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GIS-Based Framework for Local Spatial Planning in Hill Areas

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Abstract: Spatial planning plays an important role in achieving efficient and sustainable development in hill areas. It is more critical in hill areas because of the scarcity of land having potential for development. One of the problems frequently faced by planners is the absence of a quantitative approach for spatial planning at the local level. In the present study, an attempt has been made to develop the framework for spatial planning at the local level for hill areas. In the process of development of the framework, three tasks have been completed. First, existing spatial planning approaches and frameworks used at the local level have been reviewed. Second, the conceptual framework has been developed for spatial planning based on the review of existing frameworks. Third, the geographic information system based methodology has been developed to execute the developed conceptual framework. The developed framework has been executed for validation on one of the proposed spatial planning projects in hills. The developed framework has been found useful in making spatial planning decisions for both practitioners and researchers involved in the development of hill areas.

1. INTRODUCTION

Hill areas are defined as 'all kinds of weathered highlands' without reference to the level of which they are situated (Kapos et al., 2000). A total 24 percent of the earth's land surface is occupied by hills. Any area with altitude more than 600 meters from mean sea level or any area with an average slope of 30 degrees is classified as hill area (Bureau of Indian Standards (BIS), 2016). Hill areas have gained much attention in recent years because of the challenges involved in planning and continuously increasing demand for infrastructure in these areas. Any development activity without due consideration given to the geo-environmental context affects the ecological balance of hill areas (Kapoor, Kohli, & Menon, 2009).

The planning and development of spaces in hill areas is a challenging task because of a number of factors like rapid urbanization, population growth, scarcity of developable land, proneness to natural disasters, and its ecological sensitivity (Maitra, 2003). Moreover, topographical variation at the micro level poses enormous problems in the adoption of generalized norms and standards of planning. Each locality has some peculiar problems and prospects, therefore, needing special care while planning for its development. The major constraints for planning and development in hill areas are sloping terrain, sharp gradients, complex geological structure, extreme climatic conditions, and rich vegetation. Further, planning becomes more critical in hill areas due to conflicting goals of environmental protection, economic growth, and sustainable development (Kapoor, Kohli, & Menon, 2009). Researchers identified various issues associated with the development of hill areas which are described briefly in *Table 1*.

Table 1. Issues associated with the development of hill areas

Issues	**Description**	**Sources**
Unauthorized construction	Unprecedented haphazard and unauthorized development on irregular plots due to lack of serviced land.	Ministry of Urban Development (2014)
Mobility and connectivity	Inefficient mobility and connectivity due to steep slopes and difficult terrain.	
Vulnerable to disaster risks	Geographically younger hill areas with high seismic activities have resulted in making settlements vulnerable to disaster risks.	
High-density development	High-density development consisting of multistoried buildings has emerged without necessary services and safety measures.	Shekhar (2011)
Urban sprawl	Use of fertile agricultural land in suburbs or outskirts of existing hill towns for development, because of weak land policies, improper development plan, and lower price.	
Congestion on desirable slopes	Crowding of buildings on desirable orientations has resulted in illegal increase in ground coverage, encroachment of setbacks, increase in height, change in land use, change in the utility of the building, encroachment of right of way, and water scarcity.	Hassan (2008)
Development on shaded slopes	Increase in population has resulted in development on steep and shaded slopes which are not desirable for construction.	Sekar and Thirumeni (2002)
Inadequate safety provision	The congested localities are developed without adhering to inadequate safety provisions. Also, many areas have inadequate or no access for emergency vehicles which result in a heavy loss to human life and wealth during any disaster.	Institute of Town Planners India (ITPI) (2004)
Development on unstable slopes	Development activity on high and unstable slopes, more than 35 and up to 60 degrees, with no tree/greenery amidst congested localities thereby limiting natural light, air, and ventilation.	
Contextually inappropriate	Because of lack of proper planning, new development is contextually inappropriate in terms of scale, material, and style.	Jutla (2000)

Because of the lack of efficient and quantitative spatial planning strategies, land use, in general, is allocated without attention to topography, solar exposure of the site, slope direction, green cover, and type of soil. The site is not checked for its vulnerability to natural disasters. Even the land holdings which follow the profile of natural topography are not regular in shape and are without basic services and infrastructure. This leads to unplanned and unauthorized development in hill areas. So the major concern in most of the hill towns is unprecedented haphazard development on irregular plots due to improper planning decisions (Maitra, 2003). All these issues are because of poor spatial planning strategies adopted (Shekhar, 2011). The spatial plans developed on these poor strategies specifically at the local level appear to be subjective, large, and their analysis is based on revenue records prepared long back thus failing to provide a contextual response to the problems.

With the increase in complexity of urban systems in hill areas, there is a need to make the spatial planning process more dynamic, realistic, and effective. It requires a more flexible system to deal with the complex and dynamic reality of the problem than what has been used presently (Sengupta & Banerji, 2012). There is a need for modern tools/techniques for better measurable, rational, and structured planning processes which can assist in data handling as well as provide a necessary platform for implementation. Keeping all these problems in view, research is going on in various geographic regions to develop a flexible and effective system or process for the development of comprehensive spatial plans for sustainable development.

