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WILDLIFE HABITAT SUITABILITY ANALYSIS USING ANALYTIC HIERARCHY PROCESS AND GEOSPATIAL TECHNIQUES

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Abstract – *Conservation of wildlife species is done by evaluating suitable habitat using geospatial techniques. The habitat suitability analysis for the common leopard (Panthera Pardus) was conducted in three districts of Uttarakhand State- Dehradun, Haridwar, Pauri Garhwal. Prediction of potential suitable habitat for common leopard was done by integrating geospatial techniques with Analytic Hierarchy Process (AHP), an expert opinion-based model. The input parameters for this model were generated using SRTM-DEM and Landsat 8 satellite image for the year 2020. The thematic layers used were land use/cover (LULC), Normalized Difference Vegetation Index (NDVI), slope, aspect, distance from stream, road and settlement. The result from AHP model revealed that out of total area 29.73% area was very low suitable, and 25 % area was highly suitable. Very low suitable area was dominated by agriculture and built-up. The most influential parameters according to expert were land use/cover (35 %), NDVI (24 %) and distance from stream (16 %).*

Key Words: AHP, Common leopard (*Panthera Pardus*), GIS, habitat suitability, LULC

1.INTRODUCTION

Remote Sensing and GIS have been applied in several fields ranging from oceanography to meteorology and from military applications to wildlife conservation. The determination of change in the landscape pattern can be useful for conservationists in saving the species. Conservation planning can be done by habitat analysis (Charry et al., 2018). The common leopard (*Panthera Pardus)* is the one of the most widely found and adaptable wild cat among the other carnivore cats (Marker et al.,2005; Maharjan et al., 2017). Whenever there is a fragmentation in habitat patches, integrated approach of multi criteria along with remote sensing and GIS is useful. This was showed as in the study conducted for the assessment of suitable habitat for sambar, rhinoceros and waterbirds by Porwal et al., (1996), Singh et al., (2009),Dong et al., (2013) in their respective studies. An expert opinion based multi criteria decision making- Analytic Hierarchy Process (AHP) was used for wildlife habitat suitability analysis such as elephant, tiger by (Porwal et al., 1996;Sanare et al.,2015; Talukdar et al., 2020; Mandal et al.,2021). Kushwaha et al.,(2002) and Areendran et al., (2011) showed that AHP weights can be assigned to various parameters based on their influence with context to the wild animal's habitat. Therefore, geospatial techniques were used to identify suitable habitat for the common leopard in three districts of Uttarakhand state.

1.1 Study Area

The study area considered the regions of Dehradun, Haridwar and Pauri Garhwal, three districts in the state of Uttarakhand, India. The total area was around 10678 Km^2, which included 3088 Km^2 of Dehradun, 2360 Km^2 of Haridwar, 5230 km^2 of Pauri Garhwal. Figure 1 shows the location map of study area.

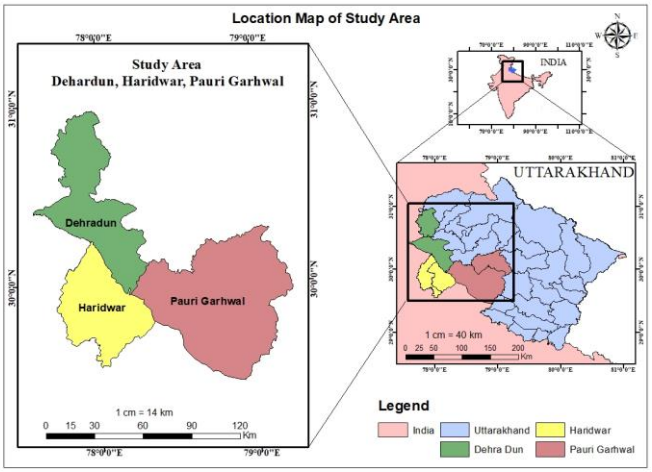

Figure 1: Study area showing Uttarakhand Districts- Dehradun, Haridwar, Pauri Garhwal

1.2 Data and Tools

Satellite images and software used in this study are shown in Table 1.

