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RELIEF ANALYSIS OF KAUSHALAYA RIVER WATERSHED USING REMOTE SENSING AND GIS TECHNIQUES

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Abstract

The present study is aimed at analyzing the relief characteristics of Kaushalaya River watershed using Google Earth (Digital Globe Images) and digital elevation model (DEM) generated from Survey of India toposheets in GIS environment. GIS techniques are being used for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information for better understanding. In the present study GIS analysis techniques were used to evaluates the relief characteristics in terms of absolute relief, relative relief, hypsometry and landscape profiles. These elements of relief have been analysed using the DEM of 20m spatial resolution and grids of 1 km². The spatial variations in absolute relief and relative relief have been shown with the help of maps. The hypsometric curves have been computed and prepared based on sliced DEM at an interval of 1km distance in x,y direction. The study reveals that 42 per cent area of the watershed comes under the category of 1000-1500m elevation. The areas of high relative relief coincide with areas of high absolute relief. The study indicates that with the increase in elevation specifically beyond 1400m height, the areal coverage decreases in the watershed. It is more evident from the fact that only 17.82 per cent area falls in higher altitudes above 1400m. The hypsometric integral computed for Kaushalaya River watershed is 61.50 per cent which indicates its early mature stage. The superimposed and composite profiles portray both the sharpness of relief features in the northern part and moderate slope in the piedmont zone located in the southern part of the watershed. The slope analysis reveals that about 39 per cent of study area has very gentle slope. The area lying in very steep slope category is merely 2.76 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). Dury (1952) also favours this idea as follows:

"*Subjective assessments, however, can be of very little use in comparing one drainage system with another, unless they are made by a single observer who maintains a constant standard of judgment. It is now possible to supersede subjective assessment and qualitative descriptions by quantitative measurement" (Dury, 1952).*

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 (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 GIS techniques for studying the relief characteristics. However, such a study on relief analysis using these modern techniques has not been undertaken in Kaushalaya River watershed so far.

Objectives and Research Questions

The present study seeks to analyze the following morphometric attributes of Kaushalaya river watershed and investigate research questions related to them:

i) To express and discuss quantitatively the relief properties of Kaushalaya River watershed;

ii) To study the relationship among the relief properties of Kaushalaya River watershed and to examine that how

these properties are associated with each other.

iii) To evaluate the denudational level and slope variations of Kaushalaya River watershed.

Database and Methodology

The present study is based on both traditional (toposheets) and modern (digital globe) data sources. The Survey of India toposheets (53B/13, 53F/1, 53B/14) published in 1972 at 1:50,000 scale were scanned and georeferenced with appropriate projection parameters (Projection UTM, Zone-43 and Datum WGS 84). The high resolution satellite images (1m spatial resolution) acquired on March 26, 2007 have been downloaded from Google Earth for visual analysis of the landforms, present drainage network and land use/land cover of the watershed. Google images have been geometrically rectified with reference to the georeferenced Survey of India toposheets.

The digital elevation model (DEM) has been generated from surface contours with 20 meter interval and spot heights from the toposheets on GIS platform. The Kaushalaya River watershed has been demarcated from DEM using spatial analysis tool in ARC GIS 9.2 software. The drainage network has been initially digitized from SOI toposheets and later integrated with remote sensing data (Google Images) to update the current position of drainage channels. The spatial and non-spatial data have been integrated using Arc GIS 9.2 software.

The relief characteristics in terms of absolute relief, relative relief, hypsometry, landscape profiles and slope have been analysed using DEM of 20m spatial resolution. Superimposed profiles have been drawn at an interval of 1 km^2 grid. The distribution of absolute relief and relative relief has been calculated using spatial analyst in GIS and shown with the help of choropleth maps. The hypsometric integral 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 Kaushalaya river watershed has been calculated in degrees.

Study Area

The Kaushalaya river watershed covering an area of about 138.76 sq km with 72.17 km perimeter is located between 300 44' 30" N to 300 54' 30" N latitudes and 760 52' 17.45" E to 770 05' 21" E longitudes (Fig.1).

The Kaushalaya River originates from the Siwalik hills at an altitude of 1850 metre above mean sea level near Kasauli town, district Solan in Himachal Pradesh. Kaushalya river is a moderate size right bank tributary of the river Ghaggar. It joins Ghaggar river near Tanda village in Panchkula district of Haryana. The landscape of watershed is dotted by Siwalik hills in the north, east and central parts mainly found in Himachal Pradesh. As the river enters in Haryana, the relief structure is dominated by piedmont zone under the influence of break in slope in the southern part (Fig. 2).

Results and Discussions

Absolute Relief

Absolute relief refers to the maximum elevation of any morphological area, including the existence of erosion surfaces. The values, of absolute relief range from a minimum of 400 m in Tanda village at the confluence point with Ghaggar river in the southern part to a maximum of 1850 m in Kasauli ridge in

