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Geomorphological Classification of Western Western Doon of Dehra, Uttarakhand, India

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ABSTRACT

Morphological units are those sections of landforms, which have uniform morphological property. The identification of morphological or terrain units is an exercise of regional classification of terrain with similar properties on varying scales. Morpho units enable the planners to determine land use planning, infrastructure development and natural resource management. Such type of terrain classification also highlights the hazardous unit, particularly in mountainous areas. Doon of Dehra is an important geomorphic unit in terms of both natural and cultural point of view. Dehradun, which is the capital city of Uttarakhand is also situated in this geomorphic unit. So, it becomes important to delineate the unit in smaller geomorphic units for proper land use planning and infrastructural development and to mitigate the hazards as well. Topographical sheets published by the government of India are the database of study. In the present study 'principle component analysis' based on the centroid method of Holziger and Herman (1941) has been adopted as this is manageable manually. The components, like - relief, drainage derivatives and slope has been taken for meso and micro level division of area into morpho units. The study area consists of 4 major morpho units and 28 micro units.

Keywords: Dehra, Mapping, Morphological, Mussoorie, Siwaliks Ravineous, Z- Scores,

INTRODUCTION

The study area falls in Himalayan region. It lies between lesser Himalayas and Siwaliks. It is one of the famous doons situated between these two ranges. The crests of lesser Himalayas and Siwaliks respectively in north and south, Song water divide in the east and Yamuna in north-west and west make the boundaries of Western Doon of Dehra. This doon covers an area of 834.28 square kilometers. The latitudinal extension of the area is from 30° 14' 10" to 30° 31' 32" north. Its longitudinal extension is from 77° 34' 15" to 78° 05' 39" east. Politically, this area falls in Dehradun district of Uttarakhand. Asan is the major stream in this geomorphic unit. It is a sixth order stream. Six fifth order tributaries - Upper Asan, Nun, Darer, Sitla Rao, Tons, Surna join the major stream (Asan). Doon of Dehra is an important geomorphic unit in terms of both natural and cultural point of view. Dehradun, which is the capital city of Uttarakhand is also situated in this geomorphic unit. So, it becomes important to delineate the unit in smaller geomorphic units for proper land use planning and infrastructural development and to mitigate the hazards as well.

Morphological units are those sections of landforms, which have uniform morphological property. The present research paper focuses on the classification of such terrain units which have certain association or relationship with physical attributes. The variation in scale creates a hierarchical pattern of morphological units. The highest order of morphological units could be a very simple exercise of identifying broad section; such as mountain, plain, Plateau etc. These broad units of landform can be further classified into subunits by considering parameters like climate, vegetation, parent rock and broad alignment. The next order of morphological units involves a detailed exercise of identifying micro levels of patterns and their similarities. Such patterns are recognized first by splitting a landform in terms of its element, like altitude, slope, drainage, textures etc. The second stage involves the establishment of relationships between different elements of landform like slope with altitude, slope with drainage, drainage with texture and texture with developmental stage of the topography etc. After establishing such a relationship the conclusions are grouped together and synthesized. This synthesis results in identification of morpho-units of different hierarchical order.

