Habitat Suitability Area Analysis for Leopard to Mitigate Human-Wildlife Conflict in Junnar Forest Division of Pune Forest Circle

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Abstract  Human wildlife conflicts (HWC) issue has been experiencing across the country, mainly in adjoining area of the wild animal habitat since historical period. This conflict has become severe problem due to wild animal presence such as leopard (Panthera pardus), which is frequently noticed and expanding at sharing landscapes in contiguous human settlements areas and, results in adversely affecting both human and wildlife each other. The significant existence of leopards in Junnar Forest Division of Pune district, Maharashtra has caused this problem at grave scale. The forest division area is a mixed-use landscape covering about 5337 sq. km area and also covers some part of Western Ghats. Therefore, the human-wildlife conflict has been explored in the northern part of the Pune district in Maharashtra. The main objective of the research paper is to identify the habitat suitability area for leopard in the Junnar forest division by using Analytic Hierarchy Process (AHP) method. The methodology incorporates process, which include creation of thematic raster layers of parameters like Normalized Difference Vegetation Index (NDVI), land use land cover (LULC), distance from stream, distance from road, conflict risk zone, settlement, slope and aspect map. These thematic layers weighted according to their significance. The results of the analysis revealed that western mountainous and forest area is suitable for leopard habitat and in fact, it was original habitat of leopard. The study also highlights spatio-temporal aspect of the conflict. The most of the attacks on humans were reported near the agricultural area mainly adjacent to the sugarcane field or near human settlements. The attacks on humans and their pet animals occurred mostly between August, September and October months because it is sugarcanes cutting period. This study is pertinent to explore balance on dilemma of human safety and livelihood at one side and protection and conservation of the threatened species at other side.

Keywords: leopard, wildlife, habitat, Western Ghats, sugarcane field, analytic hierarchy process

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1. Introduction

Human–wildlife conflict (HWC) occurs when human or wildlife having a negative impact on each other. Wildlife can cause conflicts when it damages crops, threatens, kills, or injures people and domestic animals. There are serious issues that have arisen as a result of the growing human population in and around wildlife habitats. The frequency and intensity of such conflicts increase as the human population increase and the demand for resources grows. Increasing human encroachment in wildlife habitats create the problem to wild species. As a result, wild species that are unable to adapt to altered habitats can attack marginal habitats or suffer population declines. Human-wildlife conflicts endanger to human welfare, health, and protection, as well as incurring financial and social costs [1]. The conflicts are becoming more active in areas where livestock and agriculture are predominant part of people's rural livelihoods. It has raised wildlife management concerns on one side and on the other side life of people and domesticated animals. However, there is also severe conservation problems when carnivore ranges overlap with elevated human density. The most widespread carnivore is the leopard [2], which occurs in southern Africa, southern Asia, and India [3]. The leopard (Panthera pardus), globally listed as almost endangered species on the IUCN Red List, has the largest distribution of any wild felid species, although it has decreased drastically in Asia [4]. The Leopard can move large distance and also have phenomenal adaptivity capabilities [5,6] mainly because of its highly adaptable hunting and feeding behavior [7,8,9,10,11].

The density of domesticated animal helps to sustain leopard in and around the human settlements areas in India [12], with low levels of conflict, leopards can live near human settlements [13]. In several parts of India, there is a declining trend in leopard populations due to shrink habitat and reduction of prey. The habitat degradation
has brought this species in close contact with the human. The conflict between humans and wildlife is described as any relationship between humans and wildlife that has a negative impact on human economic, social, cultural life, environment and the protection of wildlife populations [1].

In the western part of Maharashtra existence of the leopard and its appearance in nearby rural and urban areas has made challenges of conflict between leopard, human life, and domesticated animal. The leopard is found in most of the forests in the state of Maharashtra, as well as specifically predominant in the division of the Junnar forest. The density of carnivores is known to depend on the density of prey (such as dogs) [14,15] and the leopard is no exemption for it [7,16,17,18]. The important role of the domestic animal like dog, sheep and goats in the diet of the leopard has been confirmed by numerous studies around the globe. Leopards may also survive in human-dominated landscapes with low conflict levels [19,20,21,22,23]. In many areas, such as Sanjay Gandhi National Park, Himachal Pradesh, Uttaranchal, Maharashtra (Junnar Forest Division) the dogs, pigs and goats are an important part of the leopard diet [9,11].