2. SPATIAL PLANNING AND ITS APPROACHES

Spatial planning is defined as a technique used by architects and planners for locating different facilities in a given space by considering the best land use, transportation, and environmental preservation. The fundamental role of spatial planning is to encourage a more rational organization of activities associated with various facilities (Haughton et al., 2009). Spatial planning is also defined as an interdisciplinary activity which involves planning land use, determining conditions for the arrangement and location of activities, identifying methods for improving existing physical structures, and defining the conditions for the location and execution of planned physical structures. It focuses on the judicious use of land with a greater understanding of the internal spatial structure of the area under consideration and its external relationship.

The spatial planning approaches proposed in different geographic locations are enlisted in *Table 2.* The frequency of use of various approaches for spatial planning is shown in *Figure 1*. The study reveals that the participatory planning, scenario development, and Geographic Information System (GIS) based methods are widely used among professionals. These approaches help in making spatial planning decisions more rational and logical and provide a scientific base to the solution (Lian, 2018). Participatory planning and scenario development can be made more efficient by using GIS. Scenario development is a method of creating different alternatives for planning solutions to the site by giving different weights to the factors considered and by the more active participation of stakeholders. Scenarios are generated in GIS with inbuilt multi-criteria decision making (Malczewski, 2006). Moreover, GIS also assists in active public participation (Geertman, 2002). Hence, the present study focuses on the development of the spatial planning framework supported by GIS.

GIS is data-based information technology that provides tools for generating information from different database sets and use in the procedure of rational spatial planning. It has geospatial analysis capabilities which help to take a more informed, rational, and sustainable decision based on scientific methods (Ervin, 2011). GIS is used for solving a wide range of problems including defining suitability of land through an ecological approach, planning of different habitat spaces for animal and plant species (Store & Jokimäki, 2003), physical and environmental favourability, land suitability analysis for farming activities, evaluating existing landscape and planning interventions, and choosing location of best site for the urban facilities for various activities related to public and private sector (Church, 2002; Sugihara & Shen, 2017).

Table 2. Spatial planning approaches

Spatial planning approaches	**Geographical location**	**Main planning topics addressed**	**Sources**
Resource Planning	Australia	Water management	Gilmour, Walkerden, and Scandol (1999)
Ecosystem Approach	UK	Planning theories and practices	Scott et al. (2013)
	Denmark	Green infrastructures	Vejre, Jensen, and Thorsen (2010)
	China	Urban development, urban/regional governance and policies	Fang, Zhang, and Hong (2005)
Participatory Planning	Mexico	Water management strategies and technologies	Nanninga et al. (2012)
	India	Water management	Poricha and Dasgupta (2011)
	Australia	Housing	Newton (2010)
	Mexico	Informal settlements, urban/regional governance and policies	Wigle (2010)
	Australia	Urban development	Pearson and Gorman (2010)
	South Africa	Informal settlements, urban development, housing	Jiusto and Hersh (2009)
	Canada	Safety, building and urban design	Saville (2009)
	-	Urban development, equity, and environmental justice	Watson (2009)
Scenario Planning	Turkey	Green infrastructures; urban functions and land uses	Kuşuluoğlu and Aytaç (2013)
	Italy	Urban development	Moccia (2012)
	UK	Urban form; urban functions and land use	Rice (2010)
	Europe	Urban functions and land use	Haase et al. (2010)
	Germany	Ecosystem services and landscape functions	Wolf and Meyer (2010)
	Thailand	Urban form	Hara et al. (2010)
GIS-Based Analysis	Estonia	Urban form	Roose et al. (2013)
	Indonesia	Green infrastructures	Kim (2012)
	USA	Urban form; urban functions and land uses	Talen (2012)
	Canada	Tools for local sustainability planning	Klinsky, Sieber, and Meredith (2010)
Suburban Retrofit and Regeneration	USA	Urban form, urban development	Amstrong et al. (2012)
	Spain, USA	Urban form, urban functions, and land use	Vall-Casas, Koschinsky, and Mendoza (2011)
	Australia	Urban functions and land use	Newton (2010)
	Australia	Urban development, urban governance, and policies	Wilson and Berry (2005)
Conservation Planning	Algeria	Urban and peri-urban agriculture	Boudjenouia, Fleury, and Tacherift (2006)
Transit Oriented Development	USA, China	Mobility	Loo, Chen, and Chan (2010)
	USA, Germany	Mobility, urban form	Ryan and Throgmorton (2003)
Smart Growth	USA	Housing, urban form	Atkinson-Palombo (2010)
	Canada	Urban development, urban/regional governance and policies	Tsenkova and Damiani (2009)
	Canada	Planning theories and practices	Grant (2009)
New Urbanism	USA	Building and urban design	Berke (2002)
	Australia	Housing; building and urban design	Binder and Dalton (2007)
	Canada	Mobility	Randall and Baetz (2001)

A GIS-based planning support system (PSS) has been used to identify and analyse development control factors (Long, Shen, & Mao, 2011). Carsjens and Ligtenberg (2007) used a GIS-based support system to incorporate environmental consideration into spatial planning. Baz, Geymen, and Er

(2009) used GIS for evaluating environmental sustainability. Bansal (2014) suggested the use of GIS in spatial planning. Kumar, M. and Biswas (2013) used GIS-based evaluation to identify potential sites for urban development.

