SITE SUITABILITY ANALYSIS FOR FUTURE URBAN DEVELOPMENT USING ANALYTIC HIERARCHY PROCESS (AHP) MODEL: A CASE STUDY IN HISAR CITY, HARYANA (INDIA)

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ABSTRACT

This study focuses on site suitability analysis for urban development in Hisar City, India, using the analytical hierarchy process (AHP) model. It aims to identify the most suitable sites for future urban development based on various criteria, such as land use/land cover parameters, proximity to road networks, soil salinity, and the depth and quality of ground water. The LISS-IV satellite image from October 17, 2022, was used to create a land use/land cover map for future urban development in Hisar City and its fringe area. A total of 50 samples (25 from water and 25 from soil) were collected within Municipal Corparation (MC) boundary and fringe area of the Hisar City. These samples were tested in a laboratory located at the CCS Haryana Agricultural University (HAU) in Hisar, India. The study emphasizes the importance of using a data-driven approach for urban development planning and highlights the AHP model as a valuable tool for analyzing site suitability. It identifies different categories of land based on their potential for future development in which 773.53 hectares (1.35 %) of land is found highly suitable, 13818.94 hectares (24.07 %) is moderately suitable, and 38274.74 hectares (66.68 %) is low suitable. Additionally, 4377.78 hectares (7.63 %) of land is not suitable, and 159.01 hectares (0.28 %) remain unclassified. The study suggests that by using such tools, urban planners and administrators can create more sustainable and fair urban environments that meet local population needs while reducing negative impacts.

Keywords: Analytic hierarchy process, urban growth, land suitability and urban planning.

INTRODUCTION

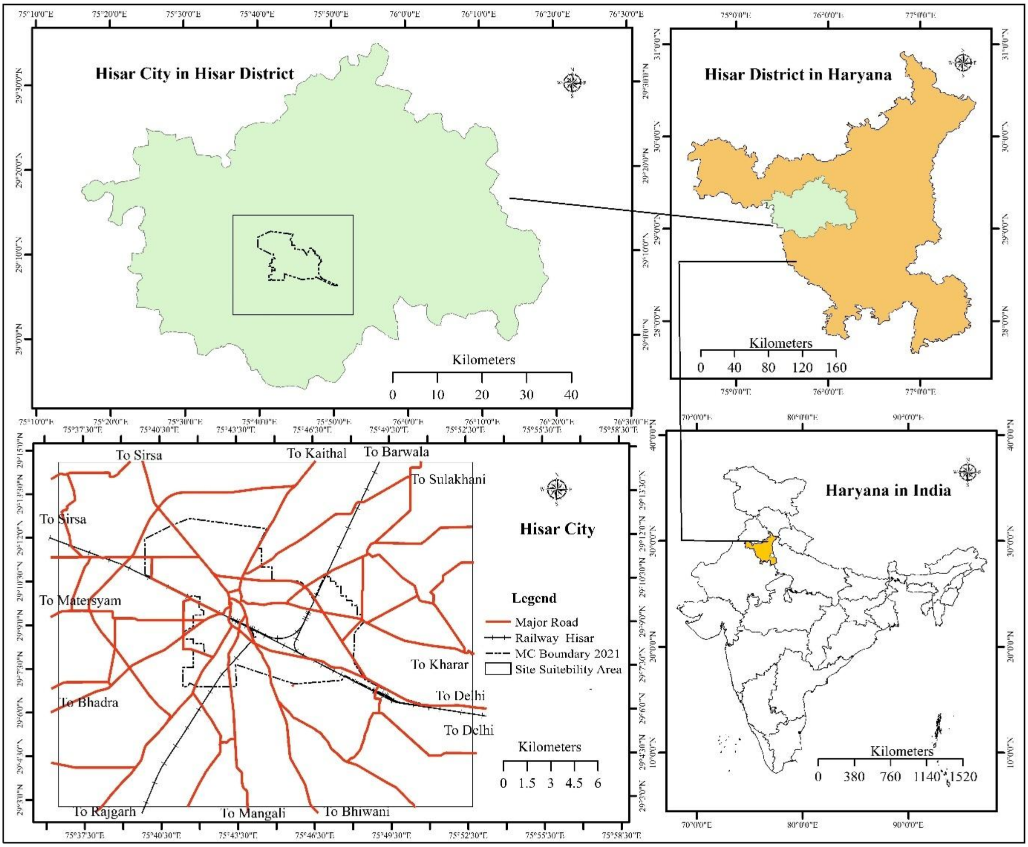
The human instinct of striving for more has always remained the key reason for the development of civilization from the early to modern periods. This tendency has no prospects of ending in the future, although the need for future well-being in terms of employment, education, health care, security, and lifestyle will be further fueled by the development of human society. The origin of urban centers, as the conversion of rural areas, is an example of such a pursuit. Continuous growth in population size, adaptation of diversified economic activities (other than agriculture), and growing immigrants are the root causes of urbanization. Urbanization is a dynamic phenomenon that continues to shift to the next higher order over time, along with the development of some apprehensions (Sharma *et al*., 2024). It has now become a universal phenomenon, and agricultural societies are being converted into industrial one. This has resulted in the origin of new urban areas across the world and the growth of existing ones. This rapid growth in urban centers, especially in developing nations, are causing various adjustments in their natural and artificial aspects (Yeh, 1999). Therefore, the observation and regulation of urban progression in systematic and empirical ways is the most urgent need of hour. In the absence of efficient monitoring and relevant management, the uncontrolled and expeditious upsurge in population creates many difficulties for the administration in providing safe shelter and food to millions of deprived and migrants in urban areas. It also creates several hurdles for planners to execute development plans, care for the environment, and manage slums, squatters, and illegal occupancies in cities and metropolises (Sharma & Kumar, 2022). It is necessary to obtain real-time and precise statistics of ongoing changes in urban areas for better urban planning and implementation. In such cases, a suitability analysis by assigning weights to different indicators is the best and most effective approach for identifying suitable sites for future urban growth (Javadian *et al*., 2011; Alexander *et al*., 2012). Such evaluations suggest appropriate locations for development by mapping the suitability index in a particular area (Joerin *et al*., 2001).

Site suitability analysis is a key determinant of urban planning and is extensively approached by urban organizers to facilitate smart growth. It has a multi-order analytical practice that deals with an assortment of standards related to social, economic, and ecological arenas in the arithmetic procedure. It also advocates the land suitability model (GIS-based) amalgamation for site selection (Mendoza, 2000; Malczewski, 2004), which makes the analysis easy and enhances the accuracy of the assessment (Alfanatseh, 2022). Such model-based spatial analysis, attached to geo-informatics, assists the decision system of the urban landscape in selecting optimal locations to manage the development (Yeh & Chow, 1996). The phenomena ranked in the land suitability analysis belong to social, economic, and ecological arenas, and rankings are assigned according to the particularity and preference of that particular aspect (McHarg, 1981; Collins *et al*., 2001; Malczewski, 2004). Moreover, the information and data collected by conventional methods, professionals' knowledge, priorities of determinants, and other scientific methods are coupled with such spatial analysis. Urban geographers and planners have developed several methods and approaches to solve or manage the adversities of rapid urbanization. The analytical hierarchy process (AHP) is a cost-effective and high-potential multi-criterion decision-based analysis (MCDA) that supports planners in choosing ideal land for urban growth and escorts (Youssef *et al*., 2011; AlFanatseh, 2022; Kumar & Jain, 2017). In addition to manage urban space directly, the examples, maps, or results of AHP are referred to for ranking and demarcation of sites according to their weightage for different facilities (Chandio et al., 2013), such as dumping of waste material (Santhosh *et al*., 2018), manufacturing units, recreational settings or parks, agricultural land use, etc. The simple calculations and structured procedure of suitability analysis make land selection easy and efficient (Ullah & Mansourian, 2016), especially for research in social sciences, where researchers are not involved or interested in complex mathematics (Kumar *et al*., 2017). Moreover, satellite data and GIS technology make it holistically important to process vast geographical data while searching for suitable land for urban development. This study proposes a fundamental integrated approach that uses geospatial technology and an analytical hierarchy process to address the urgent issue of urbanization. The approach is applied to Hisar City, a specific area of interest and growing urban center, and focuses on five criteria related to the natural and artificial situations of the city. This study aims to identify suitable sites for future urban growth in Hisar City to strengthen the decision-making power of administration and investment in the urban landscape.

