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Case Study

GIS-based methodology for sustainable spatial planning at site level for hill areas: case study of a University Campus

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Abstract

Traditional spatial planning at the site level in hill areas was done manually based on the experience of a planner. With the increasing spectrum of spatial complexity in hill areas, the use of Geographic Information Systems(GIS) in spatial planning is increasing nowadays. GIS deal with spatial planning problems in a structured manner by optimizing the planning process. GIS has advanced to a stage where geospatial analysis techniques are mature enough to assist spatial planning decisions for hill areas. GISallows planners to plan, receive real-time feedback, and find probable impacts of the proposed planning decisions. The present study focuses on the development of a GIS-based methodology for sustainable spatial planning at the sitelevel for hill areas of developing countries like India. The developed GIS-based methodology has been executed on one of the proposed university campuses in hill areas.

Keywords: GIS, geospatial analysis, sustainable spatial planning, hill Areas.

Introduction

Sustainable spatial planning is the process of developing a spatial plan that ensures the best use of land to fulfill the needs of stakeholders. It deals with the utilization of land as a resource for the efficient functioning of allocated activities. The significance of land as a resource is increasing because of rapid urbanization. The condition is more critical in hill areas because of the scarcity of land having the potentialfor development. The traditional forms of planning approach have failed to provide sustainable spatial development which is apparent from the review of existing planning approach and experiences of hill towns over the pastdecades[1,2]. In spite of the various planning regulations which have been enforced, development has been haphazard and fragmented. Some of the deficiencies of the traditional approach of spatial planning reported in the literature[3,4] are long-term plan period and long time taken for preparation of the plan. The plan is based on the weak database and without proper base maps. The traditional spatial planning is done on the basis of experience and imagination of the planner without any rational and quantifiable method. There is no monitoring mechanism to check the plan for its contextual appropriateness. There is a mismatch between the actual needs and the growth projection. Also, there is a lack of cooperation and coordination among service providing agencies as well as implementing agencies.

Keeping this in view, there is a need for sustainable spatial planning based on scientific and transparent methods. GIS is the technology-based tool already in extensive use by planners which help to make a more informed, rational, and sustainable decision based on scientific methods. It has advanced geospatial analysis capabilities, which may be used for taking sustainable spatial planning decisions. Over the last fifty years around, there is a tremendous increase in the use of geospatial analysis capabilities of GIS for urban, regional, and environmental planning in addition to spatial planning at national, state, and district level spatial plans/development. GIS has advanced to the third stage, from data compilation capabilities, to analysis capabilities, and to the use of analysis for the creative work of planning[5]. The third stage of evolution of GIS is helpful in spatial planning at the site level. The objective of the present studyis to develop a GIS-based methodology for providing sustainable spatial planning solutions at the site level for hill areas.

Hill Areas: The present study focuses on the site level of spatial planning specifically for hill areas. Hill areas are challenging, still the most interesting areas for the development of infrastructural facilities. The major constraints for planning and development in hill areas are sloping terrain, sharp grades, complex physical structure, extreme climatic settings, and rich vegetation[6]. Major factors which make spatial planning critical in hill areas are a scarcity of developable land, the susceptibility of natural disasters, ecological sensitivity of hill areas, increasing urbanization, and growing population as shown in figure-1. Moreover, the topographical variation at micro level poses enormous problems in the adoption of generalized norms

and standards of spatial planning. Each locality has some peculiar problems and prospects, therefore, needs special care while planning for its development. Hence, spatial planning becomes more critical in hill areas.

Figure-1: Major factors which make planning critical in hill areas.

Spatial planning decisions in hill areas need a comprehensive evaluation of various aspectsincluding topography, existing drainage, land cover, existing infrastructure facilities/utilities, etc. which need spatial analysis capabilities. Databases and spatial information systems are integral components of planning activities which adds to the complexities of planning problems. To deal with spatial planning problems in hill areas, large datasets are required. The mapping and combining of these datasets become difficult by manual method, which can easily be handled by the computer-assisted overlay techniques available in GIS[7,8].