In hill areas, spatial planning decisions need a comprehensive evaluation of various factors including topography, soil conditions, existing infrastructure facilities/utilities, etc. which need spatial analysis capabilities. GIS has advanced spatial analysis capabilities, which can assist in taking spatial planning decisions in hill areas. To deal with spatial planning problems, large datasets are required. Analyses of large datasets becomes difficult following manual methods, which can easily be handled by computer-assisted overlay techniques available in GIS. Keeping in view the importance of GIS in the planning process, the methodology to execute the proposed framework was planned to be developed in GIS.

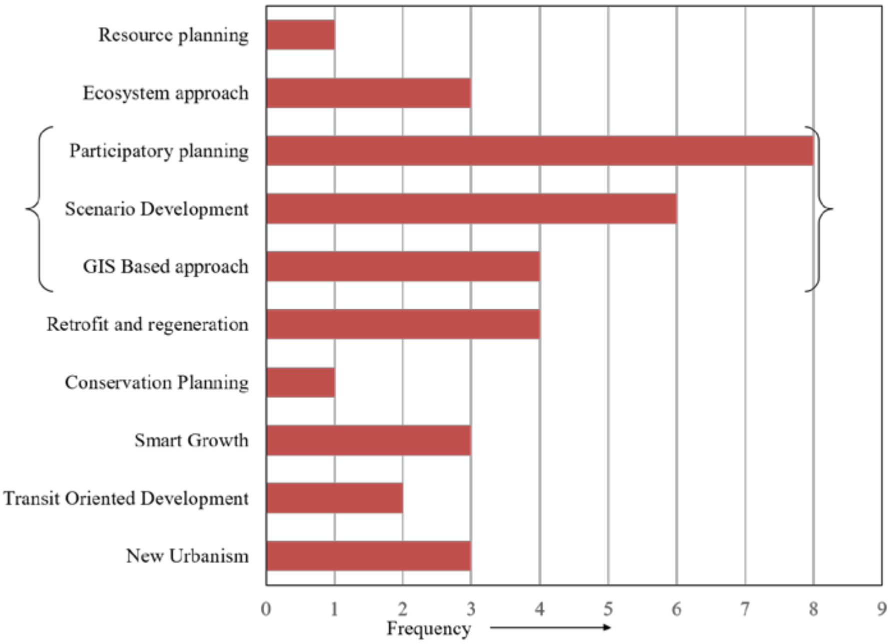

Figure 1. The frequency of use of spatial planning approaches

3. STUDY OBJECTIVE

The main aim of the present study was to develop the GIS-based framework for spatial planning in hill areas for addressing various issues in a structured manner. In order to fulfil the main aim, the following objectives were framed:

1. To develop the GIS-based framework for spatial planning in hill areas,
2. To review the national/international codes and reported literature for identifying the critical factors and their related code provisions for spatial planning in hill areas, and
3. To develop a methodology in GIS for the execution of the proposed framework using a suitable case study in hill areas.

4. DEVELOPMENT OF FRAMEWORK

There are several notable frameworks which provide basic steps of traditional spatial planning at the local level as well as site level. A review of existing spatial planning frameworks was done at the preliminary stage of formation of the framework. The gaps were identified in the adoption of these frameworks for hill areas. Out of these, the most accepted frameworks were provided by Lynch and Hack (1984) and Simonds (1997). The two frameworks reveal a strong agreement between the different steps involved in solving spatial planning problems. The intent of the different steps suggested broad classification of the framework into four stages as shown in

Lynch and Hack (1984)	**Simonds (1997)**	**Stages**
Defining problem	Problem definition	**Understanding the problem**
Analysis of site and user	Research/Data collection	**Data collection and analysis**
	Site/User program	
Schematic design and cost estimate	Schematic design	**Decision regarding proposed solution for implementation**
Final design and detailed costing	Design refinement	
Contract documents	Contract documents	
Bidding and contracting		
Construction		
Occupation and management	Inspection/Evaluation	**Evaluation**

Table 3. These stages are: understanding the problem, data collection and analysis, decision of the solution to be proposed for implementation, and evaluation.

Table 3. Comparison of the existing spatial planning framework

Development in hill areas is done mostly at a small scale because of the scarcity of land available for development. Because of the small scale of development and lack of base data, all the steps specified in both the frameworks were processed on the basis of subjective judgment, knowledge, experience, and imagination of the planner (Flaxman, 2010). The problem space is not defined in a meaningful way, there are no “rules” as such and no way to evaluate the developed plan for its sustainability. Moreover, evaluation is done after the implementation of the plan, which is the major reason of contextually inappropriate planning in hill areas. Thus, there is a need of a framework for spatial planning at the local level in hill areas (Zheng, Shen, & Wang, 2014). For better measurable, rational, transparent, and structured planning decisions, the proposed framework is required to be supported by modern tools/techniques which can assist in data collection, storage, manipulation, and analysis.

