Distribution and Habitat Preference of Chinese Pangolin (*Manis pentadactyla*) in Godavari Forest, Lalitpur, Nepal

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Submitted to

Central Department of Zoology

Tribhuvan University

Kirtipur, Kathmandu, Nepal

May 2023

DECLARATION

I hereby declare that the work presented in this thesis "**Distribution and Habitat Preference of Chinese Pangolin (*Manis pentadactyla*) in Godavari Forest, Lalitpur, Nepal"** has been done by myself and has not been submitted elsewhere for the award of any degree. All sources of information have been acknowledged by reference to the authors or institutions.

Date: 04 May 2023

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This is to certify that **Ms. Bijeeta Kunwar** has finished this dissertation work entitled **"Distribution and Habitat Preference of Chinese Pangolin (*Manis pentadactyla*) in Godavari Forest, Lalitpur, Nepal"** as a partial fulfillment of the requirement of Master's Degree with special paper Ecology and Environment. This work has been conducted under my supervision and guidance. To my best of my knowledge this research has not been submitted elsewhere for any other degree, anywhere. Therefore, I recommend the dissertation for acceptance and approval

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LETTER OF APPROVAL

On the recommendation of supervisor "Dr. Laxman Khanal" this dissertation submitted by "**Ms. Bijeeta Kunwar**" entitled "**Distribution and Habitat Preference of Chinese Pangolin (*Manis pentadactyla*) in Godavari Forest, Lalitpur, Nepal**" has been approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements of M.Sc. Degree of science and Zoology with special paper Ecology and Environment.

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LETTER OF ACCEPTANCE

This dissertation entitled "**Distribution and Habitat Preference of Chinese Pangolin (*Manis pentadactyla*) in Godavari Forest, Lalitpur, Nepal**" submitted by "**Ms. Bijeeta Kunwar**" has been examined and accepted as a partial fulfilment of the requirements of M.Sc. Degree of science and Zoology with special paper Ecology and Environment.

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ABBREVIATIONS

DBH	Diameter at Breast Height
GPS	Global Positioning System.
IVI	Importance value Index
RD	Relative Density
RF	Relative Frequency
CF	Community Forest
IUCN	International Union for Conservation of Nature.

ABSTRACT

Chinese pangolin (*Manis pentadactyla*) is a burrowing, nocturnal animal. It is listed as critically endangered in the IUCN Red List of Threatened Species because of rapid decrease in population and distribution range. This study was conducted to find out distribution of Chinese pangolin and its determining habitat factors in the Godavari Forest, Lalitpur, Nepal. Field explorations were carried out in Kunda Community Forest and Naudhara Community Forest of Godavari Municipality, Lalitpur. Line transect method was used to assess distribution and habitat preference of Chinese pangolin. A total of 20 line transects each of 300 m length having 100 survey plots were established to record presence of Chinese pangolin and their burrows. The burrows were categorized into new burrows and old burrows. Habitat variables including elevation, slope, ground cover, canopy cover, soil colour, aspect, nearest distance to ant nest, distance to termite colonies, distance to human settlement, distance to road, distance to water source were recorded in each surveyed plot. Altogether 74 burrows were reported from 43 plots out of 100 surveyed plots. Chinese pangolin burrows showed a clumped distribution pattern in the Community Forest. The burrows were observed at the elevation range from 1578 to 1844m, where the most preferred elevation range was 1500–1600m. Mostly burrows found to prefer in south–west aspect having canopy cover 75–100%, in 20–30° slope. The red coloured soil was much preferred for digging burrows. Higher preference of the burrows was found within 10m distance to ant nest and termite colonies.

1. INTRODUCTION

1.1 Background of the study

Pangolins belong to the Manidae family under the order Pholidota (Marler 2016). There are eight extant species of pangolins reported worldwide (Lim & Ng 2008). Among the eight species, four species are found in Africa and found in Asia (Heinrich et al. 2016). The Chinese pangolin and Indian pangolin are found in Nepal (DNPWC & DoF 2018). A national survey conducted in 2016 revealed that Chinese pangolin were distributed in 25 districts while Indian pangolin was distributed in 7 districts (DNPWC & DoF 2018). Besides Nepal, it is distributed in Asian countries including Bangladesh, Bhutan, China, Hong Kong, India, Lao People's Democratic Republic, Myanmar, Taiwan, Thailand, and Vietnam (Challender et al. 2019).

Pangolins are in the high risk of extinction in their natural home range mainly due to illegal hunting and poaching (Mohopatra et al. 2015, Zhang et al. 2017). The reason behind the illegal hunting and poaching of pangolin scales, meat, bile even nails were use as medicine, jewellery etc (Katuwal et al. 2015, Soewu and Adekanola 2011, Wang et al. 2020). Therefore, the IUCN Red List of Threatened Species listed the Chinese pangolin as critically endangered species, on Appendix I (Challender et al. 2019).

The Chinese pangolin has been reported in protected areas and nonprotected area of Nepal. It is found within protected area including Chitwan National Park, Langtang National Park, Makalu Barun National park, Parsa National Park, Shivapuri Nagarjun National Park, and Annapurna, Gaurishankar, Kangchenjunga Conservation areas (Khatiwada et al. 2020, Sharma et al. 2020). In Nepal, the Chinese pangolin highly occurrence elevation range was 1500–1844m (Suwal et al. 2020). Although, in Taplejung district highest occurrence range was found to be 3000m from sea level (Wu et al. 2020).

The Chinese pangolin is an intermediate between the Indian pangolin and the Malayan pangolin but presence of large size pinna and postanal glandular depression in the male makes it of distinguishable from them (Pocock 1924). The Chinese pangolin scales are dark brown or yellow brown, a body structure is streamlined, absence of teeth, the tongue is 16–40cm long which they use to lap their food and the scales are mainly composed of protein containing keratin (Heath 1992).

It is a small, non-aggressive and slowly moving species and has a poor defence mechanism. They remain active at night, comes out from burrow to forage insects and in the daytime spend they remain inside (Pocock 1924, Heath 1992, Tong et al. 2000). The pangolins have a low rate of reproduction (Lim & Ng 2008). Their scales have the ability to anti-adherence against the soil (Tong et al. 2000). The Chinese pangolin digs a burrows for resting as well as for the feeding (Dorji et al. 2020). They dig burrow with the aid of front leg and by sticking tail into ground while digging they move their body side by side as they dig, soil deposit towards the entrance of burrow (Heath 1992). Burrows play an important role in the pangolin's life which they use to stay, prevent from predators and protect from extreme weather conditions without burrows they cannot live (Liu & Xu 1981, Bao et al. 2013).

Pangolins have ability to adapt to a variety of habitats across their geographic range (Karawita et al. 2018). The Chinese pangolins prefer to live in various habitat including in primary forest, secondary forest, bamboo forest, limestone, mixed coniferous forest, broadleaf forest, grasslands area and even agricultural fields (Gurung 1996, Wu et al. 2020). The burrows location used by pangolins at the different seasons reveals that the habitat choice is affected by the environmental factors (Wu et al. 2003). Habitat characteristics such as elevation, canopy cover, slope, aspects, water distance, distance to agricultural land, distance from the human settlements and food availability influence in distribution of the pangolins (Wu et al. 2003, Karawita et al. 2018, Dorji et al. 2020). In Nepal, few studies have been conducted about population status, habitat preference, distribution (Gurung 1996, Katuwal et al. 2017, Acharya et al. 2018, Dhital et al. 2020, Dhami et al. 2023). There are still information gaps in our knowledge regarding the distribution and habitat preference by the Chinese pangolin (DNPWC & DoF 2018). Identification of geographic location, suitable habitat and prospective distribution are the essentials of preservation of the species (Johnson et al. 2004). Hence, this study helps to provide some information on distribution and habitat preference of Chinese pangolin.

1.2 Research objectives

1.2.1 General objective

The general objective of the study was to determine distribution and habitat preference of Chinese pangolin in the Godavari Forest, Lalitpur, Nepal.

1.2.2 Specific objectives

i. To determine the distribution pattern of Chinese pangolin in the study area.

ii. To assess the habitat factors that affect the distribution of Chinese pangolin.

1.3 Rationale of the study

In Nepal, the Chinese pangolins are found in both protected areas and outside of protected areas, the information with respect to presence data of pangolin more in outside of protected areas (Khatiwada et al. 2019). Few studies have been conducted on distribution and habitat preference of pangolin in our country (Acharya et al. 2018, Katuwal et al. 2017, Panta et al. 2023, Suwal et al. 2020) and in current study area the distribution and habitat preference it is still not known yet. For the conservation of it, the baseline knowledge about its habitat preferences and distribution is require**.** Thus, this study helps to fulfil the knowledge gap regarding the habitat preference and distribution in the study area. Additionally, it provides baseline data for the conservation and management of pangolin.

2. LITERATURE REVIEW

2.1 Distribution pattern of Chinese pangolins

Globally, the Chinese pangolin are distributed in eastern to southern regions of Asia (Challender et al. 2019). In Nepal, Chinese pangolin is distributed widely across eastern to western parts (Suwal et al. 2020). The distribution of Chinese pangolins affects by habitat factors (Katuwal et al. 2017, Acharya et al. 2018, Dhital et al. 2020, Dhami et al. 2023).

The habitat factors such as presence of high abundance of food resource, water source and similar type of vegetation might result in the clumped distribution pattern of Chinese pangolin (Dhami et al. 2023). In Bunkot and Namjumg of Gorkha districts the clumped distribution pattern of pangolin burrows in the absence of other ecological parameters reported by (Panta et al. 2023). The non–uniform pattern of distribution of pangolin was reported in Nagarjun Forest of Shivapuri Nagarjun National Park (Bhandari & Chalise 2014).

2.2 Habitat factors that of affect in the distribution of Chinese pangolin

The Chinese pangolin can withstand some degree of disturbance which found to prefer to live in primary and secondary tropical and subtropical rainforest, bamboo forest, limestone forest, low mountain or hill forest elevation range from 400–500m, mixed coniferous and broadleaf forest (Gurung 1996, Wu et al. 2020).

