Forecasting the probable range and environmental variables Linked with Indian pangolin habitats in Chakwal District of Pakistan

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Research Article

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Abstract
The population of Indian pangolin in Chakwal district is under serious threat due to various biological and human induced factors leading to rapid decline. Limited data on their habitat in Pakistan hinders conservation efforts. To address this issue, we conducted a comprehensive study combining a literature review, expert interviews and field surveys. We identified the presence of pangolins at 50 sites through direct observations and features such as burrows and scats along 15 transects and 11 quadrats covering different habitats. Our findings reveal that forested areas, characterized by medium-textured brown soil at altitudes between 400 and 1,300 meters above sea level, host the highest concentration of pangolin burrows. Maximum Entropy Model (MaxEnt) version 3.4.1 was used to model potential habitat distribution of Indian Pangolin in the study area with more than 100 sightings data from survey and literature. The results of the logistic regression analysis indicated strong correlations between pangolin sightings with distance from waterbodies, termite site presence, topographic diversity, open forest cover and precipitation. It was found that 7.8% (517 sq. km) of Chakwal district has been identified as highly suitable, consisting of fragmented upland forest and grassland and another 26% (1,579 sq. km) as moderately suitable habitat. These findings are essential for understanding the distribution of pangolins in Chakwal district and formulating effective conservation strategies. They provide the basis for local management plans aimed at protecting pangolin natural habitats and ensure their continued protection amid ongoing environmental challenges.

Keywords: Wildlife Conservation, Endangered, Indian pangolin, Habitat Suitability, MaxEnt, Chakwal

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Introduction

Out of the four Pangolin species found in Asia, only Indian pangolin (*Manis crassicaudata*) is found in Pakistan (Mehmood *et al*., 2015). The Indian pangolin faces a grave threat from the widespread illegal trade from illicit hunting and heightened instances of poaching driven by the demand for its scales and meat, that it has garnered an "Endangered" status since 2014 due to its vulnerability (Waseem *et al*., 2020). Indian pangolins have been declared as protected species under the Punjab Wildlife (Protection, Preservation, Conservation and Management) Act, 2007. This predominantly nocturnal creature displays remarkable behavioral plasticity, allowing it to inhabit a variety of environments, including tropical rain forests, subtropical thorn forests, deciduous forests and open scrublands, both in natural settings and those modified by human activity(Ashokkumar, 2017 and Karawita 2018). This encompasses diverse croplands like rubber, cinnamon, coconut, oil palm, tea plantations, and even rural home gardens, provided there is an ample supply of its prey and minimal disturbances. The Indian pangolin diet comprises ant eggs, insect larvae, and specifically *Leptogenys sp*., an ant genus known for its propensity to colonize tropical deciduous forests.

In Chakwal district, Indian pangolin prefer to occupy barren areas with hilly topography on the Potohar Plateau and dry thorn forests, and their habitat has been recorded near Chakwal district villages with sandy soil and access to fresh water resources (Mehmood *et al*., 2014). Pangolins in general are exceptionally susceptible to habitat degradation, heightened rates of poaching, and excessive exploitation. This vulnerability arises from their extremely slow reproductive rate, wherein female pangolins typically give birth to only one offspring per year (Mohapatra *et al*., 2018). The Indian pangolin faces significant threats from unlawful hunting and poaching, primarily for its meat and scales, occurring at the local subsistence level. Moreover, this menace is intensifying due to the escalating illegal international trade in pangolin products (Heinrich *et al*., 2016). During the time span of 2011 and 2012, approximately 60 Indian pangolins were reportedly lost due to killings within the Chakwal district (Mehmood *et al*., 2019) and on the broader level about 118 pangolin killings were recorded from Potohar Plateau. Although the Indian pangolin exhibits adaptability to various habitats, populations of this species are currently experiencing a decline throughout their geographical range (Parera *et al*., 2020). As the population of Indian pangolin in Pakistan is rapidly decreasing, with incidents of poaching and trafficking for Chinese traditional medicine and profit surpassing drug trafficking (Dawn, 2018; Zhang *et* al., 2021). National stats show that approximately 10,000 Indian pangolins have been trafficked annually in recent years (Naqvi, et al., 2014).

