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Research Article

# Narrow range of suitable habitat and poaching driving Indian pangolin (*Manis crassicaudata*) towards extirpation in Mardan District, Pakistan

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## Abstract

Indian pangolin (*Manis crassicaudata*), a medium sized scaled mammal, categorized as "Endangered", is mainly confined to India, Nepal, Sri Lanka and Pakistan. This endangered species plays an important role in the food web by consuming insects and termites. Its population is declining alarmingly in Pakistan because of its poaching and illegal killing for its scales, which are smuggled to other countries like China and Vietnam to be utilized in preparing traditional medicines. In the current study we investigated the habitat suitability and illegal trade of pangolin in Mardan District, Pakistan. We recorded occurrence of the species at only three out of total fifteen selected sampling sites at an elevational range between 338 m to 399 m. The data collected from sampling plots along with environmental layers (including; elevation, slope, land cover, distance to nearest settlement) and bioclimatic layers (including annual mean temperature and precipitation) were processed to generate habitat suitability maps in MaxEnt software. In order to identify habitat preferences, we divided the Indian pangolin's habitat into three categories: forests, agricultural lands and grasslands. The species found to exhibit higher occupancy in forest habitat type as compared to grassland and agricultural land in the study area. Average population density was estimated to be 0.09 pangolins per km$^2$. The MaxEnt analysis showed only 3.99 % area of the total available habitat to Indian pangolin, as the most suitable habitat, followed by 8.77 % area, that is moderately suitable habitat, while most of the study area (87.23 %) is less suitable habitat for Indian pangolin. The result revealed that precipitation, mean temperature, elevation and slope were the important environmental and habitat variables affecting the distribution of Indian pangolin. The questionnaire survey conducted showed declining trend of the species population for the last 10 years, mainly because of hunting, poaching, and trafficking but habitat loss and changes in land use patterns are also among the primary causes of the declining population of pangolin. The study concludes that the species is under pressure from illegal killing and requires urgent conservation measures to save the small remaining population and avoid the extirpation of this vital insectivorous predator from the area and it is important to change the community perceptions and beliefs about Indian pangolin and public awareness is mandatory for its conservation

## Introduction

Indian pangolin (*Manis crassicaudata;* Manidae, Pholidota) is one of the eight extant species of pangolin in Asia, categorized as "Endangered" by the IUCN Red List of Threatened Species (Mahmood et al., 2019). It occurs in five countries: Pakistan, India, Nepal, Bangladesh and Sri Lanka (Mahmood et al., 2019). In Pakistan the distribution is localized, with the species occurring in the provinces of Sindh, Baluchistan, some parts of Khyber Pakhtunkhawa and Punjab, including the Potohar Plateau (Roberts, 1997) although, it shows patchy distribution in the country with few records in northern Pakistan. The Indian pangolin occurs in barren hilly areas and subtropical thorn forests (Roberts, 1997), usually ranging from moist to dry and thorn to grassland (Pai, 2008). It occurs at naturally low population densities and prefers forested environments of various types (Gaudin et al., 2006). It is also found in ruined wasteland near human settlements (Yang et al., 2007). The pangolin's scales provide defense against predators; when threatened, it rolls up into a ball to protect its delicate, vulnerable underside. Demand for the scales for use in traditional medicine has fueled intensive poaching of the species, resulting in a decline 79 % in its native range (Irshad et al., 2015).

The population of Indian pangolin in the country has been declining since the last decade (Irshad et al., 2015; Mahmood et al., 2019), because of illegal hunting and increased levels of poaching for its scales which are thought of having medicinal importance and are used in traditional Chinese medicines. The two major countries, China and Vietnam, are the biggest and most significant illegal markets for its scales. Recent trade trends in Asia involving pangolins indicate that the species is now regularly present in illegal international trade for its scales and meat. The traded pangolins originate primarily from India, Pakistan, and Nepal (Challender and Hywood, 2011; Mahmood et al., 2019). All eight species of pangolins (four Asian and four African) are on Appendix I of CITES (2017), and are considered to be the most trafficked wild mammal globally (Challender et al., 2014), with an estimated >277,000 individuals of both Asian and African origin traded since 2000. This trade is recognized as having a severe impact on the status of pangolin populations (Challender et al., 2014).

The Indian pangolins have unique adaptations for digging burrows; it has powerful forelimbs with tough claws, adapted for digging (Swart et al., 1999). Like many other semi-fossorial species, it frequently excav-

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ates burrows in the earth for its living purpose. Its body is roofed over by hard scales and these scales are anti-wear along with characteristics of anti-adhesion against soil and rock. They sleep in burrows during the daytime and leave their burrows at night for foraging (Tong et al., 1995). The literature suggests that *M. crassicaudata* is capable of adapting to a variety of habitats across its geographical range (Chakkaravarthy, 2012). Habitat features such as tree species composition, vegetation cover and geological features (such as the presence of rock boulders, water sources and soil characteristics) have been identified as important parameters worth considering in the characterization of burrowing habitats of pangolins (Mahmood et al., 2015; Pabasara et al., 2015). In addition, the species prefers natural forests over agricultural land and human vicinity areas (Mahmood et al., 2021). Vegetation analysis of the habitat of Indian pangolin showed that pangolin burrows were associated with a specific tree and shrub species including *Acacia nilotica*, *Zizyphus nummularia*, and *Ziziphus Mauritian,* showing species preference for certain type of vegetation in its habitat (Mahmood et al., 2015).