In Samste district, Bhutan, the Chinese pangolin inhibit in agricultural land, warm broadleaved forest and cold broad−leaved forest. Habitat factors such as, aspects, soil colour, food presence, water presence and elevation were the main factors that affects in the distribution (Dorji et al. 2020). The new distribution of Chinese pangolin in cardamom cultivation area during winter season in Bhutan (Kinley et al. 2018). According to Wu et al. (2003), the Chinese pangolin inhibits in evergreen broadleaf, mixed coniferous and broadleaf forest and shrub forest prefer 30−60° slope, 760−1500m elevation and medium 31−70% of the canopy cover in Dawuling Natural Reserve, China. In Bangladesh this species recorded from Lawachara National Park having semi−evergreen forest where high level of disturbed sites in the forest due to patchwork plantation and from Chittagong Hill tracts consisting mixed evergreen forest, bamboo forest, primary and secondary evergreen forests and disturbed sites (Trageser et al. 2017).

The burrows of the Chinese pangolin distributed from 1126–2406m elevation range in Taplejung, Eastern Nepal (Thapa et al. 2014). The burrows number were found higher in between 1400–1500m elevation range in nine Community Forests of Balthali village where preferred canopy cover was 31–75%, near to the water source (Shrestha et al. 2021). A total of 348 burrows were recorded in Mahabharat CF and Chure CF of Sinduli district. Maximum burrows were encountered in between 1400–1700m elevation range with 30–40°slope preferred, mainly in *Schima wallichii* and *Shorea robusta* dominant forest (Timsina & Baral 2021).

Katuwal et al. (2017) carried out study in protected areas and non–protected areas of Nepal. They found the burrows from agricultural area, forest areas. The suitable elevation range was 555–1740m with closed canopy cover. However, with forest fire and livestock grazing shows the negative relationship. Panta et al. (2023) recorded 124 burrows of which 86 were old and 38 were new in Shahid Lakhan Rural Municipality of Gorkha district. The highest percentage frequency of occurrence of burrows occurred between 650– 800 m asl, in areas with a south facing aspect, red soil with moderate canopy cover and gentle terrain.

In Gorkha district, 141 active burrows were found mainly distributed in the dense cover forest dominanted by *Castanopsis indica, Schima wallichii, Shorea robusta, Clerodendron infortunatum* and *Nepherolepis auriculata.* Most of the burrow were located from 450–750m elevation facing toward the North–west or South–east aspect (Dhami et al. 2023).

In Amritdharapani Community Forest of Chitwan, total 39 burrows were recorded where burrows were found in 51–75% of canopy cover having 15–20° slope (Shrestha et al. 2021). The species inhabited in *Castonopsis tribuloides, Schima wallichii, Betula alnoides* and *Castonopsis indica* dominant forest with brown colour soil in North–west aspect and altogether 235 burrows were found where most of the burrows were in 1450–1550m elevation range in Nagarjun Forest (Bhandari & Chalise 2014). The burrows were majorly detected near to prey species abundant area in Shivapuri Nagarjung forest (Dhital et al. 2020). Few studies have been carried out related with habitat and distribution of Chinese pangolin. In my study area, no study has been carried out. So, this study is carried out to fulfil the gap of research regards with distribution and habitat preference of Chinese pangolin.

3. MATERIALS AND METHODS

3.1 Study area

This study was conducted in two Community Forests of Godavari Forest. The Naudhara Community Forest and Kunda Community Forest (27°60'15.73" to 27°58'00.46"N and 85°39'74.41" to 85°37'97.47"E) located in the south–east part of Kathmandu in Godavari Municipality. The highest peak Phulchoki (2782m), is popular for hiking and wild flora and faunal diversity is also located in Godavari Forest (Khanal et al. 2015). The Naudhara Community Forest covers 1.74 km^2 of area. While Kunda Community Forest covers 1.47 km^2 of area.

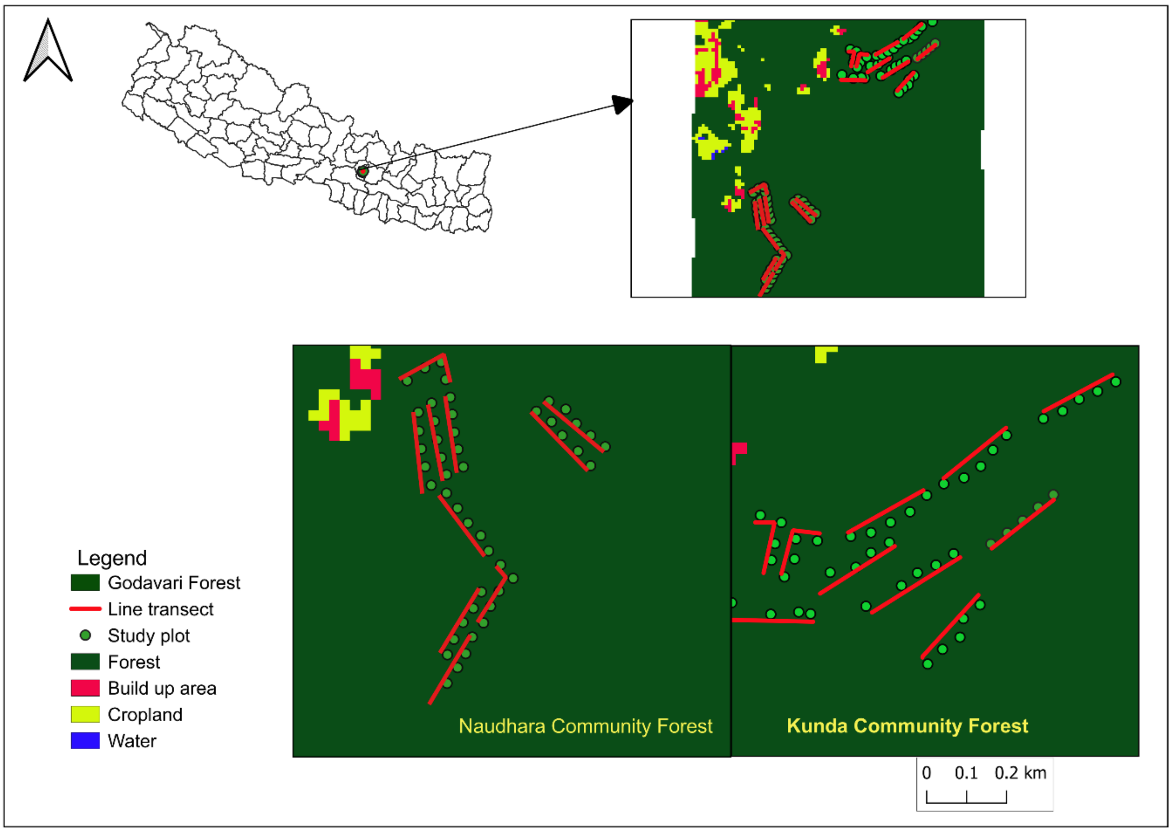

Figure 1. Map of the study area showing established line transect.

The forests comprise major wild animals including yellow-throated marten (*Martes flavigula*), Chinese pangolin *(Manis pentadactyla)*, leopard (*Panthera pardus*), barking deer (*Muntiacus vaginalis*), wild boar (*Sus scrofa*). The forest major vegetation comprises Indian chestnut *(Castanopsis indica*), rhododendron *(Rhododendron arboreum)*, chinkapin *(Castanopsis tribuloids*), needlewood *(Schima wallichi*).

3.2 Materials used

- Measuring tape
- DBH tape
- GPS: Garmin Etrex 10
- Clinometer (Mobile application)
- Canopy Capture (Mobile application)
- GLAMA application (Mobile application)
- Digital compass (Mobile application).

3.3 Method

3.3.1 Data collection

The study was conducted from October 24 to 30 December 2022. To identify the potential distribution site of pangolin consultation with locals, forest community group staff, as well as with Division Forest office was done. After that the two Community Forest the Kunda Community Forest and the Naudhara Community Forest were selected based on the information provided.

3.3.2 Line transect method

The line transect method was used following (Tamang et al. 2022). In each Community Forest, 10 transects each of 300m length were established having a total 20 transects. The first transect was laid at the point of burrow encountered. In each transect the five $10 \times 10m^2$ plots were laid at every 50m interval distance. The burrow presence or absence and habitat parameters were recorded in each plot. The burrow was classified in two types: old burrow and new burrow. If a burrow had presence of compacted soil with spider web, and presence of dead leaves, it was classified as old burrow, while the new burrow had presence of loose soil, recently dug soil with absence of spider web, fresh footmarks, no dead leaves (DNPWC 2019). Elevation, soil colour, slope, aspects, canopy cover, ground cover, distance to ant nest, distance to termite colonies present around also the distance to the nearest water source, distance to nearest road and settlements were recorded at each plot. The elevation was recorded from the centre of the plot with GPS. The slope was recorded from the centre of the plot with the mobile application Clinometer. The aspect was recorded from the centre of the plot with the mobile application Digital Compass. The visual estimation was done for the soil colour. The canopy cover was measured by averaging the four–corner value of the plot and the centre value with mobile application Canopy Capture. The ground cover was measured by averaging the four–corner value of the plot and the centre value with GLAMA mobile application. The nearest distance to ant and termite was measured from the centre of the plot with the help of 50m long measuring tape. The nearest distance to road, water source and human settlement were measured using google earth pro. The individual's tree was counted and dbh >10cm of each tree was measured in each plot following (Schemnitz 1980).

3.3 Data analysis

3.3.1 Distribution pattern of burrows

The ratio of variance to mean $\left(S^2/a\right)$ was calculated to determine the distribution pattern of burrows of the Chinese pangolin in the study area (Odum 1971).

$S^2 = \frac{1}{n}\sum(x-a)^2$ where,

x= Sample value and a= mean value.

