Distribution and Habitat Use of the Chinese Pangolin (*Manis pentadactyla*) in Bhimsen Thapa Rural Municipality, Gorkha, Nepal

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A dissertation submitted

In partial fulfilment of the requirements for the award of the degree of Master of Science in Zoology with special paper Ecology and Environment

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Declaration

I hereby declare that the work presented in this dissertation "Distribution and habitat use of the Chinese pangolin (*Manis pentadactyla*) in Bhimsen Thapa Rural Municipality, Gorkha, Nepal" has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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Certificate of acceptance

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Reetu Panta

Abstract

The Chinese pangolin *(Manis pentadactyla)* is one of the critically endangered nocturnal mammalian species that is experiencing rapid population decline, mainly due to habitat loss and degradation. There is still limited data on the distribution and habitat preferences of the species. Its distribution in rural and remote areas of Nepal is also little known. Using line transects, this study investigated its distribution and factors affecting its occurrence in four community forests of Bhimsen Thapa Rural Municipality, Gorkha, Nepal, from January 2023–March 2023. A total of 20 line transects and 100 plots of 10 m×10 m were established in the study area, and the presence of the Chinese pangolin burrow was recorded in each plot. Factors like elevation, aspect, slope, canopy cover, ground cover, distance to the nearest ant and termite nest location, water source, human settlement, and agricultural land were also recorded in each plot. A generalized linear model (GLM) was used to identify the effects of the factors on the occurrence of the Chinese pangolin. The burrows were distributed in areas dominated by tree species like *Shorea robusta*, *Schima wallichii*, and *Castanopsis indica*, at the elevation range of 500–852 m above sea level, and showed clumped distribution. Burrow occurrence was significantly influenced by elevation, slope, distance to the nearest water source, nearest road, and ant nest and termite mound. The majority of the burrows was found in red soil with 20–30° slope, 25–50% canopy cover, and were facing south-east. The studied forests support the occurrence of the Chinese pangolin which should be maintained for the conservation of the species. The findings from this study can provide deficient data on the distribution and factors affecting its occurrence and provide the baseline data for its conservation in rural areas.

शोध सारांश

कालो सालक एक रात्रिकालीन स्तनधारी जनावर हो जसको वासस्थान र जनसंख्या घट्दै गएको छ। यो अन्तर्राष्ट्रिय प्रकृति संरक्षण सङ्घको रातो सूचीमा अत्यन्तै लोपोन्मुख अवस्थामा सूचीकृत छ। साथै ग्रामीण तथा दुर्गम क्षेत्रमा यसको बारेमा सीमित तथ्याङ्क छ। त्यसैले ग्रामीण क्षेत्रमा कालो सालकको वितरण र यस्को वितरणमा असर पार्ने कारकतत्वका बारेमा जानकारी लिन गोरखा जिल्लाको भीमसेन थापा गाउँपालिकाका चार वटा सामुदायिक वनमा यो अध्ययन गरिएको थियो । अध्ययन क्षेत्रमा ५० मिटरको अन्तरालमा कुल २० लाइन ट्रान्सेक्ट र १०० प्लटहरू स्थापना गरिएको थियो। प्रत्येक प्लटमा कालो सालकको दुलोको उपस्थिति हेरिएको थियो। प्रत्येक प्लटमा उचाई, पक्ष, ढलान, क्यानोपी कभर, ग्राउन्ड कभर, सबैभन्दा नजिकैको कमिला र धमिराको गुँडको दूरी, पानीको मुहानको दूरी, मानव बस्तीको दूरी, र कृषि भूमिको दूरी जस्ता कारकहरू पनि टिपोट गरिएको थियो। दुलोको वितरण पाँच कारकहरूद्वारा महत्त्वपूर्ण रूपमा प्रभावित भएको थियो जुन उचाइ, ढलान, सबैभन्दा नजिकैको पानीको मुहानको दूरी, कमिला र धमिराको गुँडको दूरी र सडकको दूरी थए। दुलोहरू साल, कटुस र चिलौने जस्ता रूखका प्रजातिहरूको प्रभुत्व भएको स्थानहरूमा वितरण भएका थए। दुलोहरू समुद्री सतहबाट ५०० देखि ८५२ मिटरमा वितरण भएका थए। अधिकांश दुलोहरू रातो माटो र दक्षिण पूर्व पक्षमा फेला परेका थिए। अध्ययन गरिएका सबै वनहरूमा कालो सालकको उपस्थिति पाइएको थियो। त्यसैले यस्को संरक्षणका लागि वनको संरक्षण जरुरी छ। यस अध्ययनको निष्कर्षले ग्रामीण क्षेत्रबाट यस प्रजातिको तथ्याङ्क प्रदान गर्न सक्छ र नेपालमा कालो सालकको दीर्घकालीन संरक्षणका लागि संरक्षण र व्यवस्थापन योजनाको विकास गर्न मदत पुर्याउन सक्छ।

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Abbreviated form	Details of abbreviations
CF	Community Forest
DBH	Diameter at Breast Height
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature
IVI	Importance Value Index

1. Introduction

1.1 Background

Habitat structure is one of the important components of the ecosystem (McCoy & Bell, 1991). Knowledge of habitat selection can provide information on resource utilization (Alldredge & Griswold, 2006), and this information is important for conservation (Gavashelishvili & Lukarevskiy, 2008; Guisan et al., 2013 as cited by Sharma et al., 2020a) and management of the species (Maes & Bonte, 2006; Van Teeffelen, 2012; Vilardell-Bartino et al., 2015). Effective management of an organism requires in-depth knowledge of variables that are currently influencing species distribution and local factors that restrict their distribution (Badiane et al., 2017). An extensive understanding of preferred habitats and distribution is also required for the development of suitable conservation measures of threatened species (Wiktander et al., 2001; Bajaj & Amali, 2019; Dorji et al., 2020), which is lacking in the case of the Chinese pangolin (*Manis pentadactyla*), whose population has been declining rapidly; habitat loss and degradation are one of the main reasons for population decline of the species (DNPWC and DoF, 2018; Challender et al., 2019), along with livestock grazing, forest fires, poaching, and illegal trade (Katuwal et al., 2015; DNPWC and DoF, 2018). Despite a recent rise in publications about the Chinese pangolin, there are still many knowledge gaps regarding many elements of the species (Heighton & Gaubert, 2021), such as distribution and habitat preference (Jnawali et al. 2011; DNPWC & DoF, 2018; Acharya et al., 2021; Zhang et al., 2020; Zhang et al., 2024) which is mainly due to the insufficiency of monitoring and surveying (Zhang et al., 2024). In addition, the Chinese pangolin shows preference for some particular habitat (Wu et al., 2004) due to effects of environmental factors like aspect, and slope (Sharma et al., 2020b; Wu et al., 2003). Hence, an extensive understanding of the distribution and habitat is required for the development of suitable conservation measures of this threatened species (Wiktander et al., 2001; Johnson et al., 2004; Dorji et al., 2020). Knowledge on distribution and habitat can also aid in its in-situ conservation (Zhang et al., 2024) as well as provide information on anthropogenic threats (Sutherland et al., 2009).

Pangolins are one of the smallest groups of mammals. Globally, eight species of pangolin are recorded, out of which four inhabit Asia. In Nepal, two species of pangolin, Chinese pangolin and Indian pangolin (*M. crassicaudataa*) are found (DNPWC and DOF, 2018). The Chinese pangolin is also found in China, India, Thailand, Bangladesh, Bhutan, Vietnam, Myanmar, and Lao PDR and is included in the IUCN Red List of Threatened Species as critically endangered (Challender et al., 2019). The Chinese pangolin is one of the most traded animals in the world due to its meat and traditional medicinal value (Newton et al., 2008; Sharma et al., 2020b). Excessive hunting and poaching at the local and international levels are the main threats to the species (Wu et al., 2020). In addition, due to its nocturnal temporal niche, the species can tolerate anthropogenic activities and coexist with humans, which makes it even more susceptible to poaching and illicit hunting activities (Khatiwada et al., 2022). Along with anthropogenic activities, climatic factors also influence the local extinction of the species (Gao et al., 2022).

The Chinese pangolin is a nocturnal mammal and has poor self-defense (Wu et al., 2004). It is a non-aggressive, shy, slow-moving, burrowing, and solitary mammal that has tough, overlapping scales all over its body except the inner surface of the limbs, head trunk, and footpads (Heath, 1992; Challender et al., 2019). It is a small to medium-sized mammal that can weigh 3–8 kg and grow up to 90 cm in length. Compared to other species of pangolin, its ear pinna is prominent, its tail is shorter, and the claws on the forelimbs are large (Wu et al., 2020). It has pink-beige feet and face, protective ear flaps, a short tail with a naked tip, and 15–18 small overlapping scales (Jnawali et al., 2011). The scales are yellow-brown or dark-brown. It has a small cone-shaped head, eyes with limited use, a small, toothless mouth, and a tongue adapted for feeding ants and termites, which is thin and long (16–40 cm), with the help of which food is broken down in the stomach (Heath, 1992).

The Chinese pangolin is insectivorous and lives inside burrows (Gaubert, 2011). Burrows are dug to look for prey, rest, breed, and hide from enemies (Wu et al., 2004). Depending on different geographical locations, 15–50° slopes are preferred by the Chinese pangolin for digging burrows (Rai et al., 2019; Suwal et al., 2020; Sharma et al., 2020b; Acharya et al., 2021; Shrestha et al., 2021a, b). The Chinese pangolin avoids slopes > 50° when choosing a burrow site (Wu et al., 2003). The species is often called “scaly anteater” and mostly eats ants and termites (Wu et al., 2003). It is prey selective like all pangolins, although it eats all stages of its prey’s life cycle, encompassing eggs, larvae, and imagoes (Fang & Wang, 1980). It has a huge role in the ecosystem. Its burrows help other animals create shelter and breeding habitat (Hansell, 1993). By feeding on ants and termites, it maintains the population of insects and balances the ecosystem. Burrow creation by the

Chinese pangolin also influences organic matter turnover and mineralization (Chao et al., 2020).

