Distribution, habitat use, threats and conservation of the critically endangered Chinese pangolin

(*Manis pentadactyla)* in Samtse District, Bhutan

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Abstract

The study was carried out to assess the habitat preference and current distribution of Chinese pangolin (Manis pentadactyla) in Dorokha Dungkhag, Samtse. Belt transect method was used to assess the habitat preference and estimate burrow density, coupled with extensive search method to determine current distribution. Modelling of winter habitat was carried out using ARCGIS and Maxent. A total of 181 burrows were recorded from 48 plots (100 x 100 m). Burrow density for the study area was 0.104 per hectare. These were mostly distributed in the habitat dominated by Schima wallichii, Castanopsis hytrix and Viburnum sp. Preferred habitat ranged from 1300 - 1700 m, with highest feeding activities recorded within the periphery of cardamom plantation and adjacent forested area. A higher burrow density was recorded in humid soils, high termite presence, and in the vicinity of human settlements. Habitat modelling revealed 23.57 km^2 *of the study area was highly suitable and 37.88 km*^{2} *as suitable habitat for the species. Similar studies must be carried out in other parts of Bhutan in different seasons to fully substantiate the total population, distribution and range of Chinese pangolin.*

Keywords: ArcGIS, burrow, density, distribution, habitat, Maxent, modelling

Abbreviation and Acronyms

ASCII	American Standard Code for Information Interchange
AUC	Area under the curve
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CNR	College of Natural Resources
CP	Chinese pangolin
CSV	Comma-Separated Value
DEM	Digital Elevation Model
GIS	Geographic Information System
GPS	Global Position System
IP	Indian pangolin
IUCN	International Union for Conservation of Nature
IVI	Important Value Index
Km^2	Square Kilometer
LULC	Land Use/ Land Cover
MaxEnt	Maximum Entropy
MoAF	Ministry of Agriculture and Forests
NSSC	National Soil Service Centre
PCQ	Point-Centered-Quarter
PPD	Policy and Planning Division
RGoB	Royal Government of Bhutan
ROC	Receiver- Operating Character
SP	Sundra pangolin
S_R	Species Richness
SPSS	Statistical Package for Social Science

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Chapter One

Introduction

1.1 Background

Chinese pangolin (*Manis pentadactyla* Linnaeus, 1758) is one of the eight species belonging to monotypic order: Pholidota, family: Manidae, and genus: *Manis* (IUCN Pangolin Specialist Group, 2015). The word 'pangolin' is derived from Malayan phrase 'Pen Gulling' meaning 'rolling ball', while the term "Pholidota" came from a Greek word meaning 'scaled animals' (Atkin, 2004). Generally, Pangolin are nocturnal, elusive, non-aggressive, solitary, insectivorous, and burrowing strange (Gaubert, 2011). They require reclusive and strict habitat due to its poor self-defensive mechanism and its low reproductive rate (Wu *et al*., 2004).

The Chinese pangolin (CP) known as "scaly mammal" under Mammalia class is native to many Asian countries. It is found in Nepal, Bhutan, Northern India, Bangladesh, Myanmar, China, Hainan, and Taiwan (Challender *et al.*, 2014b). The species occupies a number of different habitats within its range including primary and secondary forest, tropical forests, bamboo forest, grassland and agriculture field (Katuwal *et al*., 2015). In Bhutan, CP is mostly found in southern districts such as Samtse, Samdrup Jongkhar, Sarpang, Pemagatshel and Chukha (Wangchuk *et al*., 2004).

In recent decades, there has been notable decline in the population of CP. Its number and population appear to be decreasing, primarily due to hunting, poaching, and habitat destruction (Chao *et al*., 2005; Challender *et al.*, 2014b). CP is poached mainly for their scales that are used in traditional medicine and for their meat which is considered delicacy in many countries (Newton *et al*., 2008). In Vietnam, the main threat behind declining of CP is illegal logging, rampant economic development and conversion of forest for rubber plantation (Newton *et al*, 2008). Due to rampant population decline, it was listed as critically endangered as per (International Union for Conservation of Nature [IUCN], 2014). Simultaneously, it was categorized in Appendix I (Convention on International Trade in Endangered Species of Wild Fauna and Flora [CITES], 2016).

The Pangolins play an important role in maintaining reasonable ant and termite levels in various ecosystems (Roberts, 1997). It also helps in improving soil quality due to their feeding habits (Fairhead *et al*., 2003). Although CP played significant ecological roles, still their ecological roles remain under-studied in context to Bhutan. There is a lack of information on the current status, distribution, habitat preferred by CP in Bhutan. This has hampered conservationists in protecting and monitoring the species.

1.2 Problem statement

Southern Bhutan falls within the prime habitat zones of Chinese as well as Indian Pangolin, out of which central and western part of southern Bhutan are predicted to have higher abundance of Pangolin species (Challender *et al*., 2014b). Indian Pangolin was mostly sighted within the lower foothills of Samtse Dzongkhag (Wangchuk, 2013), while Chinese pangolin are usually found at mid elevation zones. Dorokha, Dumtoed and Denchukha falls within mid elevation zones where Chinese pangolin are being found under Samtse Dzongkhag (Jamtsho, 2010).

Habitat destruction and illegal poaching had become rampant issues in the study area which might lead to local extinction. For that, understanding of clear habitat ecology, habitat preferences and local distribution pattern is immensely important for any species-specific conservation plan. However, no studies have ever been conducted on the habitat preference and distribution of CP in Bhutan despites their paramount ecological roles in the ecosystems. This may be attributed to the illusive and nocturnal behavior of CP.

Although the global distribution of CP is widely known, the habitat preferences and distribution in Bhutan and in particular the current study area is still unknown. This could have severe implications on the conservation of the critically endangered Chinese pangolin. Adequate understanding of overall habitat ecology, habitat preferences and mapping the current distribution of CP are immensely important for long-term conservation of targeted species. Therefore, this study will document the scientific information about the habitat preferences and also locate the current distribution of Chinese pangolin within the study area.

1.3 Objectives:

The objectives of the study are:

1. To assess the habitat preferences of Chinese pangolin
2. To determine the current distribution of the Chinese pangolin in study area,
3. To develop the habitat modeling of Chinese pangolin in Dorokha Dungkhag and,

4. To assess the conservation threats of Manis pentadactyla in depth including human awareness of and attitudes toward pangolins.

Chapter Two

Literature Review

2.1 Evolution and origination of Pangolins

Pangolin have had a long and complex evolutionary history, having first appeared on the planet just after stegosaurids went extinct as early as the Paleocene, more than 66 million years ago, based on early fossil records (Norman, 1985). According to Gaudin *et al*. (2006) pangolins were widely distributed throughout Laurasia during the Eocene. It is consistent with a Laurasian origin for pangolins. Pangolins are nested within Laurasiatheria and Scrotifera and are considered as the sister group to carnivore after repeated DNA test (Murphy *et al*., 2007). According to Gaudin *et al*. (2009), the ancestors of modern day pangolins are first inhabited in Europe with subsequent dispersal into sub-Saharan African, and then, to southern Asia based on fossil record.

The name pangolin is derived from Malayan phrase 'Pen Gulling' meaning 'rolling ball', while the term Pholidota came from a Greek word meaning 'scaled animals' (Atkin, 2004). They are also known as 'Scaly Anteaters' because of their structure and food habits (Shrestha, 1997). In Bhutan, it is called as Salak (Southern Bhutanese Dialect), Saghu (Dzongkha), Bechu (Doyap) and Bajra kit or Bajra Kapta (Hindi) due to its scaly armored body (Wangchuk, 2013).

2.2 Taxonomy and classification

The phylogenetic position of the Pholidota remains a disputed topic. Pangolins were once included together with the anteaters, sloths, armadillos due to the lack of the teeth. Based on these debates of its phylogeny, later it was placed under Pholidota order based on morphological studies of placental phylogeny (1904 as cited in Gaudin *et al*., 2006). The specific taxonomy of CP belongs to the Kingdom: Animalia; Phylum: Chordata; Class: Mammalia; Order: Pholidota (Weber, 1904); Family: Manidae (Gray, 1821); Genus: *Manis* (Linnaeus, 1758); and Species *pentadactyla* (Linnaeus, 1758) (Srinivasulu, 2004). Pholidota is one of the smallest of the placental mammals, containing just one family, the Manidae, with eight living species (Gaudin *et al*., 2009).

2.3 Morphological characteristics

In general, all pangolin have similar external characteristics covered with armor of imbricate scales. Scales are grown from thick underlying skin and protect every part of the body except the muzzle, cheeks, the underside and the inner surfaces of the limbs (Francis, 2008). They can be distinguished from each other based on their number and size of scales, size of foreclaws and ears and the ratio of head and body to tail length (Wu *et al*., 2004 & Gaubert, 2011). According to Wangchuk *et al*. (2004) the CP can be distinguished from the Indian pangolin (*Manis crassicaudata)* due to smaller in size and ear flaps which are absent in Indian pangolin (IP) and has a shorter tail. Similarly, in Sunda pangolin (*Manis javanica*) fore feet and hind feet are equipped with sharp claws but CP has relatively longer front claws than hind claws and shape of the tail being shorter and blunter (Wu *et al*., 2003).

According to Wangchuk *et al*. (2004), CP has length of 45 – 60 cm from head to body, length of tail with 18cm and length of 45 – 73 cm from head to body, 33 – 45cm length of tail for Indian pangolin (IP). The scales of IP are relatively larger than the CP and have 11–13 rows of scales (Heath, 1988) across the back compared to 15 – 18 rows in CP and up to 30 rows of scales in Sunda pangolin (SP) (CITES, 2016). The average body mass of CP weighs up to 9 kg and around 6 - 35 kg for IP (Wangchuk *et al*., 2004).

CP have long and powerful claws for ripping open termite nests and a long, thin, sticky tongue which can measure up to 40 cm in length (Wu *et al*., 2004; Francis, 2008). Pangolins have no teeth or chewing muscles so food is ground up in a specialized horny stomach (Challender *et al*., 2014a). To minimized ant bites/stings, the external ear is reduced or absent, ear canals can be closed (Francis, 2008) there are specialized muscles to close the nostrils during feeding and there are also thick eye lids (Challender *et al*., 2014a).

CP's elongated and streamlined bodies are covered with large, rounded scales measuring 2 - 5 cm in diameter (Wu *et al*., 2004) These scales are formed from fused hair and contribute to around 25 percent of the animal's total body weight. Ranging in color from light yellow - brown to black, the scales cover everywhere except the face, underside and inner surface of the limbs and foot pads (CITES, 2016). The pointed head is small in comparison to the body, with small eyes and a narrow mouth (Shrestha, 1997).

2.4 Global distribution of Chinese pangolin

Pangolins (order: Pholidota; *Manis* spp.) are insectivorous mammals confined to the Afrotropical and Indomalayan regions. Among eight extant of pangolins species, four species occurs in Africa and four in Asia. The CP is one of the 4 species of Asiatic pangolins and is found in most parts of the Southeast Asian region (Waterman *et al.,* 2014). According to Challender *et al*. (2014b), CP occurs in northeastern Bangladesh, northern and western Myanmar, to northern and

Annamite regions of Lao PDR and northern Viet Nam, northwest Thailand, through southern China to Hainan, Southern part of Bhutan and northern part of India.

In India, the species is marginally present in Bihar and has been recorded in Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Tripura, Mizoram, Sikkim and the northern part of West Bengal (Mohapatra *et al*., 2015). In Nepal they are distributed in sunny shaded hills of Kathmandu, Dhading, Kavre, Ramechap, Sindhulli, Gorkha and Bardia (Chalise, 2012). Similarly, in China the extends of distribution occurs from the provinces of Sichuan, Guizhou, Yunnan, Anhui, Jiangsu, Zhejiang, Jiangxi, Hunan, Guangdong and Fujian, and in the Guangxi Zhuang, Tibet as well as Hainan Island (Wu *et al*., 2004). In Bhutan it is mostly found in Samtse, Sarpang and Samdrupjongkhar (Wangchuk *et al*., 2004).

2.5 Habitat use

In general, pangolins are found in a wide range of habitats including primary and secondary tropical forests, limestone forests, bamboo forests, broad-leaf and coniferous forests, grasslands and agricultural fields (Gurung and Singh, 1996; Azhar *et al*., 2013; Katuwal *et al*., 2015). According to Thapa *et al*. (2014), CP in Taplejung District in Eastern Nepal are mostly inhabited from sub-tropical to temperate region at the elevation of 1126 to 2406 m with highest number of burrows in southwest aspect and least in north. Similarly, in Nagarjun Forest of Shivapuri Nagarjun National Park, Nepal CP is mostly found in the Broad-leaved forest dominated by *Schima wallichii, Castonopsis tribuloides, Castonopsis indica* with canopy cover between 25 - 50% and in northwest aspect in the elevation range between 1450 - 1550 m (Bhandari and Chalise, 2014).

In China, CP mostly preferred broad-leaved forest dominated by *Schima superba, Adinandra millettii, Machilus chinensis, Machilus thunbergii, Diospyros morrisiana* and undergrowth with good shelter condition which is mainly comprised of *Woodwardia japónica, Blechnum orientale, Dicranopteris dichotoma, Dicranopteris ampia, Gahnia tristis, Miscanthus floridulus, Miscanthus Sinensis* (Wu *et al*., 2003). The presence of more pangolins in broad-leaved forest is due to presence of more numbers of plant species as termites' favorite diet (Wu *et al*., 2003). According to (CITES, 2016), primary forest support more pangolins probably due to presence of a larger number of old trees with hollows suitable for sleeping and for use as den and support lower levels of human activity.

Besides primary and secondary forest, pangolins have been recorded to occurs in oil palm and rubber plantation and near human settlement (Gurung and Singh, 1996; Azhar *et al*., 2013; Katuwal *et al*., 2015). In Nepal, pangolins are found in forest patches and agricultural land near human dominated landscapes (CITES 2016). Similarly, in Bhutan pangolin are mostly found in cardamom area in winter for feeding (Wangchuk, 2013). This is due to high significant rates of loss and degradation of primary and secondary forests across the pangolin range States in Asia (CITES, 2016). The distribution of pangolin is also known to be highly influenced by the altitude, aspect, soil type and vegetation type as well as amount of the food available, water, degree of human interferences and also weather conditions (Bhandari and Chalise, 2014). The study conducted by Suwal (2011), reported that although CP was found in both red and brown soil, they preferred brown soil.

Suitable temperature is another key factor for pangolins' naturalistic habitat. Pangolin will suffer, when temperature were between 12 – 15°C in the pangolin cage due to little body hair to maintain their body warm (Heath, 1988). Pangolin are highly susceptible to pneumonia in low temperature, which often leads to death (Chang, 2004). The most optimum ambient temperature for CP in winter is not less than 18°C (Bao *et al*., 2013).

2.6 Behavior

Pangolins are solitary mammals and are nocturnal and highly secretive (Wu *et al*., 2004), thus it is difficult to study them in the wild. Some pangolin species such as CP sleep in underground burrows during day time (Sopyan, 2008) and other including Malayan and African tree pangolins are known to sleep on the trees (Lim and Ng, 2008). They emerge in the evening and find their own food more by the scent than vision. Pangolin has unique adaptations for digging burrows. It has powerful forelimbs with harsh claws, adapted for digging using their tails and rear legs for support and balance (Swart *et al.*, 1999; Francis, 2008). They dig their own burrows by moving their bodies side to side and excavating both sides and the roof of the passage (Heath, 1995).

