



# Terrain Sensitivity Guided and People's Perception Based Risk Area Management of the Hills of Darjeeling District, India

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## Abstract

The hills of the Darjeeling district having litho-geomorphologically complex and diversified landform, have been subjected to rapid human agglomeration since the post-independence time with establishment of ordered Government and hill tourism in the panoramic sites of the Darjeeling hills. Human pressure on the landscape in the hills of Darjeeling district has given rise different magnitudes of Terrain Sensitivity and inhabitants of the hills equally perceived human activities on the landscape as the cause of different degrees of 'Risk Area occurrences' which are hazardous in different degrees for safe human habitation. Therefore, the present paper takes an attempt to identify and propose management strategies for the different risk areas for human habitation guided by Terrain Sensitivities appeared on the landscape and based on People's Perception that mandate various degrees of fragility associated with landforms with human impact or use. Result reveals four categories of risk areas associated

with the hills of Darjeeling district for which appropriate management strategies have been proposed.

## Keywords

Human pressure on the landscape · Terrain sensitivity · People's perception · Risk Area occurrence · Management strategies

## 17.1 Introduction

The panoramic hills of the Darjeeling district experienced quite rapid human agglomeration with a motive of grabbing lands following the establishment of ordered Government after independence as well as flourishing hill tourism over the geologically complex (Mallet 1874; Pawde and Saha 1982; Acharyya et al. 2017) and geomorphologically form-process interacted diversified landscape. As a consequence, the region has undergone deforestation (Bhattacharya 2009) with gradual expansion of settled areas and arable lands. Hill tourism, moreover, has become a very attractive recreational medium for the outside visitors in the panoramic and scenic sites in the hills which have added impetuous on rapid agglomeration of population and accelerated expansion of urban areas and business induced settlement growth in the hills of Darjeeling district. All these resulted dwindling

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of forest and expansion of concrete areas and substantially contributed the change in the natural setup of this region with increase of built environment. This change of natural set up and human pressure on the geologically and geomorphologically complex landscape is seen to have significant bearing upon the stability of this region (Bhattacharya 2016) because human pressure has been randomly exerted upon the landscape irrespective of the degree of tolerance the landscape can endure. Such human pressure is manifested by frequent occurrence of devastating landslides almost every year after rain as well as soil erosion in the present time (Bhattacharya 1999, 2002, 2012a, b, 2014; Ghosh et al. 2009; Ghosh 2011).

In the present time, the great challenge of the human being is to look into the consequences on nature resulted from the activities done by human itself. Many important works have been carried out by the different experts all over the world on the activities of human being on the nature and alteration of nature and related consequences (Bathrellos et al. 2012, 2013; Bhattacharya 2012a, b; Papadopoulou-Vrynioti et al. 2013). Over exercise by human on the nature has become consequent boomerang (Bhattacharya 1993) in many ways like temperature increase in the atmosphere, increasing contamination and pollution in the biosphere, human pressure on the landscape and the resultant increase in soil erosion, slope failure, and many more Bhattacharya (2014, 2016). Therefore, appraisal of the human activities on nature is necessary. Terrain Sensitivity assessment is such a way to measure and perceive terrain's degree of ability to sustain the pressure of land use developed over a region (Bhattacharya 2018, 2021). With terrain sensitivity appraisal it is also necessary to see what local people think over the status of the area they live in so that both spatial terrain sensitivity status and human perceived terrain's condition can pave a way of environmental planning for sustainable habitation.

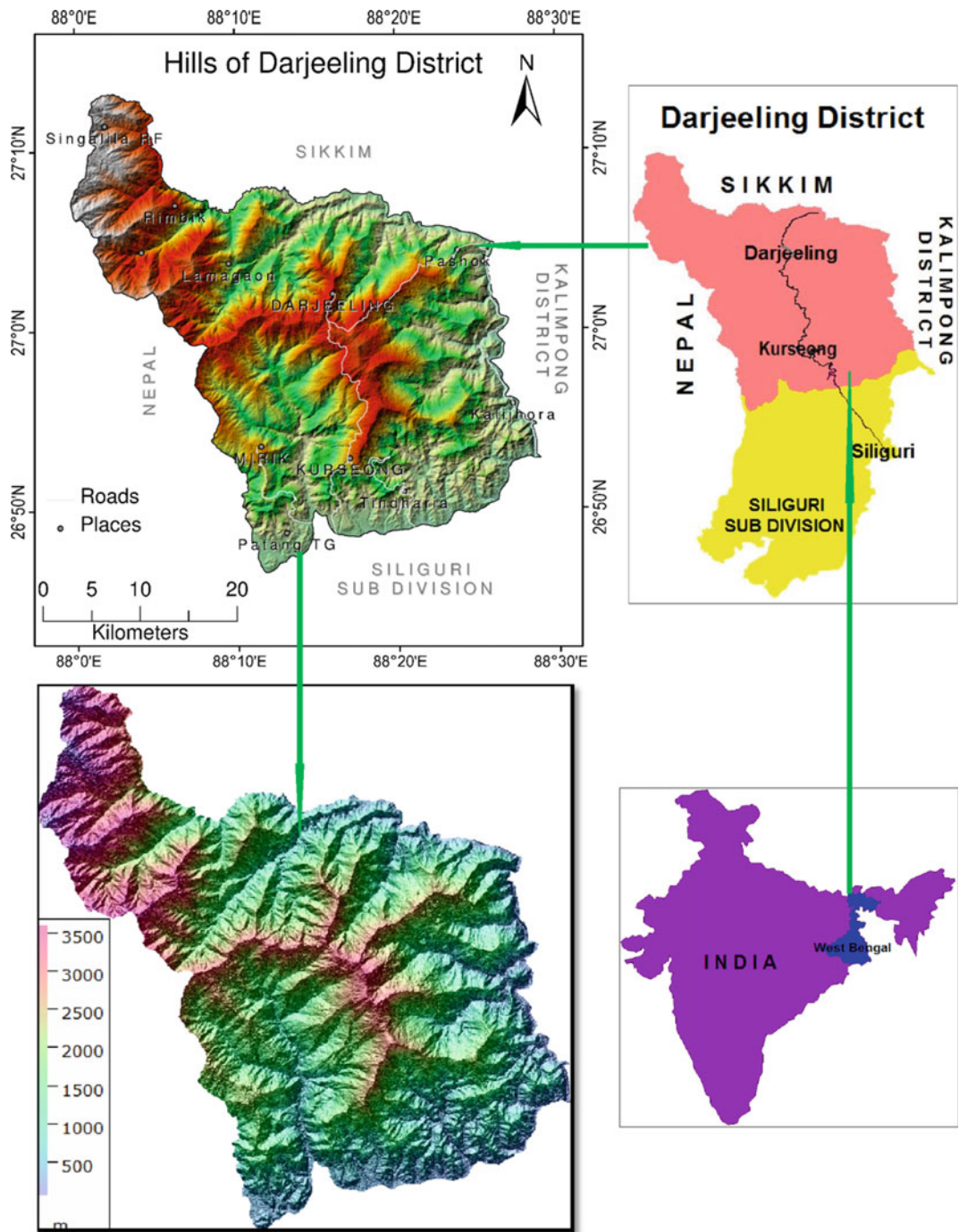
## 17.2 Area of Study

The hills of the Darjeeling district after being separated from Kalimpong part is extended from  $26^{\circ} 46'' 32'$  to  $27^{\circ} 13'' 13'$  N and  $87^{\circ} 59'' 42'$  to  $88^{\circ} 28'' 53'$ . The hills of Darjeeling district has been delineated by sharp break of slope from the contiguous undulating Terai plains. The entire hill region of the Darjeeling district covers an area of  $1206.3 \text{ Km}^2$  bounded by Nepal on the West, Kalimpong district on the East, Sikkim on the North and Terai undulating plains on the South (Fig. 17.1).