The Chinese pangolin is widely distributed throughout Nepal. It is found in central and eastern regions (Baral and Shah, 2008), mid-mountain regions, mid-hills, Tarai, and Siwalik regions (Jnawali et al., 2011; DNPWC & DoF, 2018; Sharma et al., 2020a). The species has been reported from forests, artificial and natural habitats, and protected areas (Gurung, 1996; Sharma et al., 2020b). In Nepal, the species is distributed more in forests than in other places (Sharma et al., 2020a), but forest area is decreasing in Nepal (Paudel et al., 2016) which is posing a huge threat to the species. The majority of the Chinese pangolin is distributed in non-protected areas, and this could increase the risk of poaching of the species (Sharma et al., 2020a) though it is illegal to hunt or kill the Chinese pangolin in Nepal and it is a protected species (Jnawali et al., 2011), due to the lack of proper laws for wildlife conservation in non-protected areas (Khatiwada et al., 2020). Also, suitable habitat and distribution of the species should be known for its conservation (Johnson et al., 2004) but in contrast, there is a shortage of data regarding the distribution and habitat of the species in Nepal (DNPWC & DoF, 2018). For the conservation of the Chinese pangolin, it is crucial to study and comprehend the habitat ecology, habitat use, and distribution pattern at the local level (Dorji et al., 2020). In addition, knowledge of the specific habitat of the species at the local level is necessary for successful conservation of the species, environmental and anthropogenic factors at the local level might influence the species habitat (KC et al., 2024). Furthermore, different environmental factors affect its habitat choice (Wu et al., 2003) like aspect, and slope (Sharma et al., 2020b; Wu et al., 2003). Its nocturnal behavior makes it difficult to monitor its population status and habitat, so the study of its burrows is a useful method to study habitat selection for pangolin since it is difficult to observe pangolin in the field. Hence, this study can provide some information on the Chinese pangolin burrow distribution and the factors affecting its occurrence, which can help understand the species habitat use and use it for knowledge and conservation plans.

1.2 Statement of problem

There's still limited knowledge about the distribution, habitat, and protection status of the Chinese pangolin habitat globally as well as in Nepal (Jnawali et al., 2011; DNPWC & DoF, 2018; Rai et al., 2019; Acharya et al., 2021; Zhang et al., 2024) which has caused problem in its assessment and conservation (Zhang et al., 2024). The lack of information regarding its status and distribution is due to its nocturnal and highly secretive nature (Thapa, 2013) and difficulty to observe it (Zhang et al., 2020). In Nepal, its potential suitable habitat lies outside the protected areas of Nepal (DNPWC & DoF, 2018; Sharma et al., 2020a; Suwal et al., 2020) where anthropogenic threats like poaching and hunting are high (Deguignet et al., 2014 cited from Acharya et al., 2021; DNPWC & DoF, 2018). As the present extent of the Chinese pangolin habitat in protected areas is minimal, improving their population and management of habitat outside protected areas is necessary (Zhang et al., 2024) so it is equally important to collect information on their distribution and factors affecting their habitat from non-protected areas too. In addition, there's limited information on the species from mid-hills (Dhami et al., 2023), and less is known about the species from rural areas. So, it is important to get information from the areas where its distribution and habitat use are unknown or limited.

1.3 Objectives

1.3.1 General objectives

The general objective of the study is to identify the distribution and habitat use of the Chinese pangolin in Bhimsen Thapa Rural Municipality, Gorkha, Nepal.

1.3.2 Specific objectives

i. To assess the distribution of the Chinese pangolin burrow in the study area.

ii. To identify the factors affecting the occurrence of the Chinese pangolin in the study area.

1.4 Research questions

i. What is the distribution of the species in the study area?
ii. Which factors affect the occurrence of the Chinese pangolin in the study area?

1.5 Significance of the study

The population of the Chinese pangolin, which is critically endangered, has been declining in Nepal and globally, mainly due to persecution, habitat loss and fragmentation, poaching, illegal trade, and ethno-medical practices (Jnawali et al., 2011; Katuwal et al., 2017; Sharma et al., 2020). In Nepal, information on its distribution and habitat is limited (Katuwal et al., 2017; DNPWC & DoF, 2018; Suwal et al., 2020; Acharya et al., 2021). The limitation of such ecological data is one of the main obstacles to pangolin conservation in the nation (Khatiwada et al., 2020; Suwal et al., 2020) as the species shows preference for some particular habitat (Wu et al., 2004) due to the availability of food, slope, and aspect (Wu et al., 2003; Sharma et al., 2020b). So, knowledge of its distribution and habitat is crucial for making site specific conservation plans for its conservation. The Chinese pangolin is mainly found in the hilly regions (Suwal et al., 2020) and mid-hills of Nepal (Sharma et al., 2020a) but there is a lack of data from many mid-hill districts (Dhami et al., 2023). In addition, less attention is given to such species and there is limitation of data in rural areas. This study is expected to fulfill this knowledge gap to some extent by providing deficient data on the species from the study area, where its existence is unknown. This study investigated its distribution in the study area and aims to provide information about the factors affecting the occurrence of the species. It can give an insight into the habitat use of the species to other researchers and guide policymakers to come up with good management initiatives and conservation plans targeted outside the protected areas to minimize the threat to the species and the ecosystem.

2. Literature review

2.1 Distribution of the Chinese pangolin

Pangolins can live in numerous habitat types across different geographic ranges (Karwita et al., 2018). Pangolins are mostly found in tropical and subtropical areas of Southern Africa and Southeast Asia (Yu et al., 2015). The Chinese pangolin is found across East Asia and parts of Northern Southeast and South Asia (Wu et al., 2020). It is found in China, the Himalayan regions of Nepal, Northern India, Thailand, Bangladesh, Bhutan, Myanmar, Vietnam, and Lao PDR (Challender et al., 2019). In India, it is found in Assam, Manipur, Arunachal Pradesh, Mizoram, Nagaland, Tripura, West Bengal, and Sikkim (Srinivasulu and Srinivasulu, 2004). It is distributed in southern regions of Bhutan like Samtse, Sarpang, Chukha (Wangchuk et al., 2004). In Dorokha Dungkhag, Bhutan, the species was found at an altitude of 1300–1700 m (Dorji et al., 2020). In Dawuling Natural Reserve, China, the Chinese pangolin was found at elevations of 760–1704 m (Wu et al., 2003). In Eastern China, the distribution range of the species which was wide in the past, decreased massively by 52.2% in time span of 30 years (1970s to early 2000s) due to anthropogenic pressures (Yang et al., 2018).

The species is found mostly in forests, followed by cultivated land and grasslands (Zhang et al., 2024), shrubs, and barren lands. In Nepal, it is distributed throughout the country and more outside protected areas, in forests where its habitat is invaded by human settlements or infrastructure projects, which affects its distribution (Khatiwada et al., 2020; Sharma et al., 2020a; Suwal et al., 2020). It is potentially distributed in the mid-hill region at elevations of 1000–3000 m, Tarai at elevations below 300 m, mid-mountain region at elevations of 3000–5000 m, and Siwalik region at elevations of 300–1000 m, out of which it is found to be highly distributed in the mid-hill region (Sharma et al., 2020a). In central Nepal, more Chinese pangolin burrows were detected in protected areas (Gaurishankar Conservation Area) than non-protected areas (Ramechhap District), which may be due to fewer human activities in protected areas (Sharma et al., 2020b). Chinese pangolin are found to be distributed in 25 districts in Nepal (DNPWC & DoF, 2018).

2.2 Factors affecting the occurrence of the Chinese pangolin

Due to the influence of factors like food, slope, aspect, soil, canopy cover, distance to water sources, and road (Wu et al., 2003; Khatiwada et al., 2017; Sharma et al., 2020a,b), preference for a specific habitat is shown by the Chinese pangolin (Wu et al., 2004). The distribution of the species is highly affected by factors like elevation, aspect soil color, soil texture, ant and termite nests, tree canopy, and distance to water source (Dhital et al., 2020; Timsina & Baral, 2020). The distribution of the burrow is more in areas with moderate canopy cover, south-facing burrow openings, 30–60° slope, and the species avoids sharp slopes steeper than 60° and sites near human disturbance (Wu et al., 2003). The species likes lower altitudes, but during winter it prefers mid-altitudes (Dorji et al., 2020). It lives in primary and secondary tropical forests, grasslands, hill forests, coniferous forests, shrub forests, mixed coniferous forests, warm and cool broadleaf forests, limestone, bamboo, cardamom cultivation areas, and agricultural areas (Wu et al., 2003; Wu et al., 2020; Dorji, 2020). It is also distributed in bamboo forests, thorny bushes, grasslands, agricultural lands, coniferous forests, and soy bean farms in Nepal (Suwal, 2011). It is distributed in both forest and agricultural land, though its distribution is more in forests (Thapa et al., 2014; Katuwal et al., 2017). A higher Chinese pangolin burrow density is found in areas with strong termite populations, humid soil, and areas near human settlements. Burrows are found in different kinds of soil, like clayed loam soil, silty loam soil, and sandy loam soil. The Chinese pangolin prefers moist soil for easy digging (Rai et al., 2019) so it typically makes its burrow in soft, humid, thick soil with a thick covering of organic materials on the surface, in places with less human interference, near water sources. The primary reasons for excavating burrows is to hibernate, rest, hunt termites, breed, and protect them from enemies. Burrows are usually made by avoiding north-facing entrances and entrances with poor hiding conditions (Wu et al., 2004). In addition, active burrow of the species is located close to water sources, roads, and human settlements. Active burrows are found more in red soil, in forested areas, and in regions where ant and termite colonies are present (Dhital et al., 2020; Dhami et al., 2023). Active burrows are found, mainly in dense forests with less human disturbance (Sharma et al., 2020c). The presence of the species is negatively impacted by livestock grazing, forest fires, proximity to the closest household, and footpath (Thapa et al., 2014; Katuwal et al., 2017).