Use of GIS for Planning

GIS is the technology-based tools already in extensive use by planners which help to make a more informed, rational, and sustainable decision based on scientific methods[9]. The GIS-based approach has been used in a wide range of problem solving, including defining suitability of land through ecological approach, planning of different habitat spaces for animal and plant species, physical and environmental favorability, land suitability analysis for farming activities[10], evaluating existing landscape and planning interventions[11], environmental impact assessment[12], choosing the location of best site for the urban facilities to cater to various activities related to the public and private sector[13], and spatial planning[14]. GIS assist in wide range of planning applications[15-19]. GIS-based planning support system (PSS) has been used to identify and analyze development control factors[20]. Carsjens and Lightenberg[21] used GIS-based support system (SS) to incorporate environmental consideration into spatial planning. Baz et al.[22] used GIS for evaluating environmental sustainability. Bansal[23]suggested the use of GIS in spatial decision making. Kumar and Biswas[24]used GIS-based evaluation to analyze the potential sites for urban development. Over the last fifty years around, there is a tremendous increase in the use of geospatial analysis capabilities of GIS for urban, regional, and environmental planning in addition to spatial planning at national, state, and district level.

GIS-Based Methodology to Support Sustainable Spatial Planning Process at Site Level

The structure of the spatial planning process at site level proposed in the present study has been depicted in figure-2. The process consists of different modules. Each module has different purposes and is connected to each other for the process of data flow. The first module is a land information database, which has different layers of geospatial data in the form of digital maps. The database is created to provide the required information for the geospatial analysis. The second module is planning regulation mechanism. It represents the regulations and policies, their assessment criteria and weighting for spatial planning. These multiple criteria are analyzed in the third module which is the evaluation mechanism. This suggests the changes and their impacts on spatial planning in the fourth module which assists planners in taking spatial planning decisions for the development of the area under consideration. GIS-based methodology has been developed for the execution of the proposed process of spatial planning at the site level for hill areas. The developed methodology has been tested on a proposed university project in hill areas.

Case Study

Himachal Pradesh Technical University campus proposed at Hamirpur, Himachal Pradesh, India was chosen for the execution of the developed methodology, because of the focus of study on the site level. The different modules of the developed process to deal with spatial planning problems at site level are discussed below:

Land Information Database: The first step of the developed process is to create the land information database. The different map layers which were created to find out a suitable location for various facilities through spatial analysis were: elevation raster of the site and other existing features of the site which include existing village road, water channel, campus boundary, pathways, buildings, state roads, and vegetation. The land information database was prepared by adding all these features and surface model of the site was prepared as shown in Figure-3. This delineates the study area in different digital layers.

Planning Regulation Mechanism: The next step of the process is planning regulation mechanism which helps in the identification of critical factors for planning and their weighing based on the literature review and code provisions. A detailed study of national and international regulations and policy control was done to find out the code provision for spatial planning of campus in hill areas which helped in finding out the critical factors which are essential for any development in hill

areas. Based on the literature, five critical factors for the spatial planning in hill areas are identified which are slope, existing run-off pattern, slope aspect, hill shade, and the existing vegetation density[24, 25]. The different code provision for these factors has been compiled from national and international codes, which includes National Building Code[26], IS Code 14243[27], and International Building Code (IBC)[28]. Layers were created corresponding to each of the five critical factors.