Species Distribution Models (SDM) help pinpoint areas with suitable geographic conditions by analyzing and considering various predictor variables. (Mouafo *et al*., 2023). Such spatial models help represent the species' distribution and site preferences based on environmental parameters (Newton *et al*., 2008). SDM utilizes the rule of thumb in habitat modeling, where the presence of a species in specific sites with environmental parameters may indicate its presence in other sites with similar conditions (Kushwaha *et al*., 2012). Species distribution models enable the projection of wildlife species distributions in regions where comprehensive surveys are lacking (Sinclair *et al*., 2010. In contemporary times, the range of techniques compatible with presence-only data has broadened (Naqibzadeh *et al*., 2021). Among these techniques is the Maximum Entropy (MaxEnt) model, which was used in this research. This study emphasized to highlight the significance of environmental layers that influence the habitat of Indian pangolin and predict the distribution of Indian Pangolin in the study area. This research offers valuable information and a theoretical foundation for developing and executing strategies to protect remaining pangolin species in Chakwal district.

Materials and Methods

Study area

Chakwal district (33°40’N, 72°51’E) consists of four subdivisions, namely Chakwal, Talagang, Choa Saidan Shah, and Kallar Kahar and is situated in the Potohar Plateau of Panjab province, Pakistan (Figure 1). This landscape represents a classic arid environment characterized by prevailing scrub vegetation. The primary landscape attributes encompass cultivated fields interspersed with rainwater streams and compact water storage reservoirs. Additionally, there are stretches of scrubland and tropical thorn forests, permanent wetlands, as well as urbanized zones (Rais et al., 2015). Agriculture in this area is reliant on rainfall, and the district consists of four tehsils and 68 union councils (Gillani et al., 2023). Chakwal district also holds significant protected areas i.e. Chinji National Park, Kallar Kahar Game Reserve, Chumbi Surla Wildlife Sanctuary, Diljjba-Domeli Game Reserve and Rakh Ara Forest. It receives an average annual precipitation of 620 mm. During the summer months, the temperature range varies between 15°C and 40°C. (Baloch, 2016). The district's altitude ranges from 200 meters to 1500 meters , covering a total area of 6,614 Sq.km.). Among the various shrubs, "Calotropis procera, Ziziphus jujube," and grass "Cynodon dactylon" are dominant. Moreover, having a diverse topography Chakwal district serves as a hub for wildlife including mammals and migratory waterfowl (Safi, 2018).

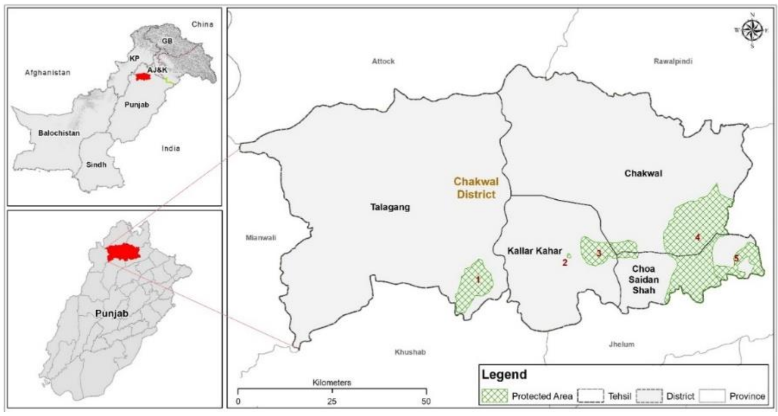


Figure 1. Map of the study area showing 1) Chinji National Park, 2) Kallar Kahar Game Reserve, 3) Diljabba-Dobeli Game Reserve, 5) Rakh Ara-Parera Reserve Forest.
*Protected Area draft boundaries Protected Areas were obtained from several sources

Data collection

The baseline survey was conducted in the outskirts of potential sites selected from the literature review and native interviews. These sites included the Chumbi Surla Wildlife Sanctuary and the outskirts of Bhoun, Budhail, Choa Saidan Shah, Dheedhwal, Dullah, Kallar kahar, Khokhar Zair, Lawa, Mureed and Neela villages (Figure 2). The purpose of the survey was to collect Indian pangolin sightings and scats data, physically observe the details of Indian pangolin habitat, and acquire land use data for ground-truthing.