In Nepal, burrows of the species are mostly found on 30–50° slopes, 50–75% canopy cover, at elevation range of 500–1500 m, in forests dominated by *Schima wallichii, Castanopsis indica,* and *Alnus nepalensis*, and in places dominated by humans (Suwal et al., 2020). In Dolakha, burrows were distributed in a clumped pattern, mostly at elevation range of 1500–1700 m, in dark reddish brown soil, facing south, and on a 20–30° slope.

In Chandragiri, burrows were found at an elevation range of 1450–1800 m. The maximum number of burrows was found close to roads, ant nests, an increasing slope gradient and water source in a 30–40° slope, and close canopy cover (Tamang et al., 2022). Burrows were found at an elevation range of 1550–2095 m, 7–48° slope, and factors like slope, noise, ground cover, canopy cover, and distance to settlement had a significant impact on the burrow occurrence (KC et al., 2024). In Kavrepalanchok district, the majority of the burrows were found on gentle slopes, while they avoided slopes > 60° and were found near water sources and ant nests. More burrows were found at an elevation range of 1400–1500 m in brown-colored soil (Suwal, 2011; Shrestha et al., 2021a). In another study done in Kavrepalanchok, burrows were found in both forest and agricultural land on a 5–25° slope. The species preferred places with open canopy cover, a 15–22° slope, a west aspect, and an elevation range of 1450–1600 m (Acharya et al., 2021).

In Mahabharat community forest, Sindhuli district, burrows were recorded at an elevation range of 1400–1700 m, and maximum burrows were found in brown-colored soil on a 30–40° slope, while burrows were found in Chure community forest at an elevation range of 900–1300 m, and maximum burrows were found in light yellow-colored soil on 20–30° slope. The majority of the burrows were recorded in forests dominant with *Schima wallichii* and *Shorea robusta* in open canopy cover, soil with 10–20% moisture, and southern aspect (Timsina & Baral, 2020). In Nagarjun and Ranibari forests in Shivapuri Nagarjun National Park, burrows were found at an elevation range of 1385–1537 m. The burrow distribution was affected by habitat factors like elevation, canopy cover, and vegetation in the area. The majority of the burrows were found near roads facing south-east aspects in brown-colored soil (Aryal & Poudel, 2018). In a study done in protected and non-protected areas of Nepal, more burrows were found in protected areas, which can be due to more human disturbance in non-protected areas. Burrow occurrence was affected by food source, forest, and red soil in protected areas and food source and farm land in non-protected areas (Sharma et al., 2020a). In Shivapuri Nagarjun National Park, the majority of the burrows were found at elevation range of 1400–1600 m and 25–50% canopy cover (Dhital et al., 2020). In Chitwan, burrows were recorded at an elevation range of 300–413 m, 5–22° slope, 40–800 m distance from the nearest water source, and 0–140 m distance from the nearest food source. The majority of the burrows were recorded on a 15–20° slope with 51–75% canopy cover, a northwest aspect, and red soil

(Shrestha et al., 2021b). In Taplejung, the Chinese pangolin was found in both forests and agricultural lands at an elevation range of 1126–2406 m, and their burrows were primarily located at an elevation range of 1520–1620 m, with 0–25% canopy cover around *Imperata cylindrical*, *Nephrolepis auriculata*, *Dendrocalamus*, and *Pinus roxburghii* (Thapa et al., 2014). In Dhankuta and Illam, burrows were at an elevation range of 555–1740 m, mostly distributed close to water and closed canopy cover (Katuwal et al., 2017). In CF of Makwanpur district, burrows were found in clumped distribution and the majority of burrows were found at an elevation range of 500–600 m (Lamichhane and Pokhrel, 2019).

3. Materials and methods

3.1 Study area

The study was conducted at Bhimsen Thapa Rural Municipality (27°56′16.8″E to 28°3′54″E and 84°38′24″N to 84°49′33.6″N) of Gorkha District, Central Nepal (Figure 1). The municipality comprises an area of 101.35 km^2. The study was performed in four community forests (CF), i.e., Jageshwar CF, Ghatbesi CF, Bhawani CF, and Powalichap CF of Bhimsen Thapa Rural Municipality. The total area of the community forests was 408.37 ha (Jageshwar forest: 126.70 ha, Ghatbesi forest: 96.55 ha, Bhawani forest: 143.40 ha, and Powalichap forest: 41.72 ha). Map of the study area was made using QGIS software.

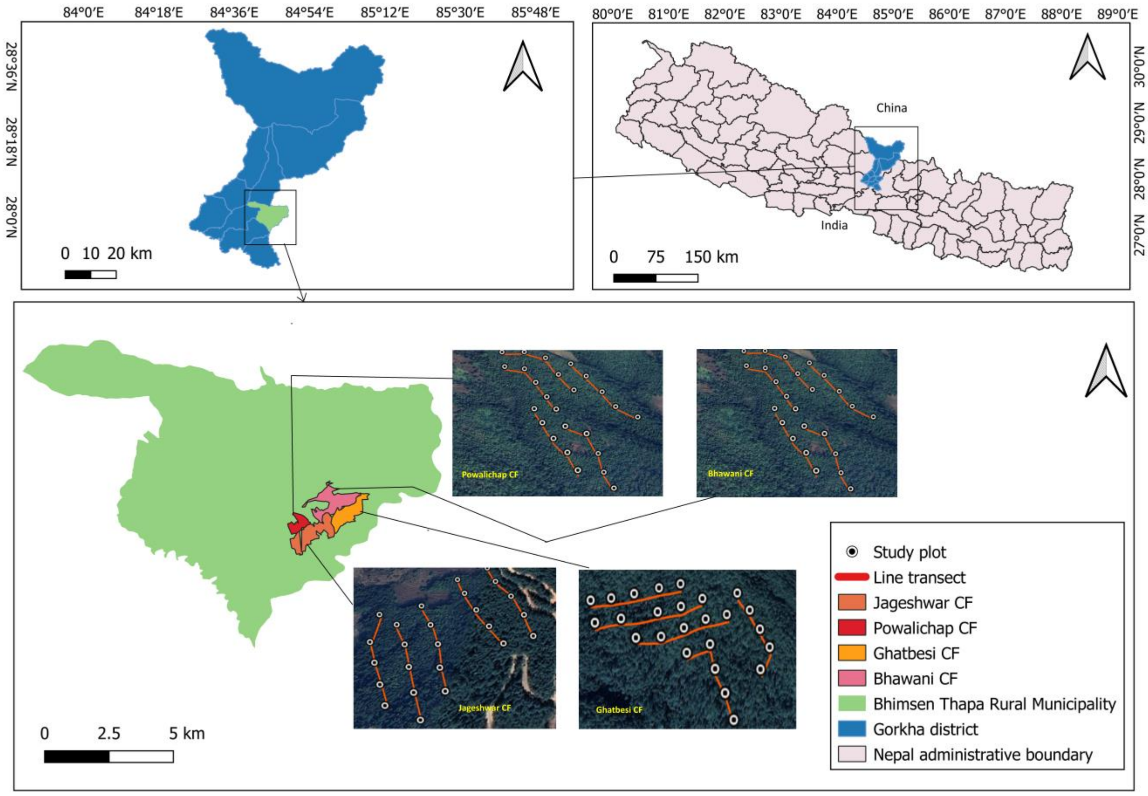

Figure 1. Map of the study area with established line transects and plots in Bhimsen Thapa Rural Municipality, Gorkha, Nepal.

The vegetation of the study area is mostly comprised of sal (*Shorea robusta*), katus (*Castanopsis indica*), chilaune (*Schima wallichii*), bhalayo (*Semecarpus anacardium*), jamun (*Syzygium cumini*), and mauwa (*Engelhardia spicata*). The forest comprised fauna including common pigeon (*Columba livia*), common myna (*Acridotheres tristis*), leopard (*Panthera pardus*), porcupines (*Hystrix* spp.), and the Chinese pangolin.

3.2 Methods

A preliminary survey was carried out from 17–21 November 2023. During the preliminary study, community forests with the Chinese pangolin occurrence were identified with the help of local people, Division Forest officials, and members of the community forest user groups. The extensive study was conducted from 9 January to 2 March 2023.

A total of 20 line transects were established in the community forest (four in each forest). The average length of transect was 269 ± 6.5 m (Minimum: 265 m; Maximum: 295 m). The interval between two transects was 50 m. A total of 100 plots of 10 m×10 m were established in the study area and each forest had equal plots. The plots were established at the interval of 50 m and were sampled systematically. The burrows were categorized into two types: new and old burrows. The burrow that had compacted soil, plant seedlings, dry fodder, and spider webs was considered as old burrow, and the burrow that had fresh pugmarks, loose, fresh soil, and neither dry fodder nor plant seedlings was considered to be a new or fresh burrow (DNPWC, 2019). In addition, elevation, aspect, slope, canopy cover, and ground cover were recorded in each plot. The elevation was recorded using GPS Garmin Etrex 10. The aspect and slope of the plot was recorded from the center of each plot using clinometer. Canopy cover of each plot was recorded using Gap Light Analysis Mobile Application (GLAMA) and ground cover using Canopeo. For estimating ground cover and canopy cover, centre value and four corner values of the plot were taken and averaged. In addition, the nearest distance to ant or termite nest location, water source, human settlement, and agricultural land were also measured from the centre of each plot. The nearest distance to these variables were measured using measuring tape if these were < 100 m, and was measured using GIS if these were > 100 m. In addition, the number of tree in each plot was counted only those are with > 10 cm DBH (Schemnitz, 1980). The DBH was measured at the standard height of 1.3 m using a measuring tape. Important value index (IVI) of the trees in the study site was calculated following (Curtis, 1959).

