HABITAT CHARACTERISATION OF ASIAN ELEPHANT (*Elephas maximus*) IN WAYANAD WILDLIFE SANCTUARY, KERALA

By

ASHWIN S (2016-17-009)

THESIS

Submitted in partial fulfillment of the requirement for the degree

MASTER OF SCIENCE IN FORESTRY

Faculty of Forestry

Kerala Agricultural University

DEPARTMENT OF WILDLIFE SCIENCES

COLLEGE OF FORESTRY

KERALA AGRICULTURAL UNIVERSITY

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2018

DECLARATION

I, hereby declare that this thesis entitled **"Habitat Characterisation of Asian Elephant (*Elephas maximus*) in Wayanad Wildlife Sanctuary, Kerala"** is a bonafide record of research done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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ACKNOWLEDGEMENT

With deep admiration I express my heartfelt gratitude to my major advisor, ***Dr. P. O. Nameer****, Professor and Head, Department of Wildlife Sciences, College of Forestry for his valuable guidance, support, inspiration, critical advice, encouragement and friendly co-operation throughout the course of my research work. I consider myself lucky to have him as my advisor.*

I owe my sincere thanks to my advisory committee member ***Dr. T. K. Kunhamu****, Professor and Head, Department of Silviculture and Agroforestry, College of Forestry, for his co-operation and intellectual advice extended to me during the course of my study.*

I extend my wholehearted thanks to ***Dr. S Gopakumar****, Professor, Natural Resource and Management, College of Forestry and member of advisory committee for his valuable suggestions and support, provided to me throughout the course of the study.*

My earnest thanks to ***Jayasree Krishnankutty****, Professor, Department of Agricultural Extension, College of Horticulture and advisory committee member for her wholehearted co-operation and valuable advice given to me during the course of the study.*

I take this opportunity to recognize ***Dr. K. Vidyasagaran****, Dean, College of Forestry for his support during the study.*

Many thanks are due to ***Kerala Forest Department****,* ***The Chief Wildlife Warden, Kerala****,* ***Mr. N. T Sajan IFS****, Wildlife Warden, Wayanad Wildlife Sanctuary,* ***Mr. Ratheeshan V****, Assistant Wildlife Warden, Tholpetty Range,* ***Mr. Ajay Gosh V****, Assistant Wildlife Warden, Muthanga Range,* ***Mr. Baburaj K****, Assistant Wildlife Warden, Kurichiatt Range,* ***Mr. Krishnadas R****, Range Forest Officer, Meppady range,* ***Mr. Dinesh Shankar N T****, Range Forest Officer, Kalpetta Range and* ***Ms. Ashalatha A****, Depot Officer, Kuppadi Depot for sanctioning the permission for carrying out the research work and for providing field staff, support, information and accommodation in the aid of the same.*

My sincere gratitude to ***Vishnu O****, Conservation Biologist, Wayanad Wildlife Sanctuary and* ***Mr. Madhavan****, Watcher, Muthanga Range, and all the staff who accompanied us during field visits.*

I express my earnest thanks to ***Ms. Syamili M S, Mr. Sreekumar E R, Mr. Vishnu, B R*** *and* ***Mr. Kiran Mohan,*** *Assistant Professors, for their sincere co-operation and intellectual advice during the course of the study.*

I am wholeheartedly obliged to ***Ms. Chitra P****, for her timely advice, moral support and constant aid while analyzing data.*

The help rendered by ***Mr. Vishnu M.*** *and* ***Mr. Vishnu Chandran M****, in helping me during field work is also remembered with immense gratitude.*

Special gratitude to ***Mr. Sachin K Aravind****,* ***Ms. Devika Sangamithra*** *and* ***Ms. Abhirami M Jayakumar*** *for their unconditional help when I was in need.*

I would also like to thank ***Dr. Suma Mukthesh****, Professor and Head, Department of Fruit Science, College of Horticulture for her constant support throughout the course of two years in KAU.*

I sincerely thank my ***Mother, Father, Brother, Grandmother and other Relatives*** *who have supported me a lot during the entire duration of the course.*

Well wishes, lots of love, encouragement and blessing from all my ***colleagues, juniors and seniors*** *were a great support for me during the study.*

Above all, I owe my sincere thanks to ***Mother Nature*** *for without her, this study of her bounties would never have been possible.*

ASHWIN S

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INTRODUCTION

INTRODUCTION

The Asian Elephant (*Elephas maximus*) is listed under the Endangered category A2c by IUCN (International Union for Conservation of Nature and Natural Resources). The species has been accorded this category due to a reduction of at least 50% of its population within the last three generations (Choudhury *et al.,* 2008). Formerly, the Asian Elephant used to range across West Asia, the Indian subcontinent, South-East Asia and China, covering about 9 million km^2 (Sukumar, 2003). Today, the Asian Elephant occurs in isolated and highly fragmented populations in 13 countries of Asia. The approximate range today is estimated to be 486.800 km^2 (Blake and Hedges, 2004). The countries in which Asian Elephant populations still survive are Bangladesh, Bhutan, India, Nepal, and Sri Lanka in South Asia and Cambodia, China, Indonesia (Kalimantan and Sumatra) Lao PDR, Malaysia (Peninsular Malaysia and Sabah), Myanmar, Thailand, and Vietnam in South-east Asia.

The global population size of the Asian Elephant is estimated to be about 41,410-52,345 (Sukumar, 2003). More than 50% of the remaining wild elephant population occur in India. Except the Western Ghats area in South India (recent increase in population due to conservation efforts), the overall population of the elephants in all ranges has been downwards for many centuries (Choudhury *et al.* 2008). Although poaching and hunting of elephants has been banned by IUCN and CITES, illegal poaching still occurs in many parts of the elephant range states. Since some males and all females lack tusks in Asian Elephant, poaching for ivory is said to be a relatively minor threat as compared to the African Elephant (Dawson and Blackburn, 1991). That being said, ivory poaching has caused serious problems in many parts of Asia (Menon *et al.* 1997). Selective male poaching for ivory has also greatly skewed the sex ratio of adult elephants in Periyar Tiger Reserve and elsewhere (Chandran, 1990; Sukumar *et. al.*, 1998; Sukumar, 2003).

Since elephants require large home ranges for satisfying their daily requirements of food and water, as well as reproduction, they are regarded as umbrella species. The conservation of elephants will also help in the protection of other species that occur within their range. This also has a direct impact on human-elephant conflict since habitat destruction by humans result in

limiting the home range of elephant thereby leading to dependence of elephants on agricultural crops. Such conflict results in the death of hundreds of humans and elephants per year as well as destruction of property and agriculture. This in turn increases antagonism among the people against elephants leading to less co-operation for elephant conservation. This situation is exacerbated due to the fact that Asian Elephants occur in the areas where there is dense human population as well (Choudhury *et al.* 2008, Desai and Riddle, 2015). Extreme cases of habitat destruction and degradation lead to elephants being confined to 'pocketed herds' in patches of natural forests completely surrounded and isolated by human habitation.

Elephants require large amount of space. This is directly related to their social organization, ranging behaviour, as well as ecological needs. Matriarchal societies form the basis of elephant social organisation. Females mostly form cohesive groups with strong social bonds and males are solitary. Although males interact with other males and females within their home range especially during the mating season. Several clans and independent males could together constitute a population or sub-population. Clans have well defined home ranges and show strong fidelity to these ranges. All clan members show coordinated movement within the clan's home range. Within their home range, clans may also have well defined seasonal ranges and show strong fidelity to these. They rarely alter the routes they utilise to move between these seasonal ranges as well. Different clans may have different home ranges which overlap partially or totally. There is a temporal separation in resource use which depends on both the availability of resources and dominance hierarchies of various clans (Desai and Riddle, 2015). Even when there is 80% overlap between the home ranges of different clans, the use of different vegetation types and food plant species varies significantly (Baskaran, 1998).

In South India, the home range size of the Asian Elephant were found to be as large as 350 km^2 for males and 600 km^2 for females (Baskaran et al., 1995). In North India, the home range size was found to be about 188 to 408 km^2 for males and 184 to 327 km^2 for females (Williams et al., 2001). Home range sizes from 53 to 345 km^2 for males and 29 to 160 km^2 for females have been reported in Sri Lanka (Fernando *et al.*, 2005). This would indicate that habitat patches less than 250-300 km^2, even when having suitable shape/structure, would be barely enough to hold an undisturbed home range. Exposure to severe stress such as, severe

poaching extreme droughts, severe human disturbance, overpopulation or habitat degradation can make a clan leave their particular home range. The home ranges of many clans and solitary males are not protected per se and major parts of some home ranges of elephants extend into areas outside the protected areas, even though many areas have declared large tracts as PA in most elephant range states (Baskaran *et al.,* 1995).

One of the major problems for Asian elephant conservation is habitat loss. Asian elephant ranged across an estimated 9 million km^2 originally. Today it has declined to about 500,000 km^2. The problem became serious and accelerated mainly in the second half of the last century. Rapid human population growth and economic development had occurred in Asia during this period and this could be the reason for such a rapid deterioration of habitat. During the period between 1991-99, nearly 1800 km^2 of forest (mostly elephant habitat) was lost in Northeast India. Similarly, rapid decline of forest tracts have occurred all over the Asian elephant range states due to human population expansion and economic development (Desai and Riddle, 2015). Elephants need vast area to satisfy their ecological requirements, thus elephants have large home ranges that stretch across the forest reserves and other nearby habitats (Baskaran *et al.*, 1995; Baskaran, 1998) which are connected through corridors. As elephants are known to show high fidelity to home ranges and the seasonal corridors that they traditionally use habitat loss and fragmentation are major threats to the Asian Elephant (Baskaran et al., 1995).

Habitat fragmentation occurs due to unplanned and diffuse development which results in habitat loss and also splits up larger habitats into smaller fragments or habitat patches. A mechanism that monitors and guides development is absent which also takes into account elephant population. The problem of habitat loss has been compounded with the problem of habitat fragmentation through poorly planned human developmental activities. Elephant habitat becomes fragmented also due to railway lines, pipelines, irrigation canals as well as other linear constructions that restrict free movement of the elephants within their habitat or during seasonal movement between habitats.

The objective of the present study is to:

- understand the habitat preference of Asian Elephants in Wayanad Wildlife Sanctuary

- understand human-elephant interaction in the sanctuary through perception studies of local communities and forest officials.

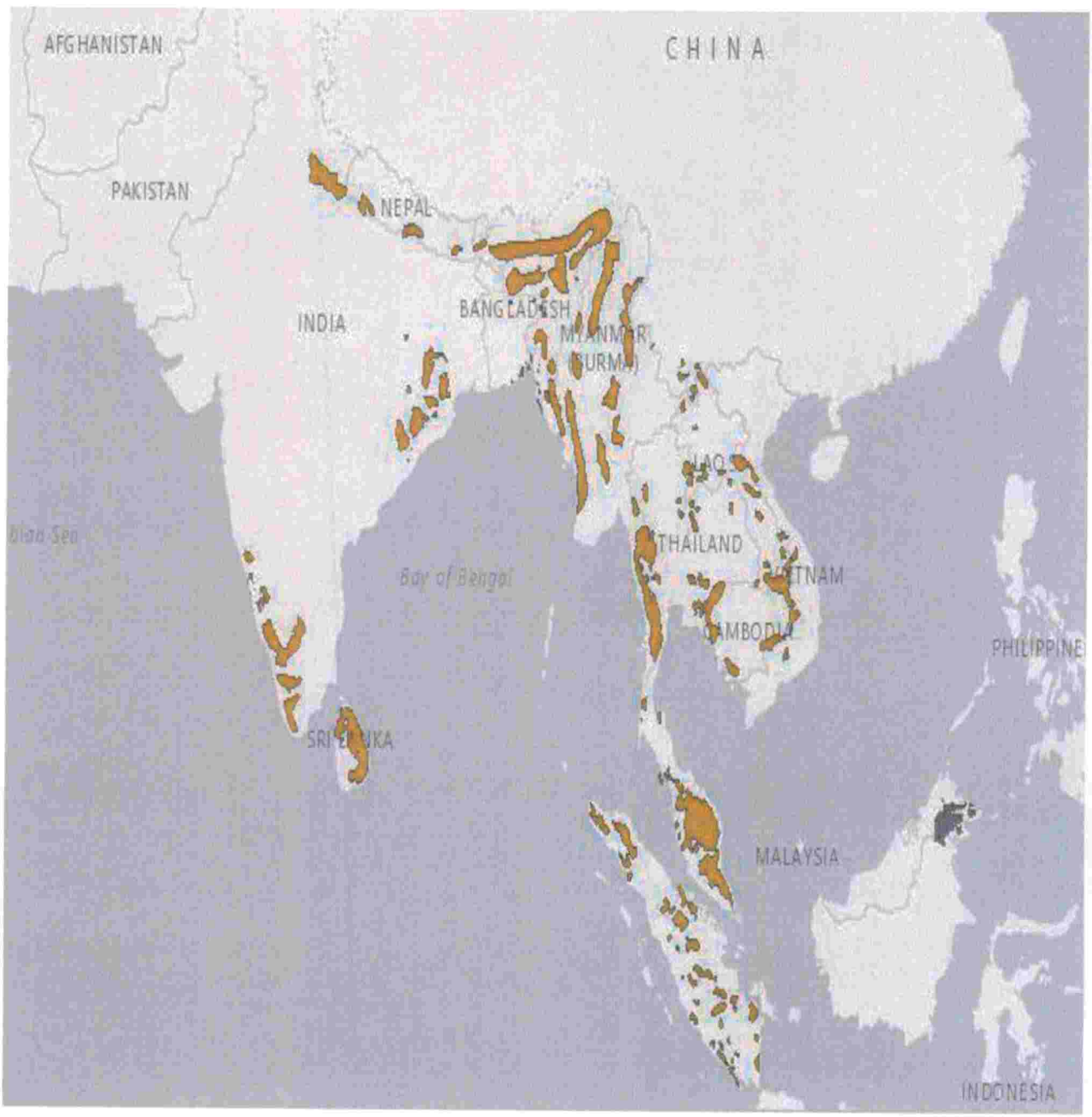

Figure 1. Distribution map of Asian Elephant (*Elephas maximus*) (Choudhury *et. al.*, 2008)

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The Asian Elephant (*Elephas maximus*) comes under the family Elephantidae. The order to which Elephantidae belongs is Proboscidea (Wilson and Reeder, 2005). The two surviving genera within this family are *Elephas* and *Loxodonta* (Johnsingh *et. al.,* 2015). *Elephas maximus* (Asian Elephant) and *Loxodonta africana* (African Elephant) are the two recognized species, although the two races of the African Elephant, the savannah elephant (*Loxodonta africana africana*) and the forest elephant (*Loxodonta africana cyclotis*) have been recommended to be treated as two distinct species (Roca *et. al.,* 2001). Rohland *et. al.* (2010) provided evidence through genomic DNA analysis to conclude that there is speciation among the savannah and forest elephants although doubts have been raised by Zachos *et. al.* (2013) as to the validity of this speciation . Where Asian Elephants are concerned, three subspecies have been recognized (Chasen, 1940; Shoshani and Eisenberg, 1982). These are *Elephas maximus maximus, Elephas maximus sumatranus and Elephas maximus indicus*, which are seen in Sri Lanka, Sumatra and in the Asian mainland respectively. The elephants seen in Borneo were suggested to be classified as a distinct subspecies, *Elephas maximus borneensis*. (Fernando *et. al.,* 2003; Cranbrook *et. al.*, 2008).

2.1 Asian Elephant (*Elephas maximus*)

2.1.1 Physical characteristics

The size of the Asian Elephant is comparatively smaller than the African Elephant. The highest body point of the Asian Elephant is the top of the head and not the shoulder, unlike its African counterpart. The Asian Elephant has comparatively smaller ears, and the dorsal borders in mature individuals are folded laterally instead of medially. One finger-like proboscis is present at the tip of the Asian elephant trunk, while its African cousin has two. Each forefoot usually has five nail-like structures and each hind-foot has four. Only the male of Asian Elephant sport tusks, unlike the African Elephant in which both genders carry tusks. Some males may also be tuskless and these individuals are called *makhnas*. The skin of the Asian Elephant in smoother in comparison to the African Elephant (Deraniyagala, 1955; Shoshani and Eisenberg, 1982).

A weight of over 5000 kg has been observed generally in large bulls, and they rise to a height of more than 3 m at the shoulder level. The highest record height measured by Pillai

(1941) was 3.43 m. Where female elephants are considered, large individuals mostly exceed a height of 2.40 m at the shoulder, and generally weigh over 4000 kg. Although, their average weight has been recorded to be around 2720 kg and average height is 2.24 m (Johnsingh *et. al.*, 2015). It has been observed that the body size tends to decrease in the Asian Elephant populations that occur in the eastern ranges, Borneo being home to the smallest ones (Payne *et. al.* 1985).

The thick skin of the elephants provides protection against insect bites, injuries, as well as adverse weather conditions. Like other large mammals, elephants have a small surface area to mass ratio helping them to tolerate cold conditions more than excessive heat (Benedict, 1936). The skin colour usually varies between black to grey and is usually masked by dirt due to the regular habit of wallowing and dusting, which in turn helps in thermoregulation and insect bite protection (Sukumar, 2003).

The ambient temperature does not have any influence on the skin temperature of the elephants (Benedict and Lee, 1938). Tusks are primarily used for fighting and display. They are also sometimes used for digging of salt at mineral licks, for debarking trees and for handling food (such as shoots, branches and bamboos). Ivory has been used in arts and crafts and in manufacturing tools. Artisans prefer the ivory of the African elephant over that of the Asian, since they claim it is denser and more suitable for carving (Wylie, 1980).

2.1.2. Range and distribution

Asian elephants still occur in isolated populations in 13 states, with a very approximate total range area of 486,800 km^2 (Sukumar 2003; Blake and Hedges 2004). The species occurs in Bangladesh, Bhutan, India, Nepal, and Sri Lanka in South Asia and Cambodia, China, Indonesia (Kalimantan and Sumatra) Lao PDR, Malaysia (Peninsular Malaysia and Sabah), Myanmar, Thailand, and Viet Nam in South-east Asia. Feral populations occur on some of the Andaman Islands (India).

The Asian Elephant used to be widespread in India, but today the species is restricted to four main areas: southern India, central India, northwestern India and northeastern India. In the north eastern part of India, the elephant range extends from the border of Nepal in northern West

Bengal across western part of Assam towards the Himalayan foothills and ends in the Mishmi Hills. It also extends from this part towards the east, into Arunachal Pradesh, the upper Assam plains, and the Nagaland foothills. They can also be seen towards the Garo and Khasi hills of Meghalaya, lower plains of Brahmputra and the Karbi Plateau. Isolated herds have also been observed in Mizoram, Tripura, Manipur and the Barak districts in Assam (Choudhury, 1999).

The population of elephants in central India is highly fragmented. They occur in the states of Jharkand, Orissa, and southern West Bengal, although recent migration of animals into Chattisgarh has occurred after local extinction in the state during the early part of the 20th century (Singh, 2002). The population of north-western India is also highly fragmented. This population ranges from the foothills of the Himalayas in the states of Uttarakhand and Uttar Pradesh, towards the Yamuna River in the west (Choudhury *et. al.*, 2008).

The population in southern India is the largest and most genetically viable population in India (Sukumar, 2003). They occur in most of the hilly tracts of the Western Ghats in some parts of the Eastern Ghats. The states where elephants have been observed are Kerala, Tamil Nadu, Karnataka, and recently in Andhra Pradesh (Syam Prasad and Reddy, 2002). Eight main populations have been defined within the broad population category of southern India. These are Agasthyamalais; Anamalais-Parambikulam; Periyar-Srivilliputhur; Nilambur-Silent Valley-Coimbatore; Brahmagiri-Nilgiris-Eastern Ghats; Bhadra-Malnad; northern Karnataka; the crestline of Karnataka-Western Ghats (Choudhury *et. al.*, 2008).

2.1.3. Population biology

In the wild, both female and male elephants may live up to 55-60 years of age. They may reach up to an age of 70 years in captivity due to extra medical care as well as supplemental feeding (Johnsingh *et. al.*, 2015). The fecundity data of over a thousand captive elephants were analysed in southern India. This revealed that the earliest age of calving documented was 13.3 years, even though some cows had given birth between 14 and 18 years of age. Maximum breeding age of females was reported to be 55 years (Krishnamoorthy, 1995).

Habitat quality, availability of bulls and health condition of the animals influence the calving interval in elephants. Since the availability of bulls especially varies between different seasons, this can influence the fertility rate (Baskaran and Desai, 2000). Studies on the Asian elephant have shown that calving interval can vary between 4 and 4.8 years (Daniel *et. al.*, 1987; Sukumar, 1989; Williams. 2002). The growth rate could be expected to reach up to a maximum of 2.4 per cent in an elephant population (Sukumar, 1989).

The sex ratio is believed to be almost equal at birth as recorded in captivity to be a ratio of 107 males to 102 female calves (Krishnamoorthy, 1995). However, wild populations in India are known to range between 1:12 (where poaching is less) to 1:100 (where poaching is rampant) (Daniel *et. al.*, 1987; Chandran, 1990; Sukumar, 1991). However, in places where poaching is scarce such as Sri Lanka due to rarity of tuskers, the sex ratio was found to be 1:1.86 (Katugaha *et. al.*, 1999).

A non skewed sex ratio of 1:1.87 was recorded during 1995-2000 in Rajaji National Park, due to strict protection activities undertaken by the Forest Department (Johnsingh *et. al.,* 2002). Selective removal of large tuskers affects the female choice, and interferes with the sexual selection process in the long run. This makes the population less genetically viable rendering it more vulnerable to stochastic forces such as drought, forest fire and epidemics (Baskaran and Desai, 2000; Sukumar, 2003).

Both human and natural factors can cause mortality in elephants. The common causes of natural death of elephants is through diseases and parasitic infections leading to various ailments in different parts of the body (Chandrasekharan *et. al.*, 1995). Human causes of mortality include poaching for ivory and meat; poisoning in areas of human-elephant conflict; electrocution and snaring. Deaths have also been known to occur due to train collisions (Johnsingh *et. al.,* 2015). Mass death due to drought has not been reported in Asia, although such an incident has happened in Africa (Myers, 1973).

2.1.4. Social organization and group size

The basic social units of both the African and Asian elephants are the family groups. These groups may range from two to seven in number. Family groups are mostly matriarchal and their leader is usually an older cow (Mckay, 1973). A herd is formed by several family groups joining together, and several herds together constitute a clan. All the clans of a particular area form a distinct population (Douglas-Hamilton, 1972).

Formation of clans may not always happen, since it is limited by a variety of external factors. The elephant population in Kenya was studied and there was no evidence of clan formations. This could be due to the relatively longer distances travelled by elephants due to rainfall patterns and disturbances (Thouless, 1996).

A comparison of social organization of Asian and African elephants have revealed that Asian elephants are found in smaller groups, do not maintain coherent core groups, demonstrate markedly less social connectivity at the population level, and are socially less influenced by seasonal differences in ecological conditions (de Silva *et. al.*, 2012)

Social communication of elephants is not based much on visual signals. Adults and calves are seen to perform tactile communication frequently (Gadgil and Nair, 1984). Communication is mainly done through vocal signals to transmit messages of aggression and alarm. Low frequency calls which can travel long distances are emitted by separated members of a herd in order to maintain contact (Payne, 1989).

Non-invasive DNA sampling techniques can be useful to study the social behavior and communication between elephant groups in more detail (Vidya and Sukumar, 2005). Nearby danger or predator presence is also communicated between different elephants through various vocalizations. Different combinations of eight basic sounds were distinguished to be used by elephants in a variety of situations (Mckay, 1973).

2.1.5. Ecology

2.1.5.1. Habitat

In the wild, the Asian Elephant is known to occupy many varieties of vegetation types. ranging from scrubs and dry and moist deciduous forests in the north, sal forests in the north, evergreen forests in the northeast and south, as well as the alluvial flood plains of West Bengal and Assam. Habitat mosaics seem to be optimum for the Asian Elephant to thrive with a mixture of different habitats like marshy areas, grasslands, riverine forests, deciduous forests and evergreen forests (Kemf *et. al.*, 2000). A profuse availability of browse, grass and water has made them preferable for the Asian Elephant. Water is mostly a limiting factor for the elephants and this parameter governs their distribution and movement patterns. For example, in Rajaji National Park, where summer season usually has scant water availability, the crude density may fall to 0.3/sq. km. while ecological density may increase to about 1.0/sq. km (Johnsingh *et. al.*, 2002). A recent study on influence of habitat and governance on Asian Elephant population by Calabrese *et. al.* (2017) showed that an equal proportion of forest and agricultural land tends to support a higher abundance of elephants among the 13 range states studied.

2.1.5.2. Ranging patterns and habitat use

Home ranges of the Asian Elephant are fixed. They move around within these habitats seasonally in search of food, water and shelter. A mosaic of various vegetation types may constitute a home range (Desai and Riddle, 2015). Free-ranging elephants were studied both in India (dry deciduous forests as well as Malaysia (wet evergreen forests), which revealed that female groups usually range over a total area between 32 sq. km and 650 sq. km. On the other hand, males usually utilize an area of around 160 sq. km to 400 sq. km (Olivier, 1978; Baskaran *et. al.*, 1995; Joshua and Johnsingh, 1995; Williams, 2002).

Home range size is mostly a function of habitat quality, where human disturbance can also wield considerable influence over movement patterns. A study of distribution of elephants in

Karnataka in the Western Ghats revealed that sixty percent of total distribution of the elephants were outside protected areas and nearby high density human habitations (Madhusudan *et. al.*, 2015) showing that elephants regularly venture far and wide outside the protected areas. Yet another study in the Western Ghats showed that the home ranges of two herds were in fact very small (124 sq. km and 157 sq. km). The partial submergence of the range by a reservoir could be the reason behind this (Easa, 1988).

A major role is played by rainfall in determining the seasonal movement of elephants, since water availability is one essential constituent of habitat quality. Elephants converge around a perennial water source in areas with severe dry seasons, remaining close to the water source until the advent of monsoon (Desai and Bhaskaran, 1996). In North India as well, elephants in the Corbett National Park congregate on the banks of the Ramganga river around Dhikala chaur from March-June (Johnsingh *et. al.*, 2015).

The age class of an individual can also determine the home range size. Younger males who are in the age of dispersal time have smaller ranges (Baskaran *et. al.*, 1995). Adult bulls in musth on the other hand are observed to have larger extent of home range (Joshua and Johnsingh, 1995; Williams, 2002). Studies on ranging behavior in Yala protected area complex, Sri Lanka also confirmed this and showed that elephants have high fidelity to home ranges (Fernando *et. al.*, 2007).

2.1.5.3. Food habits

Asian Elephants have two distinct times when feeding reaches a peak, although they have been observed to feed at any time of the day. Most of the time in an elephant's life is devoted to foraging activities. It has been observed that 70-90 per cent of an adult elephant's daily activities revolve around foraging (Shoshani and Eisenberg, 1982). In southwestern Sri Lanka, elephants have been known to spend around 17-19 hours feeding in a single day (Vancuylenberg, 1977).

The Asian Elephant is both a grazer and a browser. The rate of feeding is usually low during a regular bout of feeding, until it comes across a primary food source. This is followed by a bout of rapid feeding which gradually decreases (Eisenberg, 1980). Adult elephants have been recorded to consume between 150 to 200 kg (wet weight) of forage and consequently defecate up to 80 kg in a feeding cycle (Vancuylenberg, 1977).

Wild Asian Elephants have a variety of plant species as their diet. About 40-100 species of plants have been recorded to be consumed by them, mostly belonging to families like Fabaceae, Poaceae, Areceae and Cyperaceae. About 10-25 favourite species make up more than 85 percent of the diet of the elephants (Sukumar, 1990; Williams, 2002).

An analysis of feeding behavior of elephants in Sri Lanka showed that as many as 116 species belonging to 35 families were fed on by them. The study also revealed that about 25 percent of the species belong to the family Fabaceae, and about 19 percent belong to family Poaceae (Samansiri and Weerakoon, 2007).

The most favoured browse species in the decisuous tracts of South India are bamboo (*Dendrocalamus strictus*, *Bambusa arundinaceae*), *Acacia intsia* and *Kydia calycina*, while the most preferred grass species are *Themeda cymbaria*, *T. triandra* and *Apluda mutica* (Sivaganesan, 1995; Sivaganesan and Johnsingh, 1995).

The elephant is capable of digesting only around 44 percent of the dry matter that it consumes, since it is a hindgut disgester. This is comparatively less than foregut digesters like cattle and sheep. Due to this, the chemical composition of the dung is akin to that of bad quality hay (Benedict, 1936).

Elephants require soil rich in mineral salts. They visit salt licks to consume the mineral-rich soils. In coastal habitats such as Thailand, it has been observed that use of salt licks is not as widespread as compared to interior areas where the soil itself has sparse sodium content. In such areas, even dry waterholes with high amounts of sodium salts are preferred (Seidensticker and McNeely, 1975).

2.1.5.4. Elephant-vegetation interaction

Elephants can cause widespread damage to trees and trample grass in the process of feeding. This is common phenomenon in the deciduous forests of Peninsular and northern India. The tree species that are especially favoured by the elephants experience widespread mortality. The damage is somewhat mediated through disturbances of habitat like lopping of trees by humans, and forest fires (Johnsingh *et. al.*, 2015).

A dramatic reduction in the density of *Boswellia serrata* was reported due to elephant debarking. Debarked trees become easily vulnerable to fire (Desai *et. al.*, 1987). Tree such as *Grewia tiliifolia* and *Bridelia retusa* were observed to tolerate or withstand debarking by the elephants (Williams, 2002). An elephant is more liable to pushing trees because of an individual disposition (Johnsingh, 2004).

The mortality and destruction of trees can cause serious problems in new habitats or in altered habitats. It was reported from Interview Island in the Andaman archipelago that tropical evergreen forests were converted into deciduous forests by the activities of feral population of around 70 elephants over a time period of 31 years (Sivaganesan and Kumar, 1993). Wild elephants were also reported to have caused damage to trees in teak plantation in Parambikulam Wildlife Sanctuary (Nair and Jayson, 1992).

2.1.6. Studies on population estimation techniques

Counting methods were developed and standardized for large mammals, including elephants (*Loxodonta africana*), during the 1960s-70s in open habitats of eastern and southern Africa (Jolly, 1969; Caughley, 1974; Caughley and Goddard, 1972). At present the only practical alternative to count elephants is to use dung counts (Barnes, 1993). Since the first use of elephant dung counts by Wing and Buss (1970), census methods for forest mammals, and especially elephants, gradually have been improved over time with advancement of technologies (Barnes and Jensen, 1987, Barnes, 1993).

2.1.6.1. Line Transect: Direct Count

This method of line transect sampling belongs to a family of density estimation approaches collectively known as distance sampling. Estimation of densities of elephants in areas with relatively open vegetation using line transect sampling based on direct visual citing is an efficient method (Dawson and Dekker, 1992; Karanth and Sunquist, 1992; Hedges, 1993; Varman and Sukumar, 1995; Wegge and Storaas, 2009).

Line transect surveys are actually conducted by investigators on foot, seated on domesticated elephants or from vehicles; the latter methods can only be conducted in areas where cross country driving along true straight lines is possible (Wilson *et al.*, 1996). In the context of line transect surveys of elephants, where densities of groups of elephants are estimated and thereafter animal densities are obtained by multiplying these estimates by cluster size estimates, the consideration of 'sample size' involves both number of detections of clusters as well as number of the spatial replicates used . If elephants are attracted to the transect lines then density will be overestimated; if they are repelled, it will be underestimated (Buckland et al. 2001).

2.1.6.2. Line Transect: Dung Count

There are two main types of dung count: fecal standing crop (FSC) methods and fecal accumulation rate (FAR) methods. FAR methods measure the rate of dung pile accumulation between two points in time. This is achieved by visiting the same plots or transects twice and counting the number of dung piles deposited since the first visit. Provided the interval between visits is shorter than the most rapidly decaying dung pile's lifetime, animal abundance can be calculated from fecal accumulation rates and the mean defecation rate over the period of accumulation.

Fecal standing crop (FSC) methods, unlike FAR, determine dung pile density (without revisiting areas) and relate this to dung pile decay rate and mean defecation rate (Buckland *et al.*, 2001; Laing *et al.*, 2003; Walsh and White, 2005; Jenkins and Manly, 2008). In a study in Asia by Hedges *et al.* (2002) recces and line transects were used within a non-purposive stratified

random sampling strategy in order to produce design-unbiased estimates of elephant density. They found recces to be quicker than line transects by a factor between 1.5 and 3, depending on terrain and dung pile density. The decay rates varies highly within and between sites (spatial heterogeneity). An example of this is, the reciprocal of mean duration time, which is or was often used to calculate decay rates (Dawson, 1990), has been calculated from several studies in Africa due to difficulty in the actual sites and the results nicely illustrated the problem of between site variations.