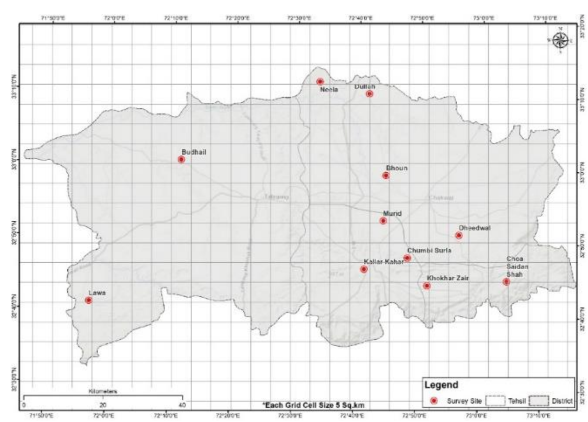


Figure 2. Map of surveyed villages

As the study, area covers a huge expanse so it was divided into 5 * 5 km grids using ArcGIS software and 11 potential quadrants with 100m radius were selected for survey. In total 500 survey plots were established and regarded as single occasion and thoroughly searched. The remaining plots were left surveyed in result of rugged inaccessible terrain. About five fortnightly baseline surveys were conducted from the month of July to August 2023, utilizing a handheld Global Positioning System (GPS), specifically the Garmin 64 s. These months were chosen as they coincide with the mating season of Pangolins, during which the Indian pangolins are expected to be highly active (Trageser et al., 2017). Indian pangolin is nocturnal mammal species (Mohapatra et al., 2014), therefore a field team of 05 people having knowledge about pangolin characteristics, conducted the surveys during the dusk and dawn times with the aid of torches. In total 35 transect surveys were performed to cover 11 quadrants using 100 m radius. Each plot was surveyed for Pangolin direct/indirect sightings, burrow or scats (dropping, tail tracks, footprint etc.) Moreover, the data related to termite mounds, ant colonies, vegetation cover type, distances from road, drainage and settlements as well as land use practices were documented using a survey sheet (Table 1). During the survey, approximately 75 sampling points were recorded. These sampling points included direct and indirect sightings, 12 active burrows, 08 feeding burrows and 15 old burrows. The observed Indian pangolin burrows from the survey can be categorized into three distinct types: 1) Active Burrow: These burrows are presently inhabited by Pangolins and are distinguished by soft and damp soils (Figure 3.a.). They are sealed from the top, providing a secure dwelling for the animals. Evidence of crawling, leaves, and deceased ants are frequently visible around the entrances of active burrows. 2) Feeding Burrows: Pangolins create specific burrows to hunt for termites and black ants, satisfying their appetite for these insects. Feeding burrows are relatively compact in size and can be identified by their slender dimensions, shallow depth, and the presence of soil mounds adjacent to termite or ant mounds (Figure 3.b.). 3) Old Burrows: These burrows are places where Pangolins once resided but have subsequently moved or relocated in search of food (Figure 3.c.). Such burrows consist of weathered, solidified soil and might exhibit distorted appearances. Similar types of burrows were also documented during a pangolin study conducted in the Potohar region (Mehmood et al., 2018).



Figure 3.a.) Active burrow 3.b.) Old burrow 3.c.) Feeding burrow

Ten environmental layers, including two climatic layers (temperature and precipitation), were incorporated as criteria for evaluating the habitat suitability with the help of literature review (Jayasekara, 2022 & Akrim, 2017), (Stracquadanio.L 2023 and Panjang, 2024) and wildlife experts already working on Indian Pangolin conservation.

