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Land Suitability Analysis for Vegetation in Central University of Punjab, Ghudda Campus using GIS and Multi-Criteria Decision Making

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Keywords

GIS;
Multi-Criteria Decision Making;
Weighted overlay;
Analytical Hierarchy Process;
Vegetation

Abstract

The sprawling population and rapid urbanization have led to the conversion of arable land into various built-up and development. This unprecedented growth in infrastructural development has put immense pressure on land. The ecological balance is also greatly affected by this uneven pattern of land use. This has created a need to strategically plan land use. This paper presents the site suitability analysis for vegetation in the Central University of Punjab, Ghudda Campus using GIS and multi-criteria decision making. This analysis is based on different land features such as roads, built-up areas, vegetation, fallow land, lawns, playground, tracks, and water canal as criteria. An analytical hierarchy process (AHP), is used to give the criteria the weights based on their relative importance. Weighted overlay analysis is carried out in ArcGIS for the present study. Final suitability maps revealed, three suitability categories in the CUPB Ghudda campus which were: 'very high suitability, high suitability, and moderate suitability'. No site in the entire campus area was found to be unsuitable for vegetation.

1. Introduction

Land, being a finite resource, requires strategic usage planning to balance human activities like industrialization and settlement with environmental goals such as ecological preservation and biodiversity protection (Vivekananda et al., 2021). Unplanned land development can lead to land use conflicts and ecological damage, making meticulous planning essential to sustain ecosystems and human well-being. Human actions fundamentally alter the Earth's surface, leading to changes in land cover that impact natural systems and ecosystem services (Mustaquim and Islam, 2023). Inappropriate land management activities may result in disturbing the ecological balance. Natural and traditional rural landscapes are drastically altered, perished, and replaced by new and extremely active ones (Antrop, 1997). Land-use change is an irrevocable change, which in turn affects other parts of the ecosystem of that particular region as well. The hydrological cycle is

altered by changes in land use, land cover (LULC), and climate, in addition to soil deterioration. This leads to an ecosystem's gradual degradation and lower levels of biodiversity, agriculture, and other land resources (Roy and Inamdar, 2019). Therefore, the need to plan sustainable utilization of this resource becomes mandatory.

The conversion of natural land in rural settings into urban spaces, such as residential complexes, many industrial setups, and universities, may be seen as a result of the growing population and people moving from rural to urban locations. One of the most difficult planning jobs is figuring out the suitable locations for these developmental processes. In order to give users of Geographic Information Systems (GIS) and Remote Sensing (RS) the right tools to address challenging geoanalytical problems, land suitability spatial models have been advanced (El-Nahry and Khashaba, 2005). Site suitability gives information about the quality of the existing site and further helps in the characterization of the site for future activity. Finding the best location for a project, such as a new college, an apartment complex, or a bus station, is typically the responsibility of a group of people or institutions (Mukhopadhaya, 2016).

The process for determining whether a certain piece of land is suitable for a particular use is called suitability analysis. It is becoming more and more important to find suitable sites for new construction or evaluate the viability of land for urban land use planning in order to stop undesirable urban growth and protect the environment around cities. (Parry et al., 2018). With the aid of GIS technologies, spatial data may be subjected to geospatial queries, and the resulting data can be processed to create maps that depict the consequences of all actions:

- The Analytical Hierarchy Process (AHP)
- About Suitability
- About multi-criteria decision making

In AHP, comparisons and a numerical scale must be established in order to demonstrate how much more significant or dominating one element is over another one with regard to the criterion or characteristic being compared. This technique was developed in 1980 by Dr. Thomas Saaty to aid in the resolution of managerial and technical issues (Palcic, 2009). This technique's main strength is its systematic organisation of both physical and intangible factors, which produces a structured yet comparatively simple solutions to decision- making problems. Analytical Hierarchy Process (AHP) along with Geographic Information Systems (GIS) was used in this study to evaluate the suitability of land for vegetation in the study area, using criteria such as roads, lawns, tracks, water canal, buit-up, fallow land, playground and vegetation.

2. Materials and Methods

2.1. Study Area

Central University of Punjab, Bathinda is located in the village Ghudda, district Bathinda. The University campus is lying between the coordinates 38º 08’N Latitude and 74º 47’E Longitude. Figure 1 shows the location of study area on Google Earth portal. The campus is spread over an area of 500 acres. Ghudda village is located on Bathinda-Badal Road. The nearest town from the campus is Mandi Dabwali.