The works of White (1995), Barnes *et al.* (1997), Nchanji and Plumptre (2001), Barnes *et al.* (2006) and Breuer and Hockemba (2007) show that climate, and especially rainfall, irradiance and temperature, play a major role in determining dung decay rates. Thus inter-site differences in rainfall regime and elephant diet (especially the fruit content of the diet), and probably vegetation type, prevent simple extrapolations between sites and seasons. These have major implications for dung based elephant surveys and is a strong argument against the use of decay rates from other sites.

2.1.6.2. Capture and Re- capture Sampling

Capture–recapture, also known as mark–recapture or capture– mark– recapture methods have a long history of application in wildlife biology. Capture–recapture methods were originally developed for situations in which it was possible to physically catch and mark animals with tags that permit individual identification (Silvy *et al.*, 2005). Another generally useful option for identifying individual elephants in replicated 'samples' drawn from wild populations is to use DNA obtained from their dung samples collected in the field. We term this genetic capture–recapture (Lukacs and Burnham, 2005; Schwartz *et al.*, 2007]. This approach has been successfully applied to elephants (Eggert *et al.*, 2003, Hedges *et al.,* 2007) and can provide precise estimates of elephant population size as well as much other useful data about the populations in a relatively quick and cost effective manner (Hedges *et al.*, 2007).

2.1.6.3. Occupancy Modelling

Most of the sign survey methods aim to estimate spatial distributions of elephant populations rather than their abundances. Habitat occupancy-related metrics play an important role in studying elephant habitat selection (Martin *et al.,* 2010). Occupancy surveys can be viewed as being analogous to the capture– recapture surveys. Instead of 'identified individual elephants' being captured, 'identified patches of elephant-occupied habitat' are detected by means of replicated field surveys in occupancy surveys. If the home range sizes are large relative to patch or grid cell size, then a home range may cover several habitat patches, and the occupancy parameter can be considered as a measure of 'intensity of habitat use' (MacKenzie and Royle, 2005).

2.1.6.4. Aerial Surveys

Aerial surveys are conducted as either total counts or sample counts (Douglas-Hamilton, 1996; Mbugua, 1996). For aerial surveys of terrestrial mammals, including elephants, strip sampling has typically been the preferred option because of easy navigation and there is no need to search for block or quadrat boundaries (Wilson *et al.*, 1996). Aerial surveys tend to suffer from low precision because they are based on the instantaneous distribution of animals, and hence the variation between transects is usually very high (Barnes, 2001). Studies have shown that an aerial count of eight African large herbivore species returned only 23% of known numbers (Spinage *et al.*, 1972); and only 56% of known numbers of Indian rhinoceros were detected in an aerial survey (Caughley, 1969).

2.1.7. Threats

Currently, the population of Asian Elephants in the wild is roughly estimated to be about 50,000. This population is under the imminent threat mainly due to habitat loss, fragmentation, poaching for meat and ivory, as well as frequent conflicts with humans (Sukumar 1986; 1996; 2003; Desai, 1991; Johnsingh and Panwar, 1992; Menon *et. al.*, 1997).

2.1.7.1. Habitat loss

Humans extensively modify elephant habitat which leads to severe compression of the range of the species and also causes fragmentation in the distribution pattern (Johnsingh *et. al.*, 2015). Habitat loss can occur through conversion of natural forests into plantations, encroachment by humans from fringe areas, and resettlement projects of people (Kemf and Santiapillai, 2000). Continuous tracts of forests are still left only in a few countries like Malaysia, Myanmar and Laos. Even these are not safe from threats of land use conversion (Johnsingh *et. al.*, 2015).

2.1.7.2. Habitat fragmentation and degradation

Contiguous elephant habitats are becoming fragmented because of developmental projects, plantations and agriculture, and expanding settlement of humans. Fragmented habitats become more susceptible to degradation, leaving them sub-optimal for survival of elephants (Kumar *et. al.*, 2004). In the Anamalai, elephants have resorted to using tea plantations as corridors because of habitat fragmentation leading to increased conflicts with humans (Kumar *et. al.*, 2004). Extensive lopping for fodder also reduces availability and regeneration of favored plant species, leading to invasive weed infestation (Johnsingh and Joshua, 1994).

2.1.7.3. Human-elephant conflict

Severe conflicts between humans and elephants arise due to forest fragmentation and habitat loss. Crop-raiding by elephants has been identified to be the principal form of conflict (Johnsingh *et. al.*, 2015). Each year, elephants damage around 0.8-1.0 million hectares of farm land annually, in which at least 500,000 households are effected on top of causing millions of rupees of economic loss (Bist, 2002). About 400 people are reported to have lost their lives each year in encounters with wild elephants and around a 100 elephants also are killed at the time of crop raiding (Datye and Bhagwat, 1995; Anon, 2010).

Other than habitat degradation being the primary cause for crop raiding, a higher nutritive content and palatability of crop plants may also attract elephants to raid crops (Sukumar, 1990; 1991). Studies on crop raiding in contiguous tracts of habitat have shown that not all the elephant individuals within a certain population are involved in raiding of crops (Balasubramaniam *et. al.*, 1995; Williams *et. al.*, 2001). Only in highly degraded and fragmented landscapes, all individuals may resort to crop destruction and raid.

2.1.8. Conservation

The Indian government initiated the Project Elephant scheme in 1990's, which led to the establishment of eleven Elephant Reserves in India (Government of India, 1993). This model of setting aside exclusive areas for protection of elephants can be reproduced in other parts of Asia (Sukumar, 2003). Protection of elephant corridors is also a necessity. The Government is now in the process of establishing 10 Elephant Landscapes including 25 Elephant Reserves connected together through crucial corridors (Anon, 2010)

At the landscape level, establishing a network of Elephant Reserves connected through corridors could ensure the movement of herds and long-term genetic viability between various sub-populations. The elephant can be projected as a flagship species which will further empower the conservation strategy of this charismatic species (Johnsingh *et. al.*, 2015).

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1. STUDY AREA

3.1.1. Name, Location, Extent and Ranges

Wayanad Wildlife Sanctuary, the second largest wildlife sanctuary in Kerala extends over an area of 344.44 sq. km. with four ranges namely Sultan Bathery, Muthanga, Kurichiat and Tholpetty. The sanctuary being an integral constituent of Nilgiri Biosphere Reserve and Elephant Reserve No. 7 nurtures one of the world's largest population of Asiatic elephants. The sanctuary was formed in the year 1973 by demarcating areas out of the Wayanad and Kozhikode territorial divisions. The Wayanad Wildlife Division constituted in 1985 comprises two discontinuous unit of the sanctuaries called WS-I (77.67 sq.km.) and WS-II (266.77 sq.km.). The larger unit lies within the geographical extremes of latitude 11°35' N-11°49'N and longitudes 76°13' E-76°27' E and falls in the Sulthan Bathery taluk of Wayanad revenue district. The smaller unit lies within latitudes 11°50' N-11°59' N and longitudes 76°02' E-76°7' E and fall in the Mananthavady taluk of Wayanad District. The sanctuary is divided into four ranges, two stations and 13 sections.

Francis (1994) described the political history, forest, agriculture and wildlife in Wayanad in earlier days. The name Wayanad is derived from two local words 'vayal' meaning swamp and 'nadu' meaning place.The sanctuary is significant due to its continuity with the protected areas of Nagarhole and Bandipur on the north east and Mudumalai National Park in the South and Southeast. It is potentially one of the best habitats for Asiatic elephants. The study area is unique with its large number of settlements scattered as in spotted in and around the forests.

3.1.2. Geology, Soil and Topography

The soil is primarily made of geological formations of age group from "Recent to Pleistocene" to "Lower pre-Cambrian to Archaean". Midland and highlands falls in the age group of lower pre-Cambrian to Archaean. High rainfall prevalent in Western Ghats lead to the formation of laterite in its foothill areas. The principal rock types are granite and their gneiss derivatives. The rocks are typically biotite gneiss, their chef constituents being quartz, feldspar, biotic and granite. The terrain is undulating with several streams and swamps spotted in and

around. The general slope varies from 5^0 to 10^0. The altitude varies from 700 m to 1,158 m. Two of the highest peaks are Karadimala in Kurichiat Reserve (1,158 m) and Narati-Betta in Mavinahalla Reserve (1,147 m).

3.1.3. Climate

The sanctuary has an invigorating climate. The area receives both southwest and north east monsoon with major contribution from the former. Three seasons has been identified based on the rainfall pattern, viz., dry season (Jan – April), first wet season (May – Aug) and second wet season (Sep – Dec). The mean annual rainfall during the past 10 years is 1787.90 mm with minimum and maximum annual limits of 1,123.90 and 2,168.20 mm. The mean monthly minimum temperature ranges from 15.0^0 C to 19.4^0 C and monthly mean maximum and minimum temperatures range from 31.2^0 C and 15.0^0 C respectively. The maximum and minimum relative humidity in the last 10 years was 93.6% and 42.9% respectively. The area experiences high velocity winds from November to April with the peak in December. Westerly wind blows over the whole area during south west monsoon.

3.1.4. Water sources

Most of the streams flowing in the sanctuary are shallow, slaggy and frequently with many of them originating from within the sanctuary. Kabini and its three tributaries the Panamaram, Mananthavady and Kalindy rivers drain almost the entire district of Wayanad. The Banasurasagar dam is built on one of the tributaries of Kabini river. Northern portion of Kurichiat Range is drained by Kannarampuzha and Kurichiat Thodu flowing northward and joining Kabini river. Cheru Puzha, Bavali Puzha, Kurichiatu Puzha and Chedalathu Puzha are the other drainage systems in Wayanad WLS (Nair, 1991; Easa and Sankar, 2001). The sanctuary has 42 functional check dams and 168 waterholes (KFD, 2012).

3.1.5. Vegetation

The natural vegetation of the sanctuary is broadly classified in to South Indian moist mixed deciduous forests, Southern dry mixed deciduous forests and bamboo brakes. Large extent

of marshy grasslands locally known as Vayals is also seen in the sanctuary. The major forest types (Champion and Seth, 1968) are as follows:

3.1.5.1. Southern moist mixed deciduous forest ($3B/C_2$)

The Southern Moist Mixed Deciduous Forest covers most of the area of sanctuary. Moist deciduous forests are interspersed with seasonally waterlogged areas in the depressions known as *vayals* (marshy/wet lands). *Vayals* are dominated by grass and are devoid of tree cover. The moist deciduous forest has a moderate canopy cover (50-70%) during the wet seasons. During the dry season, most of the trees shed leaves and canopy cover is comparatively less (10-20%). Bamboo brakes (*Bambusa arundinacea*) are distributed sporadically all over the habitat. It is also found all along the perennial streams and in the wet areas. The upper canopy consists of *Terminalia elliptica, Terminalia bellirica, Terminalia paniculata, Pterocarpus marsupium, Tectona grandis, Grewia tiliifolia, Adina cordifolia* etc. A few climbers like *Butea parviflora, Caesalpinia sp., Calycopteris floribunda* are also seen. Grasses such as *Cyrtococcum patens, Apluda mutica and Oplismenus compositus* are thinly distributed with low productivity. Fire occurrence is comparatively less in this type of forests.

3.1.5.2. Southern dry mixed deciduous forest (5A/C3)

The dominant tree species are *Shorea roxburghii, Anogeissus latifolia, Terminalia elliptica, Terminalia chebula, Pterocarpus marsupium, Gmelina arborea, Schrebera sweitenioides, Diospyros montana, Schleichera oleosa, Grewia tiliifolia, Dalbergia latifolia, Mitragyna parvifolia, Bauhinia racemosa, Xeromphis uliginosa* and *Tectona grandis*. Grass species such as *Themeda cymbaria, Themeda triandra, Cymbopogon flexuosus* and *Imperata cylindrica grow* more than 200 cm in height and form a dominant ground cover. The canopy layer of the trees is broken due to the spatial distribution as well as comparatively low tree density. Canopy cover is less (10-20%) during dry season. The bamboo (*Bambusa arundinacea*) is less frequented compared to moist deciduous forest. In the dry deciduous forests, the *vayals* are comparatively less and are dominated by tall grass (*Themeda sp.* and *Pennisetum hohenackeri*). The forest floor is highly covered with dry twigs and leaves. Biotic interference is also high due to the presence of human habitations in and around the sanctuary.

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3.1.5.3. The bamboo brakes

There was gregarious flowering of bamboos during 1990-'91 to 1993-'94. The dominant bamboo species is *Bamboosa bamboo*. *Dendrocalamus strictus* is also seen in some parts. The gregarious patches of bamboos in the form of continuous brakes within forest types are seen coming up in Ponkuzhy area on Mavinahalla and Rampur RF boundaries, Arankunji area of Rampur RF, Marode and Manimunda areas of Kallur RF, Pulithookki - Pankalam and Kalladikolly – Vattavayal areas of Mavinahalla RF, Karakkara - Kannangode and Chettiyalathur areas in Noolpuzha RFs. These brakes are aggressive enough to suppress growth of other tree species. *Bamboos* has come up in highly fertile and well drained soils of Kudirakode RF, Alathur RF, the edges of the swamps and streams.

3.1.5.4. Plantations

The sanctuary has about 10,148.7 ha of plantations, which includes pepper, eucalypts, teak and mixed softwood species. Eucalypts plantations do not have any other tree species except a few saplings of *Cassia fistula* and *Terminalia sp*. The whole plantation is occupied by *Lantana camara.* Tall grasses *viz*., *Themeda cymbaria, Themeda triandra* and *Cymbopogan flexuosus* are found in open areas in the plantations. In Teak plantations, apart from a few deciduous tree species, *Helicteres isora* occupy a large proportion of the area. No silvicultural operations, including extracting of timber, are carried out in the sanctuary for past many years. They are allowed for conversion in to natural forests.

An increase in area under commercial plantations has largely caused for the deterioration and fragmentation of the habitats of large mammals, especially elephants. The competing demands made the sanctuary habitat poor and associated problems leading to man- animal conflict. Crop raiding by elephants is one of the severe problem occurring in the fringe villages of the sanctuary.

Plate 1a. Vegetation Types in Wayanad Wildlife Sanctuary

Teak Plantation

Eucalyptus Plantation

Plate 1b. Vegetation Types in Wayanad Wildlife Sanctuary

Natural forest

Grassland (Vayal)

Table 1. Shift in Land Use Pattern in Wayanad District (sq.km.)

Shift in Land Use Pattern in Wayanad District (sq.km.)			
Land cover	1952	1980	Difference
Forests	1811.35	724.54	-1086.81
Agricultural plantations	63.93	532.75	468.82
Cultivation	255.72	873.71	617.99
Total	2131	2131	

Source: 1950 SOI topographical maps 49 M 13 & 14 (Easa and Sankar, 2001)

3.1.6. Fauna

The sanctuary is rich in diversity of flora and fauna, with the advantage of the confluence of the three major protected areas of the country. It harbours many endangered, threatened and rare species. Forty five species of mammals including 6 Western Ghats endemics are reported from this area. The sanctuary shelters 203 species of birds of which 10 are endemics, 6 are range restricted and 5 are globally threatened species. Reports say there are 31 species of amphibians (Easa, 1998) and 44 species of reptiles (Thomas *et al.*, 1997) recorded from the sanctuary till date. The type locality for *Philautus ochlandrea* is the reed brakes of Kakkayam dam site, the only known site for this species. The sanctuary is known to be the ideal habitat for King Cobra, the largest venomous snake in the world. The streams of Kakkayam supports 52 species of fishes. A total of 143 species of butterflies and 54 species of dragonflies are reported from the sanctuary (Shaji and Easa, 1997).

3.1.7. Tribal communities

The Wayandan Chetties, the tribes of Kurichiar, Kurumar, Kattunaickars and Paniyars are the predominant residents in the study area. The residents in and around the sanctuary are mainly dependent on daily wage labour and agriculture with paddy as the commonest crop. Most of the agricultural lands have been acquired by deforestation and the trend in agriculture had a significant shift towards the cultivation of plantation crops reducing the area under forest cover. Coffee is the first plantation crop introduced to Wayanad. Crops like Arecanut, tapioca, banana and jackfruit have been cultivated by the farmers. Gopinathan (1990) has given a detailed description and history of the Sanctuary.

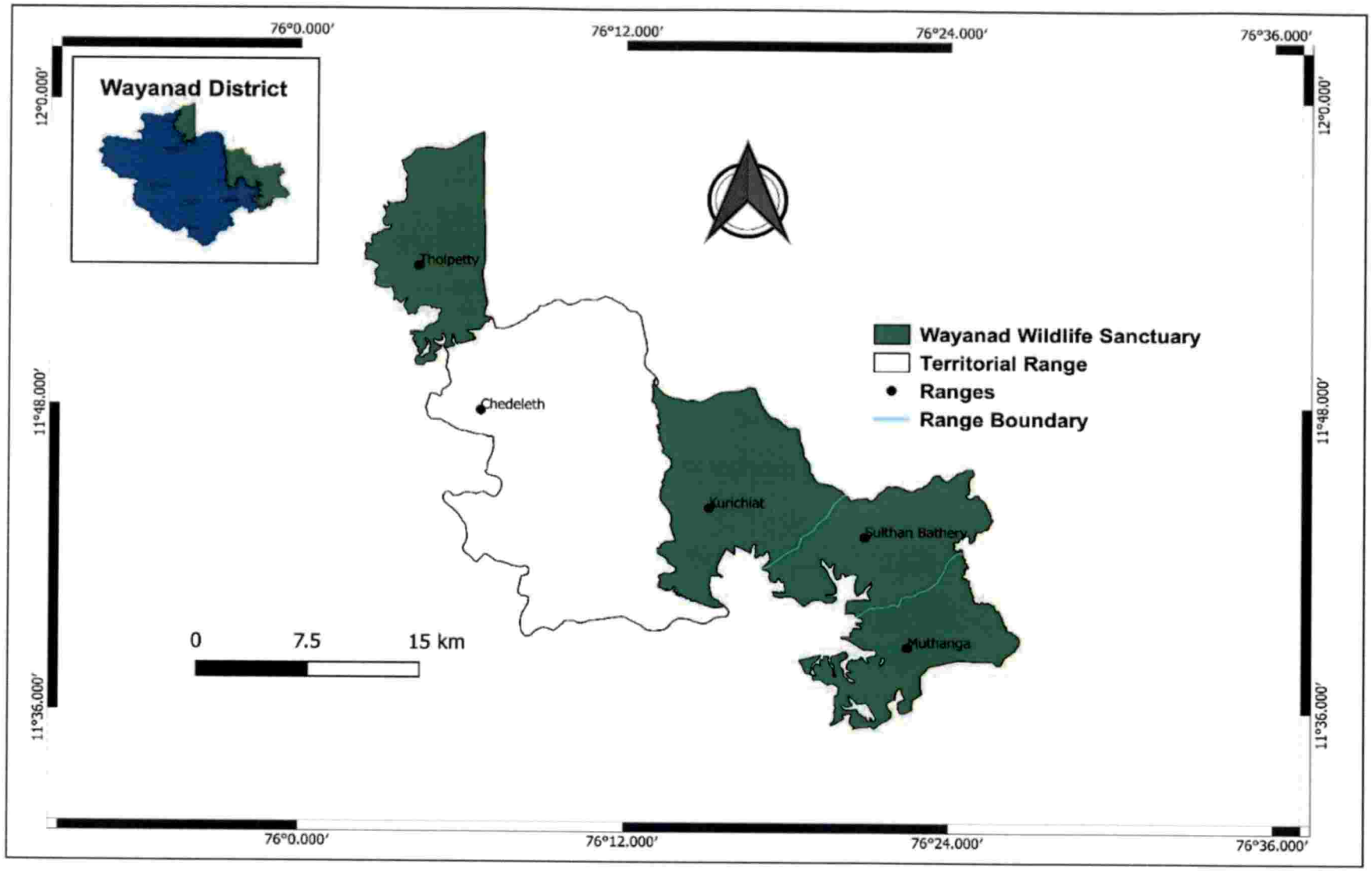


Figure. 2 Location map of Wayanad Wildlife Sanctuary

3.2. METHODS

3.2.1 Population and density estimation of Asian Elephant using dung count method

3.2.1.1. Period of study

The study was conducted from September 2017 to April 2018. Reconnaissance survey was conducted in September 2017 to assess the practicality of methods for population estimation. As a result of the reconnaissance survey, it was decided to adopt dung count method for elephant population density estimation since direct sightings were hard to obtain. The study was carried out across two seasons, namely wet season (October-November) and dry season (March-April). The wet season was chosen during the October-November months as the predominant monsoon season in Wayanad region is the North-East monsoon.

3.2.1.2 Selection of population estimation method

The population density and distribution of elephants within the sanctuary was estimated using the dung count method. Sixty transects of 1 km length were taken randomly within selected grids of 1 km^2 area. Transects were taken in two different seasons to understand the difference in seasonal distribution of elephants.

3.2.1.3. Selection of transect locations and completion of transects

In the wet season (October-November 2017), a total of sixty 1 km transects were taken across the entire sanctuary. 15 transects were taken each in Sulthan Bathery and Tholpetty ranges, while 16 and 14 transects were taken in Muthanga and Kurichiyat ranges respectively. One of the transect in Muthanga was abandoned since it was inaccessible, and an additional transect was taken in Kurichiyat range to compensate this. During the transect as soon as the dung piles were recorded, the perpendicular distance to the dung from the transect line was measured. Direct sightings of elephant herds were also recorded as opportunistic records. The transects were recorded using the Locus free app (Android), as well as GPS device (Garmin GPS etrex 30). The map of the transects taken in the wet season are given in Plate 2a.

In the dry season (March-April 2018), a total of 40 transects were walked. A combination of higher density of elephants as well as greater chances of forest fires in the dry season led to a

reduction of transects taken in this season. Although the number of transects taken were less than the first season, sufficient dung pile observations could be made for estimating population density in an accurate manner. Twelve transects were taken each in Sulthan Bathery and Kurichiyat ranges, while ten and six transects were taken in Tholpetty and Muthanga ranges respectively. Inaccessibility due to forest fires and fear of elephants prevented the forest staff from accompanying us for taking more number of transects in Muthanga range. Observations were made similar to that of the first season. The transect map for season 2 is given in Plate 2b.

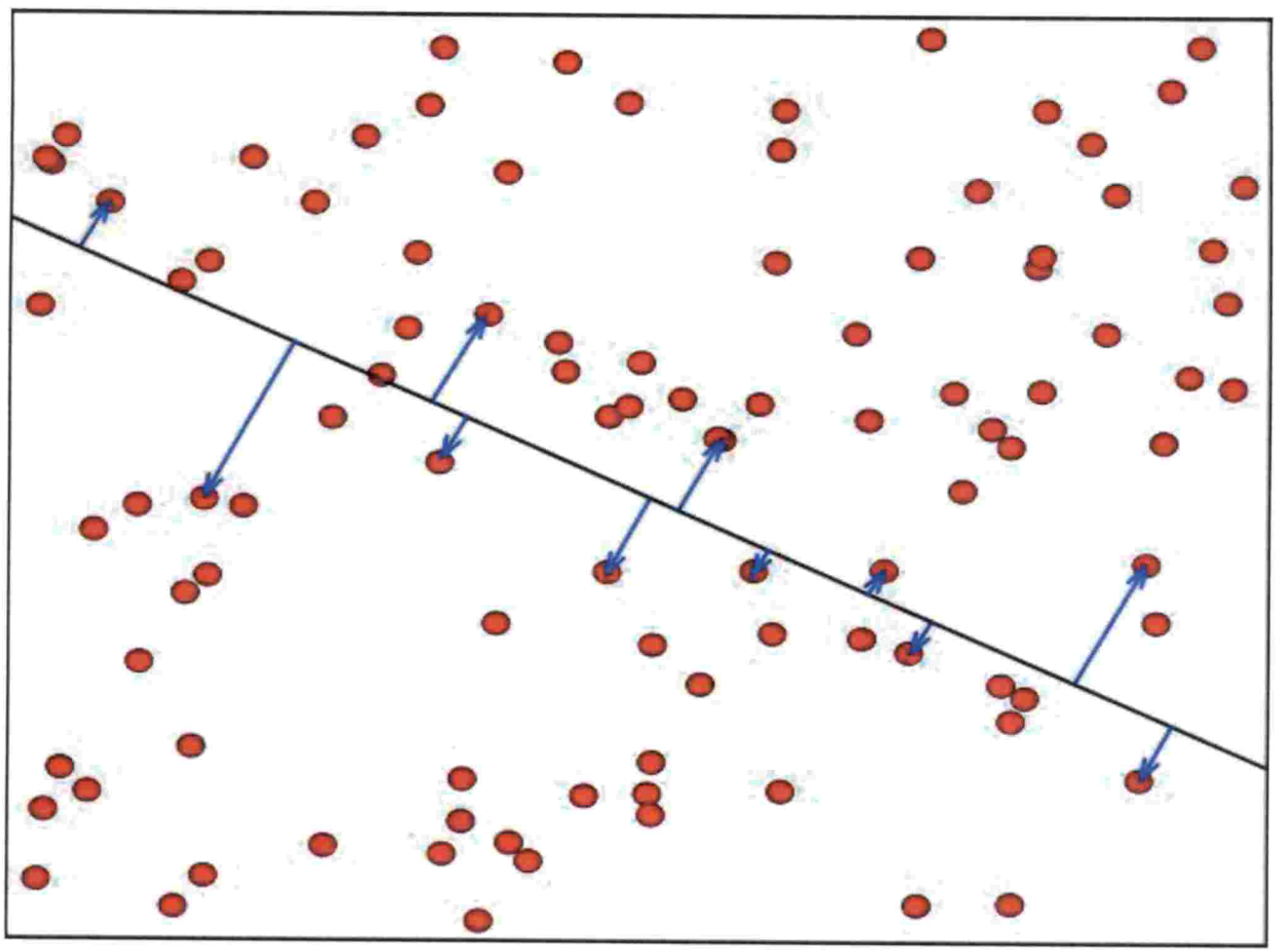


Figure. 3 Schematic view of line transect showing transect line, dung piles and perpendicular distance

3.2.1.4. Classification of dung piles into different classes based on stage of decomposition

The state of dung decay was also recorded and classified into 6 different classes based on the state of decomposition of dung. The A-E system of Barnes and Jensen (1987) was adopted to classify the dung piles into different categories.

Table 2. The A–E system of dung classification by Barnes and Jensen (1987)

A	Boli intact, very fresh, moist, with odour
B	Boli intact, fresh but dry, no odour
C1	Some of the boli have disintegrated, but more than half are still distinguishable as boli.
C2	50% of the boli are distinguishable; the rest have disintegrated.
D	All boli completely disintegrated; dung pile now forms an amorphous flat mass.
E	Decayed to the stage where it would be impossible to detect at 2 metres in the undergrowth; it would not be seen on a transect unless directly underfoot.

3.2.2. Tree species composition and diversity in Asian Elephant habitat by quadrat sampling

3.2.2.1. Period of study

The vegetation enumeration was done during October-November 2017.

3.2.2.2. Selection of quadrats

The vegetation enumeration was done along the sixty 1 km transects, that were laid for the dung count. In each of these 1 km transects, 10 m × 10 m quadrats were taken at every 100 m distance. Thus on each 1 km transect, 10 quadrats of 10 m × 10 m were taken. A total of 600, 100 m^2 quadrats were enumerated for vegetation analysis.

3.2.2.3. Recording of observations and parameters

At each quadrat. all the tree species above 10 cm GBH (Girth at Breast Height) and 1 m height were identified and recorded. Plant nomenclature followed Gamble (1935) revised by Saldanha (1984) and Mathew (1983). The GBH and height were measured using measuring tape and Vortex laser hypsometer respectively. The quadrats were classified into either of the three major vegetation types present in the sanctuary based on species observed.

Plate 2a. Transect map of wet season (Vegetation analysis done on the same transects)

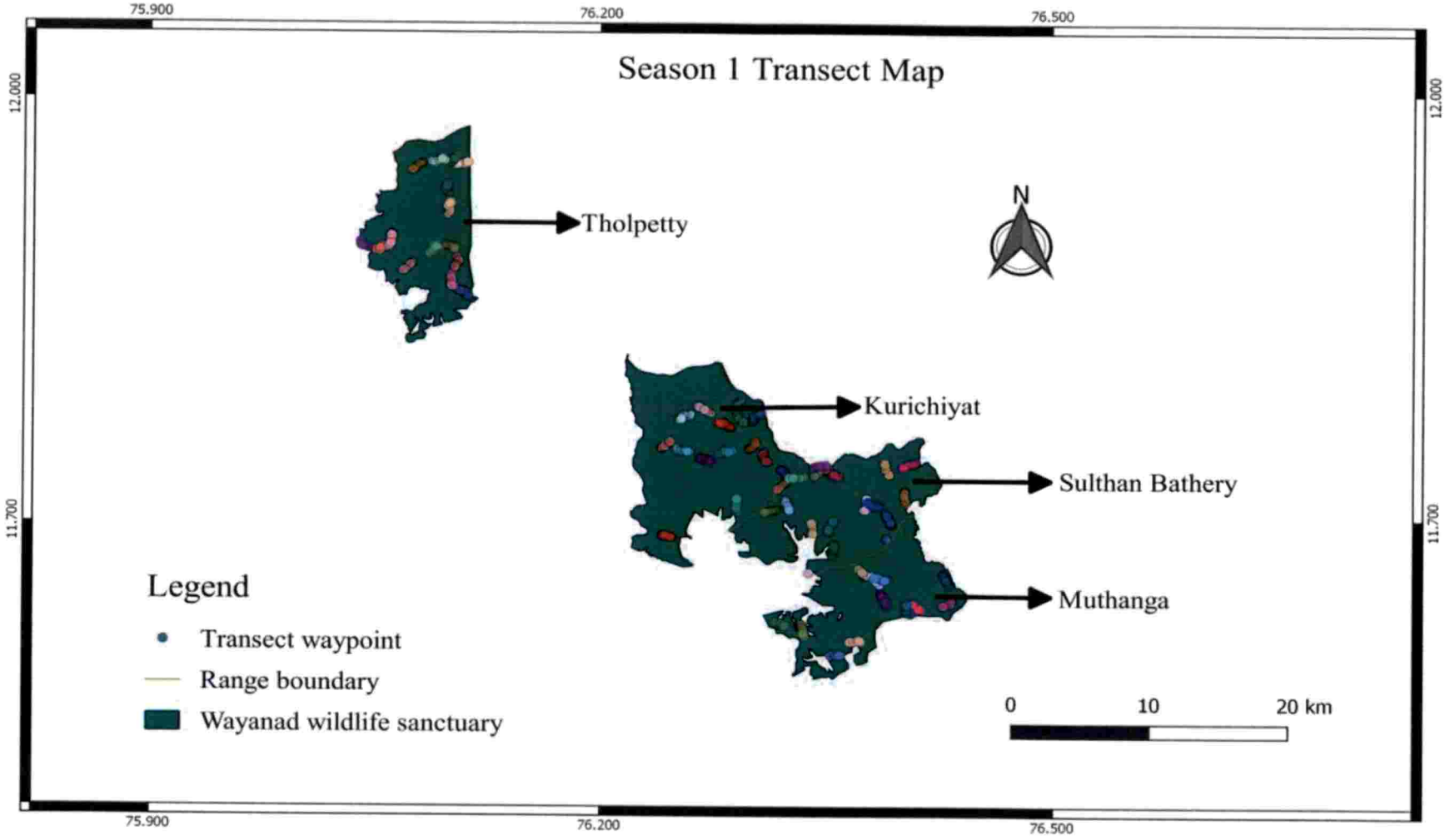


Plate 2b. Transect map of dry season

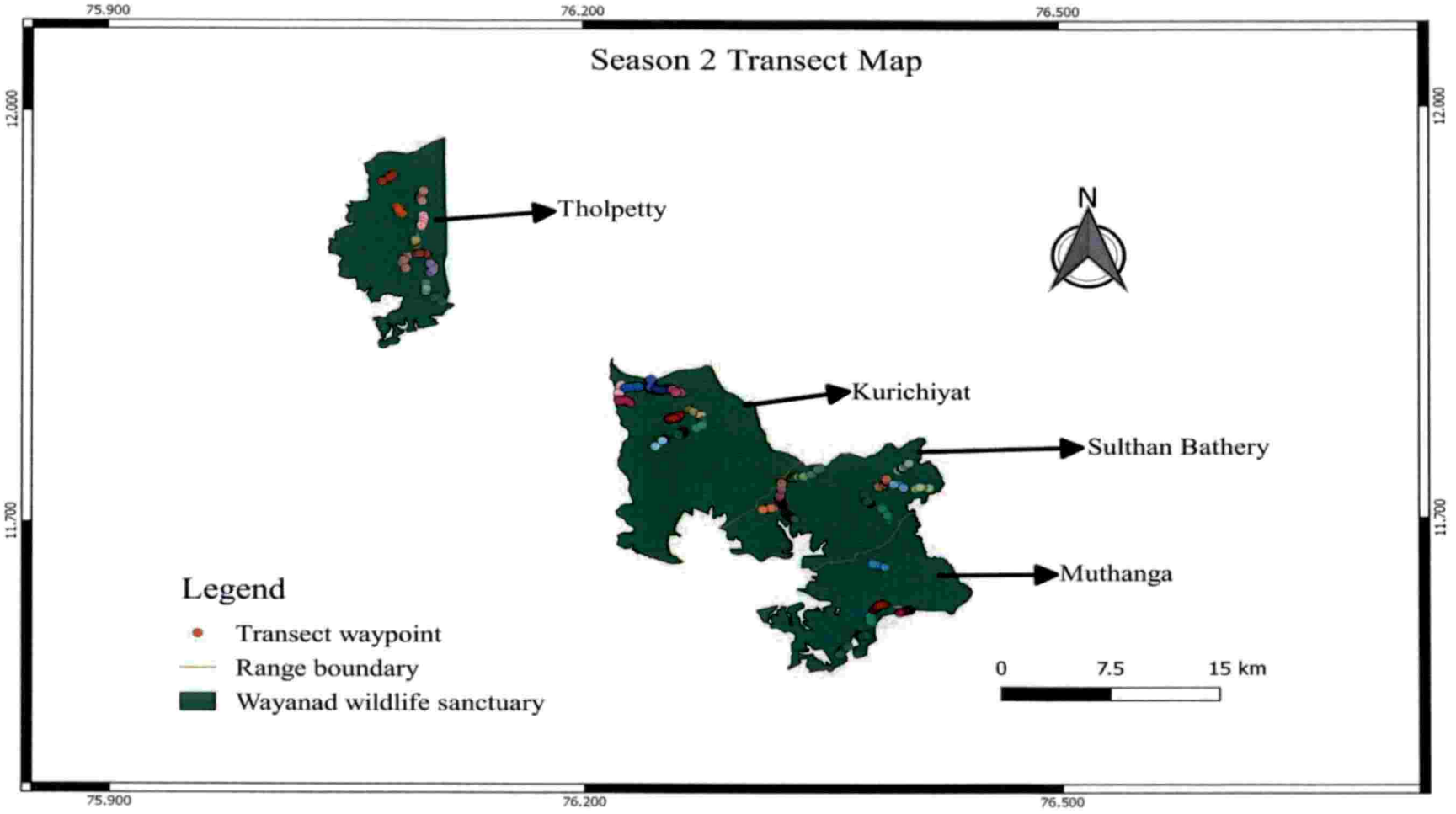


Plate 3. Different Stages of Dung Decay (Barnes and Jansen A-E System of Classification)

A stage

B stage

C1 stage

C2 stage

D stage

E stage

Plate 4. Measurement of perpendicular distance of dung from transect line, Quadrat Survey and Interview Schedule

Measurement of GBH of tree species

Measurement of perpendicular distance of dung from transect line

Interview of local farmer

Interview in a tribal village in Muthanga

3.2.3. Interview Schedule of local communities and forest officials

The local communities living on the fringe areas of the sanctuary were interviewed. Basic information about the families like age, sex, education, economic conditions and proximity to the forest were collected. Information on incidences of crop raiding were also obtained from the families that were surveyed. Perception survey of the local communities as well as forest officials was conducted in this study.