MaxEnt Model Processing

For assessing the habitat sites of Indian pangolins, the researchers utilized the Maximum Entropy Model (MaxEnt 3.4.1). Maximum entropy modeling exhibits significant promise in discerning wildlife distributions and habitat preferences, primarily due to its utilization of solely presence-based data. The integration of environmental layers bolster the efficacy of Maxent in the realm of wildlife investigation and management (Naqibzadeh *et al*., 2021). This model was run with 25% data for random test, 15 replicates, 5,000 maximum iterations and subsample replicated run type. Whereas the rest of the parameters were left as default. The Maxent operates solely on presence data combined with relevant environmental layers, and it does not require absence data (Zare *et al*., 2016). The model accuracy and performance were evaluated using the Area Under Curve (AUC) and Receiver Operating Characteristic (ROC). AUC values range from 0 to 1, with higher values indicating better model performance (Young et al., 2011); values above 0.8 represent excellent predictive ability (Xian et al., 2022). Additionally, the jackknife technique was employed to assess the relative importance of the variables (Young et al., 2011). The results of the MaxEnt simulation were visualized using ArcMap 10.5 software and corrected before calculating the habitat area. The cells were categorized from not suitable to highly suitable based on the predicted area, threshold and balance training omissions.

Development of Environmental Layers

The environmental layers used in this research consisted of elevation, land use, soil (Irshad *et al*., 2015), slope (Pabasara *et al*., 2015), distance to settlement (Zoological Survey of India, 1994), distance to water (Mahmood, 2012 and Dorji, 2020), NDVI (Atta-Kusi *et al*.,2013) and topographic diversity. The climatic data sets included average temperature and precipitation. Topographic diversity (TD) is a surrogate variable that reflects the range of temperature and moisture conditions available to species in local habitats (Guo *et al*., 2024) and was acquired from Global ALOS website. It expresses the idea that a greater variety of topo-climate niches should support higher biodiversity, particularly plant diversity, and aid in species persistence amid climatic changes. Google Earth Engine (GEE) was employed to extract land cover classes for Chakwal district using 30-meter spatial resolution Landsat-8 OLI satellite imagery for May 2023. The land use/land cover (LULC) classes extracted using GEE included barren land, built-up area, agriculture, forest, shrubs/grasses, bare soil and water bodies. About 50 training samples for each class were used to extract the research relevant LULC classes. GEE provides efficient classification algorithms including Random Forest classifier, which improves the LULC accuracy (li et al., 2020). NDVI values were extracted from the same year's Landsat imagery to assess the vegetation health in a specific area. NDVI is proven to effectively predict the distribution and abundance of both herbivore and non-herbivore species across different times and locations (Mouafo et al., 2023). The 30 meter resolution Aster DEM (Digital Elevation Model) was obtained from available GEE data repository of United States Geological Survey (USGS) https://earthexplorer.usgs.gov/, which was further processed to extract slope and aspect angle (Shrestha et al., 2021). The elevation in the study area ranges from the maximum of 1,500 meters above Annual Sea Level (asl) in the southern part to the lowest of 200 meters in the North. Most of the study area consists of slopes between 0° to 30°. As pangolins have preference of soil type for making burrows (Perera et al., 2017), the soil texture data was acquired from Soil Survey of Pakistan, 2023. Chakwal district's soil covers 11.3% silt loam, 30.9% sandy loam and 4.49% loamy sand. The remaining 53.31% consisted of miscellaneous areas like water bodies, impervious surfaces and rocks. In order to develop separate layers in regard to pangolin associated environmental variables the distances from urban and water bodies hold special importance (Shrestha et al., 2021). Euclidean distance (100, 1,500, 3,000 and 5,000 meters) was performed on built-up areas and 500, 2,000, 8,000 meters from water bodies and drainage network extracted from the satellite imagery and DEM data using ArcMap software. The data related to climatic variables including temperature and precipitation were downloaded from World-Clim (https://www.worldclim.org/), which was later spatially rescaled accordingly. All environmental parameters were standardized on same spatial extent, pixel size (30 meter) and coordinate system using Arcmap software version 10.5.

Results

The model showed an excellent accuracy of 0.827. It was found that distance from waterbodies, topographic diversity and elevation played a crucial role in shaping the model with cumulative percent contribution 72.8%. Whereas, the elevation, average precipitation, topographic diversity and soil had higher permutation importance of cumulative importance 68.7%. (Figure 4.a.) The land use and soil texture class had a moderate contribution, while the environmental layers including NDVI, slope, and distance from settlement had a minor contribution. The Jackknife analysis indicate distance from waterbodies and average temperature had high gain when used in isolation but the average temperature decreased gain the most when omitted from all variables (Figure 4.b.).