## 17.3 Environmental Planning

Environmental planning is targeted to save an area from further deterioration and to recover the area to a certain extent from the damage what has already been done. Environmental planning has attracted both physical and human geographers since a long time as it provides the statutory instruments for changing land use designations, for instance protecting national parks from certain types of development. It is also a key forum for mediating between those with different views of the future for particular areas, most notably with regard to whether or not to allow development on a particular piece of land and, if allowed, what kind of development should be permitted (Haughton 2017).

The terrain sensitivity map (Fig. 17.2) of the hills of Darjeeling district gives a clear picture of the spatial variation of sensitivity ranging from high to stable zones resulted from different degrees of human pressure on the landscape for which some kinds of damage related to the stability over the different magnitudes of sensitivity is inevitable and higher sensitive zones are in no way congenial for further development. Investigation has depicted (Bhattacharya 2016, 2021) that the hills of the Darjeeling district, has been subjected to steady development by the human

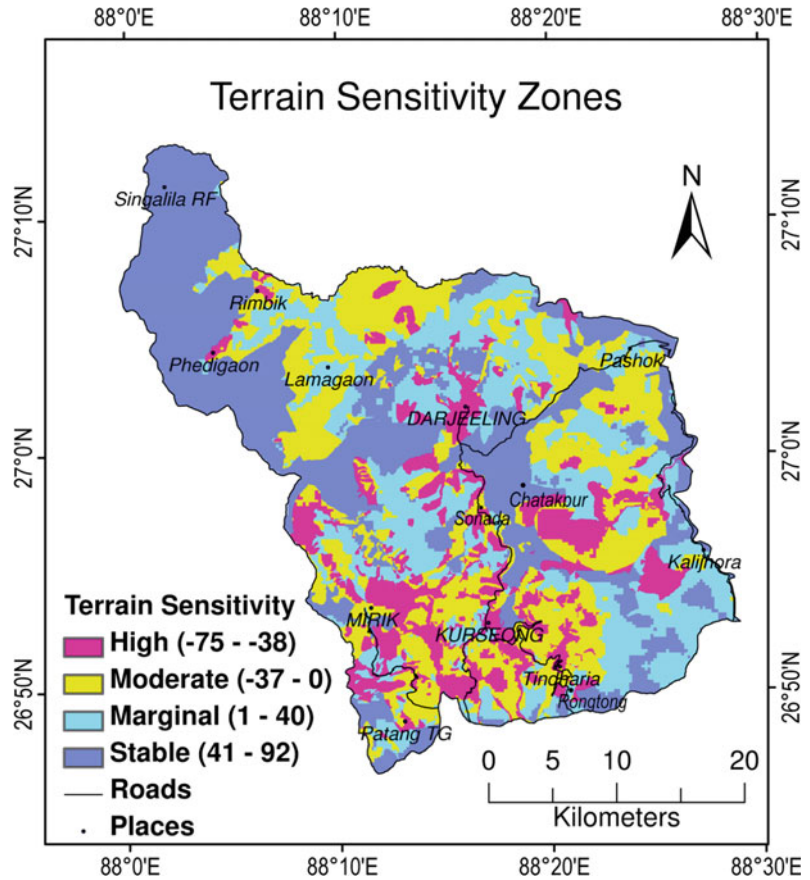


**Fig. 17.1** Location map of the hills of Darjeeling district

being for which human induced pressure has converted congenitally better tolerable zones to a zone of increased terrain sensitivity where

immediate planning and management is necessary. Where the terrain parameters being considerably weak, made the area least tolerable;

**Fig. 17.2** Terrain Sensitivity map of the hills of Darjeeling. Source Bhattacharya (2021)



human activities like settlement growth, improper use of the land for cultivation, deforestation, and conversion of land in to scattered tree fields, converted the area into highly sensitive terrain for human habitation (Bhattacharya 2021). So, it is the crucial time to think over how much we will spread our hands over the hills of the Darjeeling district where many areas are in no way congenial for further development. Moreover, what will be the strategy to recoup (with utmost effort) the damage that has already been done on different terrain sensitivity zones in study area?

Therefore, the terrain sensitivity guided environmental planning can be a way out. Along with this the investigator also has taken an attempt to see the humans' perception on the 'built environment' and their grown up need for planning. Both humans' perception and spatial terrain sensitivity, therefore, will be used for a well

thought planning and management for the sustainable use of the terrain of the study area.

## 17.4 Materials and Methods

The map of terrain sensitivity zones (Fig. 17.2) is the product of Proportional Value-added Rating (PVR) algorithm-based Terrain Tolerance (TT) appraisal through multi-criteria decision analysis (MCDA) followed by a deductive method of human influence (pressure) estimation on the landscape (Bhattacharya 2021). ASTER DEM Version 3 data for terrain tolerance appraisal and SOI topographical maps (RF = 1:50,000) and LISS-IV satellite images (5.8 m resolution) for estimation of human influence on the landscape, i.e., land use factors have been used along with thorough field investigation.

Perception study has been carried out to see what is the opinion of the people about an area; whether the locality or the concerned terrain has been changed to a different condition due to peoples influence over the terrain through their developmental activities and for which the area need a specific level of planning and management. The perception study has been carried out by different experts in the different field of study (McDonald 2012, Ghosh and Debajit 2012). For this study a questionnaire has been prepared. The questionnaire has been framed in such a way that all the important aspects of built environment and need of planning and management have been covered. The term 'built environment' refers to "the human-made surroundings that provide the setting for human activity, ranging in scale from buildings and parks or green space to neighbourhoods and cities that can often include their supporting infrastructure, such as water supply or energy networks. The built environment is a material, spatial, and cultural product of human labour that combines physical elements and energy in forms for living, working, and playing" (Kaklauskas and Gudauskas 2016). It has been defined as "the human-made space in which people live, work, and recreate on a day-to-day basis" (Wikipedia 2021). Therefore, the built environment and its significance as perceived by human being has been used as a tool to evaluate the status of environment of an area to compare with the achieved Terrain Sensitivity of different grades (Fig. 17.2). This comparison will also help in validating the spatial magnitudes of Terrain sensitivity of the study area. Finally, the humans perception on the **need of planning and management** of selected localities will be checked with various magnitude of terrain sensitivity zone to propose some comprehensive management measures to restore the hills of Darjeeling district from further damage and for sustainable use of the terrain.

The material used for this purpose is a close-ended questionnaire having thoughtfully chosen questions for both the built environment and need of planning and management. Survey has been carried out on reasonably conscious people at least have completed their secondary

education. Scaled questions have been answered by those people of selected localities ticking on the appropriate ratings of the questions in the given Questionnaire as 1, 2, 3, and 4. At least five numbers of answered questionnaires have been collected from each locality to get the opinion of the respondents for both the built environment of the locality and need of planning and management of the concerned area. On the basis of these the Tables 17.1 and 17.2 have been prepared where the maximum number of similar opinions given by the respondents of each question has been considered as the right answer for that question having certain assigned rating value. Finally, analysis has been done on the basis of the data obtained in the Tables (17.1 and 17.2) and its cartographic representation by column and pie diagrams in respect of the ratings of each question (Figs. 17.3 and 17.4).