3.2.4. Data Analysis

3.2.4.1. Population and density estimation analysis

In the dung count method, the elephant population is estimated by extrapolating the dung density. The dung density was calculated by enumerating the dung samples observed from the transect and measuring their perpendicular distance from the centre of the transect line (Barnes, 1996). This method also requires the dung decay rate (disappearance rate) within the study area as well as defecation rate of the elephants (Barnes *et. al.*, 1997). The dung decay rate of 0.007 per day was obtained from the results of dung decay experiments conducted by the State Forest Department in the Wayanad Wildlife Sanctuary sanctuary (KFD, 2017 *unpublished data*). The defecation rate of 16.33 dung piles/day was taken from studies conducted in similar conditions of the neighbouring Mudumalai tiger reserve (Watve, 1992). These data thus collected were analysed using the software DISTANCE 6.2 (Thomas *et. al.*, 2010) and the dung density was calculated using the equation,

$$D = n.f(0)/2L$$

Where 'D' is dung density, 'n' is the number of dung piles, and 'L' is the total length of the transects walked for recording dung piles.

From the dung density thus calculated, the elephant density was computed using the following function (Barnes and Jensen, 1987)

$$E = (Y \times R) / D$$

where,

E = Elephant density

Y = Density of dung

R = Decay Rate (Daily rate of decay)

D = Defecation Rate (Number of times an individual elephant defecates per day)

Using the same method, the elephant population was calculated for the whole Wayanad Wildlife Sanctuary and the different administrative ranges of the Wayanad Wildlife Sanctuary. The elephant population was also estimated for the different vegetation types in the Wayanad Wildlife Sanctuary. The elephant population and density was also estimated for the wet season and dry season separately.

Analysis was run on all the 4 models, *viz.* Uniform, Half-Normal, Hazard Rate and Negative Exponential. Akaike Information Criteria (AIC) was almost similar in all 4 models. Hence, a combination of CV% and 95% Confidence Interval was considered to select the best model. Accordingly the Half-Normal Model was chosen for the data analysis using DISTANCE software. Truncation was done at 15 m effective strip width to avoid any introduction of noise by 'outliers' which are the observations spotted at larger distances with very less frequency. This was done to improve model robustness and precision of the population estimate. Encounter rates of dung were also analysed and estimated by the DISTANCE software.

3.2.4.2. Vegetation analysis

Quantitative analysis of the sampled vegetation was done to obtain their frequency, density, basal area and their relative values and important value index (Curtis and Macintosh, 1950) in order to determine the quantitative relationship between the species.

$$\text{Relative Density (RD)} = \frac{\text{No. of individuals of the species}}{\text{No. of individuals of all species}} \times 100$$

$$\text{Percentage frequency} = \frac{\text{No. of quadrats of occurence}}{\text{Total no.of quadrats studied}} \times 100$$

$$\text{Relative Frequency (RF)} = \frac{\text{Percentage frequency of individual species}}{\text{Sum percentage frequency of all species}} \times 100$$

$$\text{Basal area} = \frac{\text{Girth at Breast Height (GBH)}^2}{4}$$

$$\text{Relative Basal Area (RBA)} = \frac{\text{Basal area of the species}}{\text{Basal area of all species}} \times 100$$

$$\text{Important Value Index (IVI)} = \text{RD} + \text{RF} + \text{RBA}$$

The trees were also classified into girth classes with an interval of 10 cm and the girth class distribution curves were plotted to assess the stability of the habitats. Diversity indices such as Shannon-Wiener index (Shannon, 1948) and Simpson's index (Simpson, 1949) were computed to understand the level of diversity of tree species in the sanctuary between different habitats, with respect to abundance and evenness of species.

$$\text{Shannon Index (H)} = -(\sum_{i=1}^{s} p_i \ln p_i)$$

In the Shannon index, 'p' is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, 'Σ' is the sum of the calculations, and 's' is the number of species.

$$\text{Simpson Index (D)} = \frac{1}{\sum_{i=1}^{S} p_i^2}$$

In the Simpson index, 'p' is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), 'Σ' is the sum of the calculations, and 's' is the number of species.

3.2.4.3. Interview schedule analysis

Each question in the interview schedule was assumed to be a category and the sub questions were taken as subcategories. The response of the household members and forest

officials were separately tabulated and was subjected to various statistical tests such as frequency of the response to a question and its percentage, Chi Square test, Pearson Correlation and Mann-Whitney U test (Singh *et. al.*, 2013). The latter three methods were completed using the SPSS software. Mann-Whitney U test was conducted to test for analysing the differences between the responses of the household members and the forest officials to the same category of questions and to establish the relation between the opinions of two groups, if any present. The Chi Square Test compares the observed and expected frequencies in each category to test either that all categories contain the same proportion of values or that each category contains a user-specified proportion of values. The association of different variables in the interview schedule were separately studied for household members and forest officials

RESULTS

RESULTS

4.1 Distribution and population density

4.1.1 Overall elephant density and population

Elephant population was carried out using dung count method. Since 60 transects of 1 km length were taken in the wet season, effective transect length of the study is 60 km. In the dry season, 40 transects of 1 km length were taken leading to an effective transect length of 40 km. The entire area of the sanctuary can be considered as elephant habitat, hence the total study area is 344.44 km^2. A total of 667 dung piles were recorded in the wet season from a transect of 60 km. This leads to an encounter rate 11.12 dung piles per kilometre of transect. In the dry season, a total of 997 dung piles were recorded from a transect of 40 km. This leads to an encounter rate of 24.82 dung piles per kilometre of transect.

The dung density for the wet season was estimated to be 1582.1 dung piles per km^2 (1350.9-1852.8 at 95% CI). Thus elephant density was estimated to be 0.68 elephants/km^2 (0.50-0.79 at 95% CI), which accounts for an elephant population of 233 ± 18.52 (SE) during the wet season at Wayanad Wildlife Sanctuary (Table 3). The elephant population ranges between 199 to 273 (at 95% CI) at Wayanad Wildlife Sanctuary during the wet season.

However, the elephant population during the dry season was estimated to be 301 ± 19.27 (SE) with a population range of 265-342 (at 95% CI). The dung density during dry season was 2039.2 dung piles/km^2 (1793.4-2318.7 at 95% CI) and the elephant density was estimated to be 0.87 elephants/km^2 during the dry season (0.77 to 0.99 at 95% CI) (Table 3).

The detection probability of the Asian Elephant dung at Wayanad Wildlife Sanctuary during the wet season was at a lower perpendicular distance of about 8 to 10 m (Fig. 4) while during the dry season the perpendicular distance was about 12 to 14 m (Fig. 5). This could be due to the better visibility owing to fewer undergrowth during the dry season, when compared to the monsoon (wet) season.

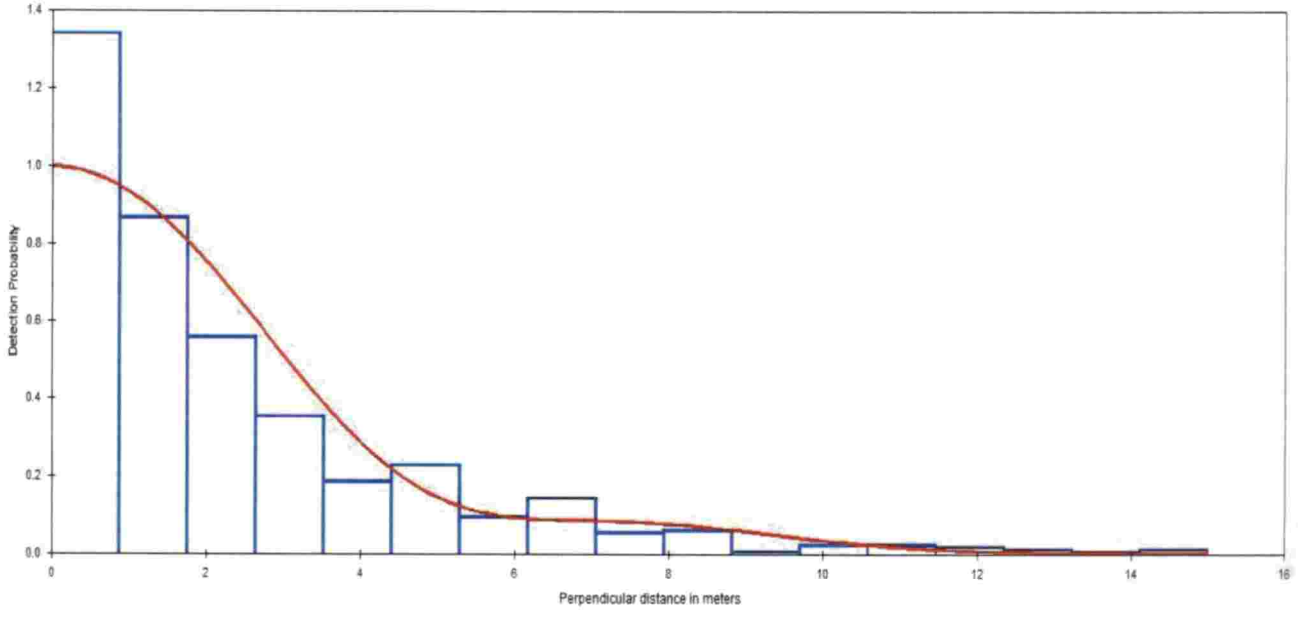


Figure 4. Detection probability and effective strip width of Asian Elephant dung in wet season

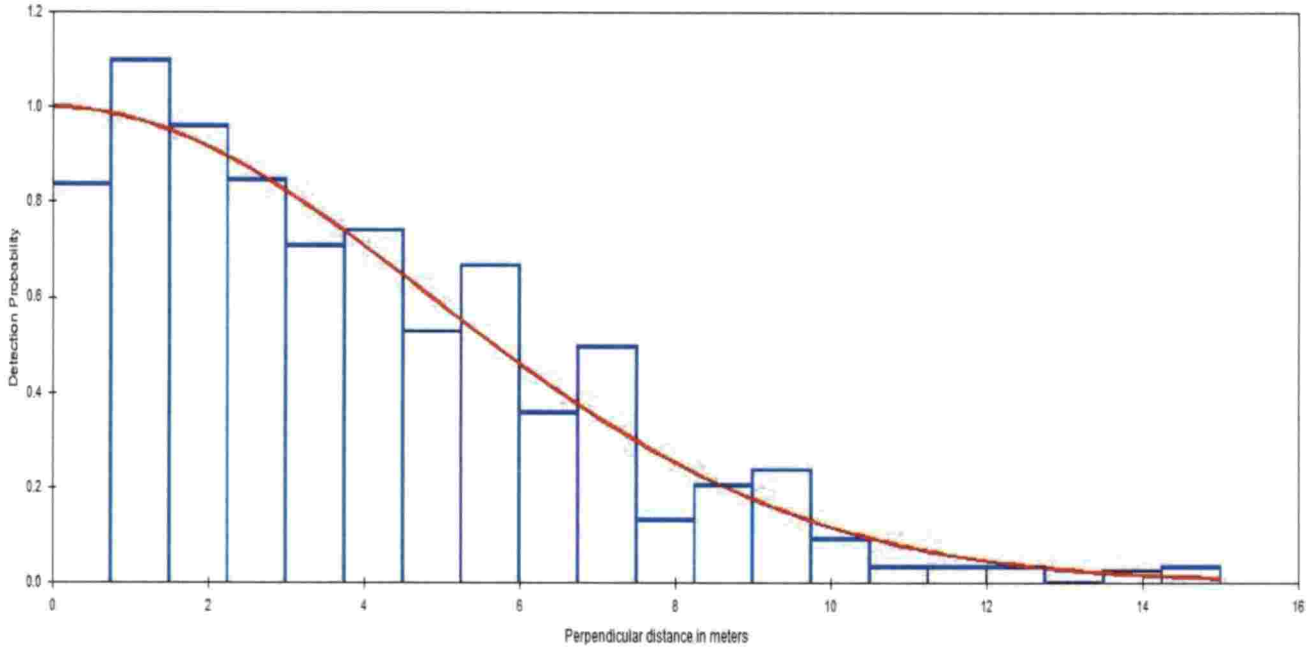


Figure 5. Detection probability and effective strip width of Asian Elephant dung in dry season

4.1.2 Elephant population density and distribution in different ranges

The elephant density varied between the forest ranges and also between the wet and dry season. In the wet season, the elephant population was greatest in Sulthan Bathery range while lowest in Tholpetty (Table 3; Fig. 6). While in the dry season, elephant population was greatest in Kurichiyat range, and lowest in Sulthan Bathery range (Table 3; Fig. 6).

Table 3. Elephant density in different forest ranges of Wayanad Wildlife Sanctuary

Range	Encounter rate (Number of dung piles/km)		Elephant density (Number/km^2)		95% CI values of density		Elephant habitat (km^2)	Estimated population (Number)	
	Wet	Dry	Wet	Dry	Wet	Dry		Wet	Dry
Muthanga	11	22.86	0.65	1.03	0.47-0.90	0.72-1.48	74.29	48	75
Sulthan Bathery	13.13	24.83	0.87	0.79	0.64-1.2	0.62-0.99	86.02	75	66
Kurichiyat	10	26.18	0.61	0.92	0.47-0.80	0.72-1.18	106.45	65	97
Tholpetty	10.4	24.7	0.58	0.84	0.38-0.88	0.59-1.18	77.67	45	63
Total	11.12	24.82	0.68	0.87	0.58-0.79	0.77-0.99	344.44	233	301

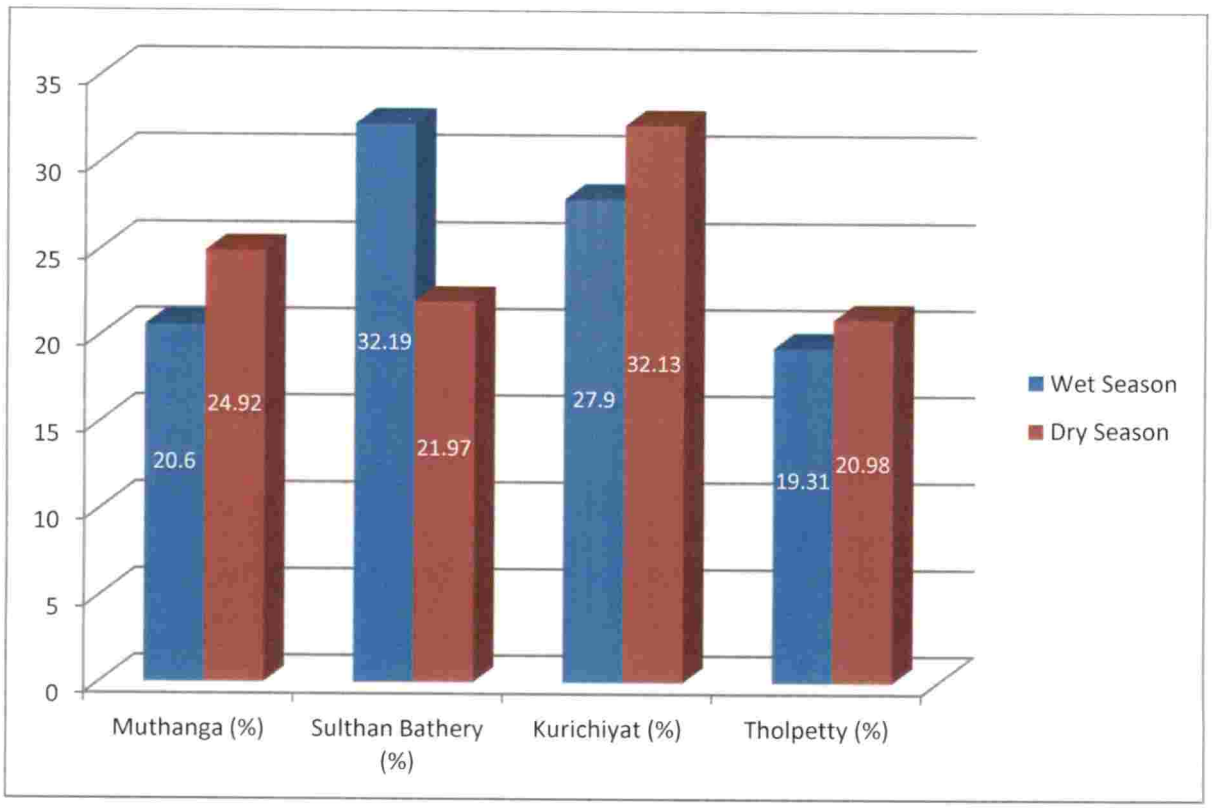


Figure 6. Percentage elephant distribution in different forest ranges of Wayanad Wildlife Sanctuary in both seasons

4.1.3 Elephant population density and distribution in different vegetation types

The data gathered from the same transects was also stratified among the three major vegetation types that occur within the sanctuary. Almost equal number of transects were taken in the two vegetation types seen within the natural forests, dry deciduous and moist deciduous forests. Only four transects were taken in the plantations (Teak and Eucalyptus) in the wet season. In the dry season, three transects were taken in the plantations. In the wet season, the elephant density was highest in dry deciduous forests (0.86 elephants/km^2) and it was lowest in the plantations (0.37 elephants/km^2). The moist deciduous habitat had a population density of 0.52 elephants/km^2. In the dry season, the elephant density remained highest in dry deciduous forests (0.90 elephants/km^2) but there was a marked increase in elephant density in both moist deciduous forests (0.86 elephants/km^2) as well as plantations (0.77 elephants/km^2).

The total area of each vegetation type within the natural forests is not known accurately, hence they were collectively taken as natural forests to estimate total elephant population. The area of plantations was taken from the latest management plan published by the Forest

Department (KFD, 2014), which estimated the area as 101.48 km^2. Hence, the rest of the area of the sanctuary can be considered as natural forests comprising of both the vegetation types which constitute 242.95 km^2. The estimate of total elephant population in natural forests was obtained by subtracting the elephant population estimate in plantations from the overall elephant population estimate in both seasons. As a result, the total elephant population in natural forests in the wet season was estimated to be about 194 individuals and about 223 individuals in the dry season. The percentage distribution of elephants in natural forests and plantations across the two seasons is given in Figure 7. Hence, it can be seen that elephants mostly prefer natural forests over plantations.

Table 4. Elephant density in different vegetation types of Wayanad Wildlife Sanctuary

Habitat	Encounter rate (Elephant dung piles/km)		Elephant density(No. of elephants/km^2)		95% CI		Elephant habitat (km^2)	Estimated population (Number)	
	Wet	Dry	Wet	Dry	Wet	Dry		Wet	Dry
Natural forests	11.15	25.09	0.69	0.88	0.55 - 0.86	0.72- 1.07	242.95	194	223
Plantations	7.6	21.33	0.38	0.77	0.14- 0.96	0.38- 1.17	101.48	39	78

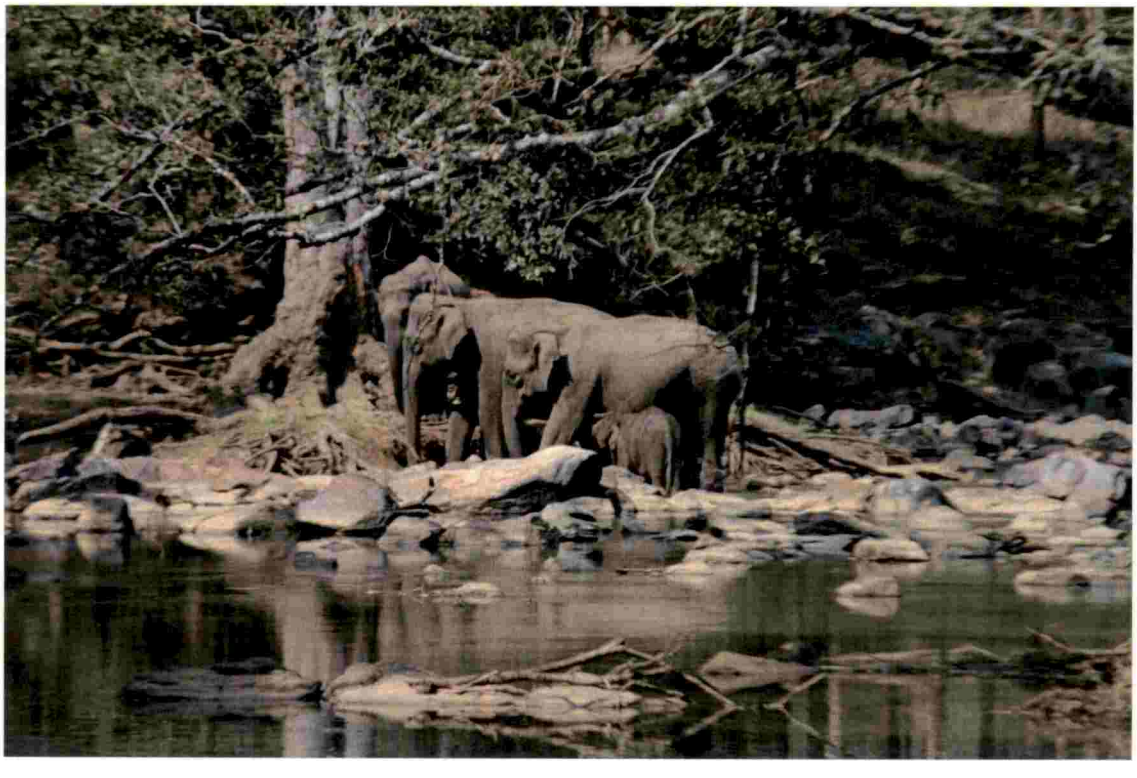
Plate 5a. Direct sightings of Asian Elephant

Solitary male

Elephant herd

Plate 5b. Direct sightings of Asian Elephant

Mother and calf (male)



Elephant herd near Noolpuzha river

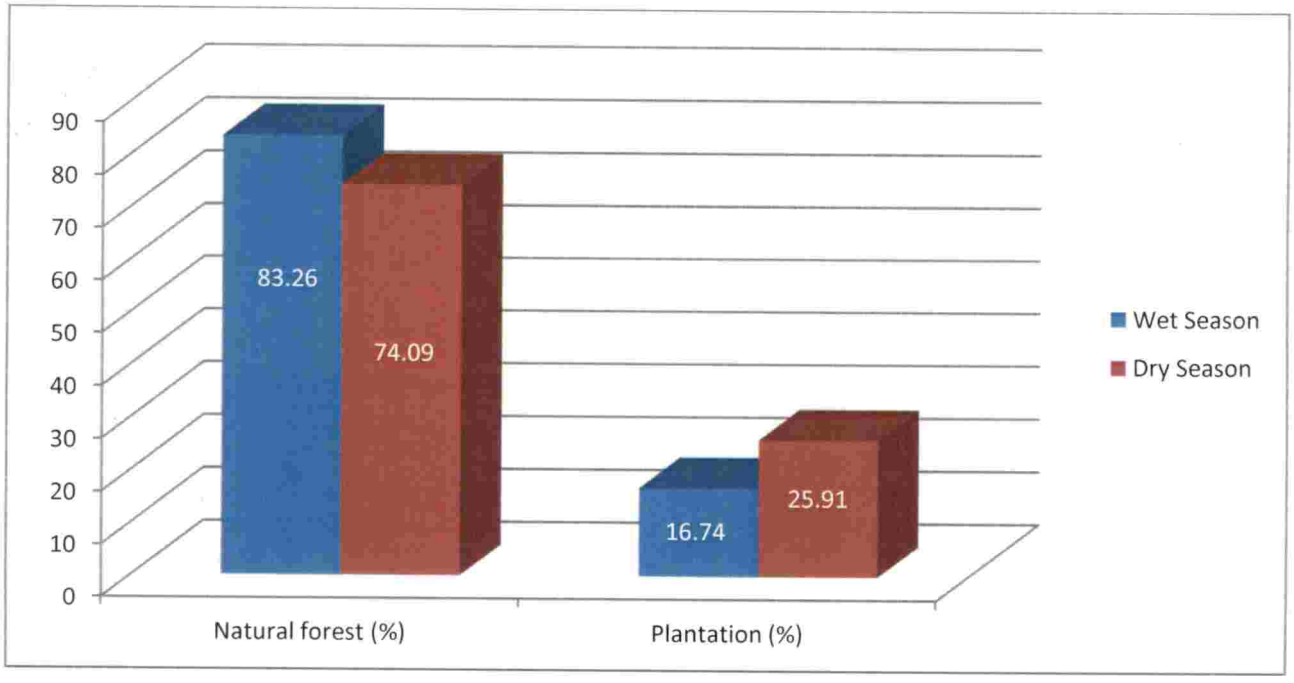


Fig 7. Percentage distribution of Asian Elephants in different habitats and different seasons in Wayanad Wildlife Sanctuary

4.2 Vegetation analysis of elephant habitat

A total of 600 quadrats having 100 m^2 area were sampled for studying the vegetation of the elephant habitat. Parameters such as GBH and height of all tree species with GBH greater than 10 cm were measured. A total of 67 species from 33 families were recorded from the 600 quadrats sampled. A total of 2525 individuals were obtained with a total basal area of 486.36 m^2 or 81.06 m^2 per ha. The density of tree species across the sanctuary was calculated to be about 420 trees/ha. The density of tree species in natural forests was found to be 418 trees/ha, while density in plantations was found to be much less at 288 trees/ha.

4.2.1. Relative density and abundance of tree species in the sanctuary

Tree species such as *Terminalia elliptica*, *Tectona grandis*, *Anogeissus latifolia*, *Terminalia elliptica*, *Dalbergia latifolia* and *Lagerstroemia microcarpa* were found to be the most abundant species in the sanctuary. The southern ranges of Muthanga and Sulthan Bathery mostly harbored dry deciduous forest as well as some teak and eucalyptus plantations, with some moist deciduous patches interspersed in between. Kurichiyat range was mostly covered with moist deciduous vegetation as well as some teak plantations. Tholpetty mostly consisted of teak

plantations as well as patches of moist deciduous forest on the boundaries of territorial ranges of Tirunelly and Begur.

The dominant species in dry deciduous forest was *Terminalia elliptica* and *Tectona grandis*. The dominant species in moist deciduous forest was *Tectona grandis*, *Terminalia elliptica* and *Lagerstroemia microcarpa*. Since plantations were mostly teak and eucalyptus, these were the dominant tree species in the respective plantations, but some tree species like *Dalbergia latifolia*, *Terminalia elliptica* were also recorded within the plantations. Regeneration was mainly observed in *Anogeissus latifolia, Cassia fistula*, *Tabernaemontana heyneana* as well as patches of regeneration of *Shorea roxburghii* in Ponkuzhi and Ottipara of Sulthan Bathery range. Weed infestation has been observed in most parts of the sanctuary. The undergrowth in the Teak plantations in many areas were covered by invasive weeds like *Lantana camara* and *Eupatorium odoratum*, while some natural forests have also been infested. *Senna spectabilis* infestation was also observed near the Eucalyptus plantations in Muthanga range, as well in parts of Tholpetty range.