In the Junnar Forest Division, the human-leopard conflict has two dimensions: one is human safety and livelihood problems at one side, and protection and conservation of endangered species at other side. Junnar forest division (JFD) is covering agriculture and forest land, hence agricultural practice is common in the region. The western part of the study area comes under the forest area of Western Ghats, this is the original habitat of the leopard due to the human encroachment in natural forest area the human leopard conflict has emerged is a serious issue in the region. Precise habitat suitability for leopard maps will decrease conflict vulnerability in this region. Therefore, an attempt has been made in this analysis to delineate habitat suitability for leopard zones in the Junnar forest division using the AHP method.

2. Study Area

The research work of human-wildlife conflicts was restricted to the Junnar Forest Division's affected talukas, i.e. Junnar, Shirur, Khed and Ambegaon in Pune district of Maharashtra. The Junnar forest division is one of the most susceptible areas of leopard conflict with humans in the Pune forest circle. It is administered by the state forest department of Maharashtra. It ranges from 18°28'46" to 19°24'15" N and from 73°30'25" to 74°34'42" E in the northern part of the Pune district; it is a mixed-use landscape covering about 5337 sq. km area. Thane and Ahmednagar districts are the neighboring districts of study area. (Figure 1).

Figure 1. Location map of Study area. Junnar forest division is northern part of Pune district of Maharashtra
Junnar forest division is situated on the leeward side of the Western Ghats and Western Ghats crest line is situated along the western border of the study region from where the most of rivers are originated like Mina, Pushpavati, Kukadi, Ghod, Bhima and Bham. The average height of the study area is 600 meters. The Junnar forest division was reported only protected area of Wildlife Sanctuary of Bhimashankar (19°03’N, 73°33’ E) in 1985, with 132 sq.km of forests area and adjacent to the Western Ghats crest-line. The research area covers a part of the Deccan volcanic province (DVP) from a geological perspective. The Junnar forest division come under the tropical monsoon climate which shows the seasonal variation in temperature and rainfall. The western part of study area is cold, while the eastern portion is hot and dry. The western area of the study region is beside the west coast and is a hilly region with dense forest cover, causing a high rate of rainfall in the area compared with the eastern parts. The monsoon reaches in the month of June, with the highest rainfall throughout the months of July to August. Based on the rainfall the Ambegaon, Junnar and Khed talukas are fall in moderate intensity zone. The lowest rainfall is received by the Shirur taluka and falls in the dry and semi-arid regions. The annual precipitation in study area fluctuates from 6000 mm in Western Ghats Scarp to 600 mm in Deccan Plateau. The Western Ghats is a biologically rich and the house of biodiversity means a biogeographically unique area. It comprises more than 30% of all the species of flora, fauna, fish, birds, and mammals found in India.

3. Data and Methodology

The work is based on the compilation of field visits, conflict data from primary data and secondary data sources. Secondary data collected from various sources such as forest department records of wildlife injury compensation, literature, newspaper, published research, and reports etc. Using simple computer computation techniques based on MS-Excel, the collected data were analyzed and interpreted. The places of the conflict for human-wildlife were attached using the Gat Number of agricultural farms. For mapping, ArcGIS software was used to understand the spatial distribution of human-leopard conflict in the JFD region by the interpolation method. For this analysis, the accepted methodology is represented through a flow diagram (Figure 2). The identification of habitat suitability for leopard has been analyzed based on various data sources like satellite images and traditional data sets such as toposheets and fieldwork data and with relevant information from government and non-governments agencies. Multi-thematic layers were created for the identification of leopard habitat suitability. The parameters like land use land cover (LULC), Normalized Difference Vegetation Index (NDVI), distance from the stream, distance from the road, conflict risk zone, settlement, slope, and aspect considered for the thematic layer.

