Geo-environmental Assessment for Determining Suitability of Buildable Land in Context of a Hill Town

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Abstract

Inappropriateness of the building and construction activities taking place in preferred locations in the lower Himalayan region is a cause of concern on account of environmental degradation that is often witnessed along with increased construction activity in most of the popular hill towns of north India. Considerations of stability of hill slopes- considered to be the most important for any development by technical experts are often superseded by locational considerations of proximity to work centres and community facilities, land values, accessibility and solar exposure, in deciding the preferred locations for development, the type of buildings and their builtform in urban settlements in hills. Therefore, a comprehensive appraisal of areas in and around hill towns is important for determining their suitability for development for ensuring their social acceptability, as well as, sustainability. This paper discusses the methodology for geo-environmental assessment of hill slopes for determining their suitability for building purposes, after discussing the problems and issues related to urban development and construction of buildings and roads, which can then become a basis for planning for future urbanization in hill regions. This methodology is demonstrated in context of Almora- a hill town in Uttarakhand, which is witnessing rapid urban growth.

Introduction

Increased construction activities are natural outcome of urbanization in an area. However, these activities, though at much smaller scale and pace than that in plains, have the potential to adversely affect and have already affected in some cases the sensitive environmental context in which they are located. Building and construction activity taking place in most of the popular hill are often considered to be a cause of environmental degradation. Therefore, a proper understanding of various problems, their causative factors and issues related to rapid urbanization and consequent construction activities is essential for evolving the methodology for geo-environmental assessment for determining suitability of buildable land.

Problems and Issues of Urban Development in Hill Towns

Various problems faced by hill towns are consequent upon unplanned growth and/or inappropriate planned efforts in some cases. These problems range from those related to instability of hill slopes and ecological disturbances to those related to accessibility of residential areas from work centers and community facilities, traffic and transportation, infrastructure development and visual incompatibility of builtforms. In addition, towns that is centres of tourist attraction face problems consequent upon unplanned/excessive tourism. More instances of landslides/subsidence of hill slopes/roads, failure/cracks in buildings are observed in areas with increased construction activities. Quantitative and qualitative changes in

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hydrology have also taken place, besides loss of vegetation cover and increased soil erosion. Micro-climatic changes are also reported in some areas (Anbalagan, 1992); B.I.S., 1998; Pushplata, 2000; Sinaj. 2007 and Venkatesh, 2007).

High land values due to shortage of suitable land for building purposes in proximity to existing centre of development and low affordability of the majority of inhabitants in hill towns has resulted in building of houses in areas that are located away from centres and/ or building on slopes that are climatically unsuitable or unstable(with lower land values). Expansion of residential areas in far off locations necessitates longer walking distances and time to reach work centers and community facilities and inadequate infrastructure on account of its high cost. Whereas, building on relatively unstable slopes obviously aggravates and sometime causes problems of instability- resulting in frequent instances of landslides, subsidence of hill slopes/roads and failures/ cracks in buildings. In some cases natural drainage courses are also disturbed leading to further instability. In addition, buildings with greater bulk are built on steeper slopes requiring extensive cutting of slopes/ development of large terraces for functional and economic reasons, which result not only in disturbances to slope stability and ecology of the areas, but in these buildings looking out of place as well. Provision of roads, parking and other infrastructure required for these buildings/ uses further aggravates the problems. All these not only disturb the slope stability but also disturb the vegetation cover and natural drainage patterns leading to environmental problems as shown in Fig.1 below.

Thus, it is primarily the lack of proper understanding of the natural environment and their affect on the built environment and its incorporation in planning and design of urban settlements that has led to a multitude of

