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Terrain Classification of the Dulung Drainage Basin

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Terrain analysis concerns extraction and analysis of geomorphological properties of a terrain in order to identify similar or identical geomorphic units. It is important and also useful from the perspective of hydrology, pedology, morphology, and finally, human usage of the earth's surface. The major objectives are to identify the terrain classes based on the attributes of physiography, lithology, and geomorphology of the Dulung basin. This will facilitate the formulation of strategies to engineer the development of the basin area.

Introduction

Terrain is the expression of the geological character, the soil, and the surface geometry of the earth's crust. Its general nature can be easily understood by inspecting the maps revealing the spatial distribution of these three aspects. Thus, as a process terrain evaluation involves— analysis (*the simplification of the complex phenomenon which is the natural geographic environment*), classification (*the organization of data distinguishing one area from another and characterizing each*), and appraisal (*the manipulation, interpretation, and assessment of data for practical ends*).

The main specialist interests concerned with terrain evaluation and their requirements are academic— earth science, agriculture, civil engineering, military activities, meteorology and climatology, hydrology, urban and rural residential and recreational planning, nature conservancy and wildlife planning, and finally, archeology. Problems associated with terrain classification fall into three main groups: those of complexity, extent, and association, to which a fourth, scale, might be added. Every spot on the earth's surface has a multitude of varied but intricately interrelated attributes which make it unique and difficult to compare with any other. It is necessary to try to understand and simplify this complexity so that the characteristics of different places can be defined, described and compared.

Methodology

The principle of terrain classification has been based on the simple principles of map algebra that combines elements of the sets defining the attributes of a terrain. It is universally and specially used in raster analysis, where two different sets of thematic data layers are superimposed through overlay operation. In the current analysis, three different strategies of classification have been used as follows—

1. The first one is based on lithological and geomorphic units. Mathematically speaking, let there be two sets defining the attributes of the above variables— lithology (L) and geomorphology (G) as :
   $L_i = \{L_1, L_2, L_3, \ldots L_n)$, and
   $G_j = \{G_1, G_2, G_3, \ldots G_k\}$.
   Hence, the terrain classes will be defined by the elements derived by the union of the sets L_i and G_j as— $T_{i\,j} = \{L_i\,.G_j\,\}$
   where i = 1, 2, 3, ... n and j = 1, 2, 3, ... k
2. The second one is based on lithological and morphometric units. Mathematically speaking, let there be two sets defining the attributes of the above variables— lithology (L) and geomorphology (M) as:
   $L_i = \{L_1, L_2, L_3, \ldots L_n)$, and
   $M_j = \{M_1, M_2, M_3, \ldots M_k\}$.
   Hence, the terrain classes will be defined by the elements derived by the union of the sets L and M_j as — $T_{i\,j} = \{L_i\,.G_j\,\}$
   where i = 1, 2, 3, ... n and j = 1, 2, 3, ... k
3. The run-off potential index (RPI) is a simple measure of runoff generated from any surface per unit area as a percentage of the total precipitation on it. Higher runoff leads to greater soil erosion affecting agricultural

activities that forms the staple livelihood in rural areas. Terrain units producing similar amounts of runoff have then been delineated within the basin and accordingly prioritisation has been done for planning and necessary mitigation.

Lithological Divisions

The Dulung basin is mainly comprised of Cenozoic cover sediments (*particularly in the northwestern part of the basin*) with some basic and ultrabasic volcanics and associated sediments formed as intrusives within the geosynclinal to platform meta-sediments of schists, phyllites and quartzites. The basin area exposes a wide area of Tertiary and Quaternary sediments. Within the Tertiary, a distinction can be made between the lithified (Durgapur Beds, *not present in the basin area*) and the non – lithified, raised gravel beds (*present*), the latter probably grading into the red soils of Quaternary age that dot the landscape as islands of high ground, the width and thickness of which increases towards the south and east within the basin.