The 30 m resolution digital elevation model (DEM) and Landsat 8 satellite images of the Junnar Forest Division were obtained from the official website of the United States Geological Survey (USGS). In ArcGIS 10.3, the DEM was processed to prepare the slope map and the aspect map. The Landsat 8 images were used for NDVI, Settlement and land use land cover classification. The road-network was digitizing from the Toposheet, human leopard conflict risk zone map was prepared using the LULC and conflict incident location data by using ArcGIS 10.3. All parameters have been transformed to raster format with a uniform 30 m resolution after preparing of the thematic layers. The raster thematic files have subsequently been reclassified using AHP ranks method. In the AHP, weights assigned for each parameter, and calculated it by using Microsoft Excel and ArcGIS 10.3 software. The multi thematic layers overlay on each other and the process used to generate habitat suitability map for leopard by using weighted overlay in ArcGIS 10.3.

![Figure 2. Flow Chart of Methodology](image-url)
Table 1. Pairwise comparison matrix which holds the preference values

| Parameter                   | LULC | NDVI | Dist. from Stream | Dist. from Road | Conflict Risk Zone | Settlement | Slope | Aspect |
|-----------------------------|------|------|-------------------|----------------|-------------------|------------|-------|--------|
| LULC                        | 1    | 1/2  | 1/3               | 1/4            | 1/5               | 6          | 7     | 8      |
| NDVI                        | 1    | 1/3  | 2                 | 2              | 3                 | 4          | 5     | 6      |
| Dist. from Stream           | 1/3  | 1/2  | 1                 | 2              | 3                 | 4          | 5     | 6      |
| Dist. from Road             | 1/4  | 1/3  | 1/2               | 1              | 2                 | 3          | 4     | 5      |
| Conflict Risk Zone          | 1/5  | 1/4  | 1/3               | 1/2            | 1                 | 2          | 3     | 4      |
| Settlement                  | 1/6  | 1/5  | 1/4               | 1/3            | 1/2               | 1          | 2     | 3      |
| Slope                       | 1/7  | 1/6  | 1/5               | 1/4            | 1/3               | ½         | 1     | 2      |
| Aspect                      | 1/8  | 1/7  | 1/6               | 1/5            | 1/4               | 1/3       | 1/2   | 1      |

Table 2. Standardized pairwise comparison matrix and their weights

| Parameter                   | LULC | NDVI | Dist. from Stream | Dist. from Road | Conflict Risk Zone | Settlement | Slope | Aspect |
|-----------------------------|------|------|-------------------|----------------|-------------------|------------|-------|--------|
| LULC                        | 0.37 | 0.44 | 0.40              | 0.35           | 0.31              | 0.27       | 0.25  | 0.22   |
| NDVI                        | 0.18 | 0.22 | 0.27              | 0.27           | 0.25              | 0.23       | 0.21  | 0.19   |
| Dist. from Stream           | 0.12 | 0.11 | 0.13              | 0.18           | 0.19              | 0.18       | 0.18  | 0.17   |
| Dist. from Road             | 0.09 | 0.07 | 0.07              | 0.09           | 0.12              | 0.14       | 0.14  | 0.11   |
| Conflict Risk Zone          | 0.07 | 0.05 | 0.04              | 0.04           | 0.06              | 0.09       | 0.11  | 0.11   |
| Settlement                  | 0.06 | 0.04 | 0.03              | 0.03           | 0.03              | 0.05       | 0.07  | 0.08   |
| Slope                       | 0.05 | 0.04 | 0.03              | 0.02           | 0.02              | 0.02       | 0.04  | 0.06   |
| Aspect                      | 0.05 | 0.03 | 0.02              | 0.02           | 0.02              | 0.02       | 0.03  | 0.02   |