3.3 Statistical analysis

A descriptive statistics was calculated to identify the location of data of continuous variables around the mean. A generalized linear model (GLM) was calculated to identify the effects of habitat factors on occurrence of the Chinese pangolin. Presence absence of the Chinese pangolin's burrows was used as response variable and elevation (m), aspect, slope (°), canopy cover (%), ground cover (%), nearest distance to food source (m), nearest distance to water source (m), nearest distance to human settlement (m), nearest distance to agricultural land (m), and IVI was used as predictive variables. Before model run, a correlation test was performed to avoid multi-collinearity among the predictive variables (Figure 2). Two variables, nearest distance to agricultural land and settlement were highly correlated. Therefore, the nearest distance to settlement was not used for the analysis.

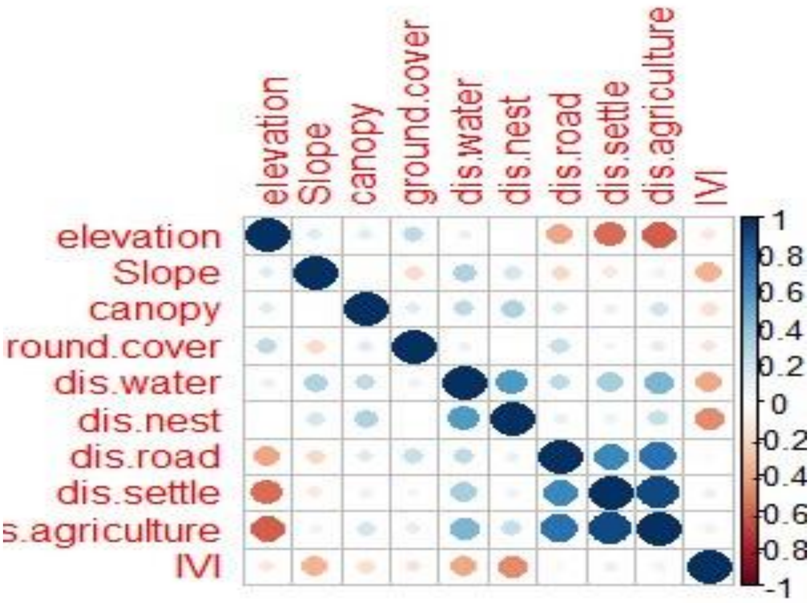

Figure 2. Correlation matrix between predictive variables to estimate the factors affecting the Chinese Pangolin occurrence in Bhimsen Thapa Rural Municipality, Gorkha in 2023. dis.water=distance to the nearest water source, dis.nest=distance to the nearest ant/termite nest, dis.road=distance to the nearest road, dis.settle=distance to the nearest human settlement and dis.agriculture=distance to the nearest agricultural land.

Analysis of distribution pattern of the Chinese pangolin in the study area was done following (Krebs, 1999) by calculating the ratio of variance to mean (S^2/a):

$$S^2 = \frac{\sum_{i=1}^{n} (X - a)^2}{n - 1}$$

Where, X=Number of burrows

a=Mean value

n=Total sample number

If $S^2/a=1$, Distribution is random

If $S^2/a < 1$, Distribution is uniform or regular

If $S^2/a > 1$, Distribution is clumped

3.4 Vegetation analysis

Important value index (IVI) of tree species in the study site was calculated following (Curtis, 1959):

IVI=Relative Dominance+ Relative Frequency+ Relative Density

Relative Frequency (%)

$$= \frac{\text{Number of quadrates in which a species occur}}{\text{Total number of all species in the quadrates}} \times 100$$

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

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

$$\text{Basal area} = \frac{\pi \text{d2}}{4} \times 100$$

Where, d=Diameter at breast height

4. Results

4.1 Distribution pattern of the Chinese pangolin

Presence of the Chinese pangolin burrow was found in 42 plots from 100 survey plots from four community forests of Bhimsen Thapa Rural Municipality. Altogether, 80 burrows were recorded, and 59 old burrows (73.75%) were found in 34 plots and 21 new burrows (26.25%) in 15 plots. The average number of burrows per plot was 0.8, the variance was 0.846, and the ratio of variance to mean was 1.37 which is greater than 1. Hence, the distribution of the burrows in the study area was clumped. The highest number of burrows (32.5%, n=26) were found in Powalichap CF, followed by Bhawani CF (31.25%, n=25) and Jageshwar CF (26.25%, n=21) (Figure 3). The maximum number of new burrows (47.6%, n=10) were also found in Powalichap CF, followed by Bhawani CF (38.09%, n=8).

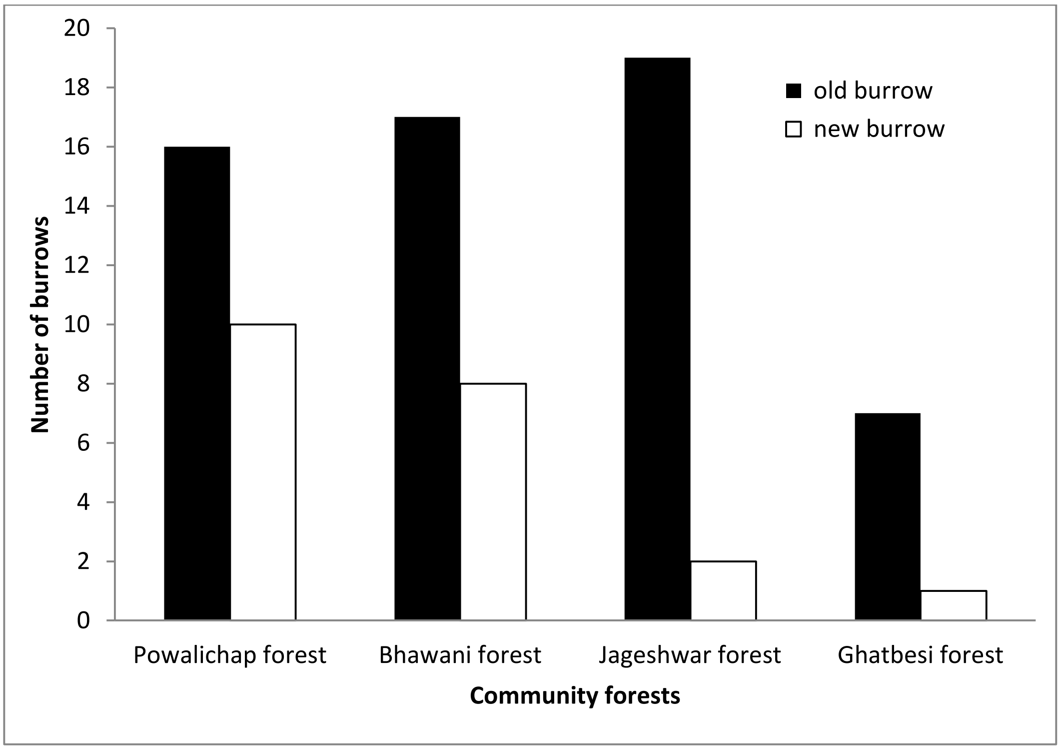

Figure 3. Number and types of the Chinese pangolin burrows found in the community forests.

The burrows were at an elevation range of 500–852 m above sea level [(average 697.83 ± 89.86 m (SD)]. The majority of the burrows (40%, n=32) were recorded at an elevation range of 700–800 m above sea level, out of which 23 were old and nine were new. The least number of burrows were recorded at the elevation range of 500–600 m (Figure 4).

The maximum number of burrows were found on South-east face (36.3%, n=29), followed by South face (30%, n=24). The least number of burrows were found in the north face (Figure 5). The average slope of the study plot was 25.08 ± 7.08° (range: 11–44°). The majority of the burrows (47.5%, n=38) were recorded between slope 20–30°, out of which 26 were old and 12 were new, followed by slope range 30–40° (28.75%, n=23). The least number of burrows were recorded between slope 40–50° (Figure 6). The average canopy cover percentage in the study plot was 51.60 ± 16.31% (range: 25–86%). The majority of the burrows were found in areas with canopy cover 25–50% (53.75%, n=43), followed by areas with canopy cover 50–75% (32.5%, n=26). The least number of burrows were found between 75–100% canopy cover (Figure 7). The average ground cover in the study plot was 53.56 ± 18.91% (range: 12–86%). The majority of the burrows were found in ground cover 50–75% (53.75%, n=43), followed by 27 burrows (33.75%) in ground cover 25–50% (Figure 8). Fifty three out of 80 burrows (66.3%) were found in red soil, out of which 42 were old and 11 were new burrows. Out of the total burrows, (33.8%, n=27) were found in brown soil (Figure 9).

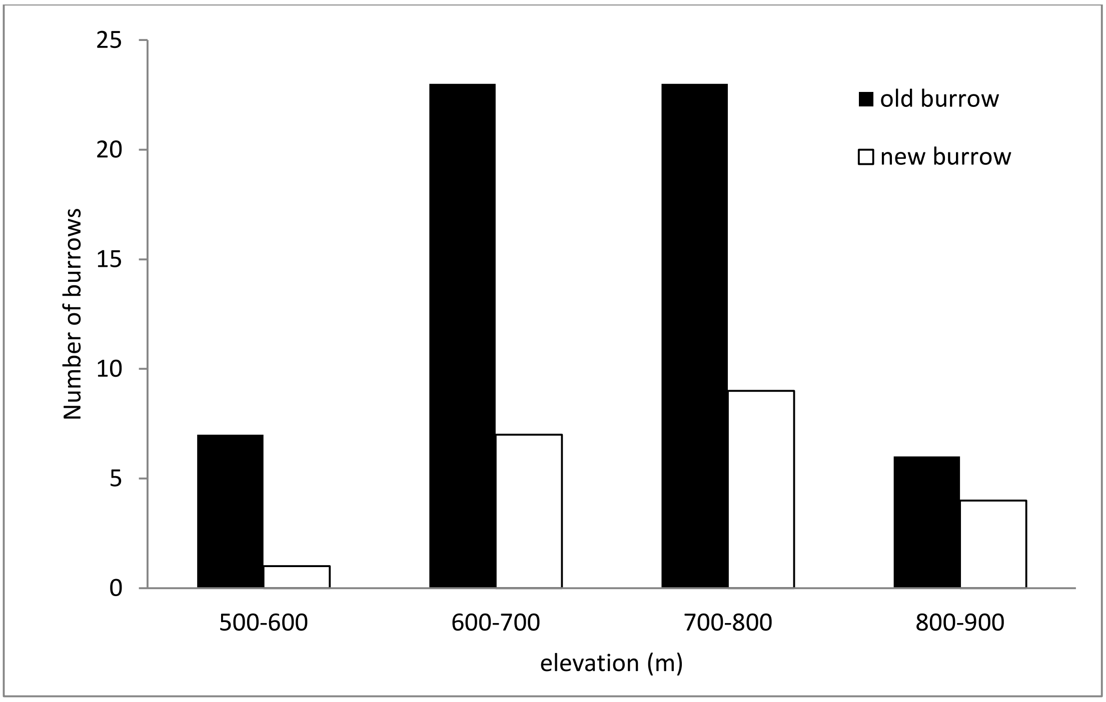

Figure 4. Distribution of the Chinese pangolin burrows with elevation in Bhimsen Thapa Rural Municipality.