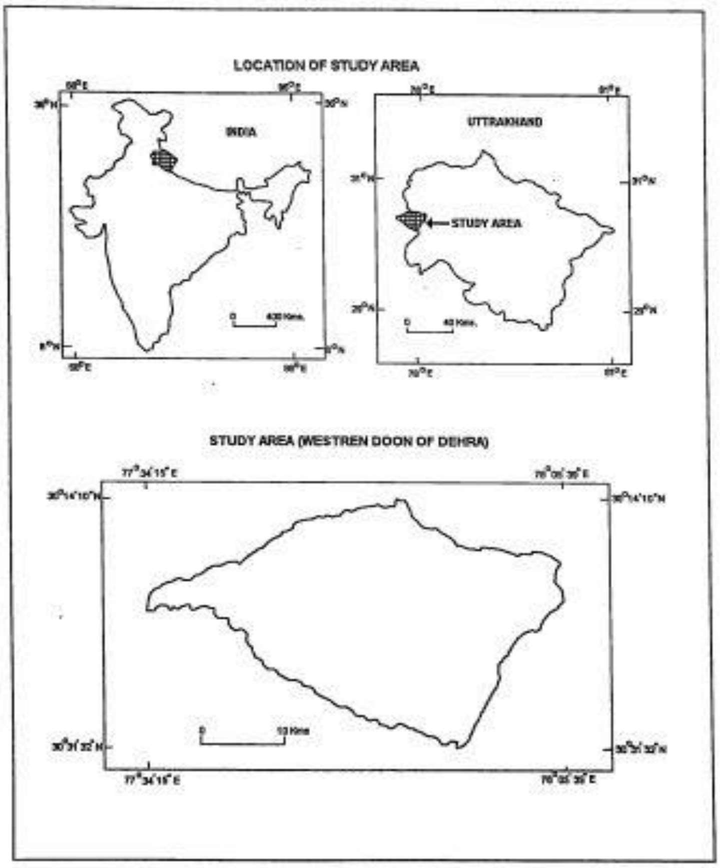

Figure1. Study Area

Several attempts have been made to classify the terrain and identify the morphological units of different hierarchical order on different bases. Joerg (1914) adopted both inductive and deductive methods to divide North America into morphological regions; which, he called 'natural regions', on the basis of uniformity of geochronology. Bourne (1931) used the term 'morpho-units' for morphological regions, which were based on the concept of 'characteristic site assemblage; wherein the first order morpho-units were demarcated on the basis of uniform topographic features as shaped by the denudational processes; whereas second order morpho-units were based on environmental conditions. Hammond (1954) made 'terrain characteristics of landscape components' as the basis for the mapping and identification and demarcation of morpho-units. Savigear (1965) demarcated morpho-units by superimposing morphological maps of selected geomorphometric variables and named the morpho-units on the basis of natural regions. R.L. Singh (1967) adopted 4 elements for identification and classification of terrain into morpho units. These are relative relief, dissection index, drainage texture and