$\left(S^2/a\right)$ =1, denoted distribution pattern is random. $\left(S^2/a\right)$ <1, indicate uniform pattern of distribution and $\left(S^2/a\right)$ >1, indicate the distribution pattern is clumped.

3.3.2 Distribution of Chinese pangolin burrows based on habitat features

Chi-square test was performed to find out the significant difference between distribution of burrows and elevation, canopy cover, slope, aspect, ground cover, soil colour, nearest distance to ant nest, distance to termite, distance to water and distance to human settlements.

3.3.3 Habitat factors affecting the burrow distribution

Both old burrows and new burrows were included in the analysis as both burrows served as the indicator of the presence of pangolin. To determine the habitat factors influencing the Chinese pangolin a binominal distribution model with logit link function (logistic regression) was used following (Dhami et al. 2023). For the selection of independent variables multicollinearity was done to ensure that selected independent variables of data were not highly correlated with each other, which might cause problems with model and interpretation of the results. There was no strong correlation between the independent variables (Figure 2). Therefore all nine independent variables were used in the model were elevation, slope, distance to nearest ant nest, distance to nearest termite colonies, distance to nearest road, distance to nearest water source, distance to nearest human settlement, ground cover and canopy while the dependent variable was used as burrows presence and absence with a value "1" denoted presence of burrows while "0'' denoted absence of burrow and the family of the model was binomial and the link function was logit. All analysis tests were performed in R studio and Excel was used for making graphs and a map of study area was prepared in QGIS.

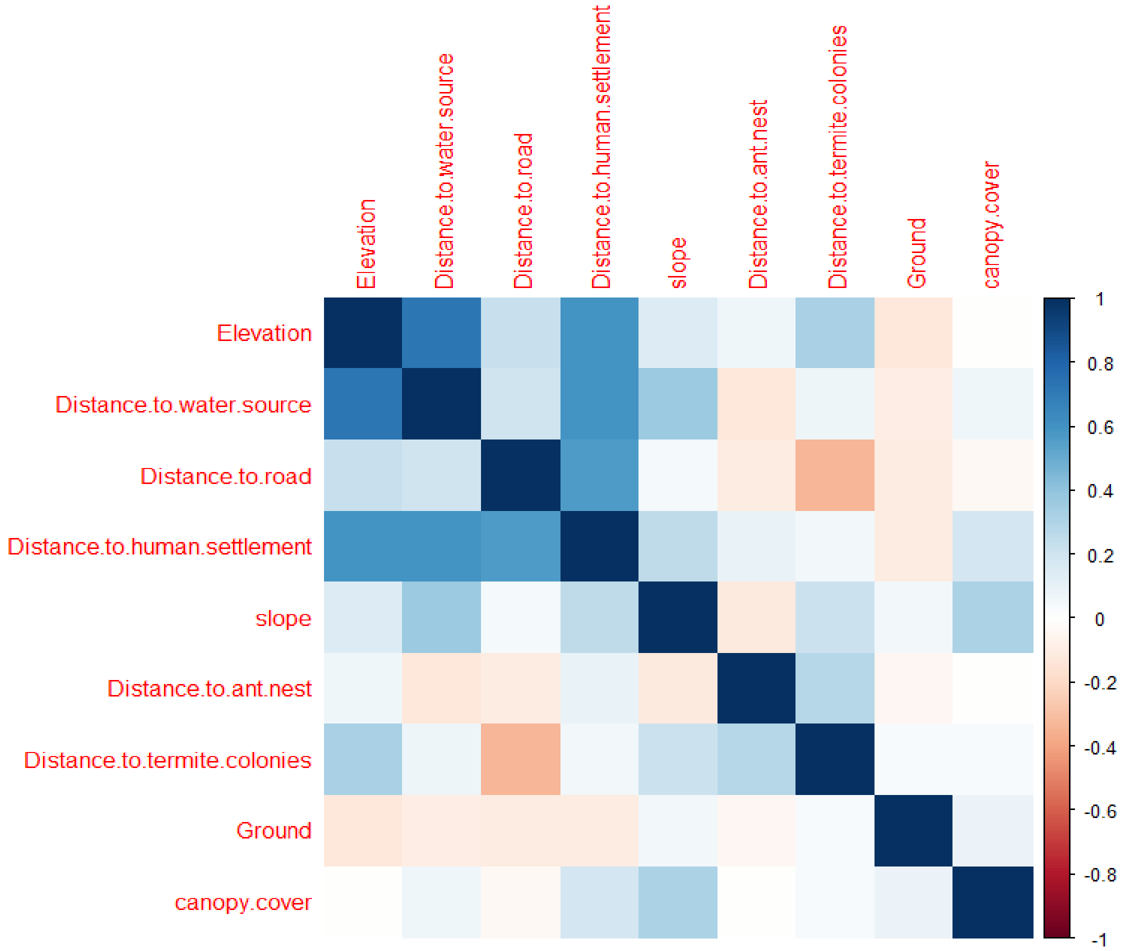

Figure 2. Correlation matrix representing the relationship between the independent variables

3.3.4 Vegetation analysis

The vegetation analysis was done by following (Curtis 1959). Chi-square test was performed to find out the significant difference between tree species and burrow.

Relative frequency (%) = $\frac{\text{Number of quadrat in which a species occur}}{\text{Total number of all species in quadrat}} \times 100$

Relative Density (%) = $\frac{\text{Number of individuals of species}}{\text{Total number individuals of all species}} \times 100$

Relative Dominance (%) = $\frac{\text{Total basal area of a species}}{\text{Total basal area of all species}} \times 100$

Where,

basal area= $\pi d^2/_4$

IVI = Relative Frequency + Relative Density + Relative Dominance.

4. RESULTS

4.1 Chinese pangolin burrow distribution pattern

The presence of pangolin was observed in 43 survey plots out of 100 plots. Altogether 74 burrows, 68% (n=51) old burrows while 31.08% (n=23) new burrows of the Chinese pangolin were recorded in the study area (Table 1). The maximum number of burrows were found in the Kunda Community Forest compared with in the Naudhara Community Forest. The value of the variance to mean was 1.52, greater than 1 so, the distribution pattern of the Chinese pangolin burrow was clumped (Figure 3).

Table 1. The number of burrows and their types found in two community

Community Forest	Old burrows (n)	New burrows (n)
Kunda Community Forest	29	22
Naudhara Community Forest	22	1

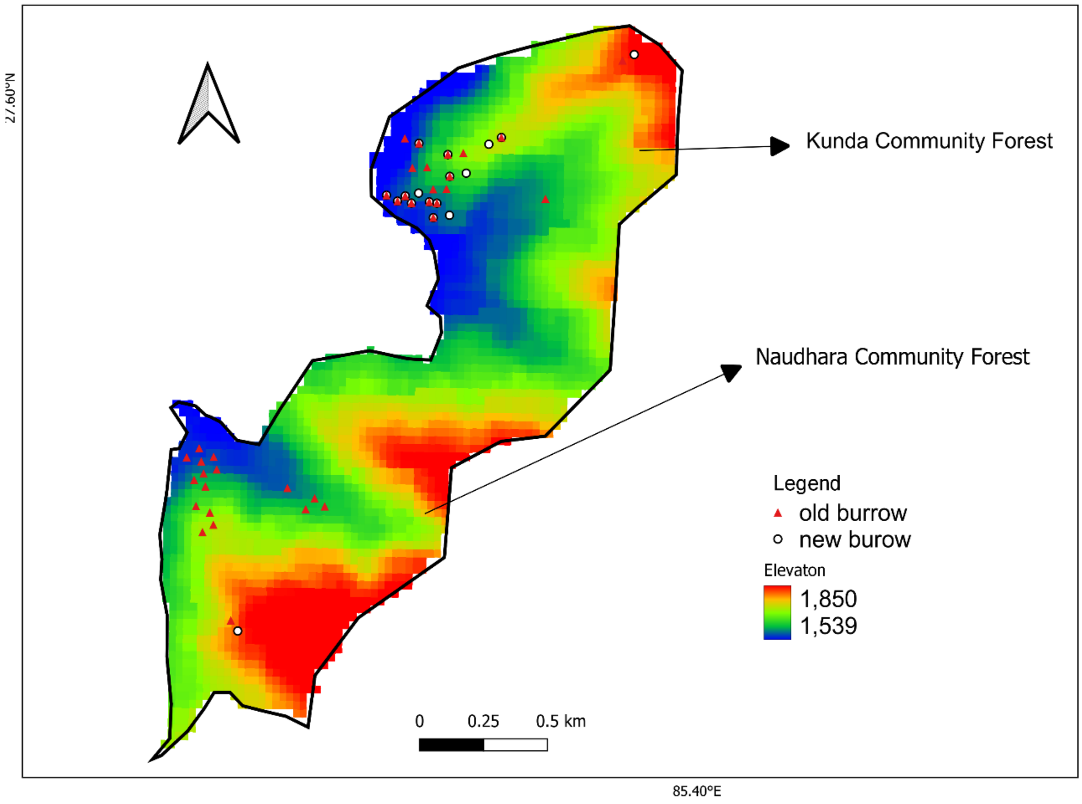

Figure 3. Distribution pattern of burrows in Kunda CF and Naudhra CF.

4.2 Distribution of Chinese pangolin burrows based on habitat features

4.2.1 Topography (elevation, slope and aspect)

The pangolin burrows were distributed from 1578m to 1844m elevation range. The highest frequency of the burrows was found in the 1600–1700m elevation range where 67% (n=50) out of which 37 were old and 13 were new burrows. While least burrows with 5.4% (n=4, old=2, new=2) were recorded at the 1800–1900m elevation range (Figure 4). It was found that the number of burrows differed significantly among the four elevation range categories ($\chi2=72.919$, df=3, $p<0.05$).