Mahmood et al. (2013) reported that the Indian pangolin digs two types of burrows; living or resting burrows and feeding burrows. Resting burrows are used for sleeping/resting during the daytime and breeding while feeding burrows are dug to reach or expose prey species. Parameters such as burrow depth, burrow-opening diameter and the presence of prey remain as well as faecal matter are considered as useful signs to distinguish the two types of burrows (Irshad et al., 2015). Some reports suggest that a pangolin burrow can have several outlets sealed with loose earth (Prater, 1980), but this may not be the case under all habitat conditions, and remains to be verified by further research. Burrows are usually made under large rocks or boulders and sometimes in the base of trees with the depth of the burrow tending to vary depending on the soil type (Prater, 1965). Studying the burrow characteristics of *M. crassicaudata* in Potohar region of Pakistan, Mahmood et al. (2013) concluded that the Indian pangolin usually abandons its resting burrow after a few months of use, and digs a new one within its home range but re-occupy an older resting burrow for up to a year afterward. Feeding burrows, in contrast, are significantly less in depth and have smaller entrances compared to resting burrows (Mahmood et al., 2013).

The published data indicates that population of Indian pangolin has been declining in the country for the last decade and much more alarmingly in the Potohar Plateau where up to 79 % decline has been estimated (Irshad et al., 2015; Mahmood et al., 2019). The above-mentioned studies also highlight the factors responsible for pangolin decline, which include mainly poaching and illegal trade of the species for its scales and meat, and to some extent the habitat loss or degradation due to change in land use practices. Indian pangolin is the easy target for the poachers and illegal traffickers in the country because of weak law enforcement. The species is further included in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). In Mardan District, Pakistan, the information on habitat preference and den characteristics of *M. crassicaudata* is scant in the literature, and the few published studies are highly localized and confined to a single habitat or environment (Mahmood et al., 2013, 2014, 2015). Since no studies has been conducted so far on the habitat preference of the Indian pangolin in Mardan District. So keeping in view the importance of the study area as an important habitat and the core distribution range of the Indian pangolin, the current study aimed at investigating pangolin population, its habitat suitability and illegal trade in Mardan District of Khyber Pakhtunkhwa province of the country.

## Materials and methods

### Study Area

The current study was conducted in Mardan district of Khyber Pakhtunkhwa province, Pakistan. The study area is located between 34°32′ to 34°5′ north latitude and 72°25′ to 71°48′ east longitude (Fig. 1). The total area of Mardan district is approximately 1,632 square kilometres (km$^2$), study district is generally divided into 2 components, southwestern plain and north-eastern hilly area. The district is administratively sub-divided into five tehsils including Katlang, Takht Bhai, Rustam, Lund Khwar, and Mardan itself. The summers are long, sweltering, humid, while the winters are short, cold, and partly cloudy. Over the course of the year, the temperature typically varies from 3.8 °C to 40.5 °C and is rarely below 1.1 °C or above 44.4 °C. Average annual rainfall is 599 mm.

### Study Design

Field surveys to the study area were conducted on a fortnightly basis from March 2021 till June 2022 for data collection. Sampling sites (a total of 15 sites, 3 from each tehsils) were selected in different tehsils of Mardan district, for further data collection. Direct (sightings, capture, dead bodies) and indirect (burrows, faeces) signs of the species were recorded. Thorough searches were carried out at sites where the species was reported to occur. Geographical coordinates of the locations of occurrence were recorded using a global positioning system, and were used to construct distribution maps of the species and estimate its distribution range in the study area. The population of the species was estimated using "Line Transect" method by using counts of active living burrows of the species. Burrows were identified by their characteristic shape and size, scat was identified by its texture, shape, and location, scale prints detected on suspected trails or burrows and photographed and checked using a field guide, direct sightings were recorded when live or dead pangolins were observed. Habitat Suitability was studied by recording species signs in the field at selected sampling sites as well as recording the environmental variables and analyzing all these data by "MaxEnt" software. The placement of transects was dependent on the size of the study habitat, environmental gradient, and accessibility. For this purpose, the study area was divided into grids of 10×10 km$^2$ size by using Arc GIS (Fig. 1). The data about illegal trade of the species were collected using self-designed questionnaires (Supplementary Material 2), getting filled from local communities (including hunters, shepherds, shop keepers and school children) living around the habitat of Indian pangolin in the study area.

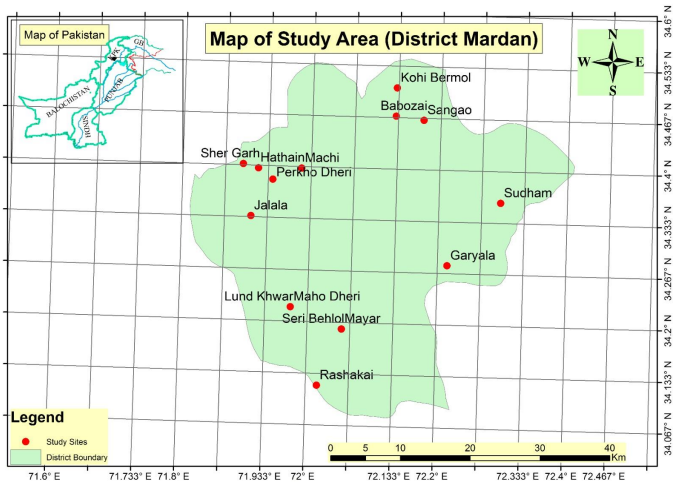


**Figure 1** – Map of Pakistan showing location of Mardan District where the study was conducted.

### Methodology

#### *Population Estimation*

For population estimation of the Indian pangolin, a total of fifteen (15) sampling sites were selected in the study area, including three sites from each of the five tehsils of the district (Tab. 1). The population of the species was estimated at each selected site by using the "Line Transect" method, where each transects was approximately 5 km in length and 1 km in width (Perera et al., 2022). The study area was divided into 240 grids of 10×10 km$^2$ size each. Total 10 plots in each grid having radius of 100 m for sampling were selected. The potential areas of