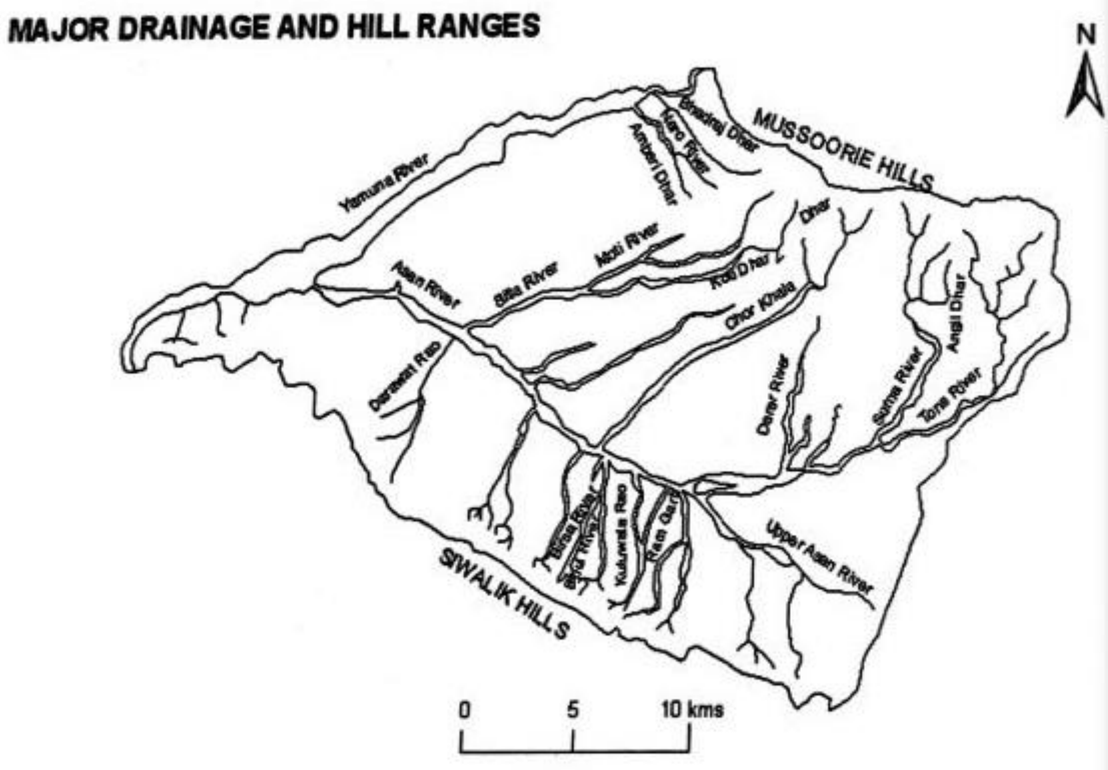

Figure2. Drainage Map

slope. He also proposed the range of these attributes on a countrywide appreciation of landforms. Asathana, V.K. (1968) has not only presented a scheme of classification of different order of morpho-units but has successfully correlated with the density of settlements and find out adhesive and non-adhesive character of different morpho-units in Almora and it's environs.

Gellert (1982) propounded the concept of morphological regionalization and identified 'morpho-tops' or 'morpho facies' as basic units for morphological regionalization. According to him, 'the morphotops or morphofacies never occur as isolated forms but they together form joint regional units in the form of complexes and form-groups with similar but heterogeneous geomorphological marks as orographical, morphological, morphometric, lithological, sedimentological, morphogenetic and morphostructural kind' (Gellert, 1982). He identified five morpho-units in ascending order viz. (1) morphotops (MT), (2) groups of morphotops (MTG) or morphnanochores (MNCh), (3) morpho-microchores (MMich), (4) morphomesochores (MMech) and (5) morphomacrochores (MMach). Peltier (1950) divided the world into morphogenetic regions on the basis of climatic parameters and intensity of morphodynamic processes.

DATABASE AND METHODOLOGY:

Database of study is topographical sheets (RF 1: 50,000) published by the Survey Department of India. Topographical Sheets no. 53F/10, 53F/11, 53F/14, 53F/15 and 53J/3 have been used. Aerial photographs and satellite data have also been used for analysis.

The details of aerial photographs data is as under:

Total No of Aerial Photographs - 55

Task No. ………………….... 346A Total strips. ……………………… 7 Camera used ………… Agle IX, MK-II Focal length of camera. ………… 152.24 Year of photography. …………….. 1980 Format size. ………………. 23×23 cm. Flying height. ……….……….. 3810 m. Scale. ……………………. 1:25000	**Strips**	**Photo No**	**Total No of Photo**
	7	38-42	5
	12	16-22	7
	15	1-8	8
	16	12-15	4
	22A	1-7	7
	22	16-26	11
	24	41-53	13

Satellite Data

Landsat 5TM imagery (1:50000). (For Visual Interpretation).		IRS - 2A Imagery (1:25000) (For Visual Interpretation).
Path No 143.	Row No 39.	IRS 1A (CCT) (For Digital Image Processing)
Quadrant No. 3.	Vol. 1 & 2.	Year of Data 1991 Sensor Type - LISS 1 No of Bands - 4

In the present study 'principle component analyses based on the centroid method of Holziger and Herman (1941) instead of 'axis method of Rummel (1970) has been adopted as the former is manageable manually. Principle components (table 6.3 and 6.4) have been derived from correlation matrix (table 6.1); involving six geomorphic variables viz. absolute relief, relative relief, average slope, dissection index, drainage density and stream frequency for the identification and determination of terrain units. The entire computational process involved the calculation of correlation matrix, Z-scores, component scores, loading of principle components, eigen-values, variance etc.

Table1: Correlation Matrix

		Ar	***Rr***	***As***	***Df***	***Dd***	***Di***
Coorelation	*Ar*	1.000					
	Rr	0.864	1.000				
	As	0.405	0.439	1.000			
	Df	0.518	0.634	0.324	1.000		
	Dd	0.231	0.357	0.176	0.666	1.000	
	Di	0.111	0.121	0.056	0.166	0.067	1.000

Ar – Absolute relief, Rr – Relative relief, As – Average slope, Df – Drainage frequency, Dd – Drainage density, Di – Dissection index.