STUDY AREA

Hisar City is one of the largest cities located in west of the Haryana State in northern India. However, the city is basically characterized as educational and residential city owing to various national and state levels research and learning institutions and an amiable environment for settling one-to-one, though the presence of steel manufacturing units' aids in its industrial identity and tags as 'steel city.' The city is located between the north latitudes of 29°06'54" and 29°12'45" and the east longitudes of 75°39'24" and 75°51'37" (Fig. 1). Its closeness to the desert state of Rajasthan has a significant impact on its weather and climate, resulting in semi-arid and arid conditions.

Fig. 1: Location Map of Study Area



Source: Municipal Corporation Office, Hisar, 2021

Reconnecting history, the city has existed since the Tughlaqs dynasty and was established by *Firoze Sah Tughlak* (1354-1356 AD) with its original name '*Hisar-a-Firoza*,' which means fort of King *Firoze*. In the past, the city was guarded by four gates, *Mori, Talaqi, Delhi*, and *Nagori*, in four directions: east, west, north, and south respectively. Their remnants are still visible and glorify the historical and strategic importance of the city. Currently, serving as the headquarters of Hisar District, the city is recognized as a first-rate infrastructure in terms of transport, communication, trade and commerce, knowledge, medical, and research centers that enhance its distinctiveness in the surrounding areas.

DATA SOURCES AND METHODOLOGY

This research mainly uses primary data, with the inclusion of some secondary data. For the primary data, groundwater and soil samples were collected from different sites in the city and its nearby areas in June 2022. A stratified random sampling method was used to ensure accurate and reliable results. The city's different wards, marked by the municipal corporation for good administrative functioning, were treated as separate groups (strata), and smaller or neighbouring wards were combined into single groups. Some samples have been selected from the periphery also. All the sites, selected as samples are based on their respective importance to the city. A total of 50 samples; 25 water and 25 soil were collected from both, the city and its surroundings. These samples were tested in a laboratory at CCS Haryana Agricultural University (HAU) in Hisar. Additionally, a LISS-IV satellite image on October 17, 2022, was used to create a land use/land cover (LULC) map to identify potential sites for future urban development in the study area. The tasks of image processing, classification, and map-making were designed using ERDAS and ArcGIS software.

Table 1: Classification of Land Use/Land Cover (LU/LC) Classes

Sr. No.	Class Name	Descriptions
1	Built-up Area	Uses for the residential areas, surrounding rural regions, commerce, manufacturing, services, and the construction of transportation infrastructure (such as roads and railways) or any other urban characteristics.
2	Agriculture Land	It encompasses the region selected for the cultivation of food products and certain facilities associated with this process.
3	Bare/open Land	Exposed soil, waste disposal or garbage sites, ongoing mining locations, vacant land in urban regions.
4	Vegetation	The green space consists of trees and shrubs, along with isolated trees found in parks, woodlands, and various other green zones.
5	Parks	The outdoor public sites with recreation, relaxation or enjoying nature, often green space, walkways and other facilities are considered as parks.
6	Water Bodies	Channels, bodies of water, open drainage systems, artificial ponds, storage tanks, etc.

The study also used secondary data and other information obtained from the municipal office, Hisar City and Central Ground Water Board (2020-21). To conduct suitability analysis, it is essential to have appropriate foundational data. Various land qualities that can be considered for suitability modeling include the current land use/land cover, slope, proximity to transportation networks, flood risk, and groundwater conditions (Sunil, 1998). The attributes of a location (such as existing land use, accessibility of roads, availability of water, and other factors) affect its potential for further urban development. A scoring and weightage system was used to evaluate overall suitability by considering the different factors involved. Suitable sites are identified by aggregating all layers that influence site suitability (Jain & Subbaiah, 2007). The complete procedure for the related methodology is presented in Fig. 2. The authors here have used the analytical hierarchy process (AHP) method that Saaty (1980) proposed. It is an eminent practice to specify suitable weight by cross-comparing all factors against each other with a standardized preference. The model primarily works on expert acquaintances and preference values. It determines the land suitability by assigning relative importance to the selected parameters as land use/land cover, proximity to major transport routes, proximity to built-up areas, soil salinity, and depth with ground water quality. The model follows the following steps:

i) Construction of AHP Hierarchy

The first step, called evaluation criteria, involves constructing a hierarchy to decompose the complex decision procedure into a simpler conclusion (Erkut & Moran, 1991). In this part, the goal is placed at the top, and the selected relevant indices are arranged at different levels to achieve the most suitable sites for the proposed objective (Keeney & Raiffa, 1976). The six criteria concerning the natural and artificial situations of the study area are selected to find the appropriate sites**.**

ii) Ranking of the Indices

In the second step, after standardizing the indices, a ranking was made according to the study’s preference, experts' opinions, and the existing literature (Fig. 2). Four classes ranging from 1 to 4 were allocated to each layer, where the values 1, 2, 3, and 4 refer to very low, low, medium, and high suitability of sites, respectively (Hazarika & Saika, 2020).

iii) Pairwise Comparison

In pairwise comparison, the selected indices are compared to determine the intensity and importance of one factor over another and the generation of a ratio matrix. For pairwise comparisons, the study used Satty's proposed 9-point weight scale (Table 2). The numerical values are represented on a scale ranging from 1 to 9 in the pairwise matrix, where the lowest value (1) represents the 'equal importance' with low suitability, whereas the highest value (9) expresses the ‘extreme importance of an aspect with the highest suitability (Saaty & Vargas, 1991; Marinoni, 2004).