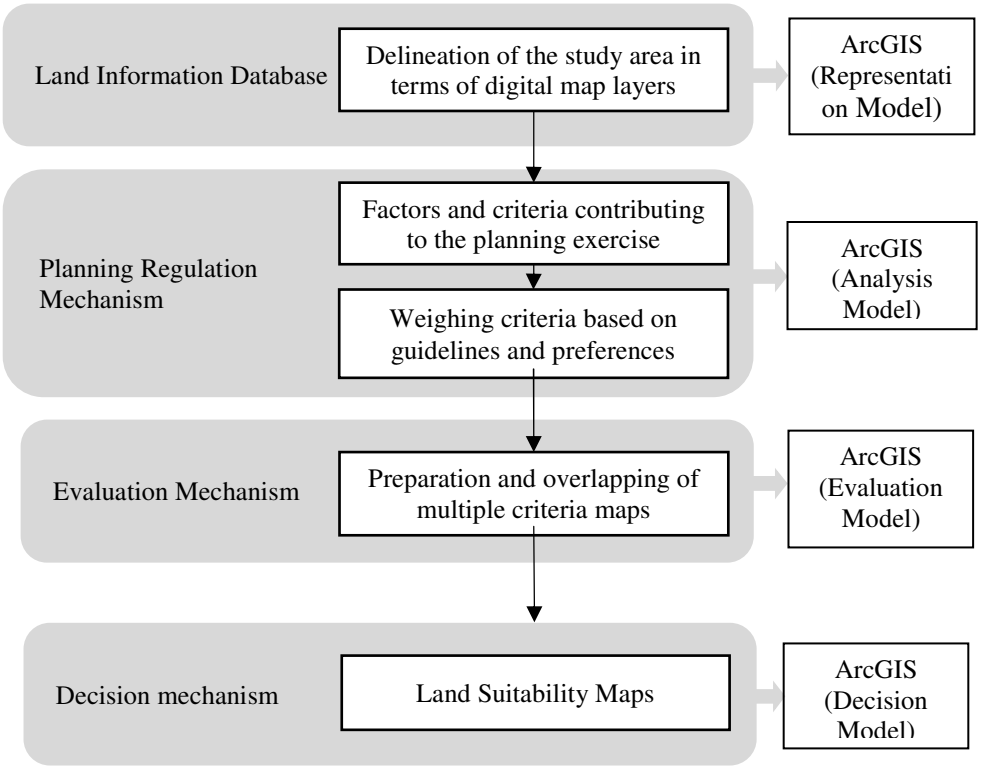

Figure-2: Developed structure of spatial planning at site level in hill areas.