Table 1 Data and Tools

Satellite Images	Path / Row	Resolution	Software
USGS Landsat 8 Level 2, Collection 2, Tier 1- Year 2020	145 / 039, 146 / 039	30 m	ArcGIS 10.5, Google Earth Engine
NASA SRTM Digital Elevation 30m			

2. Method

Google Earth Engine (GEE), a cloud-based platform for geospatial analysis. In this platform, USGS provides an atmospherically corrected dataset. Landsat 8 Level 2, Collection 2, Tier 1 for the year 2020(Landsat Collections in

Earth Engine | Earth Engine Data catalogue (google.com)) and NASA SRTM Digital Elevation (NASA SRTM Digital Elevation 30m | Earth Engine Data Catalogue (google.com)) at 30m resolution is used for the preparation of land use land cover map of the study area (Agarwal et al., 2019, Tassi et al., 2020). Land use/cover (LULC), NDVI, slope, aspect was prepared using Google Earth Engine. These layers were further exported to GIS platform for habitat suitability analysis.

A habitat suitability map was prepared by integrating decision-making process known as Analytic Hierarchy Process (AHP) with remote sensing and GIS. The AHP was first introduced by Saaty (1977) and is a multi-criteria decision making process. It helps in finding solution to the multi criteria complex problems. With respect to the overall aim, ranks are assigned to set of criteria. Then, the pairwise comparison between (Table 4) each factor is done, and according to the degree of importance, each factor is assigned relative dominant value between 1 to 9 as shown in the Table 2. Based on the AHP rank method, experts had assigned weights to these layers thus standardised comparison matrix was prepared (Table 5).

The explanation about AHP process is from

$$A = (a_{ij})_{n*n} = \begin{bmatrix} a_{11} & a_{12} \dots \dots & a_{1n} \\ a_{21} & a_{22} \dots \dots & a_{2n} \\ a_{n1} & a_{n2} \dots \dots & a_{nn} \end{bmatrix} \quad (1)$$

where, $a_{ii} = 1, a_{ij} = \frac{1}{a_{ji}}, a_{ij} \neq 0$

Arithmetic mean was used to measure weights by using –

$$A_w = \lambda_{maxw} \quad (2)$$

The degree of consistency is measured to examine the rationality of weights assigned to each criterion. The formula used to calculate consistency ratio (CR) by (Saaty,1977) –

$$CR = \frac{CI}{RI} \quad (3)$$

$$CI = \frac{\lambda \max - n}{n - 1} \quad (4)$$

where, λ_{max} is the principal matrix eigen value, RI is the random index, CI is the Consistency Index, n is the number of criteria in the matrix. For the leopard's habitat suitability, seven parameters were used thus, value of RI = 1.33 and CR= 0.025.

Table 2 Scale of binary comparison(Saaty, 1977)

Degree of Importance	Definition
1	Equal importance
3	Weak importance
5	Essential or strong importance
7	Demonstrated importance
9	Absolute importance
2,4,6,8	Intermediate values between two adjacent judgements.
1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9	Reciprocal values of the previous appreciation

Table 3 Parameters used for AHP Modelling

Parameters used for AHP modelling		Source	Spatial Resolution(m)
Environmental Parameters	Land use/land cover	Landsat 8	30
	NDVI		
	Slope	SRTM-DEM	
	Aspect		
	Distance from stream	Open source (Diva-GIS)	-
Anthropogenic Parameters	Distance from road		
	Distance from settlement		

The consistency ration CR < 0.10 was an acceptable value otherwise due to inconsistency, scores were to be readjusted (Saaty, 1980).

Thematic layers used were LULC, NDVI, slope, aspect, distance from road, distance from stream, and distance from settlement (Table 5 and Figures 2-8). AHP model take raster as an input layer so each vector layer (distance from stream/road/settlement) was converted into raster format. AHP extension for ArcGIS 10.5 was used to prepare potential habitat suitability map for common leopard. All layers were reclassified into four potential habitat suitability sub criteria: very low, low, moderate and high. The potential suitable habitat was obtained based on weighted analysis method (Table 6).