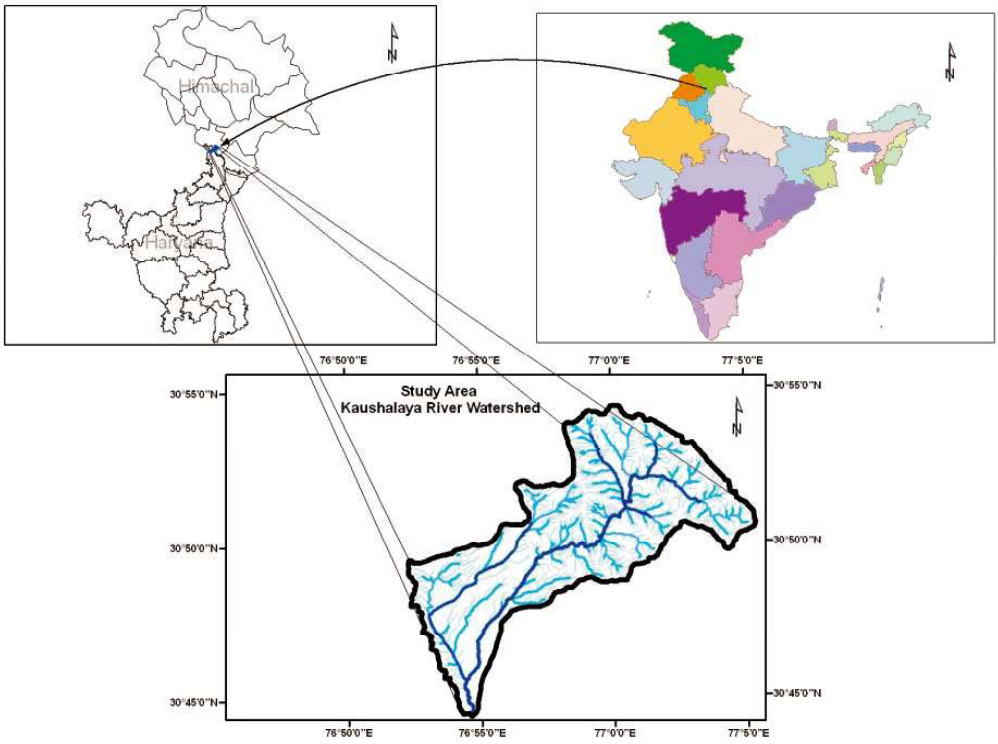
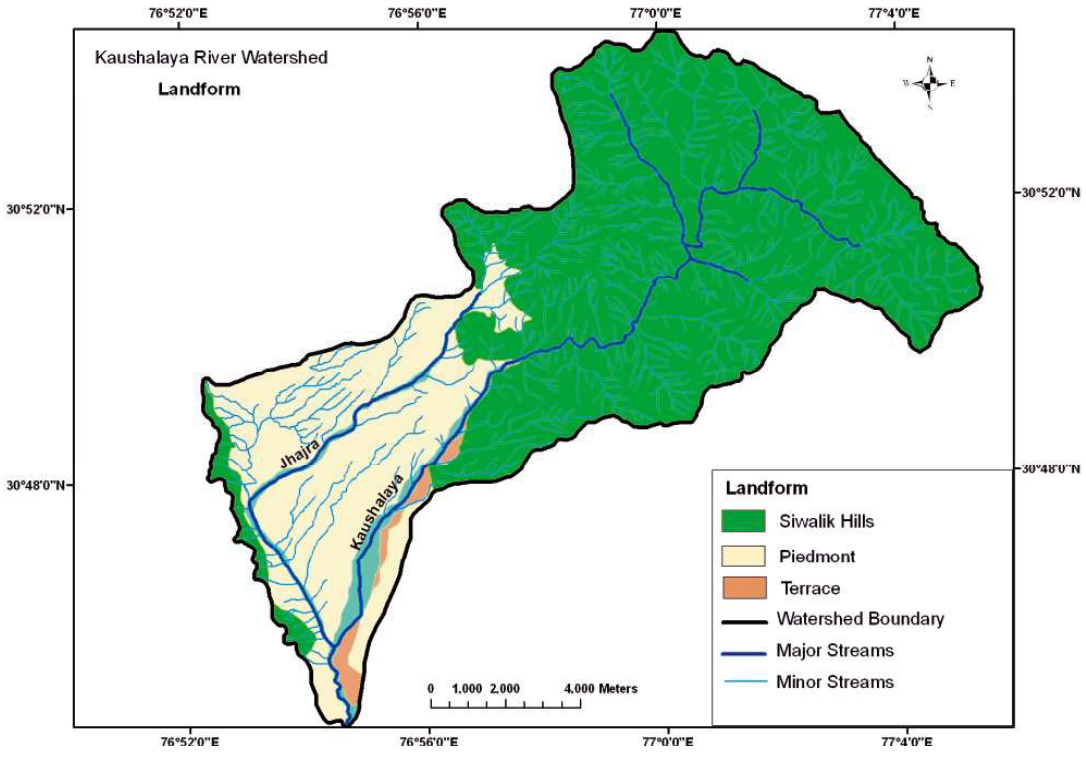

Himachal
Haryana
Study Area
Kaushalaya River Watershed
76°50'0"E
76°55'0"E
77°0'0"E
77°5'0"E
30°55'0"N
30°50'0"N
30°45'0"N

Fig.1


Kaushalaya River Watershed
Landform
76°52'0"E
76°56'0"E
77°0'0"E
77°4'0"E
30°52'0"N
30°48'0"N
Jhajra
Kaushalaya
0 1.000 2.000 4.000 Meters
Landform
Siwalik Hills
Piedmont
Terrace
Watershed Boundary
Major Streams
Minor Streams

northern part of the study area.

The spatial distribution of absolute relief categories (Table 1 and Fig.3) is enumerated as under:

i) **Areas of Low Absolute Relief (< 500 metre)**: Low absolute relief covering about one-tenth (10.49 per cent) of the watershed is observed in the tail end tract along the valley bottom, in the southern part of Kaushalaya River watershed.

ii) **Areas of Moderate Absolute Relief (501-1000 metre)**: Moderate relief comprising a large area of about 37.96 per cent includes the Pinjore town, Pinjore Garden and its surrounding areas. It largely lies in the piedmont zone.

Table 1
Kaushalaya River Watershed: Absolute Relief

Range of Elevation(m)	Area (km^2)	Area (per cent)	Explanation
< 500	14.56	10.49	Low Absolute Relief
501 - 1000	52.67	37.96	Moderate Absolute Relief
1001 - 1500	59.23	42.69	High Absolute Relief
>1500	12.30	8.86	Very High Absolute Relief
Total	**138.76**	**100.00**	

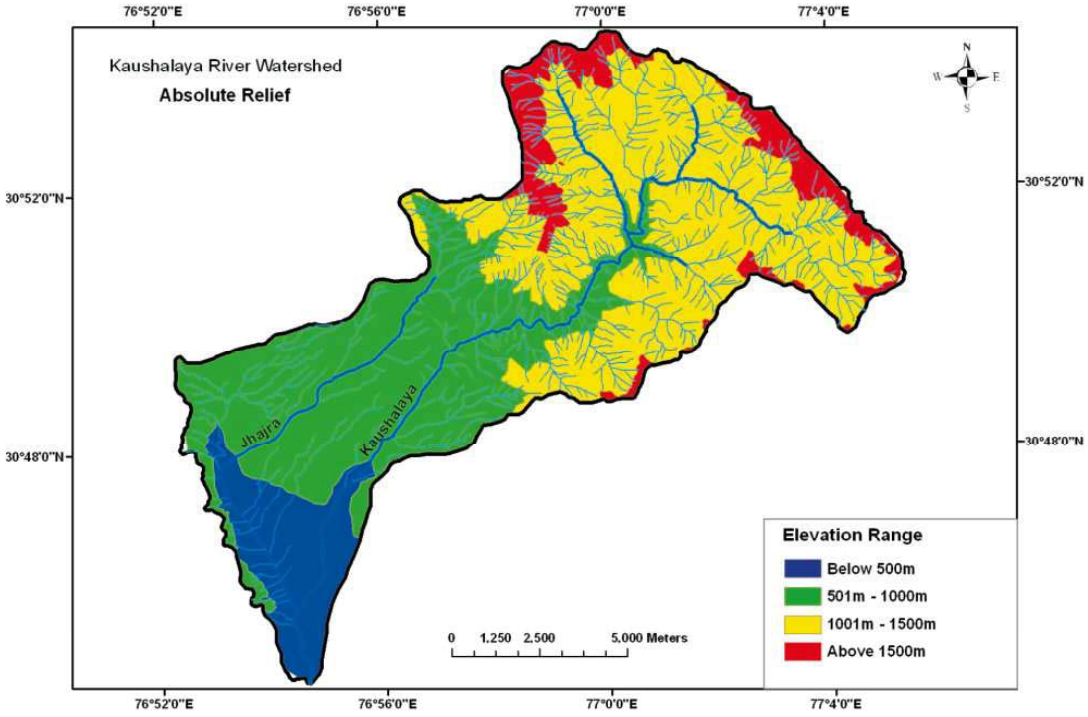


Fig. 3

iii) **Areas of High Absolute Relief (1001-1500 metre)**: High absolute relief constituting about 42.69 per cent of total watershed which is represented by lower Siwalik ranges covering Malthu Reserved Forest (RF), Chaola Protected Forest (PF), Jauhri P.F, Barbana R.F, Jagatgarh P.F, Karalghat R.F, Anun P.F, Guman P.F, Ambota P.F, Datiar P.F, Jarrag P.F, Budho P.F, and Gauri ki Dhar P.F in southern parts of Solan district of Himachal Pradesh.

iv) **Areas of Very High Absolute Relief (>1500 metre)**: Embracing about 8.86 per cent of the total watershed, this elevation range is concentrated in a small part of the high Siwalik range of the study area which includes a linear ring like strip in north and north-west part dotting Kasauli town and along the National Highway no 22 towards Shimla.