The structure of the conceptual framework proposed to facilitate spatial planning has been depicted in *Figure 2*. The framework consists of four modules. Each module has different functions and is linked to each other for the purpose of data flow. The first module is the site information database, which has the geospatial data in the form of digital map layers. The purpose of creating this database is to provide the required information for geospatial analysis and visualization. This database is the physical foundation of the framework Wang, Shen, and Tang (2014). The second module is the planning policy control mechanism. It is a set of regulations and policies related to the critical factors affecting spatial planning, their assessment, and weightage for making spatial planning decisions. The database corresponding to each critical factor is modelled in the third module which is the evaluation mechanism. The evaluation of the critical factors suggests the changes and their impacts on spatial planning in the fourth module, where planners make spatial planning decisions for the development of the area under consideration.

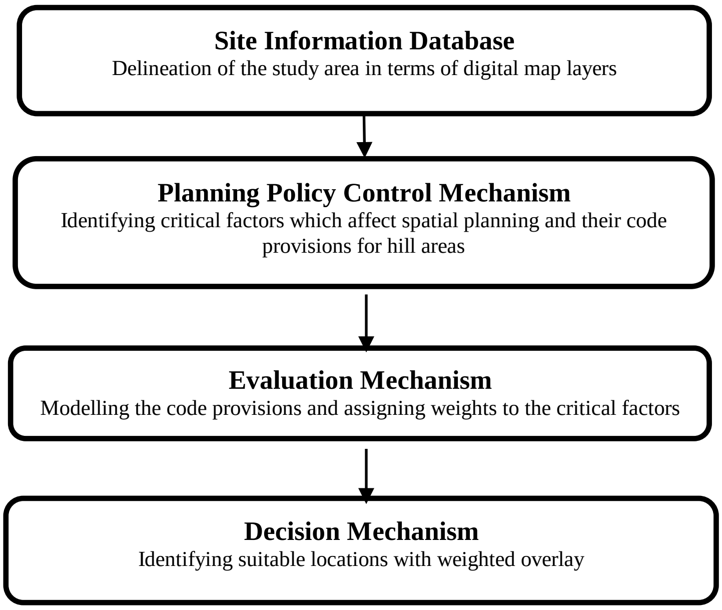

Figure 2. The proposed conceptual framework for spatial planning

5. EXECUTION OF THE FRAMEWORK

The GIS-based methodology was developed for the execution of the proposed framework. The new proposed educational campus of Himachal Pradesh Technical University (HPTU) at Hamirpur, Himachal Pradesh, India was chosen as the case study. Geospatial data of the case study includes a topographic map, existing village roads, existing water channels, campus boundary, pathways, existing buildings, state roads, and vegetation. Finally, the procedure developed in the conceptual framework was converted to the GIS-based methodology for assisting spatial planning in hill areas.

The steps of the framework which has been developed for spatial planning in hill areas were modelled in GIS to find the most suitable locations for various facilities in the campus. The suitable locations are locations where code provisions are satisfied. Spatial analysis was conducted to select a broad area that was further narrowed down to a few identifiable locations where code provisions were satisfied. The GIS-based methodology is represented in *Figure 3* and discussed below.

5.1 Development of site information database

The first step of the developed framework is to create the site information database which consists of map layers required for the delineation of the study area. The geographical information required for developing the site information database was obtained from the field survey and the existing data sources. The data from the field survey was used for the development of the surface model of the site. The surface model is a 3D digital representation of the topography. The first step in developing a surface model was to create a contour map in AutoCAD from survey data. The contour map was exported to ArcGIS to generate a geodatabase containing the locations and elevations of various contours in 2D. Data in the geodatabase was then converted to a 2D *shapefile*. The *shapefile* is a simple non-topological format for storing locations and their attributes.