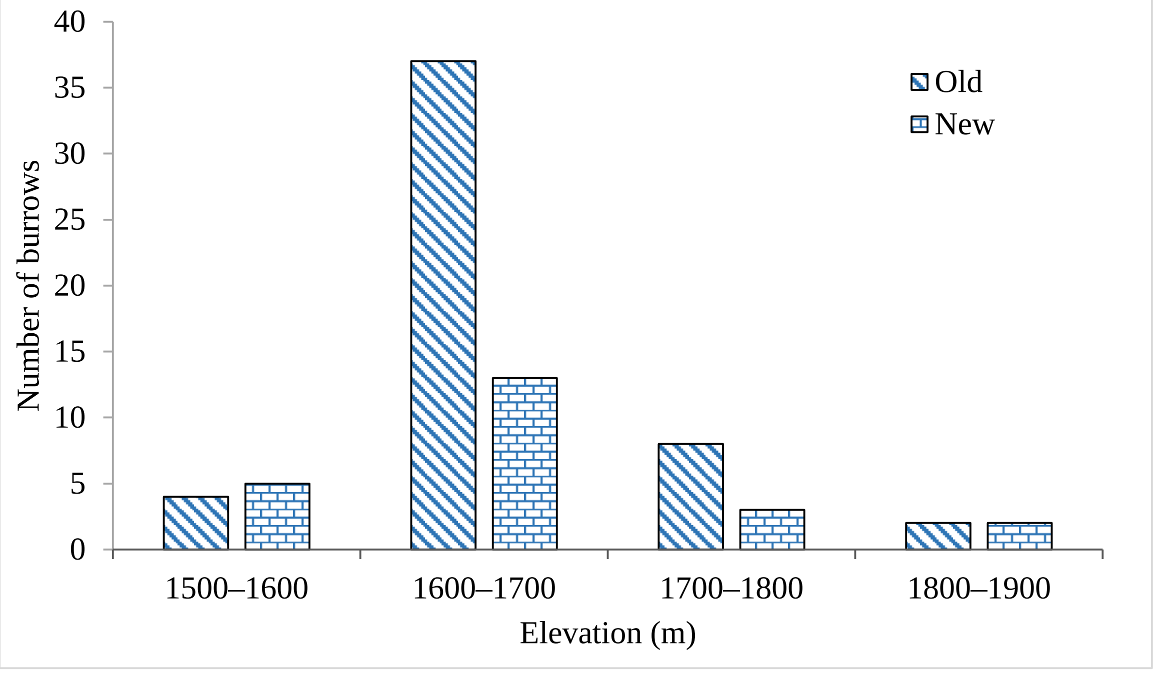

Figure 4. Distribution of burrows according to elevation.

The burrows were distributed on 4 to 50° slope. The highest occurrence of burrows was on 20–30° slope with 51% (n=33) with 22 being old and 11 being new burrows followed by 30–40° slope (32%, n=24) with being 13 old burrows and 11 new burrows (Figure 5). A significant difference on number of burrows were observed from five categories of slope ($\chi2=52.081$, df=4, $p<0.05$).

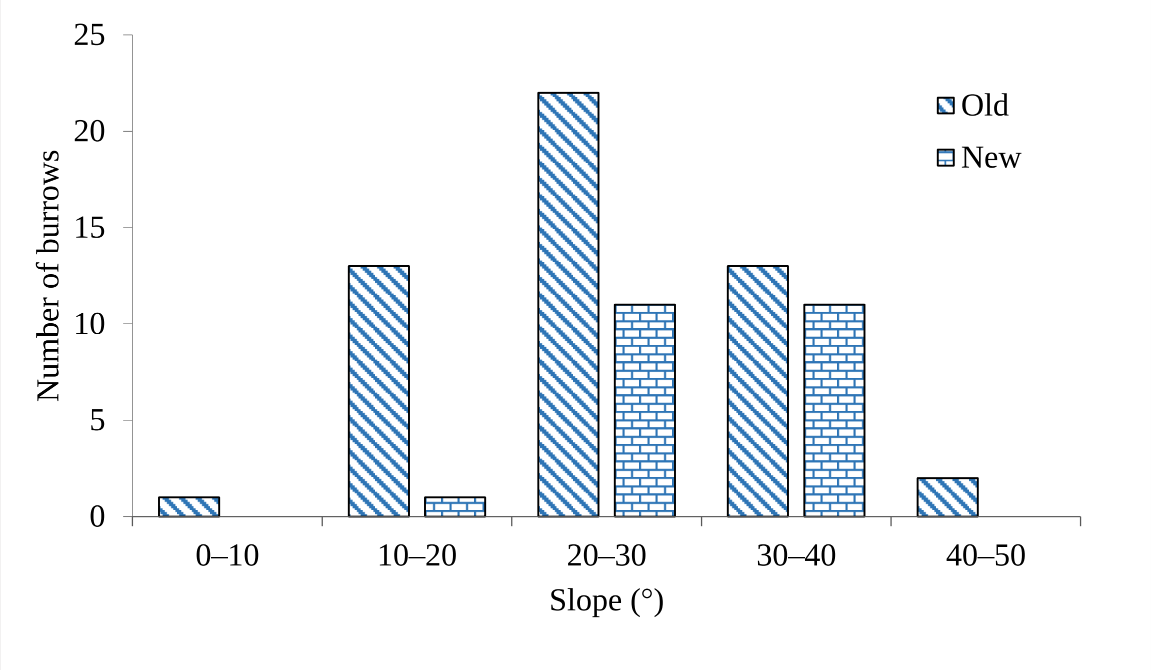

Figure 5. Distribution of burrows according to slope.

The burrows were found maximum at the south–west facing aspect with 43.24% (n=32) with 17 old and 15 new followed by North–west facing aspect 35.13% (n=26) with 25 old and 1 new burrow (Figure 6). The burrows numbers difference was significant with aspect ($\chi2$=73.081, df=5, $p<0.05$).

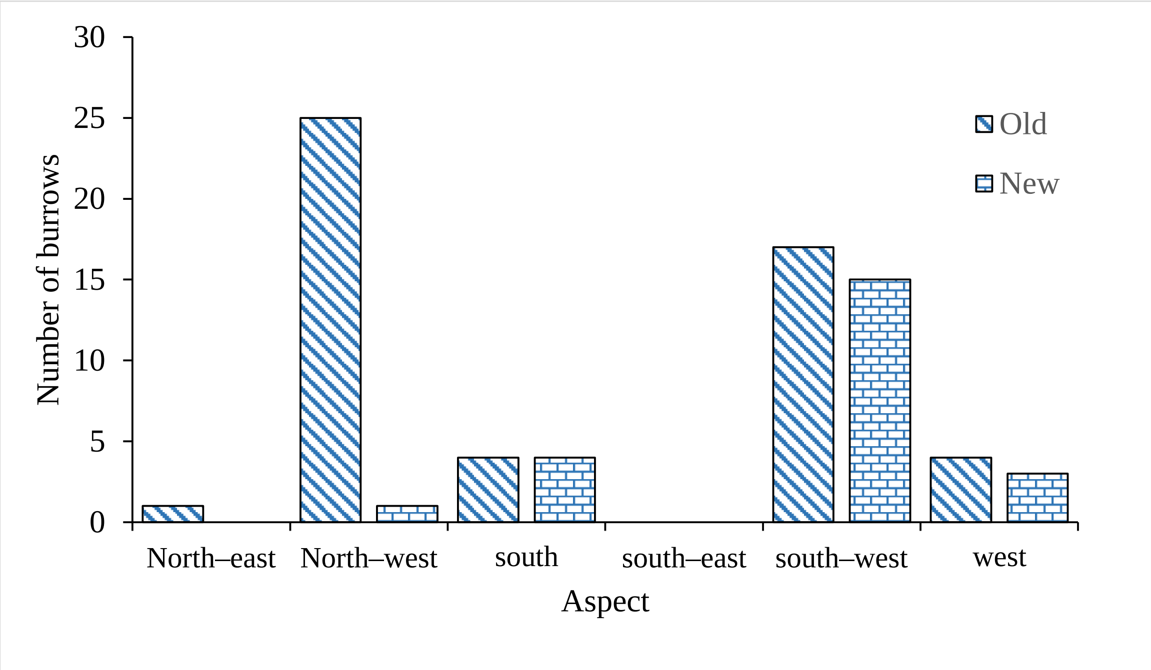

Figure 6. Distribution of burrows according to aspect

4.2.2 Vegetation characteristics (canopy cover and ground cover)

In the area having canopy cover 50–75% higher number of burrows accounting 55.05% of the total (n=40) of which 31 were old and 9 were new (Figure 7). Burrows in 75–100% canopy cover reported 45.9% of the total with 34 burrows, of which 20 were old and 14 were new burrows (Figure 6). However, the difference was not statistically significant ($\chi2=0.48$, df=1, $p>0.05$).

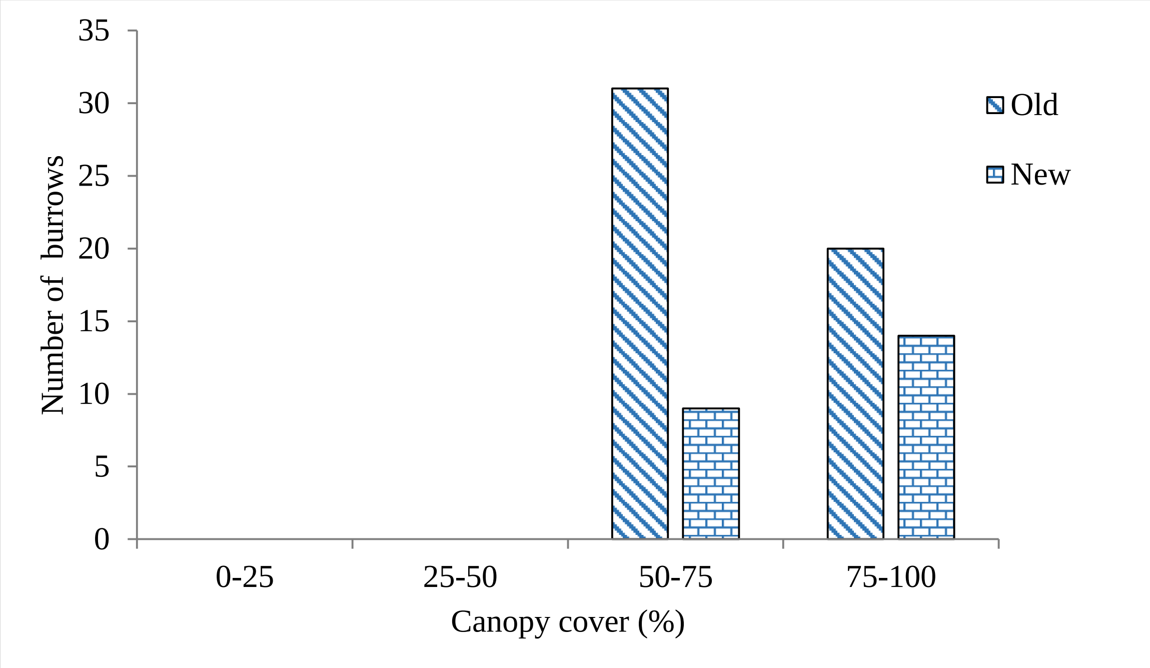

Figure 7. Distribution of burrows according to canopy cover.