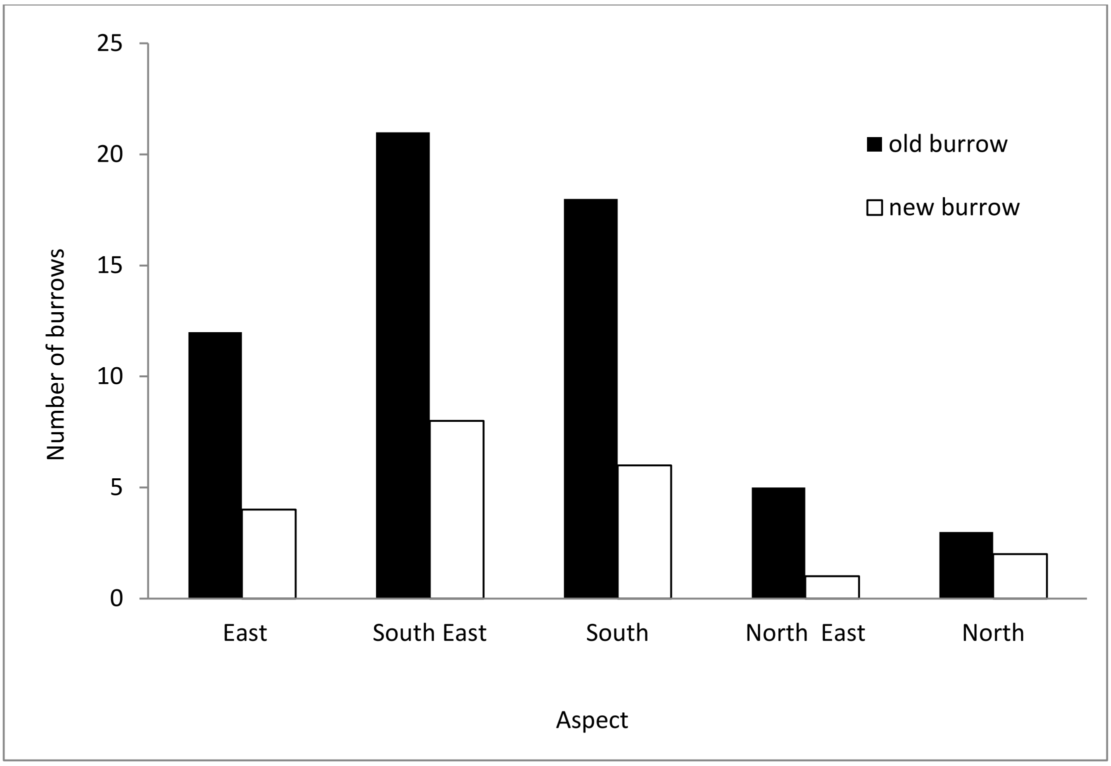

Figure 5. Distribution of the Chinese pangolin burrows with aspect in Bhimsen Thapa Rural Municipality.

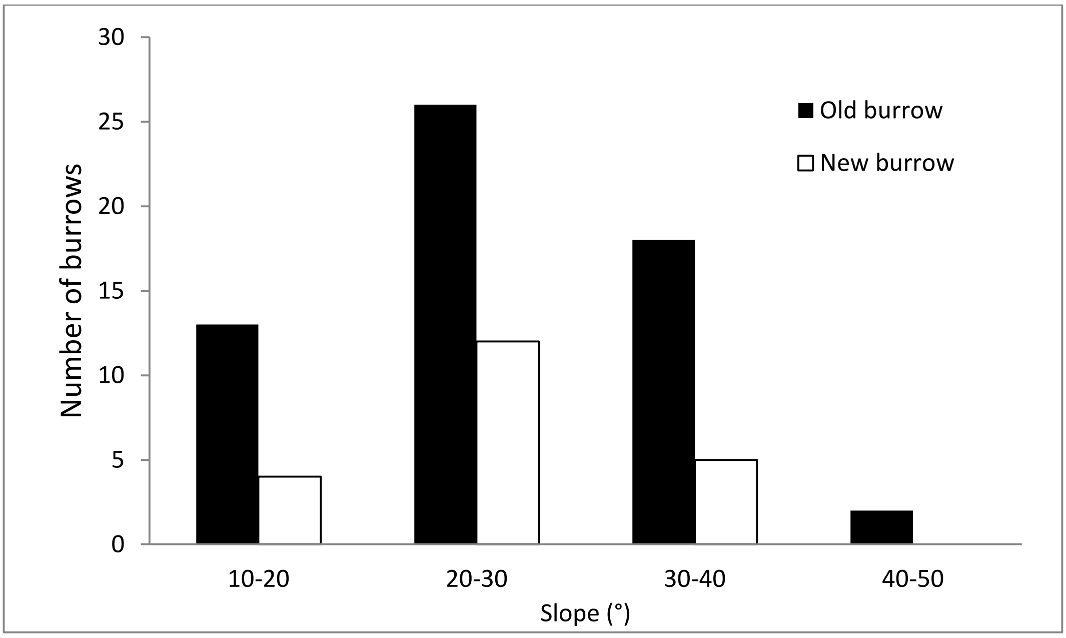

Figure 6. Distribution of the Chinese pangolin burrows with slope in Bhimsen Thapa Rural Municipality.

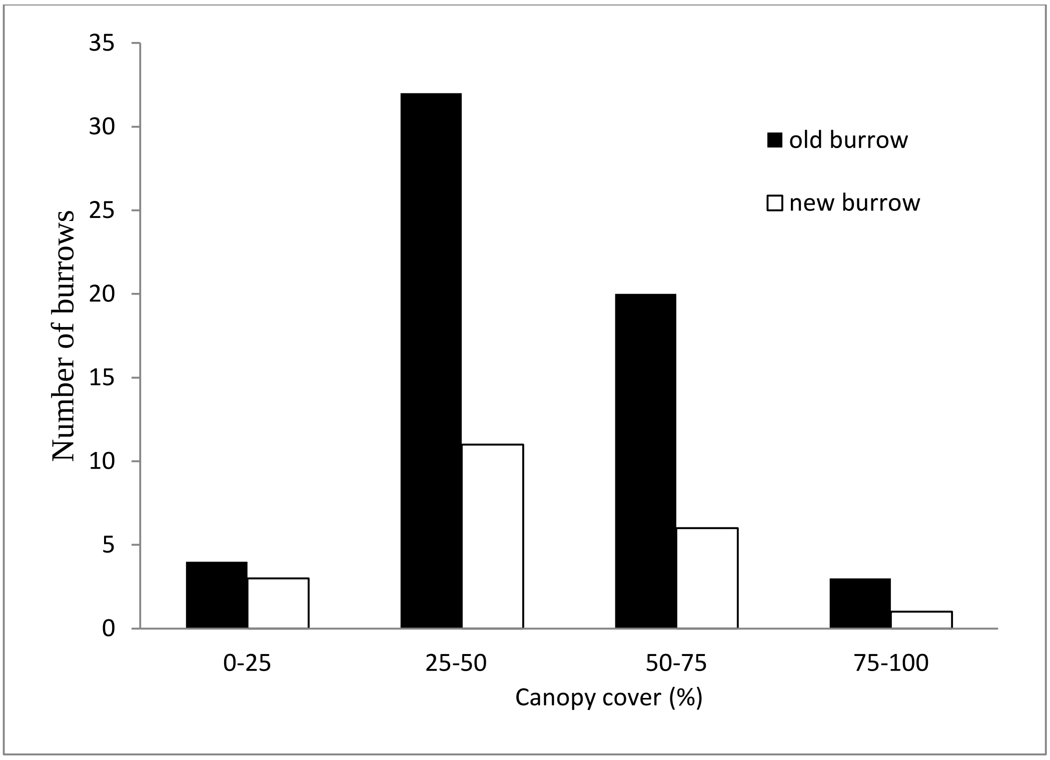

Figure 7. Distribution of the Chinese pangolin burrows with canopy cover in Bhimsen Thapa Rural Municipality.