the animal species were identified on the basis of its burrows and fecal samples present over there and also by interviewing local people. The transects were established in each selected site to determine the population using the active living burrow count method following Irshad et al. (2015) and Mahmood et al. (2018). The burrows of the Indian pangolin were distinguished from those of other vertebrates identified on the basis of their characteristics shape (being circular at their opening). However the identification of pangolin burrows posed a serious challenge to researchers during the initial field observations those from burrows of other animals that occur in the same habitat, particularly the burrows of Indian crested porcupine (*Hystrix indica*). We conducted interviews with nearby hunters and villagers before beginning transect surveys. To identify the Indian pangolins burrowing ranges and gets local knowledge about distinguishing pangolin burrows from those of other animals present in the forest and associated habitats. The main signs to identify pangolin burrows were the presence of footprints, claw marks, fecal samples, scratch marks and shape of the burrow entrance. The species excavates two types of burrows. These are the feeding burrows and living burrows. The feeding burrows are less deep and excavated during foraging on ants and termites, while the second types of burrows are "permanent" burrows or living burrows, which are excavated by the species for living purposes and these, are much deeper. The local people were also asked about the occurrence of pangolins in their area, just to confirm existence of the species in the study area. Information provided by the local people were verified by searching for and presence or absence within the plot was inferred based on both direct observations and indirect signs like foot prints, tracks, fecal matter, living burrows and foraging burrows (Akrim et al., 2017; Karawita et al., 2018; Mahmood et al., 2019) to assess the distribution and habitat utilization of pangolin. Living burrows were further divided into either active or inactive burrows. The number of active living burrows observed in transects was used to calculate the population density of the species in that area. The number of individual pangolins around each burrow was confirmed by observing species footprints or scats near each burrow during the field survey. For population density estimates, the following formula was used:

$$D = n/A$$

Where 'D' is population density, 'n' represents the number of active living burrows, and 'A' stands for the area sampled at each site. Then the total population of the Indian pangolin was estimated by extrapolating the density estimates over the whole district area as follows:

$$\text{Total pangolins} = \text{Density} \times \text{whole area of the district}$$

In total, we established 2400 survey plots randomly, and each independent plot within a grid was considered as a single occasion and was thoroughly searched during each field visit by a team of at least four people for pangolin signs, seeking help from two people serving in provincial wildlife department in the same study area, having knowledge about pangolin signs.

### *Habitat Suitability*

For habitat selection, different variables were considered in the plots such as vegetation cover, the presence of termites and ants colonies, and soil type (Mahmood et al., 2015; Akrim et al., 2017). During field surveys, the presence or absence of ants and termite colonies in each plot was also recorded. For vegetation cover, we recorded trees, shrubs and herbs and grasses in each plot, but we did not estimate their density or IVI (Importance Value Index), since Indian pangolin does not feed on vegetation. The habitat of the Indian pangolin was further stratified into three types; grassland, agricultural land, and forest land, based on the vegetation type. Data were also collected from local communities and relevant District Wildlife Department staff about occurrence of Indian pangolin in the study area, which was used to confirm the occurrence of pangolin and its field signs in the study area. In each sampling plot, we recorded direct field sightings, and indirect signs of Indian pangolin (including its feeding and living burrows, feces) and the geographical coordinates of the locations of direct and indirect signs of pangolin in all sampling plots were recorded using Global Positioning System (GPS), following Mahmood et al. (2015, 2019).

**Table 1** – List of bio-climatic variables for habitat suitability analysis of Indian pangolin in Mardan District..

| Code | Variable |
|---|---|
| | **Environmental variables** |
| BIO1 | Mean temperature |
| BIO2 | Mean Diurnal Range (Mean of monthly (max temp - min temp) |
| BIO3 | Isothermality (BIO2/BIO7) (×100) |
| BIO4 | Temperature Seasonality (standard deviation ×100) |
| BIO5 | Max Temperature of Warmest Month |
| BIO6 | Min Temperature of Coldest Month |
| BIO7 | Temperature Annual Range (BIO5-BIO6) |
| BIO8 | Mean Temperature of Wettest Quarter |
| BIO9 | Mean Temperature of Driest Quarter |
| BIO10 | Mean Temperature of Warmest Quarter |
| BIO11 | Mean Temperature of Coldest Quarter |
| BIO12 | Annual Precipitation |
| BIO13 | Precipitation of Wettest Month |
| BIO14 | Precipitation of Driest Month |
| BIO15 | Precipitation Seasonality (Coefficient of Variation) |
| BIO16 | Precipitation of Wettest Quarter |
| BIO17 | Precipitation of Driest Quarter |
| BIO18 | Precipitation of Warmest Quarter |
| BIO19 | Precipitation of Coldest Quarter |
| | **Habitat variables** |
| dem | Digital elevation model |
| glc 2000 | Global land cover |
| ndvi | Normalized Difference Vegetation Index |

To investigate the habitat suitability of Indian pangolin, MaxEnt software (Version 3.3.3) was used. Models were run with the following settings: a minimum of 20 % data were used for random test, and the maximum number of background points 2,177 were used to determine the MaxEnt distribution (background points and presence points), a maximum of 500 iterations, and 1.800 was the convergence threshold, hinge 0.500 and regularization values: linear/ quadratic/ product 0.442, categorical: 0.250. Covariates were used for soil type, presence of ants and termites, vegetation cover, habitat use NDVI, road distance, settlements and rivers, bioclimatic variables (https:/www.worldclim.org/data/bioclim.html) elevation, aspect, and slope. The covariates were one of the main reasons that could affect the spatial distribution and occurrence of the Indian pangolin in the study area. Feature types used were hinge linear quadratic.

The result of the MaxEnt model was measured using the "area under the receiver operating characteristics" training, (ROC) graph, test data, and (AUC) graph "area under the curve". Jackknife analysis was performed in MaxEnt to determine the contribution of each environmental variable and habitat to compute the habitat suitability of the Indian pangolin. In MaxEnt, Jackknifing represents the exact numbers of every habitat, and the ecological variable contributes to the exercise gain over when each model runs.

A logistic threshold value of the highest test specificity and sensitivity was used to classify the habitat suitability of Indian pangolin following Jimenez-Valverde and Lobo (2007), that is the area that is above the highest threshold value of the test sensitivity and specificity was categorized as the "most suitable habitat" of the Indian pangolin, while the area below the value was categorized as "unsuitable habitat" for the species.