Fig. 2: **Methodological Flowchart for Site Suitability**

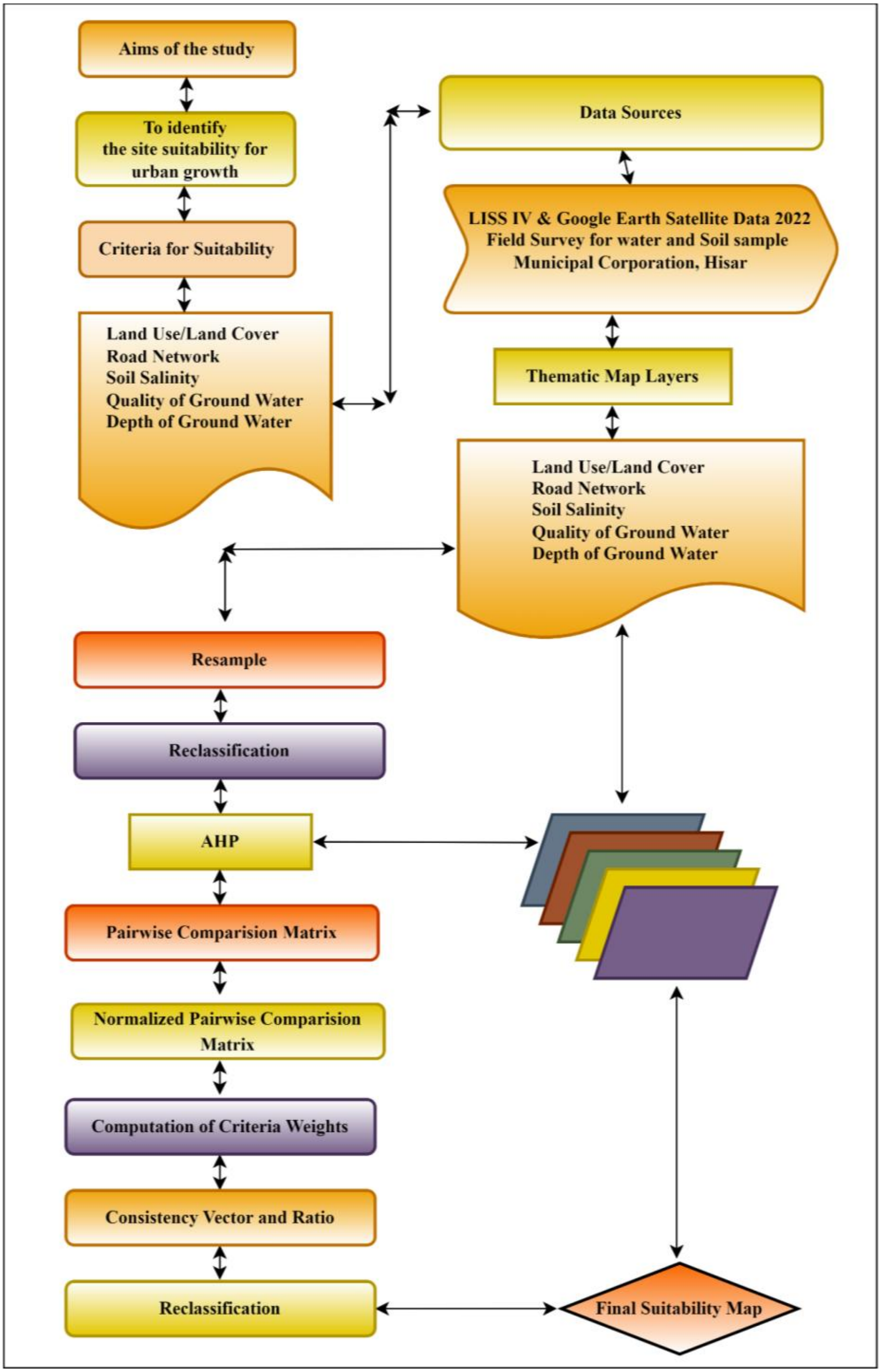


Table 2: 9-Point Scale of AHP for Paired Comparisons

Intensity of Importance	Descriptions/Explanation	Suitability classes
1	Equal importance	Low suitability
2	Equal to Moderate importance	Very Low Suitability
3	Moderate Importance	Low suitability
4	Moderate to Strong Importance	Moderately Low Suitability
5	Strong importance	Moderately suitability
6	Strong to very strong importance	Moderate high suitability
7	Very strong importance	High suitability
8	Very to extremely strong importance	Very high suitability
9	Extremely importance	Highest suitability

Source**:** Saaty, 1980.

The pairwise comparison provides the procedure to check the consistency in terms of consistency ratio (CR) with the help of the following steps:

a) For the calculation of the weights, the values are summed in each column of the matrix. For example, the first element periods to the first column, the second element times to the second column, and so on.

b) Then, the consistency vector is derived by dividing the weighted sum vector by the element weights pre-decided earlier.

c) After calculating the consistency vector, the analysis is further required to compute the values for two more expressions, i.e., lambda (λ) and the consistency index (CI). The average value of the consistency vector is called the lambda value, whereas the consistency index is based on the interpretation. In the case of a consistent matrix in pairwise comparison, 1 is always equal to or greater than the number of criteria under consideration (n) for positive, mutual matrices, and λ = n. Consequently, the value for λ-n refers to the degree of inconsistency. It can be standardized as follows:

$$CI = (\lambda - n) / (n-1)$$

d) If the consistency index fails to reach the threshold level, the comparison responses are re-examined. The term consistency index gives an estimation of departure from reliability. To establish the goodness of the consistency index, the analytic hierarchy process compares it by random index (R.I.), and its outcome is called consistency ratio (C.R.), which can be described as:

$$\text{Consistency Ratio (CR)} = \text{CI} / \text{RI}$$

e) A random index is the randomly generated consistency index during the pairwise comparison matrix of values 1-10 found by approximating random indices. It determines the intensity and importance of various factors (Saaty, 2000). These values of RI are sorted by order of the matrix (Table 3). The CR value should be less than 0.1, which refers to reasonable and acceptable consistency, whereas equal and more than 0.10 CR refers to inadequate consistency in pairwise comparison (Ying *et al.*, 2007; Park *et al.*, 2011). The table shows the random consistency indices (RI) for different order matrices. The order matrices are numbered from 1 to 10. The corresponding RI values are listed in the row below each order matrix. The RI values are used in the Analytic Hierarchy Process (AHP) to check the consistency of pairwise comparisons made by the decision-maker. The RI values indicate how much inconsistency can be tolerated in the pairwise comparisons before the decision-maker's judgments become unreliable. The first three order matrices (1, 2, and 3) have an RI value of 0 or 0.58, indicating that there is no tolerance for inconsistency in these matrices. The next two matrices (4 and 5) have an RI value of 0.90 and 1.12, respectively, indicating that some tolerance for inconsistency is allowed in these matrices. The second row of matrices (6 to 10) has higher RI values, ranging from 1.24 to 1.49, indicating that more tolerance for inconsistency is allowed in these matrices. The highest RI value of 1.49 corresponds to the last matrix (matrix 10). Overall, the table provides a reference for decision-makers to determine the acceptable level of inconsistency in their pairwise comparisons based on the order matrix they use in the AHP process.

Table 3: Random Consistency Indices

Order Matrix	1	2	3	4	5
R.I.	0	0	0.58	0.90	1.12
Order Matrix	6	7	8	9	10
R.I.	1.24	1.32	1.41	1.45	1.49

Source: Saaty, 1980.

iv) Normalized Pairwise Comparison Matrix

After that, the mean of the elements in every row of the normalized pairwise matrix is calculated by dividing the sum of the normalized score for each row by the criteria's number (Hazarika & Saika, 2020). After that, the computation of criteria weights is done.

v) Final Suitability Mapping

Finally, all maps of selected elements are integrated and overlapped to prepare the final suitability map in GIS software.

$$\text{Suitability Map} = \sum[\text{Criteria Map} \times \text{Weight}]$$

After that, the final suitability map is reclassified into different required suitability intensities classes, and locations are proposed for further uses.