Pangolin scales provide good defense against predators. When threatened, pangolins can quickly curl into a ball, protecting their defenseless undersides. They also deter predators by hissing and puffing and lashing their sharp edged tails (Francis, 2008). Pangolins are dependent on their strong sense of smell to identify their territories by scent marking with urine and secretions from a special gland and by scattering feces. CP is largely terrestrial, though it is fully capable of climbing trees and like other Pangolins, swims well (Wangchuk *et al*., 2004). Their tail is also used to carry infants (Bhandari and Chalise, 2014).

Pangolin has a habit of burrowing soil mainly to prey on termites, hibernate, rest, breed, hide and defend. CP spends most of their time in underground burrows during the day and leaves their burrows only when foraging or mating at night (Wu *et al*., 2005). Winter burrows are relatively deeper and summer burrows are relatively shallower (Wu *et al*., 2004). The CP burrows function well in maintaining a constant temperature. The burrows are usually located in habitats with higher canopy closure and most of their burrow entrances are hidden under the dense shrub/herb layer for protection (Wu *et al*., 2003).

2.7 Breeding habit

Pangolins are particularly vulnerable to overexploitation due to their low reproductive output. Male and female pangolins are sexually dimorphic; the sexes differ in weight (Wangchuck *et al*., 2004). In most species, males are 10 - 50 percent heavier than females, while Indian pangolins can be up to 90 percent heavier (Nguyen *et al*., 2014). During mating season, male pangolins often fight each other and winner will mate with female pangolin. The mating period generally last for three to five days with two to five estrous cycles during the mating season which will last for 11 - 26 days (Cen *et al*., 2010)

Gestation period for pangolins differ with species; the gestation period for CP ranges from 318 to 372 days (Chin *et al*., 2011). Therefore, CP has low reproductive rate than other pangolin species. When born, pangolins are about six inches long and weigh about 12 ounces (Soewu *et al*., 2009). Young pangolins have soft and pale scales and begin to harden by the second day. Pangolin mothers nurture their young in nesting burrows and can eat termites and ants at one month (Jenkins *et al*., 2008).

2.8 Feeding habit

Ants or termites are known to be included in the diet of about 216 mammal species (Redford, 1987). Pangolin are eutherian (plecental) mammals having specialized characteristics for eating ants and termites and a unique external armor of overlapping scales leads to called as “Scaly ant eater” (Davit *et al*., 2009). Beside ants and termites, Pangolin’s also pray on ant larvae, bees (pupas), flies, worms, crickets and insect larvae. In average, a pangolin can consume up to 300–400 g of termites per feeding (Challender 2008; Coulson, 1989).

Generally, pangolin is known to pray upon ants and termites. However, different species select different species of ants and termites in their diet compositions. CP alone feeds 15 species including nine species of termites and six species of ants according to a review of CP diet and prey preferences conducted by Wu *et al*. (2005). Similarly, Cape Pangolin feeds upon 15 species of ants and five species of termites (Coulson, 1989; Swart *et al*., 1999). For IP, they prey upon two main species of black ants (*Camponotus confucii* and *Camponotus compressus*) and one species of termite (*Odontotermis obesus*) as reviewed by Irshad *et al*. (2015).

Diet composition of pangolins is temporal in nature. They pray on the species which is mostly available on ground. In summer, ants are the main food sources which are usually found on ground. In winter, they prefer to choose termites nest for its greater biomass than the ants (Coulson, 1989). Wu (1999) reported that pangolins enjoy high protein, fat, calorie food due to strong digestive and absorption ability in their small intestine. Ke (1999) found that the epidermis of ants have chitin which is suitable for the pangolin's digestion characteristics.

2.9 Ecological importance of Chinese pangolin

Pangolins have a specialized diet and perform an important ecological role in regulating insect populations (Challender *et al*., 2014b). It has been estimated that an adult pangolin can consume more than 70 million insects annually (IUCN Pangolin Specialist Group, 2015) and has a significant impact on the control of forest termites (Shi & Wang, 1985). Therein, conservation of pangolin would play an important ecological role especially in maintaining the balanced ecosystem. It also control economic damages caused by termites and ants to agriculture crops and improve the quality of soil (Fairhead *et al*., 2003). In addition, abandoned pangolin burrows become shelters for many other species of animals (Nguyen *et al*., 2014).

2.10 Threats to Chinese pangolin and its habitat

CP's are classified as critically endangered (Challender *et al.*, 2014b), recently up listed to Appendix I (CITES, 2016) and they remain only in fragmented populations in their home ranges (Challender *et al*., 2015). Its numbers and population appear to be decreasing primarily due to hunting, poaching and habitat destruction (Challender *et al.*, 2014b; Chao *et al*., 2005). Internationally, CP are experiencing rampant threats as live animal, meats and scales through illegal hunting and poaching (Challender *et al.*, 2015: Pantel and Chin 2009). While, evidence also suggests, this is now largely forgone in favour of international trade due to high monetary value (Nguyen *et al*., 2014; Newton *et al*., 2008). Further, it is known that illegal trade is rampant due to increasing price of scales and meat (Challender *et al*., 2015; Challender & MacMillan 2014; Wu & Ma 2007). The scales are used in traditional medicine and their meat which is considered delicacy in many countries (Newton *et al*., 2008).

Besides high illegal international trafficking, loss of habitat and degradation of primary and secondary forests across pangolin range in Asia is one of the significant problems for pangolin. As per the Forest Trends, (2015) the highest percentages of forest loss globally occurred in Malaysia (14.4%), Indonesia (8.4%), Cambodia (7.1%), and Laos (5.3%) from 2000 - 2012. The reason for decline is due to illegal logging, rampant economic development and conversion of forest to plantation (CITES, 2016). In Bhutan, habitat destruction by human is the main threat faced by Pangolin in southern Bhutan besides illegal hunting (Wangchuk, 2013).

Chapter Three

Methods and Materials

3.1 Conceptual framework

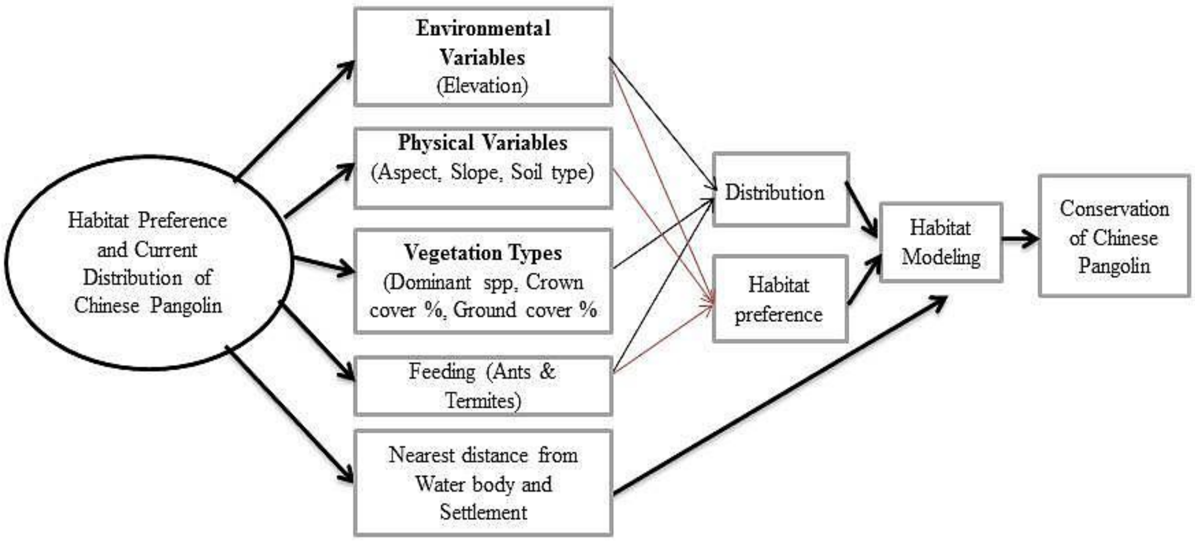

Figure 3.1: Conceptual framework

3.2 Study area description

The study site (Dorokha Dungkhag) is situated in the south-western part of the country (27˚4'30.4" N to 26˚54'00.5" N and 89˚05'30.5" E to 89˚19'30.2" E) spanning with an area of 256.4 km². The Dungkhag consists of three geog namely Dophuchen, Dumtoed and Denchukha. It is located in the north-eastern part of Samtse Dzongkhag and is bordered by Chukha Dzongkhag in the east, Haa Dzongkhag in the west and Samtse geog in the south (Samtse Dzongkhag, 2016). The altitude of study area ranges from 1000 - 2500 meter above sea level (masl), monthly temperature ranges between 15°C (degree Celsius) in winter to 32°C in summer. The climatic condition is hot and wet in summer and cold and dry in winter with mean annual rainfall ranging from 1200 - 3000 mm.

The study area is mostly covered by broad leaved forest and few shrub lands. The broadleaved forests are mostly dominated by *Schima wallichii*, *Castanopsis hytrix, Viburnum spp* and *Beischmiedia roxburghiana*. The agricultural land is covered by cardamom plantation. As per Thapa *et al*. (2014), CP was found within the elevation ranging from 1126 to 2406 m in broadleaved forest. Similar elevation range and forest type were found in the currently study area where it support most of the species including Chinese pangolin. As per the record of the Dorokha Forest Range office (2015), CP were recorded from Dogap, Mithun, Satakha, Daragon, Manidara and Jigme villages. Therefore, the site has been chosen for the study.

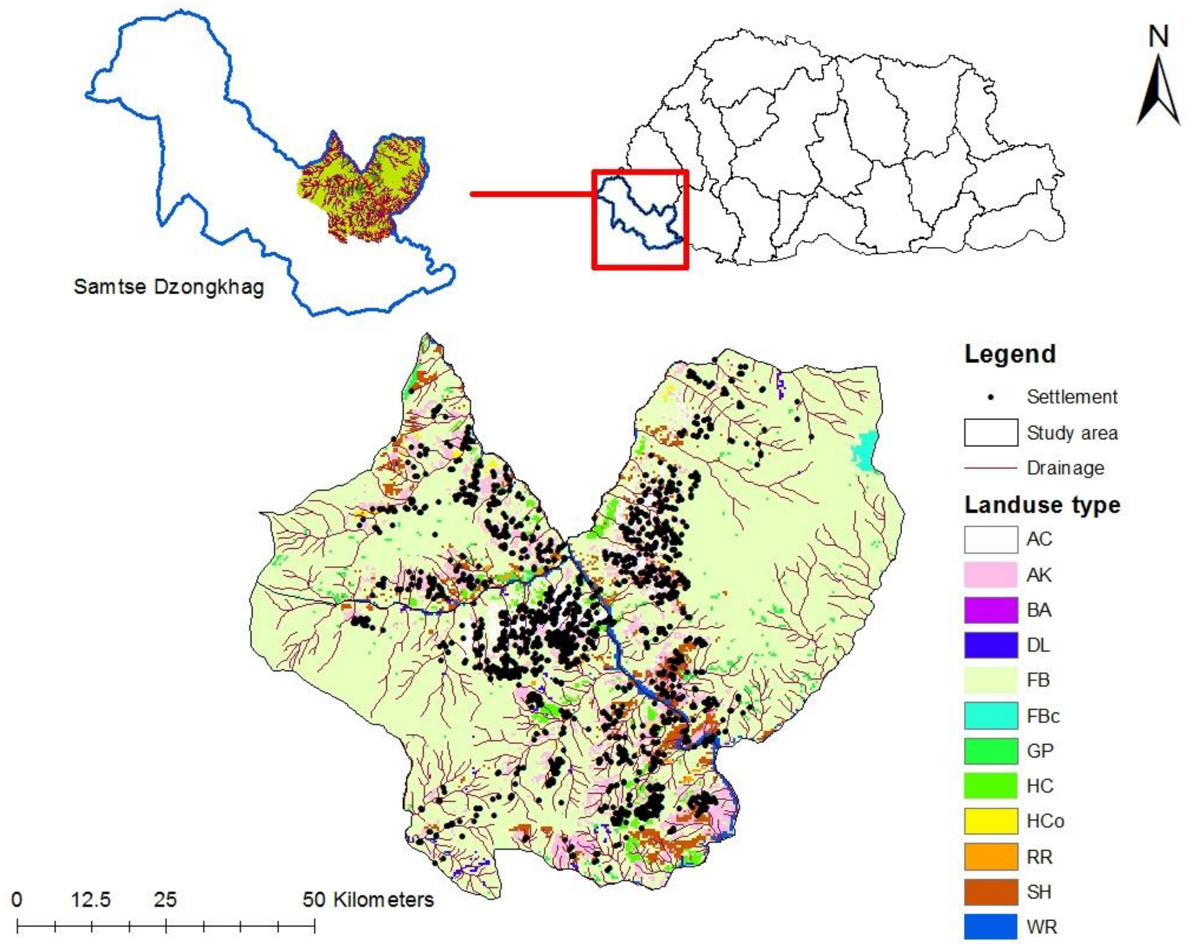

Figure 3.2: Map of study area in Dorokha Dungkhag under Samtse

3.3 Study design

3.3.1 Preliminary reconnaissance survey

A preliminary survey was carried out initially in three geog (Dophuchen, Dumtoed and Denchukha) to conceptualize the situation and to identify the potential sites where CP is sighted. The preliminary survey was conducted with discussion with Dorokha Forest Range staffs, local people and Community Forest members from three geog to ascertain and validate whether CP is present in their locality or not. Participatory mapping for the probable detection of the CP was prepared during group discussions and identified potential sites of CP in the villages of three geogs. Based on pre-information generated from focus group discussion, an extensive survey of the identified areas was conducted with local people to determine the presence/absence of species and to know the general distribution of the species in the study area. The potential habitats of the species were identified for further data collection

3.3.2 Stratified random sampling

Based on the preliminary reconnaissance survey and findings from literature review, a potential habitat in the study area was mapped using the Arc GIS version10.2.2. The potential habitat was further stratified into three habitat type: Warm broad-leaved, cool broad-leaved forest and agricultural land. The warm broad-leaved forest and agricultural land was falls within the altitude ranging from 1000 – 1500 m. Similarly, the cool broad-leaved forest falls within an altitude ranging from 1500 – 2500 m. The altitude range mentioned above was selected to cover all habitat types as per the literature, CP occur within the chosen altitude range and covers forest types where CP inhibits. Using Fishnet in Arc GIS 10.2.2, 2 km^2 grid was overlaid and random sample blocks were generated with equal sample number in each zone to assess the burrow density and habitat parameters. The centre point of the sample blocks/grids was marked and uploaded in GPS for easy finding of plots on the ground.

3.4 Data Collection methods

3.4.1 Belt transect method

A total of eight transects were laid out in the potential area of the target species through random sampling method. In each transect, a plot of 100 m x 100 m (Geographical distance) size was laid every after 100 m distance and a total of six plot was laid out in each transect. Since CP is nocturnal, elusive, shy and very difficult to encounter in direct sighting, burrows were taken as the most prominent indirect signs among others. An intensive search of indirect signs like burrows, scats, footprints, scales and scratches was conducted in each plot to assess the habitat of the targeted species.