Table 5. Relative density and abundance of species in Wayanad Wildlife Sanctuary

Sl. no	Species	Relative density (%)	Total number of trees
1	*Terminalia elliptica*	20	505
2	*Tectona grandis*	19.25	486
3	*Anogeissus latifolia*	12.55	317
4	*Dalbergia latifolia*	5.07	128
5	*Lagerstroemia microcarpa*	4.55	115
6	*Grewia tillifolia*	3.41	86
7	*Cassia fistula*	3.09	78
8	*Pterocarpus marsupium*	2.50	63
9	*Olea dioica*	2.46	62
10	*Schleichera oleosa*	2.10	53
11	*Terminalia paniculata*	1.90	48
12	*Phyllanthus emblica*	1.70	43
13	*Eucalyptus tereticornis*	1.54	39
14	*Elaeocarpus tuberculatus*	1.50	38

15	*Terminalia bellerica*	1.47	37
16	*Haldina cordifolia*	1.43	36
17	*Stereospermum chelonoides*	1.27	32
18	*Gmelina arborea*	1.07	27
19	*Dalbergia sissoides*	0.87	22
20	*Tabernaemontana heyneana*	0.83	21
21	*Lannea coromandelica*	0.75	19
22	*Syzigium cumini*	0.71	18
23	*Lagerstroemia parviflora*	0.67	17
24	*Hydnocarpus pentandra*	0.63	16
25	*Stereospermum colais*	0.63	16
26	*Schrebera swietanoides*	0.59	15
27	*Butea monosperma*	0.59	15
28	*Bauhinia racemosa*	0.55	14
29	*Erythrina indica*	0.51	13
30	*Persea macrantha*	0.48	12
31	*Terminalia chebula*	0.44	11
32	*Gomphandra coriacea*	0.40	10
33	*Bridelia retusa*	0.40	10
34	*Albizzia odoratissima*	0.40	10
35	*Mitragyna parviflora*	0.40	10
36	*Vitex altissima*	0.40	10
37	*Bombax ceiba*	0.28	7
38	*Tamilnadia uliginosa*	0.20	5
39	*Bauhinia malabarica*	0.20	5
40	*Garuga pinnata*	0.20	5
41	*Kydia calycina*	0.16	4
42	*Pongamia pinnata*	0.16	4
43	*Shorea roxburghii*	0.16	4
44	*Holigarna arnottiana*	0.12	3
45	*Schefflera wallichiana*	0.12	3
46	*Grevillea robusta*	0.12	3

47	*Melicope lunu-ankenda*	0.12	3
48	*Mangifera indica*	0.12	3
49	*Stereospermum suaveolens*	0.08	2
50	*Hopea parviflora*	0.08	2
51	*Cinnamomum verum*	0.08	2
52	*Melia dubia*	0.08	2
53	*Atlanta monophylla*	0.04	1
54	*Sterculia balanghas*	0.04	1
55	*Zizyphus xylocarpus*	0.04	1
56	*Flacourtia indica*	0.04	1
57	*Bischofia javanica*	0.04	1
58	*Trewia nudiflora*	0.04	1
59	*Cinnamomum zeylanicum*	0.04	1
60	*Dendrocalamus strictus*	0.04	1
61	*Bauhinia acuminata*	0.04	1
62	*Careya arborea*	0.04	1
63	*Sterculia foetida*	0.04	1
64	*Dysoxylum malabaricum*	0.04	1
65	*Dilenia indica*	0.04	1
66	*Santalum album*	0.04	1
67	*Aporusa acuminata*	0.04	1
68	*Magnolia champaca*	0.04	1
		Total	**2525**

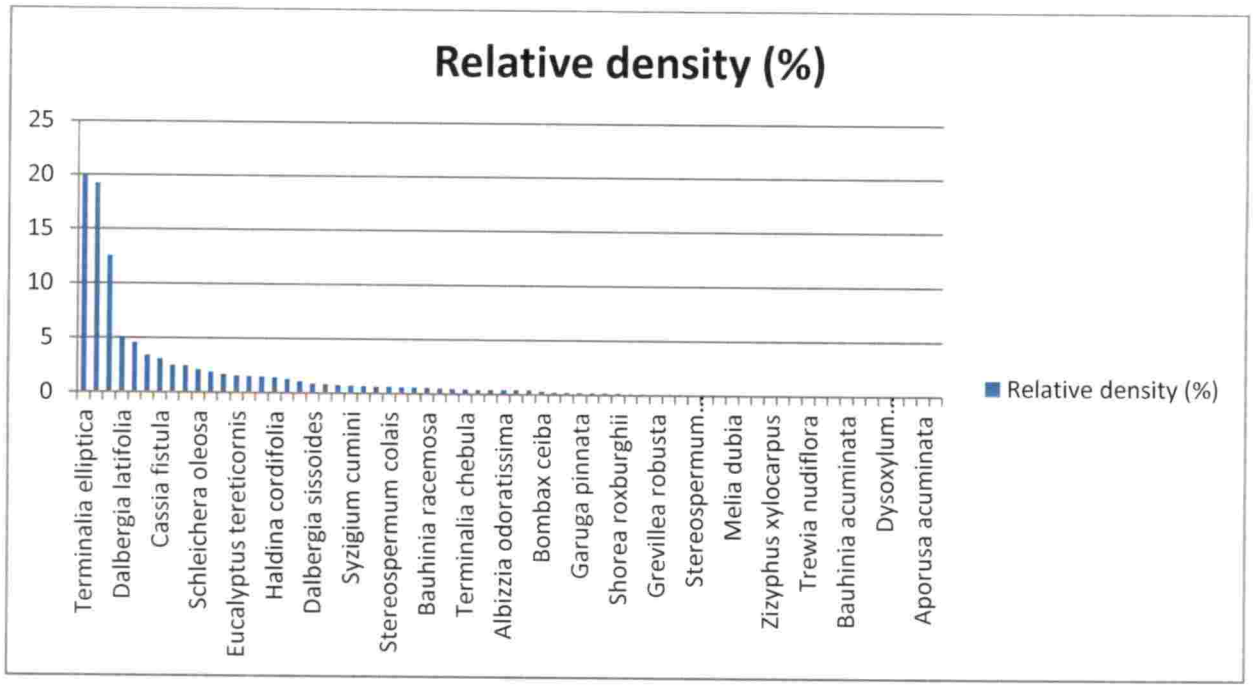


Figure 8. Relative Percentage of tree species in Wayanad Wildlife Sanctuary

Table 6. Density and number of trees in mixed dry deciduous forest of Wayanad Wildlife Sanctuary

Sl. No.	Species	Relative density (%)	Total number of trees
1	*Terminalia elliptica*	25.12	317
2	*Anogeissus latifolia*	20.84	263
3	*Tectona grandis*	14.18	179
4	*Pterocarpus marsupium*	3.49	44
5	*Grewia tillifolia*	3.33	42
6	*Terminalia paniculata*	3.17	40
7	*Dalbergia latifolia*	3.01	38
8	*Cassia fistula*	2.85	36
9	*Lagerstroemia microcarpa*	2.54	32
10	*Olea dioica*	2.22	28
11	*Phyllanthus emblica*	2.06	26
12	*Schleichera oleosa*	1.90	24
13	*Haldina cordifolia*	1.35	17
14	*Elaeocarpus tuberculatus*	1.19	15
15	*Schrebera swietanoides*	1.11	14
16	*Terminalia bellerica*	1.03	13
17	*Gmelina arborea*	0.95	12

18	*Lagerstroemia parviflora*	0.87	11
19	*Syzigium cumini*	0.79	10
20	*Stereospermum colais*	0.79	10
21	*Dalbergia sissoides*	0.79	10
22	*Tabernaemontana heyneana*	0.71	9
23	*Stereospermum chelonoides*	0.71	9
24	*Terminalia chebula*	0.55	7
25	*Mitragyna parviflora*	0.40	5
26	*Albizzia odoratissima*	0.40	5
27	*Tamilnadia uliginosa*	0.32	4
28	*Eucalyptus tereticornis*	0.32	4
29	*Shorea roxburghii*	0.32	4
30	*Lannea coromandelica*	0.24	3
31	*Erythrina indica*	0.24	3
32	*Melicope lunu-ankenda*	0.24	3
33	*Vitex altissima*	0.24	3
34	*Bombax ceiba*	0.24	3
35	*Garuga pinnata*	0.16	2
36	*Bridelia retusa*	0.16	2
37	*Butea monosperma*	0.16	2
38	*Holigarna arnottiana*	0.16	2
39	*Persea macrantha*	0.16	2
40	*Aporusa acuminata*	0.08	1
41	*Dendrocalamus strictus*	0.08	1
42	*Cinnamomum zeylanicum*	0.08	1
43	*Bauhinia acuminata*	0.08	1
44	*Bauhinia malabarica*	0.08	1
45	*Sterculia foetida*	0.08	1
46	*Santalum album*	0.08	1
47	*Gomphandra coriacea*	0.08	1
48	*Schefflera wallichiana*	0.08	1
		Total	**1262**

Table 7. Density and number of trees in mixed moist deciduous forest of Wayanad Wildlife Sanctuary

Sl. No.	Species	Relative density	Total number of trees
1	*Tectona grandis*	20.37	222
2	*Terminalia elliptica*	16.05	175
3	*Lagerstroemia microcarpa*	7.34	80
4	*Dalbergia latifolia*	6.88	75
5	*Anogeissus latifolia*	4.68	51
6	*Grewia tillifolia*	3.76	41
7	*Cassia fistula*	3.58	39
8	*Olea dioica*	2.66	29
9	*Schleichera oleosa*	2.57	28
10	*Stereospermum chelonoides*	2.11	23
11	*Terminalia bellerica*	2.02	22
12	*Elaeocarpus tuberculatus*	2.02	22
13	*Pterocarpus marsupium*	1.65	18
14	*Haldina cordifolia*	1.65	18
15	*Hydnocarpus pentandra*	1.47	16
16	*Lannea coromandelica*	1.47	16
17	*Phyllanthus emblica*	1.38	15
18	*Gmelina arborea*	1.28	14
19	*Butea monosperma*	1.19	13
20	*Bauhinia racemosa*	1.19	13
21	*Tabernaemontana heyneana*	1.10	12
22	*Dalbergia sissoides*	1.01	11
23	*Erythrina indica*	0.92	10
24	*Persea macrantha*	0.92	10
25	*Gomphandra coriacea*	0.83	9
26	*Syzigium cumini*	0.73	8
27	*Bridelia retusa*	0.73	8
28	*Terminalia paniculata*	0.73	8
29	*Eucalyptus tereticornis*	0.73	8

30	*Vitex altissima*	0.64	7
31	*Lagerstroemia parviflora*	0.55	6
32	*Albizzia odoratissima*	0.46	5
33	*Mitragyna parviflora*	0.46	5
34	*Bombax ceiba*	0.37	4
35	*Stereospermum colais*	0.37	4
36	*Terminalia chebula*	0.37	4
37	*Pongamia pinnata*	0.37	4
38	*Bauhinia malabarica*	0.28	3
39	*Garuga pinnata*	0.28	3
40	*Mangifera indica*	0.28	3
41	*Grevillea robusta*	0.28	3
42	*Hopea parviflora*	0.18	2
43	*Kydia calycina*	0.18	2
44	*Cinnamomum verum*	0.18	2
45	*Melia dubia*	0.18	2
46	*Schefflera wallichiana*	0.18	2
47	*Stereospermum suaveolens*	0.18	2
48	*Magnolia champaca*	0.09	1
49	*Careya arborea*	0.09	1
50	*Flacourtia indica*	0.09	1
51	*Bischofia javanica*	0.09	1
52	*Dilenia indica*	0.09	1
53	*Holigarna arnottiana*	0.09	1
54	*Atlanta monophylla*	0.09	1
55	*Tamilnadia uliginosa*	0.09	1
56	*Trewia nudiflora*	0.09	1
57	*Schrebera swietanoides*	0.09	1
58	*Zizyphus xylocarpus*	0.09	1
59	*Sterculia balanghas*	0.09	1
60	*Dysoxylum malabaricum*	0.09	1
		Total	**1090**

Table 8. Density and number of trees of Teak and Eucalyptus in plantations

Sl. No.	Species	Relative density (%)	Total number of trees
1	*Tectona grandis*	49.13%	85
2	*Eucalyptus tereticornis*	15.61%	27
3	*Dalbergia latifolia*	8.67%	15
4	*Terminalia elliptica*	7.51%	13
5	*Olea dioica*	2.89%	5
6	*Lagerstroemia microcarpa*	1.73%	3
7	*Cassia fistula*	1.73%	3
8	*Anogeissus latifolia*	1.73%	3
9	*Grewia tillifolia*	1.73%	3
10	*Terminalia bellerica*	1.16%	2
11	*Stereospermum colais*	1.16%	2
12	*Kydia calycina*	1.16%	2
13	*Phyllanthus emblica*	1.16%	2
14	*Bauhinia malabarica*	0.58%	1
15	*Gmelina arborea*	0.58%	1
16	*Dalbergia sissoides*	0.58%	1
17	*Bauhinia racemosa*	0.58%	1
18	*Elaeocarpus tuberculatus*	0.58%	1
19	*Pterocarpus marsupium*	0.58%	1
20	*Schleichera oleosa*	0.58%	1
21	*Haldina cordifolia*	0.58%	1
	Grand Total	**100.00%**	**173**

4.2.2. Girth class distribution of tree species in the sanctuary

Girth at breast height (GBH) of all trees above 10 cm within the sample plots were measured. *Persea macrantha* had the highest GBH of 610 cm, followed by *Bridelia retusa* (384 cm) and *Dalbergia latifolia* (380 cm). The lowest GBH of 12 cm was obtained from *Tabernaemontana heyneana.* The girth class distribution of all tree species recorded from the sample plots were taken. Girth classes were made at an interval of 10 cm. Girth class frequency distribution of the tree species in the sanctuary shows that more than 50% of sampled individual belonged to the category of 150 cm-200 cm. While there are ample amounts of individuals among the girth classes between 50 cm-150 cm, there is a lack of regeneration characterized by

few individuals below the 50 cm girth class. This holds true for all the vegetation types seen within the sanctuary. Considering the top ten abundant species sampled, only *Anogeissus latifolia* and *Cassia fistula* had individuals within the lower girth class categories. This implies that the regeneration is extremely poor and thus the long term existence of the forest is under immense challenge. Similarly, the presence of the trees above a girth class of 200 cm was also very low (Fig. 9). This condition of the regeneration is highly alarming and warrants urgent restoration action, to ensure the long term survival of the forests of Wayanad.

The habitat-wise girth class distribution of the trees is represented in Fig. 10 and Fig. 11 for the dry deciduous and moist deciduous forests. These forests also follow similar girth class distribution pattern with poor regeneration as well as absence of mature trees above a girth class of 200 m. The girth class distribution of selected dominant tree species such as *Tectona grandis* *Terminalia elliptica*, *A. latifolia*, *Terminalia elliptica*, *D. latifolia*, *L. microcarpa*, *G. tiliifolia*, *C. fistula*, *P. marsupium* and *O. dioica* at Wayanad Wildlife Sanctuary are given in Fig. 12 to Fig. 21. The general pattern of regeneration in all the dominant tree species of Wayanad Wildlife Sanctuary are extremely poor and is a matter of concern.

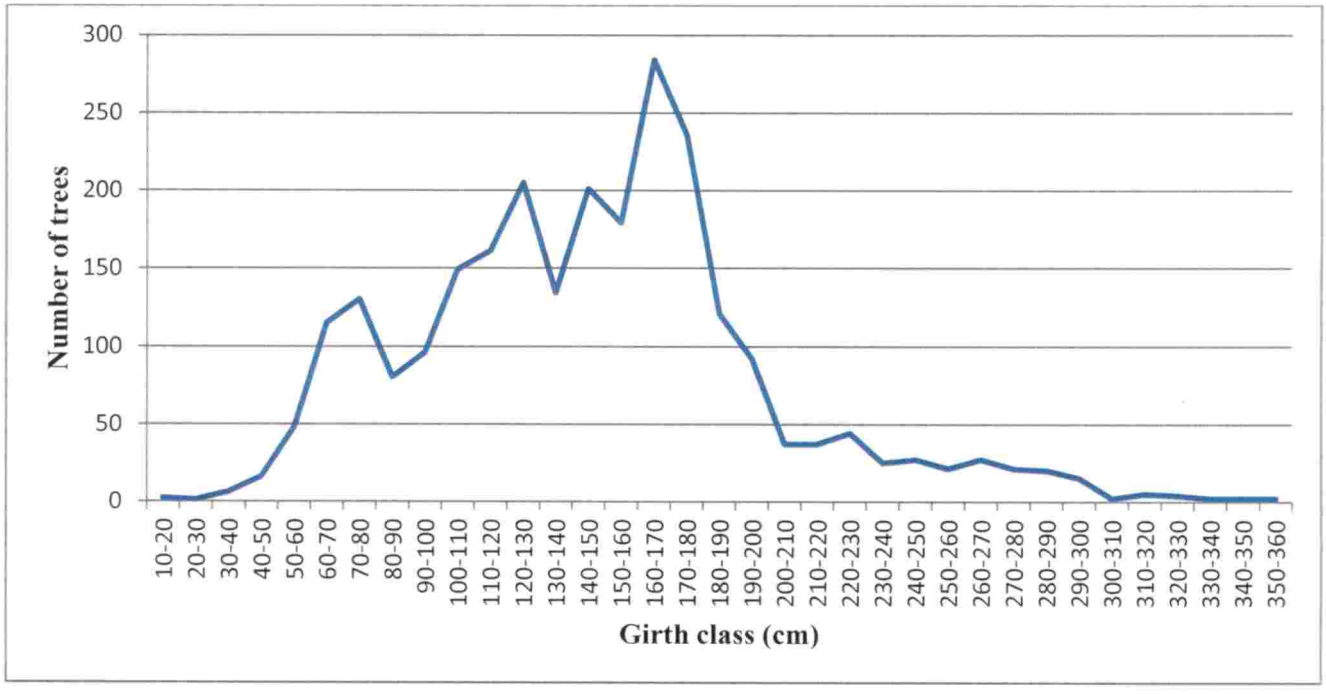


Figure 9. Girth class distribution of all tree species (above 10cm GBH) in Wayanad Wildlife Sanctuary

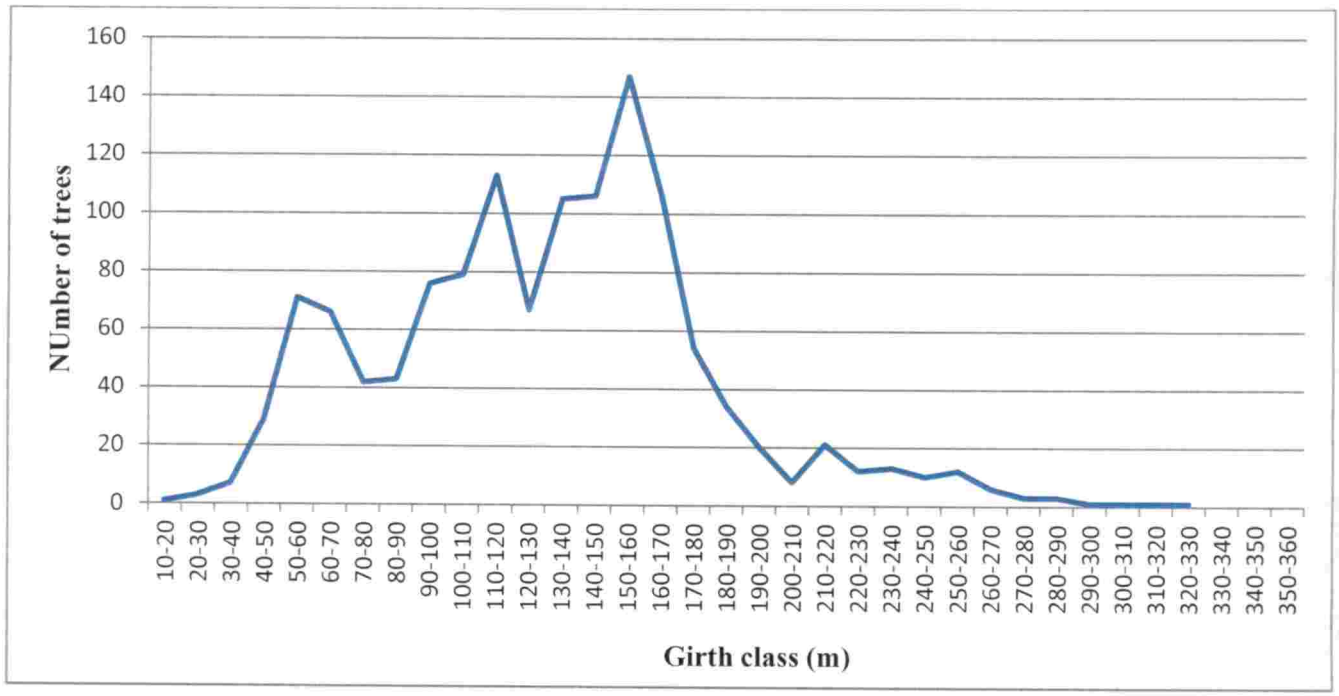


Figure 10. Girth class distribution of tree species (above 10cm GBH) in dry deciduous habitat of Wayanad Wildlife Sanctuary

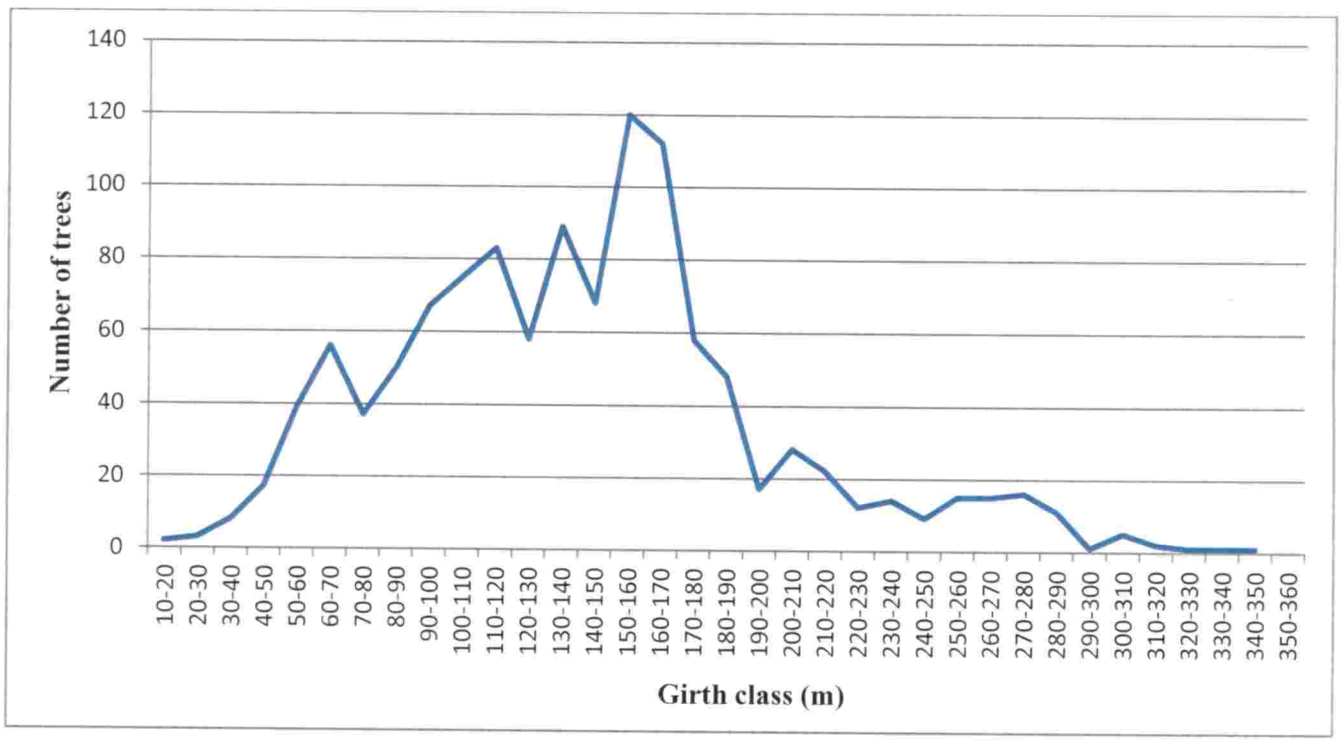


Figure 11. Girth class distribution of tree species (above 10cm GBH) in moist deciduous habitat of Wayanad Wildlife Sanctuary

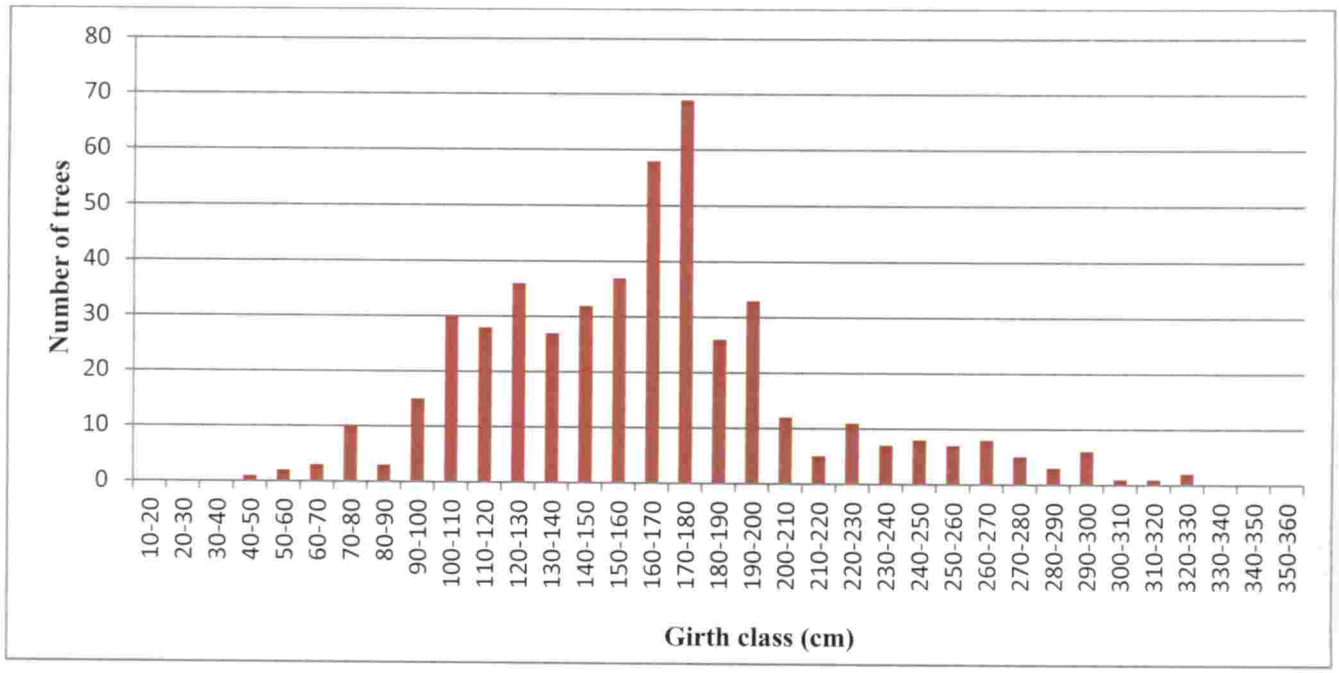


Figure 12. Girth class distribution of *Tectona grandis* at Wayanad Wildlife Sanctuary

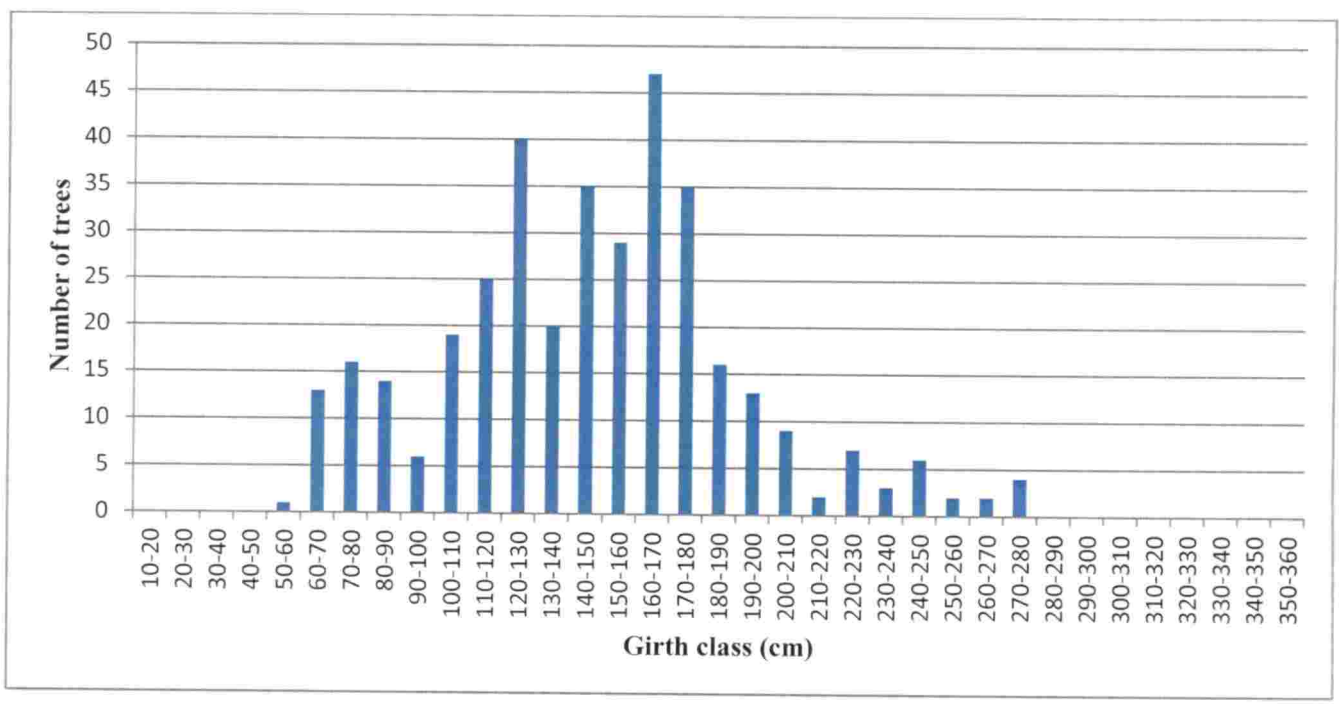


Figure 13. Girth class distribution of *Terminalia elliptica* at Wayanad Wildlife Sanctuary

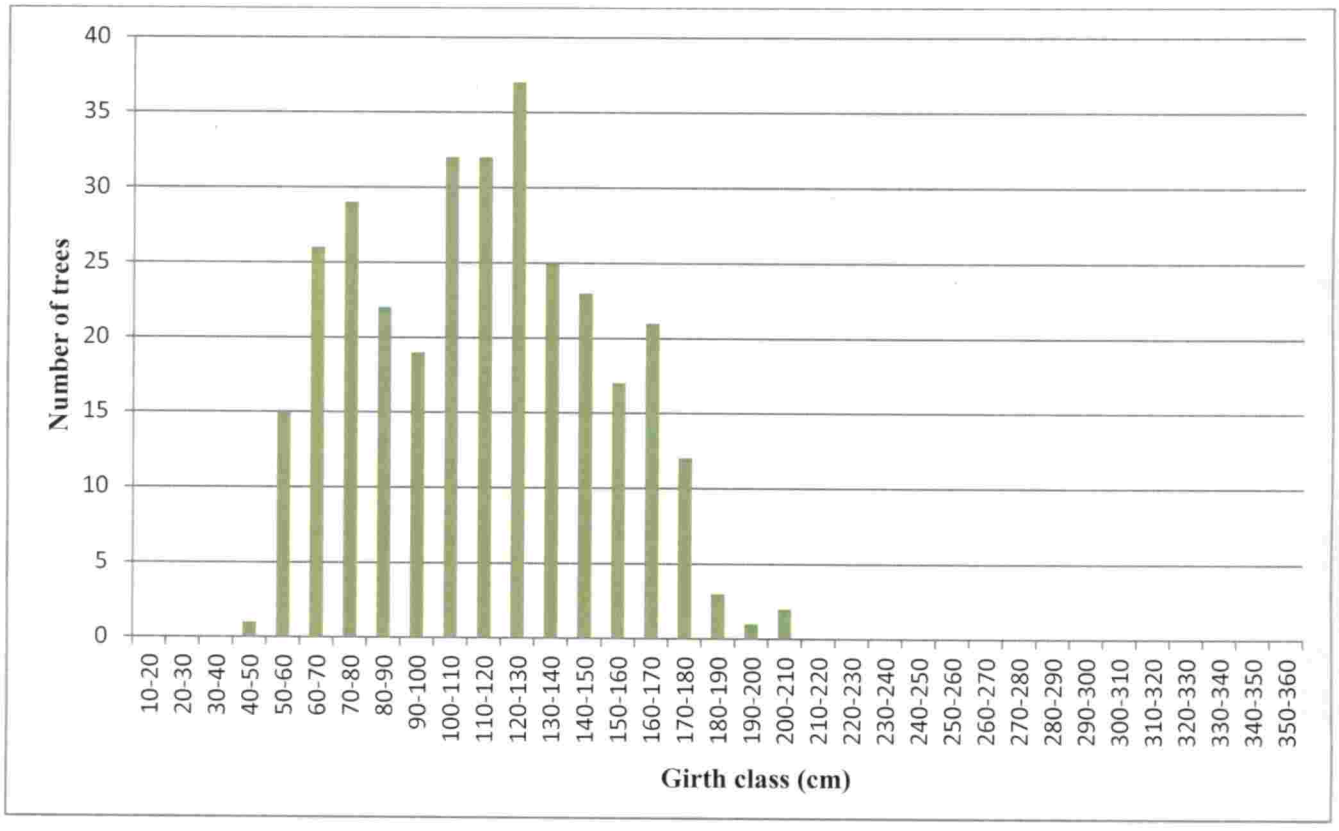


Figure 14. Girth class distribution of *Anogeissus latifolia* at Wayanad Wildlife Sanctuary