Table2: Morpho-Component Matrix

Variables	Communalities		Components	
	Initial	Extraction	1	11
Ar	1.000	0.818	0.892	0.151
Rr	1.000	0.863	0.882	0.292
As	1.000	0.503	0.709	–0.028
Df	1.000	0.823	0.508	0.751
Dd	1.000	0.773	0.162	0.864
Di	1.000	0.182	–0.026	0.426

Table 3: Distribution and Spatial Coverage of Morpho-Components for Relief-Aspect

Class Interval	Frequency	Percentage
> 1.5	133	14.57
0.5 to 1.5	111	12.16
0.5 to –0.5	373	40.85
–0.5 to –1.5	273	29.90
< –1.5	23	02.52

Table4: Distribution and Spatial Coverage of Morpho-Components for Drainage-Aspect

Class Interval	Frequency	Percentage
> 1.5	127	13.91
0.5 to 1.5	204	23.34
0.5 to –0.5	268	29.35
–0.5 to –1.5	273	29.91
< –1.5	41	4.49

Table 2 shows that out of two components, the first component named as relief aspect (absolute relief, relative relief, slope) is correlated quite highly with each of six variables, so the first component (relief aspect) is used for mapping and demarcation of maro-morpho units. The second component- the derivative of drainage has been used for micro morpho units. On the basis of Z-scores limit (from –3.00 to +3.00) ,morpho component scores have been grouped into five categories. The five morpho-component score group are very high (above 1.5), high (0.5 to –1.5), moderate (0.5 to –0.5), low (–0.5 to –1.5) and very low (less than –1.5). With the help of data, presented in table (3) very high to very low components has been plotted on the map of grid squares and major morpho-units were identified. Similarly, with the help of table (4) another such map was prepared. These two maps were superimposed to draw micro units.

Maps of macro and micro units were also prepared through superimposition of various physical parameters of relief and drainage. The maps of morpho units prepared by these two methods were superimposed. It was found that the boundaries of terrain units / morpho-units in two maps prepared by two different methods more or less matches and thus methodology adopted in present study proves to be satisfactory.

To prepare the final map of morpho-units, certain adjustment in boundaries were done by taking into account various maps of physical parameters.

ANALYSIS AND INTERPRETATION

1. **Denudational Hills (Unit 1A)**

This unit is represented by the high hills of the Lesser Himalayas, Southern limit of which is bounded by Krol Thrust. As it is much disturbed by tectonic movements, so development of mass wasting processes have been marked, particularly along some weak planes or zone. These hills are made up of Pre-Tertiary; Metasedimentary rocks viz. Mandhali-Bhadraj Quartzite, Chandpur Phyllite, Nagthat-Quartzite. Infra Krol- Slate, Krol- Limestone and Subathu- Shale. They are delineated in the aerial photograph by its homogeneous topography, prominent erosion surfaces, light to medium tone, low to medium drainage density, smoohjjjjjth to uneven texture, less vegetation, blunt hill crest, convex slopes, mass wasting and gully erosion.

2. **Structural Hills of Lower Tertiary (Unit 1B):**

This formation belonging to Lower Tertiary is represented by Main Bondary Fault and Krol- Thrust. So as per alignment of these two thrusts, this structural hill extends throughout the area. Relief is much subdued and covered by high level fans at few places. Dip-facets, strike ridge and valley, saddle, structurally controlled drainage, rough texture and sharp crest ridges are important characteristics of this terrain unit.

3. **Ravineous Zone of Siwaliks (Unit 2A)**

This zone is found in upper Siwalik boulders conglomerate. Because of high percentage of boulders and course matrix, the credibility of rock is very high. Added to this, intensity of rainfall is very high which facilitates weathering, erosion and transportation through different streams. Because of these reasons, the entire area has been converted to a ravinous zone, in which there are very often vertical eroded ridges. Rock falls are very common and streams are wide. Drainage is coarse and is of consequent pattern, as they follow a dip slope.

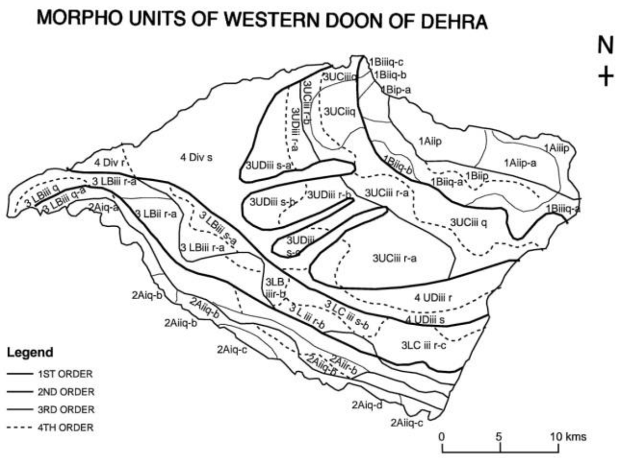

Figure3. Morphological Units Map

4. **Moderately dissected zone of Siwaliks (Unit 2B)**

This zone represents pebble bearing horizon, occurring in bottom of ravinous zone of Siwaliks. Ridge lines are poorly defined and streams are broad. Drainage pattern is generally obsequent. This zone has moderate slopes. This unit is covered by forests.