RESULTS AND DISCUSSION

Results

The analytical hierarchy process (AHP) is a multi-criteria decision-based analysis that generates the final output based on a pair-wise comparison of parameters. From identifying parameters, establishing hierarchical associations according to their relative importance, assigning weights, and preparing the suitability maps, AHP deals with quantitative and qualitative information about that area. The land features taken into account in determining the appropriate site relate to contemporary land utilization, water and soil qualities, and the infrastructural development of the region. When looking for suitable land, the local conditions that affect its limitations or benefits (like how vulnerable it is to natural disasters, how easy it is to get to basic amenities, how the land is currently being used, the runoff and underground status of water resources, the type of soil, etc.) play a significant role (Jain & Subbaiah, 2007). However, it does not distract the decision significantly because the suitability modeling deals with a combination or overall weightage of chosen land qualities, a multi-layered evaluation for terminal output, and the declaration of the suitable site.

The following five parameters have been selected for the suitability analysis of Hisar City: land use and land cover, ground water quality, ground water depth, soil salinity, and road proximity. The grounds behind the selection of aspects and their importance have been described as follows:

i) Land Use/Land Cover (LU/LC)

The running land operations and area coverage by natural singularities provide an overall prototype of the region, which can be divided into categories based on different uses. This broad segregation helps planners or administration find suitable locations that can absorb potential development without or with minimum damage to a segment of land's ecological assets. In the present case study, there are six major land use/land cover classes: built-up area, agricultural land, vegetation, open/bare land, and water bodies.

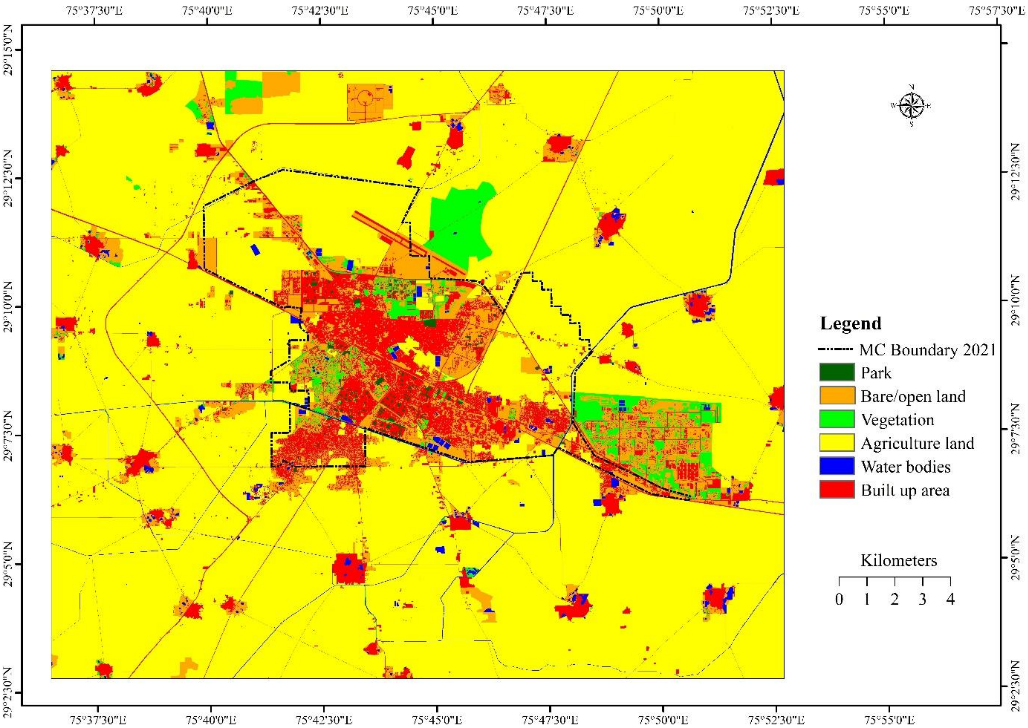
Table 4: Land Use/Land Cover (LU/LC) of Hisar City and its Periphery (2022)

Sr. No.	LU/LC	Area (in hectares)	Area (in per cent)
1	Built-up Area	4841.23	8.43
2	Agricultural Land	45377.90	79.05
3	Barren/open Land	4920.32	8.57
4	Vegetation	1536.87	2.68
5	Parks	124.22	0.22
6	Waterbodies	616.40	1.07
	Total	57404	100

Source**:** Based on LISS-IV, 2022

In general, an area already having structures, green cover, and waterbodies, mainly within municipal boundaries, has little scope for additional developmental activities. The fertile agricultural area within or outside the city limits is also exempted from urban uses. So, the open space, bare land, and less suitable land farming in the city's periphery are considered appropriate sites for future advancement plans. However, it never means that a city can expand in all directions equally or as per wish. Certain limitations in each particular area instruct the kind of urban uses and determine its extent also. Table 4 presents details of existing LU/LC in Hisar City and its periphery.