Relative Relief

The term relative relief means the difference between the highest and the lowest point in an unit area. In other words, it is defined as the amount of variation of height in an unit area with respect to its local base level. Grid method becomes more suitable and convenient for the purpose wherein the basin is covered with mesh of grid squares (one grid being one kilometre X one kilometer) and relative relief in each grid square is calculated on the bases of the highest and lowest elevations and the data of relative relief so derived are tabulated and classified into six categories as mentioned below: (Table 2 and Fig. 4)

i) **Areas of Very Low Relative Relief (0-75m)**: This category constitutes highest proportion of little more than one-fourth (27.55 per cent) of the watershed. It characterizes almost whole southern part of watershed.

ii) **Areas of Moderately Low Relative Relief (76m-150m)**: It occupies little more than one-tenth (12.94 per cent) of the whole watershed. There are small patches distributed in central and south-west portion covering Kolhai Dun Reserved Forest of watershed under this category.

iii) **Areas of Low Relative Relief (151m-225m)**: This category comprises lowest area (about 11per cent) of the watershed. It is distributed randomly in small patches mainly in extremely upper and central part of the watershed.

iv) **Areas of Moderate Relative Relief (226m-300m)**: This category covers 14.17 per cent area of the total and largely distributed in east and sparsely in some upper middle parts of the watershed.

v) **Areas of Moderately High Relative Relief (301m-375m)**: This category comprises 12.60 per cent area and randomly distributed over northern part of the watershed.

vi) **Area of High Relative Relief (Above 375m)**: It consists little more than one-fifth of the whole watershed and found in the Himachal Pradesh part of the watershed only.

Hypsometry

The hypsometric/hypsography curve is used for the measurement of the elevation of land above sea level and shows the distribution of height of a given area. Differences in hypsometric curves between landscapes arise because the geomorphic processes that shape the landscape may be different. The hypsometric curve shown as a continuous function and graphically displayed as an x-y plot with elevation on the vertical, y-axis and

Table 2
Kaushalaya River Watershed: Relative Relief

Range of Relative Elevation(m)	Area (km^2)	Area (per cent)	Explanation
< 75m	38.231	27.552	Very Low Relative Relief
76m-150m	17.956	12.941	Moderately Low Relative Relief
151-225m	15.660	11.286	Low Relative Relief
226m-300m	19.664	14.172	Moderate Relative Relief
301m-375m	17.488	12.603	Moderately High Relative Relief
Above 375m	29.760	21.447	High Relative Relief
Total	**138.760**	**100.000**	

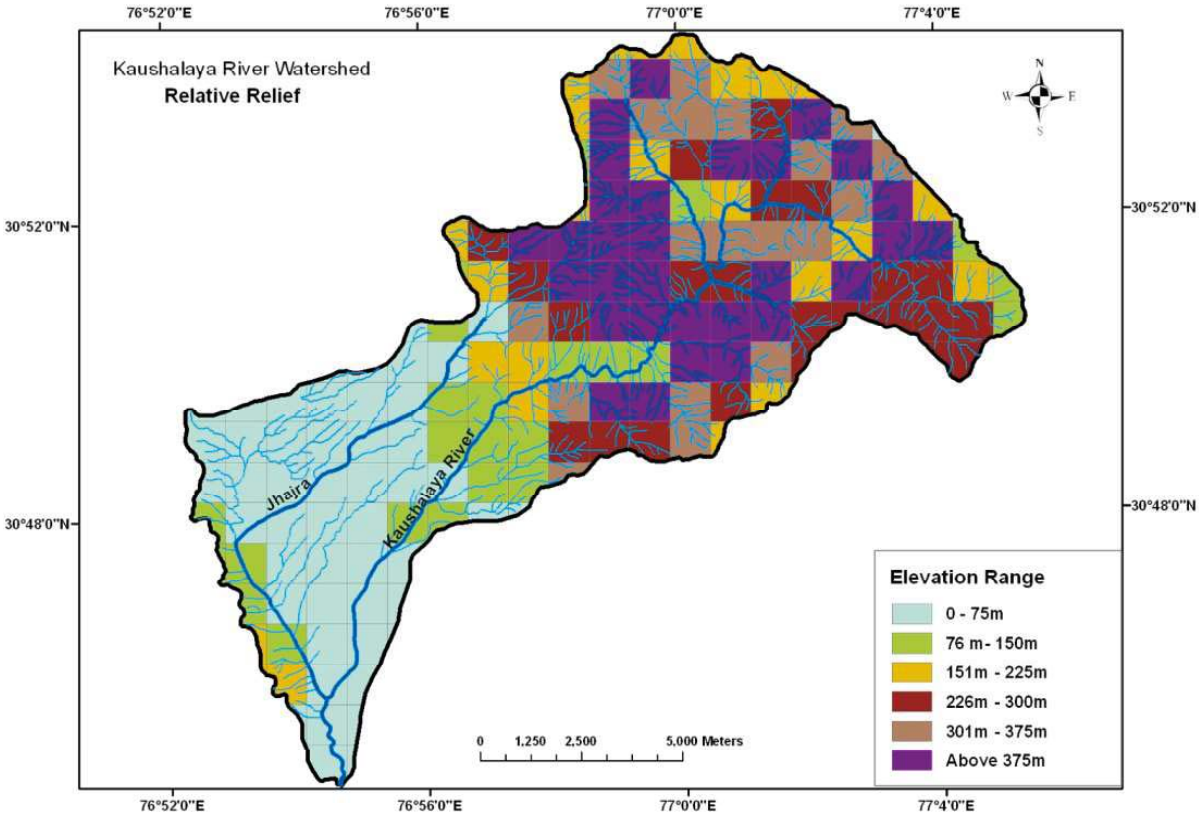


Fig. 4

area above the corresponding elevation on the horizontal or x-axis. The "percentage hypsometric curve" (Strahler, 1952) shows these quantities as percentages. Strahler, 1952 used it to infer the state of geomorphic development of the river catchments.

Area Elevation Curve

It is used to indicate the proportion of area lying at various height categories in percentage. The graph reveals that the highest area comprising about 42.32 per cent of total has an elevation between 800-1400m (moderate altitude), and about 40 per cent area falls below 800m elevation (lower altitude). The study indicates that as the elevation increases above 1400m, the areal coverage decreases in the watershed (Fig.5). It is clear from the study that only 17.82 per cent area above 1400m of Kaushalaya river watershed falls in higher altitudes.