### *Illegal Trade of Indian pangolin*

Data on illegal trade and poaching of Indian pangolins from the study area were collected using self-designed questionnaires. Given the criminal nature of this business (illegal trade of Indian pangolin), surveys were conducted with the help of teams of three persons visiting and interviewing local hunters, farmers, shopkeepers, District wildlife office staff, shepherds, and students at local schools, colleges, and universities, and also the different markets of the study area. A strategy for teams conducting the survey was devised to have a consistent procedure and method for collecting required information, as well as confirming safety protocols. The questionnaire-based survey was used to understand the volume of the traded animals (pangolins) and their sale, tendencies of pangolin trade, price of live animals and their derivatives (scales), various uses of the scales, availability status of pangolins as well as the people belonging to various aspects of life involved in this illegal trade. The length of each survey was two to three consecutive days.

### *Statistical Analysis*

We used MaxEnt (Version 3.3.3) software to analyze the habitat suitability of the Indian pangolin in the study area. Data on threats and illegal trade of Indian pangolin were analyzed using a chi-square test in SPSS (Statistical Package for Social Sciences) (18.0.2) software to check data statistically.

## Results

### Distribution and Population Estimation

A total of 22 field visits were made to the sampling sites during the study period till June 2022. Only three sampling sites were found positive for the occurrence of Indian pangolin in the study area with an elevational range between 338 to 399 m (Tab. 1). Within whole study area, a total of 75 km$^2$ areas were searched for Indian pangolin burrows and we recorded a total of 82 burrows. A total of n=34 active living burrows were observed, among them n=17 were recorded at Garyala, followed by Sudham (n=10) and Machi site (n=7). The average population density of Indian pangolins estimated at all sampling sites was 0.09 pangolins per km$^2$. However, a much greater number of feeding burrows were found at the three positive sites (Tab. 1). The total number of pangolins extrapolated over the whole Mardan District was 147 pangolins.

### Habitat suitability modeling

The results of MaxEnt revealed that out of total available area sampled 75 km$^2$, only 3.99 % habitat was the "highly suitable" habitat for the occurrence of Indian pangolin in Mardan District, followed by 8.77 % area that is "moderately suitable" habitat while remaining 87.23 |percent area falls under "less suitable" habitat for Indian pangolin (Fig. 2; Fig. 4). The habitat suitability computed through MaxEnt analysis using Arc GIS through map was based on how many survey grids fall into each habitat category. A suitable habitat was considered the one where pangolin population can thrive successively based on the covariates used in the analysis. A less suitable habitat was the one where pangolin population occurs but its field signs are less based on the covariates used. The unsuitable habitat is considered the one where MaxEnt analysis predicted that pangolin population has less chance to exist.

The jackknife test for assessing importance of environmental and habitat variables showed highest gain when precipitation was used in isolation (Fig. 5). Furthermore, land class variables were found to be decreasing gains that most when it is omitted from analysis representing that this variable has more information that other variables. Following precipitation, average temperature was found the second most important predicator variable as measured by the gain produced by a one variable model, followed by settlement, land class, slope and aspects (Fig. 5). Regularized training gain was 1.727, training AUG was 0.970, un-regularized training gain was 2.288 (Tab. S1; Fig. 3). Algorithm terminated after 500 iterations (2 seconds).

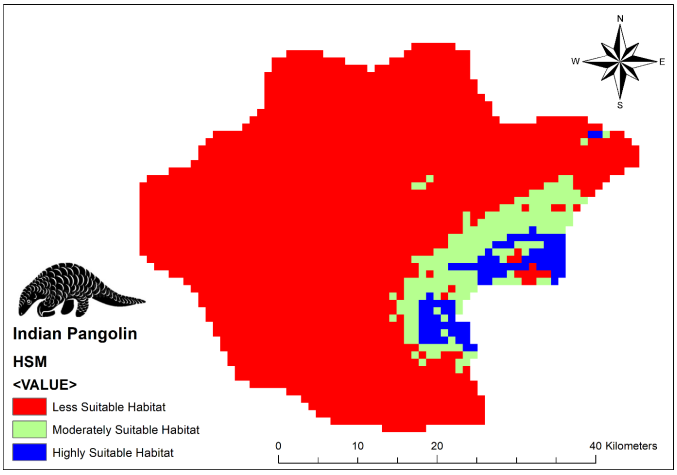


**Figure 2** – Habitat suitability map of Indian pangolin inhabiting Mardan District, computed through MaxEnt analysis.

A comparison of three different types of habitats where the Indian pangolin was recorded in the study area, forest was the more preferred/used habitat by the species as indicated by occurrence of its greater numbers of burrows (n=54; 65.8 %), followed by agricultural land habitat having less numbers of active burrows (n=20; 24.39 %), whereas grassland was used least (n=08; 9.75 %) by the species (Fig. 8).

### *Illegal Trade of Indian pangolin*

During questionnaire survey we interviewed a total of 133 respondents (from all five tehsils of Mardan District) for collecting information about poaching and illegal trade of Indian pangolin from the study area. Our respondents included local people from various work of life such as farmers, school and college students, shepherds, shopkeepers, and staff of wildlife department Mardan District, keeping in mind that, they are the people who are most likely to have encountered pangolin, its poaching, and its illegal trading. The perception of local people was found negative about the species because of the myths that Indian pangolin excavate graves and eats dead bodies of human, and it also damages crops by digging burrows in the fields.

The villagers had seen pangolins both within and outside of the hamlet and also in their immediate surroundings, and they believed that the population of the species had been declining for the previous ten years. According to the respondents, excessive killing and trapping of pangolin by local people or nomads is the major reason of the population decline. Habitat loss and changes in land use patterns were also the factors of the disappearance of pangolin (Fig. 6). Regarding different capturing techniques being used for hunting and poaching of Indian pangolin, about 10 % of respondents thought that trained hunting dogs could be used for capturing the species from the field, while other 6 % thought about using the method of tracking and 21 % of the respondents were of the opinion of using spotlighting are the major techniques for pangolin trapping, however, 63 % respondents did not respond. A Chi square test was used which showed that this difference was found statistically significant ($X^2$=14.34, df=1, p=0.000). According to 14 % of the respondents, the preferred season for capturing pangolin from the study area is summer when there is groundnut crop in the field, 26 % of the respondents were of the opinion that pangolin is captured at night time since the species comes out from the burrows at late evening and at night for foraging.