The northwest portion of the basin consists mainly of garnetiferous phyllites of the Singhbhum Group (*lower Proterozoic*) that dips towards NNE at 70° while its foliation planes dip towards SE at 55°. The northwestern part of this bed is overlain by carbon – phyllite intrusives that dip towards SE at 60° while its foliation planes dip towards NW at 60°. The above carbon – phyllite and quartzite intrusives comprise the two lowermost beds of the Dalma Volcanics. Also present in this complex are: (a) bands of hornblendes schists and epidiorites of the Singhbhum Group, (b) manganese deposits, and (c) few lateritic caps (*these are much larger and more numerous near the litho-contact between the garnetiferous – phyllite beds and the sedimentary deposits*). In the northeastern part of the garnetiferous – phyllite bed there is an arm like intrusion southwestwards of garnet – staurolite schists with kyanite belonging to the Singhbhum Group. In the central part some bands of quartzite belonging to the Dalma Volcanics are present.

Thus, the Dulung basin has been divided into six major lithological units by the G.S.I. (1998: Geological Quadrangle Map No. 73J at 1:250,000) as— 1. *Sijua formation*, 2. *Dhalbhum gravels*, 3. a *zone of garnetiferous phyllites* with sporadic occurrences of laterite, quartzite and some garnet-staurolite schist with kyanite, 4. an *area of carbon phyllites* with occurrences of horneblende schist and epidiorite, manganese, tourmaline quartz rocks, 5. *Kasai formation* and 6. *Lalgarh formation* (Fig.1). Most of the basin area is covered by the Lalgarh formation (41.04%) that occupies mostly the left half of the basin in the north – east. This is followed by the Tertiary gravel beds of Dhalbhum (26.61%) that covers mostly the right half in the west.

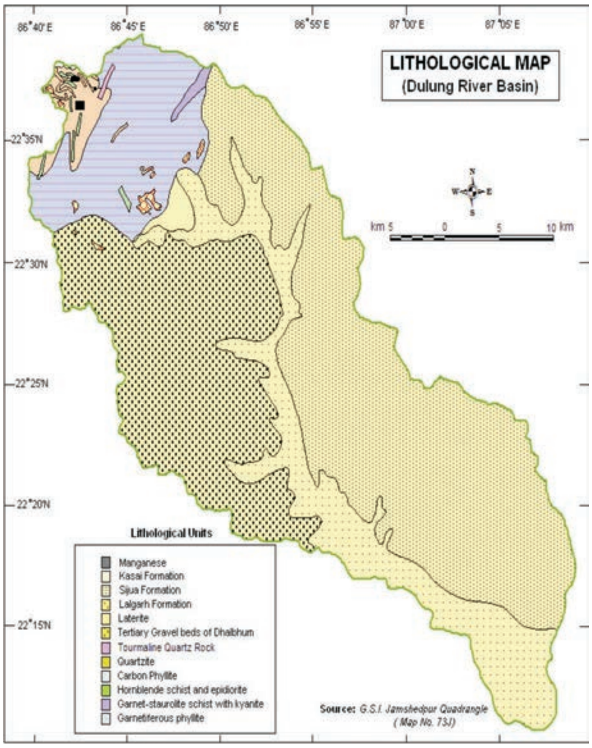

Fig.1: Lithological Divisions of the Dulung basin

The garnetiferous phyllite region occupies the plateau proper area toward the headwater region of the Dulung basin with a proportion of about 12.53%. The source region is covered by carbon phyllites which is comparatively more resistant to erosion; it occupies about 2.28% of the total basin area. The valley plains of the main channel and its major tributaries occupy about 16.74% of the total basin area in the axial region of the basin and is superficially covered with the Sijua formation. Parts of the plateau rim between the garnetiferous phyllites and the Sijua formation are covered with Kasai formation that covers about 0.84% of the total basin.