Fifty-one percentage of the total (n=38) with 26 old and 12 new burrows were found in 50–75% ground cover. In 0–25% of ground cover only 5.4% of burrows were reported (Figure 8). There was a significant difference between number of burrows with ground cover categories ($\chi2=60.27$, df=3, $p<0.05$)

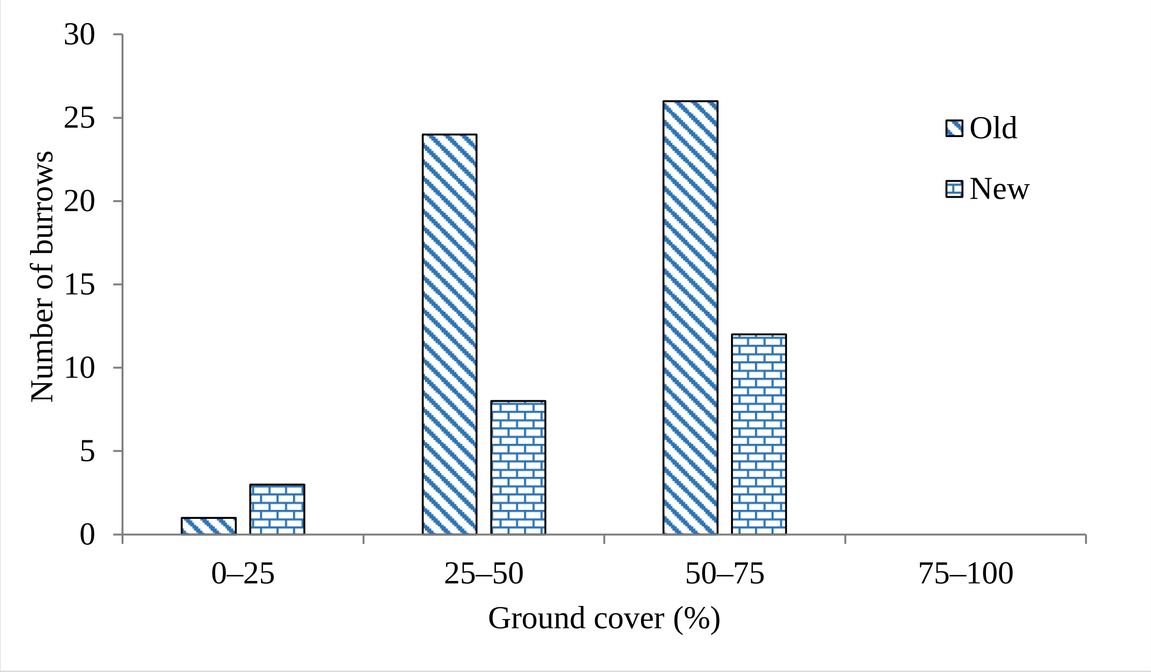

Figure 8. Distribution of burrows according to ground cover

4.2.3 Resource availability (ant nest, termite colonies and water source)

The distance between the plot centre and the nearest ant nest ranged in between 1m to 30m. Majority of burrows 77% (n=57, old=36, new=21) were recorded within 10m distance.

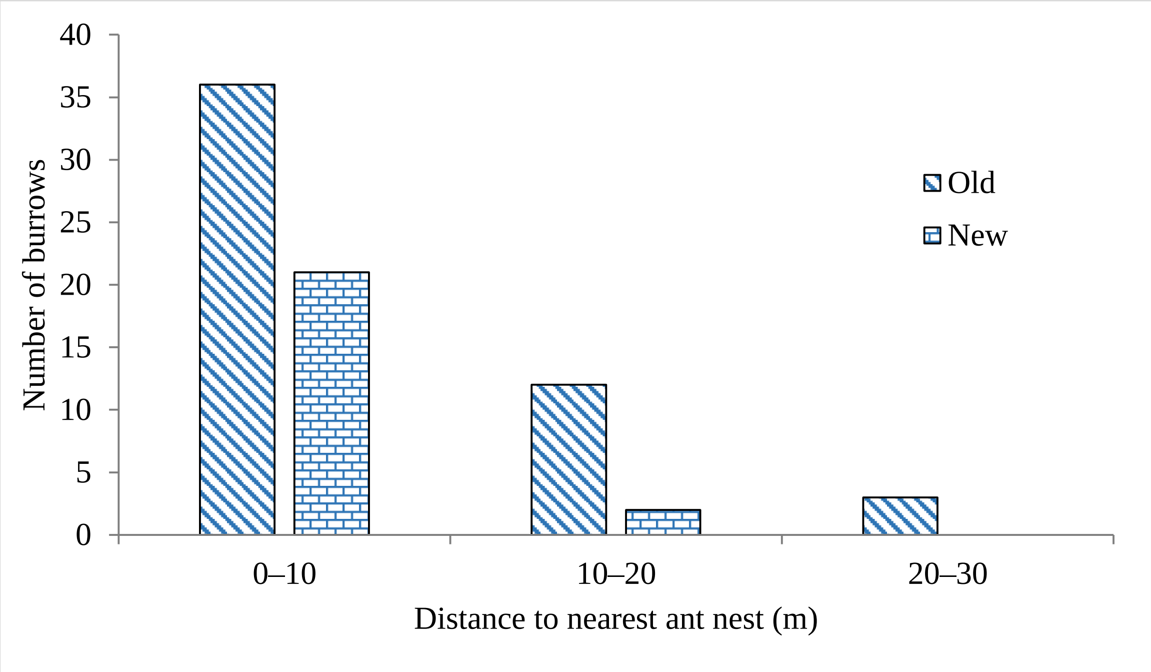

Figure 9. Distribution of burrows according to the nearest distance to ant nest.

The higher frequency of the termite colonies (60%, n=45) with 25 old and 20 new burrows were recorded within 10m distance from the centre of the plot (Figure 10). The distance between the centre of plot and termite colonies ranges from 1.3m to 49m. It was found the number of pangolin burrows significantly differed with the distance to termite colonies ($\chi2=92.216$, df=4, $p<0.05$).

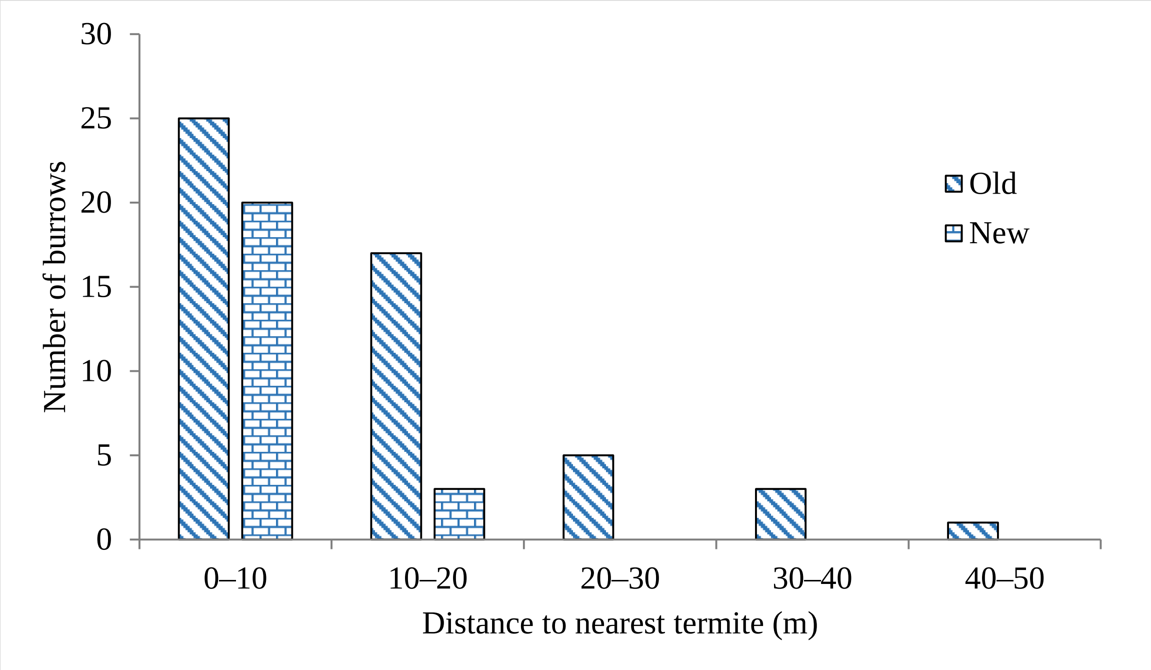

Figure 10. Distribution of burrows according to the nearest distance to termite colonies.