About capturing month, there were three different opinions, majority of respondents thought that pangolin is captured from July to September each year (13.53 %), followed by people who thought that pangolin is captured between January to April (12.78 %) each year, while approximately 7.5 % respondents thought that pangolin is captured between October to December. Similarly, majority of respondents were of the view point that summer is the best month to capture pangolin, followed by spring, autumn and winter, respectively (Fig. 7).

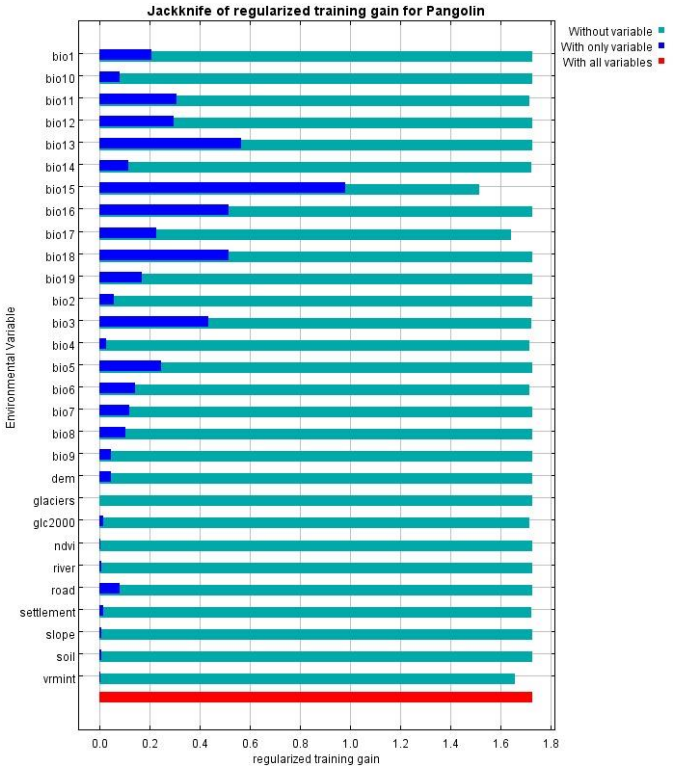


**Figure 3** – Model analysis of Jackknife test of Indian pangolin in the study area using different environmental and habitat variables
*Regularization values: linear/quadratic/product: 0.442, categorical: 0.250, threshold: 1.800, hinge: 0.500
Feature types used: hinge linear quadratic
Response curves: true
Jackknife: true.

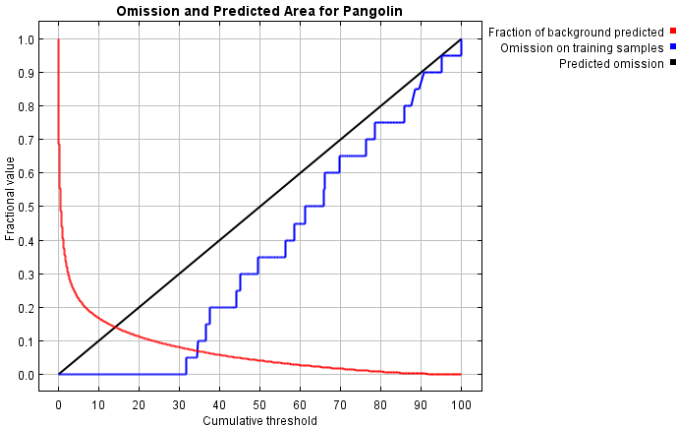


**Figure 4** – Habitat suitability map of Indian pangolin inhabiting Mardan District, computed through MaxEnt analysis.

We also asked about the specific point for selling and buying of the pangolins, 98 % of respondents were of the opinion that there is no specific point in the village where one can easily sell or buy the animal. This difference was statistically significant ($X^2$=59.23, df=2, p=0.000). However, majority of the animal stuff (selling as well as buying) had been transported from outside the village but majority of people showed no response because of the fear that they will be reported to wildlife authorities.

The data collected from the community through questionnaire survey revealed that the poachers and hunters live capture the pangolin and then kill it by putting into a large tank of boiling water or by throwing into a tank with boiled oil, then, typically skinning the dead body of the animal or peeling off the scales manually. Evidence collected also showed the involvement of nomads (gypsies) of the study area in capturing and selling of Indian pangolin on large scale. They are in direct contact with dealers (middleman) from Punjab province. It also revealed that pangolin scales were sold at the rate of Rs. 5000 per kg while live pangolin was purchased by the middleman at retailed for Rs.10000 per pangolin. Most individuals in the study area are unaware of the protected status of Indian pangolin, so they kill them to earn money, as poverty is another factor that forces individuals to do something like this illegal trade.