Geomorphic Divisions

The drainage developed over the various sedimentary deposits resembles that of a normal dendritic pattern. The drainage density intensifies in the northwestern part of the basin mainly due to the metamorphic and intrusive igneous lithounits and minerals present there, with the rocks being more jointed and having foliation planes, aiding in channelising runoff. Furthermore, schists and phyllites are prone to getting weathered easily and consequently more easily amenable to stream incision. The quartzite bands present are however very resistant and these can and do form low, elongated ridges in this area, with streams having short courses draining off either face of the ridge. There are also indications of a fault or large-scale joints running east – west that has caused the Dulung to shift its course from southward to eastward and then southeastward quite suddenly. Other splay faults or joints may also have caused the marked elbows seen along the courses of the left bank tributaries of the main channel that initially flow southwestwards but turn suddenly to the southeast. Such sudden changes of direction are absent in the right bank tributaries.

Most of the 1st order streams originate in the northwestern portion of the basin, occupied by the igneous intrusives and metamorphics of the Dalma Volcanics and Singhbhum Group respectively. Due to its relatively resistant lithology, this area has assumed a much higher elevation than the other parts of the basin covered by Quaternary and Cainozoic sedimentary deposits. Besides, the schists and phyllites are well foliated and jointed and hence, stream initiation is plentiful in the northwestern sector. They flow for short distances in widely varying directions to join and form stream segments of higher orders.

Based on the nature and characteristics of landforms, the Dulung basin has been divided into five geomorphological divisions by the G.S.I. (2002) and C.G.W.B. (1968, 1999), viz., a. *lower flood plains*, b. *higher flood plains*, c. *undulating upland plains*, d. *plateau rim* and e. *plateau proper* (Fig.2). The lower floodplain mainly covers the region near the mouth of the river. It is the lowest part with little slope, characterized by drainage congestion, sand and alluvium fills, splay channels and annual inundation. It covers about 2.26% of the basin area.

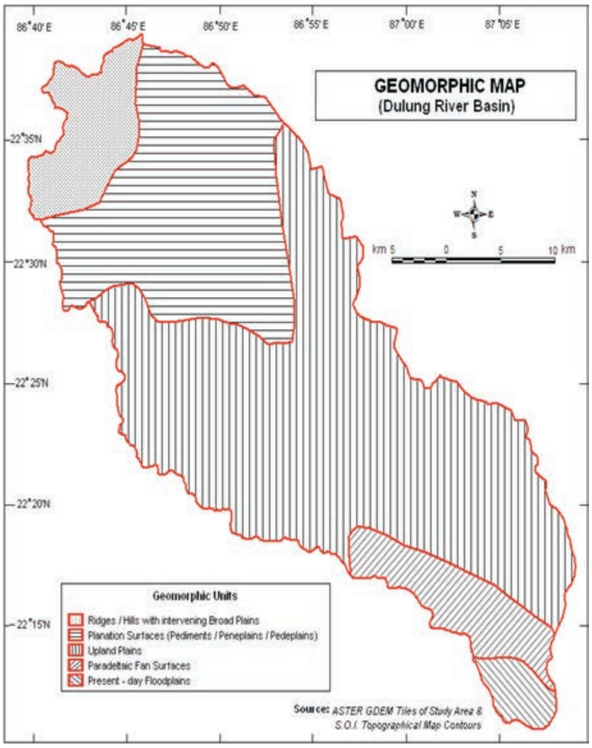

Fig. 2: Geomorphological Divisions of the Dulung basin

The higher flood plains covers mostly that in the lower reach of the Dulung river; slope being very imperceptible, flow is a dynamic manifestation between channel morphology, discharge, slope and other river variables. It covers about 7.05% of the basin area and the GSI has identified this with paradeltaic fan surfaces as the lower course of the main river shows clear signs of channel shifting toward east through transient distributaries. The upland plains occupy 56.30 % of the basin area in the middle part of the basin and is physiographically undulating capped with Dhalbhum gravels and Lalgarh lateritic formations. The plateau rim is a region with relatively steeper slopes, moderate to highly dissected in the residual formations of Dhalbhum and Lalgarh, and garnetiferous phyllitic terrain. It is also the catchment / source regions of major tributaries. It covers about 26.94% of the basin area and is geomorphologically very dynamic and most important. The plateau proper comprises ridges and hills separated by plains in the uppermost catchment area of the basin.