Similarly, the relevant habitat parameters like altitude, aspect, ground species, dominant species, canopy cover, soil type, ants and termite colonies, nearest distance from water body, road, settlements and GPS coordinates were collected in each plot to determine the habitat preference of CP (Bhandari and Chalise, 2014).

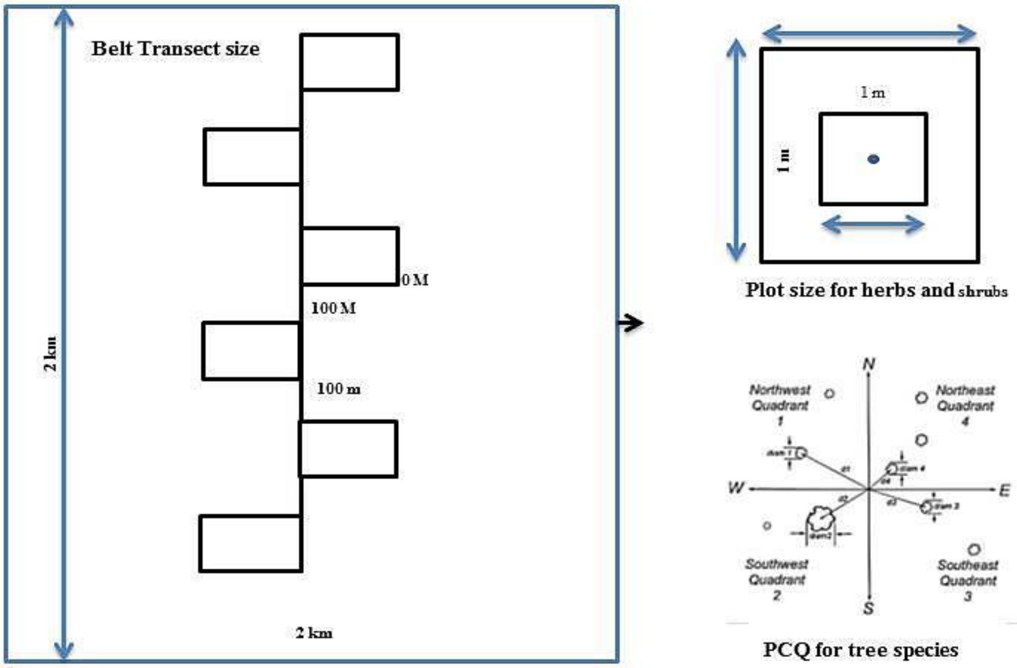

Figure 3.3: Sampling design

3.4.2 Vegetation survey

The habitat preference was ascertained through vegetation survey in each plot. A total of 48 plots were assessed from eight transects. Vegetation on each plot was analyzed by quantifying tree, shrub and herb species. Tree species were quantified by using "Point-Centered-Quarter" (PCQ) method (Cottom and Cartis, 1956), while shrubs and herbs species were quantified using "Quadrate Method" (Emlen, 1956). For shrubs, quadrates of 5 m x 5 m and for herbs quadrates of 1 m x 1 m size were used.

3.4.3 Extensive search in the potential sites

For determination of the current distribution of CP in the study area, standard ecological methods like field sightings and records of indirect signs were used (Mahmood *et al*., 2014). An extensive survey of the different parts of study area was conducted with involvement of local people to get more information on distribution status of the species for three months (January to March, 2017). The whole area of Dorokha Dungkhag was scanned for direct and indirect signs of CP. The Global Positioning System (GPS) coordinates was recorded wherever the indirect and direct sightings of the species were observed. And the map illustrating the current distribution pattern of the species in the study area was developed using Hot Spot Analysis tool in ArcMap software version 10.2.2.

3.4.4 Population estimates through burrow density (Belt transect)

The belt transect established for habitat preference was used to estimate the population of CP using the burrow density method. The burrows were classified into two different types, viz. living or permanent and feeding burrow. Living burrows are much deeper and less in numbers than those of feeding burrows. The living burrows were further classified into inactive or active. A living burrows can be categorized as active if any indirect signs of the species such as foot prints on the soil around the burrow, scale prints or presence of faecal sample are noticed around that particular burrow (Mahmood *et al*., 2014). The burrow density of CP were estimated by counting the number of active living burrows in all the plots in a transect (Irshad *et al*., 2015). Likewise, to confirm the presence of CP in the study area, night survey was conducted with the help of searchlight in each transect.

3.4.5 Interview

Samples of up to 50% of households (key informants and local people) in the project area were selected for interview. A semi-formal interview format was developed so that standard questions were asked and responses recorded. Likewise, representative from the local government, local forest office, policy makers, and other relevant organizations and individuals were also interviewed using the semi-structured interview.

3.4.6 Using ArcGIS for collecting and processing the spatial layer for modelling

ArcGIS version 10.2.2 was used for processing the spatial layers and MaxEnt version 3.3.3k for running the model. The habitat suitability map was produced using the environmental variables like land cover types, elevation class, aspect class, slope class, distance from nearest water bodies and settlements, annual mean temperature, and precipitation. These factors were established based on the data collected during the field survey, and with the help of existing information available on the species. The value of suitability for each environmental variables were assigned as 3 = highly suitable, 2 = suitable and 1= less suitable.

The land cover types were created from the Land use/ Land Cover (LULC) map of Bhutan 2010, developed by the Ministry of Agriculture and Forests (MoAF), Bhutan (NSSC and PPD 2011). The land cover types were reclassified based on the data collected from the field depending on suitability of each land cover types, and values were assigned to each land cover types in terms of suitability to CP habitat (Table 3.1). The special layer for slope, aspect and elevation were derived from the DEM using spatial analyst tool in ArcMap and further reclassified depending on suitability of each input layers to CP habitat (Table 3.2).

Table 3.1: Classification of land cover type with levels of suitability

Landuse	Value
Broad-leaved, Shrub, Cardamom	3
Dryland, Citrus orchard	2
Wetland	1
Others	Restricted

Table 3.2: Classification of slope, aspect and elevation with levels of suitability

Slope (degree)	Value	Aspect	Value	Elevation (m)	Value
< 20	3	North East/North West	3	1000 – 1300	2
20 – 30	2	South East/North	2	1300 – 1700	3
30 – 45	1	East/South West	1	1700 – 2500	1
>60	No data	South/West	No data	> 2500	No data

The layer of settlement and drainage was clipped to the study area from national data. Using the Euclidean distance tool in ArcGIS, a map consisting of difference distances from settlement point and drainages were created, which was then reclassified into four distance classes (Table 3.3). The annual mean temperature and precipitation of the study area was extracted from Bhutan Climate data by using the spatial analyst Tools.

Table 3.3: Classification of distance from settlement and drainages with levels of suitability

Distance from settlement (m)	Value	Distance from drainages (m)	Value
<300	3	<100	1
300 – 500	2	100 – 300	3
500- 700	1	300 – 500	2
>700	1	>500	2

Finally, all the spatial layers (in raster format) were converted to ASCII format with a standard cell size of 30 m x 30 m based on the resolution of the DEM. The distribution coordinates of CP was converted from Degree minute second to degree minutes in excel sheet. The database excel spread sheet containing CP occurrence was then converted to a comma-separated value (csv) format which is then was ready to import in MaxEnt software.

3.5 Materials

Equipment such as GPS, measuring tape, diameter tape, altimeter, Suunto clinometer, compass, Digital camera, Searchlight, and field data collection forms including pencil and eraser were used for the study.

3.6 Data analysis

3.6.1 Vegetation analysis

The Importance value Index (IVI), for tree species in potential sites of CP was calculated by using formulae (Cottom and Cartis, 1956):

$$\text{Relative density} = \frac{\text{number od quarter with species (k)}}{\text{4 times number of sample points}} \text{ X } 100$$

$$\text{Relative dominance} = \frac{\text{Total basal area of species (k)along the transect}}{\text{Total basal area of all the species along transect}} \text{ X } 100$$

$$\text{Relative frequency} = \frac{\text{number of samples point along transect with species (k)}}{\text{Total number of sample points on transect}} \text{ X } 100$$

$$\text{Important Value Index (IVI)} = \text{Relative density} + \text{Relative dominance} + \text{Relative frequency}$$

Shannon-wiener formulae was adopted for computation of species diversity (*H'*) and richness (S_R), it is given by;

Diversity index (*H'*)$= -\sum_{i=1}^{S}(Pi * LnPi)$

Where 'pi' = Fraction of the entire population made up of species

'i' = number of individuals of i^{th} species divided by total number of individuals of all species

'Ln' = natural logarithm and Species Richness (*N*) = Total number of species.

3.6.2 Estimating burrow density

The burrow density of the CP was calculated for each zone:

$$\text{Burrow Density (D)} = \frac{\text{Number of active living burrows}}{\text{Area sampled}} \text{ X } 100$$

3.6.3 Statistical analysis

After completing the data collection from the field, data validation was done to cross-check the missing information. The data collected was then entered in the Spreadsheets developed in Microsoft Excel. Major statistical analysis was done using Statistical Package for Social Science (SPSS) packages version 21. Graphs and charts to show trends and other important figures were developed using Microsoft Excel.

Furthermore, two types of data analysis, descriptive statistics and inferential analysis were used for analyzing the data. Since the database was both inferential and descriptive, various tools of SPSS were used to derive statistical results. Kruskal-wallis test was conducted to compare the means of CP burrow in three habitat types and different aspects. Spearman rho correlation was conducted between number of CP burrow with slope, elevation, crown, and ground cover to evaluate if they were associated to each other.

3.6.4 Using MaxEnt modelling for winter habitat suitability analysis of CP

The MaxEnt is a computer programme that estimates the probability distribution for a species and predicting potential suitable habitat for range of mammals (Jennings and Veron, 2011: Wilting *et al*., 2010). It generates an estimate of predicting suitable habitat of the targeted species that varies from 0 to 1, where 0 being the lowest and 1 the highest probability. The 59 occurrence records sign (Indirect sign, direct sighting) of CP was uploaded under 'Samples' box, and all the spatial layers in ASCII format were brought under the 'Environmental layers' box. Environmental variables are correctly classified as continuous or categorical.

3.6.4.1 Assessing model performance

Model performance was assessed by using the training and test data the area under the curve (AUC) of the receiver-operating characteristic (ROC) plot. The data were jackknifed by the inbuilt model's feature for evaluating each environmental variable's influence on the predicted suitable habitat distribution of CP. The percent contribution of each variable was calculated on the basis of how much the variable contributed to an increase in the regularized model gain as averaged over each model run. To calculate variable permutation, for each variable in turn, the values of that variable on training presence and background data were randomly varied and the resulting change in training AUC was shown normalized to percentages. The habitat suitability for wildlife was classified based on the logistic threshold value of maximum of test sensitivity and specificity (Jiménez and Lobo, 2007). The area above the logistic threshold value of maximum of test sensitivity and specificity was classified as suitable habitat and below this value as unsuitable

Chapter Four

Results and Discussions

4.1 General information on burrow characteristic of Chinese pangolin (CP)

Approximately, a total area of 103 km^2 of the study area was found potential for CP based on preliminary survey. Within this area, 48 plots were laid out randomly and recorded 181 burrows of CP. The types of burrow and their detail information were given below (Table 4.1). During the data collection period, two direct sightings of CP were encountered.

Table 4.1: Number of burrow types and size recorded

Types of burrows	Burrow condition	Number of burrow recorded	Burrow size	
			Circumference (cm)	Depth (cm)
Feeding burrow	Old	66	69.3 ± 5.7	62.8 ± 28.4
Feeding burrow	New	95	69.8 ± 7.1	66.1 ± 30.1
Living burrow	Active	05	73.8 ± 4.6	
Living burrow	inactive	15	69.2 ± 8.7	252.6 ± 23.88

4.2 Habitat preference of the Chinese pangolin

4.2.1 Habitat type and preference

A total of 48 sample plots were laid out in the CP potential habitat sites and assess the habitat preference based on the different habitat variables. There were three major habitat types in the study area: warm broad-leaved forest, cool broad-leaved forest and agricultural land. The mean of burrow recorded in each different habitat were compared to determine the habitat preference by the CP. The mean number of burrow observations indicated that habitat preference vary with the type of vegetation coverage (H (3) = 6.537, p = .038).

The mean burrows showed higher mean ranking in agricultural land (7 ± 2) with mean ranking of 35.30, followed by warm broadleaved forest (4 ± 1) with mean ranking of 27.88 and cool broadleaved (3 ± 1) with mean ranking of 20.21 (Figure 4.1). The maximum numbers of burrows were observed in the cardamom cultivated area (agricultural land). As per Wangchuk, (2011) CP mostly feed on cardamom area in winter due to soft and semi-sandy soil which are suitable for digging burrow. Similar results of the feeding burrows of CP in agricultural lands during winter were reported by Thapa *et al*. (2014) in Nepal.

In the warm broad-leaved forests, the majority of the habitats of CPs were found in dead logs, branches, and wood stump, a potential nesting sites of wood termites. The presence of more pangolins in broad-leaved forest was due to presence of more numbers of plant species as termites' favorite diet as reported by Wu *et al*. (2003) in China.

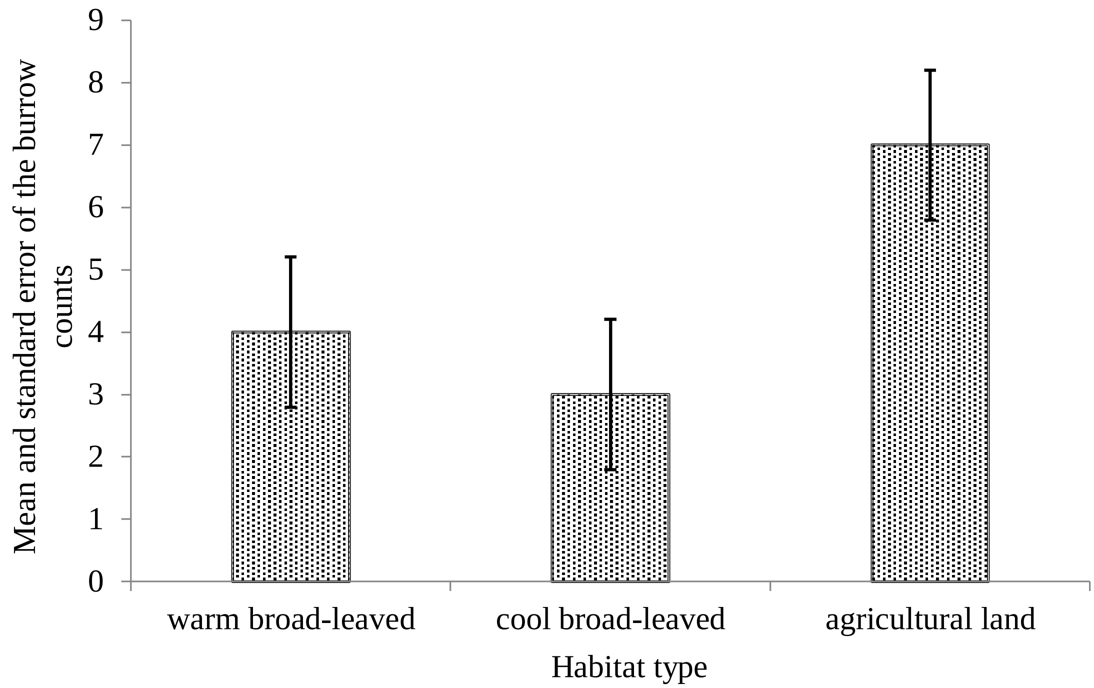

Figure 4.1: Mean and standard error of burrow counts in three different habitat

4.2.2 Preference of canopy and ground cover

The results of the analysis of the canopy occupancy of the CP in warm broadleaved forest showed high (*n* = 50 burrows) within the canopy cover ranging from 26 – 50%; and low (*n* = 1 burrow) within the canopy cover ranging from 51 – 75%. Similarly, in cool broadleaved forest, canopy occupancy showed high (*n* = 44 burrows) within the canopy cover ranging from 26 – 50%; and low (*n* = 1 burrow) within the canopy cover ranging from 51 – 75%. Statistically, the correlation between the canopy cover and the number of Pangolin burrow showed negative relationship, *r* (48) = -.310, *p* = .016 (Table 4.2). Which indicates that numbers of feeding burrows increases when crown cover decreases and vice-versa with R^2 = 0.33 (Figure 4.2).