Fig. 3: Land Use/land Cover of Hisar City and its Periphery

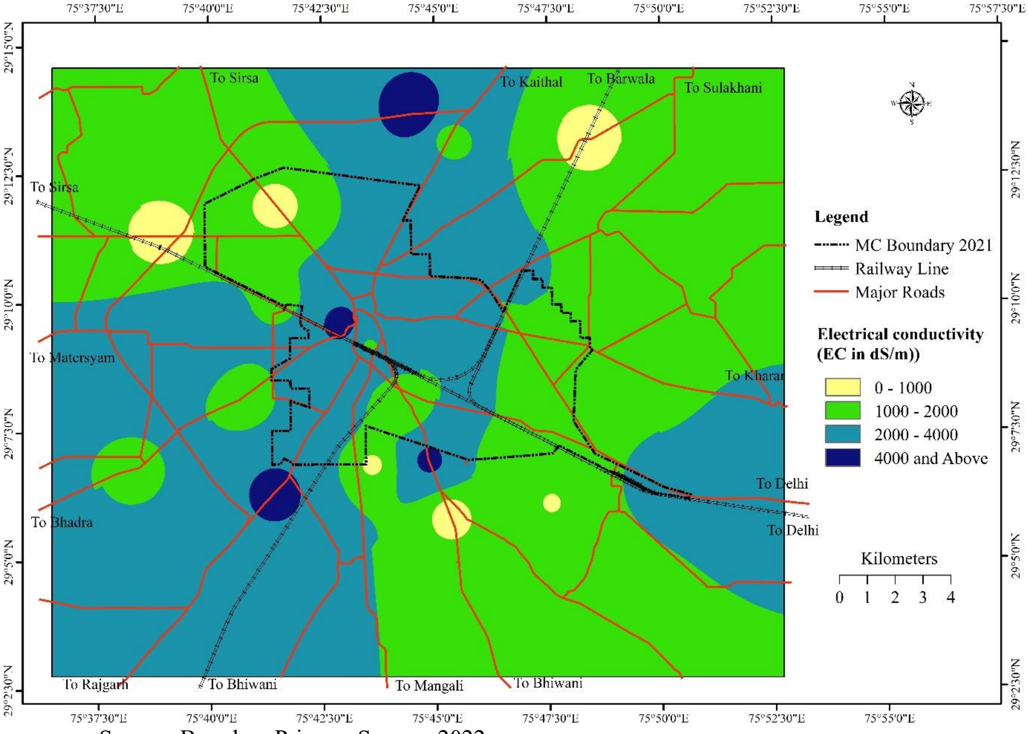


Source: LISS-IV, 2022

ii) Ground Water Quality

Ground water is a vital aspect and a key resource for urban life and development that needs to be considered while selecting an appropriate location (Jain & Subbaiah, 2007). When discussing the first aspect, it should be remembered that various actions and reactions throughout the water cycle from formation or condensation in the atmosphere to discharge through hand pumps, wells, tube wells, or any other water body over the terrain determine the water quality. Here, the compulsory presence of salt content, i.e., water salinity, is a primary determinant of water quality. However, its proportion varies according to place, mainly depending on the nature of the surface. Technically, the salinity is described as grams of salt per 1000 grams (g/1kg) of water or in parts per thousand (0/00) and measured through different methods like density, light refraction, electricity conduction, satellite information, etc. In the present case, electrical conductivity (EC) is taken as a water quality parameter and measured in micro-siemens per centimeter (uS/cm). Water samples have been collected and then tested in the laboratory. The presented Fig. 4 is based on those outcomes. The EC (uS/cm) has been categorized into four categories, viz. 0-1000, 1000-2000, 2000-4000, and above 4000 refer to fresh, marginal (less saline), saline (moderate saline), and highly saline ground water, respectively. The lower values significantly stand for good ground water quality that is recommended to be reserved for agricultural purposes.

Fig. 4: Ground Water Quality of Hisar City and Its Periphery



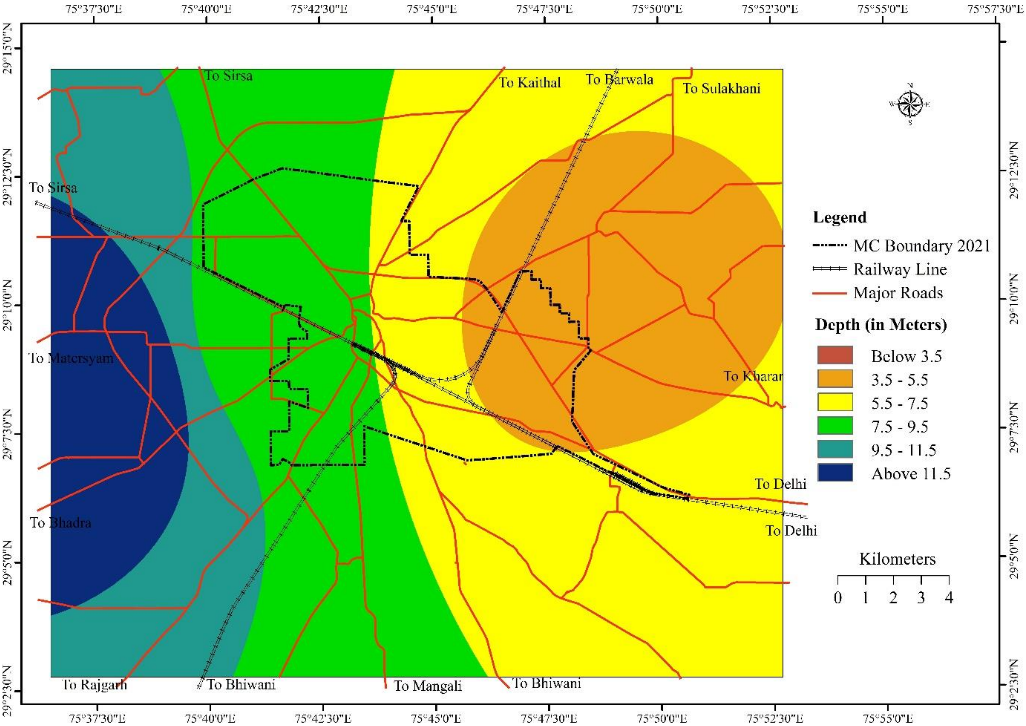
Source: Based on Primary Survey, 2022

Whereas the high values of EC correspond to poor water quality, the concerned areas can be advised as suitable sites for future development in the city. However, the domestic or drinking water supply should be managed by the authorities on a primary basis in such cases. Figure 4 depicts that except for some small patches of fresh water (less EC) in the northeast, south, and northwest, the entire area mainly has two kinds of water: marginal and saline. There is little presence of high saline water in the easternmost part. The vast belt of marginal water exists in the northeast to southeast parts, including the minor area in the north-western corner, followed by the moderate saline water strap from the center part to the west, south, and southwest.

iii) Ground Water Depth

Ground water depth, or the water table, is where water naturally occurs. It is also a key determinant of the development in any region. It is stored almost everywhere in specific but varying depths beneath the surface in unsaturated or saturated zones. Like quality, depth is also an integrated outcome, mainly of climate type. In cold or wet climate regions, the water exists in less depth and vice-versa. As semi-arid climatic conditions characterize the study area, the water is available in more depth comparatively.

Fig. 5: Ground Water Depths of Hisar City and Its Periphery



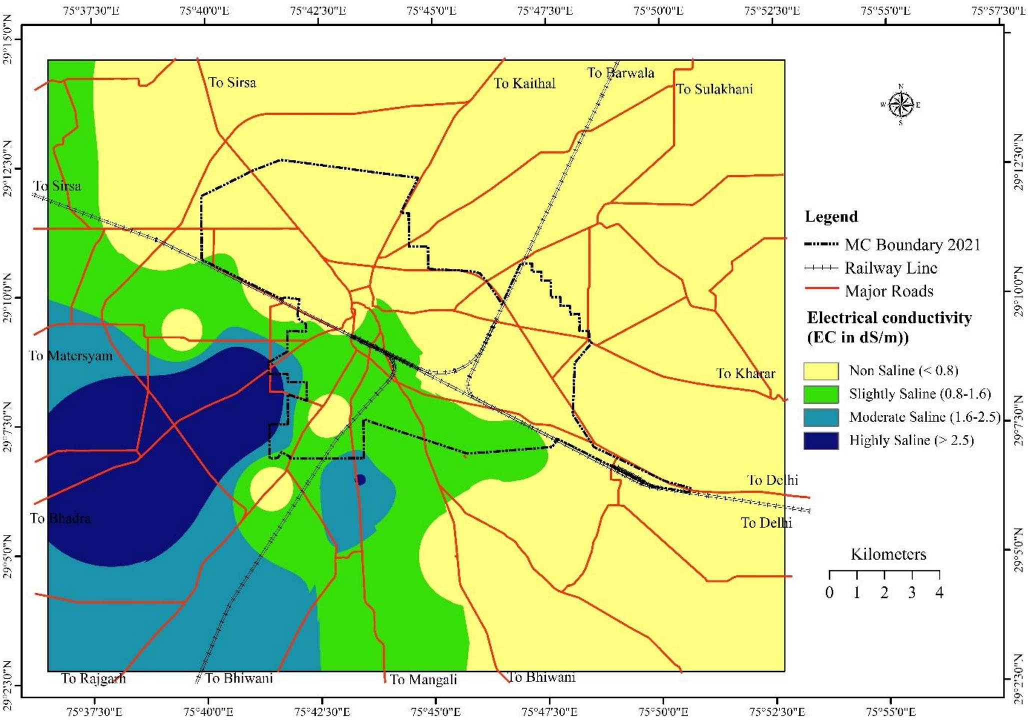
Source: CGWB, 2020-2021

However, less and higher-depth ground water have different important issues, yet the development perspective is advised for high-water depth areas as the most suitable sites for construction. The presence of water just under the surface or in less depth is vulnerable to damage to developed structures. In this situation, the hydrostatic pressure (created by standing or resting water) forces the water to seep through imperfections or small cracks. Fig. 5 shows the different ground water depths in the study area. A vertical line running from north to south divides the city into two parts. The eastern part has a groundwater depth of 3.5 to 7.5 meters, while the western part has a depth of 7.5 to more than 11.5 meters. In the northern and northeastern outskirts, the depth is around 7.5 meters. The western fringe area, which is influenced by semi-desert conditions, has deeper groundwater, often reaching more than 11.5 meters.