The Hypsometric Integral Curve

Hypsometric integral computed for Kaushalaya River watershed indicates that watershed is passing through the early mature stage. The study brings out that about 61 per cent area of the watershed has been eroded. The hypsometric integral computed for Kaushalaya River watershed is merely 38.50 per cent (Fig. 6). The location of the watershed in the Siwalik ranges which are the youngest mountains and rapidly denuding landscapes in the country also supports this observation that Kaushalaya River watershed is approaching to the mature stage of the geographic development.

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

Table 3
Kaushalaya River Watershed: Area in Different Elevation Ranges

Elevation Range	Area in sq.km	Area in per cent to Total	Explanation
401-500	14.555	10.49	39.86 per cent Lower Altitude
501-600	23.567	16.98	
601-700	11.698	8.43	
701-800	5.496	3.96	
801-900	4.043	2.93	42.32 per cent Moderate Altitude
901-1000	7.548	5.44	
1001-1100	9.408	6.78	
1101-1200	11.063	7.97	
1201-1300	12.763	9.20	
1301-1400	13.879	10.00	
1401-1500	12.117	8.73	17.82 per cent Higher Altitude
1501-1600	6.957	5.01	
1601-1700	2.376	1.71	
1701-1800	2.387	1.72	
>1800	0.902	0.65	
Total	**138.76**	**100.00**	

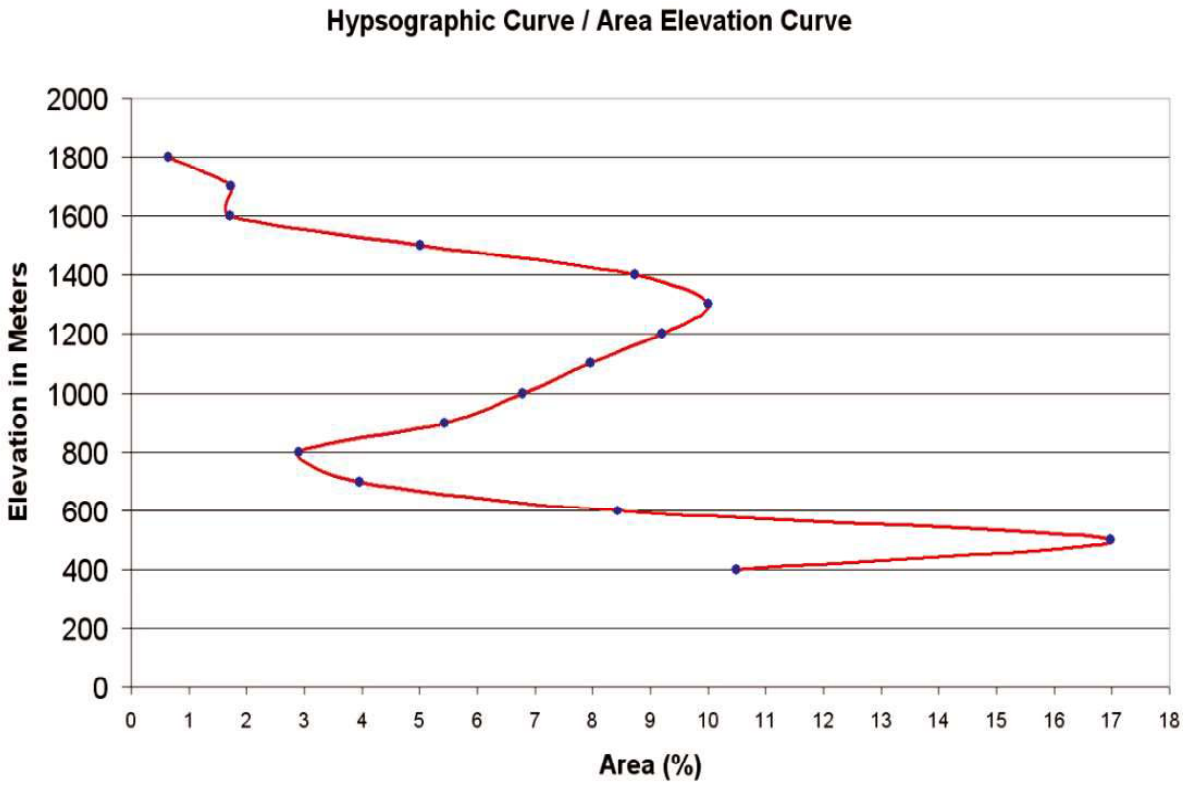


Fig.5

Table 4
Kaushalaya River Watershed: Relative Height and Relative Relief Ratio

Absolute Height m.	Relative Height m.	Relative Height (h/H)	Area (Km^2)	Cumulative Area	Relative Area (a/A)
1850	1450	1.00	0.00	0.00	0.00
1840	1440	0.99	0.00	0.00	0.00
1800	1400	0.97	0.90	0.90	0.01
1700	1300	0.90	2.39	3.29	0.02
1600	1200	0.83	2.38	5.67	0.04
1500	1100	0.76	6.96	12.62	0.09
1400	1000	0.69	12.12	24.74	0.18
1300	900	0.62	13.88	38.62	0.28
1200	800	0.55	12.76	51.38	0.37
1100	700	0.48	11.06	62.44	0.45
1000	600	0.41	9.41	71.85	0.52
900	500	0.34	7.55	79.40	0.57
800	400	0.28	4.04	83.44	0.60
700	300	0.21	5.50	88.94	0.64
600	200	0.14	11.70	100.64	0.73
500	100	0.07	23.57	124.20	0.90
400	0	0.00	14.56	138.76	1.00