CP mostly preferred within the crown cover between 25 – 50%, a result similar to Bhandari and Chalise (2014). This is mainly because the soils are observed dried within the canopy cover of 26 – 50% with a relatively un-decomposed leaf litter layer and with a greater amount of dry dead sticks and branches. However, the soil in the crown canopy between 76 -100% were observed moist with a thick layer of decomposing leaf litter where very little amount of termites nest (pangolin prey) were observed. A study conducted by Hemachandra *et al*. (2014) also revealed that termites occurrence were highest in the dry than wet area.

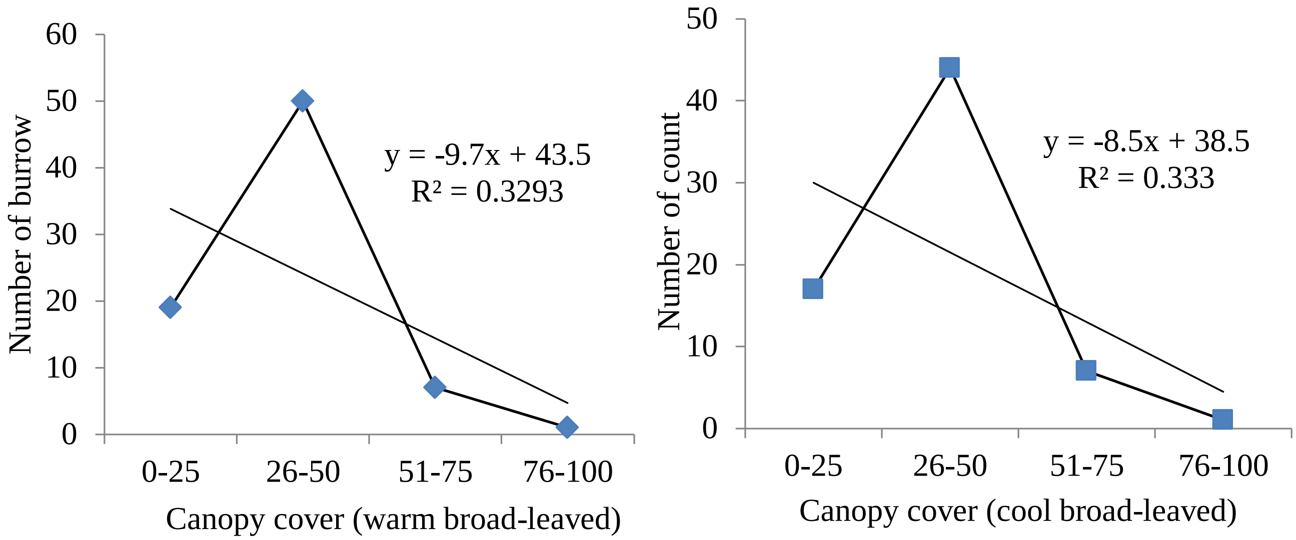

Figure 4.2: Relationship between canopy cover and burrow count

The number of burrow count in ground cover were recorded high (*n* = 33 burrows) within the ground cover of 51 -75% and low (*n* = 4 burrows) within the ground cover 0 - 25% in warm broad-leaved forest. In cool broad-leaved forest, ground cover used by CP were high (*n* = 46 burrows) within the ground cover of 76 – 100% and low (*n* = 2 burrows) within the ground cover of 0 - 25%. Similarly, in agricultural land, the number of burrow sign were recorded high (*n* = 21 burrows) within the ground cover of 76 – 100% and low (*n* = 2 burrows) within the ground cover ranging from 0 - 25%. Spearman's correlation shows that there was positive relationship of burrow counts to ground cover *r* (48) = .241, *p* = .050 (Table 4.2), which indicates that the increase in burrows with increase in ground cover and vice-versa (Figure 4.3). The result suggested that the CP tend to avoid open ground and mostly preferred dense ground cover layer for locomotion and feeding in order to prevent from the predators. The similar results were reported by Wu *et al*. (2003) the CP used dense ground cover for protection of their burrow entrance.

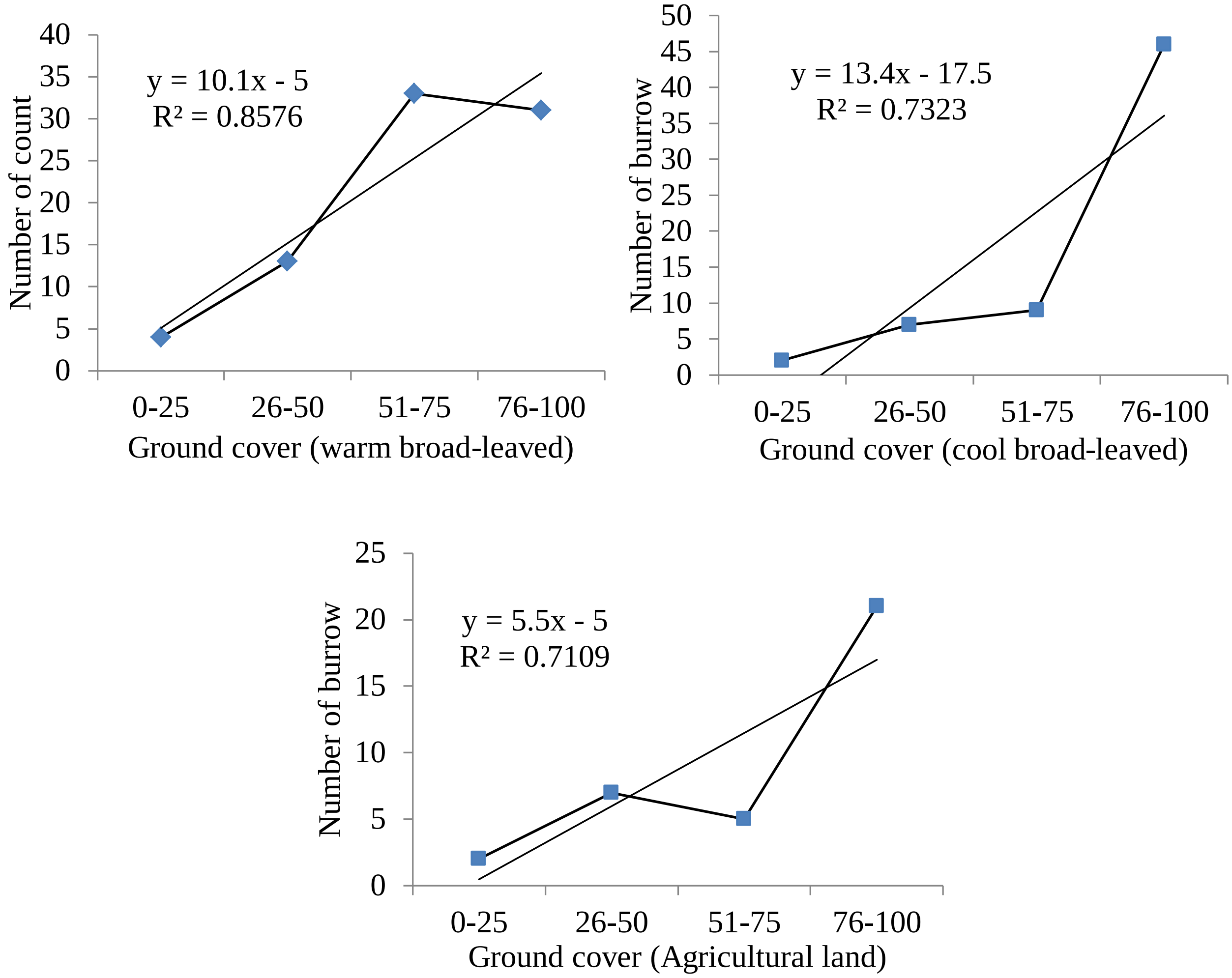

Figure 4.3: Relationship between percent of burrow count and ground cover

4.2.3 Elevation preference

During the entire survey, CP signs were observed between the altitudinal ranges from 1026 – 2100 m. In warm broad-leaved forest, indirect sign of pangolin were found mostly at altitude of (1426 ± 161) m. Similarly, in cool broad-leaved forest the burrows were encountered mostly in altitude of (1724 ± 173) m. Overall, the CP preferred altitude of (1533 ± 267) m in the study area. The number of CP burrow to elevation (Figure 4.4), showed a negative relationship, r (48) = -.585, p = .001 (Table 4.2). This indicated that the CP prefers lower altitude but mostly in mid elevation during winter season. Similar results were also reported in Nepal between 1450 – 1550m altitude by Bhandari and Chalise (2014) and Thapa *et al*. (2014). As per the Hemachandra *et al*. (2014) and Gathorne-Hardy *et al*. (2001), the termite diversity decreases with increased in elevation and this could be the reason where the number of burrow is found lesser in high altitudes.

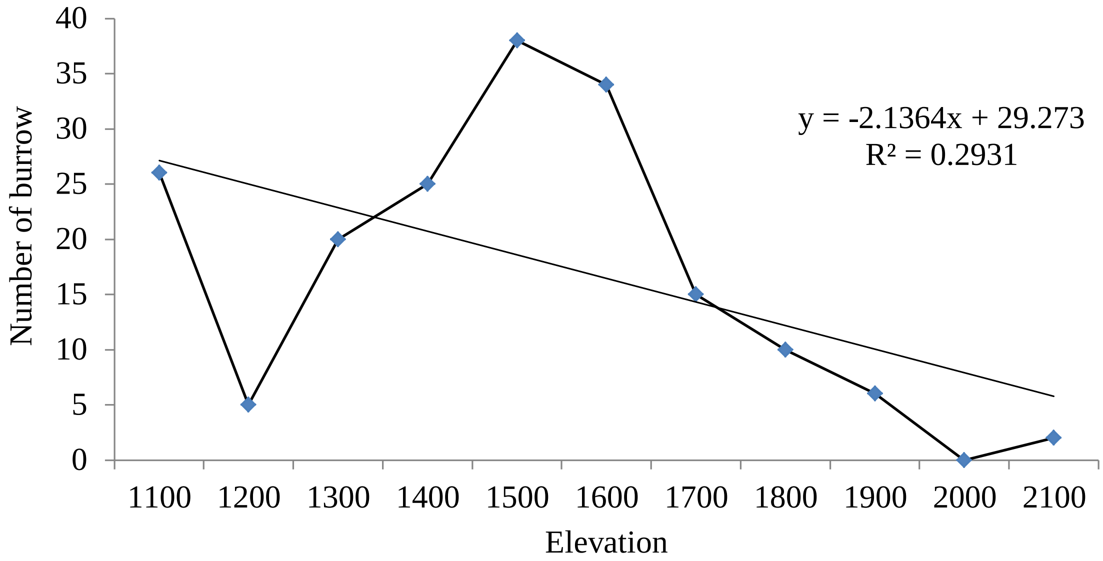

Figure 4.4: Relationship between the number of burrow and elevation

4.2.4 Slope preference

The indirect signs of CP were mostly recorded in slope range of 25 – 45% in warm broad-leaved (*n* = 61 burrows), and least within slope range of 61 - 100% with (*n* = 2 burrows). In cool broadleaved forest, maximum burrow counts were recorded in slope range of 25 - 45% with (*n* = 45 burrows). Similarly, in agricultural land, maximum burrows were recorded (*n* = 27 burrows) within the slope gradient of 25 – 45%. The overall occupancy of the slope gradient were observed mostly between the slope range of 25 - 45% with (*n* = 27 burrows) (Figure 4.5). Moreover, Spearman's rho correlation showed strong negative association between slope and the number of occurrence of CP burrow, *r* = -.551, *p* = .001 (Table 4.2). This indicated that, when the slope increases, the preferences and burrow distribution decreases. The sign of Pangolin were observed increasing from 0% till 25% slope. There was gradual decrease in signs of occurrences in a slope greater than 45%. Wu *et al*. (2004) reported that CP burrow were mostly observed at slope between 30 – 60° which was higher than the findings from the present study. This could be attributed to the proportion of study area covered within the slope degree 0 - 24%, and could be also due to the soft clayey loam soil found at a slope gradient between 24 - 45% in the study area, which are suitable for digging burrows.

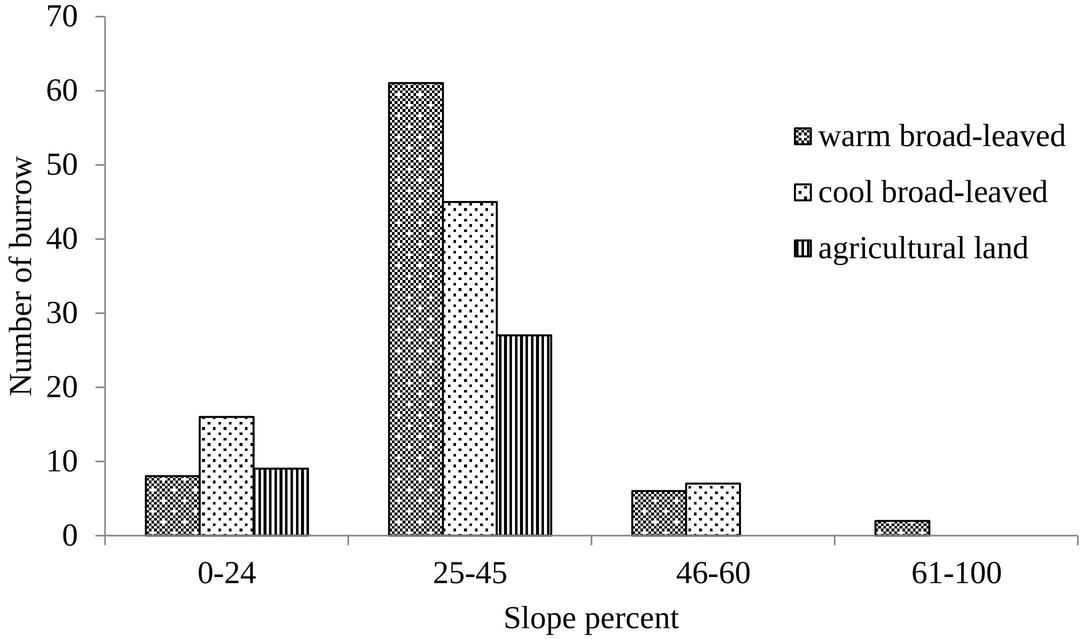

Figure 4.5: Number of burrow in different slope gradient in two forest type

Table 4.2: Correlation between burrow count with crown & ground cover, altitude and slope

	Burrow count	Canopy cover	Ground cover	Altitude	Slope
Burrow count	1	-.310*	.288*	-.585**	-.551**
Canopy cover	48	1	.173	.050	.206
Ground cover	48	48	1	-.166	-.113
Altitude	48	48	48	1	.185
Slope	48	48	48	48	1

*Significant at $p < .05$ ** Significant at $p < .01$

4.2.5 Aspect preference

The CP burrows were observed highest in the northeast aspect (n = 64 burrows) followed by Northwest (n = 63 burrows). The minimum burrows were encountered in southwest (n = 4 burrows). However, there were no burrows encountered in south and west aspect in both the forest types (Figure 4.6). Kruskal-Wallis test showed that a significant difference between the mean numbers of burrow and the aspect, (H (7) = 15.64, p = .016) with a mean rank score highest in northwest with 30.62 and minimum mean rank score 6 in west (Annexure VIII).