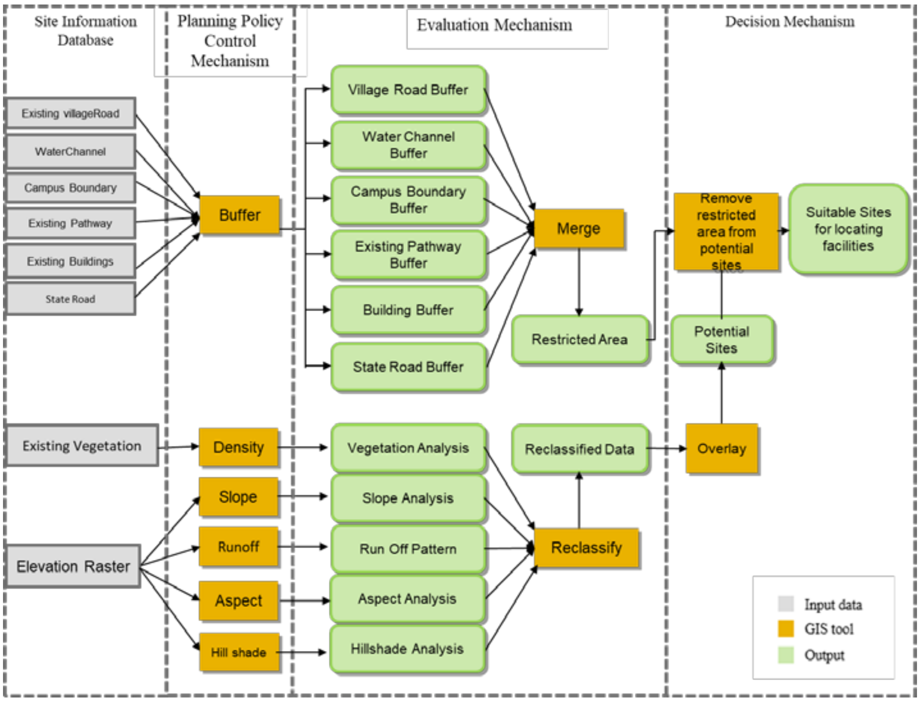

Figure 3. GIS-based methodology for spatial planning in hill areas

The elevation raster was generated from a 2D *shapefile* that is a rectangular array of cells, in which each cell represents a square area on the campus surface and has an elevation value that is static for the entire cell area. In addition to this, the dataset corresponding to other existing features of the site like existing village road, water channel, campus boundary, pathways, buildings, state roads, and vegetation were also created. The proposed site for the campus along with the existing utilities is shown in *Figure 4a*.

5.2 Planning policy control mechanism

The planning policy control mechanism helps in the identification of critical factors for planning based on the literature review and determining their weights based on the expert interview. A detailed study of national and international regulations and policy control was done to find out the code provision for spatial planning of a campus in hill areas. Based on reported literature (Aburas et al., 2015; Dai, Lee, & Zhang, 2001; Chandio et al., 2011; Kumar, M. & Biswas, 2013; Kumar, S. & Bansal, 2016; Youssef, Pradhan, & Tarabees, 2011), five critical factors for spatial planning in hill areas were identified which are as follows:

Slope- The ratio of rise to run between two locations. It indicates steepness, incline, or grade. The slope of a site under consideration has a critical role in any development activity because of the higher cost of construction on steep slopes. Moreover, any development on steep slopes affects the stability of a slope and can lead to landslides. Bureau of Indian Standards (BIS) (2016) suggests that no construction should be ordinarily undertaken in areas with slopes above 30 degrees or in areas that fall in landslide hazard zones. Variation of the slope of the proposed site is shown in *Figure 4b*.

Aspect- The compass direction that the downhill slope faces for each location. In the northern hemisphere, north-facing slopes receive very little heat from the sun in winter and south-facing slopes receive much more heat. Therefore, south facing slopes are warmer than the north facing slopes in winter. Thus, south facing slopes are desired in hill areas. Aspect variation of the proposed site is shown in *Figure 4c.*

Runoff pattern- The pattern of flow of water over the surface of the land to a drainage channel. When development activities encroach drainage channels, its ability to carry water is reduced and the potential for structural harm is increased. In the present study, runoff pattern has been modelled by using the D8 algorithm in ArcGIS 9.2 on the flow direction raster as shown in *Figure 4d*. The values represent a number of cells of raster flowing into a particular cell.