Terrain Classes

(a) Based on Lithological and Geomorphic Units

By combining the lithological units with geomorphological divisions, terrain classes have been identified as follows (Fig.3). There are thirteen distinctive terrain classes each is distinguished by their own litological matrix and geometry of the landforms produced on them. The Sijua formation includes four sub-regions, viz., 1a, 1b, 1c and 1d, respectively in the floodplains, undulating plains and plateau rim. The Dhalbhum gravels of Tertiary age has been suitably divided into two sub-regions, viz., 2c and 2d covering parts of undulating plains and plateau rims. The garnetiferous phyllites area covers parts of plateau proper and plateau rim divisions (3d and 3e). The carbon phyllites mainly covers the highest part of the basin with steeper slope and high dissection and ruggedness (4e). The Kasai formation is a single terrain unit distinctive with the physiographic character of the plateau rim (5d). The Lalgarh formation comprise two distinctive sub-regions, viz., 6d, and 6b respectively occupying parts of plateau rim, undulating upland plains and upper / higher floodplains.

(b) Based on Lithological and Morphometric Units

The parameters derived from the kilometre grids of the Dulung basin to identify the morphometric units are— maximum elevation (x_1), minimum elevation (x_2), relative relief (x_3), average slope (x_4), stream frequency (x_5), drainage density (x_6), drainage texture (x_7), ruggedness number (x_8), dissection index (x_9), coefficient of relative massiveness (x_{10}), and roughness index (x_{11}). Factor analysis has been done to extract factor scores values based on which nine morphometric units have been identified at 1.0 interval. With 6 lithological units superimposed onto this yields a set of about 24 terrain units/classes of varying dimensions, morphometric and morphologic attributes (Fig. 4). Interestingly, it is only three morphometric divisions (viz., A, B, and C) that cover bulk of the basin, i.e., more than 93% of its area. There are three terrain classes in the Sijua formation, viz., the lowest reach of the Dulung comprising the low lying confluence area and the lower flood plain, which is annually inundated during monsoon (1A), gentle upper floodplain in the middle reach (1B) and undulating plains (1C). The Dhalbhum gravel region in the right half of the Dulung river comprise two terrain classes, i.e., 2B and 2C. The garnetiferous phyllites is the most complex region with eight of the

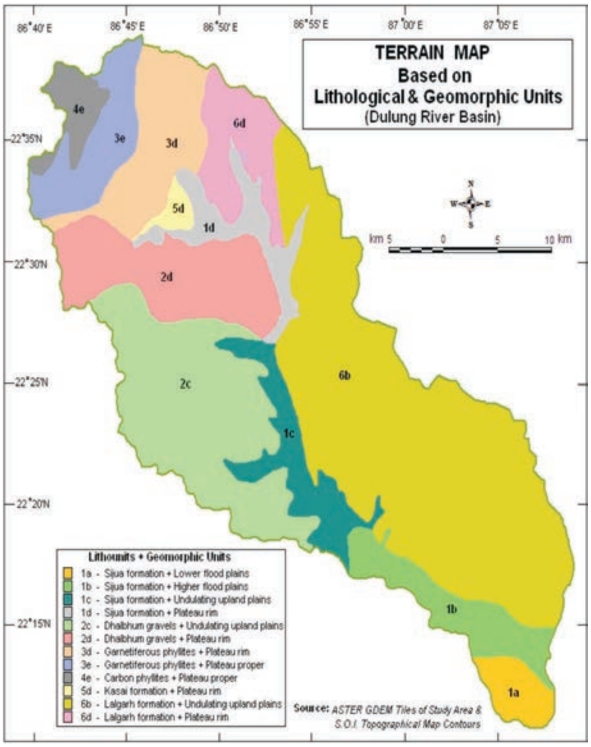

Fig. 3: Terrain Classes of the Dulung basin
(based on Lithological Units and Geomorphic Units)