Most of the pangolin burrows encountered in the study site were from northeast and northwest in the present study. This is probably because south east aspects are warmer than other aspects which make the environment conducive for their survival during the cold winter months. Similarly, this finding is in line with the finding of Bhandari and Chalise (2014), who reported that burrow of pangolin were found mostly in northwest aspect in Nagarjun Forest of Shivapuri Nagarjun National Park in Nepal. According to Wu *et al.* (2004), the openings of burrows of pangolin often face the sun, probably to make the digging more easily and to maintain the cave temperature in winter.

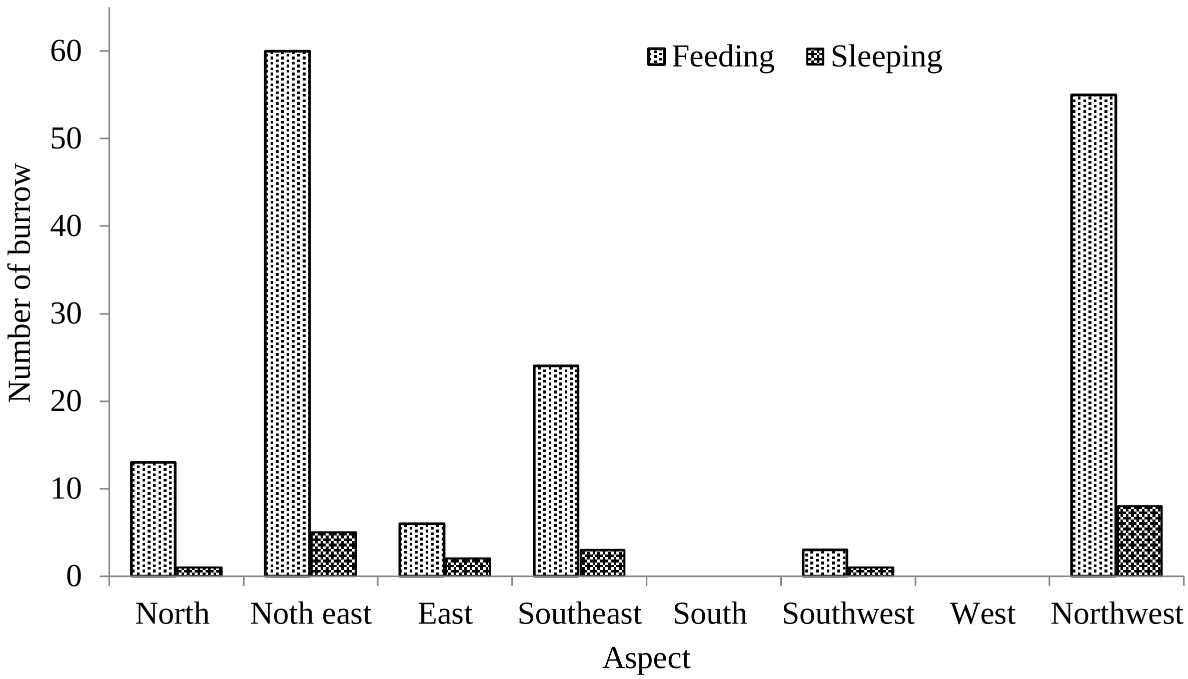

Figure 4.6: Number of pangolin burrows in different aspect

4.2.6 Soil type presence

Pangolin burrows were encountered highest in the clayed loam soil (n = 78 burrows) followed by sandy loam with (n = 53 burrows) and least in the silty loam with (n = 7 burrows). However, no burrows were found in sandy and loamy soils (Figure 4.7). This could be due to the presence of more numbers of termites in clayed loam and sandy loam soil in the present study area. The clayed loam and sandy loam and sandy loam soil were soft layer, where pangolin could easily burrow the soil and may preferred mostly. According to Wu *et al*. (2004), CP mainly chooses the soil that is moist, rich and with soft layer thickness to dig burrows.

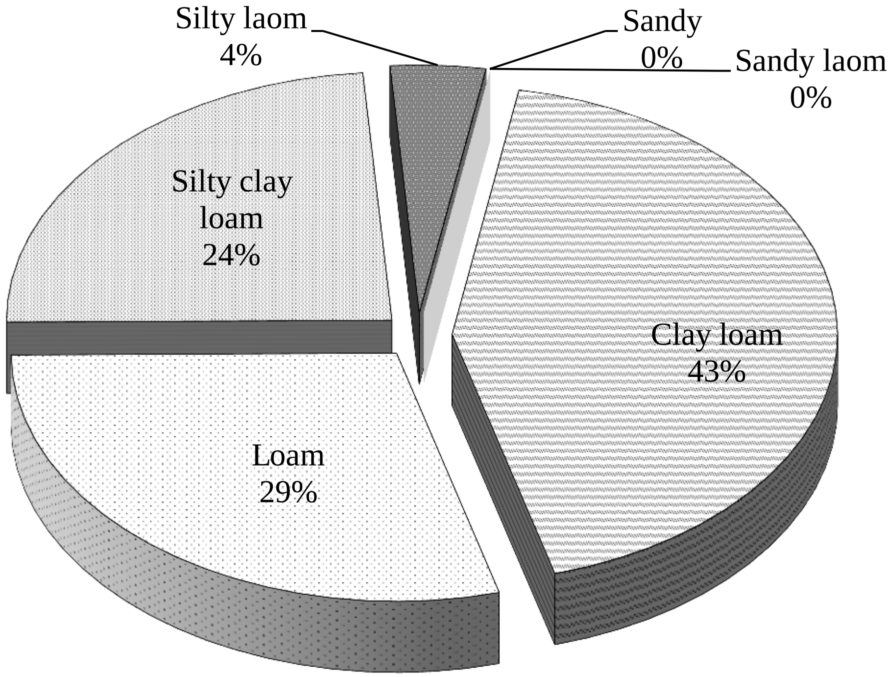

Figure 4.7: Percent of pangolin burrow occurrence in different soil types

4.2.7 Preference of distance from water bodies and settlement

CP occupied average inter-water distance of (607.65 ± 506.15) m with maximum distance of 1800 m and minimum of 57 m. Similarly, CP occupied the average inter-settlement distance of (386.79 ± 374.48) m with maximum distance of 1250 m and minimum of 30 m.

The results shows that, CP preferred maximum inter-water distances of 300- 500 m with 28.7% followed by distance above 1900 m with 19.9%, and lowest preference were between 1500 - 1700 m with 0.6%. In winter, CP is mostly habitat cardamom cultivation area and peripheries for feeding (Figure 4.8). Wu et al. (2004) reported that Pangolins habitat location are linked with their key prey species in the wild and their burrows are always found close to ant or termite nests, probably for feeding easily in winter.

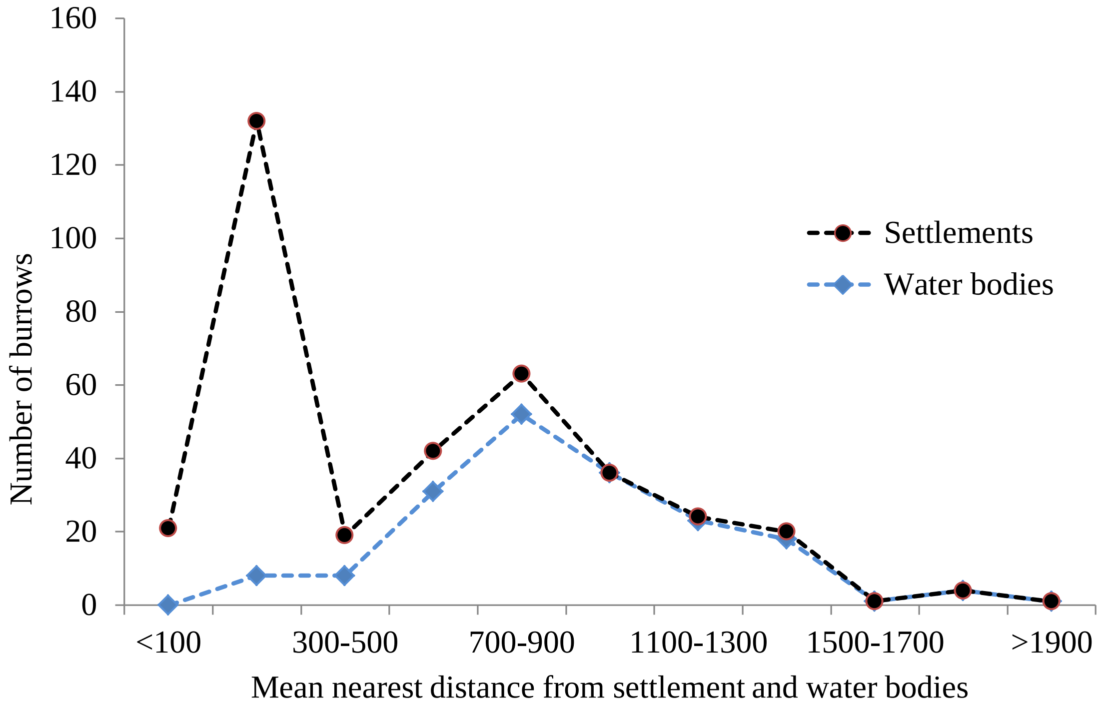

Figure 4.8: Occurrence of CP from nearest distance of water bodies and settlements

4.3 Vegetation structural in presence of Chinese pangolin burrow

4.3.1 Tree Species composition, life forms and dominance

A total of 24 families with 42 tree species were recorded from 48 plots. Trees were classified into three major life forms; evergreen (22 species), deciduous (13 species), semi-deciduous tree (1 species) and unidentified tree (5 species). Vegetation in the potential sites of CP were composed of 60% evergreen, 30.1% deciduous, 1.4% semi-deciduous and 6.4% unidentified tree species (Figure 4.9). Overall, the most dominant tree species were recorded with maximum Importance Value Index (IVI) for *Schima wallichii* (IVI = 68.16) followed by *Castanopsis hytrix* (IVI = 54.94) and *Viburnum species* (IVI = 29.05), while least for *Cinnamomum bejolghota* (IVI = 13.99) (Table 4.3).

Table 4.3: Dominant and co-dominant tree species in the study area

Species	Relative Density	Relative Dominance	Relative frequency	IVI
Schima wallichii	26.04	11.03	31.09	68.16
Castanopsis hytrix	17.08	16.14	21.72	54.94
Viburnum spp (Asaray)	10.42	3.650	14.98	29.05
Beischmiedia roxburghiana	5.630	13.62	7.490	26.73
Nyssa javanica	5.210	12.43	7.490	25.13
Engelhardtia spicata	11.46	6.660	3.000	21.11
Acer thomsonii	6.040	5.210	8.240	19.49
Macaranga denticulate	9.170	7.040	1.500	17.70
Cinnamomum bejolghota	2.920	10.69	0.370	13.99
Euaria aquaminita	3.540	8.870	1.500	13.91
Caeserea glomerita	2.500	4.960	2.620	10.09
Mean	9.09 ± 6.79	9.12 ± 3.80	9.09 ± 9.31	27.3 ± 17.28

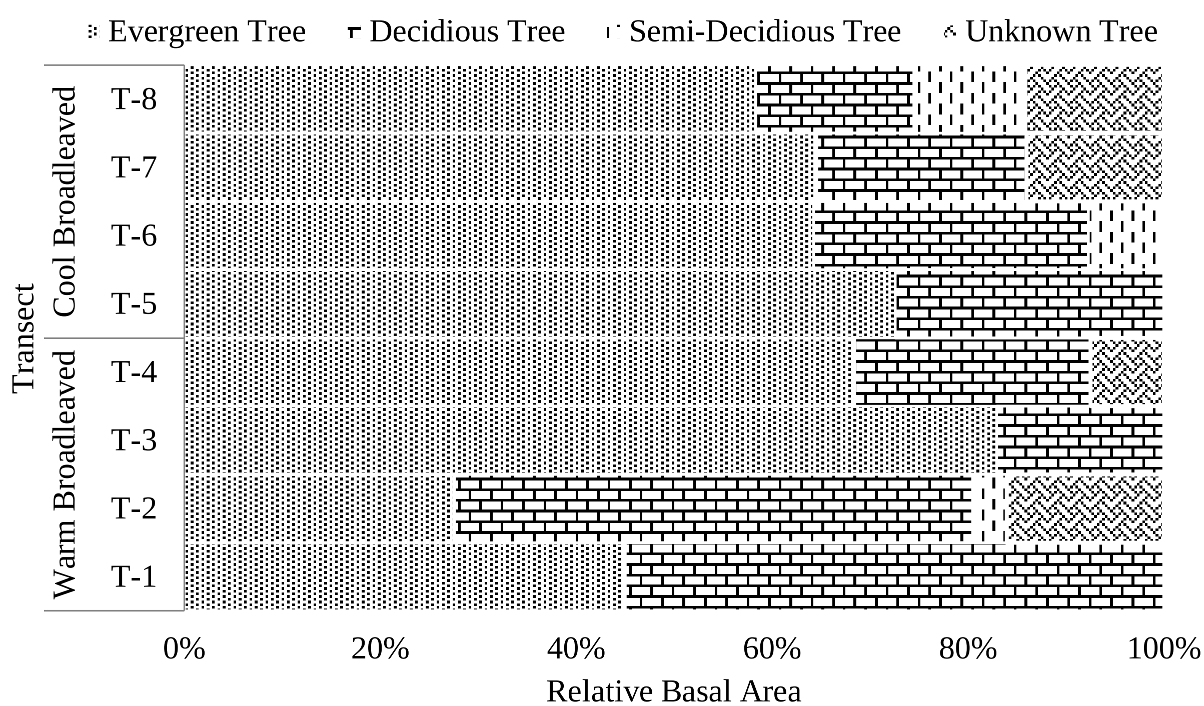

Figure 4.9: Showing the life form of tree layer

4.3.2 Shrub Layer composition, life forms and dominance

Shrub species comprised of 18 species from 14 families. It was categorized into three life forms: deciduous shrub (9 species), evergreen (12 species) and unidentified shrubs (6 species). Two dominant species (*Maesa chisia* and *Edgeworthia gardneri* were recorded from warm broad-leaved forest and *Daphne bholua* and *Daphne sureli* from cool broad-leaved forest. *Maesa chisia* was the common dominant species in both the forest types. Further, both the forest were dominated only by evergreen shrub species (Figure 4.10).