## Discussion

In Pakistan, Indian pangolin is protected under the Islamabad Wildlife (Protection, Preservation, Conservation, and Management) Ordinance, 1979 and Khyber Pakthunkhawa Province Wildlife (Protection, Preservation, Conservation, and Management) Act, 1975. It is included in the third schedule of Punjab Wildlife Act, 1974 (Amendment 2007). According to third schedule, it is protected throughout the year. The species is also included in the Appendix-I of the CITES since 2016, according to which any international trade of the species and its products (scales) is prohibited legally. Despite legislative protection provided to Indian pangolin in the country and also internationally, illegal exploitation and trade in pangolins and their body parts continue to occur in Pakistan, which is having a seemingly deleterious effect on pangolin populations. The current study showed that Indian pangolin is being hunted and killed for its keratinized scales, meat and trade purposes from its natural habitat and it is suspected that its population is declining rapidly which were supported by some past studies conducted by Mahmood et al. (2012); Roberts (1997) reported that the species has got a low reproductive output, in such scenario; it is pertinent to monitor regularly the distribution range and population of this unique insectivorous mammal in its natural habitat. Unluckily, the species has stayed neglected in the region regarding scientific investigation and so very little information (Roberts, 1997) exists about its habitat use and population estimates (IUCN, 2012). Here we investigated its habitat preference, and illegal trade of the species in Mardan district. According to Roberts (1997) the main reasons of the decline of the species are hunting, poaching and weak law enforcement; the major threats. In present research study most of the respondents thought that the population of pangolin was decreasing rapidly in their areas. Almost all respondents agreed that human were the prime cause to decline in population of pangolins. Illegal activities of human were major causes for its decline.

The findings of the current study showed that population of Indian pangolin is confined to certain sites in the Mardan District at relatively lower elevational range (338 m to 399 m) while no pangolins were recorded at elevation either lower or higher than these in the study district, this could be because of many factors, especially, the rocky type of soil unsuitable for digging burrows above this elevation. Frick (1968) and Mitchell (1975) had reported that *Manis pentadactyla,* another species of pangolin commonly known as Chinese pangolin, occurs in eastern Nepal and Bhutan at the foothills of the Himalayas, apparently confined to elevations below approximately 1.500 m in Nepal. Roberts (1997) reported that *Manis crassicaudata*, the Indian pangolins prefer unfertile mountainous ranges and subtropical forests. Pai (2008) also indicated several types of tropical forests where pangolin found, ranging from humid to dry and thorn to grassland. In current study we have found Indian pangolin distributed in the District Mardan have both plain areas and hilly regions. Roberts (1997) had reported Indian pangolin restricted in its distribution below 762 m. However, the same species (*Manis crassicaudata*) is found in elevations under 1524 meters in some Asian countries (Frick, 1968; Mitchell, 1975). The current study findings revealed very low mean population density of the species and also the population is skewed towards one side of the study district, with only three positive sampling sites while rest of the twelve sites samples being negative for occurrence of the species. Average population density was found to be 0.09 pangolins per km$^2$, which is extremely low. The density estimates of pangolins from some other parts of the country show relatively larger populations. For example, Mahmood et al. (2018) reported that the population density of Indian pangolin was 0.28 per km$^2$ in district Mansehra district (from 2015-2016) of Khyber Pakhtunkhwa

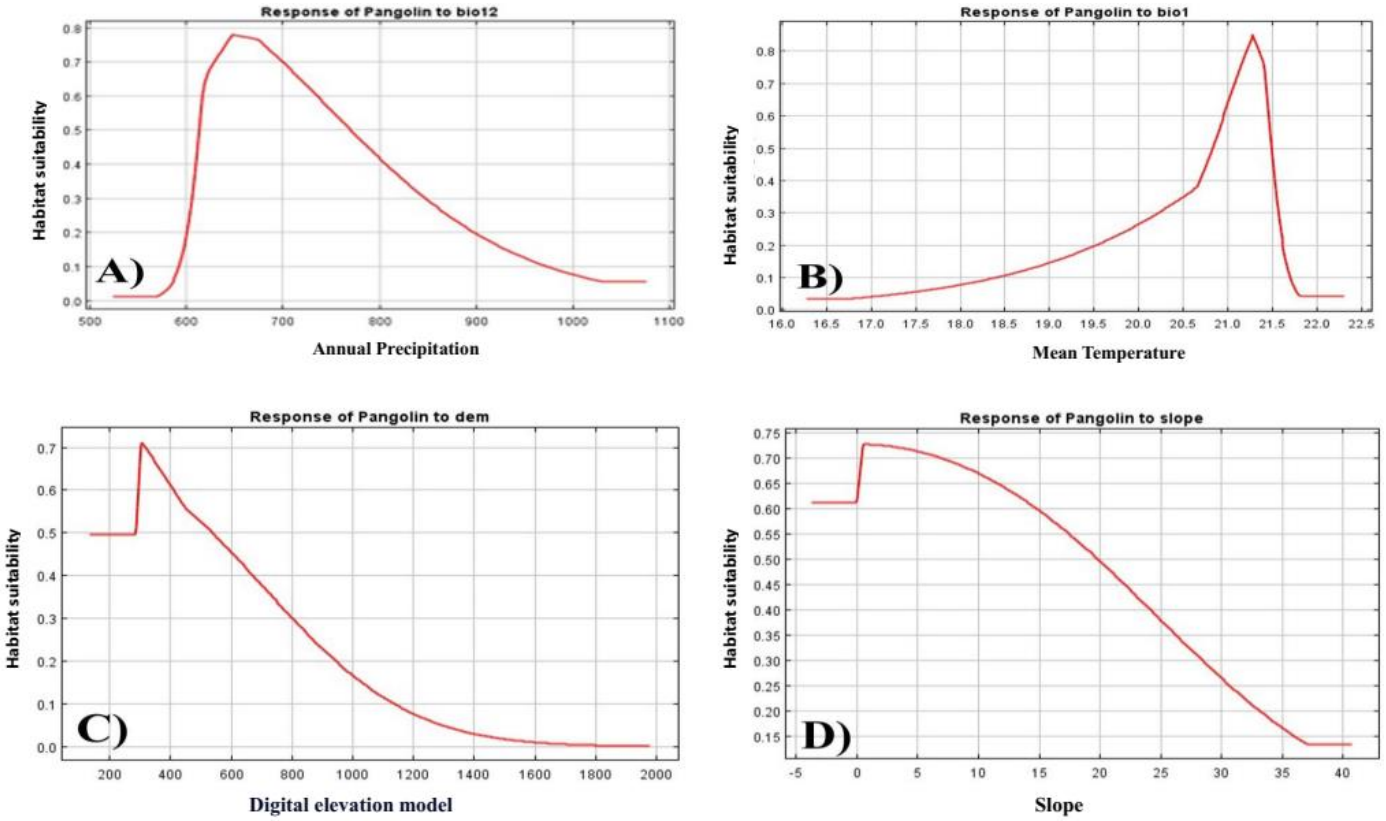


**Figure 5** – Graphs showing most important environmental and habitat variables affecting Indian pangolin distribution in Mardan District. A) Annual precipitation, B) Mean temperature, C) Elevation, D) Slope.