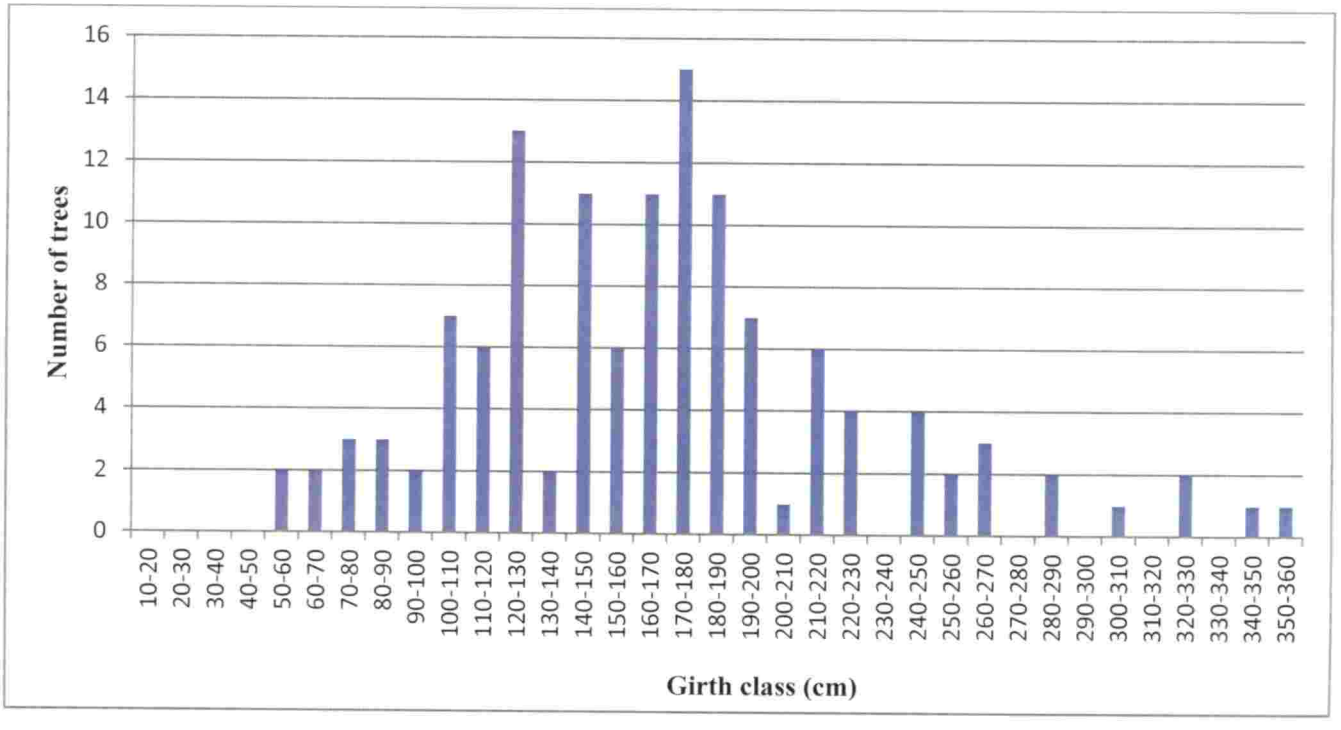


Figure 15. Girth class distribution of *Dalbergia latifolia* at Wayanad Wildlife Sanctuary

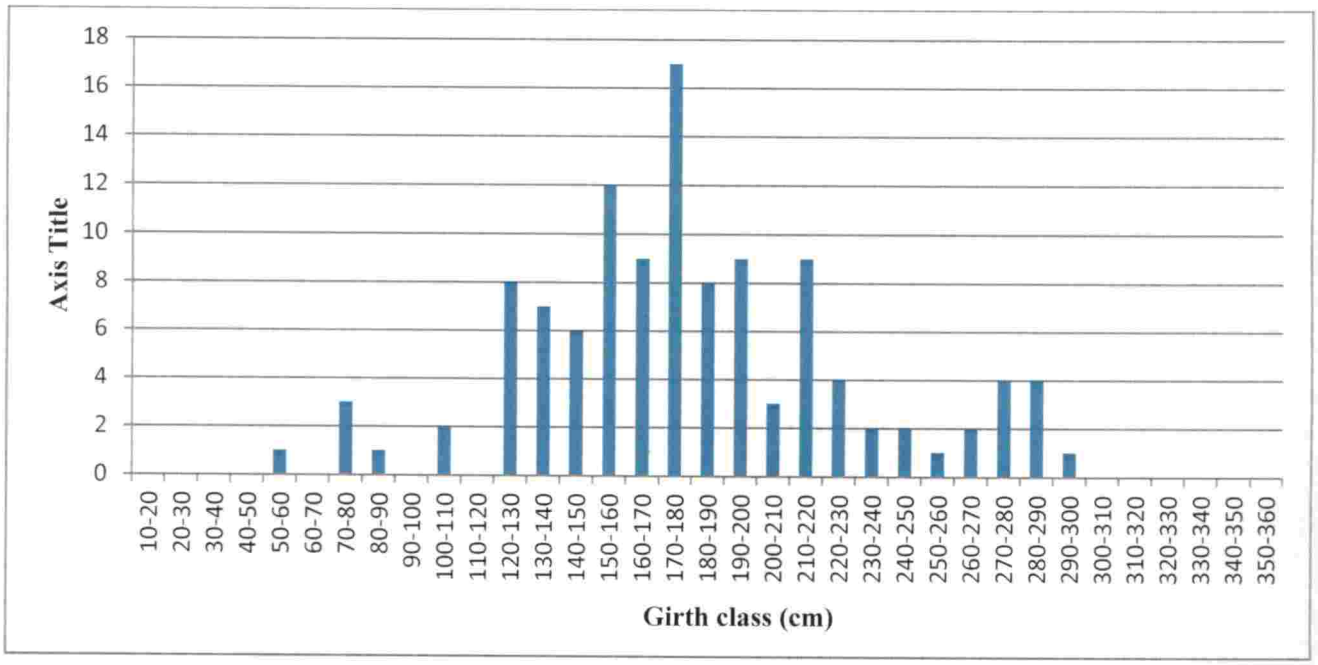


Figure 16. Girth class distribution of *Lagerstroemia microcarpa* at Wayanad Wildlife Sanctuary

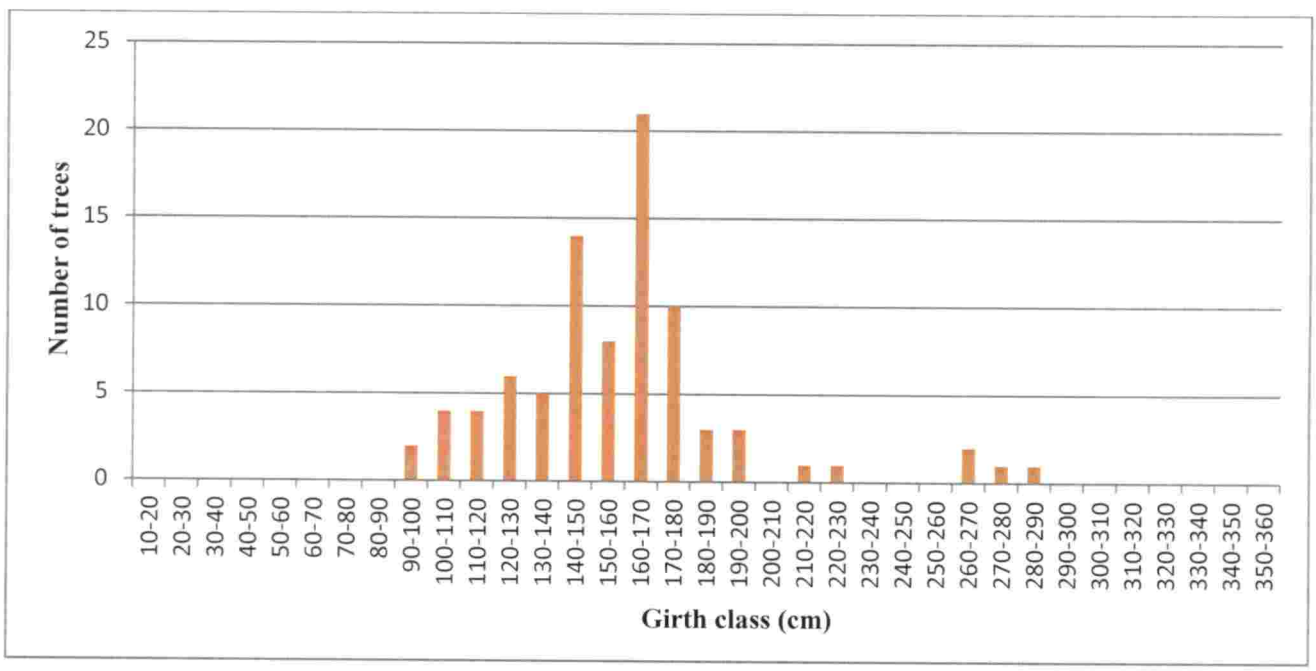


Figure 17. Girth class distribution of *Grewia tillifolia* at Wayanad Wildlife Sanctuary

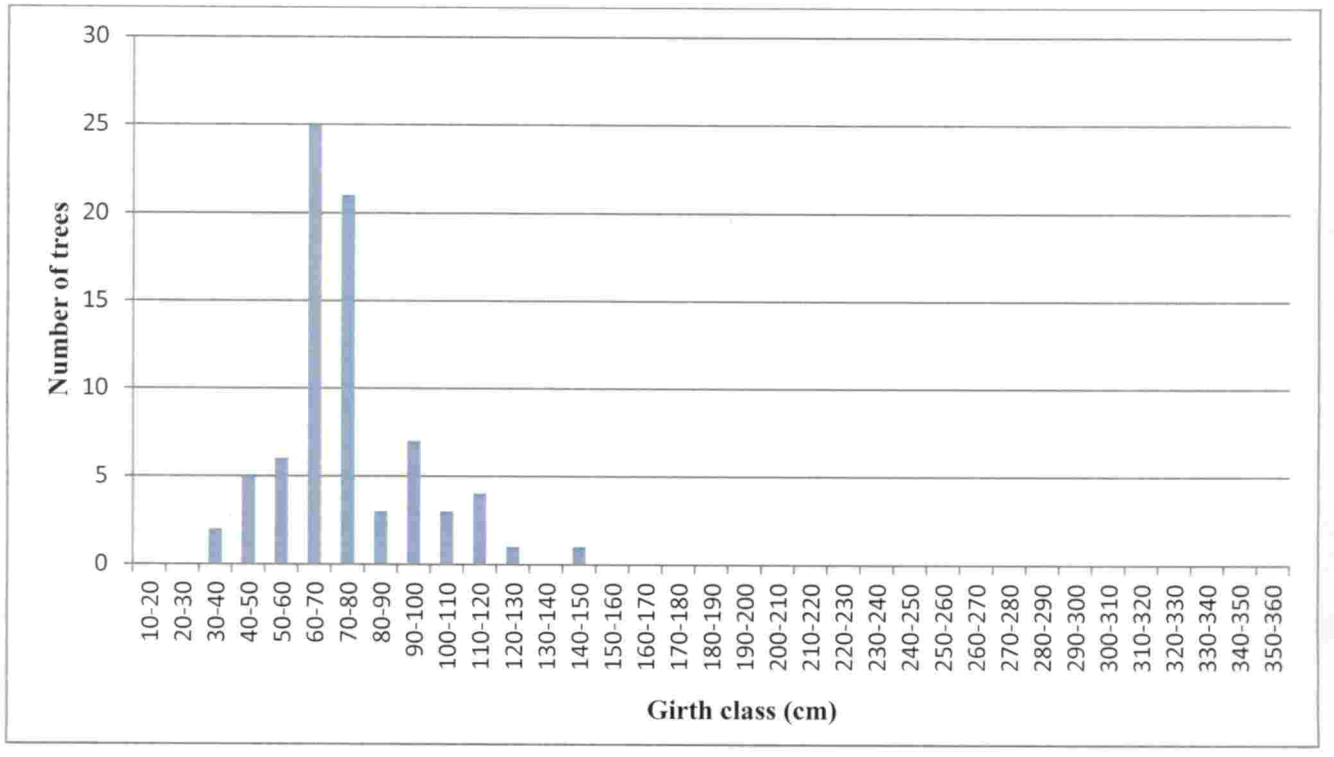


Figure 18. Girth class distribution of *Cassia fistula* at Wayanad Wildlife Sanctuary

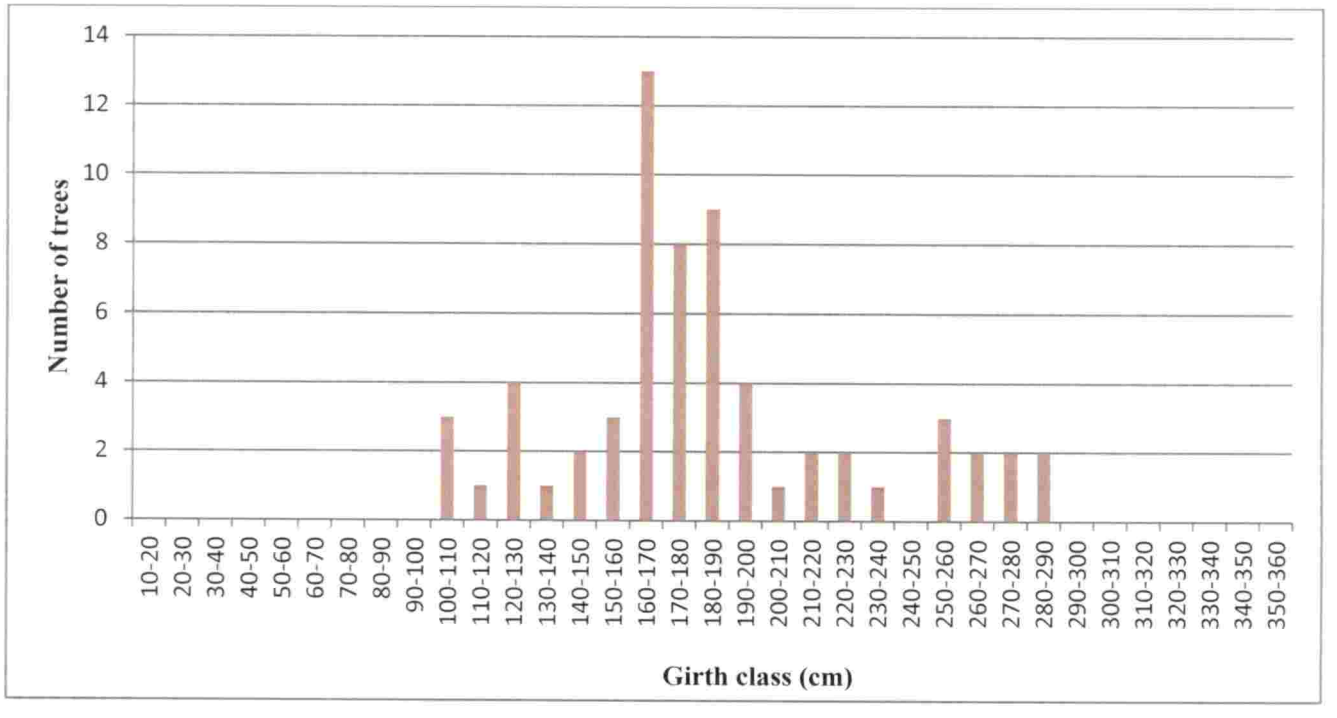


Figure 19. Girth class distribution of *Pterocarpus marsupium* at Wayanad Wildlife Sanctuary

Figure 20. Girth class distribution of *Olea dioica* at Wayanad Wildlife Sanctuary

4.2.3. Diversity indices of various vegetation types

The diversity indices of the all the vegetation in each habitat was calculated and compared between each vegetation type. The indices calculated were species richness, Shannon-Wiener index and Simpson index. It was observed that both species richness, Shannon-Wiener index and Simpson index were highest in mixed moist deciduous habitat. Plantations have the lowest diversity of species. The overall diversity index values of the sanctuary also shows that it has low species diversity and evenness.

The correlation between range-wise elephant density and range-wise tree species diversity indices (Shannon-Wiener Index) was found to be significant in the dry season elephant population density estimate. There was no significance during the wet season. The result of Pearson's correlation for wet season is given in Table 10 and that of dry season is given in Table 11.

Table 9. Tree species richness and diversity of different vegetation types at Wayanad Wildlife Sanctuary

Variables	Habitats			
	Mixed dry deciduous	Mixed moist deciduous	Plantations	Total
Area sampled (ha)	2.8	2.8	0.4	6
Species Richness	48	61	21	67
Shannon-Wiener Index	1.13	1.34	0.64	1.27
Simpson Index	0.87	0.92	0.57	0.9
Basal area per ha	78.76	81.89	80.12	81.06

Table 10. Pearson's Correlation between range-wise elephant density and range-wise tree species diversity indices during the wet season in Wayanad Wildlife Sanctuary

Variables		Shannon- Wiener Index	Simpson's Index
Elephant density	Pearson Correlation	0.768	0.860
	Sig. (2-tailed)	0.232	0.140

Table 11. Pearson's Correlation between range-wise elephant density and range-wise tree species diversity indices during the dry season in Wayanad Wildlife Sanctuary

Variables		Shannon- Wiener Index	Simpson's Index
Elephant Density	Pearson Correlation	0.955*	0.833
	Sig. (2-tailed)	0.045	0.167
	N	4	4

4.2.4. Important Value Index (IVI) of families of tree species in Wayanad Wildlife Sanctuary

The IVI of all families of trees sampled in the sanctuary was calculated. The IVI shows the relative importance of each family, and this was worked out for each habitat also. The family

Combretaceae had the highest IVI in the sanctuary, since the dominant tree species such as *Terminalia elliptica*, *Terminalia elliptica*, *Anogeissus latifolia* etc. occur in this family. Other families with high IVI were Lamiaceae (*Tectona grandis*, *Vitex altissima*), Fabaceae (*Dalbergia latifolia*, *Cassia fistula, Pterocarpus marsupium*) and Lythraceae (*Lagerstroemia microcarpa*). Some of the families with lowest IVI are Lecythidaceae, Santalaceae, Salicaceae, Euphorbiaceae and Magnoliaceae.

The IVI of the families in the two most dominant vegetation types such as moist deciduous forests and dry deciduous forests are given in Table 12 and 13 respectively. In both these vegetation types too, the plant families with the greatest IVI were Combretaceae, Lamiaceae and Fabaceae. However, in the dry deciduous forests there was a greater dominance by the Combretaceae family with an IVI of 42.65 as against an IVI of 22.70 in the case of moist deciduous forests. The Lamiaceae and Fabaceae families in the moist deciduous forests had a greater IVI of 20.00 and 16.78 respectively (Table 12 and Table 13).

Table 12. Important Value Index of the tree families at Wayanad Wildlife Sanctuary

Sl. No.	Species	Relative density	Relative frequency	Relative basal area	Important value index	RIVI
1	Combretaceae	36.04	25.40	32.29	93.73	31.24
2	Lamiaceae	19.47	15.89	23.09	58.46	19.49
3	Fabaceae	13.86	16.65	14.02	44.53	14.84
4	Lythraceae	5.18	6.80	6.78	18.76	6.25
5	Tilliaceae	3.38	4.93	3.68	11.98	3.99
6	Oleaceae	3.02	4.23	2.59	9.85	3.28
7	Myrtaceae	2.24	2.01	2.22	6.47	2.16
8	Phyllanthaceae	2.12	3.40	1.27	6.79	2.26
9	Sapindaceae	2.08	2.91	2.08	7.08	2.36
10	Rubiaceae	2.00	2.78	2.48	7.26	2.42
11	Bignoniaceae	1.96	3.05	2.30	7.32	2.44
12	Elaeocarpaceae	1.49	2.29	0.44	4.22	1.41
13	Verbenaceae	1.06	1.59	0.68	3.34	1.11

14	Anacardiaceae	0.98	1.04	0.85	2.87	0.96
15	Apocynaceae	0.82	1.25	0.19	2.26	0.75
16	Malvaceae	0.79	1.25	0.54	2.57	0.86
17	Flacourtiaceae	0.63	0.35	0.33	1.30	0.43
18	Dipterocarpaceae	0.59	0.83	0.93	2.35	0.78
19	Lauraceae	0.59	0.83	1.35	2.78	0.93
20	Icacinaceae	0.39	0.35	0.09	0.83	0.28
21	Bombacaceae	0.27	0.49	0.52	1.28	0.43
22	Burseraceae	0.20	0.35	0.37	0.91	0.30
23	Rutaceae	0.16	0.14	0.05	0.35	0.12
24	Proteaceae	0.12	0.21	0.13	0.45	0.15
25	Araliaceae	0.12	0.21	0.12	0.44	0.15
26	Meliaceae	0.12	0.21	0.26	0.59	0.20
27	Rhamnaceae	0.08	0.14	0.05	0.27	0.09
28	Euphorbiaceae	0.04	0.07	0.01	0.12	0.04
29	Dilleniaciae	0.04	0.07	0.16	0.27	0.09
30	Magnoliaceae	0.04	0.07	0.08	0.19	0.06
31	Salicaceae	0.04	0.07	0.01	0.12	0.04
32	Santalaceae	0.04	0.07	0.01	0.12	0.04
33	Lecythidaceae	0.04	0.07	0.03	0.14	0.05

Table 13. Important Value Index of the tree families in dry deciduous habitat of Wayanad Wildlife Sanctuary

Sl. No.	Species	Relative density	Relative frequency	Relative basal area	Important value index	RIVI
1	Combretaceae	50.75	32.59	44.59	127.94	42.65
2	Lamiaceae	14.43	15.11	19.43	48.97	16.32
3	Fabaceae	11.10	15.41	13.36	39.87	13.29
4	Lythraceae	3.41	5.04	3.95	12.40	4.13
5	Oleaceae	3.33	5.19	3.24	11.76	3.92
6	Tilliaceae	3.33	5.04	3.09	11.46	3.82

7	Phyllanthaceae	2.30	3.56	2.89	8.74	2.91
8	Rubiaceae	2.06	3.11	2.25	7.42	2.47
9	Sapindaceae	1.90	2.67	1.64	6.21	2.07
10	Bignoniaceae	1.51	2.67	1.40	5.57	1.86
11	Elaeocarpaceae	1.19	1.93	0.97	4.09	1.36
12	Myrtaceae	1.11	1.93	0.61	3.64	1.21
13	Verbenaceae	0.95	1.48	0.44	2.87	0.96
14	Apocynaceae	0.71	1.04	0.43	2.18	0.73
15	Anacardiaceae	0.40	0.74	0.43	1.56	0.52
16	Dipterocarpaceae	0.32	0.59	0.32	1.23	0.41
17	Rutaceae	0.24	0.15	0.26	0.64	0.21
18	Bombacaceae	0.24	0.44	0.25	0.94	0.31
19	Lauraceae	0.24	0.44	0.15	0.83	0.28
20	Burseraceae	0.16	0.30	0.15	0.60	0.20
21	Icacinaceae	0.08	0.15	0.10	0.33	0.11
22	Malvaceae	0.08	0.15	0.02	0.25	0.08
23	Santalaceae	0.08	0.15	0.02	0.25	0.08
24	Araliaceae	0.08	0.15	0.01	0.24	0.08

Table 14. Important Value Index of the tree families in moist deciduous habitat of Wayanad Wildlife Sanctuary

Sl. No.	Species	Relative density	Relative frequency	Relative basal area	Important value index	RIVI
1	Combretaceae	23.85	20.12	24.13	68.10	22.70
2	Lamiaceae	21.01	15.42	23.56	59.99	20.00
3	Fabaceae	17.52	18.36	14.46	50.34	16.78
4	Lythraceae	7.89	8.96	10.29	27.14	9.05
5	Tilliaceae	3.76	4.99	4.43	13.19	4.40
6	Oleaceae	2.75	3.38	3.15	9.28	3.09
7	Bignoniaceae	2.66	3.52	2.63	8.81	2.94
8	Sapindaceae	2.57	3.38	2.39	8.34	2.78

9	Rubiaceae	2.20	2.64	2.17	7.01	2.34
10	Phyllanthaceae	2.11	3.38	2.08	7.57	2.52
11	Elaeocarpaceae	2.02	2.79	1.71	6.52	2.17
12	Anacardiaceae	1.83	1.47	1.53	4.83	1.61
13	Myrtaceae	1.47	1.47	1.49	4.43	1.48
14	Flacourtiaceae	1.47	0.73	0.80	3.00	1.00
15	Verbenaceae	1.28	1.76	0.70	3.75	1.25
16	Apocynaceae	1.10	1.62	0.69	3.40	1.13
17	Lauraceae	1.10	1.32	0.55	2.98	0.99
18	Icacinaceae	0.83	0.59	0.54	1.96	0.65
19	Bombacaceae	0.37	0.59	0.54	1.49	0.50
20	Burseraceae	0.28	0.44	0.51	1.23	0.41
21	Malvaceae	0.28	0.44	0.35	1.06	0.35
22	Meliaceae	0.28	0.44	0.27	0.99	0.33
23	Proteaceae	0.28	0.44	0.25	0.97	0.32
24	Dipterocarpaceae	0.18	0.29	0.17	0.64	0.21
25	Araliaceae	0.18	0.29	0.16	0.64	0.21
26	Rhamnaceae	0.18	0.29	0.13	0.60	0.20
27	Euphorbiaceae	0.09	0.15	0.11	0.35	0.12
28	Salicaceae	0.09	0.15	0.10	0.34	0.11
29	Dilleniaciae	0.09	0.15	0.05	0.29	0.10
30	Lecythidaceae	0.09	0.15	0.02	0.26	0.09
31	Magnoliaceae	0.09	0.15	0.02	0.26	0.09
32	Rutaceae	0.09	0.15	0.01	0.25	0.08

4.3. Socio – economic survey done around elephant habitats in Wayanad Wildlife Sanctuary

4.3.1 Socio – economic survey conducted for local communities at Wayanad Wildlife Sanctuary

4.3.1.1. Basic Details of the respondents

The basic details about the residents in and around the sanctuary was studied through household survey (Table 15). Thirty households were surveyed to understand the severity of the problems caused due to human – elephant conflict. Analysis of these data revealed that the population of children in the households accounted to 36 percentage and the female (33.9%) to male (30.8%) ratio is more than 1. The age studies showed a significant difference between the numbers of people belonging to each group. Majority of the household members belong to the age group of 50 years – 70 years. Only 3% of the total population surveyed were in the age group less than 30 years. Thirty percent of the members were between 30 years and 50 years of age. Out of the 30 families, 20 families have been residing in the sanctuary for more than 50 years and only 3 families were belonging to the class less than 30 years. 50% of the members had an educational qualification below 10^{th} grade and 33.3% members were SSLC holders. Four among the total members were graduates. 56.67% of the families were registered under Below Poverty Line (BPL). Majority of the members (53.33%) were depending on agriculture for their livelihood and the remaining members were depending on other sources like daily wage labour, forest products etc., for their sustenance. Table 15 also shows the distance of respondent households from the adjacent forests. The results depicts that 30% of the households are more or less bordering the forests that is, at a distance less than 20m, 33% were situated at a distance less than 100m and a 20% of the household were situated at distance more than 500 m which ranged up to 2000m. The remaining 17% were dotted between a distance of 100m and 500m.

4.3.1.2. Natural Resource Knowledge and Use

The perception of residents on changes in the area around the residing village is given in Table 16 (Figure 21). Majority (66.67%) stated that an increase in forest area has occurred in the past 10 years whereas 30% of the respondents stated that neither an increase nor a decrease in the forest area has occurred and only 3% of the respondents conceded that there is a decrease in forest area. Eighty percent of the respondents stated that the wild animal population has increased over past 10 years and the remaining respondents state the population of wild animals

remains same. No change in water sources has been observed by 90% of the households while a 10% of the respondents agree that a reduction in water sources have occurred in the previous years. Ten percent of the respondents stated that the area under agriculture has increased while 56.67% of them responded that the area under agriculture has not undergone any change.

The response about the changes in the climate is given in Table 17 (Figure 22). The response to the change in temperature was invariably stated as highly increased by all the respondents. 63.33% of the interviewees had the opinion that the trend in wind velocity had changed to high velocity hot winds. When 90% of the respondents stated that the water availability has been adequate, 76.67% responded that rainfall pattern remains the same over the past 10 years.

Table 18 shows the percentage of periodicity of movement of the villagers inside the forest. Forty percent of the respondents access the forest frequently for different purposes whereas only 7% of the respondents do not enter the forest for any purposes.

Table 15. Basic details of the household respondents of Wayanad Wildlife Sanctuary

Category (N=30)	Variable	Frequency	Percentage
Gender	Male	49	47.57
	Female	54	52.43
Age	Less than 30 yrs	1	3.33
	30yrs – 50 yrs	9	30
	50 yrs – 70 yrs	16	53.33
	More than 70 yrs	4	13.33
Residing Period	Less than 30 yrs	3	10
	30yrs – 50 yrs	7	23.33
	50 yrs – 70 yrs	10	33.33
	More than 70 yrs	10	33.33
Education level	Below SSLC	15	50
	SSLC	10	33.33
	Degree	4	13.33
	No schooling	1	3.33
Economic Status	APL	13	43.33
	BPL	17	56.67
Occupation	Farmers	16	53.33
	Others	14	46.67
Household members	1.0-3.0	0	0
	3.0-5.0	8	26.67
	5.0-7.0	15	50

	7.0-9.0	7	23.33
Distance from households to nearby forests	<20m	9	30
	20-50m	5	16.67
	50-100m	5	16.67
	100-500m	5	16.67
	500-2000m	4	13.33
	>2000m	2	6.67

Table 16. Changes in the land use, wild animals and domestic animal population at Wayanad Wildlife Sanctuary

Variables	Increased		Remain Same		Decreased	
(N=30)	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Forest Area	20	66.67	9	30	1	3.33
Wild animals	24	80	6	20	0	0
Domestic animals	12	40	18	60	0	0
Water sources	0	0	27	90	3	10
Agricultural Land	3	10	17	56.67	10	33.33

Table 17. Changes in the Climate in and around the villages in Wayanad Wildlife sanctuary

Variables	Increased		Remain Same		Decreased	
(N=30)	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Temperature	30	100	0	0	0	0
Wind speeds	19	63.33	4	13.33	7	23.33
Rainfall pattern	0	0	23	76.67	7	23.33
Water availability	0	0	27	90	3	10

Table 18. The frequency of forest dependency by the villagers at Wayanad Wildlife sanctuary

Variables **(N=30)**	Frequency	Percentage
Never	7	23.33
Occasionally	12	40
Frequent	7	23.33
Always	4	13.33

Figure 21. Changes in the land use, wild animals and domestic animal population at Wayanad Wildlife Sanctuary

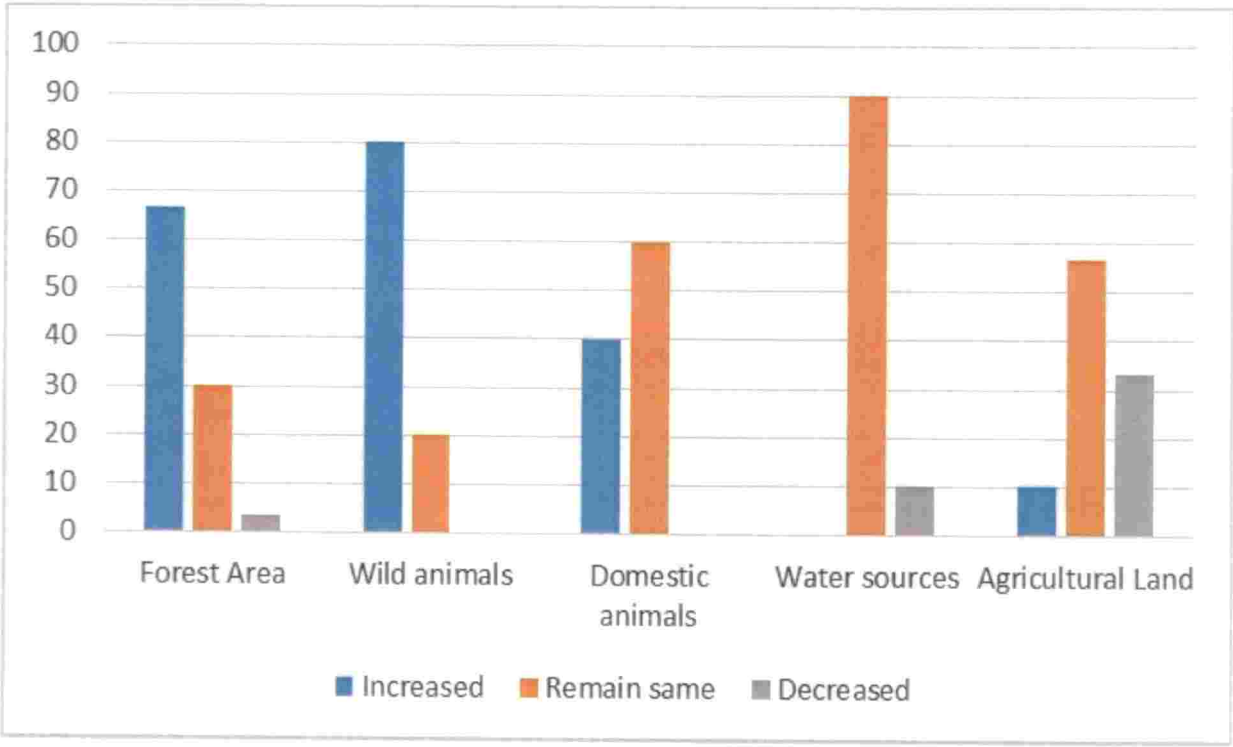
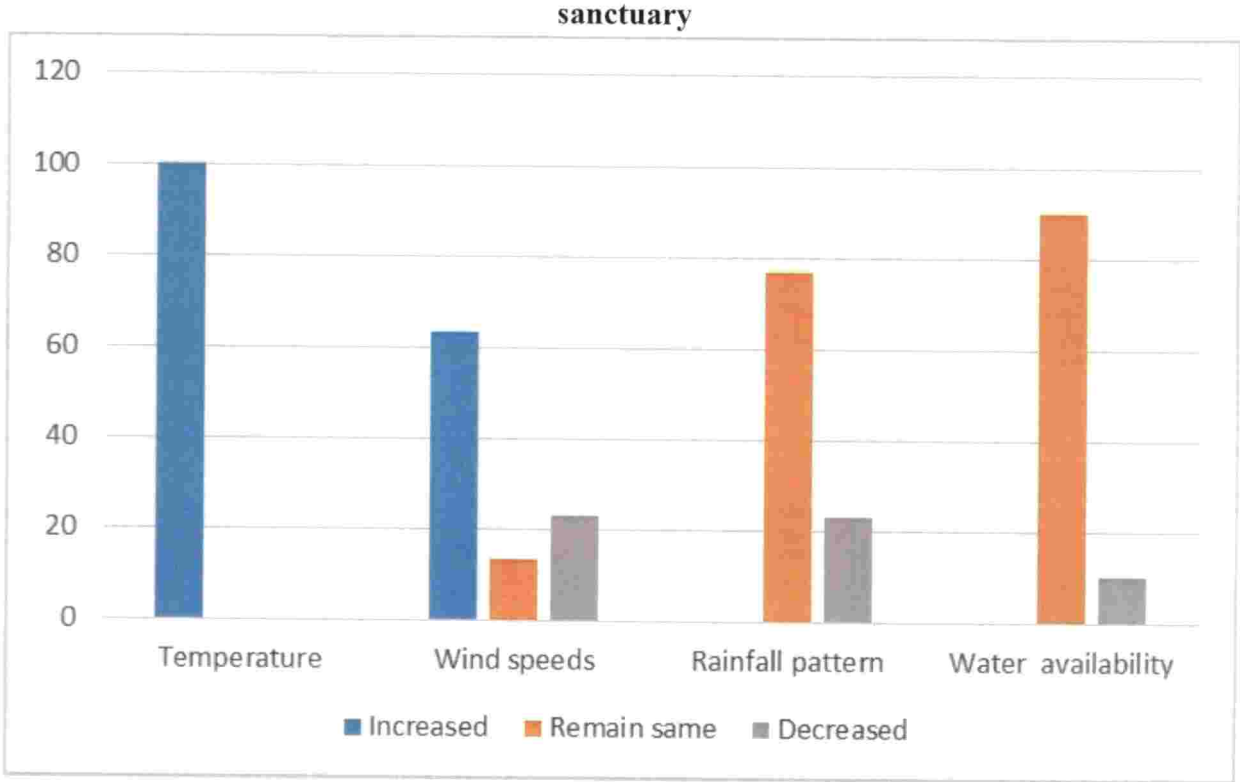


Figure 22. Changes in the Climate in and around the villages in Wayanad Wildlife sanctuary



4.3.1.3. Human-Elephant Conflict at Wayanad Wildlife Sanctuary

The foremost question of the survey under this section was to know the problematic wild animals in the area (Table 19). Ninety percent of the villagers stated that elephants are the most problematic animals at Wayanad Wildlife Sanctuary followed by Wild Boar (50%). Tiger and Spotted Deer are considered to be a relatively problematic animal by 10% and 40% respectively. Ten percent of the respondents suggested that elephants caused little or no problems.