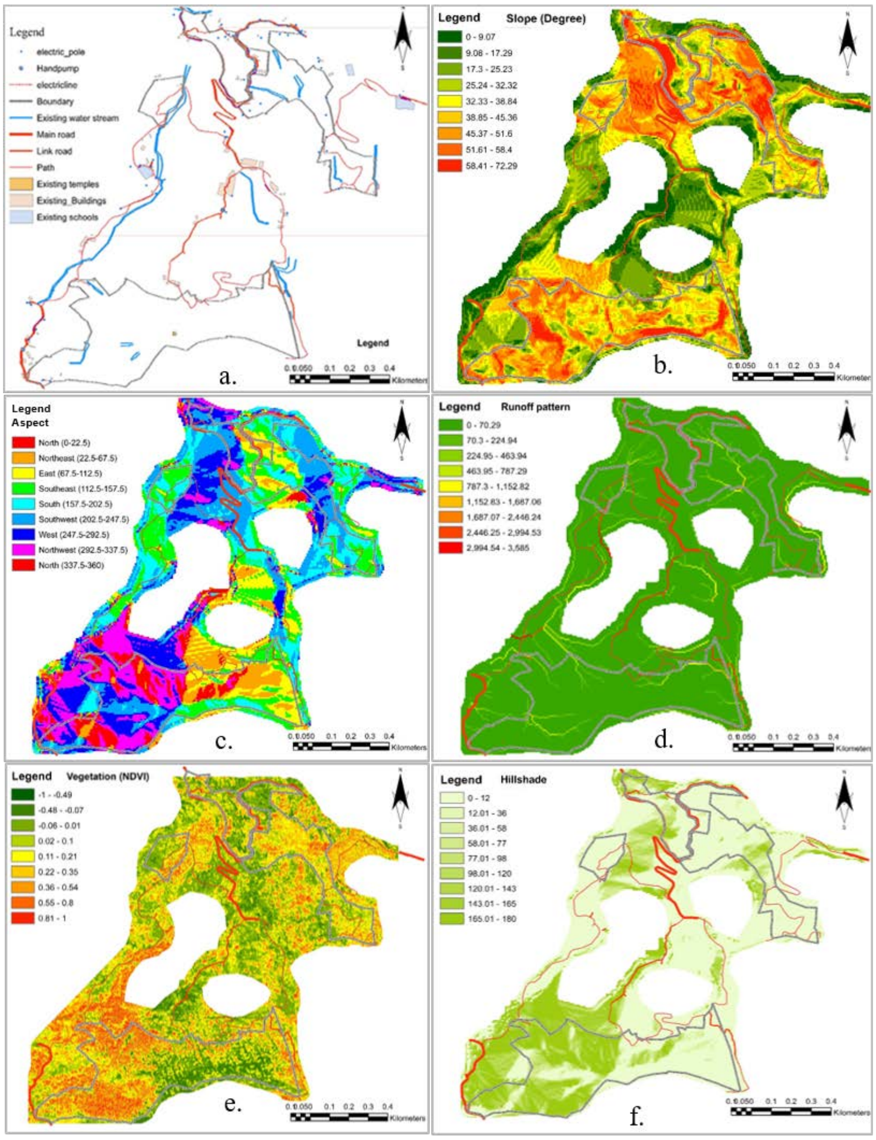

Figure 4. a. The proposed site for HPTU, *b.* Variation of the slope, *c.* Aspect variation, *d.* Runoff pattern, *e*. Vegetation, *f.* Hill shade

Existing vegetation- In the present study, vegetation has been analyzed with the help of the Normalized Difference Vegetation Index (NDVI). It quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). The values of NDVI range from -1 to +1. NDVI close to +1 represents dense green vegetation which may be restricted for development. Vegetation analysis of the proposed site is shown in *Figure 4e.*

Hill shade- Hill shade uses light and dark colors to highlight where sunlight would hit and where shadows would form in the presence of hills. Hill shade is a grayscale representation of the surface, with the sun's relative position is taken into account for shading. The altitude and azimuth analysis are required to specify the sun's position. *Figure 4f* represents hill shade analysis of the proposed site.

Datasets were created corresponding to each of the five critical factors. All these datasets were developed in raster format so that for each pixel, a score can be determined. Datasets corresponding to slope, aspect, runoff, and hill shade were generated from the elevation raster created in the first module. For generating the dataset corresponding to vegetation, a satellite image of the study area was taken as an input. Finally, the five datasets corresponding to the slope, aspect, runoff pattern, vegetation, and hill shade were developed. The different code provision for the identified critical factors has been compiled in *Table 4* from national and international codes, which includes the National Building Code (Bureau of Indian Standards (BIS), 2016), IS Code 14243 (Bureau of Indian Standards, 1995), Model building bylaws (Ministry of Urban Development, 2016), and International Building Code (International Code Council, 2009).

5.3 Evaluation mechanism

Modelling of datasets corresponding to the critical factors- The first step of the evaluation mechanism is to model the datasets created corresponding to the critical factors on the basis of code provisions compiled in *Table 4*. The slope of the site was divided into nine different classes with equal intervals of slope angle. Aspect was determined to find the direction of the slope to restrict locations falling in the north slope from development. Similarly, as per the code provision, natural drains should not be disturbed, and development should be a minimum 2.0 meters away from the existing drains. To locate the natural water flow in the site, the runoff pattern dataset was modelled. The runoff pattern matches with the existing drains on the site, this validated the accuracy of modelled datasets. The existing drains were buffered for restricting the areas for development within 2.0 meters from it. Vegetation analysis of the site under consideration was done to find out the vegetation at different locations and the site was divided into nine classes on the basis of values of vegetation analysis for evaluating the locations for development. Similarly, hill shade modelling was carried out to find the shaded locations, which were least suitable for any kind of development. In addition to this, a buffer was created around each existing feature on the site under consideration, which helped in excluding the areas which were restricted from development. In the present case study, existing features which were buffered include existing village road, water channel, site boundary, pathway, existing buildings, and state roads. However, actual numbers of input datasets are variable depending upon type and scope of a