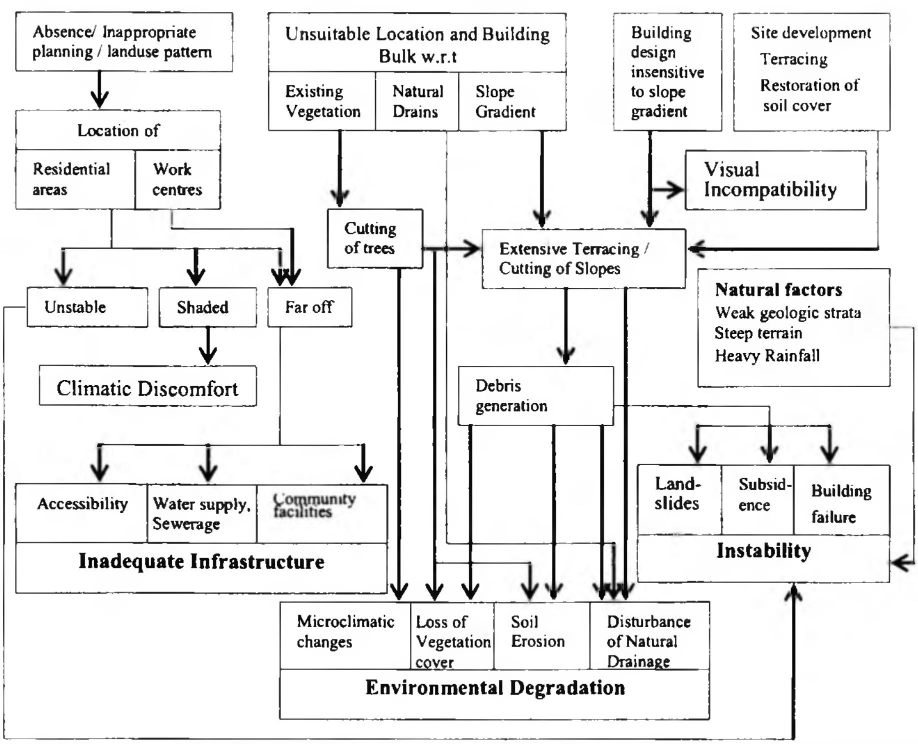

Fig. 1: Inter-relationship between Planning of Built Environment and Various Problems in Hill Towns

problems in hill towns as discussed above. In order to address the above problems and issues of a hill settlement it is essential to develop a methodology for determination of suitability of land for development/ building purposes.

Need for a comprehensive technique for site appraisal

Though techniques of geo-technical assessment like [1] Landslide Hazard Zonation [2], guidelines for selection and development of sites in Hill Areas [3] and slope analysis are available, their application is at regional level and site level respectively and do not address the issues at settlement/ area level. Some methodologies and techniques of townscape analysis and environment appraisal are available, most of which are very descriptive and/or largely subjective statements of townscape and/or landscape quality. The townscape analysis concentrates on visual qualities of the locality and the environmental appraisals primarily concentrate on natural systems in the environment. Whereas, site planning techniques are generally used for individual buildings/site level and have not been adapted at larger scale/used as a basis for preparing landuse plans and development controls; Since broader and more complex environment, planning and built form issues are involved in a hill town context, none of these techniques are applicable as such.

A comprehensive assessment of hilly terrains, taking into consideration the key concerns of natural and built environment is essential, as not only both are interdependent; the physiographic (landform, topography), ecological, climatic, locational (socio-functional) and visual contexts in a place are also interdependent. Thus, the immediate need is to develop assessment technique that are comprehensive, analytical, objective (and not very descriptive) and easy to apply.

Methodology for Geo-environmental Assessment

The proposed methodology consists of identifying main criteria, their sub-criterion and indicators/parameters, and assigning them weightages on the basis of literature review and study of hill towns of the region. Thereafter, a rating scheme on the lines of Landslide Hazard Evaluation Factor (LHEF) rating scheme has been formulated. Finally a suitability index has been worked out.

The suitability analysis has been done taking into account five major criteria, namely, hill stability, ecological sensitivity, location, micro-climate and aesthetic characteristics. The sub criteria for hill stability are those adopted for landslide hazard zonation, that is lithology, geologic structure, relative relief, slope morphometry, landuse and landcover and hydro-geological conditions [1]. Likewise, the sub criteria of second criteria of ecological sensitivity are water sources, natural drainage pattern, vegetation, topography and soil erosion. The third criterion of micro-climate is constituted of sub criteria of solar access, exposure to winds, rainfall and humidity, snowfall and skylight/daylight factors. The fourth criterion of location is constituted of proximity to existing development, accessibility, infrastructure and quality of place. The indicators/parameters of each of these have been identified. Thereafter ratings have been assigned to different categories in each of these. The suitability of areas from these criteria is determined after multiplying the sum total of ratings of all the sub criteria with the weightages assigned to them. This methodology has been demonstrated in context of Almora- a hill town in Uttarakhand, which is witnessing rapid urban growth.

