explanation
0-1	85.73	16.10	Nearly Level Surface
1-3	115.14	21.62	Very Gentle Slope
3-5	68.12	12.79	Gentle Slope
5-10	94.05	17.66	Moderate Slope
10-15	38.47	7.24	Strong Slope
15-35	63.39	11.91	Moderately Steep to Steep Slope
>35	67.50	12.68	Very Steep Slope
Total	532.40	100.00	

range partaking Solani watershed.

Concluding Remarks

The study brings out distinctive variations in absolute relief in Solani watershed. The elevation ranges from the lowest 164 m to the highest of 1144 m. The highest concentration (38.81 per cent) of absolute relief falls in moderately low absolute relief category observed in Biharigarh and its surrounding areas. The relative relief varies from 410 m to 1075 m. The areas of high relative relief coincide with areas of high absolute relief. It is evident from the fact that about three- fourth of the study area has extremely low relative relief.

The study reveals that about 12 per cent of total area has an elevation of about less than 200m. The lower the height, larger is the concentration of the area in the watershed. As the elevation increases beyond 850m, the areal coverage decreases in the watershed. It has been found that Solani watershed is passing through the youth or inequilibrium stage. It is evident from the high (82.50 per cent) hypsometric integral computed for the watershed. It could also be attributed partly to its location i.e. nearness to the youngest mountainous ranges of the world. The summits of lower and middle Siwalik ranges, scarps, valley plains, and undulating terrain like features can be easily identified on the superimposed profiles drawn both across and along the streams. The composite profile portraying only the skyline or higher elevations reveals the dominance of these elements in the northern part of the area.

The slope analysis reveals that about 16.10 per cent of study area has nearly level slope. The study also indicates that more than one- fifth of Solani watershed falls in very gently sloping (1-3 per cent) category. The area lying in very steep slope category accounts for about 12.60 per cent of total watershed.

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Dr.B.R. Thakur
Associate Director–Research,
Institute for Spatial Planning and Environment Research,
India, Panchkula, Haryana

Praveen Kumar Thakur
V. Hari Prasad and
S. P. Agarwal
Scientists, Water Resources Division,
Indian Institute of Remote Sensing
Dehradun -248001, India