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## 17.5 Findings and Discussion

### 17.5.1 People's Perception on the Built Environment

As mentioned above that built environment is the human-made condition in the natural set up of an area or region for developing supporting infrastructure for living; a material, spatial and cultural product with supported amenities for living. It is in one sentence-a human-made space in the name of development to achieve ease and comfort in living. So, it is, on the other hand, the human built energy on the nature compromising with the ecological balance to a certain extent in a particular area or region. So, with the increase of built environment it can be expected that the alteration of natural set up of an area will lead to a kind of deterioration in the nature if balanced with human activities will remain in stable condition or if not balanced will invite instability threshold inevitably. Therefore, the assessment of built environment, the way the inhabitants or the people of the area or region perceive, has been considered as an important parameter in which a set of questions have been put carefully

**Table 17.1** Built environment ratings

Questions	Darjeeling	Kurseong	Mirik	Tindharia	Pasok	Rimbik	Sonada	KaliJhora	Patang	Rangtong	Singalila	Pheddi Gaon	Chatakpur
1	3	3	4	3	2	1	2	3	2	2	1	1	1
2	4	4	4	4	3	3	3	2	2	1	1	1	1
3	4	4	3	4	3	3	2	2	2	2	2	3	2
4	4	4	4	4	3	3	3	2	2	2	1	1	1
5	4	4	4	4	3	3	3	3	3	3	1	1	1
6	4	4	4	4	2	2	3	2	2	2	1	1	1
7	4	4	3	3	1	1	2	3	1	1	1	1	1
8	2	2	3	3	3	3	3	2	4	4	4	3	3
9	3	3	3	3	3	3	3	2	4	4	4	2	2
10	4	4	4	4	3	3	3	2	2	2	1	2	2
11	4	3	3	3	2	3	2	1	2	3	2	2	2
12	3	3	3	2	2	1	2	2	2	2	1	1	1
13	2	2	2	4	2	1	2	2	3	2	1	1	1
14	4	4	4	3	3	2	2	2	2	2	1	1	1
15	4	4	4	4	3	3	3	2	2	2	2	2	2

**Table 17.2** Need of planning and management ratings

Questions	Darjeeling	Kurseong	Mirik	Tindharia	Pasok	Rimbik	Sonada	Kalihora	Patang	Rangtong	Singalila	Phedigaon	Chatakpur
1	3	2	4	4	3	2	2	2	2	3	1	1	1
2	4	2	4	4	3	3	3	3	2	2	1	2	2
3	4	3	3	3	2	2	3	3	1	2	1	1	1
4	4	3	4	3	3	2	2	2	2	2	1	2	1
5	3	3	3	4	3	3	3	2	2	2	2	2	2
6	4	4	4	4	3	3	2	2	2	2	2	2	2
7	4	4	3	3	2	2	3	2	1	2	1	1	1
8	4	4	4	4	3	3	3	3	2	2	2	2	2
9	4	4	3	4	3	3	3	2	2	4	2	1	2
10	2	4	4	4	3	3	3	2	3	4	2	2	2
11	2	4	4	4	3	3	2	2	2	3	2	2	2
12	4	4	3	4	2	3	2	2	2	2	1	1	1
13	3	4	4	4	2	3	2	2	2	2	1	1	1
14	4	4	3	4	2	2	2	2	2	2	1	1	1
15	4	4	4	4	3	3	3	2	2	2	1	1	1