5. **Piedmont Zone (Unit 3U and 3L)**

The piedmont plain of western Doon of Dehra is located in between Siwalik hills and Lesser Himalayas. It can be called an intermontane piedmont fan plain. This zone occupies more than 50% of the entire valley area. The piedmont material is derived from the Pre-Tertiary and Siwalik rocks both lying to the NE and SW of the Doon Valley. This zone consists of unconsolidated boulders, gravels, pebbles, sand and clays. The river Asan forms the boundary between these two piedmont Zones. These are upper and lower Piedmont

5.1 Upper Piedmont (3 U): This subunit is mainly composed of Doon fan gravels. The main landforms of this sub-unit are alluvial fan or fan-cut terraces. Lithologically, it is composed of coarse gravels, pebbles and cobbles, sand and sandy clay. The main land use character of this area is Reserve Forests. The pebbles and coarser components are mainly of Quartzite and Quartzitic-Sandstones. In the upper piedmont there is a distinct break in slope with the Upper Siwalik boulders beds. Lower portion of this unit is under agriculture. The lower portion of the piedmont zone is composed of sub recent fan terraces, gravels or younger Doon gravels in terms of geological unit. It is consisting of boulders, pebbles, gravels, sands, clay and sandy clay. These landforms are developed in between upper piedmont and terraces. Lower piedmont boundary almost coincides with Sub-Recent fan terrace gravels of younger Doon gravels.

5.2 Lower Piedmont (3 L): This Piedmont zone extends from southern Siwaliks to northwardly. Keeping pace with the gentle inclination of southern Siwalik strata, Piedmont zone exhibits gentle slope and covers less areas in comparison with the Piedmont zone of principal level. Unlike the later one, it consists of rounded to well rounded pebbles with a sandy and silty matrix. The earth materials are primarily derived from northerly dipping Siwalik formation.

6. **Denudational or residual hills in older Doon gravels (Unit 3 UC):**

These denudational hills are noticed in the northern part of Doon Valley. Garibnath hill, Ambari hill, Kotra Truti, Angilladhar and some other small hillocks come together under this group. These residual consists of boulders, pebbles and embedded in clay. The striking features of this unit are the presence of partly rounded boulders and pebbles embedded in yellowish, brownish and reddish brown clay. Almost all the residual hills are thickly forested.

7. **River Terraces in Piedmont Zone (Unit 3 UD):**

River terraces mark the position of former floodplains that have undergone repeated uplift due to change in long established tectonic conditions. River terraces of the Asan, Sitla Rao, Suarna and Yamuna rivers are identified from aerial photographs as gentle, flat area, adjacent to the river. It shows uniform light tone, smooth texture, flat topography and low drainage density. In the present study, lower terraces are called as younger terraces and upper terraces are called as older terraces. The terraces are overall gravelly in nature showing a vertical repeated alternation of boulders to platy material.

8. **Younger Flood Plains (Unit – 4D)**

The youngest geomorphic unit in the Doon valley is the floodplain, which is characterized by the development of channel bar, sand bar and braided river. These features of low relief are built adjacent to river stream channels like Yamuna, Asan, Surna, Sitla Rao and others; formed by unconsolidated materials such as boulders, pebbles, gravels, sands, slit and clay. Streams are flowing from high relief like Middle/Upper Siwalik and Pre-Tertiary formations in the north and Upper Siwalik in south. The major rivers like Yamuna, Asan, Surna and Sitla Rao normally form wide active flood plains; consisting of braided channels and meandering stream courses. The geological composition of this floodplain unit is mainly the Alluvium, which comprises boulders, pebbles, gravels with some sand and slit. The upstream courses of a few streams, draining to the piedmont zones from the northern side have also developed a narrow belt of flood plains along the streams. These floodplains are covered under agriculture and dense settlements