Eighty percent of the damage caused due to human- elephant conflict was crop raiding (Table 20). Property damage was minimal but a significant incidence of human casualty or injury has been reported (43.33%) by the villagers.

The most commonly raided crops by elephants over the past 5 years are paddy, banana, arecanut, coffee, jack and tapioca (Table 21). Among these six crops, paddy is the most raided crop (73.33%) followed by banana (63.33%). The percentage incidence of crop raiding in arecanut plantations is 46.67%. Considerable raiding occurs in tapioca (26.67%) and coffee (23.33%) plantations too.

The time of occurrence of damage caused by elephants are given in Table 20. Maximum occurrence of any damage is recorded in night than during any other time in a day. Eighty percent of the crop damage, 56.67% of property damage and 26.67% of human casualty plights have been reported to occur in the night. The chance of incidents to occur at any time of a day was 16.67% for crop damage, 6.67% for property damage and 33.33% for human casualty. 3.33% of crop damage and human casualty have been reported to occur during dawn.

The trend of damage caused by elephants over past 5 years have been recorded in Table 21 (Figure 23). More than 50% of the respondents revealed that the incidence of crop raiding has highly increased where as 23.33% of the respondents had the opinion that the occurrence of crop raiding remained the same. Approximately 40% the respondents stated that human casualty has increased over the past 5 years and 56.67% stated that property damage have found to have an increased occurrence.

Table 19. The animal wise severity of conflict at Wayanad Wildlife Sanctuary

(N=30)	Elephants (%)	Wild Boar (%)	Tiger (%)	Spotted Deer (%)
Most problematic	90	50	0	0
Relatively problematic	0	30	10	40
Not problematic	10	0	10	0

Table 20. The severity of types of conflict at Wayanad Wildlife Sanctuary

Variables (N=30)	Frequency	Percentage
Crop damage	24	80
Property damage	6	20
Human casualty	13	43.33

Table 21. The most raided crops by the elephants at Wayanad Wildlife Sanctuary

Crops (N=30)	Frequency	Percentage
Banana	19	63.33
Paddy	22	73.33
Arecanut	14	46.67
Jack	2	6.67
Tappioca	8	26.67
Coffee	7	23.33

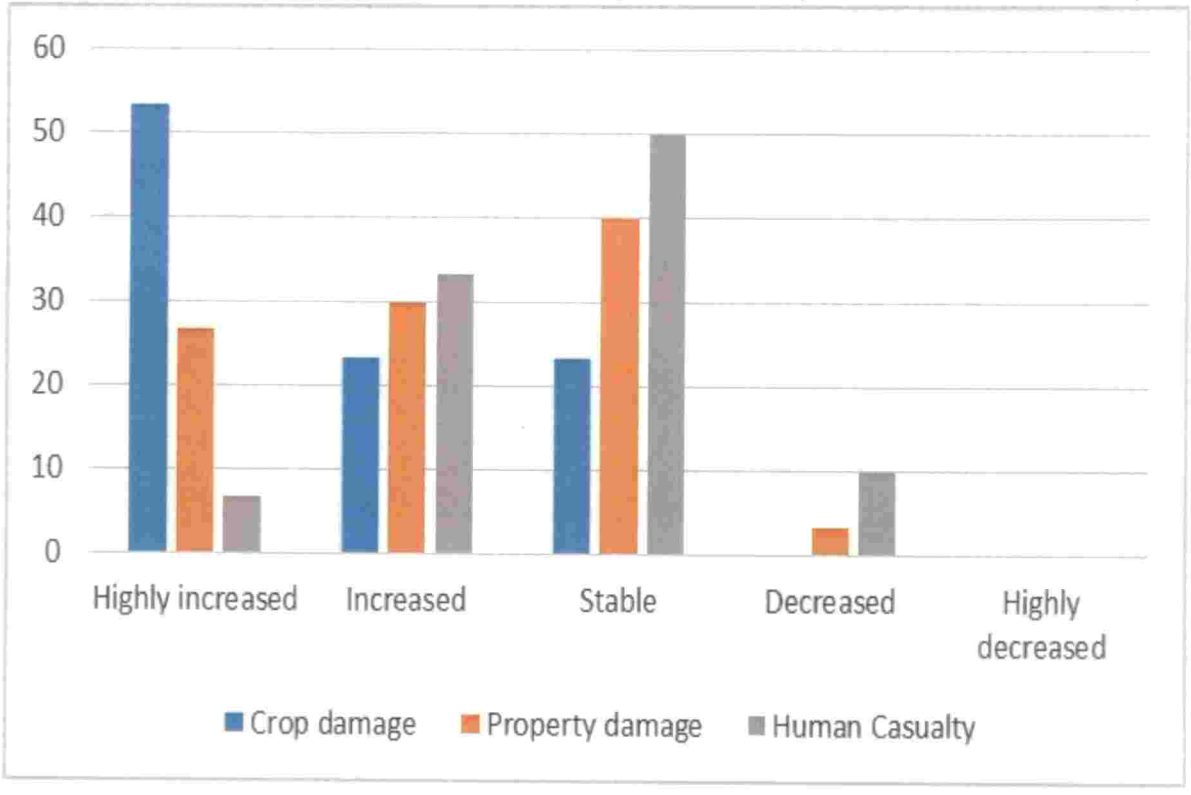
Table 22. Time of occurrence of conflict at Wayanad Wildlife Sanctuary

Variables	Crop Damage		Property damage		Human Casualty	
(N=30)	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Dawn	1	3.33	0	0	1	3.33
Morning	0	0	0	0	0	0
Afternoon	0	0	0	0	0	0
Dusk	0	0	0	0	0	0
Night	24	80	17	56.67	8	26.67
Any time	5	16.67	2	6.67	10	33.33

Table 23. Trend of damage caused by elephants at Wayanad Wildlife Sanctuary

Variables	Crop Damage		Property damage		Human Casualty	
(N=30)	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Highly increased	16	53.33	8	26.67	2	6.67
Increased	7	23.33	9	30	10	33.33
Stable	7	23.33	12	40	15	50
Decreased	0	0	1	3.33	3	10
Highly decreased	0	0	0	0	0	0

Figure 23. Trend of damage caused by elephants at Wayanad Wildlife Sanctuary



4.3.1.4 Prevention and mitigation measures to overcome the human wildlife conflict at Wayanad Wildlife Sanctuary

The various measures adopted for reducing human - elephant conflict in the sanctuary are deterrents, elephant squad, physical barriers, power fence, compensation and capturing and relocation of problem elephants. The percentage extend of implementation of these measures is given in Table 24.

The effectiveness of the different methods adopted to reduce human- elephant conflict have been analysed from the response of the villagers (Table 25 & Figure 24). The results of the survey shows that elephant squad (33.3%) was the most effective method of all the six methods adopted followed by capturing of the problem elephants (23.33%). Use of any physical barriers (16.67%) or power fence (13.33%) were reported to be less effective by the respondents. Measures like the use of deterrents and the provision of compensation were found to be the most ineffective methods.

Majority of the respondents (76.67%) who has availed compensation for various damages point out that the amount of compensation is highly inadequate to cover the loss they have

undergone. Only 6.67% of the interviewees stated that the provided compensation was adequate to make up their loss due to elephant raiding (Table 26).

Table 24. The type of human elephant conflict mitigation measures adopted at Wayanad Wildlife Sanctuary

Measures (N=30)	Frequency	Percentage
Deterrents	25	83.33
Elephant Squad	21	70
Physical Barriers	21	70
Power fence	23	76.67
Compensation	21	70
Capturing problem elephants (CPE)	24	80

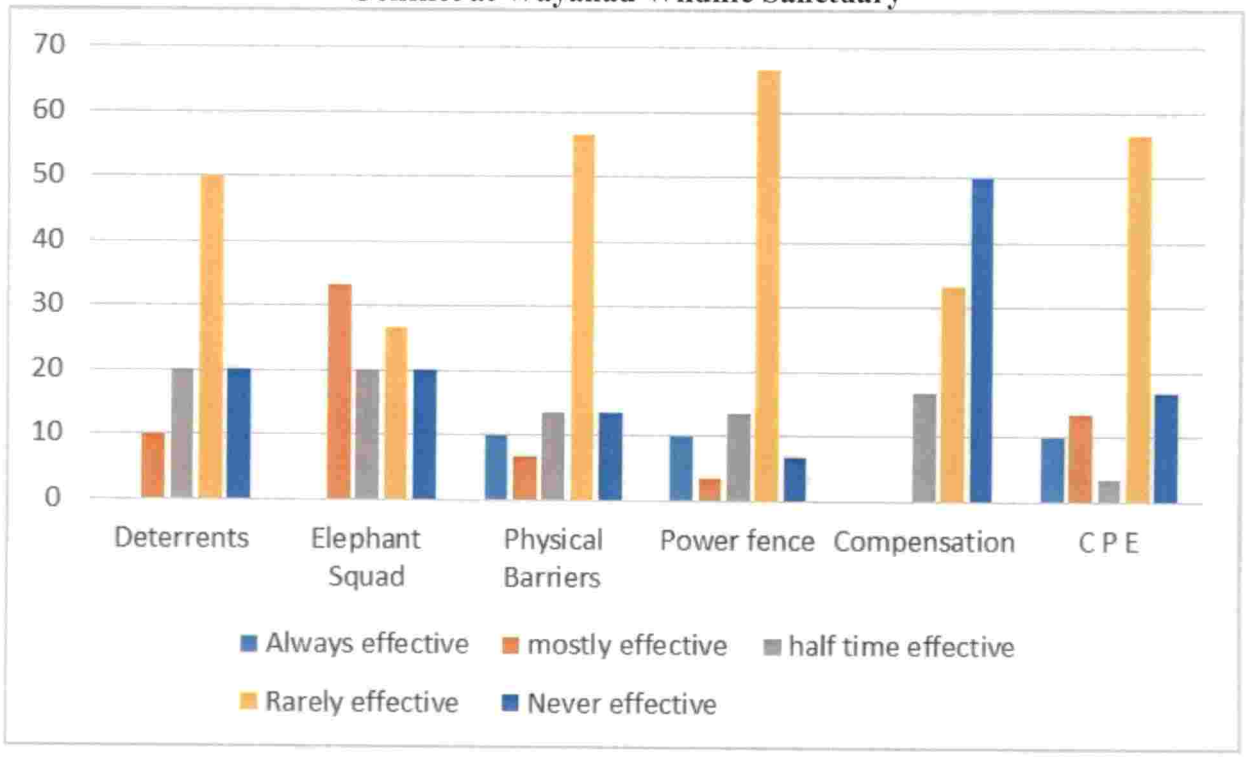
Table 25. Effectiveness of the mitigation measures adopted to reduce human - elephant Conflict at Wayanad Wildlife Sanctuary

Measures (N=30)	Deterrents		Elephant Squad		Physical Barriers		Power Fence		Compensation		Capturing Problem Elephant	
Variables	F	P	F	P	F	P	F	P	F	P	F	P
Always effective	0	0	0	0	3	10	3	10	0	0	3	10
Mostly effective	3	10	10	33.33	2	6.667	1	3.33	0	0	4	13.3
Half time effective	6	20	6	20	4	13.33	4	13.3	5	16.667	1	3.33
Rarely effective	15	50	8	26.67	17	56.67	20	66.7	10	33.333	17	56.7
Never effective	6	20	6	20	4	13.33	2	6.67	15	50	5	16.7

Table 26. Satisfaction level of respondents towards the compensation package being implemented at Wayanad Wildlife Sanctuary

Variables (N=30)	Frequency	Percentage
Adequate	2	6.67
Par adequate	5	16.67
Inadequate	23	76.67

Figure 24. Effectiveness of the mitigation measures adopted to reduce Human Elephant Conflict at Wayanad Wildlife Sanctuary



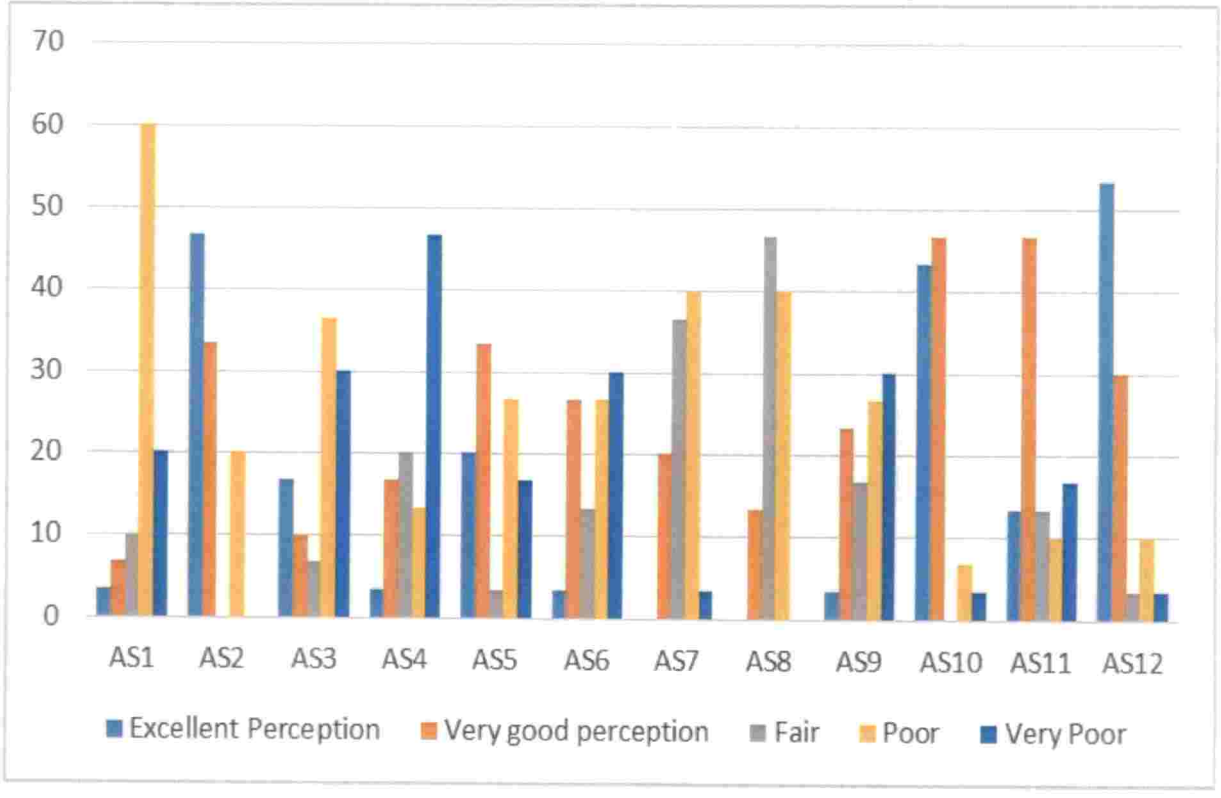
4.3.1.5 Perception about human – elephant conflict and elephant conservation

The perception of villagers about the human – elephant conflict and conservation of elephants are presented in Table 27 (Figure 25). Eighty percent of the respondents opinionated that the reduction in the availability of food and water sources in the forests associated with the cultivation of crops that attract the elephants like pineapple, sugarcane, paddy etc. is the major cause for crop raiding by elephants and the resulting conflict between human and elephants. 90% of the respondents stated that quick interventions by forest officials help in reducing elephant conflict. The perception of influence of poaching, hunting and illegal hunting had no significant role in increasing human elephant conflict. There was a very poor perception that the timely compensation to cope up with the loss due to damage can help reducing human elephant conflict.

Table 27. Perception about human – elephant conflict and elephant conservation

Variables **(N=30)**	Excellent		Very good		Fair		Poor		Very Poor	
Category	F	P	F	P	F	P	F	P	F	P
Expansion of human population into wildlife habitats(AS1)	1	3.33	2	6.667	3	10	18	60	6	20
Reduction in availability of food and water(AS2)	14	46.67	10	33.33	0	0	6	20	0	0
Lack of proper planning (AS3)	5	16.67	3	10	2	6.67	11	36.67	9	30
Poaching and hunting(AS4)	1	3.33	5	16.67	6	20	4	13.33	14	46.7
Keeping distance from forests for farming (AS5)	6	20	10	33.33	1	3.33	8	26.67	5	16.7
Farming repellent plants(AS6)	1	3.333	8	26.67	4	13.33	8	26.67	9	30
Sufficient Compensation(AS7)	0	0	6	20	11	36.67	12	40	1	3.33
Timely compensation(AS8)	0	0	4	13.33	14	46.67	12	40	0	0
Ecotourism(AS9)	1	3.33	7	23.33	5	16.67	8	26.67	9	30
Official's quick interventions(AS10)	13	43.33	14	46.67	0	0	2	6.67	1	3.33
Understanding the predictable behavioural pattern of wild animals(AS11)	4	13.33	14	46.67	4	13.33	3	10	4	16.7
Cultivation of tempting crops(AS12)	16	53.33	9	30	1	3.333	3	10	1	3.33

Figure 25. Perception about human – elephant conflict and elephant conservation



4.3.1.6 The trend of elephant population at Wayanad Wildlife Sanctuary

An approximate estimation of any change in the population of elephants in the sanctuary has been assessed during the survey. 63% stated that the elephant population in the sanctuary is increasing while 23% stated that the elephant population has decreased (Table 28).

Table 28. The trend of elephant population at Wayanad Wildlife Sanctuary

Variables (N=30)	Frequency	Percentage
Increasing	19	63.33
Stable	4	13.33
Decreasing	7	23.33

4.3.1.7. Action suggested to minimize human- elephant conflict

The perception of people towards the action needed to reduce human– elephant conflicts is given in Table 29. More than 50 percent of the householders claimed that either a support to construct permanent houses or a support for alternative livelihood or crops can help reduce the consequences of human- elephant conflict. On an average eighty five percent of the respondents were against the choices of killing the problem elephants or capturing and relocating all the elephants. Thirty three percent of the respondents stated that capturing and relocating the problem elephants can reduce the negative impacts of human - elephant conflict.

Table 29. Action suggested to minimize human - elephant conflict

Variables (N=30)	Yes		No	
	Frequency	Percentage	Frequency	Percentage
Capture and relocate problem elephants (A1)	10	33.33	20	66.67
Kill the problem elephants (A2)	5	16.66	25	83.34
Capture and relocate all the elephants (A3)	4	13.33	26	86.67
Support to construct permanent houses (A4)	16	53.33	14	46.66
Support for alternative livelihood/ crops (A5)	16	53.33	14	46.66

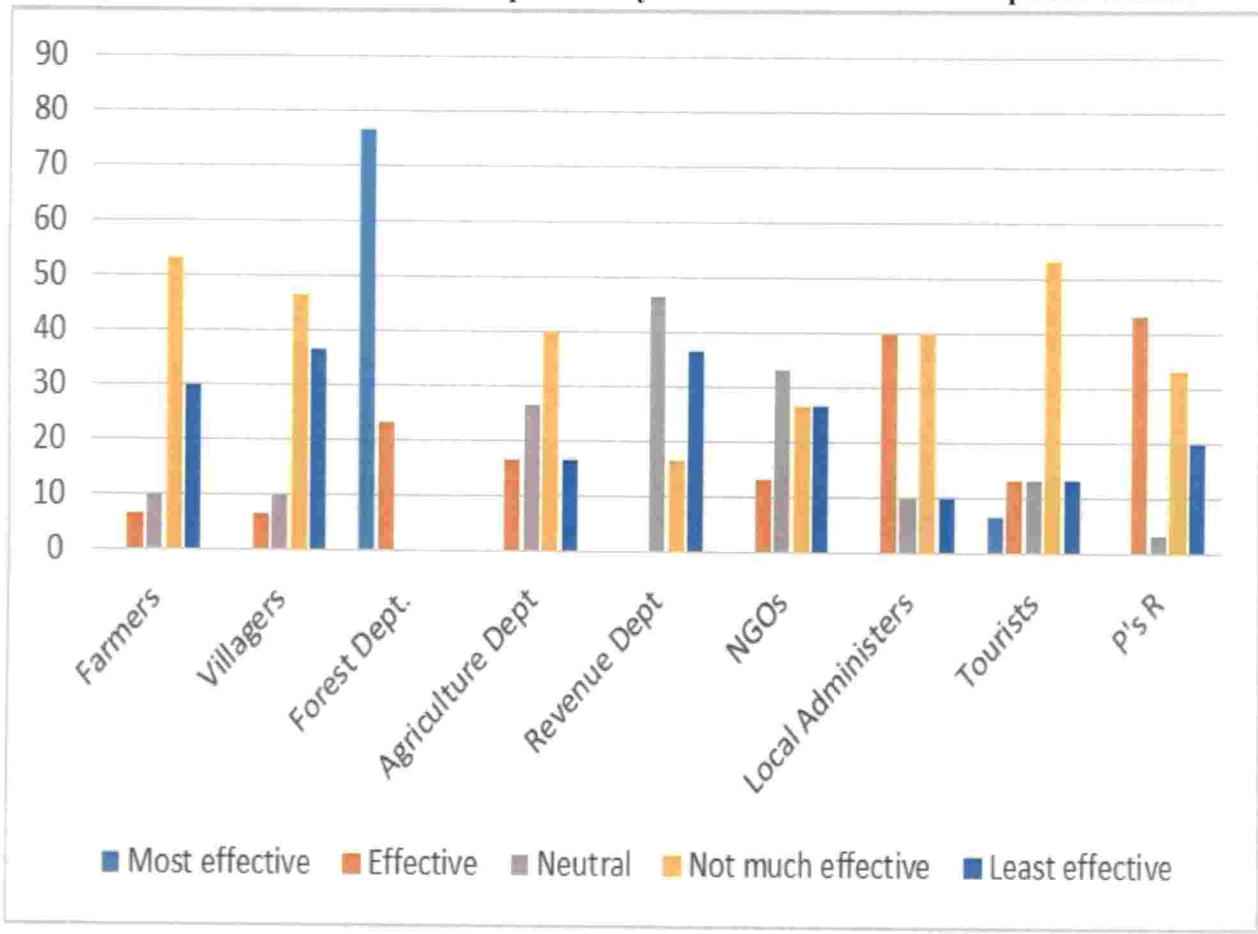
4.3.1.8. Whom to take the responsibility to reduce the human - elephant conflict

The details of different personnel in taking responsibility for reducing conflict with wildlife have been taken and is given in Table 30 and Figure 26. The role of forest department officials in reducing the human elephant conflict was invariably accepted by every respondent and is suggested as the most effective action. The results also revealed that the effectiveness of local administrators and people's representative responsibility to take actions is forty percent. The response of respondents show that the role of farmers, villagers, agriculture department and revenue department are 80% ineffective while the role of tourists and NGOs was stated as being effective by 13.33% respondents in reducing the human - elephant conflict.

Table 30. Whom to take the responsibility to reduce the human - elephant conflict

(N=30)	Most effective		Effective		Neutral		Not much effective		Least effective	
	F	P	F	P	F	P	F	P	F	P
Farmers	0	0	2	6.67	3	10	16	53.33	9	30
Villagers	0	0	2	6.67	3	10	14	46.67	11	36.67
Forest Dept.	23	76.67	7	23.3	0	0	0	0	0	0
Agriculture Dept.	0	0	5	16.7	8	26.67	12	40	5	16.67
Revenue Dept.	0	0	0	0	14	46.67	5	16.67	11	36.67
NGOs	0	0	4	13.3	10	33.33	8	26.67	8	26.67
Local Administers	0	0	12	40	3	10	12	40	3	10
Tourists	2	6.667	4	13.3	4	13.33	16	53.33	4	13.33
People's Representatives	0	0	13	43.3	1	3.33	10	33.33	6	20

Figure 26. Whom to take the responsibility to reduce the human - elephant conflict



4.3.1.9. Necessity of Human-Elephant Coexistence

Survey was conducted to study the perception of the villagers toward human - elephant co - existence (Table 31). While 43% of the respondents were willing to accept human - elephant co - existence, another 40% among the respondents demanded for relocating the villagers to the buffer zone, whereas the remaining 17% claimed for relocating the elephants.

Table 31. Necessity of Human-Elephant Coexistence

Variables **(N=30)**	Frequency	Percentage
Yes	13	43.33
No, relocate people to buffer zone	12	40
No, relocate elephants	5	16.67

4.3.1.10 Awareness about Forest and Biodiversity Rules and Laws

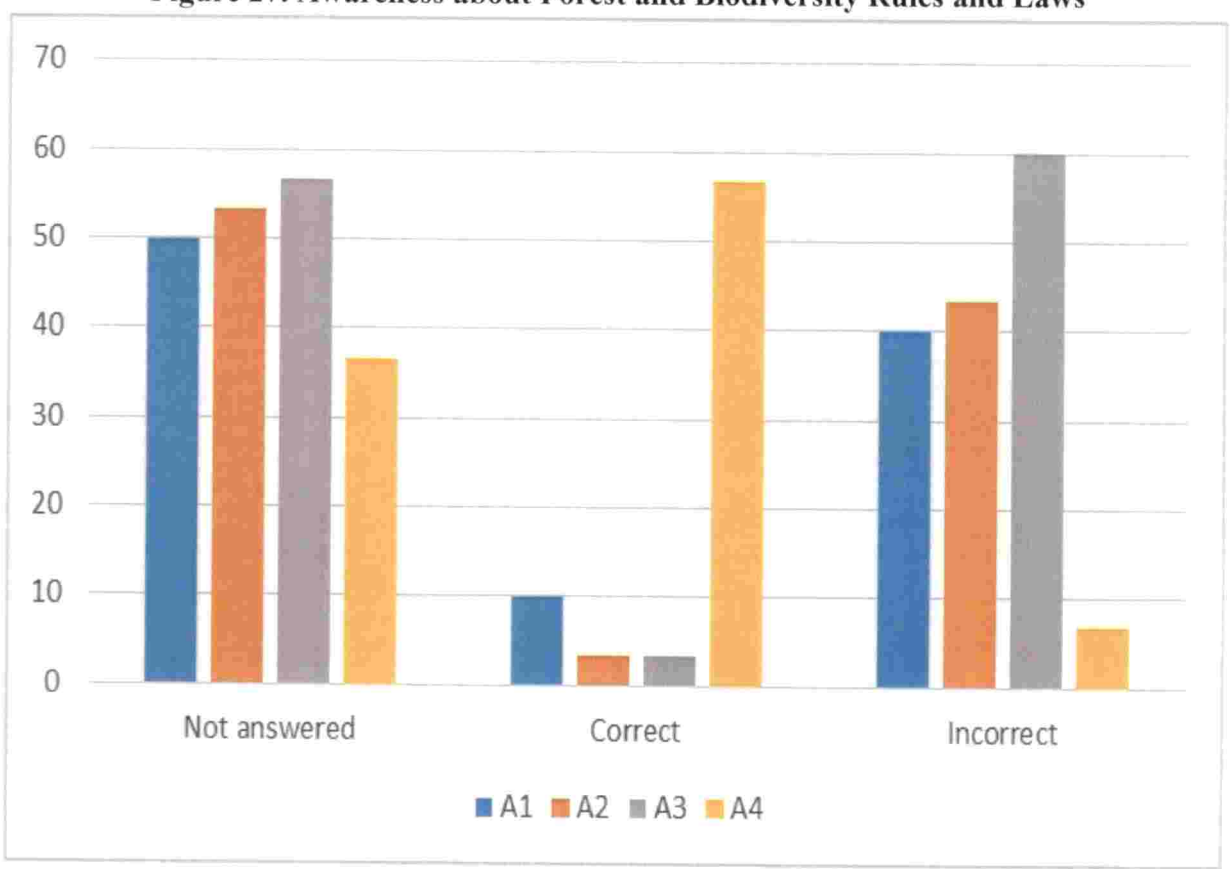
The awareness of residents about the forest and biodiversity rules and laws has been assessed and the result is given in Table 32. Ninety percent of the householders were unaware of the forest rules and laws, the schedule to which elephants belongs as per Wildlife Protection Act, 1972 and the definition of hunting as per the act. Nearly 56.67% of the respondents were

conscious that hunting or poaching of elephants are not allowed as per the Wildlife Protection Act, 1972 (Figure 27).

Table 32. Awareness about Forest and Biodiversity Rules and Laws

Category **(N=30)**	Variable	Frequency	Percentage
Name the forest rules and laws	Not answered	15	50
	Correct	3	10
	Incorrect	12	40
Elephant belongs to which schedule in Wildlife Protection Act, 1972	Not answered	16	53.33
	Correct	1	3.33
	Incorrect	13	43.33
Hunting as per Wildlife Protection Act, 1972	Not answered	17	56.67
	Correct	1	3.33
	Incorrect	18	60
Hunting of elephant as per Wildlife Protection Act, 1972	Not answered	11	36.67
	Correct	17	56.67
	Incorrect	2	6.67

Figure 27. Awareness about Forest and Biodiversity Rules and Laws



4.3.2 Socio – economic survey of forest officials at Wayanad Wildlife Sanctuary

The intensity of the human elephant conflicts cannot be completely understood by conducting household survey alone. Hence an interview schedule for forest officials have been prepared and survey was conducted to study the perception of officials on the causes and consequences of the human elephant conflict. The forest officials surveyed included 4 rangers, 6 foresters, 9 beat forest officers and 11 forest watchers. The results of the survey is presented here.

4.3.2.1 Natural Resource Knowledge and Use

Table 33 shows the response of forest officials to the change in area in and around the sanctuary. When 33.33% of the officials stated that there is an increase under the total forest area, 50% of the officials mentioned that a decrease in forest area has observed over the past 10 years. Seventy seven percent of the respondents stated that an increase in the wild animal population has been observed with a decrease in the availability of water sources. A reduction in the area under agriculture has been stated by ninety seven percent of the officials (Figure 28).

The response of the officers towards the change in climate over the past 10 years is given in Table 34 (Figure 29). The perception of every officers was found to be same on the opinion that there is an increase in the temperature and a significant decrease in the availability of water in the study area. When 53.3% of the officers stated that an increase in the wind speed associated with hot air currents have observed approximately 73.3% of the officials stated that a decrease in the rainfall pattern has occurred during the past years.