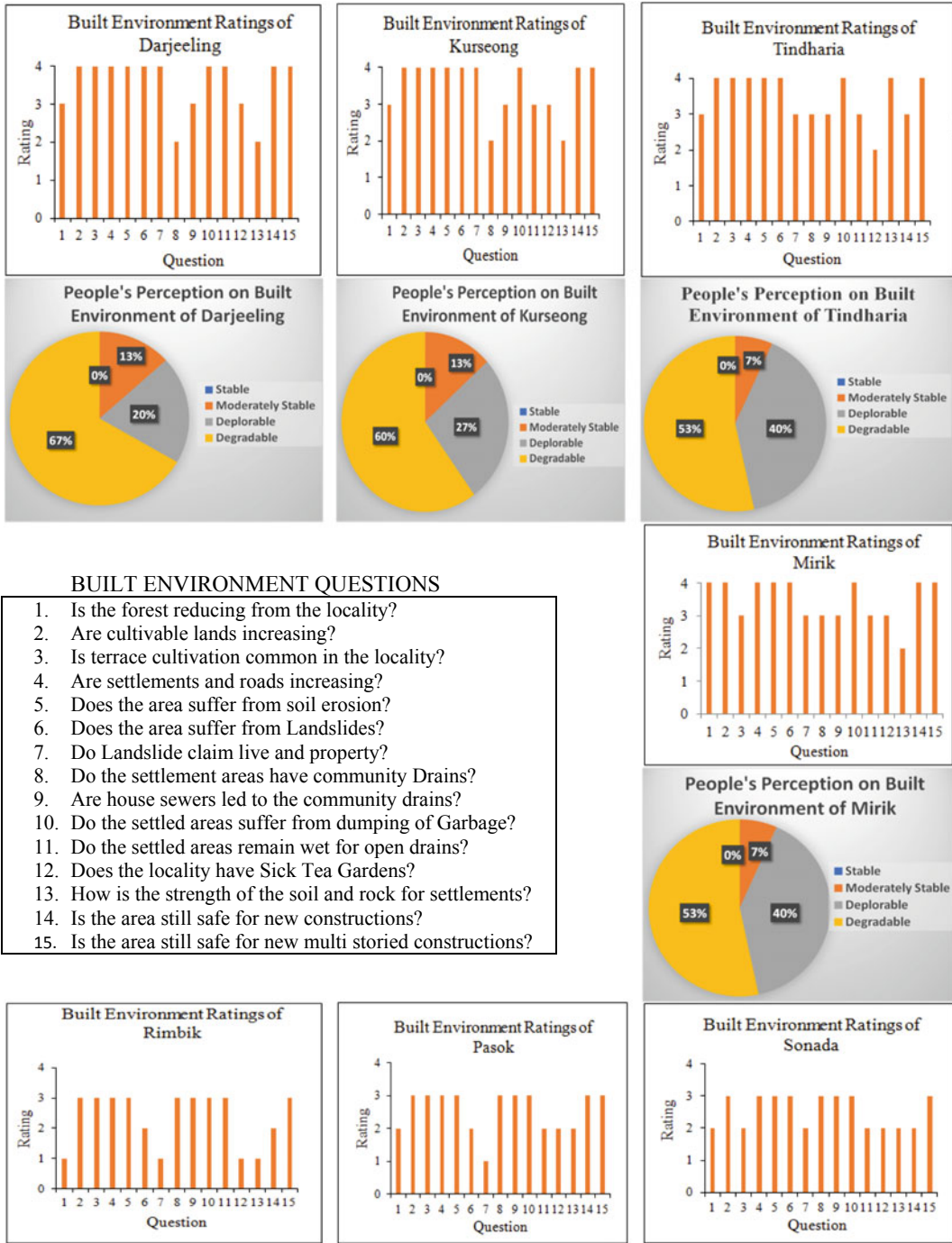


Fig. 17.3 Built environment perception study



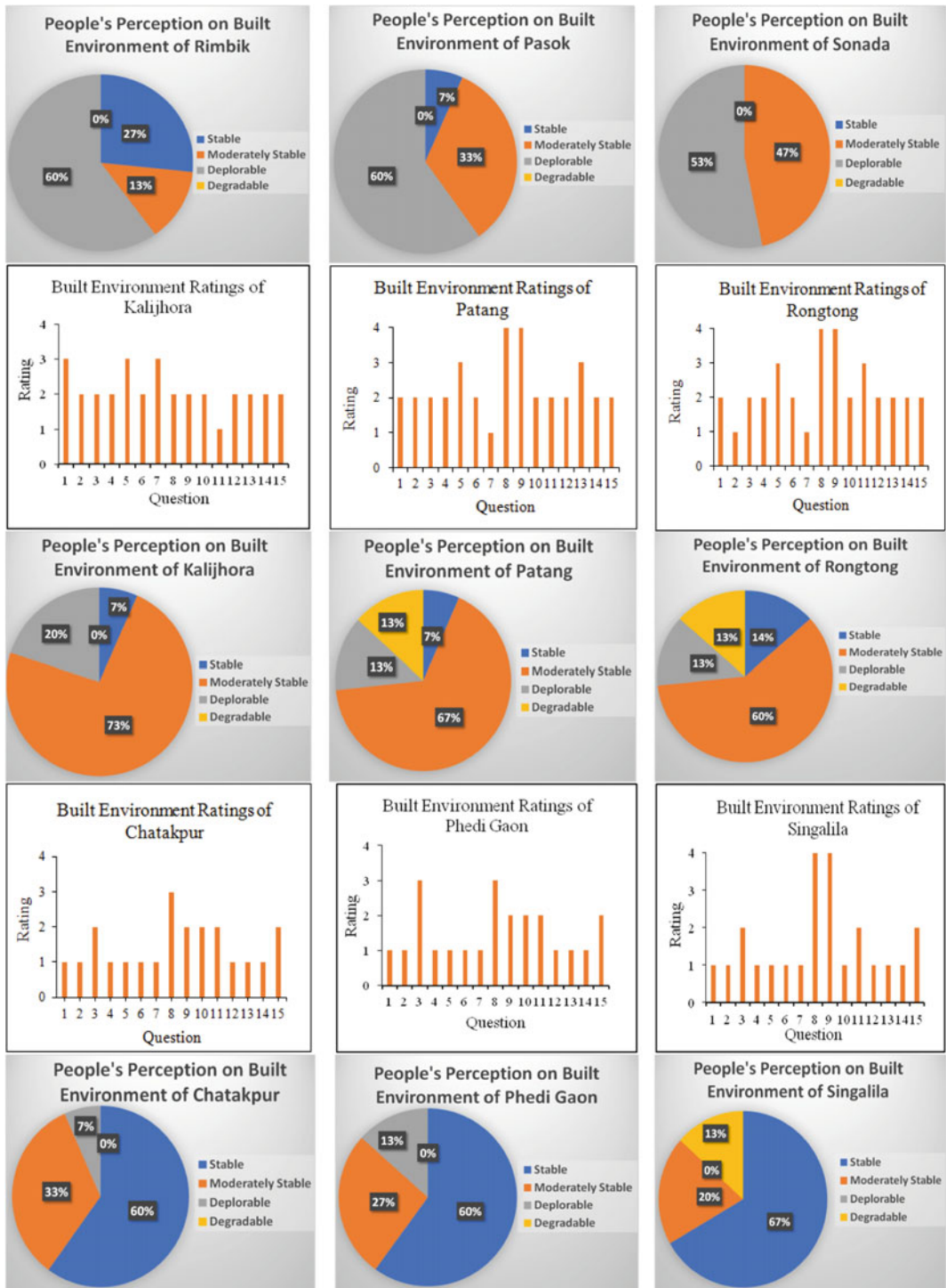


Fig. 17.3 (continued)

in such a manner (for understanding the built environment) that with the increase of human developmental activities in nature what degree of impact the nature sustain, can be achieved. This degree of impact of built environment induced by human activities has been quantified by setting diagnostic criteria, i.e., by assigning rating values for different degrees of human activities on nature with increasing generalization like no, slowly, steadily, rapidly or no, rare, few, and common as relevant to the each question for different areas. Fifteen selected questions have been put forward to cover up the aspects of human activities on nature like deforestation, increase of arable lands, nature of cultivation practice etc., as well as human-made material, spatial, and cultural space in the form of establishing, settlements. These are nothing but the land use practices which have been taken into consideration at the time of terrain sensitivity assessment of the study area. The objective of considering human's perception on the built environment is to compare the results achieved by PVR algorithm-based Terrain Sensitivity Assessment, a product of the human induced pressure on the landscape with human perceived state of stability of the built environment. This can validate how much the geospatial-data based terrain sensitivity assessment has resemblance with human perceived degree of stability related to built environment of the study area.

Figure 17.3 shows the result of the built environment perception study of the hills of the Darjeeling district where it is clear that the localities like Darjeeling, Mirik, Kurseong and Tindharia have been identified by the majority of the respondents as **degradable** because of the drastic change of the natural setup of those areas by the people with the spread and increase of built environments. These are the areas where improper cultivation practice without giving impotence of scientific terracing method, increase of settlements and roads on the sensitive slopes without giving adequate attention on the constructional rules have invited severe soil erosion and increased the magnitude and frequency of landslide occurrences (in many years

devastating in the monsoon time). All these have been revealed by the people's perception study.

Rimbik, Pasok and Sonada are those areas which have been identified by people's perception as **deplorable** where human activities like cultivation practice without adopting proper scientific method like terracing, increase of road and settlement constructions have been identified by the people living in the areas which are significantly against the physical stability of these localities. The human practices like dumping garbage in the settled areas (Fig. 17.4e) and the dearth of community drains to pass sewer water too, give indications that these localities are subjected to soil erosion and landslide occurrences, and most of these have been rated by the local people as 3 for which those areas have been graded as deplorable from environmental points of view.

Kalizhora, Patang and Rongtong areas have been perceived by the majority of the local inhabitants as **moderately stable** zones as most of the questions related to the increase of arable lands, degree of terracing practice for cultivation, occurrence of soil erosion, occurrence of landslide, presence of sick tea gardens and physical strength of the soil and rocks for human settlements commonly have yielded rating value 2 in respect to the alteration of natural environment and thereby the growth rate of the built environment. There are some questions, in those localities like rate of deforestation, lack of community drains, answered by the local people which indicate human interference on the landscape has left a few worrying signature on the lack of human awareness for which stability of those areas in respect of human use remains questionable to a certain degree for which they have been identified as moderately stable.

Perception study reveals that Chatakpur, PhediGaon and Singalila are mostly free from human interferences and steady growth of built environment as the rating value given by majority of the respondents as one which indicates degree of human energy in the natural ecosystem is almost in a balanced state although there are some negative signs like lack of



a: Congested Built Environment in Kurseong



b: Congested Built Environment in Darjeeling town



c: Highrising Building in Darjeeling Hills



d: A part of Sick Tea Garden in High Altitude



e: Garbage dump and wetness behind buildings



f: Flakey and Friable rocks in the Daling Thrust



g: Skeletal soil on the oversteepened hill slope



h: Ability of Amliso to anchor rocky surface

**Fig. 17.4** Relevant photos of the study area

community drains and unmanaged sewer. As the human has not overpowered the ecological setup of these localities they have been considered as **stable**.