Kaushalaya River Watershed: Per Cent Hypsometric Curve

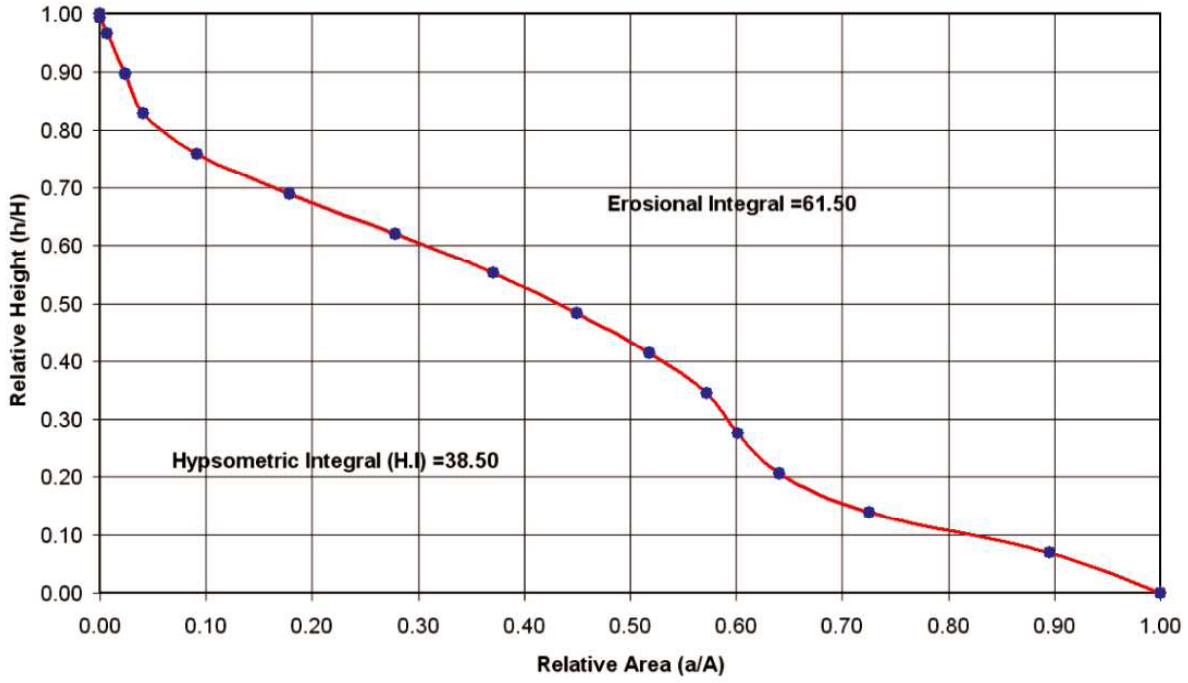


Fig.6

configuration. The landscape profiles of the study area have been drawn along east -west and north-south lines at standard 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 Siwalik ranges, scarps, piedmont zone and undulating terrain like features can be easily identified on the superimposed profiles (Fig.7 to Fig. 10). 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 can also be clearly noted on these profiles.

b) Composite profile

Composite profile portrays the actual bird's view of any area. The Figs.11 and 12 showing the composite profiles clearly reveal the dominance of skyline or higher elements of relief in the northern part of the watershed.

Slope Analysis

Slope is one of the most important elements of morphometric analysis. The slope is the angle of inclination between the surface and a horizontal plane, which may be measured in degrees or percent. Slope is the rate of maximum change in z-value from each cell unit. The area has been analyzed by Wentworth's method which indicates the relative position of slope in the study area varies from 00 to 500. The slope is derived from DEM and classified into 5 categories (Table 5 and Fig. 13).

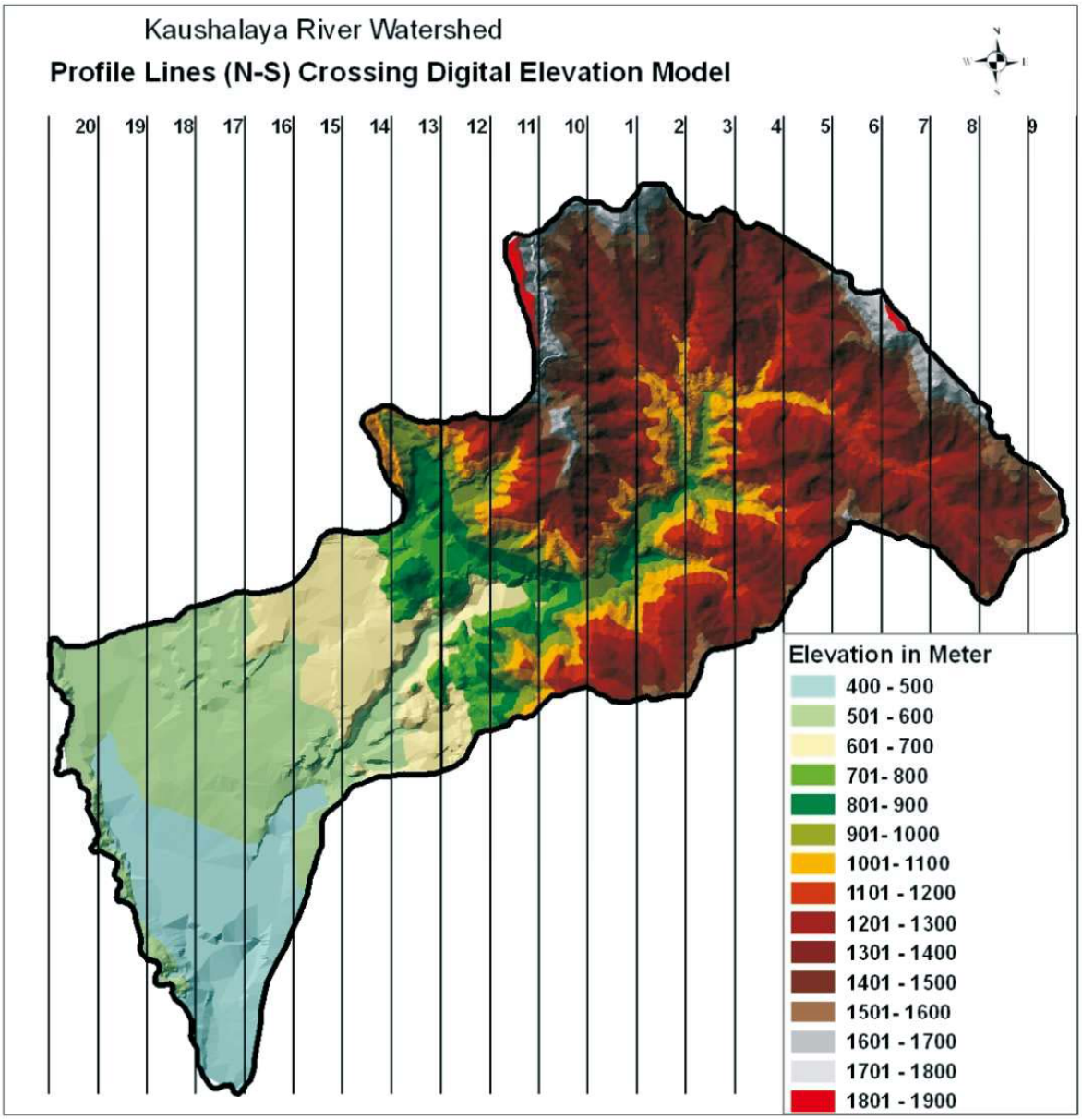
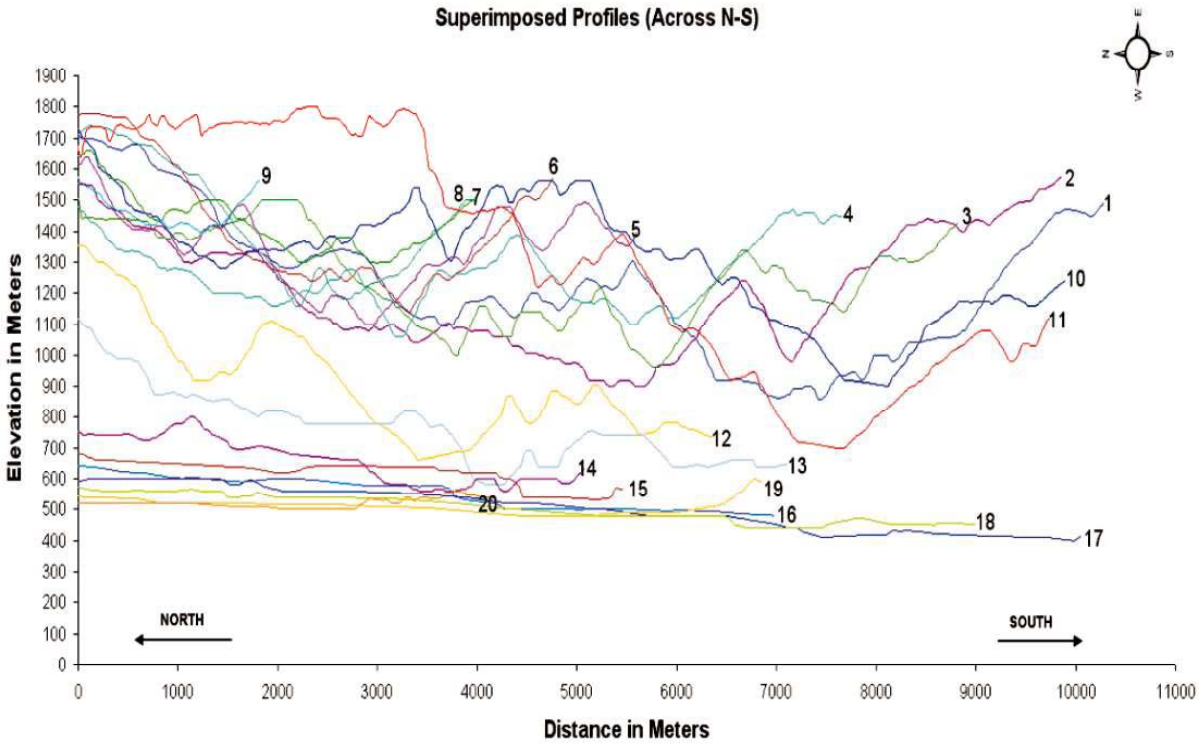