Factor	NBC (2016)	IS-14243 (1995)	Model Building Bylaws (2016)	IBC (2009)
Slope	Areas with a slope above 30 degrees should be restricted from any type of construction.	Building sites should be located on a hillside with not more than 30 degrees' slope. Non-residential temporary buildings may be constructed on steeper slopes up to 45 degrees.	Building sites should be located on a hillside with not more than 30 degrees' slope. Non-residential temporary buildings may be constructed on steeper slopes up to 45 degrees.	Slopes for permanent fill shall not be steeper than one unit vertical in two units horizontal (50% slope).
Aspect	Buildings shall be located on the south slope of a hill for better exposure to solar radiation.	Nil	Nil	Nil
Hill shade	Nil	Buildings should not be located on the bottom of the valleys or permanent shadow zones of ridges, and high wind zones.	Nil	Nil
Runoff pattern	The natural flow of water shall be diverted away from the foundations. Suitable lined or unlined drains shall be provided all around the building.	The construction of buildings should not obstruct the existing surface drainage courses to avoid instabilities to the building.	The inlet and outlet point of the natural drain system should be maintained with the adequate size of the channel for ensuring unrestricted flow of water.	Excess or concentrated drainage shall be contained on site or directed to an approved drainage facility.
Existing vegetation	Trees on the proposed site shall be cut only after obtaining the permission of the authority designated for this purpose.	Hillsides with thick vegetation with tall trees should be avoided as far as possible for the location of building complexes.	Compensatory plantation for felled/transplanted trees in the ratio 1:3 should be done. Provision of a minimum 1 tree every 80 square meters of plot area should be planted.	Ground surface shall be prepared to receive fill by removing vegetation, topsoil and other unsuitable materials to provide a bond with the fill material.
Existing features (Buildin-gs)	There should be no construction in the 6 meters buffer of the buildings.	Nil	Nil	Open space around buildings should be minimum of 9.14 meters.
Existing features (Electric power line and poles)	Horizontal clearance of 1.2 meters and a vertical clearance of 3.7 meters is required for the electric power lines.	Nil	Horizontal clearance of 1.2 meters and a vertical clearance of 3.7 meters is required for the electric power lines.	Electric wires and other accessories shall not cross or encroach upon any street or other public space.
Existing features (Water channel)	Construction should be done 4 meters away from the water channel	Nil	Nil	Nil

project under consideration.

Table 4. Critical factors and their code provisions

Table 5. Assignment of weights and scale value to the reclassified datasets

S. no.	Factor	Weight (%)	Range	Scale value
1.	**Slope (degrees)**	**30**	00-9.07	1
			9.08-17.29	2
			17.3-25.23	3
			25.24-32.32	4
			32.33-38.84	5
			38.85-45.36	6
			45.37-51.6	7
			51.61-58.4	8
			58.41-72.29	9
2.	**Aspect (degrees)**	**25**	South (157.5-202.5)	1
			Southwest (202.5-247.5)	2
			Southeast (112.5-157.5)	3
			West (247.5-292.5)	4
			East (67.5-112.5)	5
			Northwest (292.5-337.5)	6
			Northeast (22.5-67.5)	7
			North (0-22.5)	8
			North (337.5-360)	9
3.	**Runoff pattern (number of cells)**	**20**	0-70.29	1
			70.3-224.94	2
			224.95-463.94	3
			463.95-787.29	4
			787.3-1152.82	5
			1152.83-1687.06	6
			1687.07-2446.24	7
			2446.25-2994.53	8
			2994.54-3585	9
4.	**Vegetation (NDVI)**	**15**	-1- -0.49	1
			-0.48- -0.07	2
			-0.06-0.01	3
			0. 02-0.1	4
			0.11-0.21	5
			0.22-0.35	6
			0.36-0.54	7
			0.55-0.8	8
			0.81-1	9
5.	**Hill shade (brightness scale)**	10	0-12	1
			12.01-36	2
			36.01-58	3
			58.01-77	4
			77.01-98	5
			98.01-120	6
			120.01-143	7
			143.01-165	8
			165.01-180	9

Assigning weights to the datasets- Datasets corresponding to each critical factor were assigned a suitable weight based on its influence for making spatial planning decisions in hill areas. The weights were assigned on the basis of in-depth interviews conducted with practitioners and academics. Several methods have been reported in the literature to find the weights of the factors using expert opinion (Li, Yamaguchi, & Nagai, 2007). These are ranking, rating, pairwise comparison, and trade-off analysis. Any method out of these may be used depending upon the context of the project, experts available, and time required to complete a project. Ranking (arranging in rank order) is the simplest method to use, the results are viewed as an approximation of the true weights. Because of its simplicity, ranking has been used in the present study. The weights of critical factors used in the present study are given in *Table 5*. The higher the weight for a particular dataset, the more effective it will be in deciding the most appropriate location for the proposed facility.

Reclassification of the datasets- The values in the modelled datasets corresponding to the critical factors were in different ranges which were reclassified to a common scale value of 1 to 9. The higher scale value was given to the range within each dataset that was the least suitable, and lower values to the range which was the most suitable for locations for development. For example, the slope dataset was reclassified by dividing the values into 9 intervals. A lower value was assigned to the most suitable range of slope (00-9.07 degrees) and the higher value was given to the least suitable range of slope (58.41-72.29 degrees). Similarly, all the datasets were reclassified depending on the suitability of each of the critical factors. The reclassified values of the datasets are given in *Table 5*.