The burrows were observed between 16–543m nearest water distance. The higher frequency of the burrows was found within 100m distance from the water to the plot 43.24%, (n=32) of total in which 25 old and 7 new burrows. The frequency of the burrows was declined beyond 300m distance from the water source (**Figure 11**). There was a significant difference between nearest distance to water sources and frequency of burrows ($\chi2=78.432$, df=5, $p<0.05$).

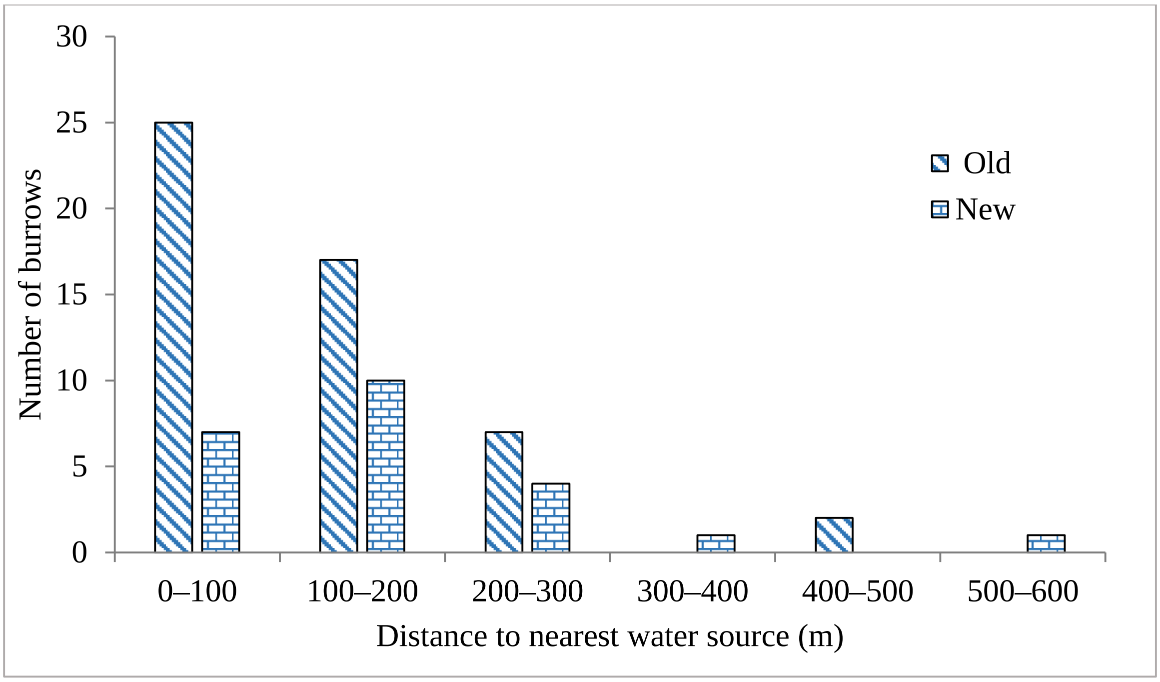

Figure 11. Distribution of burrows according to the nearest distance to the water source.

4.2.4 Edaphic factors (soil colour)

The most of the burrows were recorded in the brown colour soil (72.9%, n=54) of which 37 were old and 17 were new. The least burrows were found in the red colour soil with 27.02% (n=20, old=14, new=6) (Figure 12). The burrows distribution was found to be significantly difference with soil colour ($\chi 2=15.622$, df=1, $p<0.05$).

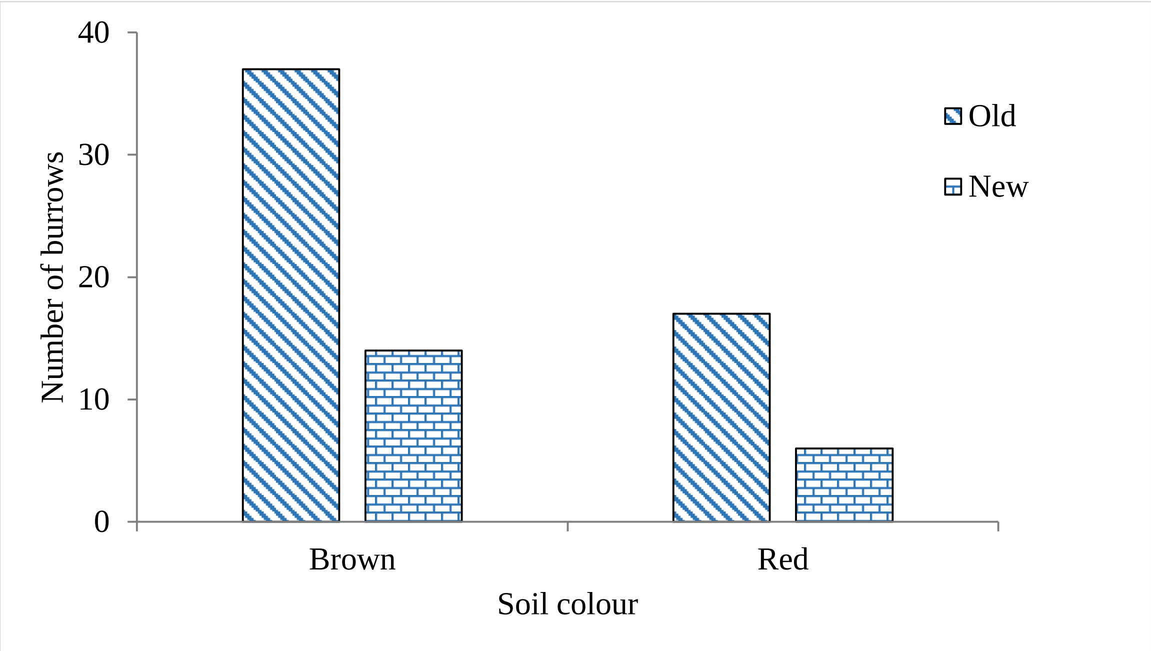

Figure 12. Distribution of burrows according to soil colour.

4.2.5 Disturbance factors (road and human settlement)

The nearest distance to road ranged between 42–792m. The occurrences of burrows in between 0–200m were high with 58% (n=40, old=27, new=16) followed by 21% (n=21) of total with 17 old burrows and 4 new burrows were found within 200–400m distance (Figure 13). There was a significant difference in the number of burrows with four categories of distance to road ($\chi2$=55.189, df=3, $p<0.05$).

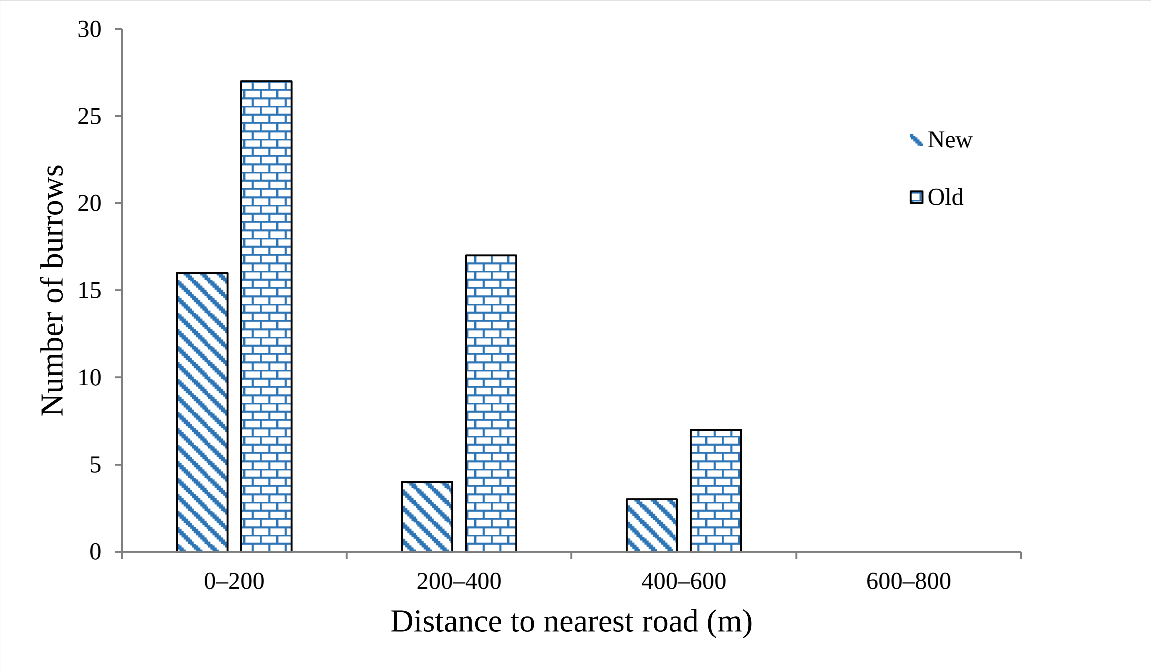

Figure 13. Distribution of burrows according to the nearest distance to road.

The range between the nearest distance to burrow and human settlement was 150–1241m. The high number of burrows were recorded between 500–700m distance (n=27, old=15, new=12) followed by 300–500m distance to human settlement (n=24, old=16, new=8) (Figure 14). There was a significant difference in the number of burrows with six categories of distance to human settlement ($\chi2$=49.405, df=5, $p<0.05$).