Table 33. Changes in the land use, wild animals and domestic animal population at Wayanad Wildlife Sanctuary

Variables	Increased		Remain Same		Decreased	
(N=30)	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Forest Area	10	33.33	5	16.67	15	50
Wild animals	23	76.67	4	13.33	3	10
Domestic animals	6	20	8	26.67	16	53.33
Water sources	0	0	7	23.33	23	76.67
Agricultural Land	0	0	1	3.33	29	96.67

Table 34. Changes in the Climate in and around the villages in Wayanad Wildlife sanctuary

Variables	Increased		Remain Same		Decreased	
(N=30)	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Temperature	30	100	0	0	0	0
Wind speeds	16	53.33	4	43.33	1	3.37
Rainfall pattern	0	0	23	26.67	22	73.33
Water availability	0	0	27	0	30	100

Figure 28. Changes in the land use, wild animals and domestic animal population at Wayanad Wildlife Sanctuary

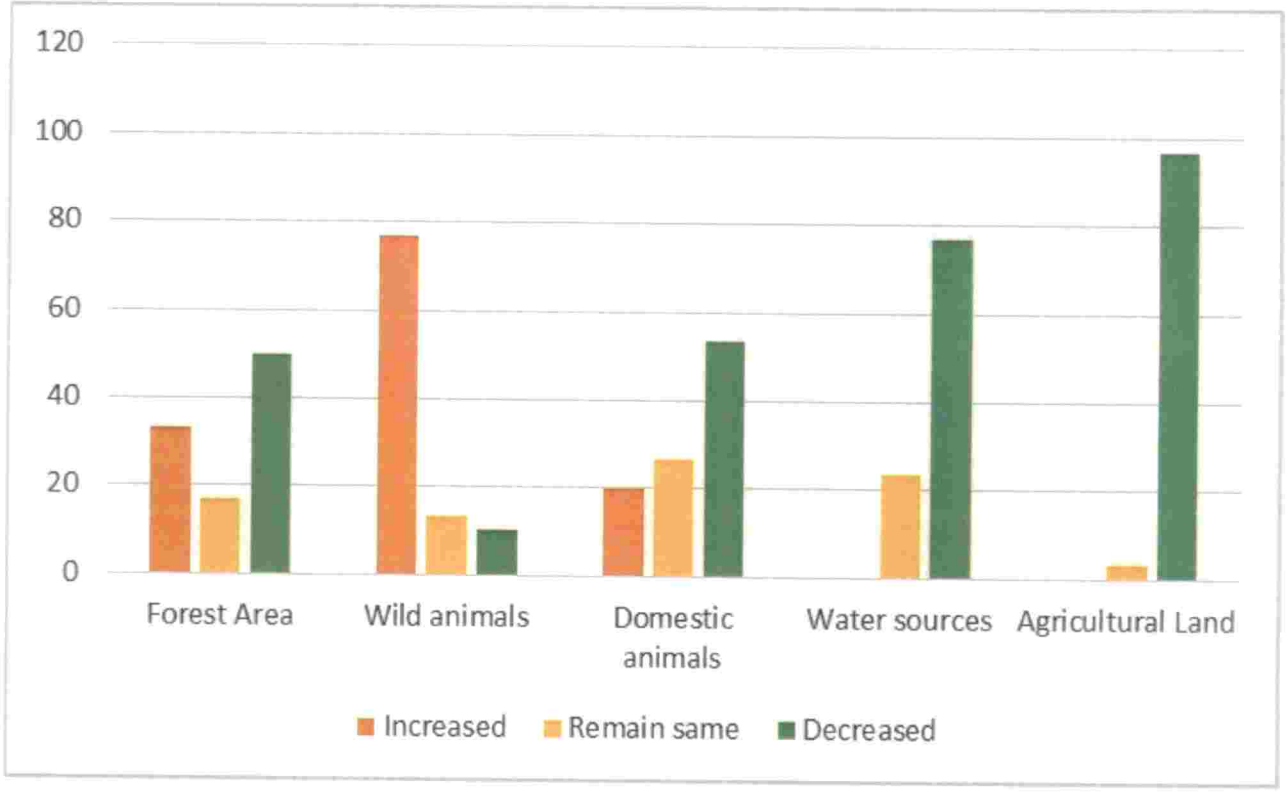
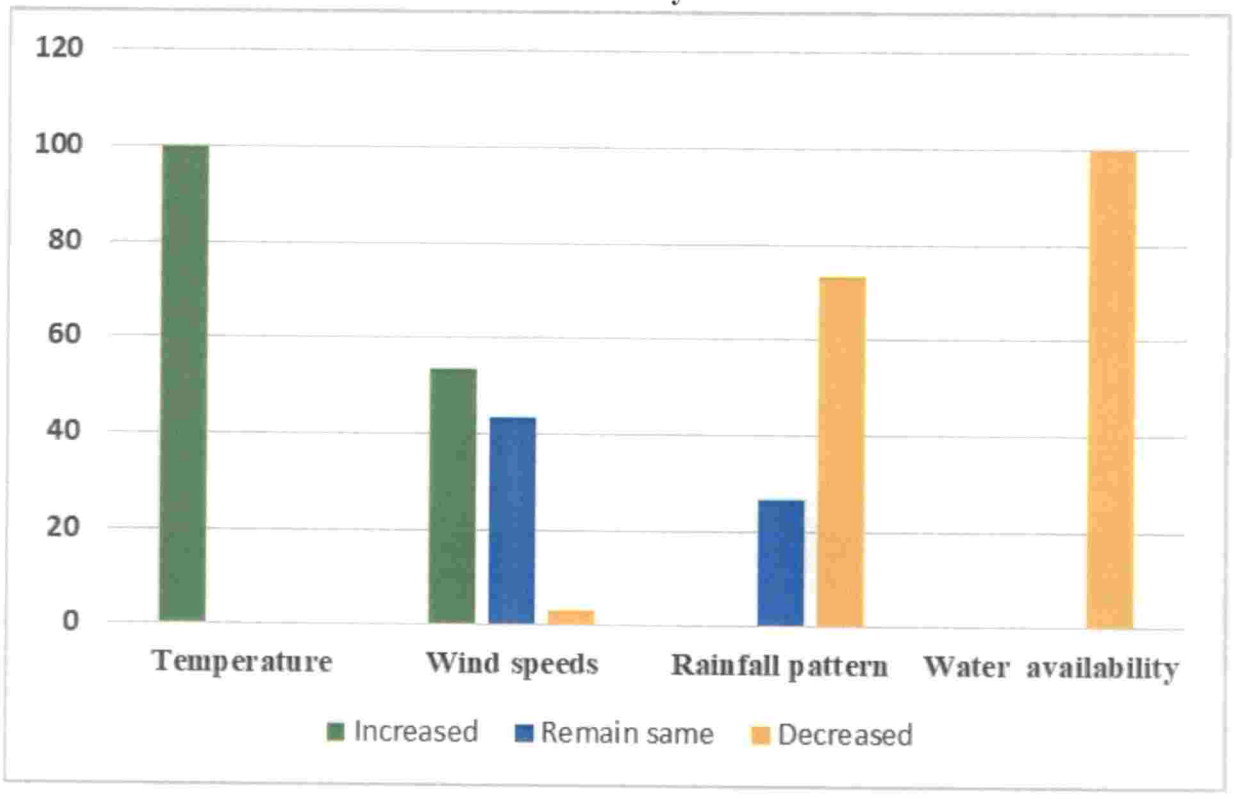


Figure 29. Changes in the Climate in and around the villages in Wayanad Wildlife sanctuary



4.3.2.2 Human- Elephant Conflict at Wayanad Wildlife Sanctuary

One of the main aim of the study was to find the problematic wild animals in the sanctuary (Table 35). As per the survey conducted for forest officials, ninety percent of the officers stated that elephants are the most problematic animals followed by spotted deer (50%). Tiger and Wild Boar were considered to be relatively problematic animals by 10% and 30%, respectively.

Table 35. The animal wise severity of conflict at Wayanad Wildlife Sanctuary

	Elephants		Wild Boar		Tiger		Spotted Deer	
Variables **(N=30)**	F	P	F	P	F	P	F	P
Most problematic	30	90	10	33.3	0	0	15	50
Relatively problematic	0	0	9	30	3	10	12	40
Not problematic	0	0	0	0	3	10	0	0

4.3.2.3 The type of human elephant conflict mitigation measures adopted at Wayanad Wildlife Sanctuary

The measures implemented for minimizing the conflicts within the boundary of sanctuary have been presented in Table 36 (Figure 30). The results of the survey conducted for forest

officials reveal that the measures like elephant squad, compensation, physical barriers and power fence had been implemented to its fullest availability. The use of deterrents and the capturing of problem elephants have not exceeded more than 87% and 57% respectively.

The effectiveness of the various methods adopted to lower the risk of conflicts as understood from the forest officials are given in Table 37 (Figure 31). The officers suggested that elephant squads (69.3%) are the best strategy for minimizing the conflict, the effectiveness of which can be added by adopting deterrents (33.3%), power fence (60%) and physical barriers (66.7%). The officers suggested that giving compensation had no significant effectiveness which were in direct agreement with the opinion of the residents in the sanctuary.

According to the officials the level of satisfaction of the residents towards receiving compensation (Table 38) was on par that the compensation is adequate and the compensation is inadequate.

Table 36. The type of human elephant conflict mitigation measures adopted at Wayanad Wildlife Sanctuary

Measures **(N=30)**	Frequency	Percentage
Deterrents	26	86.67
Elephant Squad	30	100
Physical Barriers	30	100
Power fence	30	100
Compensation	30	100
Capturing Problem Elephants (CPE)	17	56.67

Table 37. Effectiveness of the mitigation measures adopted to reduce human - elephant conflict at Wayanad Wildlife Sanctuary

	Deterrents		Elephant Squad		Physical Barriers		Power Fence		Compensation		CPE	
Variables **(N=30)**	F	P	F	P	F	P	F	P	F	P	F	P
Always effective	4	13.33	10	33.33	3	10	3	10	0	0	2	6.67
Mostly effective	6	20	11	36.67	17	56.7	15	50	1	3.33	8	26.67
Half time effective	3	10	2	6.67	6	20	7	23.3	14	46.67	3	10
Rarely effective	12	40	4	13.33	2	6.67	3	10	14	46.67	15	50
Never effective	5	16.67	3	10	2	6.67	2	6.67	1	3.33	2	6.67

Figure 30. The type of human elephant conflict mitigation measures adopted at Wayanad Wildlife Sanctuary

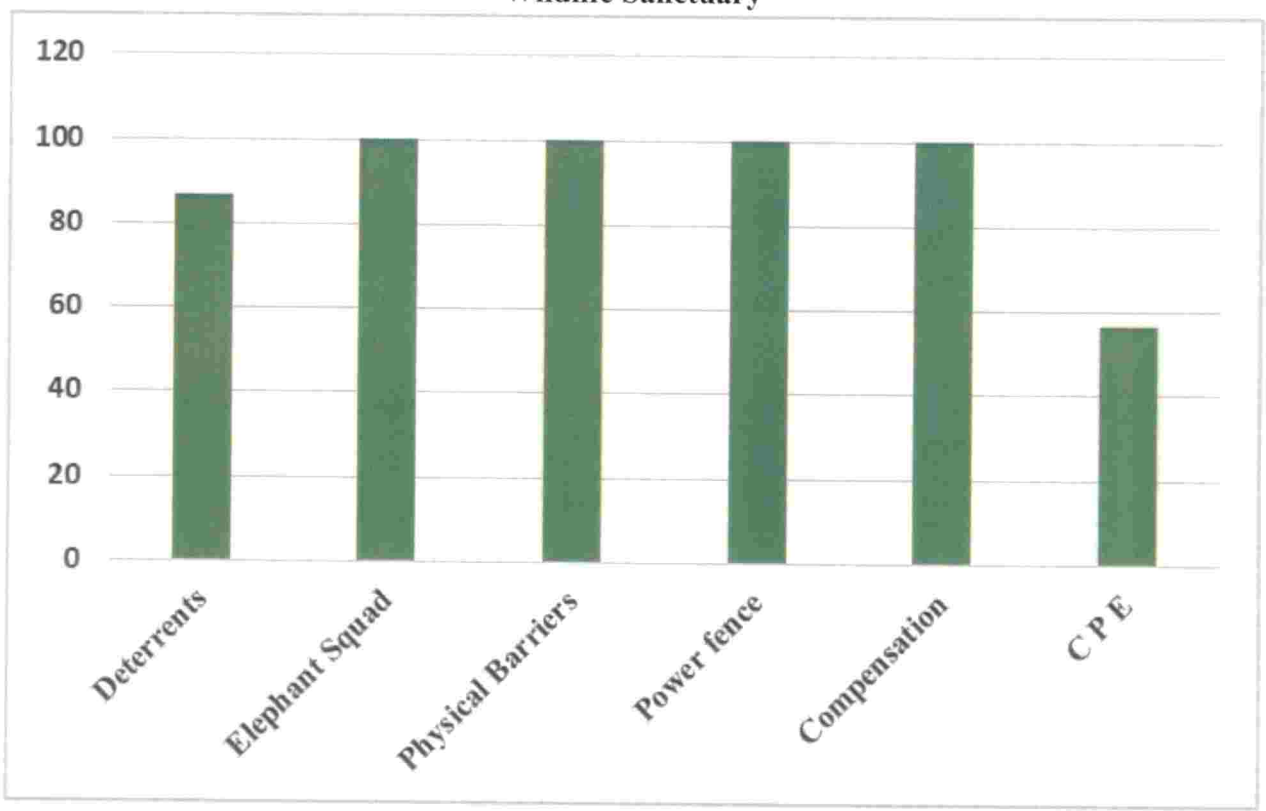


Figure 31. Effectiveness of mitigation measures in reducing human – elephant conflict in Wayanad Wildlife Sanctuary

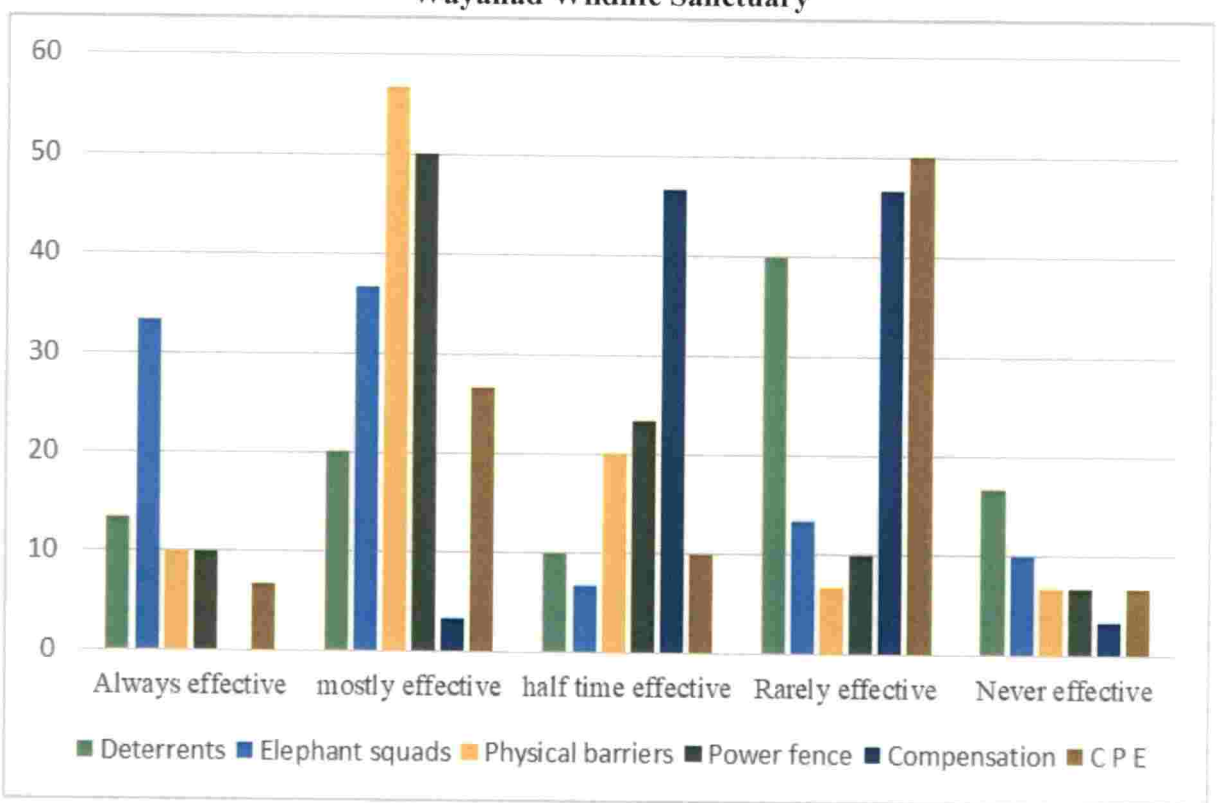


Table 38. Satisfaction level of respondents to the compensation package being implemented at Wayanad Wildlife Sanctuary

Variables (N=30)	Frequency	Percentage
Adequate	13	43.33
Par adequate	4	13.33
Inadequate	13	43.33

4.3.2.4 Perception about human – elephant conflict and elephant conservation

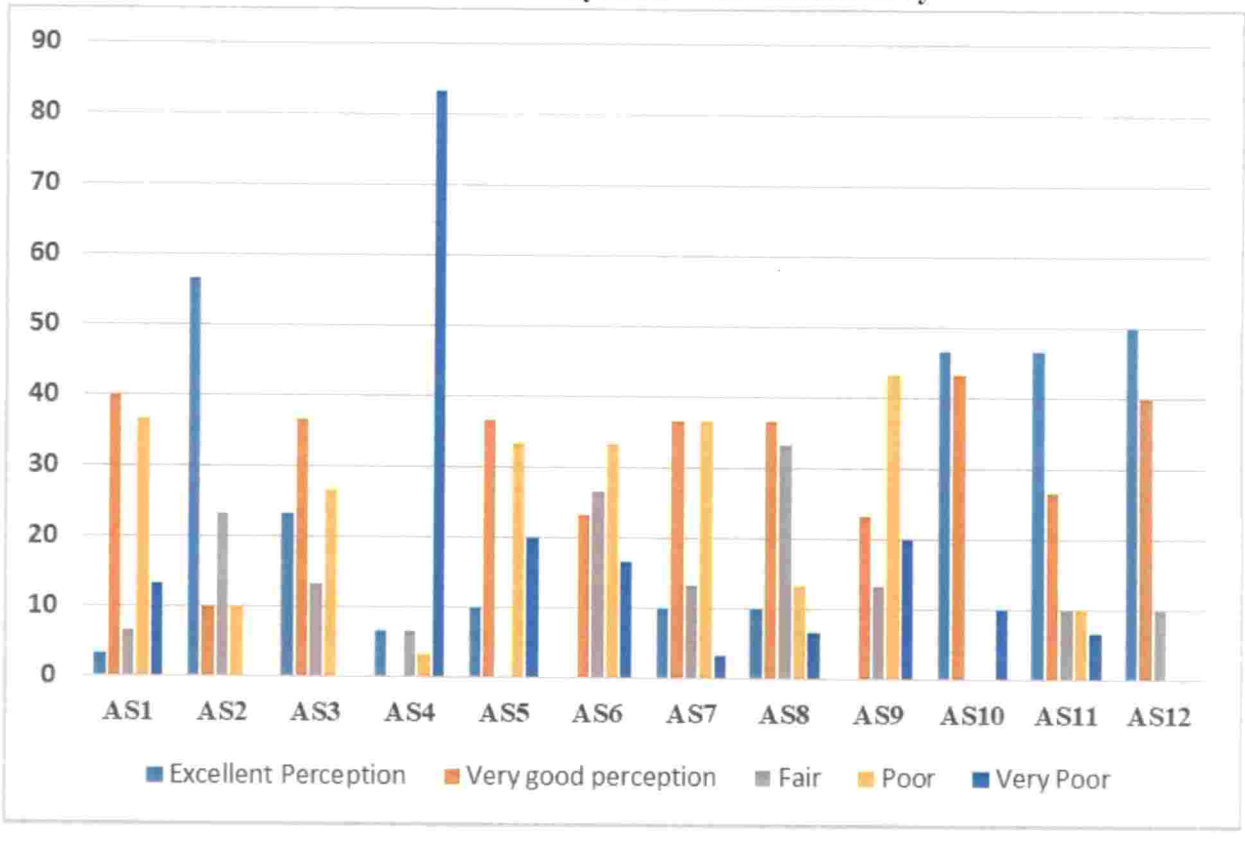
The perception of the forest officials towards the causes of human elephant conflict and the efficiency of different actions taken to minimize the consequences are presented in Table 39 (Figure 32). The response of the officers conceded that the major causes for the increased incidence of the human elephant conflict over the past 5 years are the expansion of human population into wildlife habitats, a reduction in the availability of food (43%) and water in the natural forests (77%), the cultivation of crops that attract the elephants like banana, sugarcane etc. (90%), and lack of proper planning of implementing various steps by the forest department (60%). Their feedback also suggests that the quick interventions by the forest officials and understanding the behavioural changes of the animals help reduce the risk of the conflicts. Their perception of providing sufficient compensation on time was very good which does not agree with the perception of villagers.

Table 39. Perception about human – elephant conflict and elephant conservation in Wayanad Wildlife Sanctuary

Variables (N=30)	Excellent		Very good		Fair		Poor		Very Poor	
Category	F	P	F	P	F	P	F	P	F	P
Expansion of human population into wildlife habitats(AS1)	1	3.33	12	40	2	6.67	11	36.67	4	13.33
Reduction in availability of food and water(AS2)	17	56.67	3	10	7	23.33	3	10	0	0
Lack of proper planning (AS3)	7	23.33	11	36.67	4	13.33	8	26.67	0	0
Poaching and hunting(AS4)	2	6.67	0	0	2	6.67	1	3.33	25	83.33
Keeping distance from forests for farming (AS5)	3	10	11	36.67	0	0	10	33.33	6	20
Farming repellent plants(AS6)	0	0	7	23.33	8	26.67	10	33.33	5	16.67
Sufficient Compensation(AS7)	3	10	11	36.67	4	13.33	11	36.67	1	3.33
Timely compensation(AS8)	3	10	11	36.67	10	33.33	4	13.33	2	6.67
Ecotourism(AS9)	0	0	7	23.33	4	13.33	13	43.33	6	20
Official's quick interventions(AS10)	14	46.67	13	43.33	0	0	0	0	3	10
Understanding the predictable	14	46.67	8	26.67	3	10	3	10	2	6.67

behavioral pattern of wild animals(AS11)										
Cultivation of tempting crops(AS12)	15	50	12	40	3	10	0	0	0	0

Figure 32. Perception of forest officials about human – elephant conflict and elephant conservation in Wayanad Wildlife Sanctuary



4.3.2.5 Action suggested to minimize human – elephant conflict at Wayanad Wildlife Sanctuary

The feedback of the officials on the action suggested to mitigate human elephant conflict is presented in Table 40. According to the officials the best action that can be taken to reduce the conflict is providing support for alternating livelihood/ crops and capturing and relocating the problem elephants. The perception of the officers towards killing the elephants or capturing and relocating all the elephants were minimal.

Table 40. Action suggested to minimize human – elephant conflict at Wayanad Wildlife Sanctuary

Variables **(N=30)**	Frequency	Percentage
Capture and relocate problem elephants	14	46.67

Kill the problem elephants	1	3.33
Capture and relocate all the elephants	0	0
Support to construct permanent houses	8	26.67
Support for alternative livelihood/ crops	16	53.33

4.3.2.6 Whom to take responsibility to reduce the human – elephant conflict at Wayanad Wildlife Sanctuary

The role of different personnel in taking responsibility for reducing conflict with wildlife is pooled in to Table 41 (Figure 33). Eighty percent of the officers suggested that forest department plays the most effective role in reducing the risks of conflicts followed by NGOs (43.3%), agriculture department (33.3%), tourists (33.3%) and farmers (33.3%). The results show that the revenue department and local administrators have no significant role in reducing the risks of conflict.

Table 41. Whom to take responsibility to reduce the human – elephant conflict at Wayanad Wildlife Sanctuary

	Most effective		Effective		Neutral		Not much effective		Least effective	
(N=30)	F	P	F	P	F	P	F	P	F	P
Farmers	0	0	10	33.33	3	10	8	26.67	9	30
Villagers	0	0	8	26.67	5	16.67	8	26.67	9	30
Forest Dept.	24	80	4	13.33	1	3.33	0	0	0	0
Agriculture Dept	0	0	10	33.33	2	6.67	4	13.33	1	3.33
Revenue Dept	0	0	4	13.33	2	6.67	5	16.67	0	0
NGOs	1	3.33	21	70	2	6.67	2	6.67	3	10
Local Administrators	0	0	6	20	13	43.33	3	10	7	23.33
Tourists	0	0	10	33.33	8	26.67	5	16.67	7	23.33
People's Representatives	0	0	6	20	13	43.33	2	6.67	8	26.67

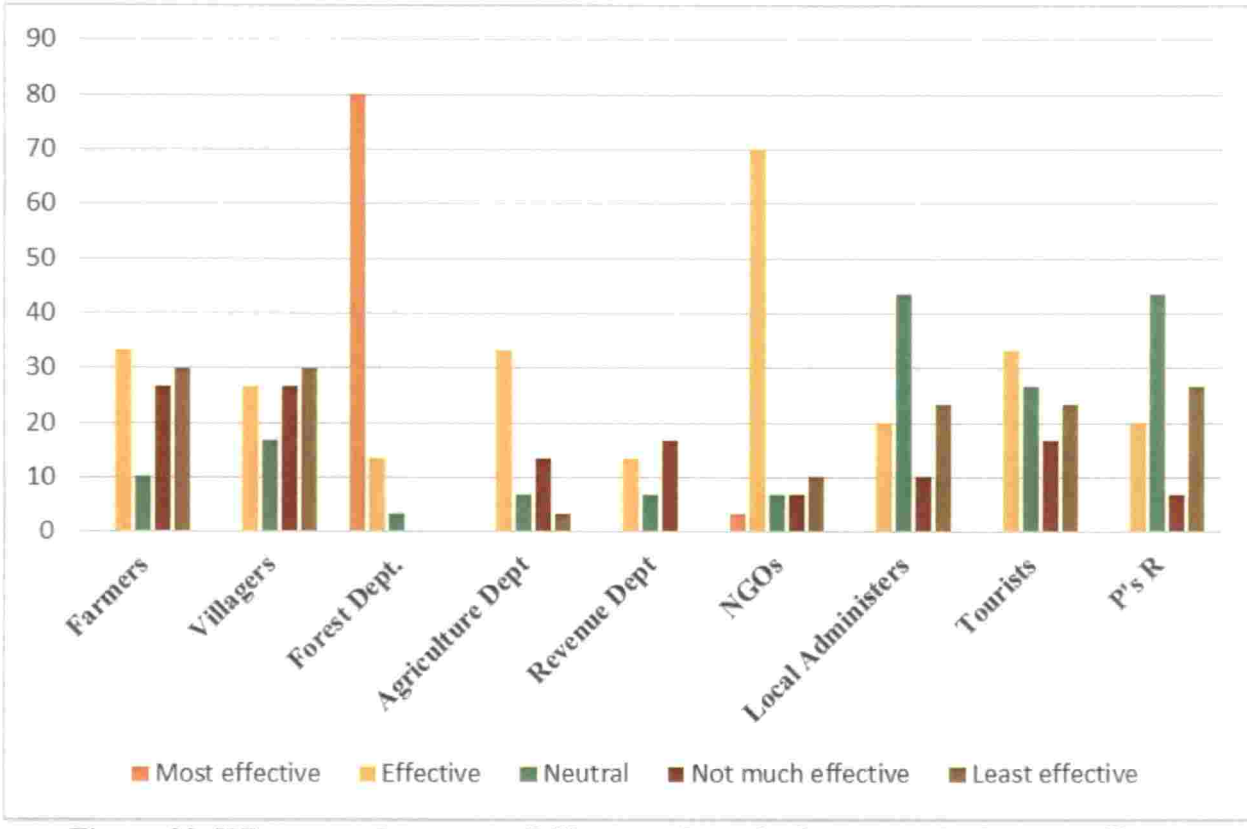


Figure 33. Whom to take responsibility to reduce the human – elephant conflict at Wayanad Wildlife Sanctuary

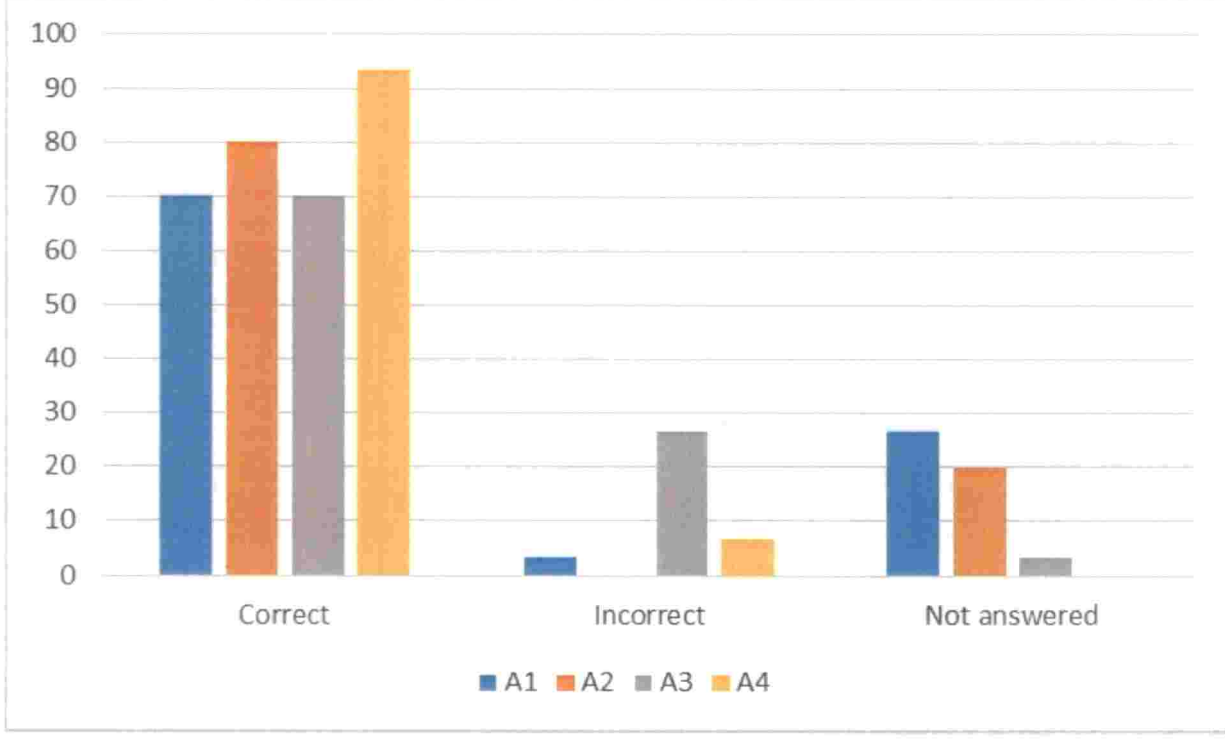
4.3.2.7 Awareness about Forest and Biodiversity Rules and Laws

The knowledge of forest officials about the forest and biodiversity rules and laws is presented in Table 42 (Figure 34). Seventy percent of the officials surveyed have correctly answered about the rules and laws associated with forest and biodiversity, the schedule to which elephant belong in the wild life protection act and the definition of hunting as per the Wildlife Protection Act, 1972. Twenty eight of the thirty forest officials surveyed correctly answered if hunting or poaching of elephants are allowed as per the Wildlife Protection Act, 1972.

Table 42. Awareness about Forest and Biodiversity Rules and Laws

Category (N=30)	Variable	Frequency	Percentage
Name the forest rules and laws	Correct	21	70
	Incorrect	1	3.33
	Not answered	8	26.67
Elephant belongs to which schedule in WPA, 1972	Correct	24	80
	Incorrect	0	0
	Not answered	6	20
Hunting as per WPA, 1972	Correct	21	70
	Incorrect	8	26.67
	Not answered	1	3.33
Hunting of elephant as per WPA, 1972	Correct	28	93.33
	Incorrect	2	6.67
	Not answered	0	0

Figure 34. Awareness about Forest and Biodiversity Rules and Laws



4.3.4 Chi Square Test

The association of different variables describing the household members to their responses on aspects of human- elephant conflict and related fields have been studied through Chi Square test. The variables being chosen for the association study are age, educational status,

occupation and the duration of the residing period of the household members interviewed. Chi Square test was conducted to study the association of these variables towards the response of respondents about the change in area around the village, change in climate around the village, and the perception of the people towards the causes of human elephant conflict and its remedial measures.