Almora – the study context

The hill town of Almora, situated at 29° 30' N latitude and 79° 40'E longitude at a height of 1646m above msl, is the administrative headquarter of Almora district in the state of Uttarakhand (Fig. 2). The town is located on a saddle shaped ridge and its elevation varies from about 1500 m to 1800 m above mean sea level in the lesser Himalayan physiographic belt. River Kosi on the West and river Suyal on the East flows from NE to

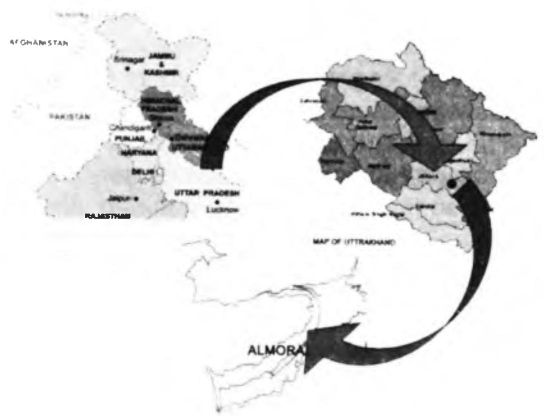

Fig. 2 : Geographic location of Almora

SW and from E to SW of the town, respectively.

Almora was the capital of Kumaun region for three centuries (since its establishment in 1564), and remained the most important town of the region till 1884. The town started growing after independence with setting up of number of departmental offices and institutions and has grown considerably again over the last two decades, stimulated by setting up of the large institutions like Kumaun University campus, BASE hospital, research institutes. Construction of Dhara naula road and lower Mall road facilitated the development in areas far off from the existing town. The permanent population of the town has increased from 13,094 in 1951 to 30,613 in 2001. This along with increase in tourist population has resulted in expansion of town in almost all the directions.

Whereas, most of the growth of town has taken place on slopes along the main access roads of the town (the upper and the lower Mall roads, Dharanaula road), some development has taken place in far off areas, from Khatyari on the south-west to Narain Tewari Dewal (NTD) ,Heera Dhungari and Ranidhara on the north-north west and Pande khola on the slopes opposite the main town as shown in the Fig. 3 above. This spread out pattern of growth of the town, particularly the residential development and the location of work centres in far off areas along with the pattern caused due to construction on unsafe and shaded area as discussed earlier causes inconvenience to people.

General Geological Setting and Lithology

Almora is located in the central part of the synclinal Almora Nappe of Kumaun Lesser Himalaya on a ridge which is delimited by the North Almora Thrust and South Almora Thrust. The lithology exposed in the north western slopes of the town , as observed in the areas along the lower mall road,is schist which is inter- bedded with quartzite, granite and phyllite which are covered by soil (fig 4). Quartzite occurs interbedded with schist in this area and are highly micaceous in nature. Being fine to medium grained in grain size, quartzite are bedded and compacted but slightly weathered on the surface and along the joint planes. There are two to three sets of joints and well developed foliation planes in quartzites. Whereas schists are interbedded with quartzite and are micaceous. These are fine grained rocks and characterised by well developed schistosity. Being moderately to highly weathered, schists along with quartzites cover almost the major part of the area. At places phyllite are interbedded with quartzite. Phyllites are also fine to medium grained and having relatively less mica content as compared to the schist. Foliations are well developed in phyllites but are rough in nature. Phyllites cover minor part of the area. The southern part of the town area consists of massive granite. These Granites are fractured at places and are moderately to highly weathered along the fractures resulting in formation of gauges. In the area, granites are rich in microcline and are medium to coarse grained [3].

The lithology exposed in the area on the opposite south-eastern slopes is phyllites and schists which are interbedded with micaceous quartzites of Almora group (Fig. 5). Intrusion of granite and granodiorite are also observed at places as shown in fig.4

Fig. 3: View of Almora showing extent of development and detailed study area

below. The quartzites in the area mainly occur as interbedded with schists. The quartzites are highly micaceous in nature, at places where they show well developed foliation planes. They are fine to medium grained and are thickly bedded. They are slightly weathered on the surface and along the joint