Soil Salinity

Soil has remained the primary source of meeting the direct and indirect demands of almost all creatures, and human beings are one of them. Directly, soil satisfies the hunger of the growing population through its food production ability. As food is one of the most basic requirements of humans so, the acquisition of fertile agricultural land for any development is strictly prohibited by all intellectuals and planners. Most preferably, an area with unfertile or barren properties or unsuitable for agriculture is recommended for urban growth. Hisar City has desertic and semi-desertic soil characteristics that are less fertile for crop production and have varying strengths to support construction or other uses. So, choosing the soil as a suitable parameter becomes more necessary for identifying the site for further development. In analysis, the less suitable or fertile soil for farming has been ranked high because this site will be most suitable for adjusting the urban growth. Open space can also be referred to as a suitable site for growth. Electric conductivity (EC) of soil is a measure to determine soil quality or fertility status within a region. The dissolved amount of salt in the soil decides the ability of soil moisture to carry the electrical current. It indirectly affects the plant's health by minimizing the nutrients owing to the inability to hold water even after being present. Soil having high EC properties refers to a high presence of sodium that is not a suitable or poor supporter of crops and is suitable for urban expansion. However, towering or multi-story buildings are avoided in such less fertile pieces of land because salt mobilizes the water and declines the structure's durability. Such sites should be recommended for general urban uses, especially in horizontal form.

Fig. 6: Soil Salinity of Hisar City and Its Periphery



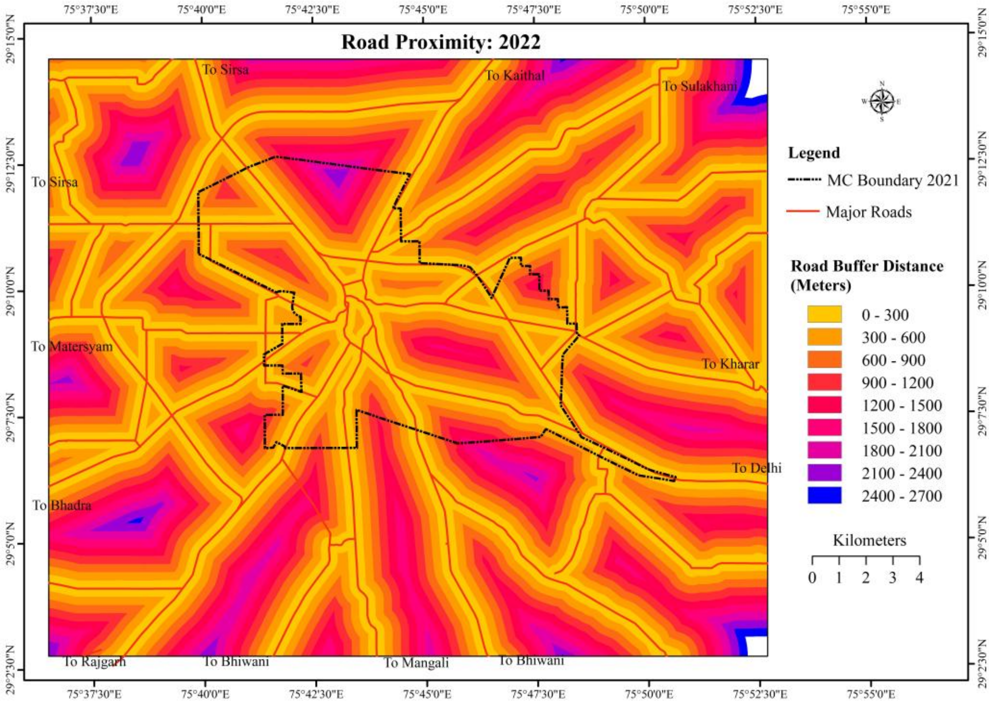
Source: Based on Primary Survey, 2022

Figure 6 states to soil salinity (derived from EC) in Hisar City and its periphery. It has been divided into four categories, i.e., non-saline (<0.8), slightly saline (0.8-1.6), moderate saline (1.6-2.5), and highly saline (>2.5). The region has a clear distinction between highly saline and non-saline, and salinity increases from east to west. The city's north, eastern, and south-eastern parts have non-saline soil followed by slightly saline in central and southern parts, moderate saline in the next elongated patch towards the west, and high saline in the westernmost parts (Fig. 6).

iv) Road Proximity

The proximity to roads is an essential factor that should be taken into consideration for future site suitability (Mahmoud & El-Sayed, 2011). As urban areas grow, considerably towards lands adjacent to significant transport corridors, especially National Highways and state highways, the regions undergo the most substantial urban development (Sridhar & Sathyanathan, 2022). Undoubtedly, well-organized and interconnected transportation routes are not only essential parameters of development but also crucial needs for decentralizing progress in any area or minimizing the regional imbalance in advancement.

Fig. 7: Road Proximity of Hisar City and Its Periphery



Source: Based on LISS-IV, 2022

So, transport infrastructure, especially national and state highways, is another selected phenomenon in the present case. Road network maps have demarcated the possible sites close to roads. At the next level, buffer zones were created at 300 meters to determine accessibility to conveyance ways and develop proximity maps. An area in close proximity to national or state highways has been assigned a higher value that continued to decline with increasing distance from the roads (Fig. 7).

Pairwise Comparison Matrix, Normalized Pairwise Comparison Matrix and Computation of Criterion Weights

Table 5 is a comparison matrix for different criteria, including land use/land cover (LU/LC), ground water quality, ground water depths, road proximity, and soil salinity. The table also includes a normalized pairwise comparison matrix and a computation of criterion weights. In the present study, the matrix compares LU/LC, road proximity, soil salinity, ground water quality and ground water depths. For example, the comparison between LU/LC and ground water quality has a value of 3, indicating that LULC is considered three times more important than the quality ground water.