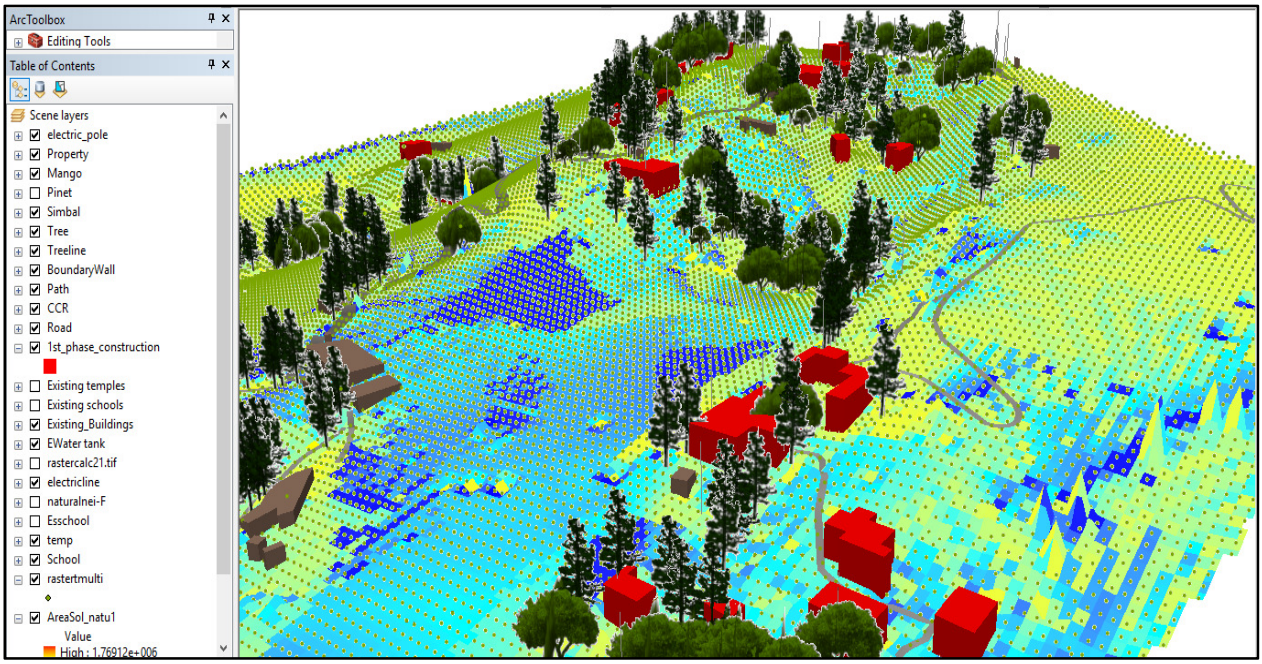

Figure-3: Surface model of the proposed campus.

Evaluation Mechanism: The code provision related to spatial planning in hill areas were modeled in GIS. Vegetation analysis of the site under consideration was done to find out the intensity of vegetation at different locations. Similarly, slope analysis of the site was carried out and on the basis of the variation in slope angle. As per the code provision, natural path of drainage should not be disturbed and the development should be minimum 2 meters away from the natural existing drain on the site. To visualize the natural water flow in the site runoff pattern dataset was derived, so that no construction should take place on the path of natural drains. Aspect analysis was carried out to find out the direction of the slope so that locations falling in the north slopes can be restricted from development. Similarly, hill shade analysis was carried out to find the shaded locations, which were the least suitable for any kind of development.

In addition to this, the buffer was created for each existing feature on the site under consideration, which helps in excluding the areas which are restricted from any type of development. In the present case study, existing features which were buffered include existing village road, water channel, campus boundary, pathway, existing buildings, and state roads. However, the number of input data sets is determined by the type and scope of a project under consideration.

Decision Mechanism: By overlaying different layers, a plan was generated which identify the land parcels which are most suitable for locating various facilities. The restricted areas identified is subtracted from the derived land parcels. The areas which are less in magnitude for any facility development, or which doesn't fulfill the minimum area requirement of the proposed facilities were excluded from the identified suitable locations. This resulted in the identification of location which was most suitable for locating various facilities as shown in Figure-4. The developed GIS-based methodology can facilitate the decision-making process for spatial planning in hill areas.

Limitations

Although the present study is a step towards spatial planning at site level in hill areas, by the quantifiable and rational approach, still it has few limitations. The methodology developed was executed only in one institutional campus located on a hilly terrain. For further improvements in the developed framework, these need to be tested on more institutional campuses located in different locations. Also, its utility for existing campuses can be enhanced by changing the methodology, in terms of critical factors and their code provisions. Although various critical factors have been taken from the codes, 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 is based on the existing literature for giving weight to the identified critical factors. A suitable scale to access the degree of importance assigned to each factor needs to be evolved to draw some definitive conclusions.