When compared the human mandates, regarding the conditions of these localities, with the various zones of terrain sensitivity resulted from human pressure on the landscape, it reveals that high, moderate, marginal and stable terrain sensitivity zones have fairly good resemblance with human perceived conditions of those localities, since the **degradable** localities like Darjeeling, Kurseong, Mirik and Tindharia; the **deplorable** localities like Rimbik, Pasok, Sonada; **moderately stable** areas like Kalizora, Patang and Rongtong and **stable** locations like Chatakpur, Phedi Gaon and Singalila almost correspond with high, moderate, marginal and stable terrain sensitivity zones (Fig. 17.2), respectively. So, the People's Perception adequately validates that PVR algorithm-based assessment of the spatial distribution of terrain sensitivity zones are significant.

### 17.5.2 People's Perception on the Need of Planning and Management

Human's perception about their need of planning and management for their localities have also been studied and the following results have been obtained (Fig. 17.5):

In the areas of Darjeeling, Kurseong, Mirik and Tindharia **very high** level of planning and management have been proposed by the majority of the respondents who feel strong to high necessity of tree and grass plantation for retaining slope stability along with high demand of terracing practice on the cultivated fields in association with strong to high need of mulching practice on the crop fields to protect the slopes. No respondent encouraged building or multi-storied building construction over all these localities and in these localities majority of the respondents demanded maintenance of drainage system in the settled areas with dense and high rising buildings and addition of community

drains for free passage of water from house sewers except only in Darjeeling town area where present status of draining system with community drains to lead all the house sewers is better being the head quarter of the district. Most of the respondents of these localities also felt high need of landslide, soil erosion managements since they felt these areas are environmentally highly fragile.

Rimbik, Pasok and Sonada areas have been perceived by majority of the local respondents as the places which need **high** level of planning and management for restoration of the stability of these areas as in the opinion of the respondents these are the places which are adequately fragile from environmental points of view. These areas strongly need plantation of slope stabilizing grasses and/or trees, mulching and terracing on the crop fields as well as moderate to strong level of landslide and soil erosion management as perceived by the local inhabitants. People are strongly against the construction of multi-storied buildings, they feel necessity of garbage removal from the settlement areas by community effort as well as community drains to lead house sewer in their locality.

People's perception about the Kalijhora, Patang and Rongtong denotes that these areas are partially fragile from environmental points of view where **moderate** level of management and planning are needed keeping attention on the maintenance of ground cover, mulching and terracing on the cultivable fields. People also need moderate level of garbage removal by community effort, improvement of drainage system in the settled areas along with addition of community drain in the locality for free passage of sewer water so that the ground surface of the settled areas will be free from unwanted wetness. Most interesting feature of these locations in common is that the need of management and planning on the basis of the majority of the aspects taken into consideration, proposes moderate level, but there are some aspects which need even higher level of management as reflected in the people's perception too.

Need of planning and management for Chatakpur, Phedi Gaon and Singalila as perceived by