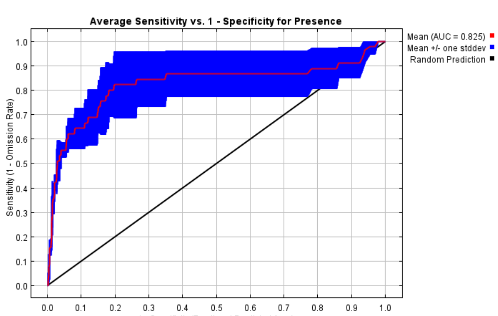
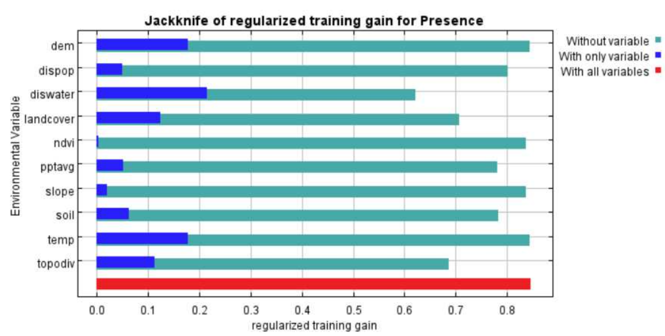
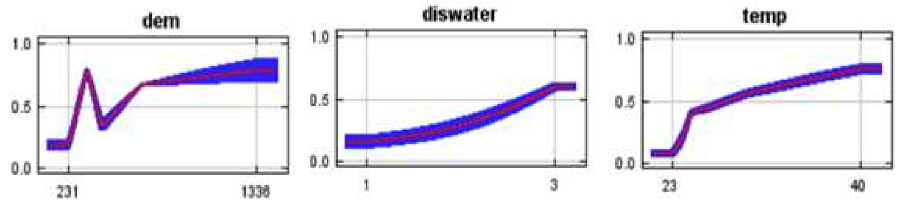


Figure 4.a.) ROC graph

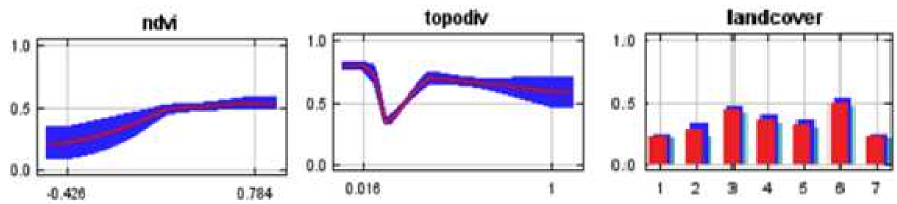


4.b) Results of ROC and Jackknife analysis

The following graphs depict the trend of data for most important variables. Indian pangolin presence was detected at elevations spanning within 400-1,300-meter elevation in the study area (Figure 5.a.), while the presence of termite and ant mounds was also recorded within this elevation range. Sightings were observed within a distance of 500 meters from water bodies and interconnected drainage networks (Figure 5.b.). Observations of Indian pangolins were concentrated in locales featuring moderate temperatures ranging from 26°C to 40°C (Figure 5.c.). There existed a positive correlation between precipitation and the presence of Indian pangolin, with the highest number of sightings documented in vegetated regions Pangolin presence was observed within a distance of 500 meters from water bodies and interconnected drainage networks (Figure 5.d.). Topographic diversity graph shows a sharp trend of pangolin sightings from 0.4 to 1 (Figure 5. e.). Majority of observed burrows and sightings were concentrated in proximity to forests, nestled within shrub-covered grasslands and away from urbanized regions Pangolin presence was observed within a distance of 500 meters from water bodies and interconnected drainage networks (Figure 5.f.).



5.a. 5.b. 5.c.