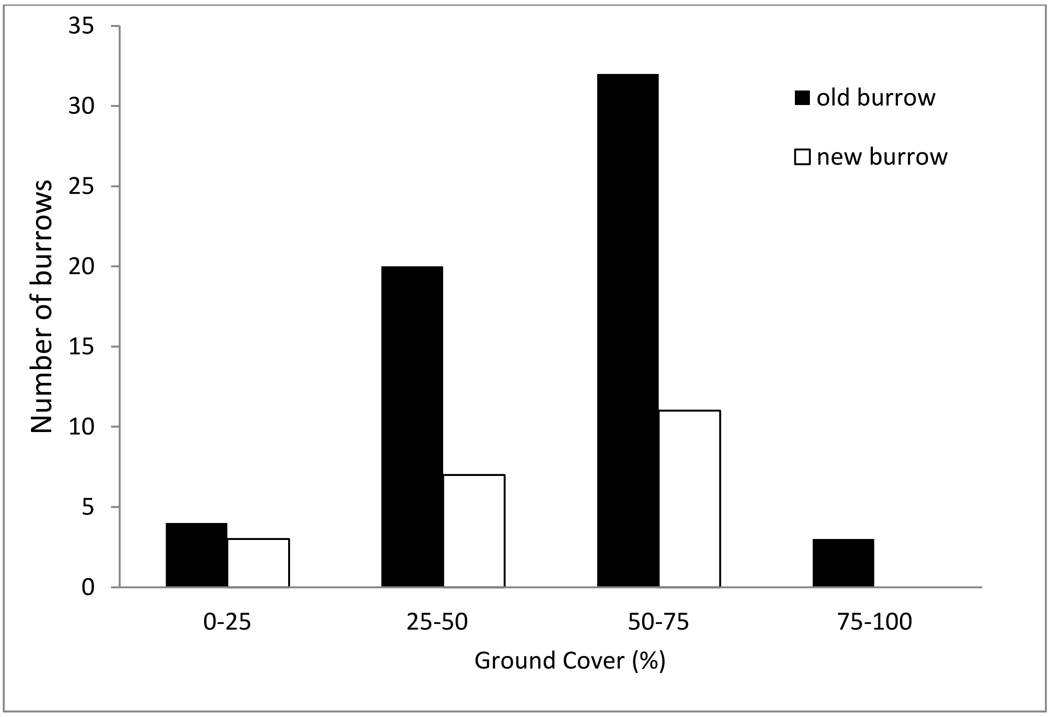

Figure 8. Distribution of the Chinese pangolin burrows with ground cover in Bhimsen Municipality.

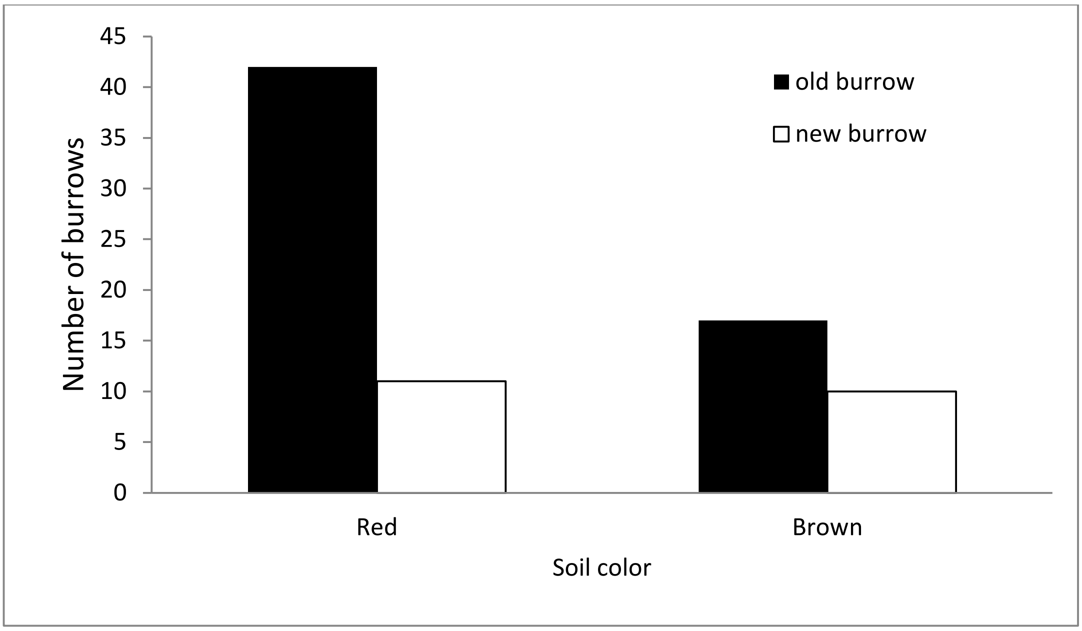

Figure 9. Distribution of the Chinese pangolin burrows with soil color in Bhimsen Thapa Rural Municipality.

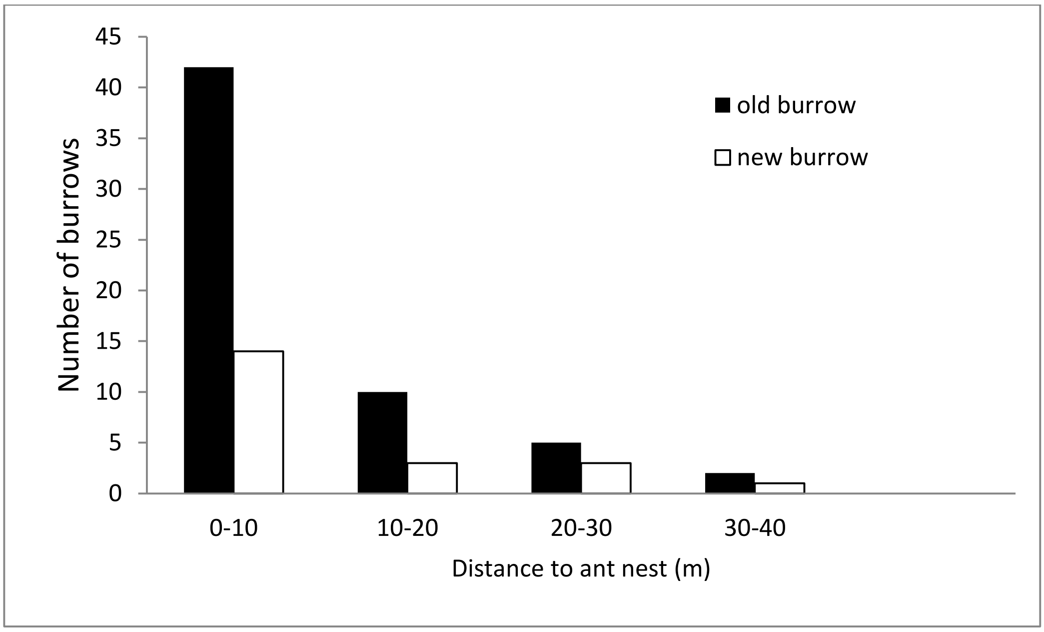

Figure 10. Distribution of the Chinese pangolin burrows with distance to the nearest ant nest in Bhimsen Thapa Rural Municipality.

The average nearest distance of plots to the ant nest and termite nest was 9.52 ± 8.23 m (range: 0.5–33 m) in the study area. The maximum number of burrows were found within 10 m from the nearest ant and termite nest (70%, n=56), out of which 42 were old and 14 were new burrows (Figure 10). The average nearest distance of plots to the water source was 130.9 ± 80.9 m (range: 38–347 m). The majority of the burrows were found within 100 m of the nearest water source (50%, n=40), out of which 29 were old and 11 were new. No burrow was recorded beyond 400 m of the nearest water source (Figure 11). The average nearest distance of plots to the road was 328.4 ± 160.6 m (range: 55–666 m). The majority of the burrows (45%, n=36) (old=27, new=9) were found 200–400 m from the nearest road. The least number of burrows were found 600–800 m from the nearest road. No burrow was recorded beyond 800 m (Figure 12). The average nearest distance of plots to the settlement was 378.2 ± 145.6 m (range: 142–767 m). The majority of the burrows (58.7%, n=47) were found 300–600 m from the nearest settlement, out of which 34 were old and 13 were new. The number of burrows decreased beyond 600 m. No burrow was recorded beyond 900 m (Figure 13). The average nearest distance of plots to the nearest agricultural land was 205.6 ± 107.9 m (range: 47–489 m). The majority of the burrows (37.5%, n=30) were found 200–300 m from the nearest agricultural land (Figure 14), followed by (27.5%, n= 22) 200–300 m from the nearest agricultural land.

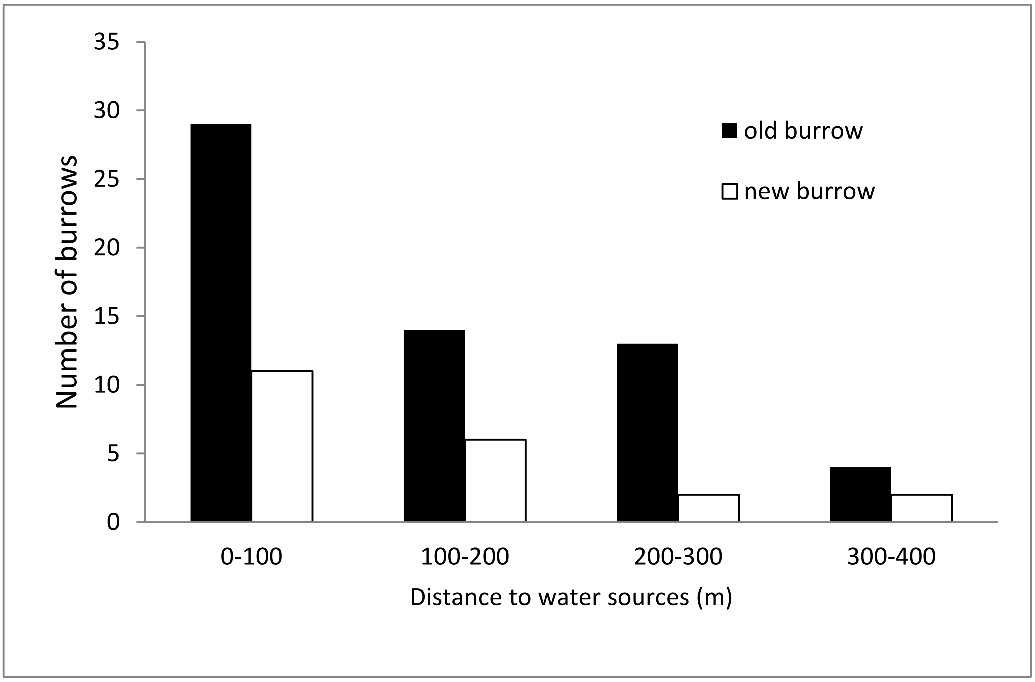

Figure 11. Distribution of the Chinese pangolin burrows with distance to the nearest water source in Bhimsen Thapa Rural Municipality.