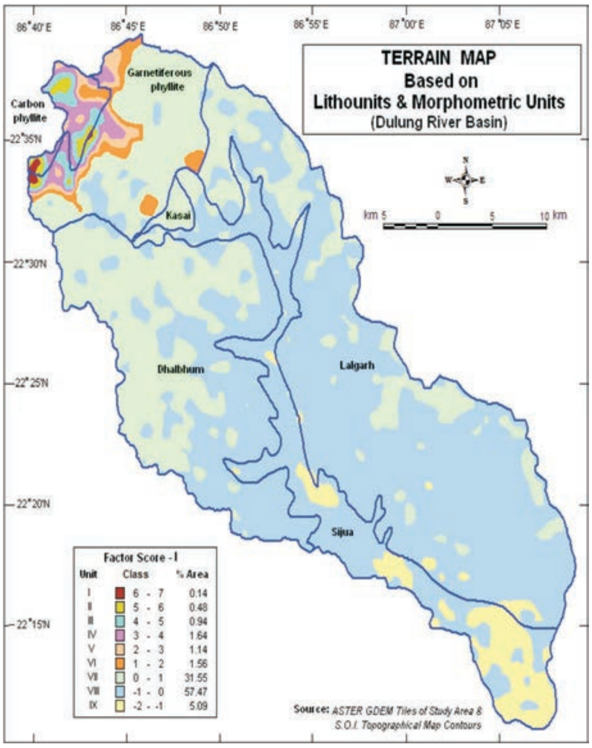

Fig. 4: Terrain Classes of the Dulung basin
(based on Lithological Units and Morphometric Units)

nine morphometric units, viz., 3B, 3C, 3D (lower piedmont of the dissected plateau rims), 3E (upper piedmont of the dissected plateau rims), 3F (dissected plateau), 3G (dissected plateau proper), 3H (well dissected upper plateau surface), and 3I (dissected summits of the highest plateau). The carbon phyllites area comprise six distinctive terrain units in the most geologically complex catchment/ headward region of the Dulung, viz., 4D, 4E, 4F, 4G, 4H, and 4I. The Kasai formation covers a small area with two terrain units, viz., 5B and 5C. The Lalgarh formation in the left side of the middle reach is one of the largest geological unit with three distinctive terran classes, viz., 6A, 6B, and 6C.

(c) Based on Run off Potential Index

The impact of denudational processes on man's activities along with its rate varies throughout the basin. Thus, there are marked differences in the physical character of land from one part of the basin to another and also their response to external inputs of mass and energy with the existing ground conditions determining the throughput rate and output amount. For this, the basin has been suitably divided into much smaller sub-watersheds with the most vulnerable ones being given the highest rank so as to merit treatment first.

It is a very important approach in our country constrained with infrastructural resources including financial/capital one and skilled manpower that makes focusing on the entire basin at once is impossible. This forms the basis of prioritization by which is created a hierarchical arrangement of the sub-watershed within a basin on the basis of a particular criteria, like—

- the physical character of the sub-watershed (morphometry/physiography),
- rates of denudational processes within the watershed,
- impact on the watershed of anthropogenic activities, leading to stress which needs to be counterbalanced

The AISLUS designed their SYI MODEL (i.e. sediment yield index) especially for the Indian environment, with a view to find out the intensity and amount of soil erosion from sub-watersheds. The principle is that greater encroachment on forests, poor grazing methods on pasture fields and faulty management of existing cultivated lands will expose soils to greater erosion via runoff, which will reflect in higher sediment yields that will then impact on any small dams across the river, silt up reservoirs, thereby reducing the available water for irrigation diversions. The RPI (i.e. run-off potential index) is a simpler derivative of the SYI Model, giving the proportional quantum of runoff that will be generated from any surface per unit area (as a fraction or percentage of the total precipitation on it). Higher runoff will lead to greater soil erosion via sheet and rill methods and poor development of mature soil layers which will then impact on agricultural activities that forms the staple livelihood in rural areas. If via prioritisation, the most vulnerable area in the basin, prone to high runoffs can be identified, necessary plans can be devised/formulated for its mitigation.