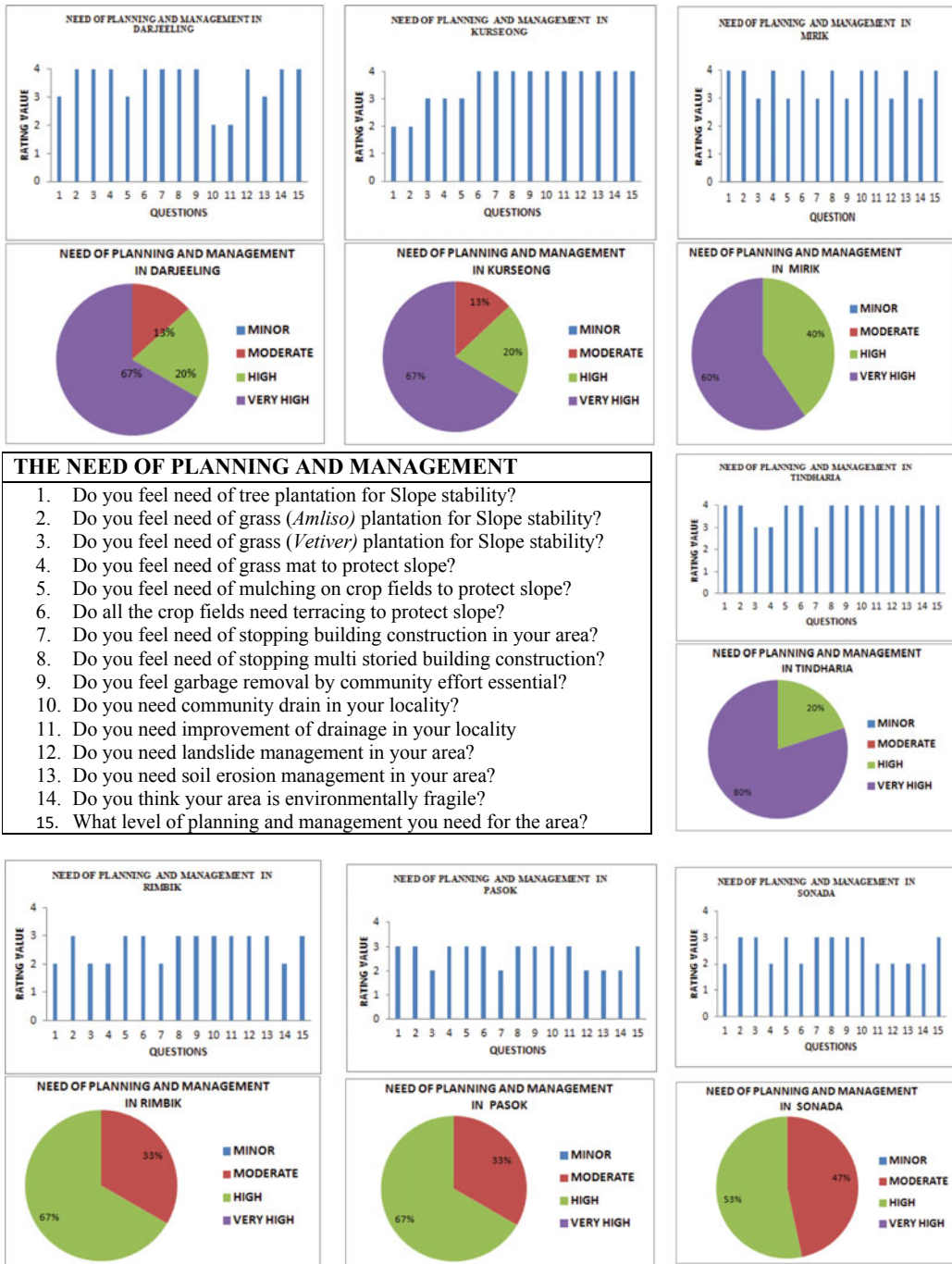


Fig. 17.5 Need of planning and management perception study

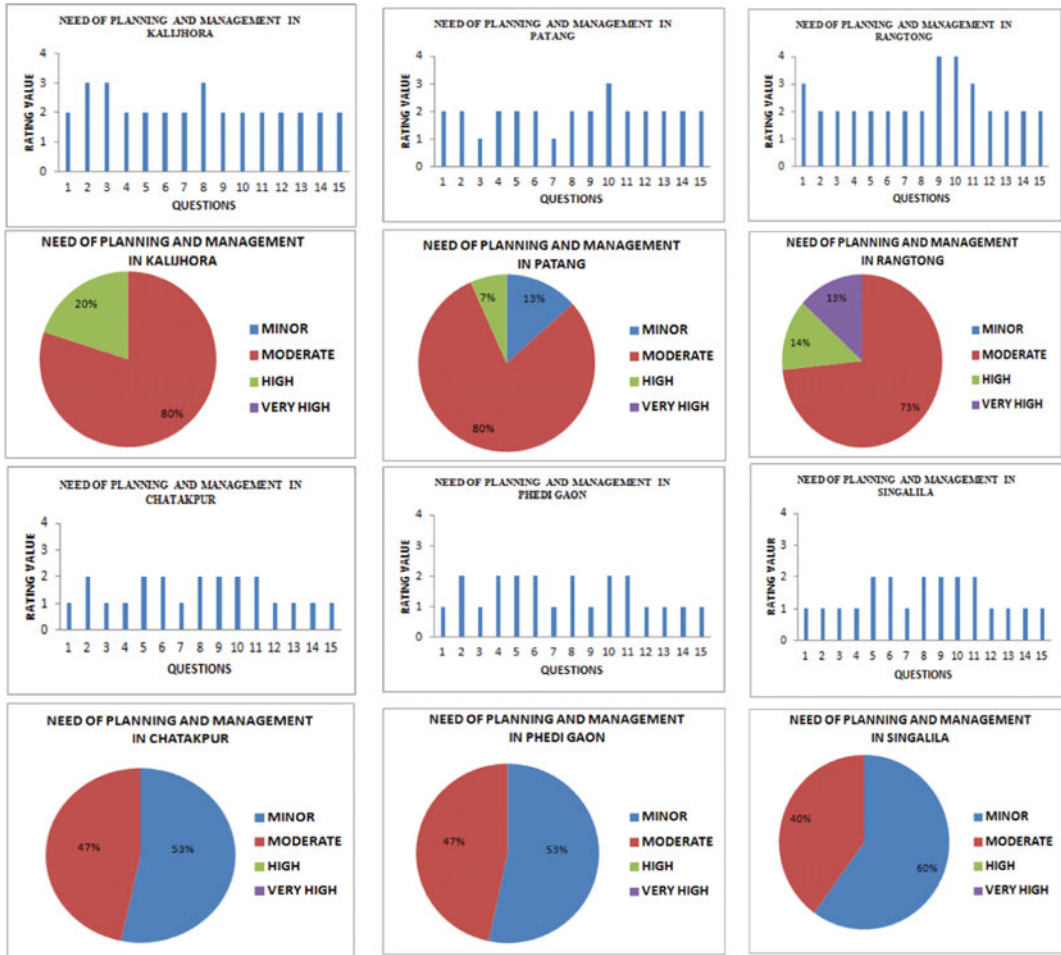


Fig. 17.5 (continued)

the people of the locality is **minor** since necessity of increasing vegetation cover by planting trees on these areas are felt by majority of the local respondents as negligible since these areas have adequate vegetation. Majority of the respondents do not have the opinion of stopping further building construction, nor do they have any urge of landslide and soil erosion management for these areas, since these areas are not environmentally fragile in their opinion in the present state. However, plantations of grass, mulching and terracing on the crop fields and

stopping multi-storied buildings in the localities have their top priority to keep the balance of nature with the built environment of these areas.

Keeping the peoples' perceived need of planning and management in mind and considering the assessed spatial distribution of terrain sensitivities having varied magnitudes, a well thought management plan is necessary for restoration of the environmental balance of the study area. Therefore, the following management plans have been proposed:

### 17.5.3 Environmental Planning and Management for the Study Area

A plan for management is intended for elevating the condition of an environment (be it built environment) from a state where the stability of the area will become free from vulnerability risk. The human activities on the landscape has exerted pressure on the study area as understood from terrain sensitivity assessment as well as from people's perception for which it is high time to think over a well thought management plan so that the built environment will have a balance with the natural setup of the area concerned. The following management strategies have been proposed:

As apparent from the Figs. 17.2, 17.3 and Table 17.3 that the terrains of high sensitivity is actually the human perceived degradable zones where human activities have flourished as an incidence mostly on geologically softer rocks

and disturbed zones (Fig. 17.6) of Lesser Himalayan Sequence (LHS) having Palaeoproterozoic and Permian sedimentary formations and on the Miocene rocks of lower Siwalik; adequately deformed (have become flakey and friable) by the effect of the Daling Thrust (DT) (Fig. 17.4f), one of the most important tectonic zone between Daling and Damuda groups as well as by the Main Central Thrust (MCT) and Main Boundary Thrust (MBT). The thrust induced flakey and friable nature of the relatively harder phylitic rocks of Daling series, Permo-carboniferous softer Damuda rocks of Lower Gondwana and foreland molasse sediments (sandstone/shale) of the Siwalik group with thrust caused fold effect (Kellett et al. 2014; Ghosh et al. 2016; Acharyya et al. 2017) altogether being deeply entrenched by the turbulent rivers have given rise high dissection and ruggedness over this part of the study area and thereby a kind of physical instability over which high congestion of concrete and multi-storied

**Table 17.3** Recommended strategies for environmental management plan

Terrain sensitivity, human perceived terrain status and grade	Present built environment and landuse status	Recommended management strategies and human perceived need of planning and management
High sensitivity, degradable zones (Grade IV, Very high risk area)	<ul style="list-style-type: none"> <li>i. Highly congested concrete settlements with many multi-storied structures in the towns and semi-town areas</li> <li>ii. Closely scattered concrete structures and buildings in the settled areas</li> <li>iii. Fallow or bare land surfaces</li> <li>iv. Row crops on the un-terraced land surfaces</li> <li>v. Sick tea garden areas</li> </ul>	<p><b>Very high</b></p> <ul style="list-style-type: none"> <li>i. Zones should be strictly prohibited for further settlement growth and multi-storied building constructions</li> <li>ii. Un-vegetated fallow or bare lands to be planted by community efforts with intense root anchoring fodder and fuel wood plants for local consumption and with profit earning Amlisho or Broom Grass (<i>Thysanolaena maxima</i>). Another grass species Vetiver (<i>Vetiveria zizanioides</i> L.) which is also economically prospective and very effective in soil and water conservation to be planted with equal importance</li> <li>iii. Row cropping practice without terracing should be restricted by enforcing rules</li> <li>iv. In the open spaces of the settled areas social forestry program to be initiated from community level</li> <li>v. Improvement of sick tea gardens to be brought under the notice of garden authority by local administration</li> </ul>

(continued)