Kaushalaya River Watershed
Profile Lines (N-S) Crossing Digital Elevation Model
20
19
18
17
16
15
14
13
12
11
10
1
2
3
4
5
6
7
8
9
Elevation in Meter
400 - 500
501 - 600
601 - 700
701- 800
801- 900
901- 1000
1001- 1100
1101 - 1200
1201 - 1300
1301 - 1400
1401 - 1500
1501- 1600
1601 - 1700
1701 - 1800
1801 - 1900

Fig.7


Superimposed Profiles (Across N-S)
Elevation in Meters
Distance in Meters
NORTH
SOUTH
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
1
2
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18
19
20

Fig. 8

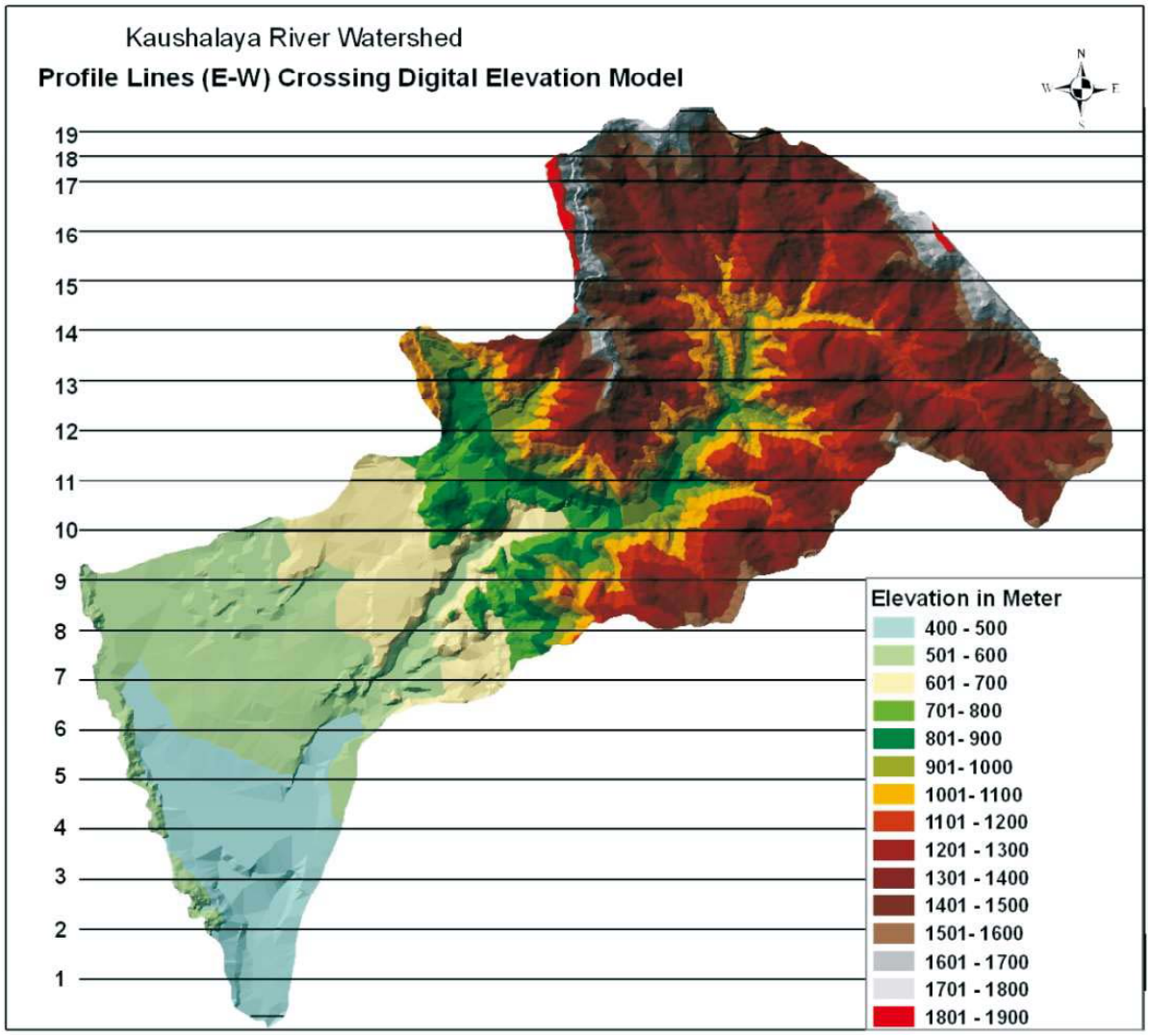
Kaushalaya River Watershed
Profile Lines (E-W) Crossing Digital Elevation Model
N
W
E
S
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Elevation in Meter
400 - 500
501 - 600
601 - 700
701- 800
801- 900
901- 1000
1001- 1100
1101 - 1200
1201 - 1300
1301 - 1400
1401 - 1500
1501- 1600
1601 - 1700
1701 - 1800
1801 - 1900