Table 3. Weights of the criteria

| Sr. No. | Main Criteria / Data type | Weight | Weighted Influence (%) | Suitability Criteria | Sub Criteria                  |
|---------|---------------------------|--------|------------------------|----------------------|-------------------------------|
| 1       | LULC (30*30)              | 0.33   | 33                     | High                 | Vegetation                    |
|         |                           |        |                        | Moderate             | Land without scrub/with scrub |
|         |                           |        |                        | Low                  | Agriculture/Barren Land       |
|         |                           |        |                        | Very Low             | Built-up area/Waterbody       |
| 2       | NDVI (30*30)              | 0.23   | 23                     | High                 | > 0.3                         |
|         |                           |        |                        | Moderate             | 0.2-0.3                       |
|         |                           |        |                        | Low                  | 0.05-0.2                      |
|         |                           |        |                        | Very Low             | < 0.05                       |
| 3       | Distance from Stream      | 0.16   | 16                     | High                 | Within 200 m                  |
|         |                           |        |                        | Moderate             | 200-500 m                     |
|         |                           |        |                        | Low                  | 500-1000 m                    |
|         |                           |        |                        | Very Low             | > 1000 m                      |
| 4       | Distance from Road        | 0.11   | 11                     | High                 | > 1500 m                      |
|         |                           |        |                        | Moderate             | 1000-1500 m                   |
|         |                           |        |                        | Low                  | 500-1000 m                    |
|         |                           |        |                        | Very Low             | < 500 m                       |
| 5       | Conflict Risk Zone        | 0.07   | 7                      | High                 | Very Low                      |
|         |                           |        |                        | Moderate             | Low                            |
|         |                           |        |                        | Low                  | Moderate                       |
|         |                           |        |                        | Very Low             | High                           |
| 6       | Distance from Settlement  | 0.05   | 5                      | High                 | > 1500 m                      |
|         |                           |        |                        | Moderate             | 1000-1500 m                   |
|         |                           |        |                        | Low                  | 500-1000 m                    |
|         |                           |        |                        | Very Low             | < 500 m                       |
| 7       | Slope (30*30)             | 0.03   | 3                      | High                 | > 30                           |
|         |                           |        |                        | Moderate             | 20 – 30                       |
|         |                           |        |                        | Low                  | 10 – 20                        |
|         |                           |        |                        | Very Low             | < 10                           |
| 8       | Aspect (30*30)             | 0.02   | 2                      | High                 | Flat and North                 |
|         |                           |        |                        | Moderate             | West                           |
|         |                           |        |                        | Low                  | South East and South West      |
|         |                           |        |                        | Very Low             | South                          |

3.1. Analytical Hierarchy Process

The analytical hierarchy process (AHP) is an effective tool for dealing with complex decision making and the resolution of different types of multi-criteria decision problems [25,26]. AHP is a model focused on a large range of parameters that aims to capture a decision's subjective and objective aspects. It provides a helpful
technique to verify the accuracy of the assessment of the decision maker, thus reducing a bias in the decision-making process. AHP is a significant factor in the area of hazard management and environmental problems [27,28,29]. The key advantage of AHP, according to Calantone et al. [30], is that it allows for marginal variations in integration depending on judgment data. It is a Multi-Criteria Decision Analysis (MCDA) approach that is implemented within ArcGIS, which specifies weights for selected parameters [31], and it is a rather flexible, well-structured method that has the potential to decipher complex issues of conclusion involving multi-factors [32,33,34]. The AHP depends on several measures [35]: selecting the parameters of multi-criteria, arranging a hierarchical order for criteria, determining importance by allocating values, determination of significance by synthesizing scores [36]. The rank scale of criterion ranges from 1 (equal importance) to 9 (extreme importance) and intermediate values between two adjacent value. The pairwise comparison matrix (Table 1) of habitat suitability for leopards indicates that according to their relative value, the hierarchical order follows. Pairwise comparison scores are standardized to prepare the standardized comparison matrix (Table 2) for leopard habitat suitability mapping.

$$A = \left( a_{ij} \right)_{n \times n} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix},$$

(1)

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

The weights are then measured using the arithmetic mean form, which can be stated as:

$$Aw = \lambda_{max}w$$

(2)

The consistency ratio (CR) were calculated by follow equation of Saaty [37]:

$$CR = \frac{CI}{RI}$$

(3)

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

(4)

Where the consistency ratio is expressed by CR, CI specifies the consistency index, $\lambda_{max}$ is the principal matrix eigenvalue, RI is the random index, and n are a number of criteria in the matrix.