Potential suitable habitat area was given as –

$$PSHA = [(LULC_W * LULC_{nr}) + (NDVI_W * NDVI_{nr}) + (DS_W * DS_{nr}) + (DR_W * DR_{nr}) + (DSt_W * DSt_{nr}) + (Slope_W * Slope_{nr}) + (Aspect_W * Aspect_{nr}) \quad (5)$$

where, the following the variables are – LULC: Land use land cover, NDVI-Normalized Difference Vegetation Index, DS: Distance from stream, DR: Distance from road, DSt: Distance from Settlement, nr: normalized value,w: weights, of individual habitat suitability factor.

Table 4 Pairwise Matrix with preference values

Parameter	LULC	NDVI	DS	DR	DSt	Slope	Aspect
LULC	1	2	3	4	5	6	7

NDVI	½	1	2	3	4	5	6
DS	1/3	½	1	2	3	4	5
DR	¼	1/3	½	1	2	3	4
DSt	1/5	¼	1/3	½	1	2	3
Slope	1/6	1/5	¼	1/3	½	1	1
Aspect	1/7	1/6	1/5	¼	1/3	1	1

Table 5 Standard pairwise comparison matrix and their weights Matrix

Parameter	**LULC**	**NDVI**	**DS**	**DR**	**DSt**	**Slope**	**Aspect**	**Weights**
LULC	0.38	0.44	0.41	0.36	0.31	0.27	0.25	0.35
NDVI	0.19	0.22	0.27	0.27	0.25	0.23	0.22	0.23
DS	0.12	0.11	0.13	0.18	0.18	0.18	0.18	0.15
DR	0.09	0.07	0.06	0.09	0.12	0.13	0.14	0.10
DSt	0.07	0.05	0.04	0.04	0.06	0.09	0.11	0.06
Slope	0.06	0.04	0.03	0.03	0.03	0.04	0.03	0.04
Aspect	0.05	0.03	0.02	0.02	0.02	0.04	0.03	0.03

Table 6 Weights of criteria

	Main Criteria	**Weights**	**Weight Influence (%)**	**Suitability Criteria**	**Sub Criteria**
1	LULC	0.35	35	Very Low	Built-up/ Waterbody
				Low	Agriculture
				Moderate	Scrub
				High	Dense forest/ Open forest
2	NDVI	0.24	24	Very Low	<0.05
				Low	0.05-0.2
				Moderate	0.2-0.3
				High	>0.3
3	DS	0.16	16	Very Low	>1000m
				Low	500-1000m
				Moderate	200-500m
				High	<200m
4	DR	0.11	11	Very Low	<500m
				Low	500-1000m
				Moderate	1000-500m
				High	>1500m
5	DSt	0.07	7	Very Low	<500m
				Low	500-1000m
				Moderate	1000-500m
				High	>1500m
6	Slope	0.04	4	Very Low	<10°
				Low	10°-20°
				Moderate	20°-30°
				High	> 30°
7	Aspect	0.03	3	Very Low	West & North West
				Low	South & South West
				Moderate	East & South east
				High	North & North East