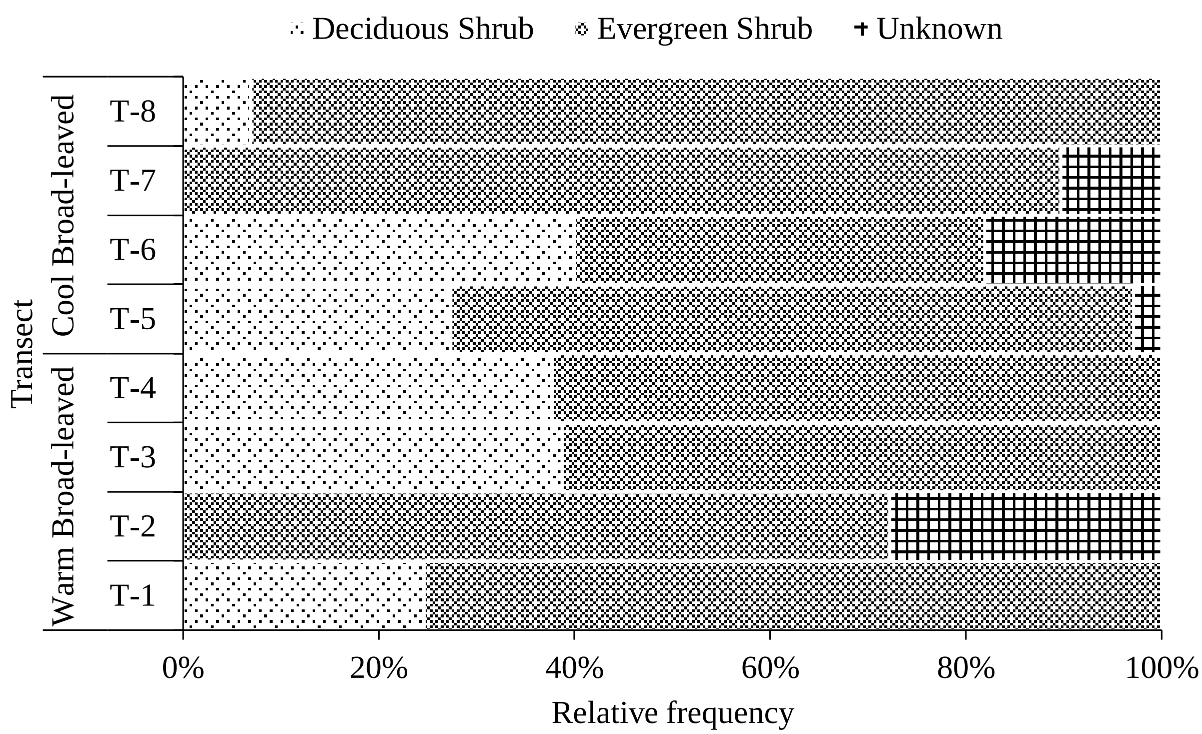

Figure 4.10: Showing the life forms of shrub layer

4.3.3 Ground Cover Composition, Life forms and dominance

Ground layer comprised of 10 families with 17 species of which constituted annual herb (2 species), perennial herb (8 species), biennial herb (1 species), fern (4 species) and climber (2 species). The dominant families recorded were Asteraceae (6 species), and rest were with single family and species. Floristically, perennial herb (59.35%) had maximum coverage followed by fern (29%), annual herb (10%), biennial herb (1%) and climber (1%) respectively. *Pteridum aquilinum* and *Eupatorium adenophorum* showed dominance in both the forest types (Figure 4.11).

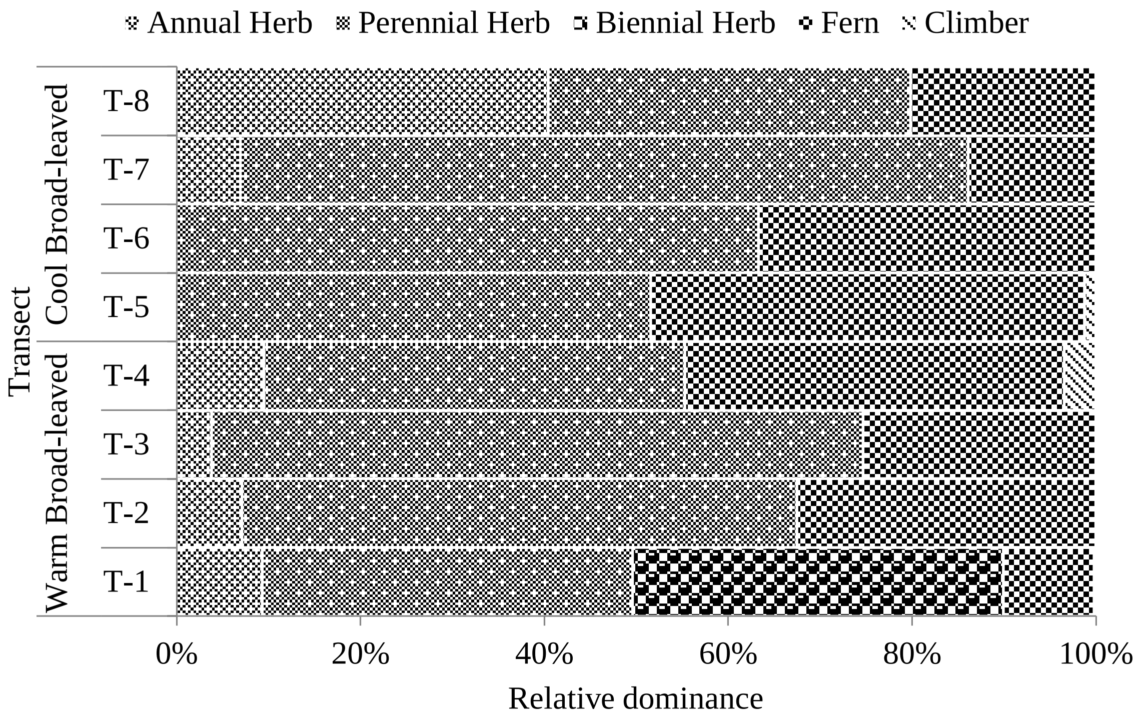

Figure 4.11: Showing the life form of ground layer

4.3.4 Species diversity and richness

Shanon-Wiener diversity index (*H'*) for the cool broad-leaved forest, where CP burrow occurs showed the highest tree diversity (*H'*= 2.36) than in warm broad-leaved forests (*H'*= 2.14). Similarly, shrub diversity observed high (*H'*= 2.23) in cool broad-leaved than warm broad-leaved (*H'*= 1.80). Species richness (S_R = 7) for trees species and (S_R = 31) for shrub species were observed comparatively lesser in warm-broad-leaved forest and (S_R = 8) for tree species and (S_R = 29) for shrub species than in cool broad-leaved forest (Table. 4.4).

Table 4.4: Indices for trees species in different transect in two forest type

	Warm Broad-leaved		Cool Broad-leaved	
	Tree species	Shrub Species	Tree species	Shrub Species
Diversity index (*H*')	2.14	1.80	2.36	2.23
Species Evenness ($E_{H)}$	0.56	0.54	0.26	0.31
Species Richness (S_R)	7	31	8	29

4.4 Current distribution and burrow density of Chinese pangolin

4.4.1 Current distribution of CP

The distribution of the CP were assessed with the indirect signs and direct sighting of the CP along the eight transects and extensive search in the study area. The distribution status of CP was assessed in three geogs under Dorokha Dungkhag. The presence of CP signs was recorded from all three gewogs. In Dophuchen geog, the signs of CP were recorded from Dagap, Manidara, Basentey, Satakha, Laptsegaon, Sengdhen, Wangchuk, Jigme, Mithin and Mithun Top villages. In Dumtoed geog, the animal was found sparely distributed at a few localities of Daragaon, Gairegaon, Khalinggaon and Kuchey villages. However, presences of CP signs were observed only from one village in Denchukha geog.

Among these villages, the numbers of CP distribution signs were found comparatively more in Dogap, Manidara and Basentry villages under Dophuchen geog, Daragaon village under Dumtoed geog as indicated by red dots (Figure 4.12). The more numbers of CP signs were found in these villages where there were cardamom cultivation since these are preferred feeding areas in winter. The numbers of CP distribution signs were found moderately in Laptsekha under Dophuchen and Relukha under Denchukha geog as indicated by green doted (Figure 4.12). The distribution of CP signs (Orange dots) in Sengdhen, Satakha, Mithun under Dophuchen and Gairegaon and Khalingtar villages under Dumtoed geog were found very low. This may be due to the high elevation in these areas.

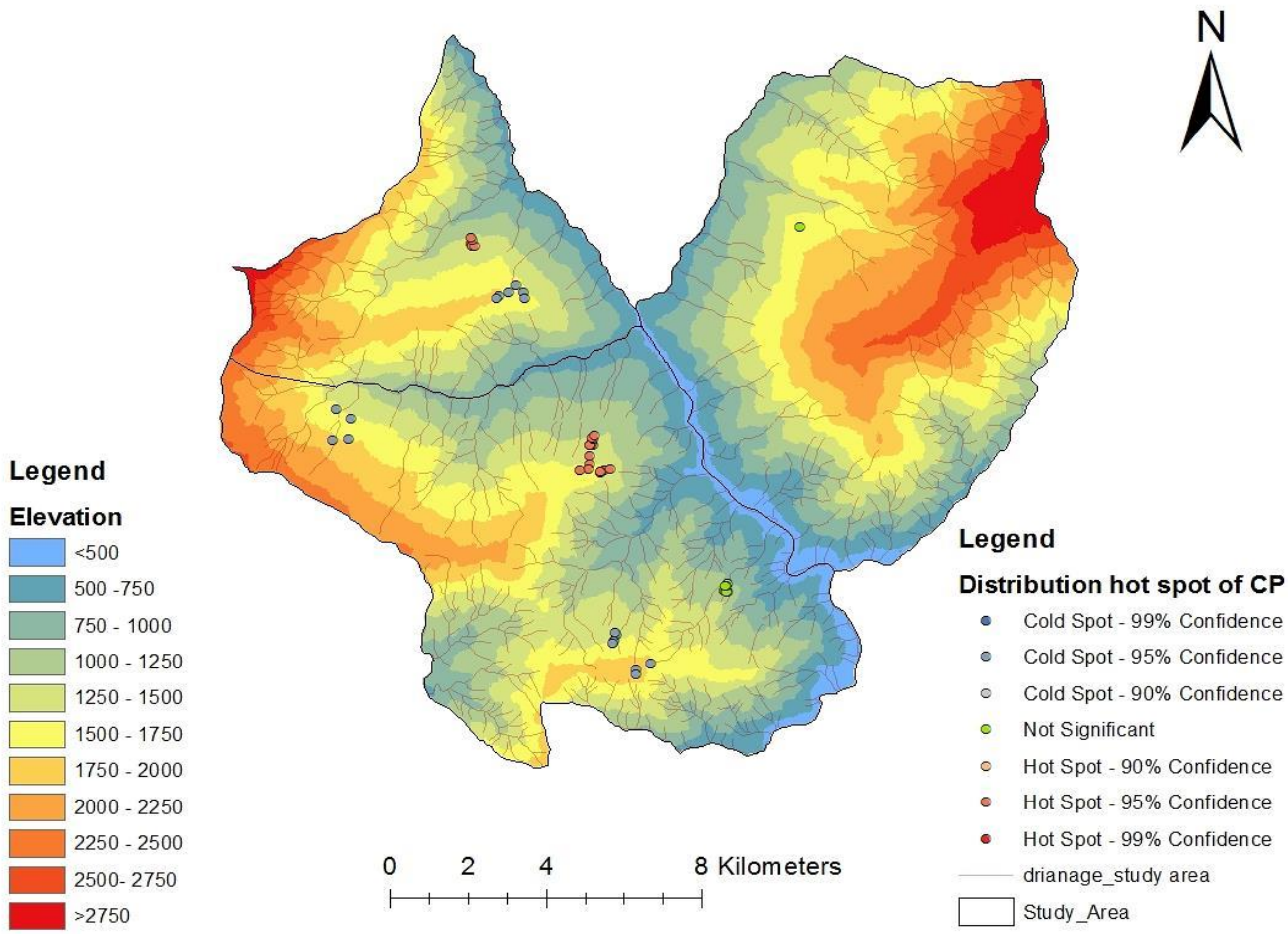

Figure 4.12: Hot spot analysis of CP current distribution

4.4.2 Burrow density of CP

The burrow density of CP was estimated at eight sites in the established belt transects. To calculate burrow density, only active living/sleeping burrows were taken (Begon, 1979). Permanent plots in the belt transect were recorded repetitively after 30 days for three months from January to March.

A total area of 48000 m^2 from a 48 sample plots were surveyed and only 5 numbers of active burrow were recorded. The result revealed that the overall burrow density of the study area were 0.104 signs per hectare. The study conducted by Bhandari and Chalise (2014) found that the burrow density were 0.833 signs per hectare in Nagarjun Forest of Shivapuri Nagarjun National Park in Nepal

4.5 Suitable Habitat of Chinese pangolin using Maxent modeling

4.5.1 MaxEnt model performance/output

The Maxent model predicted potential suitable habitat of CP as indicated by red area (Figure 4.13) corresponding to broad-leaved forest and agricultural land. Most suitable habitat for CP was predicted in area located in close proximity to settlements in Satakha, Laptsegaon, Dogap, Sengdhen, Jigme, Mithin under Dophuchen geog; Gairegaon, Daragaon, Khalingaon, Kuchi under Dumtoed geog and Relukha under Denchukha geog (Figure 4.13). The *MaxEnt* result showed that currently 23.57 km^2 of the study area falls under highly suitable habitats of CP as indicated by red color, 37.88 km^2 of the study area with suitable habitat as indicated by yellow color. The remaining study area of 194.98 km^2 was not suitable habitat for CP (Figure 4.13).