Fig. 9

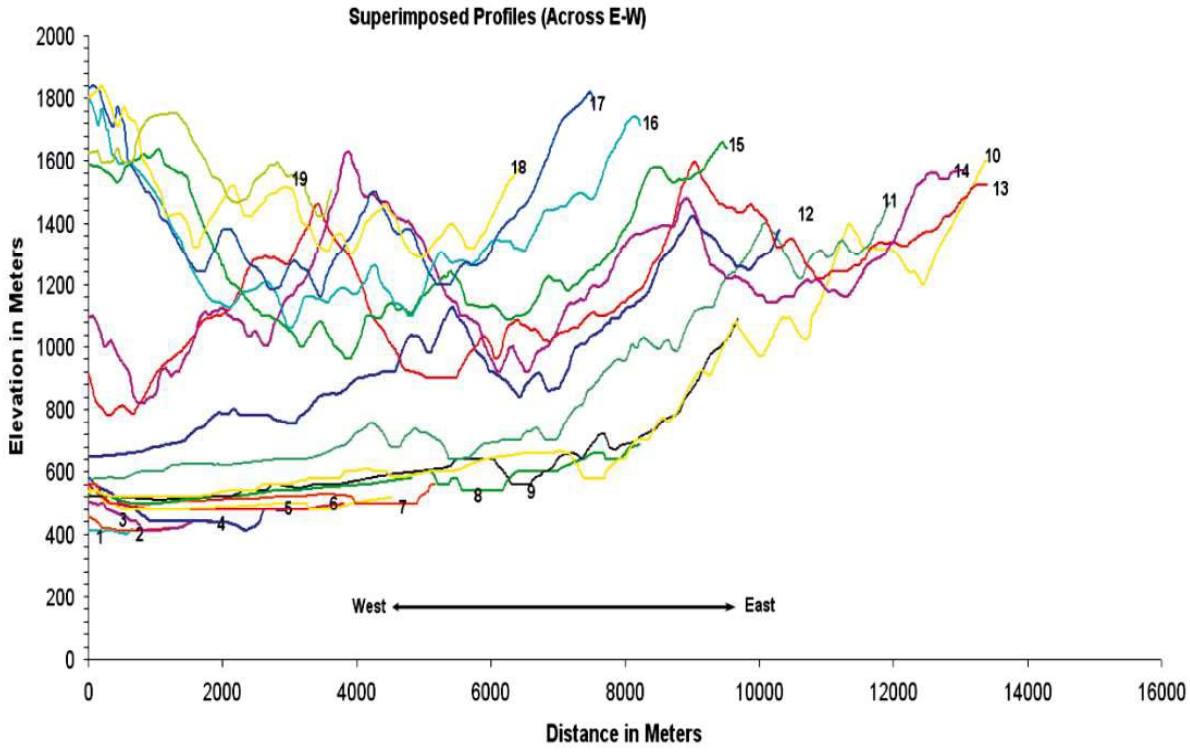
Superimposed Profiles (Across E-W)
Elevation in Meters
Distance in Meters
West
East
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
2000
4000
6000
8000
10000
12000
14000
16000
1
2
3
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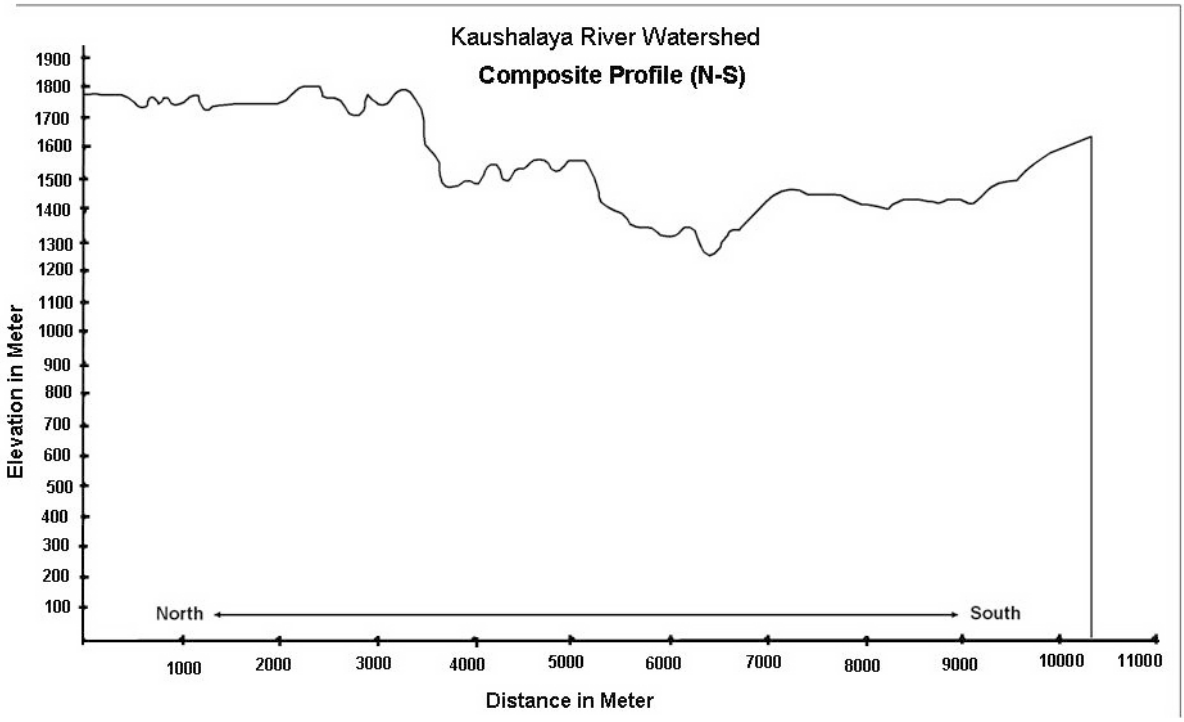
Fig.10


Kaushalaya River Watershed
Composite Profile (N-S)
Elevation in Meter
Distance in Meter
North
South
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
1000
2000
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5000
6000
7000
8000
9000
10000
11000