RI was given by Saaty [37] depending on the number of factors in the analysis, in this research components were eight parameters so the corresponding value of RI is 1.41. As the consequence of the AHP model, the value performance of the calculation consistency ratio (CR) is 0.03, which is accepted when the CR value is less than 0.10. Otherwise, subjective scores were re-adjusted according to Saaty [25] due to inconsistent AHP performance. All the parameters considered individually and classified into different subcategories are divided into the 4 suitability classes according to expert opinion for habitat suitability evaluation namely highly suitable, moderately suitable, low suitable, and very low suitable. Different suitability criteria were provided to each subgroup by relative importance using the analytical hierarchy process (Table 3).

4. Result and Discussion

Leopard habitat is mainly depending on the physical factor of an area. The assessment of physical and cultural parameter like NDVI, LULC, distance from stream, distance from road, conflict risk zone, settlement, slope and aspect using modern geospatial techniques provide a clear picture of a suitable location for leopard habitat with different extents. Above eight factors have considered in the research study to map the appropriate habitat for leopards in the Junnar forest division by using the model of the analytical hierarchy method.

The LULC patterns of study area divulge the form of human and natural use of land. Landscape planning in the forest ecosystem has many advantages for environmental conservation. The human leopard conflict is seriously affected by anthropological activities such as deforestation, forest fire, and increasing buildup area or settlements establishments. The conflict can be significantly resolved by numerous permutations of patterns of land use cover. Leopard movement is generally higher in cases of heightened crops like sugarcane and maize. At the same time, human encroachment in the forest also creates a conflict situation. Output map of land use land cover (Figure 3-a) indicates that most of the area is occupied by agricultural land mainly near water resources and natural vegetation mostly in the western region. The normalized difference vegetation index method has been used to analyze remote sensing dimensions, to understand area under green vegetation. The NDVI value indicates that the western part of a region having dense healthy vegetation and that is original habitat of leopard (Figure 3-b). The type of cultivation method or tree felling has a significant impact on habitat. As a result of the loss of green cover in western part of study area, degradation of biodiversity is forced to seek alternative habitat to leopard.

Along the streams and water bodies, occurrence of the human leopard conflict usually concentrates. Therefore, a significant geomorphic aspect considered for accurate habitat suitability mapping to understand the distance from river and water bodies. Stream or water bodies are the source of water for the animal; leopard prey density found in nears the water resources. Carnivorous like leopard density is depending on the prey density [7,16,17,18]. Similarly, Leopard use the riverine and surrounding area for movement. The lowest point of that specific region is usually a stream area. As a result, area is far from the stream are less vulnerable to the occurrence of human leopard conflicts. For this analysis, using a Euclidian distance from the stream is prepared in ArcGIS software using reclassification, and converted to the raster image (Figure 3-c).

Road network is a significant factor for habitat loss, habitat degradation, and fragmentation [38,39]. Euclidian distance from the road at the 500-meter interval was created; a disturbing factor for the wildlife is nearer to the road within the forest area (Figure 3-d). In the study region, heavy vehicle movement, its horn and sound, and the frequency of movement of vehicles and people are common. The settlement is considered a disturbance parameter that contributes to the fragmentation of the ecosystem, hence leading to a landscape change. This study area has very dispersed settlements most of the settlements are in the agricultural and near forest area (Figure 3-f).
A conflict risk zone map was prepared using the LULC and conflict incident location data by using the interpolation technique in ArcGIS 10.3. The conflict risk zone map shows the intensity of conflict sites (Figure 3-e). Slope plays a crucial role in regulating the human-wildlife conflict in environmental geographic research, and it is a very important topographical element for such studies. In an area, the slope is directly linked to the forest cover. As the gradient becomes higher, the human disturbance is lower in the region and this is a good habitat for the leopard (Figure 3-g). The aspect is substantial for understanding the slope stability of area. Aspect is known to affect the density and diversity of vegetation or plant. Sunny slopes hold less moisture because of stronger solar radiation and higher evaporation rate in study region (Figure 3-h).