Table 5: Pair-wise Comparison Matrix, Normalized Pair-wise Comparison Matrix and Computation of Criterion Weights

Criteria	Pair-wise Comparison Matrix					Normalized pair-wise comparison matrix					Computation of criterion weights (a+b+c+d+e)/5
	LULC	Ground Water Quality	Ground Water Depth	Road Proximity	Soil Salinity	LULC (a)	Ground Water Quality (b)	Ground Water Depth (c)	Road Proximity (d)	Soil Salinity (e)	
LULC	1	3	5	8	9	0.57	0.63	0.53	0.46	0.32	0.5
Ground Water Quality	0.33	1	3	3	9	0.19	0.21	0.32	0.17	0.32	0.24
Ground Water Depth	0.2	0.33	1	5	5	0.11	0.07	0.11	0.29	0.18	0.15
Soil Salinity	0.12	0.33	0.2	1	4	0.07	0.07	0.02	0.06	0.14	0.07
Road Proximity	0.11	0.11	0.2	0.25	1	0.06	0.02	0.02	0.01	0.04	0.03
Total	1.76	4.77	9.4	17	28	1	1	1	1	1	1

Source: by author

Similarly, the comparison between LU/LC and road proximity has a value of 8, indicating that LULC is considered eight times more important than road proximity. In the same way, other values also show importance for the selected parameter with respect to the other. In the present case, the adjacent or closest zone to national and state highways has been given extremely strong preference and assigned the value 9 (highest), the ahead zone to 8 (very high), and so on. It refers to the declining importance of zones with increasing distance from main roads. On the basis of soil salinity, the first is recommended for farming purposes and low suitable for development, so assigned value 3. The last or highly saline category has been assigned the highest value of 9 (extremely importance) followed by a decreasing order as 8 (strong importance) to moderate saline and 7 (moderate importance) to slightly saline. Similarly, in three categories (excluding fresh water) of ground water quality, the highest value 9 is given to highly saline, 8 to moderate saline and 7 to marginal (less saline) categories. Further, the minimum depth of ground water has been assigned to least value 3 whereas maximum depth has been assigned as highest value 9. In the next level, the pairwise comparison matrix values are then normalized in the second column, creating the normalized pairwise comparison matrix. Normalization is achieved by dividing each pairwise comparison value by the sum of the values in its respective column. For example, the normalized value of the comparison between LULC and ground water quality 0.57 is obtained by dividing the pairwise comparison value of 3 by the sum of the column that is 5. The criterion weight is calculated by adding up the normalized values for each criterion and then dividing by the number of criteria being compared. For example, to calculate the criterion weight for LULC, we add up the normalized values in its respective column, i.e. are 0.57, 0.19, 0.11, 0.07, and 0.06, and then divide by 5, the total number of criteria being compared. The resulting value is 0.5, indicating that LULC accounts for 50 percent of the overall decision-making process, whereas road proximity and soil salinity are found least important for the same.

The weighted sum vector for each criterion was first computed by multiplying the weight of each attribute with its corresponding score, and then summing up all the values. For instance, the weighted sum vector for LU/LC was computed as [(1)(0.50)+(3)(0.24)+(5)(0.15)+(8)(0.07)+(9)*(0.03)] = 2.80. The LU/LC of any region and its periphery is likely to occur in extensive growth rather than individual (Iacono & Levinson, 2009). It has significantly more impact on the overall development of the area as compared to other indicators so, it has been assigned to highest weightage in the present study. However, the availability of ground water at lower depths is good sign for public uses but, it is not suitable in any way for construction or infrastructural development so, it is assigned lower weightage. In the same way, the roads proximity or ease accessibility to transport network influences the development of city in relation to other basic amenities or spatial planning rather than autonomously (Kasraian *et al*., 2019), so it is also given lower weightage comparatively. In the same way that assigning of Next, the consistency vector for each criterion was computed by dividing the weighted sum vector by the weight of the criterion. For instance, the weight of LULC was 0.50, so the consistency vector for LULC was computed as 2.80/0.50 = 5.60. The same process was repeated for the remaining criteria, and the consistency vectors were computed as follows: Ground Water Quality (1.33/0.24 = 5.54), Ground Water Depth (0.82/0.15 = 5.46), Soil Salinity (0.35/0.07 = 5.00), and Road Proximity (0.14/0.03 = 4.60) (Table 6). The table also provides a concise summary of the computations performed and presents the results in a clear and easy-to-understand format. For example, the LU/LC (with highest consistency ratio of 5.60) is required to be analyzed extensively and on priority basis for the forecast of future urban development in Hisar city. At the next level ground water depth, ground water quality, soil salinity and road proximity should be given preference in that order.

Table 6: Computation of Consistency Vector

Criteria	Weighted sum vector	Consistency vector
LULC	[(1)*(0.50)+(3)*(0.24)+(5)*(0.15)+(8)*(0.07)+(9)*(0.03)]= 2.80	2.80/0.50= 5.60
Ground Water Quality	[(0.33)*(0.50)+(1)*(0.24)+(3)*(0.15)+(3)*(0.07)+(9)*(0.03)]= 1.33	1.33/0.24= 5.54
Ground Water Depth	[(0.20)*(0.50)+(0.33)*(0.24)+(1)*(0.15)+(5)*(0.07)+(5)*(0.03)]= 0.82	0.82/0.15= 5.46
Soil Salinity	[(0.12)*(0.50)+(0.33)*(0.24)+(0.20)*(0.15)+(1)*(0.07)+(4)*(0.03)]= 0.35	0.35/0.07= 5.00
Road Proximity	[(0.11)*(0.50)+(0.11)*(0.24)+(0.20)*(0.15)+(0.25)*(0.07)+(1)*(0.03)]= 0.14	0.14/0.03= 4.60

Source: by author
Calculation of lambda (λ) = (5.60+5.54+5.46+5.00+4.60/5) =5.24
Lambda (λ) is the average of consistency vector

Calculation of the Consistency Ratio

Consistency ratio is essential to check the consistency of comparisons. Table 6 shows the determination of weighted sum vector and consistency vector.

Condition 1: As per condition the value of lambda (λ) should be equal or greater than the number of criteria under consideration i.e. 5 in present case. Here $\lambda - n$ stands for a measure of the degree of inconsistency. Further, it is normalized through the formula:

$$CI = (\lambda - n)/(n - 1)$$
$$CI = \frac{5.24 - 5}{5 - 1} = 0.06$$

Condition 2: Consistency ratio CR (0.05) <0.10 showed a judicious level of consistency in the pairwise comparisons whereas equal and more than 0.10 CR refers to inadequate consistency in pairwise comparison (Ying *et al*., 2007). Therefore, the obtained value of CR as 0.05 satisfies the said condition, which denote that the weights obtained are agreeable.

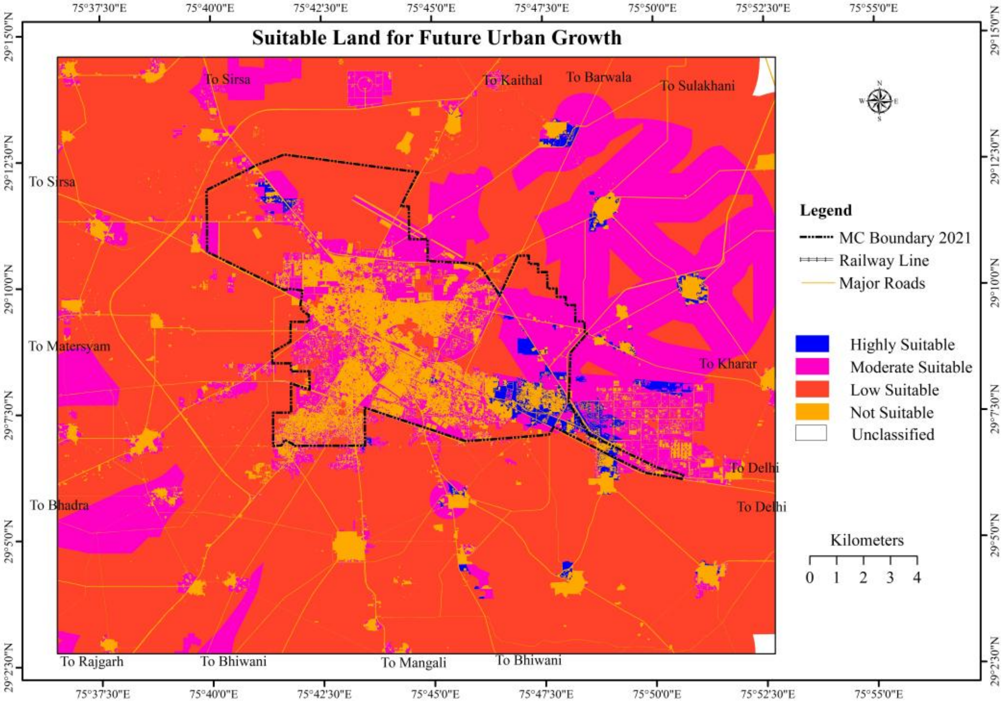
$$CR = \mathrm{CI/RI}$$
$$CR = \frac{0.06}{1.12} = 0.05$$ (As RI for n (5) is 1.12; Table 1.9)