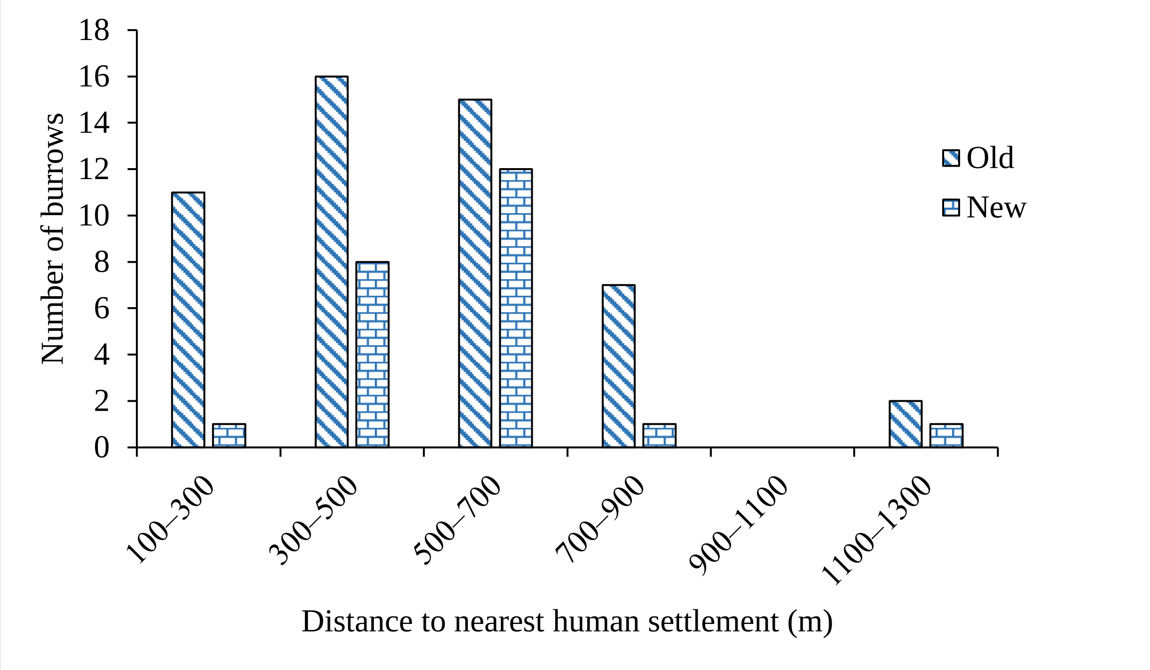

Figure 14. Distribution of burrows according to nearest distance to human settlement.

4.3 Occurrence ratio of burrows based on different habitat characteristics

The highest preference of burrows was found in the elevational categories 1500–1600m and 1600–1700m where occurrence ratios was 2.44 and 1.25 respectively (Table 2). Burrows showed a more preference on 20–30° slope with an occurrence ratio 1.5341. In 75–100% canopy cover the occurrence ratio was 1.176 indicates a higher proportion of burrows in those areas while burrows prefer more in 25–50% of ground cover having the occurrence ratio 1.13. The burrows preference was mainly in south–west aspect and red colour soil with an occurrence ratio 1.44 and 1.8 respectively. Among three categories of distance to nearest ant nest the highest preference of burrows was found in 0–10m with 1.203 occurrence ratios. Similarly, within 0–10m nearest distance to termites colonies burrows preference was maximum with 1.447. The burrows more prefer in 1100–1300m nearest distance to human settlement having occurrence ratio with 2. Additionally, the maximum preference of burrows was found in 100–200m distance to nearest water source and 0–200m distance to nearest road with 1.3 and 1.210 occurrence ratios.

Table 2. Habitat preference/occurrence ratio of Chinese pangolin burrows based on different habitat characteristics

Habitat characteristics	Category	Number of plots	Relative abundance of habitat type (RAH)	Number of burrows	Relative abundance of burrows (RAB)	Occurrence ratio (RAB/RAH)
Elevation(m)	1500–1600	5	0.05	9	0.122	**2.44**
	1500–1600	54	0.54	50	0.676	1.25
	1700–1800	31	0.31	11	0.149	0.480
	1800–1900	10	0.1	4	0.054	0.54
Slope (°)	0–10	6	0.06	1	0.013	0.216
	10–20	20	0.2	14	0.189	0.945
	20–30	29	0.29	33	0.445	**1.534**
	30–40	34	0.34	24	0.324	0.9529
	40–50	11	0.11	2	0.027	0.245
Canopy cover (%)	50–75	61	0.61	40	0.540	0.885
	75–100	39	0.39	34	0.459	**1.176**
Ground cover (%)	0–25	13	0.13	4	0.054	0.415
	25–50	38	0.38	32	0.432	**1.13**
	50–75	48	0.48	38	0.513	1.06
	75–100	1	0.01	0	0	0
Distance to nearest ant nest (m)	0–10	64	0.64	57	0.770	**1.203**
	10–20	26	0.26	14	0.189	0.726
	20–30	10	0.1	3	0.040	0.04
Distance to nearest termite colonies (m)	0–10	42	0.42	45	0.608	**1.447**
	10–20	27	0.27	20	0.270	1
	20–30	15	0.15	5	0.067	0.446
	30–40	13	0.13	3	0.040	0.307

	40–50	3	0.03	1	0.013	0.433
Distance to nearest water source (m)	0–100	36	0.36	32	0.432	1.2
	100–200	28	0.28	27	0.364	**1.3**
	200–300	23	0.23	11	0.149	0.647
	300–400	8	0.08	1	0.013	0.162
	400–500	3	0.03	2	0.027	0.9
	500–600	2	0.02	1	0.013	0.65
Distance to nearest human settlement (m)	100–300	13	0.13	12	0.162	1.246
	300–500	29	0.29	24	0.324	1.117
	500–700	35	0.35	27	0.364	1.04
	700–900	16	0.16	8	0.108	0.675
	900–1100	5	0.05	0	0	0
	1100–1300	2	0.02	3	0.040	**2**
Distance to nearest road (m)	0–200	48	0.48	43	0.581	**1.210**
	200–400	32	0.32	21	0.283	0.88
	400–600	14	0.14	10	0.135	0.964
	600–800	6	0.06	0	0	0
Soil Colour	Brown soil	85	0.85	54	0.729	0.857
	Red soil	15	0.15	20	0.270	**1.8**
Aspect	North–west	41	0.41	26	0.351	0.856
	North–east	5	0.05	1	0.0135	0.27
	south	4	0.04	8	0.108	0.27
	south–east	10	0.1	0	0	0
	south–west	30	0.3	32	0.432	**1.44**
	west	11	0.11	7	0.094	0.8545

Note: (bold number indicate the highest habitat preference value)

4.4 Habitat factors affecting the distribution of pangolin

Among nine independent variables included in model, four showed a significant effect on the presence or absence of the burrows of Chinese pangolin. The distance to termite colonies, distance to road, canopy cover and the elevation showed a negative significant effect on of the presence of pangolin. The burrow presence was decreased with increases in elevation, canopy cover, nearest distance to termite colonies and distance to road. The remaining five variables did not show any significant effect on the presence or absence of Chinese pangolin burrows (Table 3).

Table 3. Effects of environmental variables on presence or absence of Chinese pangolin burrows based on binomial distribution model.

	Estimate	**Std. Error**	**z value**	**P-value**
(Intercept)	47.95572	14.91241	3.216	0.0013
Slope (°)	-0.03708	0.02726	-1.36	0.1738
Distance to nearest ant nest (m)	-0.4245	0.337436	-1.258	0.2084
Distance to nearest termite colonies(m)	-0.65704	0.333714	-1.969	**0.04**
Ground cover (%)	0.029245	0.627784	0.047	0.9628
Canopy cover (%)	-4.81807	2.408448	-2	**0.0454**
Distance to nearest human settlement (m)	0.001884	0.001669	1.129	0.2591
Distance to nearest road (m)	-1.15512	0.512161	-2.255	**0.0241**
Distance to nearest water source (m)	0.552661	0.529953	1.043	0.297
Elevation (m)	-0.01294	0.005383	-2.404	**0.0162**

Note: (The bold number indicated these habitat parameters had a significant impact on burrow detectability with $p<0.05$).

4.5 Vegetation analysis

In the surveyed plot a total 1622 trees belonging to a total 30 different species with three unidentified species were recorded. Among the studied plots the most dominant plant was *Castonopsis tribuloides*, having the IVI of 57.31 followed by *Castonopsis indica* with an IVI of 48.13 (Table 4). A significant difference found in between tree species and burrows ($\chi2=507.39$, df=29, $p<0.05$).

Table 4. The tree species with important value index (IVI) reported in study area.

Scientific name of Tree species	Common name	RF	R. density	R. dominance	IVI
Castonopsis tribuloides	chinkapin	13.29	22.01	22.01	**57.31**
Castonopsis indica	Indian chestnut	11.51	18.31	18.31	**48.13**
Schima wallichi	needlewood	12.97	14.24	14.24	**41.45**
Quercus glauca	ring–cupped oak	8.91	8.26	8.26	25.44
Myrica esculanta	box berry	7.94	6.17	6.17	20.27
Celtis australis	honeyberry	5.02	6.78	6.78	18.59
Rhododendron arboreum	tree rhododendron	4.86	2.9	2.9	10.66
Myrica capitella	bayberry	4.38	3.08	3.08	10.54
Myrsine semmiserrata	blueberry myrtle	4.21	2.65	2.65	9.52
Eurya acuminate	tapering–leaf eurya	3.57	1.91	1.91	7.39
Lyonia ovalifolia	oval–leaf lyona	3.08	1.85	1.85	6.78
Alnus nepaleensis	Nepal alder	2.11	1.66	1.66	5.44
Leucaena leucocephala	jumbay	2.59	1.42	1.42	5.43
Prunus cerasoides	sour cherry	2.11	1.05	1.05	4.2
Semecarpus anacardium	marany nut	1.62	0.86	0.86	3.35
Choerospondias axillaris	Nepali hug plum	1.46	0.62	0.62	2.69
Ilex sp.	holly	0.97	0.68	0.68	2.33
Quercus leucotrichopora	Himalayan oak	0.81	0.62	0.62	2.04
Persea odoeatissimma	fragrant Bay	0.97	0.49	0.49	1.96
Bauhinia purpurea	Mountain ebony	0.81	0.43	0.43	1.67
Fraxinus floribunda	Himalayan ash	0.65	0.49	0.49	1.63
Pinus roxburghii	pine	0.65	0.43	0.43	1.51
Cinnamomium zeylanicum	cinnamon	0.65	0.37	0.37	1.39

Quercus semecarpifolia	brown oak	0.49	0.25	0.25	0.98
Magnolia champaca	champa	0.16	0.06	0.06	0.29
Camphora officinarum	camphorwood	0.49	0.25	0.25	0.98
Species A		0.49	0.25	0.25	0.98
Species B		0.49	0.12	0.12	0.73
Species C		0.49	0.25	0.25	0.99

Note: (The bold number indicated the highest IVI of tree species).