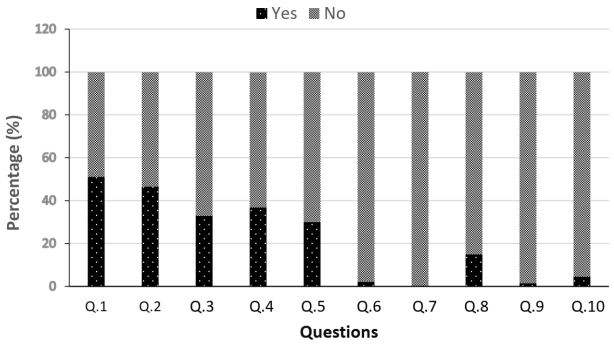


**Figure 6** – A stacked column chart showing percentage (%) of information by local people about Indian pangolin through questionnaires.

Q.1. Do you know about pangolin?
Q.2. Have you seen pangolin?
Q.3. Any particular site where pangolin is found whole year?
Q.4. Have you seen or captured a pangolin?
Q.5. Have you ever seen someone trapping a pangolin?
Q.6. Any local traditional technique used for capturing pangolin?
Q.7. Do you have knowledge about the authority responsible for conserving the Indian pangolin?
Q.8. Do you wish to conserve the Indian pangolin?
Q.9. Do you have knowledge about the conservation status of the species?
Q.10. Have you ever killed an Indian pangolin?

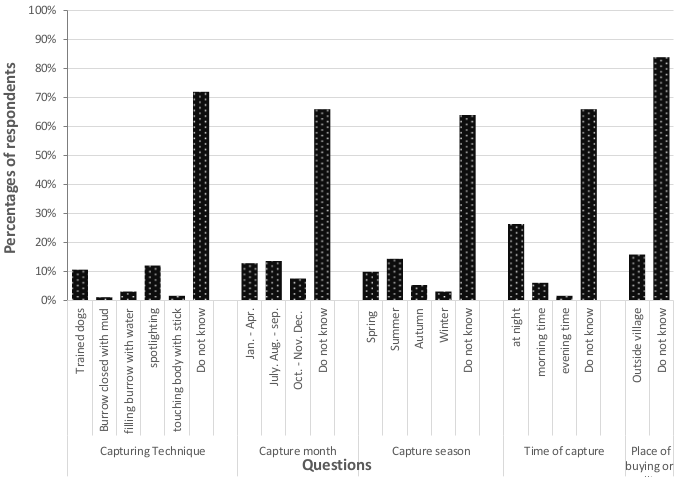


**Figure 7** – Response (%) of respondents to various questions about Indian pangolin poaching and illegal killings in Mardan District.

province. Akrim et al. (2017) reported the population of Indian pangolin was very low (0.77 individual/ km$^2$) in Pir Lasura national Park, Kotli, AJ&K, and also showed that during the years from 2013 to 2015, a total of 446 pangolins were illegally killed or hunted. Similarly, Mahmood et al. (2015) had reported a population density of 0.36 pangolins per km$^2$ in the Margalla Hills National Park Islamabad.

Our results also confirm the observations of Mahmood et al. (2013) that the Indian pangolin digs out two types of burrows i.e. feeding burrows and resting burrows. Resting burrows were much deeper and often associated with rock boulders or dug underneath rocks. This strategy may allow extended excavation of the resting burrow without the risk of collapsing due to the lower shear strength of wet soils under frequent rainy conditions in tropical lowland rainforest habitats (Karawita et al., 2018). Studying the burrow characteristics of Indian pangolins in the Potohar region of Pakistan, Mahmood et al. (2013) reported that resting burrows tend to be associated with buttresses and roots of several tree species. However, these observations were made in areas with less-dense vegetation under arid climatic conditions. Despite the presence of large trees with well-formed buttresses, the Indian pangolins seem to favor rocky substrates to dig their resting burrows in tropical wet forests (Pabasara et al., 2015). In this study, we observed the fresh burrows of the species that were distinguished from the old ones, due to presence of fresh soil around the burrow opening as well as activity signs of the species. However, we cannot realistically infer that a pangolin population is good based on these numbers of burrows since

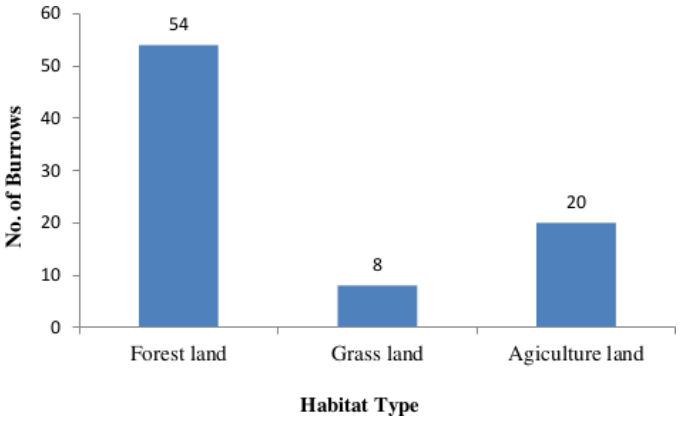


**Figure 8** – Burrows of Indian pangolin (*Manis crassicaudata*) recorded in three different habitats in the study area.