In devising the RPI, all factors such as climate (especially the precipitation regime, amount and intensity), relief, slope (amount and aspect), land cover and land use, soil (structure and texture), and existent land management practices. Relative weights have been assigned to each parameter and based on this, land units producing similar amounts of runoff (i.e., potential runoff mapping units) have been delineated within the basin (Table 1). The entire basin is then broken up into sub-watersheds, comprising one or two 2nd and 3rd order basins along with the overland flow zone between them (Fig. 5). On the basis of how much of each type of RPMU, a sub-watershed contains in proportion to its total area, its runoff generating capacity (i.e., runoff potential index) has been computed. The sub-watersheds are then ranked in descending order of RPI with the ones at the top being most affected by soil erosion and requiring most attention via changes in landuse practices. The sub-watersheds have also been classified from 'very high priority' to 'very low priority'. In many ways this methodology rather than concerning itself in trying to find out how much sediment is lost, focuses on trying to pinpoint areas that may lose the most so that those can be protected— the more important aspect from geographical perspective.

Altogether six major watersheds have been delineated as Sc1, Sc2, Sc3, Sc4, Sc5, and Sc6, each of which has been divided into sub-watersheds of varying attributes of geohydrology, morphology, and

Table 1: Terrain Units based on Runoff Potential Index

Terrain Units	Area (%)	Physiography And Slope	Soil Colour, Depth, Texture, Drainage & Erosion	Runoff Potential Index
A	14.83	Nearly level – low (slope < 1%)	Gray – grayish-brown; Very deep; Sandy clay loam – clay; Poorly drained; None – slight erosion	0.50
B	47.41	Mid upto toe slope (1 - 5%)	Dark reddish-brown – grayish-brown; Very deep – deep; Sandy clay loam – clay; Imperfectly drained; None – slight erosion	0.60
C	22.82	Convex upland, very gently – gently Sloping (1 - 5%)	Dark reddish-brown – yellowish-red; Deep – very deep; Loamy sand – sandy clay; Moderately well – well drained; Moderately – severely eroded	0.65
D	0.62	Convex upland, gently – moderately Sloping (3 - 10%)	Dark reddish-brown – yellowish-brown; Shallow – moderately deep; Gravelly sandy loam – gravelly sandy clay loam; Well drained; Severely eroded	0.75
E	3.37	Stream bank & margins, gently – moderately sloping (1 to 5%)	Yellowish-red – brown; Very deep; Loamy sand – clay; Well drained; Severely – very severely eroded, gullied lands	0.80
F	6.00	Convex upland, gently – moderately sloping (1 - 5%)	Dark reddish – yellowish-brown; Very shallow – moderately deep; Sandy loam – silty clay; Well drained; Moderately – severely eroded	0.70
H	3.16	Steep – very steep hill and hill escarpments (slope > 33%)	Yellowish-red – dark grayish-brown; Very shallow – shallow; Loamy sand – gravelly clay; Excessively drained; Severely eroded	0.90
J	1.14	Convex upland, very gently – gently sloping (1 - 5%)	Dark reddish-brown – yellowish-red; Deep – very deep; Sandy clay loam – gravelly clay; Moderately well – well drained; Moderately – severely eroded	0.65
M	0.03	Convex upland, gently – moderately sloping (1 - 5%)	Dark grayish-brown – dark gray; Very deep; Sandy clay – sand; Imperfectly – moderately well drained; Moderately – severely eroded	0.80
Q	0.63	Subarnarekha River bank margin, gently – moderately sloping (3 - 8%)	Yellowish-brown – dark brown; Very deep; Silty loam – clay loam; Moderately well – well drained; Slight – moderately eroded	0.70

Source: Compiled by the authors from Technical Bulletin No. 9, 1991, AIS & LUS, New Delhi

morphometry. Of these, the largest is Sc2, followed by Sc6, Sc5, Sc4, Sc3, and Sc1 (Table – 1). Sc2 and Sc6, each contains 13 sub-watersheds, while Sc4 nine, Sc5 eight, Sc3 six and Sc1 only four. Based on the RPI values, prioritization has been done by assigning ranks in ascending order (Fig. 1). It shows that—

- only one sub-watershed in Sc6 has been categorized as 'very high priority'
- two 'high priority' sub-watersheds are also contained in Sc6.
- Sc6 also comprise 10 'medium priority' sub-watersheds, while Sc4 nine, Sc5 eight, Sc2 six, Sc3 five.
- All the four 'low priority' sub-watersheds are in Sc1, more than half (i.e., seven of 13) in Sc2 and only one in Sc3.