2.2. Data used

1. Google Earth Pro Images
2. Master Plan of CUPB
3. Software used- ArcGIS 10.7
4. Instrument Used- Garmin eTrex GPS

Figure 1: Google Earth image showing the study area

2.3. Data Analysis

In the present study, the main criteria considered for the spatial analysis were roads, lawns, tracks, water canal, built-up, fallow land, playground and vegetation. The master plan of CUPB campus was georeferenced and then was digitized by creating a shapefile using the editor tool in ArcGIS 10.7. In order to generate the thematic layers for different land features, absolute location of the land features was taken using Garmin eTrex20 GPS and polygons were made in Google Earth Pro saved as KML file. The thematic layers for the criteria were developed in ArcGIS 10.7.

The Saaty's AHP (Analytic Hierarchy Process) method (Saaty, 1980) was then used to weight these parameters by establishing a new field in each layer in the ArcGIS 10.7 programme. Each criterion linked to a layer has a rank, which is then stored in a distinct field in the geo-database. Saaty's nine-point weighting system was used to create the pairwise comparison matrix (Table 1). For the development of a ratio matrix, certain criteria are needed. The inputs used, is this pairwise comparison matrix and the results are the relative weights.

Table 1: Saaty's nine-point weighting scale

Definition	Index	Definition	Index
Equally Important	1	Equally important	1/1
Equally or slightly more important	2	Equally or slightly less important	½
Slightly more important	3	Slightly less important	1/3
Slightly to much more important	4	Slightly to way less important	¼
Much more important	5	Way less important	1/5
Much more to far more important	6	Way to far less important	1/6
Far more important	7	Far less important	1/7
Far more important to extremely more important	8	Far less important to extremely less important	1/8
Extremely more important	9	Extremely less important	1/9

3. Results and Discussion

In the present study, the thematic maps were generated for the following criteria - roads, lawn, water canal, built-up, fallow land, playground, vegetation and track, which was overlaid to represent the final overlay map of all these layers (Figure 2).

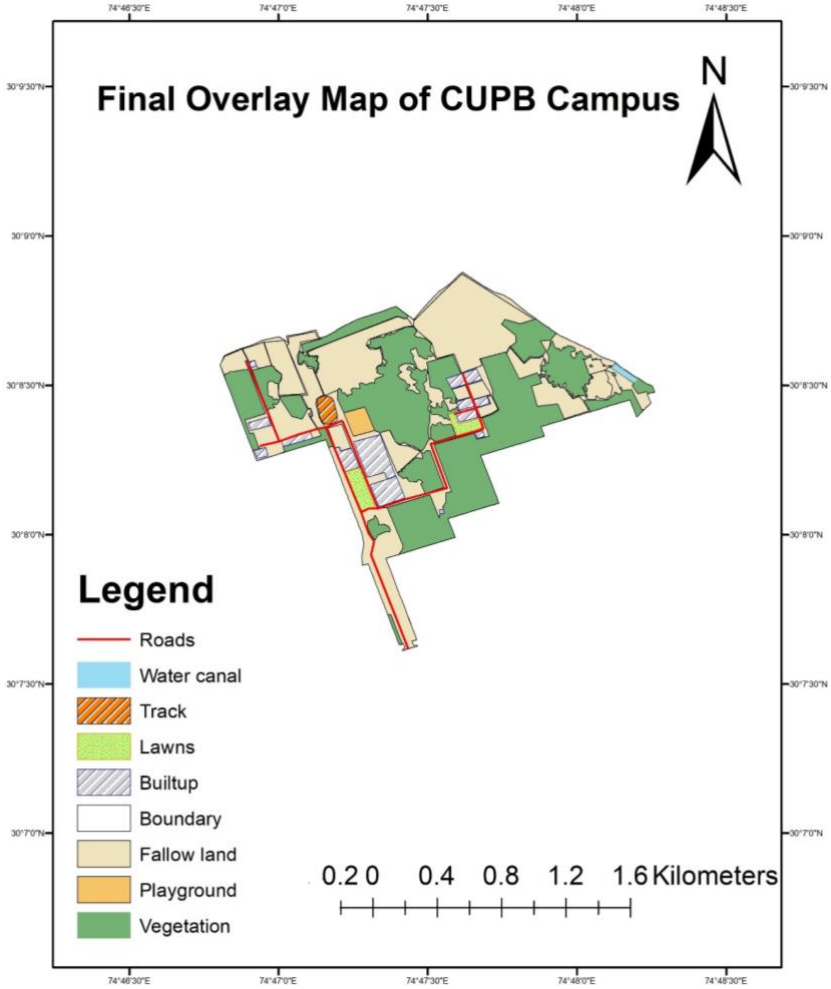

Figure 2: Overlay of all the eight thematic layers to generate Final Overlay Map of CUPB Campus

A pair-wise comparison matrix was made in which every criterion was compared with other criteria, and points were given according to their relative importance. After that Normalization of the matrix was done in order to get the final priority weights. Table 2, 3 and 4 depict calculation of Pair-wise comparison matrix, Normalized weight matrix and Relative weights of eight thematic layers for suitability analysis, respectively.