**Table 17.3** (continued)

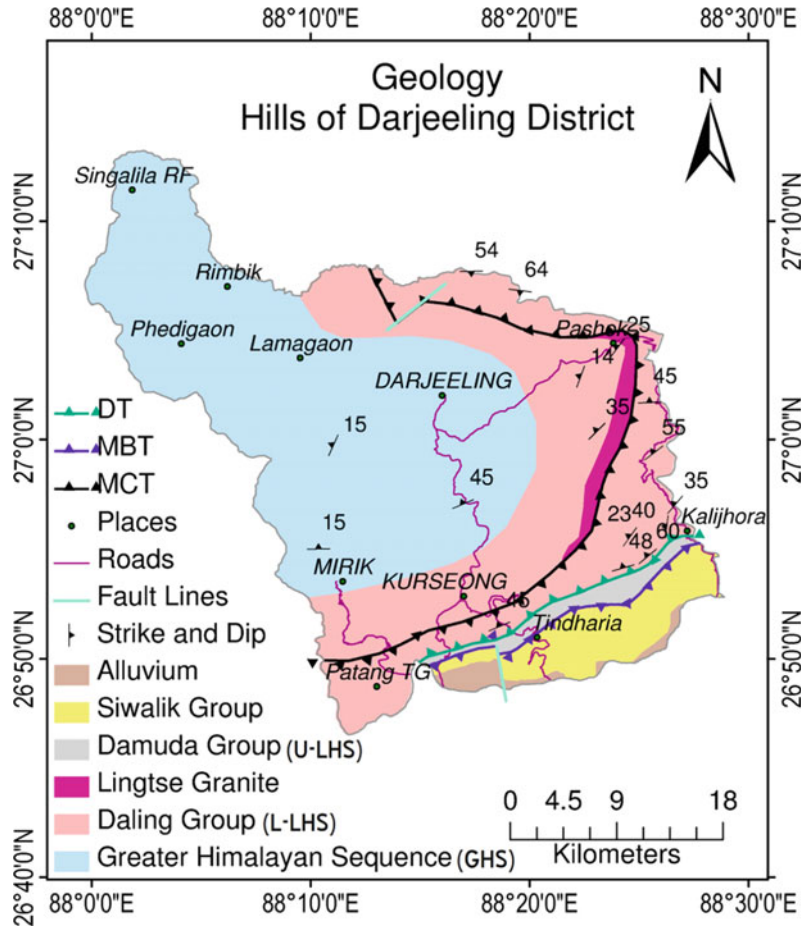
Terrain sensitivity, human perceived terrain status and grade	Present built environment and landuse status	Recommended management strategies and human perceived need of planning and management
Moderate sensitivity, deplorable zones (Grade III, High risk area)	i. Congested settlements in urban and semi-urbanized areas almost with concrete structures ii. Vast closely scattered settlement areas iii. Tea garden, row crop cultivation areas iv. Small forest patch v. Large area under scattered tree fields	<b>High</b> i. Further settlement growth on the congested areas to be strictly controlled by rule. However, fringe areas of the urban settlements and vast closely scattered settled areas to be allowed for planned growth emphasizing upon construction of single storied buildings on stable slopes ii. Vegetation density in the urban zones and closely scattered settlement areas to be increased by social/agro forestry programmes by community efforts iii. Compulsory terrace cultivation for the extensive row crop cultivated lands to be adopted iv. Govt. Forest Departments should be insisted by the local people (by demonstration) to initiate Afforestation programme on the scattered tree field areas
Marginal sensitivity, moderately stable zones (Grade II, Moderate risk area)	i. Most tea garden and cinchona plantation areas ii. Wide areas of closely scattered settlements in higher altitude zones iii. Some scattered tree field areas iv. Large and small patches of forest cover	<b>Moderate</b> i. Within the gardens of tea and cinchona plantation if further expansion of colonies and quarters are necessary, it should be done following stipulated construction rules in well planned manner on the stable hill slopes strictly with single storied constructions ii. The closely scattered settlement areas on the high altitudes can be permitted for further planned growth preferably with single storied buildings on stable slopes with approval from concerned construction authority iii. Govt. forest departments should be insisted by the local people (by demonstration) to initiate Afforestation programme on the scattered tree field areas
Stable in sensitivity, stable zones (Grade I, Low to risk free area)	i. Most of the area under forest cover ii. Low altitude few tea garden areas iii. Little area under scattered tree fields in high altitude zone	<b>Minor</b> i. No immediate measures are necessary except the scattered tree fields which should be brought under intense afforestation programme as recommended for other zones

settlements (Fig. 17.4a), closely scattered concrete structures and buildings, erosion prone fallow or bare land surface, un-terraced row crop cultivation practice, sick tea gardens, and sparse

vegetation cover made the entire zone fragile (Bhattacharya 2021) for which this landform has been graded as IV, i.e., **Very High Risk areas** from the viewpoint of terrain sensitivity and



**Fig. 17.6** Geological sequences of Darjeeling Himalaya

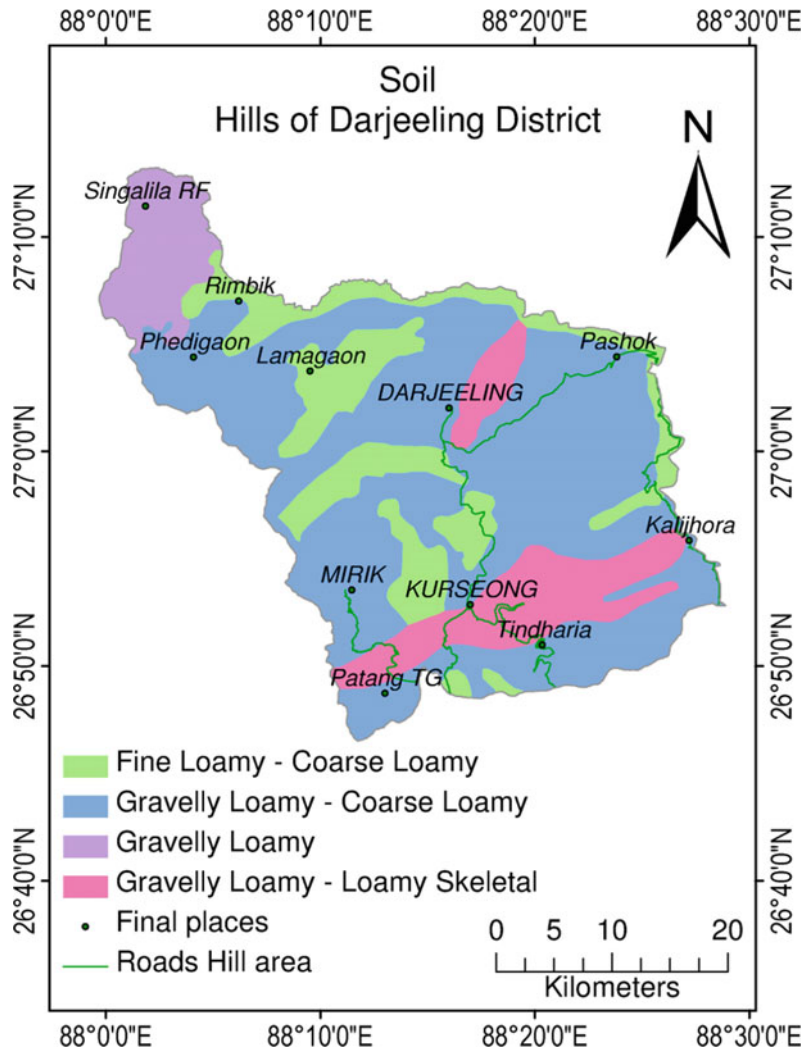


human perception. Another zone of same grade is identified over the northern part of the study area covering a region of geologically less disturbed and harder rock strata of Greater Himalayan Sequence (GHS) (Fig. 17.6) having Dharwarian Darjeeling gneissic rocks where very steady growth and expansion of urbanization in the town of Darjeeling and its fringe areas, mostly induced by flourishing hill tourism, have converted the area into a jungle of concretes and high rising buildings (Fig. 17.4b, c) on the lofty hills and on some densely settled areas developed due to rapid urban growth as well as on few congested settlements in the high altitude tea gardens. The huge pressure of settlements for urban growth and expansion along with poor condition in some tea gardens (Fig. 17.4d) on the high altitudes have converted this zone into high

terrain sensitivity and people's perception accordingly marked this zone as environmentally degradable.