5. DISCUSSIONS

5.1 Distribution pattern of Chinese pangolin burrows

The most of the burrows were old rather than new in the study area, it might be due to pangolins tends to switching into new burrows frequently mainly for the feeding purpose (Lin 2011). In the study area, the distribution pattern of pangolin was clumped might be due to suitable habitat, abundance number of prey species. Bhandari and Chalise (2014) reported the non–uniform pattern of distribution of pangolin. Dhami et al. (2023) reported a clumped pattern of distribution of Chinese pangolin. Similarly, the clumped distribution pattern was reported by (Panta et al. 2023).

5.2 Habitat factors affecting the distribution of Chinese pangolins

The burrows prefer highly in 1500–1600m elevational range. The distribution of burrows gradually, decreases with increased elevation in the study area. The burrows distribution in between 1450–1550m elevation range reported by (Bhandari & Chalise 2014). The maximum burrows at 450–750m and found number of burrows decreased with an increase in elevation (Dhami et al. 2023). Similarly, in Dorokha Dungkhag, Samtse, Bhutan (Dorji et al. 2020) found the burrows in between 1300–1700 masl elevation range and showed the negative relationship between burrow and elevation. The termites are the prey species of pangolin and increased in the elevation decline termite species richness and abundance (Hemachandra et al. 2014).

In the study area, burrows were mostly preferred in between 75–100% dense canopy cover but not significantly difference with canopy cover categories. However, burrows presence were influenced by the canopy cover in the study area. Tamang et al. (2022) reported the most burrows appeared in between 50–75% canopy coverage. Suwal et al. (2020) reported the preferred canopy cover by pangolin specifically in the range of 50–75% canopy cover. The pangolin preferences under 25–50% canopy cover (Bhandari & Chalise 2014). In winter, Chinese pangolin require dense canopy cover as they are not very adaptive to change in temperature, denser canopy cover helps them to reduce the exchange of heat between interior and exterior of the burrows (Wu et al. 2003). The dense canopy cover helps to provide feeding ground (Maurice et al. 2019). The Chinese pangolin prey species , termite mounds occurrence were high within the core area of the forest rather than the edges of the forest (Axelsson & Andersson 2012). The forest dense canopy decreased the chances of being encountered by the predators and maintained the forest moisture (Maurice et al. 2019).The Chinese pangolin prefer 25–50% of ground cover. Similarly, preference of burrows in dense undergrowth vegetation recorded by (Shrestha et al. 2021). The Chinese pangolin preferred dense ground cover as it helps them in moving, finding food, for safeguarding of their cubs and their burrow entrances (Wu et al. 2003). In this study burrows occurrence were significantly different on slope, mostly burrows were found on 20–30° slope. The Chinese pangolin preferred on 20–30° slope preferred (Bhandari & Chalise 2014). Sharma et al. (2020) the occurrence of more burrow 15–22° slopes might be due to availability of fallen log and termites and ants. Dorji et al. (2020) reported that burrow occurrence in the gentle slope might be due to ease of burrow digging. The Chinese pangolin preferred on 30–50° slope, and avoid greater than 60° might be due to pangolins do activities inconveniently on greater slope (Wu et al. 2003).

In the present study burrows preferred on south–west aspects. The study conducted in Chitwan district Amritdharapani Community Forest reported the preference of Chinese pangolin more in North–west and south–west Aspects (Shrestha et al. 2021). The presence of prey species, various climatic conditions and level of human disturbance might impact on the preference of certain aspects (Suwal 2011). The result of this finding line with the (Thapa et al. 2014). In the study area the burrows were in red colour soil. The preference of most burrows in the brown colour soil for digging revealed by (Suwal et al. 2020).

The burrows were found to be significantly different with distance to the ant nest and termite colonies. Furthermore, increase in distance to termite colonies with decreased in the presence of burrow number were observed in the study area, indicate a negative significant effect in between the burrow presence and distance to the termite colonies. Most burrows were prefer within 10m nearest distance from termite colonies and ant nest. Tamang et al. (2022) reported high number of burrows within 10m distance to ant nests. The high number of availability of termites and ant were the important factors for the occurrence of the pangolin (Swart et al. 1999). They only consume termites and ants as they are food specialist species that means for survival of pangolin there must be naturally abundance prey species should be present therefore the pangolin habitat area interlinked with the presence of their prey species (Wu et al. 2004, Maurice et al. 2019).

The Chinese pangolin burrows were found from 150m nearest distance to human settlement and mostly found to prefer in between 1100–1300m nearest distance to human settlement. Shrestha et al. (2021) found a high numbers of burrow at 1500–1700m apart from settlement. Katuwal et al. (2017) reported the burrow presence close to human's settlements within <1000m. Although, the distance to human settlements had no significant effect in the distribution of burrows. The pangolin prefers far away from human settlement >1000m, which indicate to avoidance of human disturbance (Wu et al. 2003).The species found near to the footpath and village facilitate poaching of species (Katuwal et al. 2017). The dispersion of human settlements around forested regions was a responsible factor for the occurrence of Chinese pangolin near to human settlement (Sharma et al. 2020). The burrows were mostly recorded within the road distance 0–200m. The number of burrows and the distance to road showing the negative significant effect. Dhami et al. (2023) revealed that burrows were decreased with increased in distance from the road, and most burrows were distributed within 0–700m of the road. The Chinese pangolins can also be distributed in distrusted forest edge for searching of its prey species that might be the reason for the burrows had negatively significantly affected by road distance (Lee et al. 2017). Furthermore, the presence of pangolins nearer to the road and footpath more likely increased the risk of exposure to the human that may raise the risk to the Chinese pangolin such as hunting, poaching and other negative activities (Katuwal et al. 2017). The gradual decrease in the numbers of burrows with increase in distance to water source showed the significant difference in between burrows number and distance to water source. The high number of burrows were recorded within 100m nearest distance to water source in the study area. The number of burrow occurred more in between 100–200m distance from water source (Katuwal et al. 2017). The presence of species near to water sources instead of far apart may help them to conserve their energy to travel long distances and protect themselves from the predator's attacks (Bista et al. 2017).

In the study area, the burrows distribution were found in habitat dominated by, *Castonopsis tribuloides*, *Castonopsis indica*, *Schima wallichi*. Bhandari and Chalise (2014) observed appearance of burrow in habitat dominated by tree species such as *Schima wallichi*, *Castonopsis tribuloides*, *Castonopsis indica.* The activity pattern of pangolin might be influence, by the diverse vegetation pattern comprises among elevation gradient (Suwal et al. 2020). The pangolins preferred different habitat consisting primary and secondary tropical forest, bamboo forest, limestone forest, agricultural lands (Gurung 1996, Katuwal et al. 2017, Suwal 2011).

6. CONCLUSIONS AND RECOMMENDATION

6.1 Conclusions

A clumped type of distribution pattern of Chinese pangolin burrows was observed in the two Community Forests. The Chinese pangolin burrows preference was found in 1500–1600m elevation range with 75–100% canopy cover, in red colour soil, in south–west aspect, near to termite's colonies, near to road and water sources. Elevation, canopy cover, distance to road and distance to termites showed significant relationship with the presence of burrows.

6.2 Recommendations

Based on the findings of this study, following recommendations can be made

- The forests natural habitat condition should be maintained in order to protect Chinese pangolin.

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APPENDIX

Figure 15. New burrows.

Figure 16. Old burrows.

APPENDIX 2 GPS locations of Chinese pangolin burrows observed in Kunda CF and Naudhara CF

Latitude(N)	Longitude(E)
27°.59'59.91"	85°.39'01.35"
27°.59'80.02"	85°.38'87.52"
27°.59'64.76"	85°.38'80.73"
27°.59'59.07"	85°.38'94.92"
27°.59'64.08"	85°.38'96.34"
27°.59'64.52"	85°.38'93.34"
27°.59'64.08"	85°.38'86.25"
27°.59'66.8"	85°.38'76.36"
27°.59'86.52"	85°.38'83.58"
27°.59'84.78"	85°.38'89.17"
27°.59'76.31"	85°.38'86.59"
27°.59'66.56"	85°.38'83.81"
27°.59'67.54"	85°.38'89.09"
27°.59'68.89"	85°.38'94.86"
27°.59'69.02"	85°.39'00.14"
27°.59'73.38"	85°.39'01.43"
27°.59'74.49"	85°.39'07.94"
27°.59'76.5"	85°.38'92.41"
27°.59'80.92"	85°.39'00.65"
27°.59'81.47"	85°.39'06.76"
27°.59'84.53"	85°.39'16.87"
27°.59'86.88"	85°.39'21.84"
27°.60'13.63"	85°.39'69.77"

27°.60'15.73"	85°.39'74.41"
27°.59'65.68"	85°.39'39.35"
27°.58'75.88"	85°.37'97.47"
27°.58'68.04"	85°.38'00.45"
27°.58'59.	85°.38'01.2"
27°.58'49.98"	85°.38'03.8"
27°.58'52.54"	85°.38'08.11"
27°.58'56.77"	85°.38'06.72"
27°.58'65.79"	85°.38'04.92"
27°.58'70.29"	85°.38'04.17"
27°.58'74.44"	85°.38'03.24"
27°.58'79.01"	85°.38'02.42"
27 °.58'71.68"	85°.38'09.38"
27°.58'76.05"	85°.38'08.16"
27.58'15.8"	85°.38'17.89"
27°.58'19.43"	85°.38'15.12"
27°.58'61.82"	85°.38'48.21"
27°.58'59.01"	85°.38'52.23"
27°.58'65.34"	85°.38'37.42"