Table 2: Pairwise comparison matrix of eight thematic layers for land suitability analysis of vegetation

	Roads	**Lawns**	**Tracks**	**Water Canal**	**Built-up**	**Fallow Land**	**Playground**	**Vegetation**
Roads	1	5	8	6	3	1/2	7	8
Lawns	1/5	1	4	3	1/3	1/5	4	6
Tracks	1/8	1/4	1	1/3	1/6	1/8	1/3	2
Water canal	1/6	1/3	3	1	1/4	1/8	2	3
Built-up	1/3	3	6	6	1	1/3	7	8
Fallow land	2	5	8	8	3	1	7	9
Playground	1/7	1/4	3	½	1/7	1/7	1	2
Vegetation	1/9	1/6	1/2	1/8	1/8	1/8	1/2	1

Table 3: Normalized weight matrix of eight thematic layers for vegetation land suitability analysis

	Roads	**Lawns**	**Tracks**	**Water Canal**	**Built-up**	**Fallow Land**	**Playground**	**Vegetation**
Roads	0.24	0.33	0.23	0.24	0.37	0.19	0.24	0.20
Lawns	0.04	0.06	0.11	0.12	0.04	0.07	0.13	0.15
Tracks	0.02	0.01	0.02	0.01	0.02	0.04	0.011	0.05
Water canal	0.03	0.02	0.08	0.04	0.03	0.04	0.06	0.07
Built-up	0.08	0.20	0.17	0.24	0.12	0.13	0.24	0.20
Fallow land	0.49	0.33	0.23	0.32	0.37	0.39	0.24	0.23
Playground	0.03	0.01	0.08	0.02	0.17	0.05	0.03	0.05
Vegetation	0.02	0.01	0.01	0.004	0.01	0.04	0.017	0.02

Table 4: Relative weights of criteria for land suitability analysis of vegetation

S. No	**Criteria**	**Weights**
1	Roads	25
2	Lawns	10
3	Track	2
4	Water Canal	4
5	Built Up	19
6	Fallow Land	35
7	Playground	3
8	Vegetation	2

The final suitability analysis was done using the weighted overlay tool in ArcGIS 10.7. Based on the above parameters, the final suitability map has been shown in Figure3. The final land suitability map revealed that the study area is divided into three different categories – “very high suitability, high suitability and moderate suitability”.