Hence, in case of present study, the values regarding lambda (λ) and consistency ratio (CR) satisfies the above stated both conditions.

Suitable Land for Future Urban Growth

The extraction of suitable sites is based on weight overlay approach in which analytic hierarchy process (AHP) and geographic information system (GIS) are combined to generate the final suitability maps for Hisar city. In other words, it is the integration of qualitative and quantitative information in order to help the planners or researchers for identifying suitable sites for various urban uses in future so, subjective ideas that affect the findings can be ignored. Here, area has been classified into four categories namely high, moderate, low and not suitable according to suitability preferences and the remaining area has been assigned to non-classified category (Fig. 8).

Fig. 8: Suitable Land for Future Urban Growth



Source: by authors

Table 7: Suitable Land for Future Urban Growth

Sr. No.	Classes for Suitability	Area (in Hectares)	Area (in Percent)
1	High Suitable	773.53	1.35
2	Moderate Suitable	13818.94	24.07
3	Low Suitable	38274.74	66.68
4	Not Suitable	4377.78	7.63
5	Unclassified	159.01	0.28
	Total	57404.00	100

Source: by authors

For future urban growth regarding Hisar city, the highly suitable area has been found in east and north-east directions along with national highway approaching to national capital New Delhi (via Rohtak) and state capital Chandigarh (via Barwala) respectively. In that order, some patches of highly suitable land have been traced north-west and south along Sirsa and Bhiwani roads. This land has been marked as bare/open land in the LU/LC category. Moderately suitable areas have been detected mainly in the east and north-east along transportation routes, in the surrounding built-up area of the main city and villages of the fringe area, and partially in the north-west, west, and south-west. The low suitable class has appeared in the north-west part of the controlled area and all over the area of the periphery, as this is mainly agricultural land. Not suitable area includes the existing built-up area (including roads and rail-tracks), parks, and waterbodies that lies in the center and surrounding of the city. In contrast, insignificant tract of unclassified land has been identified in the north-east and south east parts (Fig. 8). The land in the area has been classified based on its suitability for future development. About 773.53 hectares (1.35 %) are highly suitable, 13,818.94 hectares (24.07 %) are moderately suitable, and 38,274.74 hectares (66.68 %) are low suitable. Additionally, 4,377.78 hectares (7.63 %) are considered not suitable, and 159.01 hectares (0.28 %) remain unclassified (Table 7).

DISCUSSION

The rapid urbanization witnessed in Hisar, like many other developing Indian cities, necessitates a structured approach to urban planning. The unorganized growth can lead to a strain on existing resources, environmental degradation, and a decline in the overall quality of life. This research aimed to address this challenge by developing a site suitability model for future urban development using the Analytic Hierarchy Process (AHP) model. Integrating Geographic Information Systems (GIS) and the AHP has emerged as a pivotal methodology for future urban growth and site suitability analysis. The research conducted in various regions, including Indian cities and outside, underscores the effectiveness of GIS-based multi-criteria decision-making approaches in identifying optimal sites for urban expansion (Suthar *et al*., 2024). These studies highlight that land suitability analysis is not merely about identifying available land but involves comprehensively evaluating various environmental, social, and economic factors. For instance, the research in Aqaba demonstrated how different weights assigned to criteria could lead to multiple planning scenarios, allowing decision-makers to explore various urban development strategies (AlFanatseh, 2022). Similarly, West Bengal and Siliguri studies emphasized integrating expert opinions and local knowledge in determining the relative importance of different factors, thereby enhancing the accuracy of the suitability maps produced (Roy *et al*., 2022; Mallick *et al*., 2022). A study related to Lucknow City (Uttar Pradesh) revealed that the cumulative weightage of geomorphological, hydrological, and artificial parameters is highly fit for identifying suitable sites for future urban growth (Anugya *et al*., 2017). Moreover, the findings from the Himalayan districts exposed that urbanization must be approached with caution, considering the unique challenges posed by the terrain and natural hazards (Suthar *et al*., 2024). The AHP model's ability to facilitate pairwise comparisons among criteria ensures a systematic and transparent decision-making process, which is crucial for sustainable urban planning (Tiwari *et al.,* 2018). This approach not only aids in identifying suitable sites but also fosters informed decision-making that considers the intricate balance between development and environmental preservation (AlFanatseh, 2022; Saha & Roy, 2021). The application of AHP in Hisar City, Haryana, can draw valuable insights from these studies. By employing a similar multi-criteria framework, urban planners can effectively assess the suitability of land for future development, ensuring that growth is both sustainable and aligned with the socio-economic needs of the community with minimal negative impacts.

CONCLUSION

The results show how the analytic hierarchy process can be used to analyze the suitability of a location for urban development. The case study in Hisar, Haryana, offers important insights into the potential of the AHP model to help decision-makers select ideal sites for urban growth based on various variables, including accessibility, infrastructure availability, land use, and environmental issues. The findings reveal that east and north-east directions, along with the national highway approaching the national capital, New Delhi (via Rohtak), and the state capital, Chandigarh (via Barwala), offer highly suitable areas for future development. In that order, some patches with highly suitable land have appeared in the south and north-west along the Bhiwani and Sirsa transportation routes. This is mainly bare/open land in the land use and land cover categories. The transportation routes in the east and northeast, surrounding the built-up area of the main city and villages of the fringe area, refer to the moderately suitable area. Low suitable land has been detected in the north-western part of the controlled area and all over the periphery, which is primarily agricultural land. The existing built-up area (including roads and rail tracks), parks, and waterbodies in the center are unsuitable for future growth, whereas two patches in the north-east and north-west have been traced as unclassified land. While talking about the area, 772.26 hectares, 13818.14 hectares, 38218.18 hectares of land have been recognized as highly, moderate, and low suitable for future development, respectively whereas 4377.28 hectares and 218.14 hectares area has been identified as not suitable and unclassified land in that order. The repercussions are merely the first step in strategic planning, and the selected sites may significantly impact the studied area's long-term development in the coming years. The developed model may be effectively helpful for urban planners in choosing the best locations for managing urban development with substantial considerations of the city's environment, major threats, and other restrictions. The findings can be significantly useful for urban planners and policy makers by providing some direction regarding suitable sites to enhance the schemes and strategy for better plannings and management in Hisar city

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CONFLICT OF INTEREST

The authors state that they have no conflicts of interest.

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