Fig.11

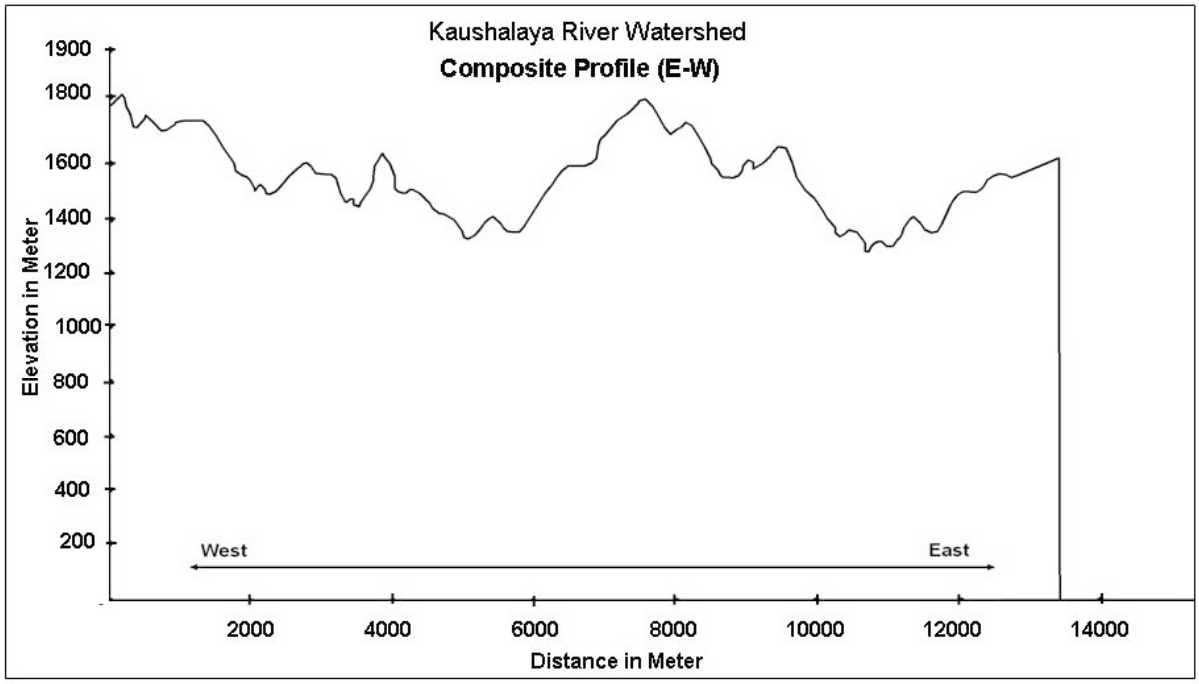

Fig.12

Table 5
Kaushalaya River Watershed: Spatial Distribution of Slope

Slope Category (in degree)	Area (Km^2)	Area in per cent	Explanation
< 10	54.15	39.03	Very Gentle Slope
11-20	29.35	21.15	Gentle Slope
21-30	35.73	25.75	Moderate Slope
31-40	15.69	11.31	Steep Slope
>40	3.83	2.76	Very Steep Slope
Total	**138.76**	**100.00**	

The slope map shows that more than one third i.e. 39 per cent area of the total watershed comes under very gentle slope and mainly distributed over the piedmont zone sprawling south and south-western part of the watershed. It covers the vast plain and agricultural area of Kalka and Pinjore regions of Haryana state. The study reveals that about one- fifth of the total area falls under the category of gentle slope (10-20 degree). It is mainly concentrated in the central part and upper most part of the watershed along the stream beds in a well distributed pattern. It is evident from the table that one-fourth of the watershed has moderate slope of 20-30 degree observed in the areas between gentle slope and steep slope. About 11 per cent area having steep slope comprises hilly area in upper Siwalik range and about 3 per cent area has very steep slope (> 400) dotting the cliffs, ridges and a few sharp vertical

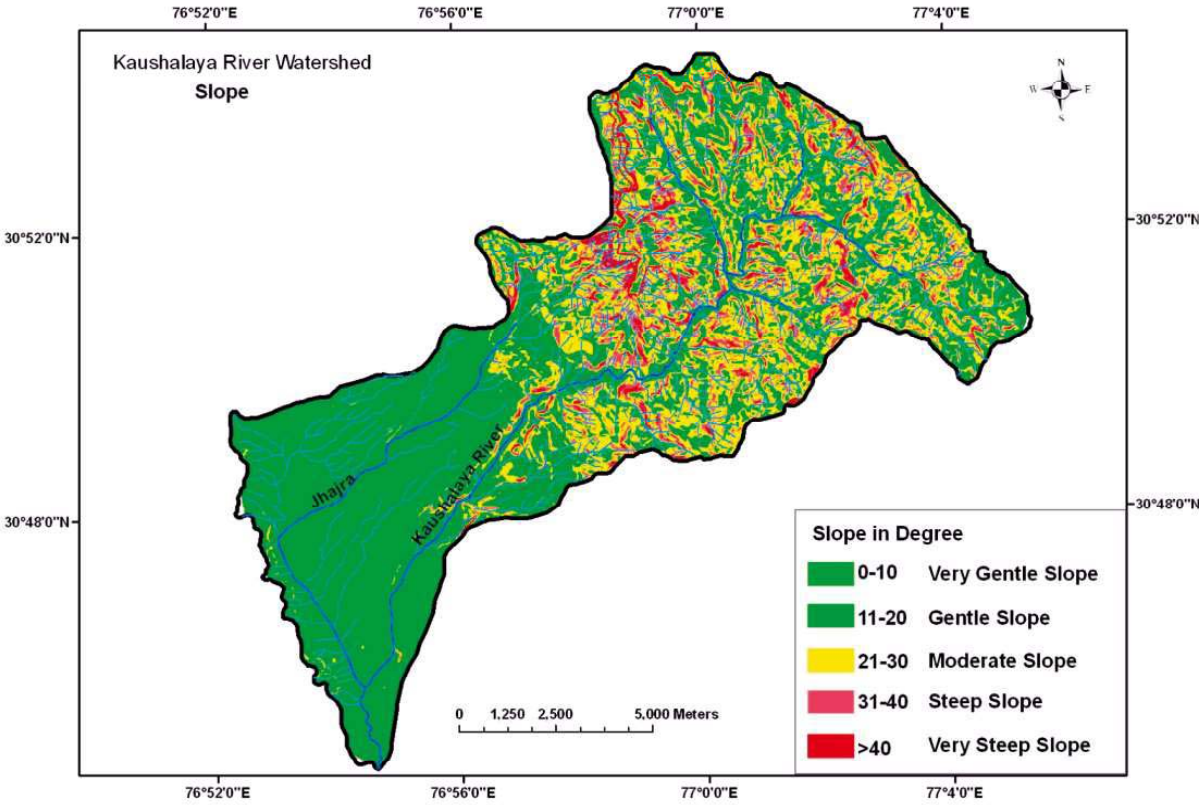

Fig.13

escarpments present in the watershed landscape.

Conclusion

The study brings out distinctive variations in absolute relief ranging from the lowest 400 m to the highest 1850 m in Kaushalaya River watershed. The highest concentration (42.68 per cent) of high absolute relief category varying between 1000m to 1500m elevation covers Malthu, Barbana and Karalghat reserved forests and Chaola, Jauhri, Jagatgarh, Anun, Guman, Ambota Jarrag, Datiar, Budho, Gauri ki Dhar protected forests in Solan district of Himachal Pradesh. The relative relief varies from the lowest of 410 m to highest of 1075 m. The study reveals that the highest area comprising about 42 per cent of total has an altitudinal variations ranging between 800-1400m and about 40 per cent area falls below 800m elevation above mean sea level. The study points out that as the elevation increases above 1400m, the areal coverage decreases in the watershed. Hypsometric integral computed for Kaushalaya River watershed indicates that watershed is passing through the early mature stage because about 61 per cent area of the watershed has been eroded. The location of the watershed in the Siwalik ranges which are the youngest mountains and rapidly denuding landscapes in the country also supports this observation that Kaushalaya River watershed has stepped in the mature stage.

The summits of Siwalik ranges, scarps, piedmont zone and undulating terrain like features can be easily identified on the superimposed profiles. 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 shows that more than one third area of the watershed comes under very gentle slope mainly distributed over the piedmont zone. It is investigated that about one- fifth of the total area falls under the category of gentle slope mainly concentrated in the central and upper most part of the watershed along the stream beds and about 3per cent area has very steep slope (> 400) dotting the cliffs, ridges and a few sharp vertical escarpments present in the watershed.

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