**Figure 9** – The Indian pangolin observed in the field, rolls up into a ball and exposing its hard scales as protection.

some pangolin individuals are known to use a burrow for one night and then move to another. Therefore, more than one burrow could merely represent one animal in some cases. But we generally consider that one single permanent active living burrow corresponds to one pangolin individual as previously mentioned by Mahmood et al. (2015); Roberts (1997). However, relying on sign detection in this way may result in overestimations (Wilcox et al., 2019). Karawita et al. (2018) recorded the depth of a resting burrow can exceed 250 cm. This possibly allows greater protection from predators (major threat was imposed by humans and domestic dogs) during the daytime while the pangolin is resting (Karawita et al., 2016). In arid habitats of Chakwal District of Potohar Plateau, Pakistan; Mahmood et al. (2014) recorded an average resting burrow depth of 143 cm, which is significantly shallower.

In the current study, we recorded evidence of pangolin occurrence in three different types of habitats in the study area; viz. natural forests, agricultural land and the grassland. Results have indicated that the natural forest land is the preferred habitat of pangolin. This preference indicates that compared to grassland and agricultural land, more cover might be available to pangolin for refuge and protection. The occurrence of pangolin in various types of tropical forests as well as open land, grasslands and degraded habitat, including in close proximity to villages (Zoological Survey of India, 2002) has already been established. The preference of forest habitat by Indian pangolin is logical, a natural phenomenon in context of cover and protection against poaching and illegal killing of the Indian pangolin in the study area. The main reason behind this very low population of the Indian pangolin in the Mardan district of Khyber Pakhtunkhwa province seems to be the poaching and illegal hunting of the species. The data collected from the local community through questionnaire survey have revealed strong evidence indicating the continuous decline in pangolin population in the study area. The local residents have reported that Indian pangolin is being poached for the last ten years, the species is captured from the natural areas outside the villages, by the local hunters and nomads, and sold to some middleman, and this practice is still continued. They are also of the view that these poachers capture pangolins at night- time when the species comes out of its burrows for foraging. They also force the pangolin to come out of its burrow by putting water into it, or by closing the burrow opening. The local community also reported that pangolin poaching is enhanced in summer season, although the species is captured from January to April and July to December each year. The local hunters sell the captured pangolins at nominal rates since they are unaware of its cost of scales in the international market. Similar findings were earlier on reported by Mahmood et al. (2019) that a total of 412 pangolins were illegally hunted between 2011 to 2013 from the Potohar Plateau. Waseem et al. (2020) reported from the Potohar Plateau that that poachers use spotlight and tracking techniques to capture pangolin in the field. The local community in Mardan district was found unaware of the protected status of the Indian pangolin in the country and this is the duty of the district wildlife department to create awareness among the local community about the species, its ecological importance, threats, and its conservation measures to be taken. Obviously, the involvement of local community is pertinent for pangolin conservation in the study area.

The illegal killing and trade of Indian pangolin has got a history in the country. It was previously reported by Mahmood et al. (2012) that massive illegal hunting and killing of the species was occurring in the Potohar Plateau. In scenario of declining population of Indian pangolin in the country (Mahmood et al., 2014; Irshad et al., 2015), it is pertinent to assess the habitat suitability of the species in the areas where it occurs. Unsustainable development of rural roads has posed additional threats to the species. Unsustainable harvesting of forest resources, such as firewood, timber and non-timber forest products continues to exert pressure on the habitat, disturb the animals and increase possibilities of poaching. Fodder and litter collection, grazing and trampling by domestic livestock, and uncontrolled wildfire have adverse impacts on the species as well as their habitats. Mahmood et al. (2012) had reported that in Pakistan the live animal is sold by the local community at a price of Rs. 10,000-15,000 per animal (US$ 163 to 108 per animal), local people helping them and receive some money from these hunters/poachers. Previous studies (e.g. Mahmood et al., 2012) have highlighted the illegal trade and killing of Indian pangolins in Pakistan and the smuggling of their scales into China via Hong Kong and perhaps Singapore. In April 2012 information was reported (GACC, 2012)) on a seizure in China of 25.4 kg of pangolin scales that were apparently sourced from Pakistan, where illegal smuggling is facilitated by weak law enforcement (Mahmood et al., 2019). This is partly because these species are widely distributed geographically, making it difficult to quantify hunting and poaching activities, localities and associated trends, and because illegal trade in pangolins is characteristically clandestine. There are no reports of consumption of pangolin meat in Pakistan, and the limited local trade in pangolin scales does not account for the large number of pangolins killed. Thus we conclude that the high level of poaching is driven by demand for the international trade. To reduce poaching of the Indian pangolin and protect the population we recommend increasing the patrol and enforcement efforts and increasing the penalties for poaching to conserve its remaining population.

## Conclusion and Recommendation

The current study concludes that Indian pangolin was recorded at only three sampling sites in Mardan district, the remaining twelve sites were found negative regarding its occurrences. Average population density of the species was found 0.09 per $km^2$ in the study area. Only 3.9 % of the total available habitat is most suitable for pangolin existence, followed by 8.7 % less suitable habitat while approximately 87 % habitat is unsuitable for pangolin occurrence in the Mardan district. Growing concerns over population declines due to poaching and trafficking have emphasized the need for more concerted conservation efforts for the species. It is recommended that immediate action must be taken to protect and conserve the species through stronger enforcement measures to curb poaching and illegal wildlife trade. Working with indigenous people and local communities living near the study area to develop community-led initiatives to protect pangolins could be a valu-

able conservation strategy. Additionally, educating and raising public awareness about the importance of pangolin conservation and the threats facing the species could help to reduce human-induced impacts on the species and their habitat. These measures could be critical for ensuring the long-term survival of Indian pangolins in the Mardan District, Pakistan. Based on the findings, it can be concluded that the suitable habitat for Indian pangolins in the Mardan District is limited and strongly influenced by several environmental and habitat factors, particularly precipitation, average temperature, elevation, and slope.

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## Supplemental information

Additional Supplemental Information may be found in the online version of this article:

**Table S1** Geographical locations of the study area.

**Supplement S2** Questionnaire used in a study.