Fig. 4: Salient lithological features

Fig. 5: Lithology map of the town

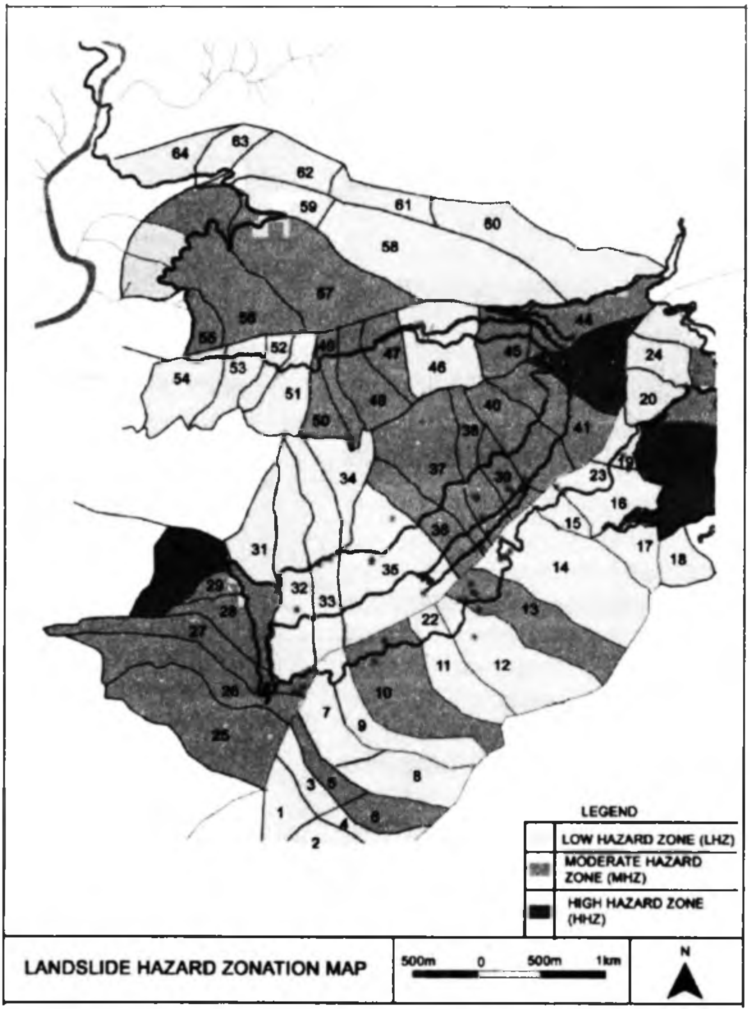

Fig. 6 : Landslide Hazard Zonation map

planes which are two to three sets in number. The schists are interbedded with quartzite and are also micaceous in nature. These are fine grained rocks with well developed schistosity planes. They are moderately to highly weathered. At places Phyllite are interbedded with quartzite. They are also fine to medium grained but having relatively less mica content as compared to the schist. The foliations are well developed but the foliation surfaces are rough in nature. The southern part of the study area consists of igneous intrusions like granite and granodiorite. They are in general massive in nature but are fractured at places and are moderately to highly weathered along the fractures resulting in the formation of gauges. They are rich in microcline and are medium to coarse grained. They lack well developed joint sets [3].

The **geologic structure** of the north western as well as eastern slopes consists of highly jointed Schists and quartzites with well developed foliation planes.

Geo-environmental assessment

First of all Landslide Hazard Zonation (LHZ) map of the town,(Fig. 6) has been prepared on the basis of the methodology of landslide hazard evaluation factor rating scheme [1]. A slope facet map has also been prepared which serves as the basis for the preparation

Table 1: LHEF rating for various causative factors and Total Estimated Hazard (TEHD) values

FACET NO.	LITHOLOGY	STRUCTURAL RELATION WITH SLOPE	SLOPE MORPHOMETRY	RELATIVE RELIEF	LAND USE AND LAND COVER	GROUND WATER CONDITIONS	TEHD VALUE	HAZARD ZONE
1	0.9	0.85	0.8	1	1.2	0	4.75	LH
6	1.075	1.2	1.2	0.6	1.2	0	5.275	MH
25	1.155	0.925	1.7	1	1.975	0	6.755	HH