5.d. 5.e. 5.f

Figure 5. Response curves for important environmental variables a) elevation, b) distance from water bodies/drainage, c) average temperature, d) NDVI, e) topographic diversity, f) categorized land use/land cover

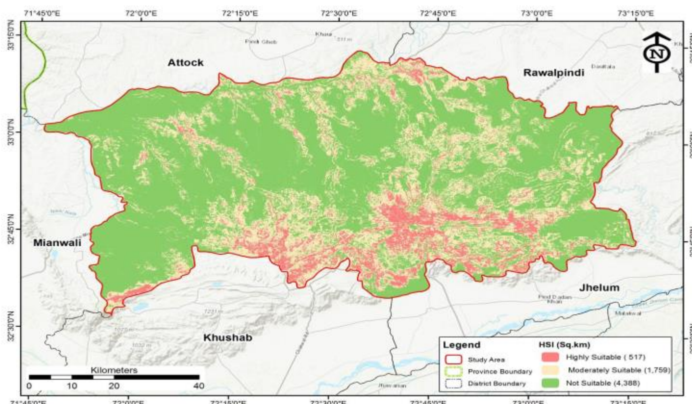


Figure 6. Indian pangolin habitat suitability map

Utilizing the Maxent model, an evaluation of habitat suitability was conducted, revealing that 7.8% of the study area exhibited a high level of favorability for Indian pangolins (Figure 6.). Additionally, 26% of the area demonstrated a moderate potential for habitat suitability.

The Habitat Suitability map was completed by segmenting the model's 10th percentile training presence thresholds and subsequently classifying the overall habitats into three groups: highly suitable (>0.6), moderately suitable (0.4 to 0.6), and unsuitable (0.11–0.4). (Zhang et al., 2022) also employed a comparable methodology of habitat segregation. The highly suitable habitat for the Indian pangolin was discovered within predefined protected areas. Specifically, Chumbi-Surla and Diljabba-Domeli comprise 26.4 sq.km and 24.1 sq.km of highly suitable habitat, respectively, with Chinji National Park covering 30.1 sq.km. Following these, Kallar Kahar and Rakh Ara contain 2.6 sq.km and 1.6 sq.km of suitable habitat areas, respectively.

Discussions

The burrows of Indian pangolin were found scattered in clusters. The pangolin presence was found between 400-1200 m elevation, while a similar observation was reported in a study in Peru, where Pangolins were linked to the decline of termites with increasing elevation (Palin *et al*., 2011). The Indian pangolin presence was observed near foothills and rising slope levels (0° to 40°) whereas no burrows or sightings were recorded on steep to very steep slopes. The presence of burrows and preference for slopes between 0°-35° may be linked to the presence of soft soils in these areas (Mehmood *et al.,* 2014). This observation aligns with a study conducted in Bhutan, which indicated that Chinese pangolin occurrence decreased with an increase in slope (Dorji, 2017). Exposed soil and agriculture area covered a large expanse among the extracted LULC classes. The burrows and sightings were scattered adjacent to forests, within shrubs, grasslands at elevated hills (Figure 7.). This finding is consistent with another study in Chakwal district that declared Indian pangolin habitat to be associated with *Acacia nilotica* and *Zizyphus mauritiana* (Mehmood *et al*., 2012). Table 3. Depict the results of LULC classes extracted from satellite image classification.