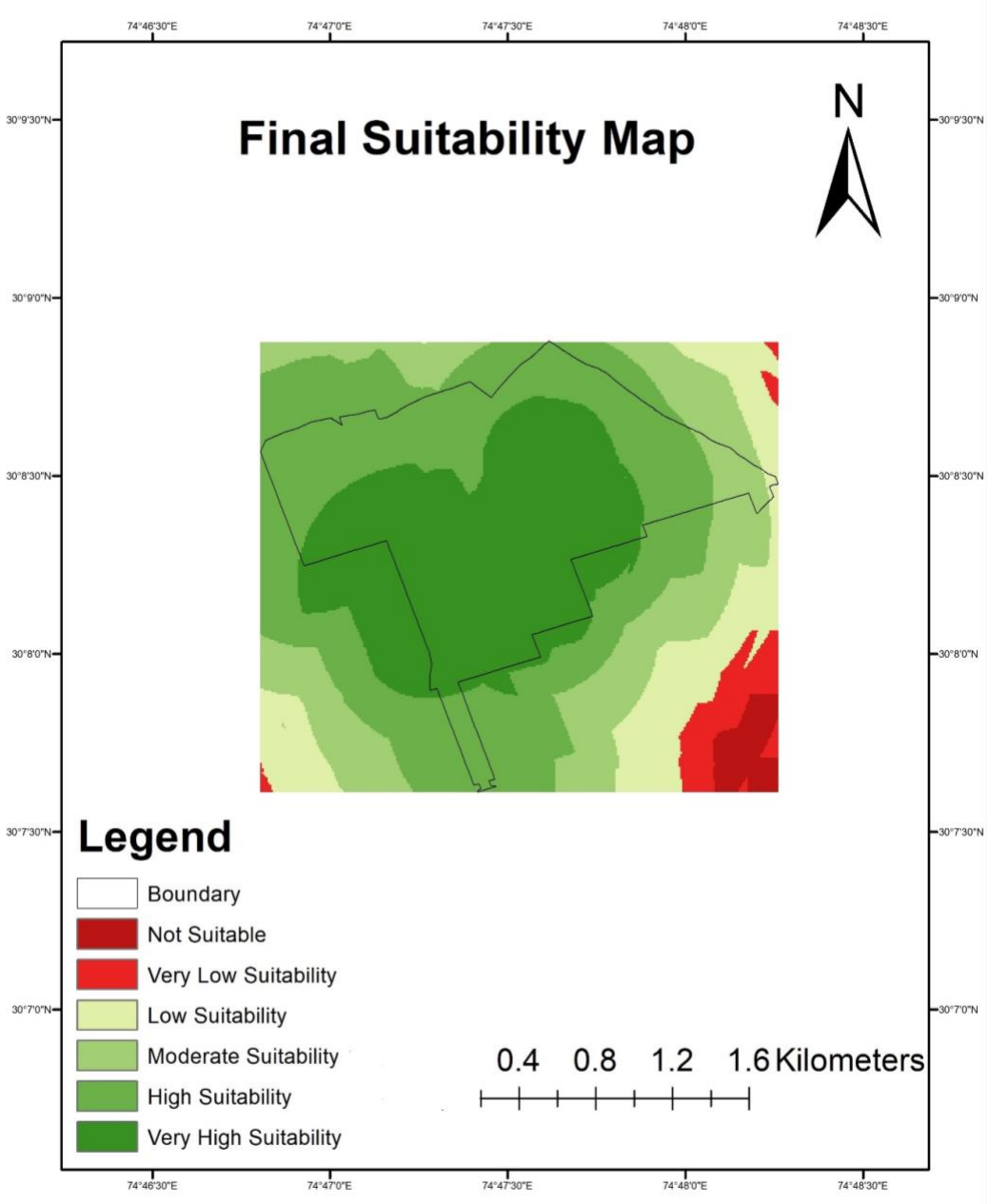

Figure 3: Land suitability map for vegetation in CUPB campus

According to the suitability analysis, the campus as a whole is suitable for the vegetation. No sites with low suitability, very low suitability, or not suitable were discovered after weighted overlay analysis. This might be the result of fallow land being the most widespread land feature assigned the highest relative value. The majority of the land area was covered by other criteria, such as built-up areas, roads, and lawns, which likewise ranked higher in terms of relative importance. There was significantly less space on campus covered by criteria that were less important, such the water canal, playground, track, and vegetation. Therefore, after the suitability analysis, no sites were found that were of low suitability, very low suitability or not suitable at all. In the campus's core, which is primarily of built-up areas, roads, fallow land, and lawns, were spots with very high suitability.

The present study's findings concur with those of Ayehu and Besufkad (2015), who found that suitability levels varied widely, with the vast majority (up to 97%) of the study region being suitable for rice production. Further, in line with research by Yalew et al. (2016) conducted in Ethiopia, where the Tana catchment (North) was deemed to be "highly suitable," no areas were identified in the present study as "low suitability" or "not suitable." The proportion of "moderately suitable" areas that were covered varied significantly by watershed and ranged from 70% in the Dinder catchment (North-West) to barely 24% in the Tana catchment. No site was determined to be "not suitable" in the study region. Mukhopadhaya (2016) conducted GIS site suitability analysis in Dehradun for setting a professional college and found 13 suitable sites for the construction of a professional college, with an area ranging from 100000 to 500000 square meters, according to the final suitability map. Tiwari et al. (2019) investigated the land suitability analysis in Bhopal, India for Groundwater potential zone (GWPZ) using AHP. This analysis helped to find important areas with adequate water supply for real-estate development in Bhopal.

4. Conclusions

The GIS technique has been proved to be more flexible and holds greater accuracy for handling spatial data. In the present study, the AHP approach was combined with GIS and it was found to be a powerful combination to apply in site suitability analysis. All of the criteria were given a weight based on Saaty's nine-point scale, with 1 being the least important and 9 being the most important. The study found that no site on the campus was unfit (not suited for vegetation) after doing the weighted overlay analysis for land suitability, which indicated three suitability classes: Very High Suitability, High Suitability, and Moderate Suitability. The study will assist planners and administrators in Central University of Punjab, Ghudda in making well-informed sustainable decisions that will further aid in proper land resource utilisation. The study's importance can be recognised from the fact that it will provide future planners in the study area with baseline data. As regards future recommendations in the study area, it is suggested that "Green roofs" may be created using the terraces of the buildings, various plantations can be done on the terrace. Heat waves in the summer are one of the biggest issues in the Bathinda district because of its semi-arid environment. As a result, the roofs of the structures may be painted with colours that are reflective in nature, such as white. This will help in regulating ambient temperature in the University campus.

Author's Contribution: The author Manisha Kumari (MK) was involved in design of the research problem, the compilation of data, analysis and its interpretation, and drafting the research article. The author Puneeta Pandey (PP) was involved in conceptualization of the study, revising it critically and approving the final version.
Author's Agreement: All the authors have seen and approved the final version of the manuscript being submitted. Further, we warrant that the article is the authors' original work, hasn't received prior publication and isn't under consideration for publication elsewhere.
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