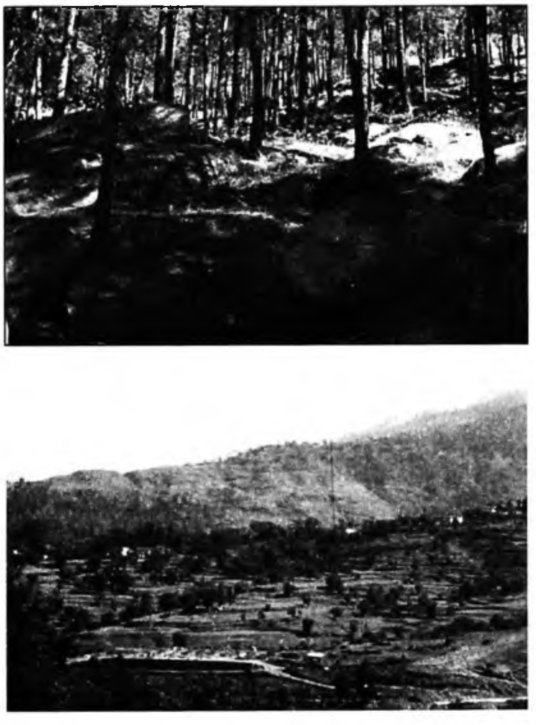

Fig. 7: Detailed study area

of the LHZ map of the area. In order to evaluate the status of causative factors, a number of thematic maps pertaining to each of the causative factors were prepared namely lithological map, structural map, land use and land cover map, slope morphometry map, relative map and hydro -geological map covering all the slope facets of study area. These maps depict the nature and distribution of corresponding causative factors over the area. Ratings for the various parameters of various facets have been awarded according to IS 14496 (part 2) [2]. Ratings for 3 facets with distinct characterstics are given in table (1).

Based on the above landslide hazard zonation map of the area in and around the town has been prepared (Fig 6). Thereafter one of the potential areas for urbanisation located in the low hazard zone has been selected for geo-environmental assessment.

The study area lies between the Toll at Syali Dhar and Matela village at a distance of 10 km from Almora along the Bareilly-Bageshwar road. The area is delineated by the ridges on south and east side, Khankal ka Ghadehra on the north and the road on the west. Kosi river flows on the west close by below the study area. Part of the area consists of agricultural fields with sparse vegetation and scattered houses, and the remaining is covered by Sitoli reserve forest (Fig. 7)

The area has been subdivided into 31 facets for the purpose of detailed analysis (Fig 8a). The area is covered with well compacted debris. Foliation is the major geological discontinuity of the area. On the basis of examination of rock types in the vicinity of the area, two sets of joints are observed. One dipping towards S,SE and the other dipping towards N,NW as compared to the slope which is inclined towards south west, hence the slope is stable from the structural point of view. The relative relief in the areas varies from low /medium in areas under agriculture to high in area under the forest and some pocket below the road. The slope gradient in most of the area is less than 15° whereas it is between 16° to 25° in few areas. Thus the area has been classified as low to medium hazard zone on the basis of LHEF rating scheme (Fig 8b). Based on this the suitability of the low hazard zone has been taken as 7 and that of moderate hazard zone as 5, on a 10 point scale.