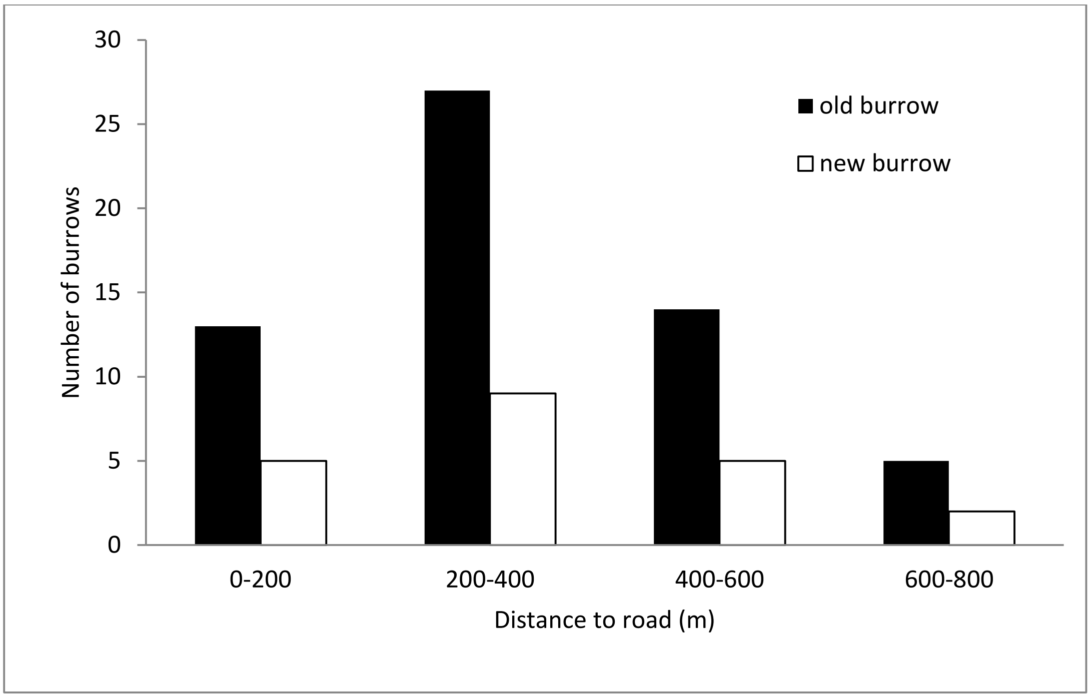

Figure 12. Distribution of the Chinese pangolin burrows with distance to the nearest road in Bhimsen Thapa Rural Municipality.

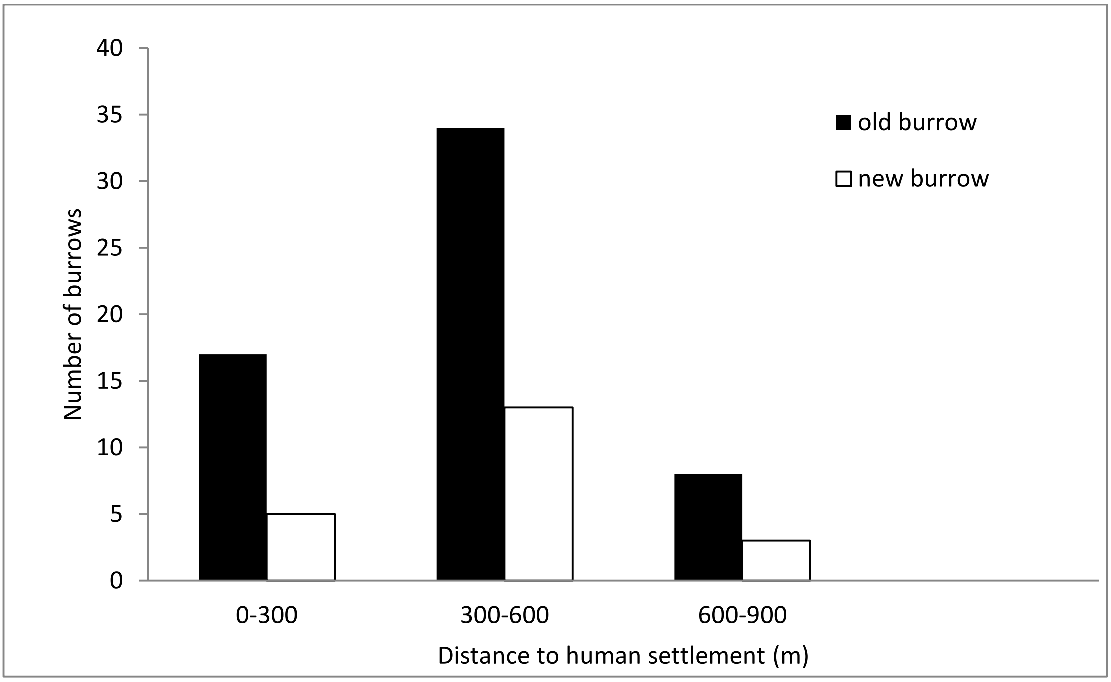

Figure 13. Distribution of the Chinese pangolin burrows with distance to the nearest human settlement in Bhimsen Thapa Rural Municipality.

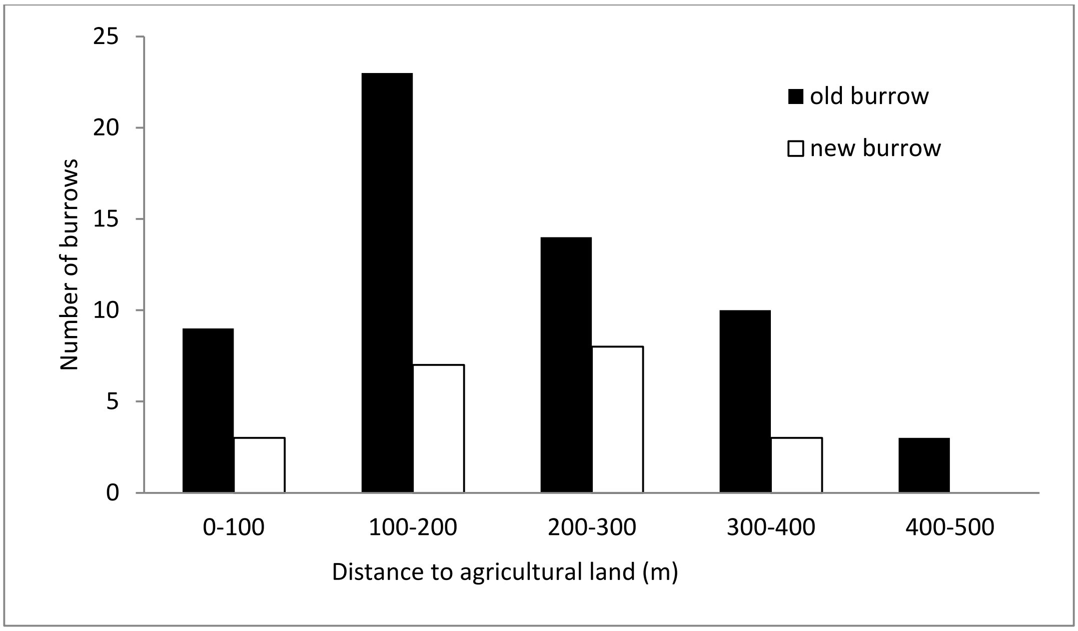

Figure 14. Distribution of the Chinese pangolin burrows with distance to the nearest agricultural land in Bhimsen Thapa Rural Municipality.

4.2 Factors affecting the occurrence of the Chinese pangolin

Out of 9 habitat parameters used in the GLM model, the Chinese pangolin burrow occurrence was highly influenced by five independent variables: slope, nearest distance to water, nearest distance to nest, nearest distance to road, and elevation (Table 1). Habitat variables like canopy cover, ground cover, and distance to agricultural lands had no significant effect on the occurrence of the burrows. According to the model, the presence of burrows increased with a decrease in slope, decrease in canopy cover percentage, decrease in ground cover percentage, decreasing distance to water resources, decreasing distance to agricultural land, and decreasing distance to ant nests. The presence of burrow increased with increasing elevation, increasing tree abundance, and increase in distance to road.

Table 1. Binomial distribution model averaged parameter estimates showing the affects of environmental variables on the occurence of the Chinese pangolin burrow in Bhimsen Thapa Rural Municipality. Estimates significant effects are in bold ($p < 0.05$).

Variables	**Estimate**	**SE**	**Z**	**P**
(Intercept)	2.284	7.256	0.315	0.752
Slope	-0.178	0.066	-2.724	**0.006**
Canopy	-0.019	0.030	-0.626	0.531
Ground cover	-0.0298	0.034	-0.868	0.385
Elevation	0.019	0.010	1.798	**0.072**
Distance to agricultural land	-0.004	0.006	-0.636	0.525
Distance to road	0.005	0.002	1.779	**0.075**
Distance to water	-0.025	0.008	-2.932	**0.003**
Distance to nest	-0.200	0.066	-3.011	**0.002**
IVI	0.003	0.005	0.524	0.600

4.3 Vegetation analysis

A total of 1458 trees of 10 different species were recorded in the surveyed plots. One of the species was not identified. Out of the 10 species, *S. robusta* (IVI=112.7) was the most dominant species in the study area (Table 3), followed by *S. wallichi* (IVI= 78.62) and *C. indica* (IVI= 51.62), *Terminali sp.* (1.89) was the least dominant species.

Table 2. Important value index (IVI) of tree species in the study area.