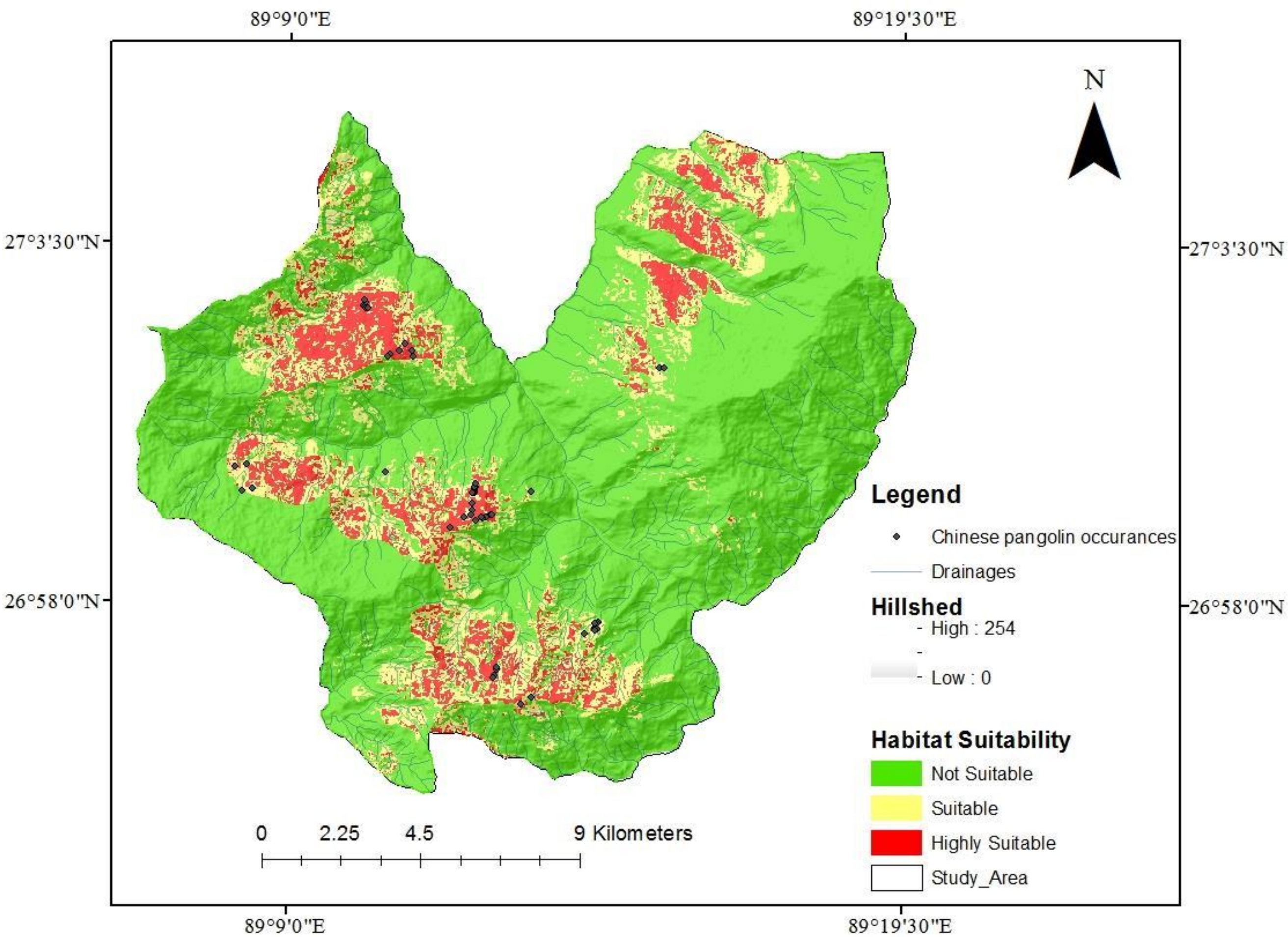

Figure 4.13: Habitat Suitability map of Chinese pangolin

4.5.2 Model output assessment

A general rule of thumb for AUC scores is that models with an AUC score over 0.8 can be considered good, and models with an AUC > 0.9 as very good (Araújo *et al*., 2005). The habitat suitability models for CP performed well based on the moderately high (> 0.80) AUC values (Figure 4.14).

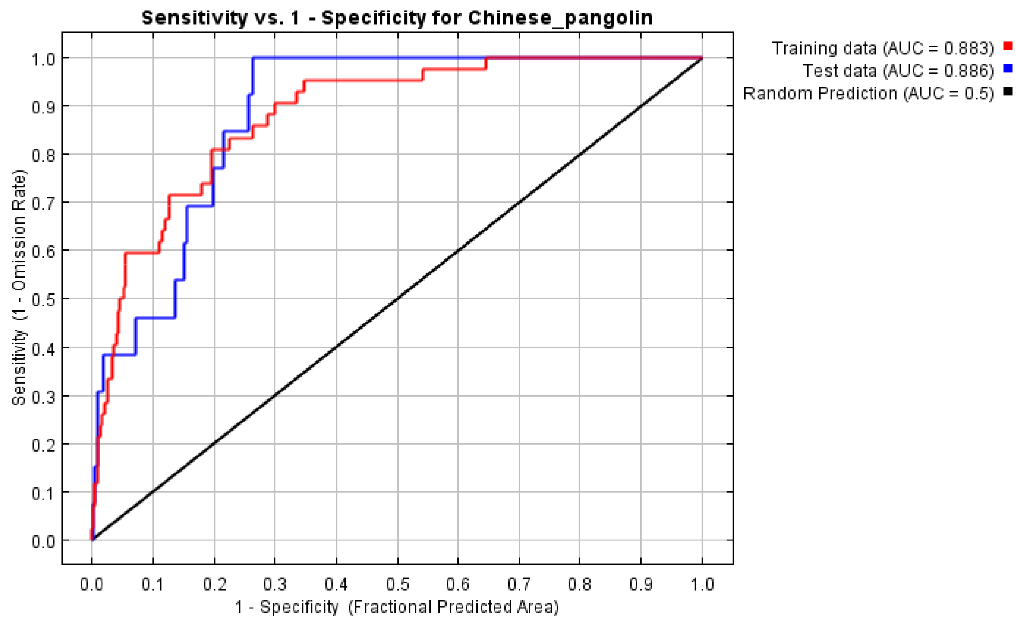

Figure 4.14: Model analysis of AUC curve of Chinese pangolin

The variables with the highest percent contribution and permutation importance for the CP habitat suitability model were elevation, settlement, aspect and drainage (Table 4.6).

Table 4.6: Percent of contribution by environmental variables

Environmental Variables	Percent Contribution	Permutation importance
Elevation	34.3	3.9
Settlement	23.4	20.3
Aspect	16.5	9.9
Drainage	10.1	8.4
Landuse	5.9	2.2
Mean temperature	4.9	33.1
Slope	4.3	5
Mean precipitation	0.6	17.2

The jackknife test of variable importance shows the highest gain when the variable mean temperature is used in isolation, which therefore appears to have the most useful information by itself (Figure 4.15). Further, the variable that decreases gains the most when settlement is omitted, which indicates that, this variable has the most information that is not present in the other variables (Figure 4.15).

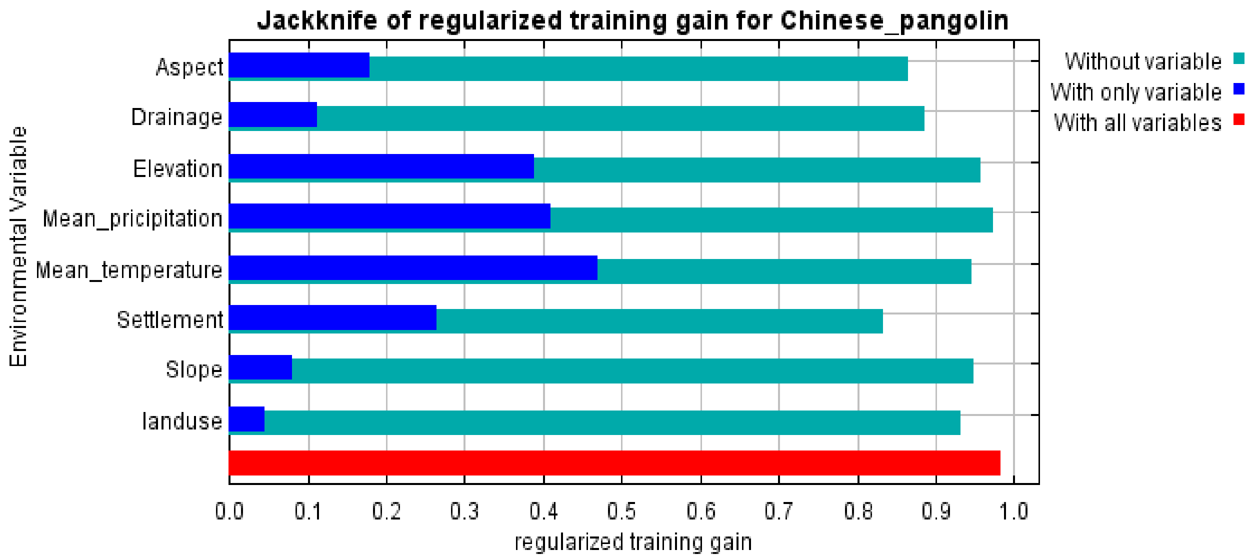

Figure 4.15: Model analysis of Jackknife test of Chinese Pangolin

4.6 Conservation Threats of Chinese pangolin

Threats to Pangolin in Samtse include rapid loss and deterioration of available habitat and hunting for local use and for international trade in skins, scales, meat and local beliefs of bad omen. Habitat destruction and farm roads pose the greatest danger to Pangolin in southern Bhutan.

The interview revealed that Pangolins are encountered on the roads during night and get killed by the people due to its poor defense ability. People interviewed in the study areas confirmed that Pangolin digs its own, long burrows underground, which they use both to eat termites and in which to sleep. This made it easy for hunters to capture them. Sometimes they also open up their scale towards hunters but they lack counter-attack behaviour.

According to the respondents, inwardly directed grass and closed burrow entrance with soil indicate the presence of Pangolin inside the burrow and outwardly directed grass and clean burrows indicate that the Pangolin had already gone out from the burrow.

Owing to uncommon appearances, unusual apathy of the common people towards Pangolins is another threat. People try to kill the animal whenever and wherever they come across it. This killing is also attached with the belief that 'coming across/sighting Pangolin brings bad luck'. Rapid loss and deterioration of habitat, steady increase in the agrarian economy combined with many developments like farm roads and improved irrigation system appears to be the most serious threat resulting in decline of Pangolin population in Southern Bhutan.

Out of 124 respondents in the study area, 93.5% felt that threats to Pangolin are human (hunting, habitat destruction), 1.7% by wild cats and 4.8% by others like natural hazards, landslides and diseases.

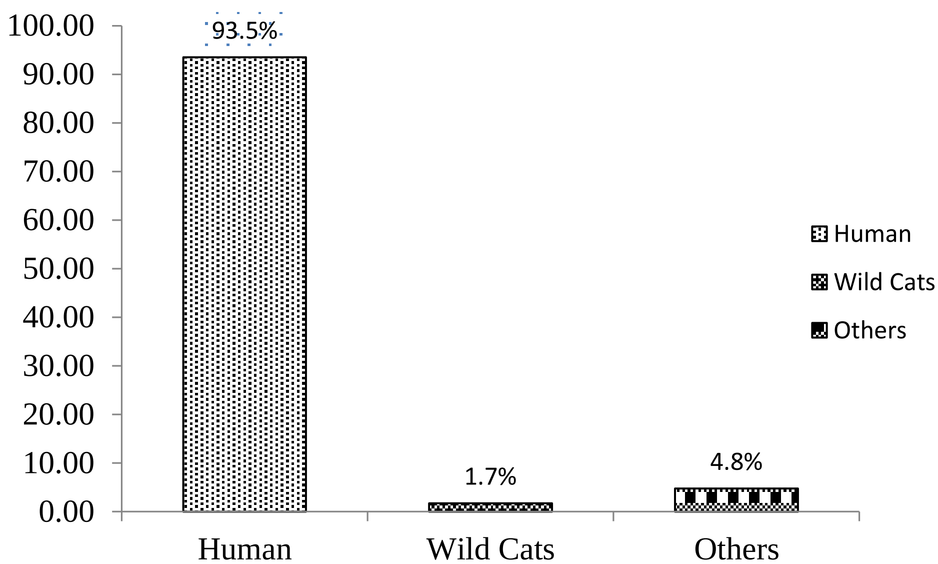

Figure 4.16: Threats of pangolin as per respondents

The result of the graph show that Human are the main threats to Pangolin. Human destroys the habitat for developmental activities, hunt the animal for different purposes, kill the animal due to uncommon appearance. Due to its protective scales wild cats cannot spot and kill the animal easily. The interview revealed that Pangolins are killed by landslides and washed away by the rivers.

4.7 Trade of Pangolin and its Products

The people along the border were interviewed informally keeping in mind the objectives as to obtain some information on the trade of Pangolin and its product. There is no open display and sale of Pangolin in Samtse (Southern Bhutan) and even in adjacent towns of India. However, it was noticed and informed that indirect sale still continue in these areas because of the porous border with our neighboring country (India). A respondent who do not wish to be named revealed that one live Pangolin fetches about Nu.7000-10000 whereas dead Pangolin would fetch a price of Nu.4000-4500 in India. Although pangolins are killed for meat and trade, there is no record of any apprehension in any of the Forest Ranges and check points in Samtse Dzongkhag but trafficking, buying and selling illegally, appears to be one of the most harmful threats to the population of pangolins.

Chapter Five

Conclusion and Recommendation

Chinese pangolin was encountered in very low density in the study area and were distributed in few wards of Dorokha Dungkhag with burrow density of 0.104/ha. A total 181 burrows (95 new, 66 old, 15 inactive, active 5) and two direct sighting were found in the study area. CP preferred warm broadleaved forest although they are also found in cool broadleaved forest for feeding in winter. The distribution of burrow was highest in the forest dominated by *Schima wallichii*, *Castanopsis hytrix* and *Cinnamomum bejolghota* and dominated shrub species by *Maesa chisia* and *Edgeworthia gardneri*.

The study revealed that burrows were not uniformly distributed. Their distribution was highly influenced by the altitude, aspect and soil type as well as amount of the food availabilities and water. The number of burrows of CP decreased with increasing elevation and ranged up to a maximum of 2100 m. CP mostly preferred between 25 – 45 % slope ranges. Analysis on the comparison between the means of CP burrow and aspect show that CP mostly found in north-east and north-west facing aspect. They mostly preferred open canopy ranging from (25 – 45 %) and with closed ground cover (76 – 100 %). CP preferred clay loam and sandy loam soil for easy burrowing and availability of food (termites) in the present study.

Habitat modelling revealed 23.57 km^2 of the study area was highly suitable and 37.88 km^2 as suitable habitat for the species. Baseline information generated from the present study can be informative in formulation of future scientific management plan for conservation of CP population in the study area. Owing to short survey period, the present study couldn't collect the distribution information for large area in different season. Therefore, future research on this species should focus on distribution of Pangolin in Bhutan throughout its range for different season so that an appropriate conservation measures could be undertaken.

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List of Annexure

Annexure I: Data Sheet for burrow information

Location:……………………………………………..Geog:………………………………………………………………………………………………

Transect ID no:……………………………………Surveyor:……………………………………………………..Date:………………………………..

Sl/ No	GPS Coordinates		Elevation	Types of burrow								Aspect	Slope	Nearest Distance (M)			Soil type	Habitat Type	Presence of ants & termits
	Latitudes	Longitudes		Feeding	Old/ New	Width	Depth	Pemt./Sleeping Burrow	Active/ Inactive	width	Depth (only inactive burrow)			WB	RD	Sett			

Feeding Burrow: Dead bodies of ants and termits colonies inside the burrow

Living/Permanent Burrow: Much deeper and less in numbers than those of feeding ones.

Active living burrow : Any indirect signs like foot prints on the soil around, scale prints or presence of faecal sample around.

Aspect: 1=North, 2=NE, 3=East, 4=SE, 5=South, 6=SW, 7=West, 8=NW

Slope:1=very steep (>60%), 2=steep (45-60%), 3=Moderate (25-45%), 4=Undulating

Distance: WB=Water bodies, Rd=Road, Sett= Settlement

Soil Type: Sandy, Loamy, Clay, Red or brown soil, Limestone soil.

Habitat type: Forest land, Grass land, Agriculture land

Annexure II: Data sheet for recording other direct/indirect signs

Location:…………………………………………..Geog:………………………………………………………………………………………………

Transect ID no:……………………………………Surveyor:…………………………………………………..Date:………………………………..