5.4 Decision mechanism

The focus of the decision mechanism is to identify the most suitable land parcels for locating various facilities. In the present study, this has been done by using weighted overlay analysis which is an effective method for decision making involving multiple factors. Five critical factors have been integrated using weighted overlay analysis. This resulted in a new dataset having a new scale value corresponding to each cell that has been calculated by multiplying the scale value with the weight of the corresponding dataset. The resultant dataset has a specific scale value of each cell in the range of 1-9, similar to the range of reclassified datasets. This range has been classified into four classes, which are most suitable in the range of 1-3, moderately suitable in the range of 3.01-4, less suitable in the range of 4.01-5, and least suitable in the range of 5.01-9 for locating various facilities as shown in *Figure 5a.*

Subsequently, buffer datasets created in the evaluation mechanism have been merged together to find out the locations which were to be restricted for development. The buffered dataset was deducted from the resultant dataset, to derive the most suitable land parcels for locating facilities. The conditional evaluation of the derived land parcels was done to exclude the land which does not fulfill the minimum area requirement of the proposed facilities. This generated the most suitable locations filtered for locating various facilities. The most suitable locations for the proposed facilities of the university campus are represented in *Figure 5b.* In total 10 filtered locations were identified with variation in areas from 1,408 square meters to 7,116 square meters. The choice of allocating the identified locations for a particular facility will depend on the planner.

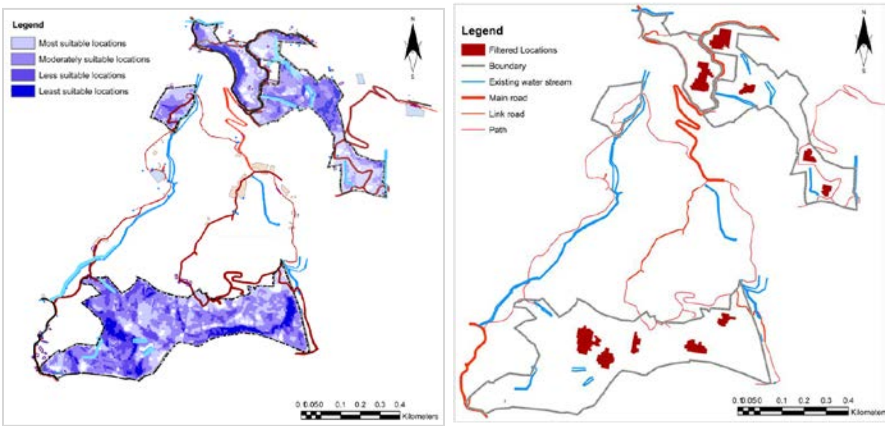

*Figure 5*a. Site classified into suitability classes, *b*. Most suitable filtered locations for different facilities

The planning process supported by the framework facilitates the decision-making process for spatial planning in hill areas. Alternate maps may also be generated by changing the factors considered and varying their weights according to the project under consideration.

6. STUDY CONTRIBUTION

Understanding the geographical condition of a site is necessary for providing contextually appropriate spatial planning solutions. The major contribution of the developed GIS-based spatial planning framework is rationally guiding the development of the area under consideration based on spatial information that is robust, nuanced, and constantly updated. Also, the detailed GIS-based methodology of the conceptual framework has been developed which deals with all the important aspects of spatial planning in hill areas. GIS-based methodology of the framework has also been validated by execution on a project proposed in hill areas. Through the execution of the framework, spatial thinking has been used to transform the data into applied data for actionable insight and solutions.

7. LIMITATIONS

Although the present study is a step toward identifying potential locations for locating facilities in hill areas by the quantifiable and rational approach, still, it has a few limitations. The methodology developed was executed only on one institutional campus located in hilly terrain. For further improvements in the developed framework, this needs to be tested on more institutional campuses located in different locations. Although various critical factors have been taken from the literature, the scope of the present study is limited to only five factors. To make it more acceptable and rational, questionnaire survey may be conducted. The study used a ranking method to derive the weights of the critical factors. The weights thus derived are an approximation of the real weights. A suitable scale to access the degree of importance assigned to each factor needs to be evolved to draw some definitive conclusions. However, these limitations do not undermine the contribution of the present study.

8. CONCLUSION

The present study explores a specific scenario of spatial planning at the local level for hill areas under development and provides a framework to support the spatial planning process. The major contribution of the developed framework is for both academics and practitioners. In academia, it fills the gap by providing a rational quantitative approach for spatial planning in hill areas. For practitioners, the framework assists in solving a practical problem faced by planners in hill areas, which is the absence of a quantitative and rational approach for spatial planning. The proposed framework considers the various critical factors identified through literature to enhance the process of decision making in spatial planning at the local level. In the present study, the code provisions of the critical factors were modelled in GIS to understand their effect in selecting suitable locations for various facilities. The identified locations are contextually more responsive in terms of minimum disturbance to the natural profile of the area under consideration. This makes the decision making process more rational and effective for providing a contextual response to the spatial planning problems in hill areas.

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