Name of tree species	**Relative dominance**	**Relative density**	**Relative frequency**	**IVI**
Shorea robusta	39.1	45.27	28.33	112.7
Schima wallichii	30.93	25.03	22.66	78.62
Castanopsis indica	16.9	15.02	19.26	51.18
Semecarpus anacardium	4.18	4.73	8.5	17.41
Engelhardia spicata	4.17	4.66	8.5	17.33
Lagerstroemia parviflora	1.78	1.99	4.25	8.02
Syzygium cumini	0.98	1.09	3.39	5.48
Myrica esculenta	0.86	0.96	2.26	4.08
Terminali sp.	0.49	0.55	0.85	1.89
Species A	0.61	0.68	1.98	3.28

5. Discussion

5.1 Distribution pattern of the Chinese pangolin

In this study area, the majority of old burrows of the Chinese pangolin were found. It might be due to the season and the short duration of the study. The study was conducted in the winter season. In the winter season and at the short period of time, the chances of recording the burrows will be varied due to moving to a new burrow (Lin, 2011) or it might be chances of the Chinese pangolin using the same burrow are very low, and they barely do that (Wu et al., 2004).

In the study, the Chinese pangolin showed clumped distribution. This might be due to the influence of food, aspect, and preferred habitat (Tamang et al., 2022; Dhami et al., 2023). Higher burrow density is found in places with high abundance of ants and termites (Dhami et al., 2023). More burrows were found in Powalichap CF, followed by Bhawani CF. All four forests included in the study had similar vegetation. The presence of burrows increased as tree abundance in the study plot increased, though the occurrence of the species burrow was not significantly influenced by it. The burrows in four CF were distributed in habitats dominated by *Shorea robusta, Schima wallichii,* and *Castanopsis indica,* burrows were found in places dominated by these species in other locations too (Aryal & Poudel, 2018; Dorji et al., 2020; Timsina & Baral, 2020; Dhami et al., 2023). In Nepal, burrows of the Chinese pangolin are mainly found in forests where tree species such as Shorea robusta, Schima wallichii, Castanopsis indica, and Alnus nepalensis are predominant (Suwal et al., 2020).

5.2 Factors affecting the occurrence of the Chinese Pangolin

In the study, the Chinese pangolin burrow occurrence was significantly influenced by elevation. Not only in this study, its burrows were influenced in other locations in both protected and non-protected areas of Nepal, where burrows were recorded from elevation range of 500–1500 m (Katuwal et al., 2017; Aryal & Poudel, 2018; Lamichhane & Pokhrel, 2019; Dhital et al., 2020; Sharma et al., 2020b; Suwal et al., 2020; Baral & Dahal, 2022; Dhami, 2023). This is not the ideal elevation range of the species, and it was also recorded < 100 m in Taiwan (Wu et al., 2020). Its burrow decreases with increasing elevation because with increasing elevation, the availability of prey species decreases (Hemachandra et al., 2014). However, this does not match with the findings of the study, as the presence of burrows increased with increasing elevation. It might be due to the narrow elevation range of this study area.

Burrows were negatively correlated with canopy cover. Not only in this study, its burrows were influenced in other locations, where the majority of the burrows were recorded in canopy cover of 25–50% (Wu et al., 2003; Dorji et al., 2020; Acharya et al., 2021; Dhami et al., 2023), potentially indicating suitable nesting places for termites due to the abundance of dead trees and tree stumps in dry areas with open canopy. Termite distribution is high in dry places with an open canopy cover of less than 50% (Hemachandra et al., 2014). Not only in this study, its burrows were influenced in other locations, where the majority of the burrows were recorded in ground cover 50–75% (Suwal et al., 2020; Dhami et al., 2023). Since they are small animals with weak defense mechanisms (Liu & Xu, 1981), dense ground cover aids the Chinese pangolin to avoid predators by shielding their burrow openings and safeguard their young as well as provide abundance of their major prey species (Axelsson & Andersson, 2012; Maurice et al. 2019; Wu et al. 2003). They favor a thick covering of ground for better mobility, feeding, and protection and tend to stay away from open ground areas (Wu et al., 2003; Dorji et al., 2017). The dense cover acts as an insulator and reduces energy consumption (Althoff et al., 1997).

The Chinese pangolin burrow occurrence was significantly influenced by slope. The presence of burrows decreased with an increase in slope. The finding of this study aligns with findings from other studies (Acharya et al., 2021; KC et al., 2024). Not only in this study, its burrows were influenced in other locations where burrows were recorded from slope 10–50° (Rai et al., 2019; Sharma et al., 2020b; Suwal et al., 2020; Tamang et al., 2022). The species selects gentle slopes to avoid the incline of the terrain and for easy mobility (Acharya et al., 2021) preferring 30–60° slope and avoids sharp slopes steeper than 60° because such terrain is not only unpleasant for their activity (Wu et al., 2003) but has low food availability (Heath, 1992). In places with lower slope, a good environment is created for ants and termites because there are fewer disruptions and a greater quantity of fallen logs (Sharma et al., 2020b). The species prefer gentle slopes in places with soft clayey loam soil, which helps them dig burrows (Dorji et al., 2020).

The Chinese pangolin burrow occurrence was significantly influenced by distance to ant or termite nest. Food availability highly influences the occurrence and distribution of the species, as it depends on a natural abundance of food, being a specialist species, whose food source in terms of quantity and species richness are ants and termites that help to sustain its distribution (Wu et al., 2004; Lee et al., 2017; Challender et al., 2019; Maurice et al., 2019). Burrows decreased as the distance to the ant/termite nest increased, indicating the likeness of the species in places with ants and termites. The occurrence of the species is highly favored by the size and abundance of termite colonies (Swart et al., 1999). The maximum number of burrows was found within 10 m from the nearest ant and termite, nest similar to (Tamang et al., 2022). Burrow preference near ants and termites is due to ease of access and availability of food (Heath & Vanderlip, 1988).

The majority of the burrows were found in red soil, similar to (Shrestha et al., 2021b; Dhami et al., 2023). The Chinese pangolin burrows are more common in red soil because more food is available in red soil than brown soil (Sharma et al., 2020b). Also, most termites favor acidic soil conditions (Li et al., 2017), and red soils have an acidic composition (Baligar et al., 2004). Generally, the Chinese pangolin prefers soft, humid, thick soil with organic matter to dig burrows, and reddish brown-colored soil is soft-layered and facilitates digging (Wu et al., 2004). Food availability, climate, and level of human disruption can have an impact on the species preference for particular aspects (Suwal, 2011). The majority of the burrows were found on the southeast face, followed by the south face. Not only in this study, its burrows were recorded on southeast face and south face in other locations (Gurung, 1996; Wu et al., 2003; Rai et al., 2019; Shrestha et al., 2021a; Tamang et al., 2022; Dhami et al., 2023), potentially indicating warmer habitat in these two aspects. The south and east aspects favor direct light penetration and help to regulate temperature, especially in the winter, which might be the reason for preferring the south aspect (Wu et al., 2004).

The Chinese pangolin burrow occurrence was significantly influenced by distance to water. Burrows decreased as the distance to the water source increased. Not only in this study, its burrows were influenced in other locations where the majority of the burrows were recorded within 100 m of the nearest water source (Dorji et al., 2020; Shrestha et al., 2021; Tamang et al., 2023), potentially indicating distance to water as an important factor that has an impact on pangolin distribution. It might be to avoid the risk of predatory animals and loss of energy while going a long distance for water (Bista et al., 2017) as the species drinks water frequently (Suwal et al., 2011). So, water sources show a positive correlation with pangolin presence since the species frequently needs water (Katuwal et al., 2017; Maurice et al., 2019).

The Chinese pangolin burrow occurrence was significantly influenced by distance to road and decreased as the distance to the road decreased. Intrinsic danger posed to the species may be the reason behind the species avoiding places near roads to make their burrows. The Chinese pangolin has a high risk of coming into contact with people when present nearer to the road, which also increases the chances of them suffering from harmful human activities like poaching and hunting (Katuwal et al., 2017). Roads also have a huge role in the loss and destruction of pangolin habitat (Suwal et al., 2020). Also, the species is naturally reserved in nature (KC et al., 2024) which might be the reason for such finding. In addition, habitat fragmentation may be caused by road construction (Katuwal et al., 2020) and unplanned construction of roads impacts the Chinese pangolin habitat and limits its distribution and movement (Sharma et al., 2020a).

Though the species favors areas with little or no human disturbances (Wu et al., 2004), the majority of the burrows were found 300–600 m from the nearest settlement. The majority of the burrows were found close to human settlements (<1000 m) (Sharma et al., 2020b), probably indicating presence of settlements of people engaged in agriculture within forested areas. Human settlements are encroaching on suitable habitats of the Chinese pangolin in Nepal, posing a hazard to the species. In addition, burrow is more evident in places with human disturbance (Karawita et al., 2018) which could be due to Chinese pangolin moving close to settlements due to natural water loss caused by climate change (Dhami et al., 2023). The presence of burrow increased as the distance to agricultural land decreased, though the occurrence of the species burrow was not significantly influenced by it. The study site was community forest which is generally close to agricultural lands which can be a reason for such finding. Agricultural lands might serve as potential habitat of the Chinese pangolin (Sharma et al., 2020a) since ants can thrive in agricultural soils (De Bruyn, 1999). Pesticide use on agricultural land can decrease the prey abundance of pangolins, while livestock, livestock guard dogs, and anthropogenic activities can cause disturbance and present a threat to the Chinese pangolin (Sharma et al., 2020b).

6. Conclusions and recommendations

6.1 Conclusion

The four community forests in Bhimsen Thapa rural municipality support the occurrence of the Chinese pangolin. Most of the burrows found were old. Distribution of the burrows in the study area was clumped, and was significantly influenced by slope, distance to water, distance to ant nest, distance to road, and elevation. The presence of burrow decreased with decreasing elevation, decreasing tree abundance, and decrease in distance to road and burrow increased with decrease in canopy cover percentage, decrease in ground cover percentage, decreased in slope, decrease in distance to water resources, decrease in distance to agricultural land and decrease to distance to ant nest.

6.2 Recommendations

Based on the results of the study, following recommendations can be made:

i. The study does not include seasonal variation. So further study is necessary to get more information on impacts of seasonal variation on the habitat and distribution of the Chinese Pangolin.

ii. The studied forests support the occurrence of the Chinese pangolin and their occurrence increased as tree abundance increased. Trees in the area need to be protected.

7. References

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Appendices

New burrows