Sl/no	Types of evidence	Habitat Types	GPS Coordinates		Elevation	Aspect	Slope	Soil type	Nearest Distance (m)			Presence of ants and termits
			Latitudes	Longitudes					WB	Rd	Sett	

Annexure III: Data sheet for vegetation survey (Tree Species)

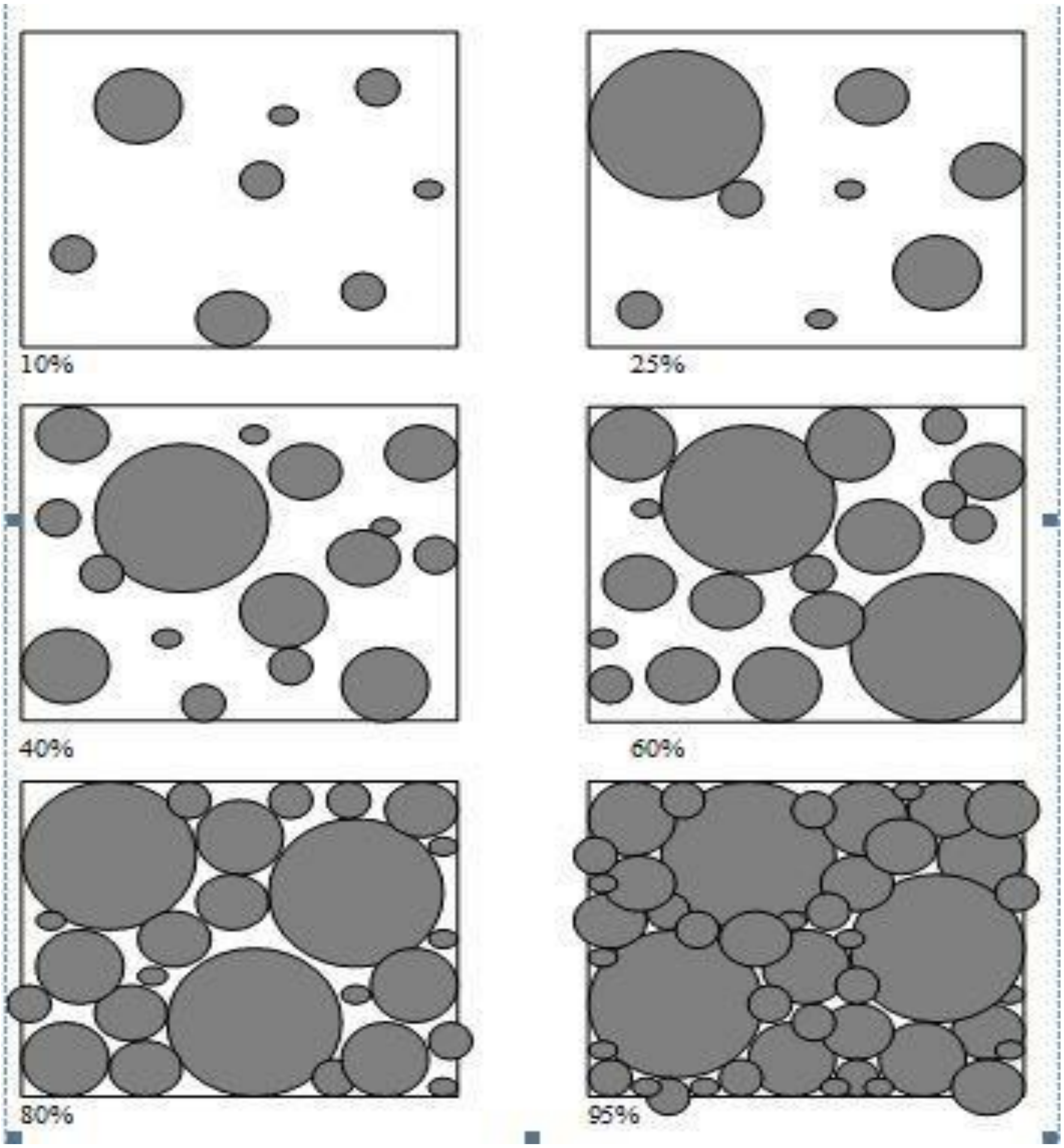
Location: …………………… ..…Transect ID No.:…………Geog:…………GPS Coordinate of Starting point:..N………………………E…………………….

Altitude:…………………………..Forest Type:………………………………GPS Coordinate of Ending point: N………………………..E…………………….

Sampling point	Quarter	Species Name	Distance from center (cm)	Dbh (cm)	Crown Cover %	Remarks
1	1					
	2					
	3					
	4					
2	1					
	2					
	3					
	4					
3	1					
	2					
	3					
	4					
4	1					
	2					
	3					
	4					
5	1					
	2					
	3					
	4					
8	1					
	2					
	3					
	4					
		Total distance				
		Mean Distance				
		Absolute Distance (^)				

Note: Select the nearest tree above 10cm DBH

Annexure IV: Figure to assist in estimation of crown cover percentage



Annexure V: Data Sheet for Herbs and Shrubs

Location:…………………………………………………………..Elevation:…………………………………..

Transect name/ID:………………………………………………Aspect:,…………………………………….

Plot No:…………………………………………………………Slope:………………………………………

GPS Coordinates: N……………………………E………………………………………Recorder:…………………………Date:……………….

Sl/No	Species Name	Common Name	Species count	Height (cm)	Remarks

Note: Shrub=plot size (5 x5 m) and Herbs= plot size (2 x 2 m)

Annexure VI: Significant test between the three habitat types and burrow count

Kruskal-Wallis Test

Ranks

	vegetation_type	N	Mean Rank
Burrow_count	WBF	17	27.88
	CBF	26	20.21
	Agri	5	35.30
	Total	48	

Test Statistics[a,b]

	Burrow_count
Chi-Square	6.537
df	2
Asymp. Sig.	.038

a. Kruskal Wallis Test

b. Grouping Variable: vegetation_type

Annexure VII: Significant test between burrow and aspect

Kruskal-Wallis Test

Ranks

	Aspect	N	Mean Rank
Burrow_count	1	4	21.75
	2	16	25.13
	3	1	42.50
	4	6	29.50
	6	7	9.07
	7	1	6.00
	8	13	30.62
	Total	48	

Test Statistics[a,b]

	Burrow_count
Chi-Square	15.642
Df	6
Asymp. Sig.	.016

a. Kruskal Wallis Test

a. Grouping Variable: Aspect

Annexure VIII: Tree vegetation composition

Species Name	Family	Life Form	Warm Broad-leaved Forest				Cool Broad-leaved Forest			
			T-1	T-2	T-3	T-4	T-5	T-6	T-7	T-8
Diversity										
Relative Basal Area %			RBA	RBA	RBA	RBA	RBA	RBA	RBA	RBA
Evergreen Tree										
Beischmiedia roxburghiana	Lauraceae	Evergreen Tree				22.0		4.5	11.5	
Castanopsis hytrix	Fagaceae	Evergreen Tree	14.43	9.5	19.8	20.4	10.2	8.6	13.1	15.5
Cinnamomum glaucescens	Lauraceae	Evergreen Tree			8.9			8.0	13.3	13.4
Daubanga grandifolia	Lythraceae	Evergreen Tree	6.79							
Elaeocarpus lanceifolius	Elaeocarpaceae	Evergreen Tree		6.8					16.4	7.7
Exbucklandia populnea	Hamamelidaceae	Evergreen Tree				3.4	2.3			
Fiscus Sp	Moraceae	Evergreen Tree	3.16							
Glochidion thomsonii	Phyllanthaceae	Evergreen Tree			1.6					
Lithocarpus spp	Fagaceae	Evergreen Tree					3.3	9.8		
Macaranga denticulata	Euphorbiaceae	Evergreen Tree	7.41	1.9	12.8		9.8			
Magnolia pterocarpa	Magnoliaceae	Evergreen Tree				10.1		0.9		
Michelia champaca	Magnoliaceae	Evergreen Tree						6.2		11.6
Phoeba attuata	Lauraceae	Evergreen Tree					9.8			
Schima wallichii	Theaceae	Evergreen Tree	9.49	4.4	14.8	12.4	11.8	20.9	10.5	8.0
Syzygium cumini	Myrtaceae	Evergreen Tree					4.4			
Talauma hodgsonii	Magnoliaceae	Evergreen Tree			6.7					
Terminalia chebula	Combretaceae	Evergreen Tree						0.5		
Terminalia tomentosa	Combretaceae	Evergreen Tree								
Ostodes paniculata	Euphorbiaceae	Evergreen Tree	3.61		7.4			2.5		
Engelhardtia spicata	Juglandaceae	Evergreen Tree		5.0	11.1		4.9			
Miliusa macrocarpa	Annonaceae	Evergreen Tree					12.1			
Aglia spectabilis	Meliaceae	Evergreen Tree						3.4		2.0
Sub-total			**44.9**	**27.6**	**83.0**	**68.2**	**68.6**	**65.1**	**64.7**	**58.2**
Decidious tree										
Acer thomsonii	Sapindaceae	Deciduous Tree	4.9	2.4				3.3		
Albizia lebbeck	Fabaceae	Deciduous Tree	8.4				2.9			
Alnus nepalensis	Betulaceae	Deciduous Tree	4.6							
Betula alnoids	Betulaceae	Deciduous Tree	18.6				6.2	9.6		
Caeserea glomerita	Vivianiaceae	Deciduous Tree		4.9	6.4					
Callicarpus arborea	Verbenaceae	Deciduous Tree	6.3							
Cinnamomum bejolghota	Lauraceae	Deciduous Tree		16.6		4.6			8.0	7.5
Euaria aquaminita		Deciduous Tree	4.6	4.3	7.1		12.6	7.4		
Castanopsis species	Fagaceae	Deciduous Tree				3.3				
Nyssa javanica	Cornaceae	Deciduous Tree				9.4		5.3	9.8	6.0
Pyrularia edulis	Santalaceae	Deciduous Tree		2.8	3.6		7.3			
Terminalia myriocarpa	Combretaceae	Deciduous Tree	5.0	20.4						
Viburnum spp (Asaray)	Adoxaceae	Deciduous Tree	2.4	1.5		6.6	2.0	2.5	3.6	2.6
Sub-total			**54.8**	**52.9**	**17.1**	**24.0**	**30.9**	**28.0**	**21.4**	**16.1**
Semi-Decidious Tree										
Erisia obliqua		Semi-Decidious		3.5				7.8		11.3
Sub-total				**3.5**				**7.8**		**11.3**
Unidentified tree										
Unknown I				9.5						
Bumshing									14.0	14.1
Chindey				6.5						
Pungshing						7.4				

Sub-total				**16.0**		**7.4**			**14.0**	**14.1**
Total			**100**	**100**	**100**	**100**	**100**	**101**	**100**	**100**

Annexure IX: Shrub vegetation composition

Species Name	Family	Life Form	Warm Broad-leaved Forest			Cool Broad-leaved Forest				
			T-1	**T-2**	**T-3**	**T-4**	**T-5**	**T-6**	**T-7**	**T-8**
Relative Freqency %			RF	RF	RF	RF	RF	RF	RF	RF
Deciduous Shrub										
Ardisia crenata	Primulaceae	Deciduous			3.75		4.3			
Artimesia sp	Asteraceae	Deciduous	10.8							
Caeselpina spp	Fabaceae	Deciduous					2.2			
Croton tiglium	Euphorbiaceae	Deciduous				23.0	2.2	12.3		
Oxyspora paniculata	Melastomataceae	Deciduous	10.8		22.5					
Symplocos sumuntia	Symplocaceae	Deciduous				14.8	10.1	14.2		
Dichroa febrifuga	Hydrangeaceae	Deciduous			7.5		6.5	13.5		6.9
Melastoma spp	Melastomataceae	Deciduous	3.1				2.2			
Strobilanthes spp	Acanthaceae	Deciduous			5.0					
Sub-total			**24.6**		**38.8**	**37.7**	**27.3**	**40.0**		**6.9**
Evergreen Shrub										
Aconogonon molle	Polygonaceae	Evergreen		7.4						
Brassaiopsis species	Araliaceae	Evergreen	41.5		1.3	23.0				
Brassaiopsis palmata	Araliaceae	Evergreen				3.3				
Callicarpa spp	Lamiaceae	Evergreen					20.9			3.4
Cinnamomum spp	Lauraceae	Evergreen					2.2			
Daphne bholua	Thymelaeaceae	Evergreen								70.7
Daphne sureli	Thymelaeaceae	Evergreen		12.0		26.2	37.4		28.2	
Edgeworthia gardneri	Thymelaeaceae	Evergreen	33.8	9.3	12.5	9.8		3.2		
Maclura cochinchinensis	Moraceae	Evergreen						5.8		
Maesa chisia	Myrsinaceae	Evergreen		34.3	47.5		7.9	11.0	61.5	19.0
Maesa indica	Myrsinaceae	Evergreen					1.4	18.1		
Ostodes paniculata	Euphorbiaceae	Evergreen		9.3				3.9		
Sub-total			**75.4**	**72.3**	**61.3**	**62.3**	**69.8**	**41.9**	**89.7**	**93.1**
Unidentified species										
Darga				23.1						
Kharaney				4.6						
Jamunay							2.9			
Haray								1.9		
Loktey								11.0	10.3	
Suntalay kath								5.2		
Sub-total				**27.8**			**2.9**	**18.1**	**10.3**	
Grand Total			**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Annexure X: Ground vegetation com**position**

Species Name	Family	Warm Broad-leaved Forest				Cool Broad-leaved Forest			
		T-1	**T-2**	**T-3**	**T-4**	**T-5**	**T-6**	**T-7**	**T-8**
Relative Dominance (%)		RD	RD	RD	RD	RD	RD	RD	RD
Annual Herb									
Ageratum conyzoides	Asteraceae	14.88	7.12	3.82	9.49				
Bidens pilosa	Asteraceae							6.94	40.47
Sub-total		14.9	7.1	3.8	9.5			6.9	40.5
Perennial Herb									
Aconogonon molle	Polygonaceae								
Artimesia sp	Asteraceae	4.25							
Caeselpina spp	Fabaceae		1.69						
Centella asiatica	Apiaceae							49.94	
Chromolaena odorata	Asteraceae	26.29	2.13	8.89		10.29	19.36	1.94	
Eupatorium adenophorum	Asteraceae	31.44	42.75	54.93	20.46	38.21	43.96	12.32	7.94
Mikania micrantha	Asteraceae	2.31	4.20	7.06		3.07			
Piper pedicellatum	Piperaceae		9.61		25.34			14.98	31.45
Sub-total		64.3	60.4	70.9	45.8	51.6	63.3	79.2	39.4
Biennial Herb									
Elatostema sp	Urticaceae	4.78							
Sub-total		4.8							
Fern									
Cheilanthes bhutanica	Pteridaceae		3.37	0.56	2.85		2.85		6.07
Nephrolepsis cordifolia	Polypodiales	0.36	1.84	7.49	0.53	2.88			
Pteridum aquilinum	Dennstaedtiaceae	15.38	27.28	15.91	37.89	41.78	33.83	13.88	14.07
Selaginella spp	Selaginellaceae			1.34		2.52			
Sub-total		15.7	32.5	25.3	41.3	47.2	36.7	13.9	20.1
Climber									
Rubia cordifolia	Rubiaceae	0.31							
Smilax prolifera	Smilacaceae				3.43	1.24			
Sub-total		0.3			3.4	1.2			
Grand Total		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Annexure XI: Photos of direct sighting and burrows of Chinese pangolin