Table 5: Attributes of Terrain Units

	Mussoorie hills	Ar(M)	Rr (M)	Df No/Km^2	As (deg.)	Dd (Km/Km^2)	Code Formation (F)
I	Mussoorie-hills	900-2229	100-700	2-18	10-40	1-7	–
I A	Denudo-Structural Hills (DSH)	1300-2229	> 300	2-18	10-40	1-6	–
I A ip	Very highly dissected DSH with steep slopes	1300-2229	> 300	> 12	> 25	> 5	Avh, Rvh, Ss, Fvh, Dh
I Aiip-a, b	Highly dissected DSH with steep slopes	1300-2229	> 300	6-12	> 25	3-5	Avh, Rvh, Ss, Fh, Dm
I Aiiip	Moderately dissected DSH with moderately steep slopes	1300-2229	> 300	2-6	10-25	1-3	Avh, Rvh, Sms, Fm, Dl
I B	Structural hills (SH)	900-1300	100-300	2-18	10-30	1-7	–
I Bip-a, b	Very highly dissected SH with steep slopes	900-1300	100-300	> 12	> 25	3-5	Ah, Rh, Ss, Fvh, Dm
I Bii	Highly dissected structural hill (HDSH)	900-1300	100-300	6-12	10-30	1-3	–
I Biip	HDSH with steep slopes	900-1300	100-300	6-12	> 25	1-3	Ah, Rh, Ss, Fh, Dl

I B iiq-a, b	HDSH with moderately steep slope	900-1300	100-300	6-12	10-25	1-3	Ah, Rh, Sms, Fh, Dl
I B iiiq-a, b, c	Moderately dissected structural hills with moderately steep slopes	900-1300	100-300	2-6	10-25	1-3	Ah, Rh, Fh, Sms, Dl
2	Structural-hills of Siwaliks	600-900	> 100	2-15	2-25	1-7	–
2A	High relief ravinous zone of Siwaliks	750-900	> 100	2-15	2-25	1-7	–
2A iq-a, b, c, d	Very highly dissected high relief ravinous zone of Siwaliks with steep slope (zone of gully erosion and mass wasting)	750-900	> 100	> 12	10-25	> 5	Ah, Rh, Sms, Dh
2A iiq-a, b, c	Highly dissected high relief ravinous zone of Siwaliks with moderately steep slopes	750-900	> 100	6-12	10-25	3-5	Ah, Rh, Sms, Fh, Dm
2A iii r	Moderately dissected high relief ravinous zone of Siwaliks with moderate slopes	750-900	> 100	2-6	2-10	1-3	Ah, Rh, Sm, Fm, Dl
2B	Moderate relief structural hills of Siwaliks	600-750	20-100	2-12	2-25	1-6	–
2B iiq-a, b	Highly dissected structural hills of Siwaliks with moderate relief and moderately steep slopes	600-750	20-100	6-12	10-25	3-5	Am, Rm, Sms, Fh, Dm

2B iir-a, b, c	Highly dissected structural hills of Siwaliks with moderate relief and moderate slopes	600-750	20-100	6-12	2-10	3-5	Am, Rm, Sm, Fh, Dm
2B iii r	Moderately dissected structural hills of Siwaliks with moderate relief and moderate slopes	600-750	20-100	2-6	2-10	3-5	Am, Rm, Sm, Fm, Dm
2C iii r	Moderately dissected structural hills of Siwaliks with low relief and moderate slopes	< 600	< 20	2-6	2-10	1-3	Al, Rl, Sm, Fm, Dl
3	Piedmont Zone	450-900	20-100				
3 U	Upper piedmont zone (North of Asan River)	550-900	40-100				
3 UC	Older Doon gravels (residual hills zone) of upper piedmont	700-900	40-100				
3UCii	Highly dissected older Doon gravels (residual hills-zone) of upper piedmont (HDODG)	700-900	40-100	6-12	<25	3-5	–
3UCiiq	HDODG with moderately steep slopes	700-900	40-100	6-12	10-25	3-5	Am, Rm, Sms, Fh, Dm
3UCiir	HDODG with moderate slopes	700-900	40-100	6-12	2-10	3-5	Am, Rm, Sm, Fh, Dm
3UCiiiq-a, b	Moderately dissected older Doon gravels with moderately steep slopes	700-900	40-100	2-6	10-25	1-3	Am, Rm, Sms, Fm, Dl