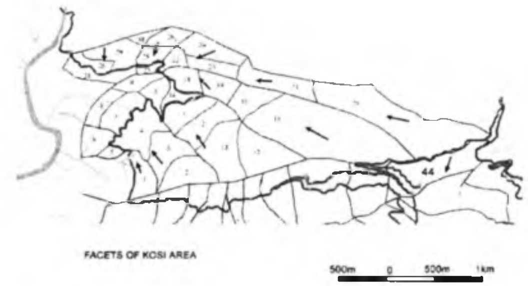

Fig. a : Facet map

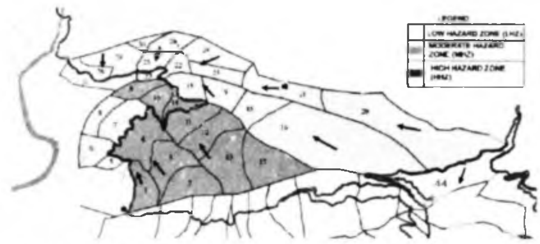

Fig. b: Landslide Hazard Zonation map

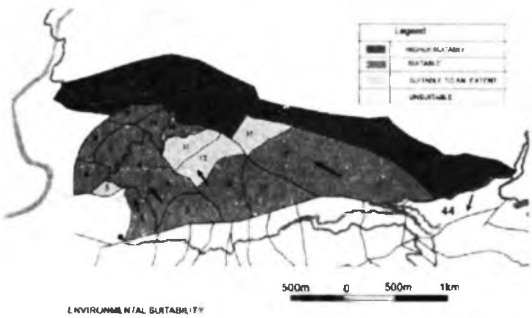

Fig. c: Ecological Suitability Map

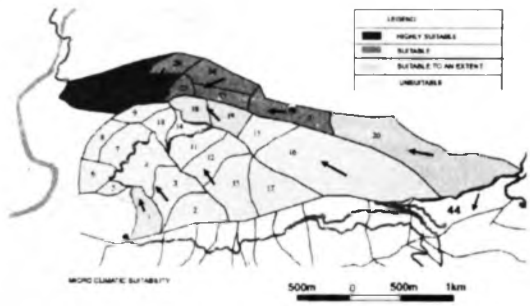

Fig d: Climatic Suitability Map

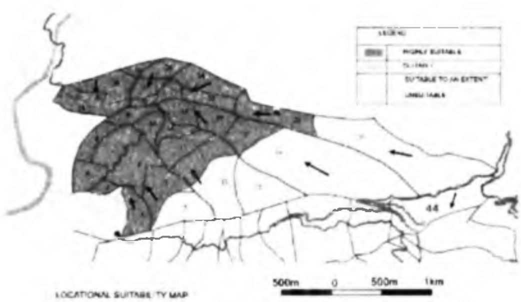

Fig. e: Locational Suitability Map

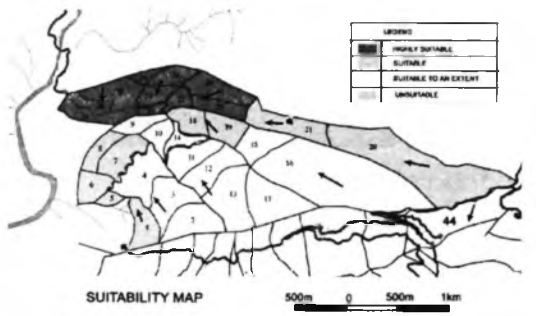

Fig. f: Integrated Suitability Map

Fig. 8 (a - f) : Locational Suitability Map

Further the ecological sensitivity of the area have been worked out on the basis of sub criteria as mentioned earlier in the methodology. Rating for vegetation having a weightage of 3, has been awarded on the basis of extent of vegetation cover, quality and scarcity of vegetation. Ratings for topography having a weightage 3 is based on the slope gradient. Likewise, rating for water sources having a weightage of 2, has been awarded on the basis of presence / proximity of springs their importance, potential of recharging and venerability of pollution. Rating for natural drainage pattern with a weightage of 1, is awarded on basis of presence/proximity to major/minor drains and their gradients. Whereas rating for erosion (weightage 1) is determined by susceptibility of the area to erosion. Ecological sensitivity of the area is shown in fig 8c below.

Like wise the suitability of the study area from microclimatic considerations is determined on the basis of solar access,which intern is dependent on the slope aspect (weightage 5) and the extent of shading (weightage 2); and exposure of wind (weightage3) (fig 8d). The suitability of locational criteria is worked out on the basis of proximity of existing development (weightage 3), accessibility (weightage 3) infrastructure (weightage 2.5) and quality of place (weightage 1.5) (fig 8e) Whereas, the visual criteria for suitability include the visibility (weightage 4),visual exposure (weightage 3) and aesthetic value of the area (weightage 3). The overall suitability of the area for development is determined according to weightages assigned to these criteria, which can vary depending upon the particular context. In this case the hill stability,locational and microclimatic criteria has been assigned a weightage of 25 each and ecological sensitivity has been assigned a weightage of 20 and aesthetic considerations have been given a weightage of 5 only. An integrated suitability rating has thus been obtained by adding the rating of all the criteria and shown in fig 8f below.

Accordingly, the facets with relatively with gentle slope, sparse vegetation, facing South/ south west and located near the vehicular road are found to have higher rating as compared to the facets with steeper gradients, forest and facing north/northeast/ north west, demonstrating the validity of methodology proposed

The same methodology can be applied to the rest of the areas for determining their suiatability for buildable land.

Conclusions

The existing pattern of expansion of hill towns in far off, unstable areas and areas without adequate solar exposure causes numerous problems to the people and effects the environment adversely. A methodology for determining suitability of areas in an around hill towns, integrating the key issues of natural and built environment as proposed, is essential for ensuring safe and sustainable growth of hill towns that is socially acceptable. Suitability of areas thus determined should become the basis of landuse planning as well as development controls for identifying building locations and bulk, thereby ensuring contextually appropriate development of hill towns.

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