Thus, 'high' to 'very high' priority sub-watershed are found in the plateau proper region, which is lithologically most tough and morphologically the head water regions. 'Low priority' sub-watersheds are mainly located near the southern portion of the

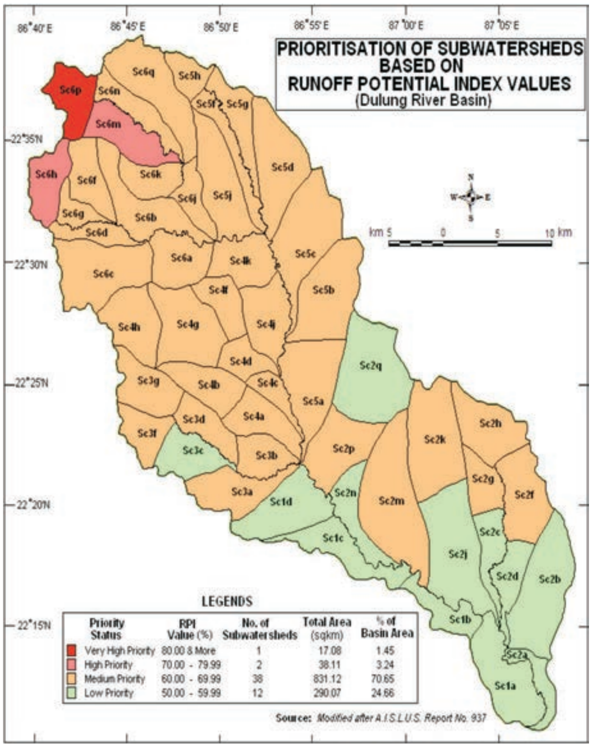

Fig.5: Terrain Classes of the Dulung basin
(based on Runoff Potential Index)

lower half that is principally composed of residual lithological matrix with lower slopes and thick soil cover.

Conclusion

The terrain of the Dulung river basin has been classified from two distinctive perspectives using three different techniques. The first classification uses map algebra by overlaying the geomorphological units over the lithological units, thereby producing a total of twelve (12) distinctive terrain units / classes that appear to be very much identical to geomorphic regions. The principle is that landscape comprising varieties of landform evolve being primarily controlled by the underlying geology. Hence these terrain units are very important and need further investigation to establish their morphological nature along with their impact on human activities. The second classification is also similar, that used overlaying operation and map algebra involving lithological units and morphometric units and yielding a total of twenty four (24) distinctive terrain classes. The principle is that morphometric attributes of the terrain of a landscape vary as a direct function of the properties of the underlying lithology, structure and tectonics.

The third classification is based on the prioritization status extracted from the values of run off potential index. The four priority classes thus derived are —low, medium, high and very high. The only very high priority sub-watershed in the carbon phyllites mainly cover only 1.45% of the basin area, while the two high priority ones mainly on the garnetiferous and carbon phyllites cover about 3.24% of the total basin. The 38 medium priority sub-watersheds cover about 70.65% of the total basin and are mostly located in the Sijua, Dhalbhum, Lalgarh and Kasai formations. The 12 low priority sub-watersheds cover about 70.65% of the total basin and are mostly located in the Sijua, Dhalbhum, and Lalgarh formations. Attention must be given to the sub-watersheds in the increasing scale of prioritization. Therefore, necessary inputs must be given immediately in the medium – high priority sub-watersheds for sustainable development. Local people, voluntary agencies and the state Govt. should jointly sit together to formulate plans and execute them without further delay to restore and maintain the dynamics of life in this part of the *Jungle Mahal* of our country.

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