The multi thematic layers overlay with raster format were used, each input raster layer was multiplied with an
equivalent weight factor and then condensed to arrive at a final suitability map in 4 classes. The extracted weights used from the previously explained AHP procedure (Table 3). ArcGIS 10.3 used a weighted sum method since it only accounted for the individual weight of the layers. The outputs produced were divided into four natural suitability classes to obtain the final leopard suitability habitat map.

5. Habitat Suitability Map

The suitable site for the leopard habitat map is classified into four classes using the method of natural breaking in ArcGIS 10.3. These classes for leopard habitat suitability are very low, low, moderate and highly suitable (Figure 4). The very low suitable area is towards eastern part of the JFD, its cover 14.46% area near settlement and dense road network. The low suitable is 15.91% and its cover central area of study area in barren land and along to settlements. The moderately suitable area is covered 36.55% and it is get maximum concentrated on the gentle slope along western hilly area and the agricultural area. The agriculture area is having heighted crops like sugarcane field, maize, fodder crops etc. that is the alternative habitat for leopard. Only 33.06% of the area is classified as highly suitable for leopard habi tat and it’s highlighted in the forest area of Western Ghats, where dense vegetation and hilly area present that is the original habitat of leopard and it needs to develop as decent habitat for leopard.

Leopards are quickly adapting to the changing landscape and which are increasing; generally, found close to human habitation. The lack of wild prey base in the forests area and decline in the forest cover may be the main reason for moving the leopards into prey-rich agriculture fields out of forest areas. In the present study, tall crops like sugarcane fields, plantations provide ideal habitats to leopards [1]. The low population of wild prey in the forest area needs to be examined from the perspective of habitat degradation, to site the needs of prey animals and maintain a healthy pre-predator relationship. Moving into the human habitation enables leopards to predate on livestock and in this act comes in direct contact with the humans accidentally, resulting in injury or death. Leopards use the riverine belts and riparian zone as a corridor and shelter in the human dominated landscape of JFD. The cultivation of sugarcane on agricultural land along these riverine areas provides a safe home for leopards. The study also revealed that leopards preferentially predate more frequently on small sized domesticated animals like dog, goats and sheep. With all this understanding, the study suggests a suitable area for leopard habitat, it may help in mitigation of the human-wildlife conflict of the area.

![Figure 4. Habitat Suitability for Leopard map](image-url)
6. Conclusion

Human and wildlife are continuously conflicting over living space and food availability and it becoming intense as the population grow, spread, and consequently decrease the natural habitats. The conflict sometimes results in adversity to people such as lose their livestock, crops, property, and even their lives also. The animals also get either injured or killed. The selected study area of Junnar forest division suffers from this serious issue of human-leopard conflict. The western part of the study area comes under the Western Ghats, which is the original habitat of the leopard, where the human and wildlife as a part of nature, had decent co-occurrence. But, due to the human encroachment in the natural forest area, the majority of the leopard moved into alternative habitat where agricultural activities are dominant. These Leopards are unable to adapt to altered habitats and induce to attack marginal habitats that created a threat to human and domesticated animals. The decision-makers and conservers are believed that instead of conflict and fear, it is essential to have decent coexistence. Hence, to avoid this conflict in the study area, identification of habitat site suitability for leopard would help to mitigate the problem. Geospatial platform with the AHP technique provides an appropriate solution based on the multi-criteria required dataset that related to the suitability result. The suitable sites for leopard habitat are classified into very low, low, moderate and highly suitable categories that shows which area is more suitable for leopard habitat. The result also shows that the problem is severe in the non-suitable area and alternative habitat region. The western part of study region is more suitable due to the mountains area and comparatively dense forest with rich in biodiversity. Hence, there is a need to demarcate the habitat zones and restore its original characteristics which are suitable for the rich ecosystem and suitable for leopard habitat.

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Competing Interests

Author declare that they have no competing interests.

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