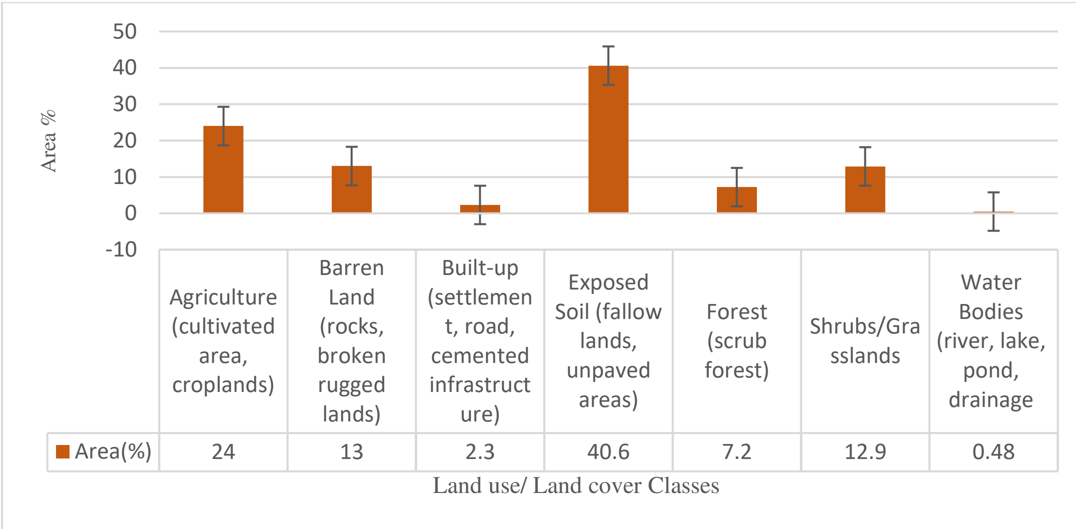


Figure 7. Land use / Land cover status of Chakwal district

The sighting records were not found within the vicinity of the settlement and the presence data suggested that Indian pangolin prefer a considerable distance from human settlements. A notable finding from the survey was that the majority of active burrows were located in undisturbed natural areas, situated at a considerable distance from human settlements and soft soils. Specifically, these areas were identified in the Chumbi Surla Wildlife Sanctuary and Mureed village. The surveyed data categorized distances of 1km, 1.5 km, 3 km, and 5 km from settlements, with the 1.5 km to 3 km distance range considered as high priority for Pangolin habitat (Figure 8). Similar findings have been reported in previous studies, which indicated that Pangolins tend to avoid disturbed and noisy places near human settlements (Wu *et al*., 2003). While sightings were observed at, a distance of 500 m meters from main water bodies and drainage networks, such as streams, marshes, lakes, and ponds. This observation aligns with a study in Sri Lanka, where the majority of Indian pangolin burrows were found within 200 meters from water sources (Karawita *et al*., 2018). In Singapore, Sunda Pangolins were observed to use drainage networks for rest during the daytime (Pantel *et al*., 2009). Indian pangolin presence was noted in areas with mild temperatures between 23°-30°C, while areas with high temperatures and dry terrain seems non-preferable. Previous records reveal that pangolins cannot survive below 18°C in winters (Bao *et al*., 2013). The downloaded precipitation was positively correlated with pangolin presence, with most sightings recorded in vegetated areas.

Conclusion

Indian pangolin habitat distribution is significantly influenced by several key factors, including elevation, average temperature, and proximity to human settlements, land cover classification, slope, aspect, and precipitation. These factors can be identified as crucial determinants of their Indian Pangolin habitat range. The final map indicates that within the 6,614 sq. km study area, a total of 517 sq. km (7.8%) exhibits high suitability for the Indian pangolin. These regions encompass a diverse blend of natural vegetation, dense shrubbery, grasslands and areas with sparse canopies. Approximately 34% of the total area offers favorable conditions for Indian pangolins to flourish, leaving the remaining study area available for strategic planning and conservation management aimed at wildlife preservation. Nonetheless, several factors such as deforestation for agricultural purposes, the development of infrastructure, urban expansion, and illicit poaching activities pose significant and imminent threats to the local wildlife. It is imperative to implement measures that address these challenges and mitigate their detrimental impacts on both the Pangolin population and their habitat. In order to safeguard the Pangolin species in the region, it is crucial to regularly maintain and protect the natural drainage channels, as they can serve as effective safeguards for the animals. Raising awareness among the native communities regarding the ecological significance of the Indian pangolin and the necessity for its conservation is of utmost importance. By actively involving and educating the indigenous population, collaborative endeavors can be undertaken to ensure the protection of these invaluable creatures and their habitat, securing their legacy for the generations to come.

Declaration

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Funding
No funding was provided for this research.

Ethical Proof
This research was conducted while keeping in view the ethical guidelines of WWF-Pakistan.Informed consent was obtained from all participants involved in the study, ensuring that they were fully aware of the research purpose, procedures and their rights to withdraw from the study at any point without any consequences. Participants' anonymity and confidentiality were strictly maintained and all data were securely stored and accessible only to the research team.

Conflict of Interest
The authors declare no conflicts of interest. The research was conducted independently to ensure objectivity and integrity in the findings.

Data Availability
The data supporting the findings of this study are available within the article. Further inquiries can be directed to the corresponding author.

Availability of data and materials
Not Applicable

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