3UCiiir-a, b	Moderately dissected older Doon gravels with moderate slopes	700-900	40-100	2-6	2-10	3-5	Am, Rm, Sm, Fm, Dm
3 UD	Younger Doon gravels and terraces	550-700	< 40				
3UDiii	Moderately dissected younger Doon gravels and terraces	550-700	< 40	2-6	< 10	3-5	–
3UDiiir-a, b, c	Moderately dissected younger Doon gravel and terraces with moderate slopes	550-700	< 40	2-6	2-10	3-5	Al, Rl, Sm, Fm, Dm
3UDiiis-a, b, c, d	Moderately dissected younger Doon gravel and terraces with gentle slopes	550-700	< 40	2-6	< 2	1-3	Al, Rl, Sg, Fm, Dl
3 L	Lower Piedmont (South of Asan River)	450-600	< 100	< 12	< 10	3-5	–
3 LB	Lower piedmont with moderate relief (LPRm)	450-600	20-100	< 12	< 10	3-5	–
3LB iir-a, b	Highly dissected LPRm with moderate slopes	450-600	20-100	6-12	2-10	3-5	Al, Rm, Sm, Fh, Dm
3LB iiir-a, b	Moderately dissected LPRm with moderate slopes	450-600	20-100	2-6	2-10	3-5	Al, Rm, Sm, Fm, Dm
3LC	Lower piedmont with lower relief (LPRL)	450-600	< 20	2-6	< 10	1-5	–
3LC iiir-a, b, c	Moderately dissected LPRL with moderate slopes	450-600	< 20	2-6	2-10	3-5	Al, Rl, Sm, Fm, Dm

3LC iiis-a, b, c	Moderately dissected LPRL with gentle slopes	450-600	< 20	2-6	< 2	1-3	Al, Rl, Sg, Fm, Dl
4	Plains	< 650	< 40	< 6	< 5	< 3	–
4D	Low relief plain	< 650	< 40	< 6	< 5	< 3	–
4D iii r	Moderately dissected undulating plain	500-650	0-20	2-6	2-5	1-3	Al, Rl, Su, Fm, Dl
4D iii s	Moderately dissected gentle plain	500-650	0-20	2-6	< 2	< 1	Al, Rl, Sy, Fm, Dl
4D iv r	Low dissected undulating plain	< 500	0-20	< 2	2-5	1-3	Avl, Rl, Su, Fl, Dl
4 D iv s	Low dissected gentle plain	< 500	0-20	< 2	< 2	< 1	Avl, Rl, Sg, Fl, Dvl

Ar – Absolute Relief; Rr – Relative Relief; Df – Drainage Frequency ; As – Average Slope ; Dd – Drainage Density

CONCLUSION

Eight major morpho units has been identified in the study area. These are: 1) Denudational Hills; 2) Structural Hills of Lower Tertiary; 3) Ravineous Zone of Siwaliks; 4) Moderately dissected zone of Siwaliks; 5) Piedmont Zone; 6) Denudational or residual hills in older Doon gravels; 7) River Terraces in Piedmont Zone; 8) Younger Flood Plains. Denudational hill- morpho unit is characterized by zones of mass wasting zone, gully and erosion, blunt hillcrest, convex slopes and with less surface vegetation. Dip-facets, strike ridge and valley, saddle, structurally controlled drainage, rough texture and sharp crest ridges are important characteristics of Structural Hills of Lower Tertiary. Upper Siwaliks morpho unit is a ravineous zone. The morpho unit named as moderately dissected zone of Siwaliks which occurs in bottom of ravinous zone of Siwaliks represents pebble bearing zone with moderate slopes and forests. The Piedmont Zone occupies more than 50% of the entire valley area. This zone consists of unconsolidated boulders, gravels, pebbles, sand and clay. The lower piedmont zone is covered by agricultural land. Almost all the residual hills morpho unit areas are thickly forested. The terraces are overall very gravelly in nature. The youngest geomorphic unit in the Doon is the floodplain, which is characterized by the development of channel bar, sand bar and braided river. These floodplains are covered under agriculture and dense settlements.

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