To restore these zones from further deterioration as well as to ensure the stability of the built environment of these zones a well thought management strategies have been recommended in the Table 17.3 where strict prohibition of further settlement growth and multi-storied building constructions have been proposed. The un-vegetated fallow or bare land surfaces in these zones have been recommended for intense root spreading and soil anchoring fodder and fuel wood plants. These plants, e.g., Chilawne (*Schima wallichii*), Gokul (*Ailanthus grandis*) and Utish (*Alnus nepalensis*) and shrubs like Guenyhlo (*Callicarpa arboria*), Amaro (*Spondius pinnata*) and Phirfira (*Firmiana colorata* R.

**Fig. 17.7** Physical soil properties of the hills of Darjeeling district



Br.) easily thrive even on most difficult sites such as cliffs and joints, road cuts, hard and dry soils and stony surfaces along the hill slopes (Bhattacharya 2018) and in turn have the economic potential for giving return to the local people (Reddy 1983; Singh et al. 2006). Other than these plants, two important grass species Amlisho or Broom Grass (*Thysanolaena maxima*) and Vetiver (*Vetiveria zizanioides* L.) can be chosen for plantation on the bare soil surfaces. Amlisho or Broom Grass can grow almost everywhere on the hill slopes (Fig. 17.4h) and is economically very profitable since this grass stems are used for making domestic brooms

(Bhattacharya 2013, 2018). Vetiver is a grass species which has been recommended by the agricultural scientists of World Bank as a soil and water conservation tool in a number of countries including Madagascar and India. Vetiver is a 'climax' plant and therefore if all plants are destroyed by draught, flood, pest, disease, fire or other adversities, vetiver will remain to protect the ground from the onslaught of the next rain (Sivamohan et al. 2010). Vetiver has economic potential too because it is a high value essential oil crop, used as fixative in perfumery and cosmetic industries (Yaseen et al. 2014). Compulsory terrace cultivation for the row crops should

be ensured in association with increase of vegetation cover in the settled areas by community effort as well as improvement of the conditions of few tea gardens in these zones of terrain sensitivity.

The zones of moderate sensitivity perceived by the local people as deplorable zones (Figs. 17.2, 17.3 and Table 17.3) are again mostly confined within the both geological provinces of upper and lower Lesser Himalayan Sequence (LHS) and lower Siwalik rocks where thrust effect induced flakey nature of the rock strata coupled with Damuda and Siwalik groups of relatively softer rocks of medium hardness (Fig. 17.6) as well as Gravelly Loamy-Coarse Loamy to Gravelly Loamy-Loamy Skeletal soils (Figs. 17.4g and 17.7) are prominent. These altogether being affected by moderate to high dissection, moderately high to very high ruggedness and higher length of drainage and overburdened with congested urban and closely scattered settlements with inadequate vegetation cover on the land surface (Bhattacharya 2021) have moderately exceeded the limit of terrain tolerance. Therefore, these terrain zones have been identified as grade III, i.e., **High Risk areas**.

For proper planning and restoration of these zones and to bring back the entire region from deplorable to stable state, a high level of management has been proposed with the appropriate measures as in the Table 17.3 where emphasis has been given upon the restriction of further growth of the congested settled areas and only expansion of the settlements on the fringe areas of the built environments, increase of vegetation density in the settled areas, compulsory terrace cultivation and people's initiative to make Govt. forest departments aware to take up afforestation programme on the scattered tree fields. Increase of vegetation density in the settled areas can be done by introducing promising agro or social forestry species on the basis of suitability of plant species in the various altitudes of the study area (Chaturvedi et al. 2017).

The zones of marginal terrain sensitivity (Figs. 17.2, 17.3 and Table 17.3) which according to peoples' perception have been identified as

moderately stable zones are extended over the lithological setup of Greater Himalayan Sequence, Upper Lesser Himalayan Sequence (U-LHS) and Siwalik formations (Fig. 17.6) having almost Fine Loamy-Coarse Loamy to Gravelly Loamy-Coarse Loamy soils (Fig. 17.7) over a wide range of terrain dissection and ruggedness where dominance of tea gardens and cinchona plantations along with large and small patches of forest cover and wide areas under closely scattered settlements in the higher altitudes of harder rocks (Bhattacharya 2021) have marginally exceeded the limit of physical terrain tolerance and thus, have been recognized as grade II i.e. **Moderate Risk areas**.

As these zones are relatively stable being the terrain sensitivity marginal and the peoples' perception about these zones as partially fragile some careful management strategies have been proposed in the Table 17.3 where growth and expansion of settlements in the tea gardens and cinchona plantation areas have been permitted for the prospect of these valuable plantation sectors (Bhattacharya 2021) with stipulated construction rules and adequate planning on the stable hill slopes strictly with single storied buildings. Similarly over closely scattered settled areas on high altitudes planned growth of the settlements have been proposed with single storied structures on stable slopes seeking approval from concerned construction authority. Regeneration of forest and vegetative growth on the scattered tree fields has mentioned here also like the grade III zones.

The zones which are stable in terrain sensitivity and perceived by the human as stable zones (Figs. 17.2, 17.3 and Table 17.3) are distributed over various geological setup, geomorphological setup and soil conditions and almost covered up by forest with few settlements (Bhattacharya 2021) provide a positive view of the importance of forest over the landscape for which terrain sensitivity of these zones did not exceed the limit of physical terrain tolerance and therefore this zones have been recognized as grade I, i.e., **Low to Risk Free areas**.

No immediate planning and measures are necessary for these zones. However, little areas

under scattered tree fields are found in the high altitude zones which should be brought under afforestation programme as proposed for other grades of terrain in the hills of Darjeeling district.

## 17.6 Conclusion

In the terrain sensitivity assessment and gradation of different risk areas, it is highly contextual to consider in mind whether landform shapes the human habitation or human habitation shapes the landform. A great deal of dilemma lies between these two propositions. From geographical perspective ‘landform shapes the human habitation’ is quite accepted because landform determines what feasibilities of life are present over a landscape on the basis of which human habitation develops accordingly. From environmental perspective, ‘human habitation shapes the landform’ is more appropriate because any feasibility of life that facilitates rapid development of an area does not obey the rule of the tolerance of the landform. Therefore, the landform becomes subjected to human pressure leading to a kind of deterioration which converts the concerned area into an area of risk for safe human habitation.

From the terrain sensitivity assessment and perception study of the hills of Darjeeling district, it becomes quite clear that the landform especially the hilly terrain becomes degradable or fragile if not used judiciously. Judicious use of the landform can otherwise provide sustainability of the landform for future use without unacceptable risk of damage to the concerned landscape.

At the present time human plays a pivotal role in every sphere of development not because of the need only, but probably because of satisfying greed too. This emerges the inevitable consequences on the hill terrain. The hills of Darjeeling district is no exception from it for which the environmental planning and strategies proposed above, if implemented, can pave a way of sustainable human habitation in the coming years.

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