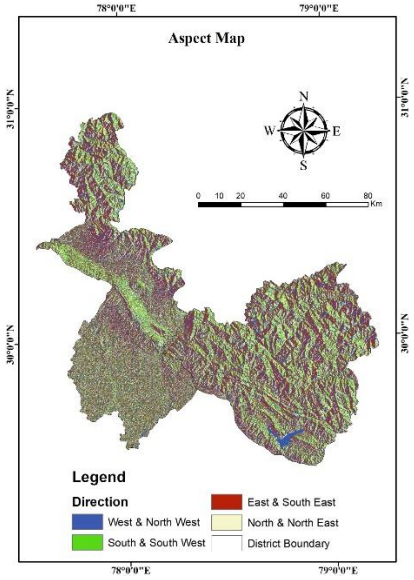

Figure 2 Aspect Map

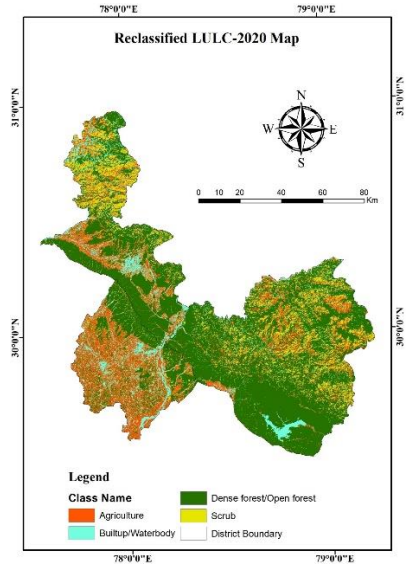

Figure 3 Reclassified LULC Map

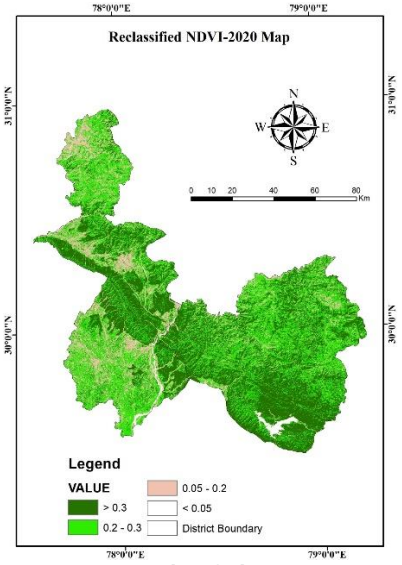

Figure 4 Reclassified NDVI Map

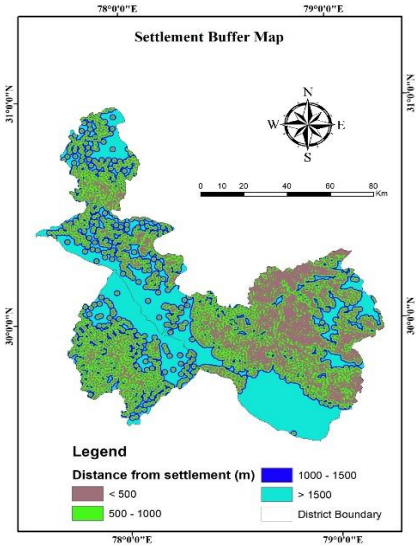

Figure 5 Settlement Buffer Map

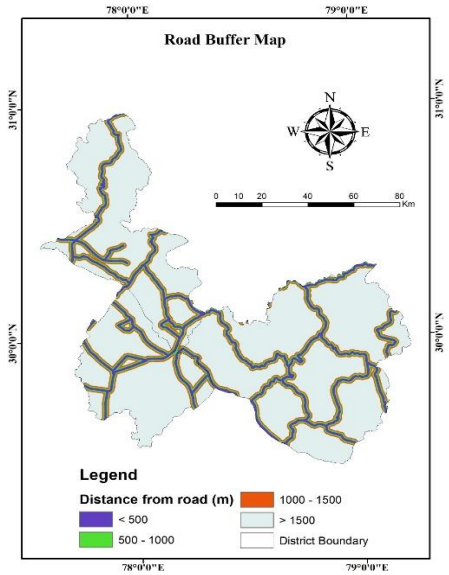

Figure 6 Road Buffer Map

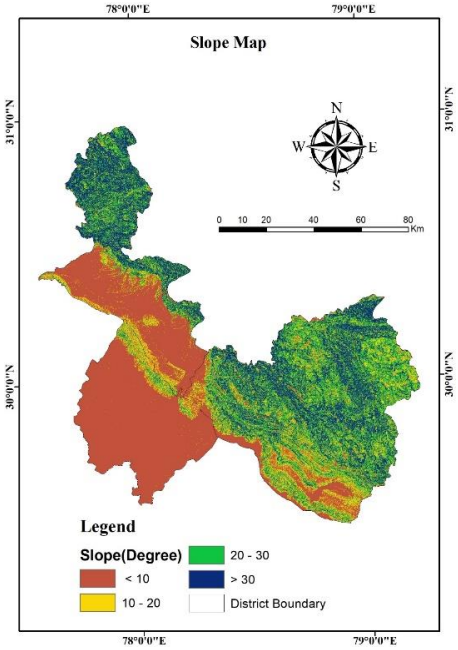

Figure 7 Slope Map

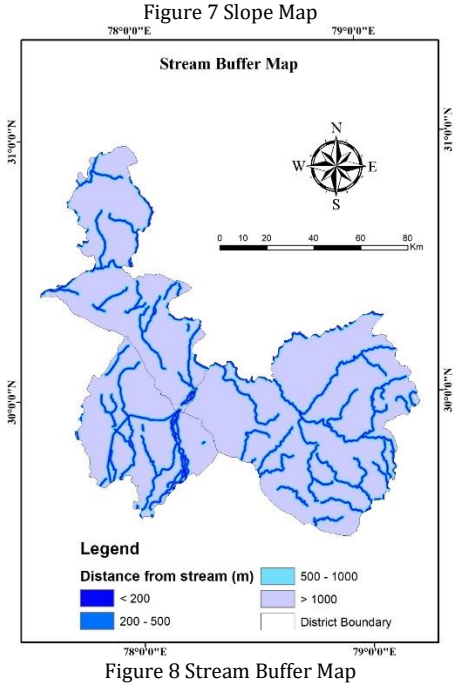

Figure 8 Stream Buffer Map

3. Result & Conclusion

Figure 9 shows the potential habitat suitable map for leopard. The seven factors were found to be playing significant role in finding potential habitat for common leopard. The most influential parameters according to expert was LULC (35%), NDVI (24%) and distance from stream (16%). It was classified into four potential habitat suitability classes which were very low, low, moderate and high. 25% of the total area was highly suitable (Table 7). Very low suitable area was dominated by agriculture and built-up area. The CR in AHP was 2.5% which is much lesser than reasonable levels of acceptance.