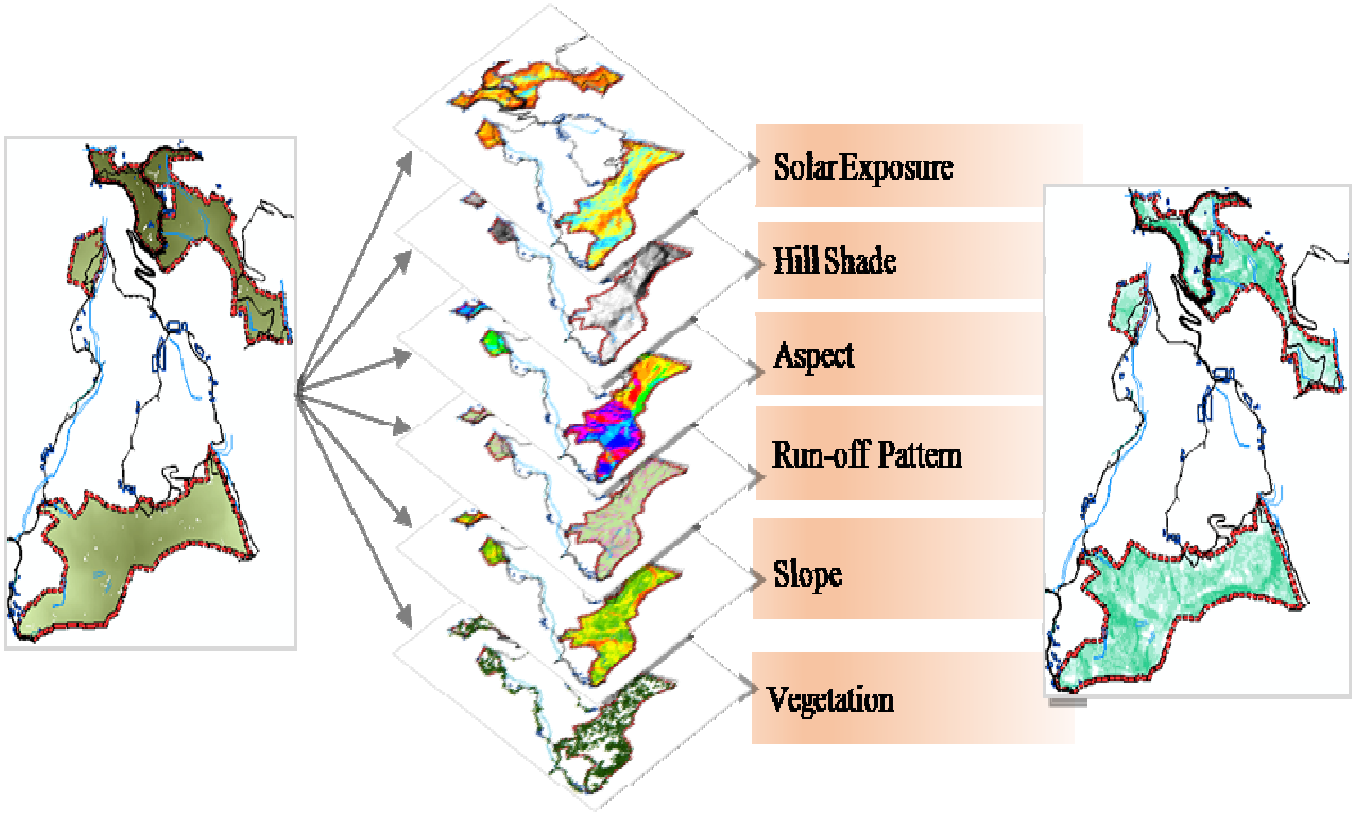

Figure-4: Identification of potential sites for construction from the analysis critical factors.

Conclusion

The present study explores a specific scenario of spatial planning at the site level for hill towns under development and provides the GIS-based methodology to support the same. The major contribution of the developed methodology is for both academicians and practitioners. In academics, it fulfills the requirement by providing a rational measureable approach for spatial planning in hill areas. For planning experts, the developed framework assists in solving the real-world problem in hill areas, which is the absence of a measurable and rational analysis approach for spatial planning. The proposed methodology considers the various critical factors identified through literature to enhance the process of decision making in spatial planning at the site level. The code provisions of the critical factors are considered in the present study, modeled in GIS to understand their effect in selecting a suitable location for various facilities. The identified locations are contextually more responsive, as it causes least disturbance to the natural context of the area under consideration. This makes the decision making the process more rational and effective for providing a contextual response for the spatial planning in hill areas.

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