Analytical Hierarchy Path technique was used to identify the areas of potential habitat suitability for the leopard. The areas were classified into potential habitat suitability classes. The highly potential habitat for leopard was predicted to be 25% of the total area with very low suitable areas dominated by agriculture and built-area. This identification and stratification of areas of suitable habitat area for leopard can be used for proper strategical use of land; and the human-activity areas falling within the highly suitable habitat leopard areas can be relocated or isolated as per the requirement.

Potential Habitat Suitability Class	Area (km^2)	Area (%)
Very Low	3247.46	29.73
Low	1466.33	13.42
Moderate	3465.56	31.73
High	2742.31	25.10

Table 7 Area under different categories of potential habitat

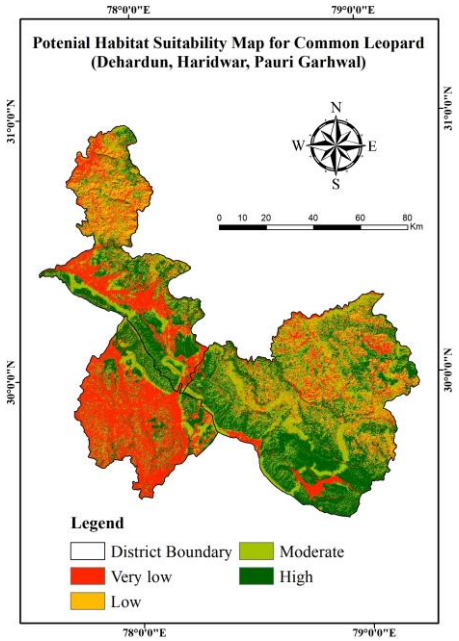

Figure 9 Potential Habitat Suitability Map for Common Leopard

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