Table 43 describes the association and correlation between the age of the respondents and their response to the change in area, climate and perception. The test statistics reveal that there exist a highly significant association between the age of the respondents and their response towards change in the area around the residing village(forest area, wild animals, agricultural land, water sources and domestic animals), change in the climate in the village(temperature, rainfall pattern, wind speed and water availability) and their perception towards causes of conflict and the remedial measures adopted to minimize the consequences of the conflict. It is evident from Figure 36, Figure 37 and Figure 38 that the respondents belonging to the age group 50 years - 70 years have stated that an increase in the area of forest, agricultural land, wild animals, domestic animals have occurred over the past 10 years respectively. The association of educational status of the respondents towards the above mentioned categories are given in Table 44. The test statistics shows that there is a strong association between the educational qualification to the perception on change in area, change in climate and perception towards conflict and conservation. A similar trend is observed in the study conducted for the association of these parameters with the duration of residing period in the village (Table 45). The occupation of the respondents was considered to be a variable to study the change in response towards the change in area around the village and change in climate in the area. This test too showed a strong association between the variables. Each variable *viz.*, age, education, occupation and residing period showed strong positive correlation towards the response made by the respondents.

Table 43. Association of Age with Response (Household)

	Age vs Area	Age vs Climate	Age vs Perception
Pearson Chi-Square	35.833**	14.933**	38.275**
Contingency Coefficient	0.738	0.576	0.749
Pearson's R	0.809	0.699	0.829
N of Valid Cases	30	30	30

Table 44. Association of Education with Response (Household)

	Edu vs Area	Edu vs Climate	Edu vs Perception
Pearson Chi-Square	41.111**	20.728**	47.522**
Contingency Coefficient	0.76	0.639	0.783

Pearson's R	0.796	0.733	0.884
N of Valid Cases	30	30	30

Table 45. Association of Occupation with Response (Household)

	Occupation vs Area	Occupation vs Climate
Pearson Chi-Square	20.000*	26.250**
Contingency Coefficient	0.632	0.683
Pearson's R	0.755	0.905
N of Valid Cases	30	30

Table 46. Association of Residing Period (RP) with Response (Household)

	RP vs Area	RP vs Climate	RP vs Perception
Pearson Chi-Square	40.533**	20.357*	29.774**
Contingency Coefficient	0.758	0.636	0.706
Pearson's R	0.86	0.779	0.783
N of Valid Cases	30	30	30

The association of the rank of forest officials towards their response to change in area, climate and the perception about the causes of human elephant conflict and remedial measures have been studied by conducting Chi Square test the result of which is presented in Table 47 (Figure 46, 47 and 48). The test statistics reveal that a strong association is present between the rank of the officials and their response towards the questions in consideration. Although the response of the officials were positively correlated to their responses, the correlation was not observed as strong as that of the household members.

Table 47. Association of Rank with Response (Forest Officials)

	Occupation vs Area	Occupation vs Climate	Occupation vs Perception
Pearson Chi-Square	21.855**	30.000**	30.000**
Contingency Coefficient	0.649	0.707	0.707
Pearson's R	0.814	0.329	0.329
N of Valid Cases	30	30	30

Figure 35. Association of age of the respondents with their perception on changes in land use pattern at Wayanad Wildlife Sanctuary

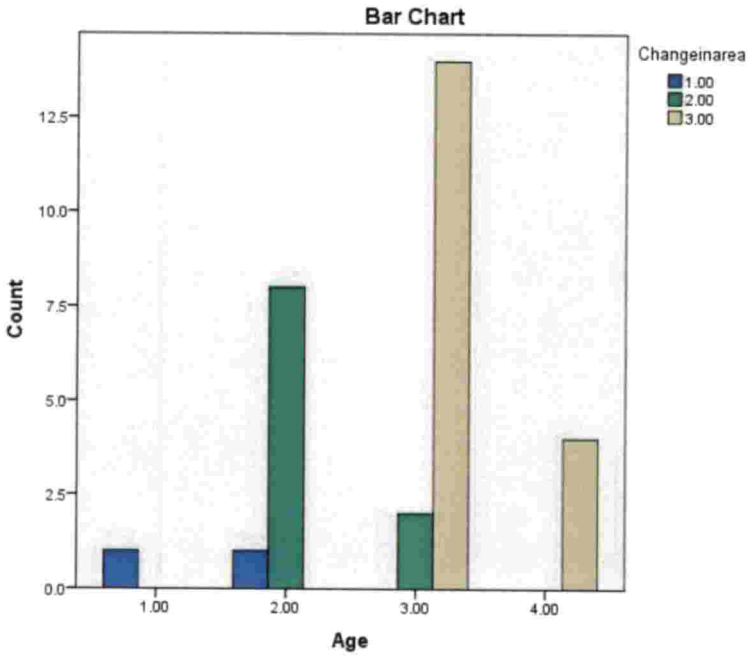


Figure 36. Association of age of the respondents with their perception on changes in climate in and around Wayanad Wildlife Sanctuary

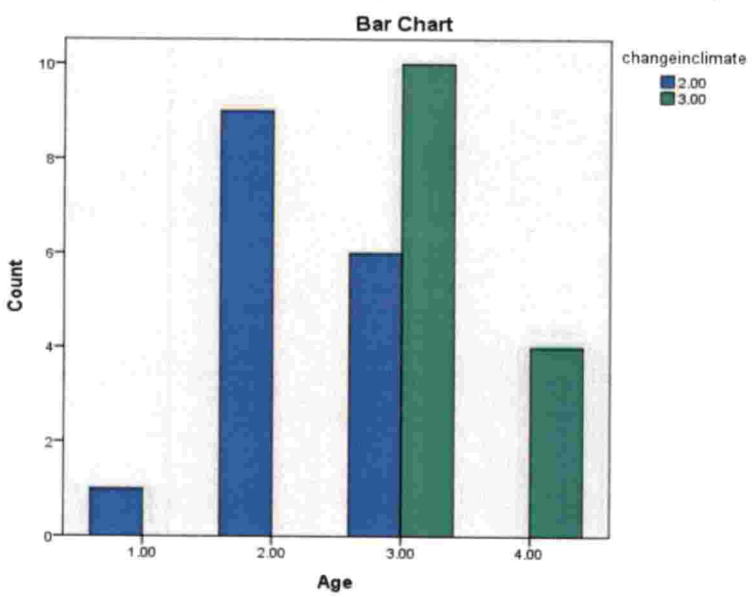


Figure 37. Association of age of the respondents with their perception on human – elephant conflict and elephant conservation at Wayanad Wildlife Sanctuary

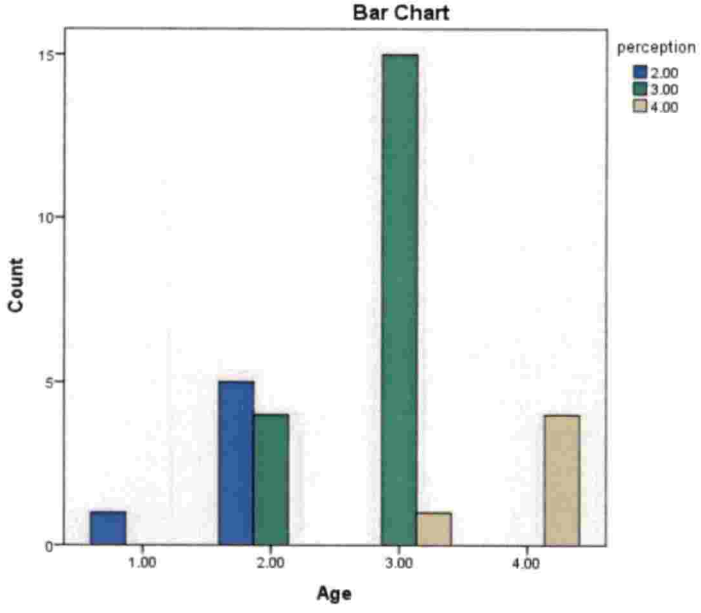


Figure 38. Association of education of the respondents with their perception on changes in land use pattern at Wayanad Wildlife Sanctuary

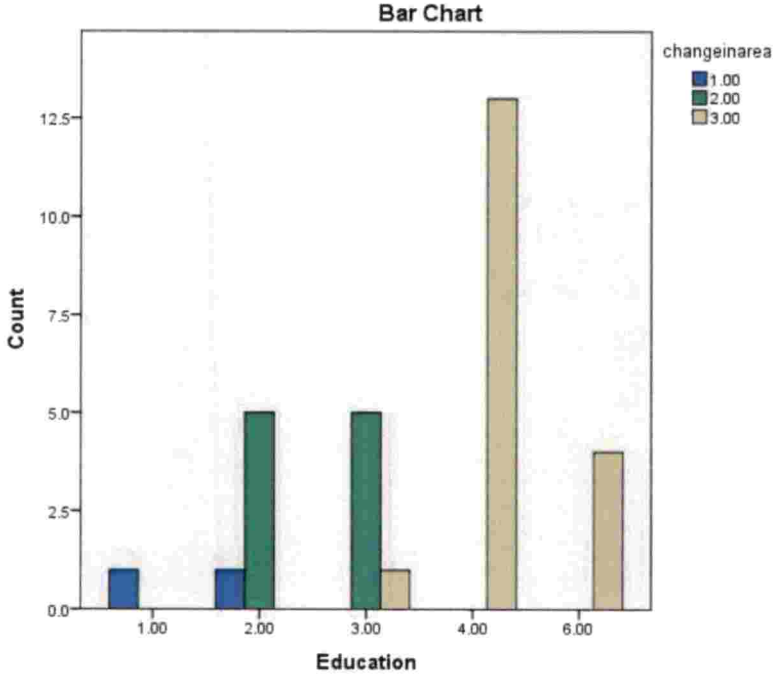


Figure 39. Association of education of the respondents with their perception on changes in climate in and around Wayanad Wildlife Sanctuary

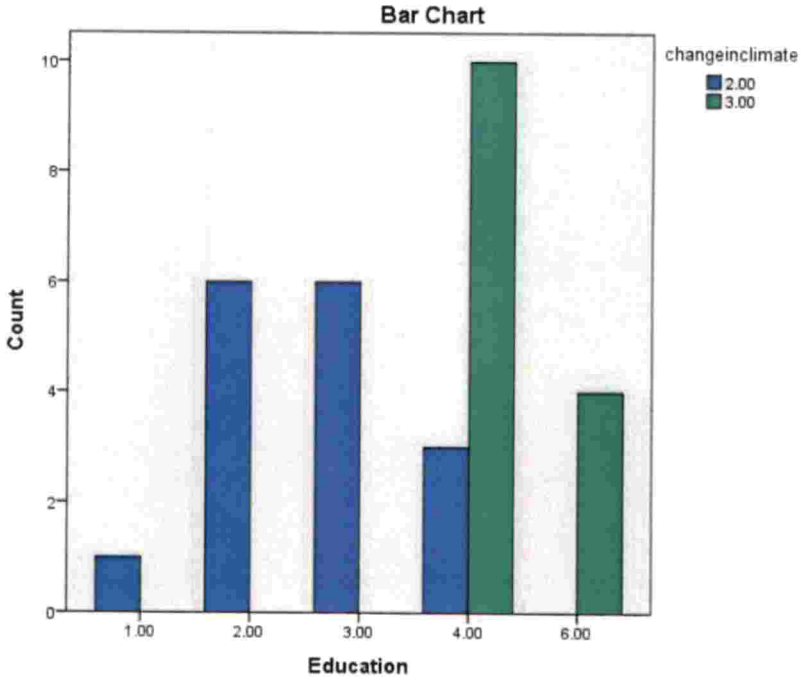


Figure 40. Association of education of the respondents with their perception on human – elephant conflict and elephant conservation at Wayanad Wildlife Sanctuary

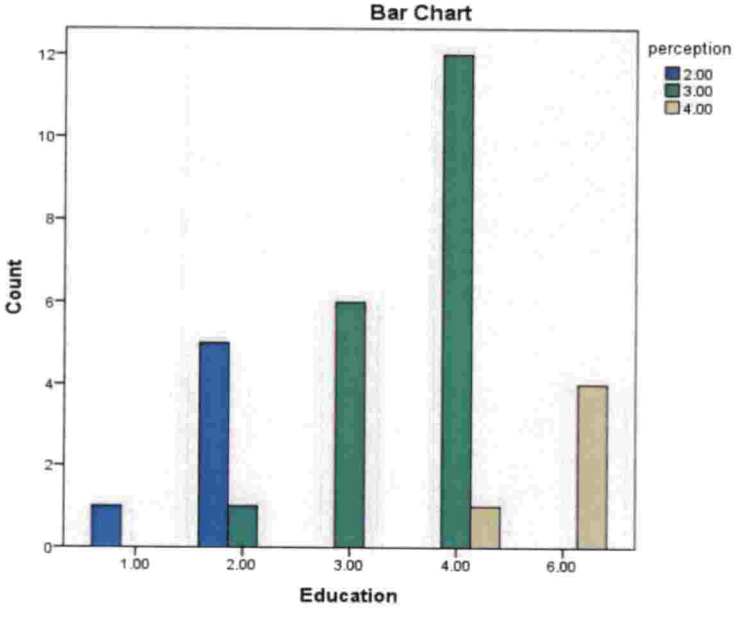


Figure 41. Association of occupation of the respondents with their perception on changes in land use pattern at Wayanad Wildlife Sanctuary

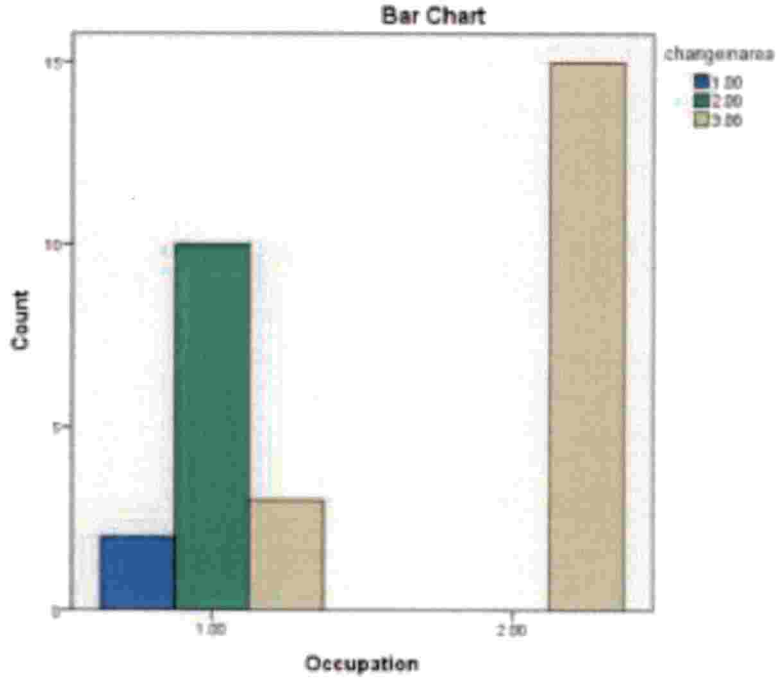


Figure 42. Association of occupation of the respondents with their perception on changes in climate in and around Wayanad Wildlife Sanctuary

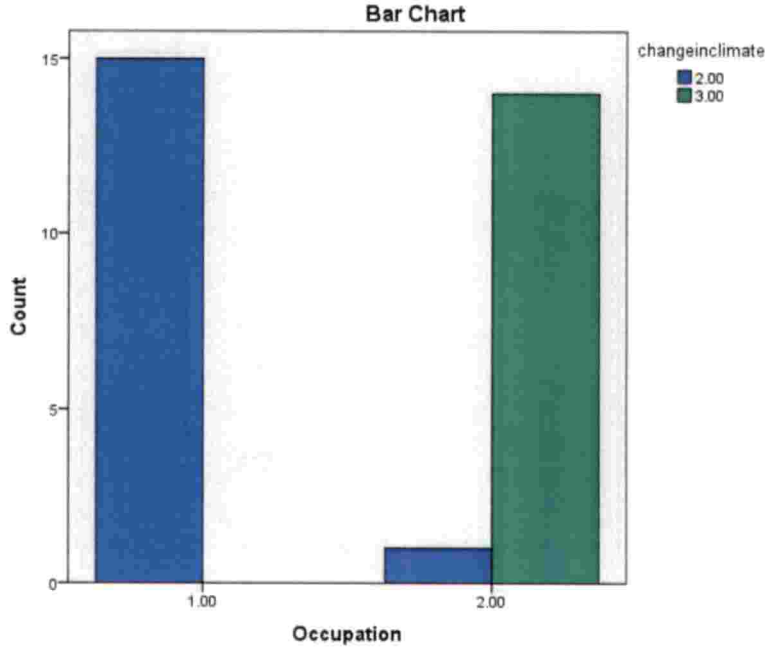


Figure 43. Association of residing period of the respondents with their perception on changes in land use pattern at Wayanad Wildlife Sanctuary

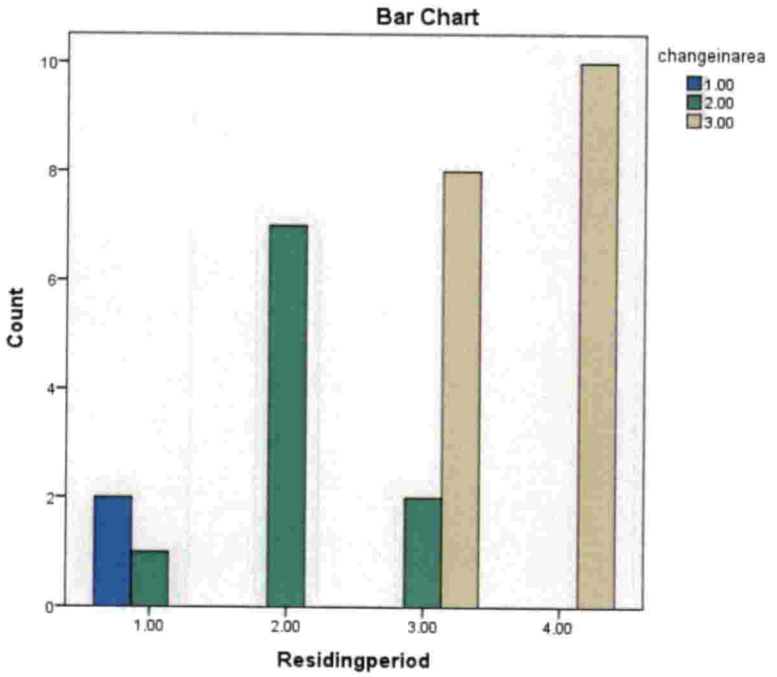


Figure 44. Association of residing period of the respondents with their perception on changes in climate in and around Wayanad Wildlife Sanctuary

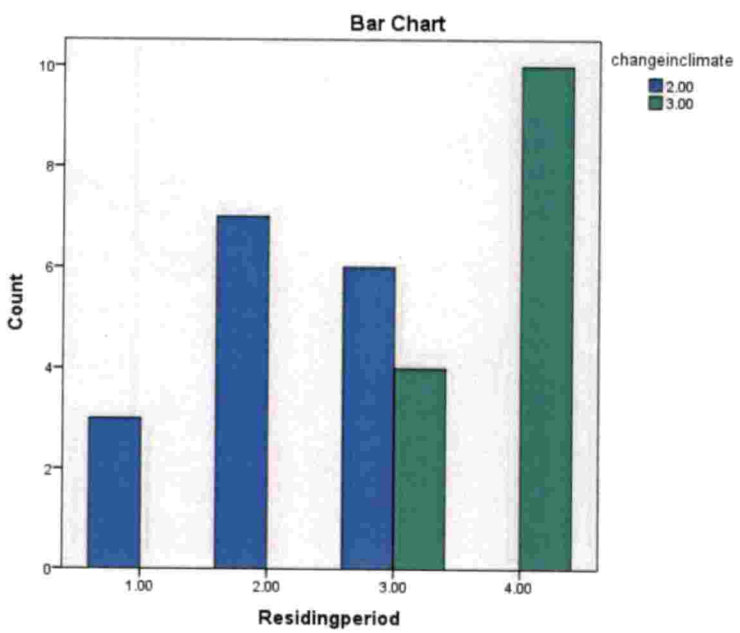


Figure 45. Association of residing period of the respondents with their perception on human – elephant conflict and elephant conservation at Wayanad Wildlife Sanctuary

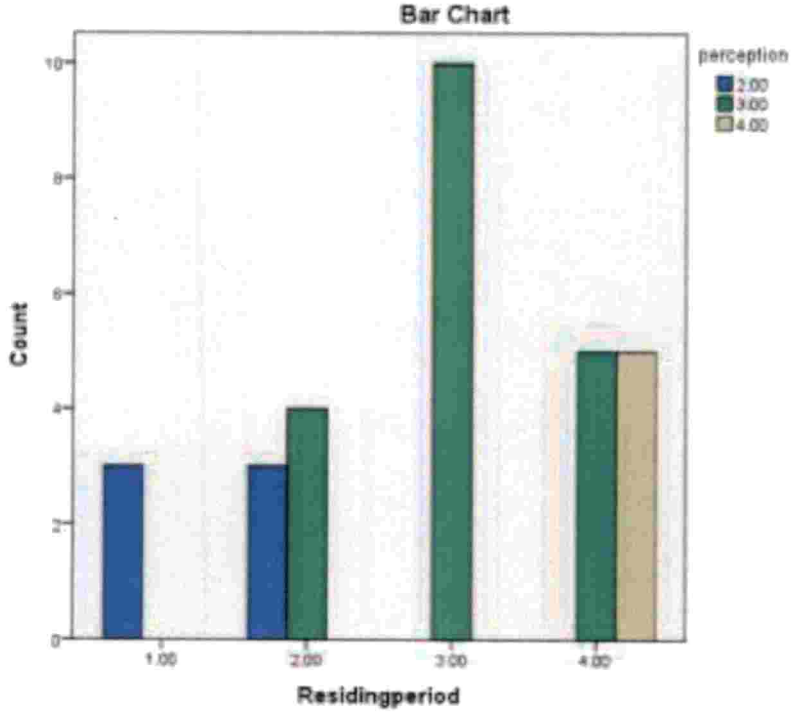


Figure 46. Association of rank of the forest officials with their perception on changes in land use pattern at Wayanad Wildlife Sanctuary

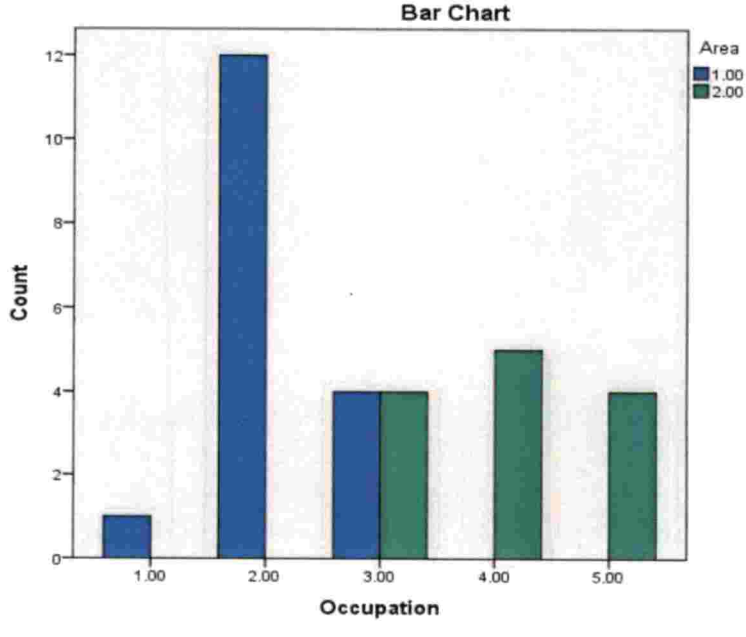


Figure 47. Association of rank of the forest officials with their perception on changes in climate in and around Wayanad Wildlife Sanctuary

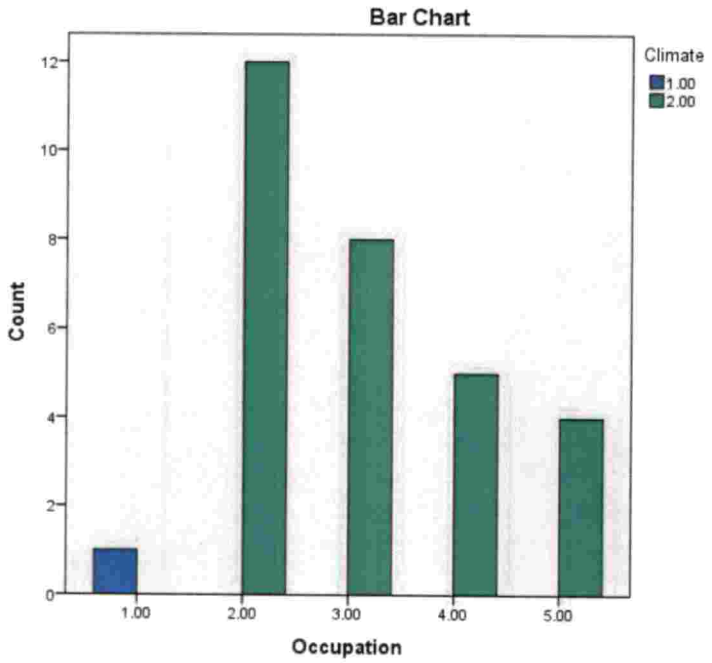
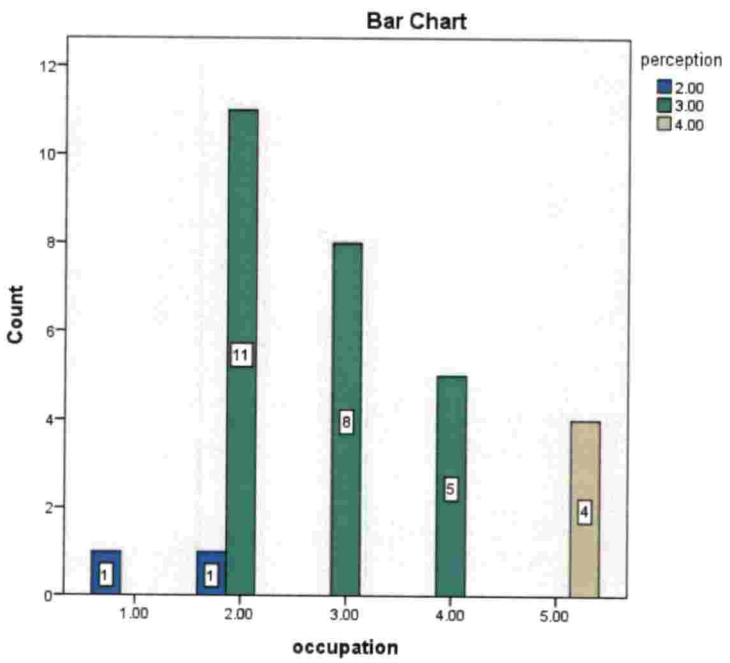


Figure 48. Association of rank of the forest officials with their perception on human – elephant conflict and elephant conservation at Wayanad Wildlife Sanctuary



4.3.5 Mann - Whitney U test to compare the response of household members with the response of forest officials

Mann - Whitney U test was conducted to understand if there exists any relationship between the response of household members and forest officials towards the same question. The test statistic reveals that the difference between the response of the two groups towards the change in area, change in climate and perception about the human elephant conflict and conservation strategies is highly significant (Table 48).

Table 48. Comparison of response between forest officials and household members in Wayanad Wildlife Sanctuary

Variables	Area		Climate		Perception	
Mann-Whitney U Test	Test Statistics	P value	Test Statistics	P value	Test Statistics	P value
Household members vs Forest officials	85	<0.01	165	<0.01	300.05	<0.05

DISCUSSION

DISCUSSION

5.1. Distribution and population density of Asian Elephants in Wayanad Wildlife Sanctuary

5.1.1. Overall elephant population density

The study of Asian Elephant population in Wayanad Wildlife Sanctuary was carried out across two different seasons. The overall elephant population density in the wet season was 0.68 elephants/sq. km. and the overall elephant population density in the dry season was 0.87 elephants/sq. km. Thus, the total population in the wet season and dry season were computed to be 233±18.52 (SE) individuals and 301±19.27 (SE) individuals respectively. The encounter rate of dung piles in the wet season was 11.12 per km and encounter rate in dry season was 24.75 per km.

This shows a seasonal variation in elephant population between wet and dry seasons. Desai and Bhaskaran (1996) observed that elephants tend to congregate in a smaller area where water is available during the dry season. Johnsingh *et. al.* (2015) reported similar observations in the Corbett National Park. Local overabundance near water sources was also reported in African Elephants (*Loxodonta africana*). It was reported that elephants congregated near artificial waterholes at a higher intensity during the dry season (Chammaille-James *et. al.* 2007). This could also be the reason behind increase in population density in Wayanad Wildlife Sanctuary in the dry season. Since neighbouring areas like Bandipur Tiger Reserve, Mudumalai Tiger Reserve and Nagarhole Tiger Reserve comparatively dry up more during the summer, elephants may tend to move towards Wayanad Wildlife Sanctuary where ample number of waterholes are dug by the Forest Department, and more perennial streams like Mavinahalla, Nulpuzha and Kurichiat thodu are also available. Varma and Sukumar (2012) have opined that elephants during summer season tend to use a smaller proportion of the actual habitat leading to increased population in certain patches as compared to wet season, where density will be more dispersed across the entire habitat. Such population distribution patterns can be studied in more detail and management of elephant populations can be done using this knowledge as has been recommended in African Elephants as well (Chammaille-James *et. al.*, 2008).

Easa (1999) conducted seasonal elephant estimation in Wayanad Wildlife Sanctuary across three years, 1994, 1995 and 1996. Population density in three different seasons (two wet seasons and one dry season) were estimated each year. The dry season density (2.04) in 1995 was significantly higher than wet season densities (1.08 and 0.89). although in 1994 and 1996, there was no significant difference. The population density in the study by Easa (1999) in the same area in 1994-1996 is higher than the population density estimated in the present study. The CV% in this study varied from a lowest value of 7.7 to a highest value of 12.7 in all the elephant density estimates.

The Wild Elephant Census conducted across the state in 2010 (Sivaram *et. al.*, 2010) gave an estimate of 2.07 through direct count and 2.96 through dung count. Both counts were conducted in the month of May. It is paramount to note that the 95% Confidence Interval values in this study showed a very high range of 2.27-3.87 which puts to doubt the precision of the study. Similar elephant census carried out in 2005 showed a very low dung density of 659.5 dung piles/sq. km as compared to 2039.2 dung piles/sq. km in the present study. This value increased to 6162.5 dung piles/sq. km in the 2007 census and again decreased to 4744.6 in 2010. This fluctuation could be a result of low precision of the studies. The "Synchronised Population Estimation Study India 2017" by MoEFCC (2017) has published the population density of Wayanad Elephant Reserve (Wayanad Wildlife Sanctuary, Aralam Widllife Sanctuary, North Wayanad and South Wayanad Forest Divisions, Kannur Forest Division and Kozhikode Forest Division) as 0.25 elephants/sq. km and density of elephants in the state of Kerala as 0.32 elephants/sq. km. Such a low density could be due to estimation using direct count methods as opposed to the 2010 census where higher densities of 0.58 elephants/sq. km (direct count) and 1.59 elephants/sq. km (dung count) were obtained in Wayanad Elephant Reserve. The elephant density estimate in the same census in the neighbouring state of Karnataka was 0.67 elephants/sq. km, while only a total count of 2761 elephants was enumerated from Tamil Nadu.

Baskaran *et. al.* (2011) have stated that southern Indian elephant population has considerable conservation value, especially Brahmagiri-Nilgiri-Wayanad-Mysore habitat which supports over 8800 elephants. The density estimate in the neighbouring Mudumalai Tiger Reserve was calculated to be 1.74 elephants/sq. km (Varman *et. al.*, 1995) and in the neighbouring Nagarhole Tiger Reserve, it was estimated to be 3.3 elephants/sq. km (Karanth and Sunquist, 1992). Elephant density from studies in other parts of the state showed

densities of 1.0 elephants/sq. km in Periyar Tiger Reserve (Nair *et. al.,* 1985) and 0.5 elephants/sq. km in Parambikulam Tiger Reserve (Easa, 1989). A recent population estimation study by Kumara *et. al.* (2012) in Biligiri Rangaswamy Temple Tiger Reserve, which is one of the protected areas within the Nilgiri Biosphere Reserve gave a density of 1.7 elephants/sq. km through the line transect direct count method. In the case of Bandipur Tiger Reserve, an Elephant Census in 2010 by Baskaran and Sukumar (2011) showed a density of 2.4 elephants/sq. km while the Synchronised Population Estimation Study India 2017 by MoEFCC (2017) gave a density of 1.13 elephants/sq. km. The results of the 2010 and 2017 census were similar in terms of overall density of elephants in Karnataka which was around 0.6 elephants/sq. km. This variation is not surprising in any way since Eisenberg and Seidensticker (1976) have mentioned that it is possible for Asian Elephant population to range anywhere between 0.12 to 1 per sq. km in suitable South Asian habitats. Variations in population estimation happens due to variation in methodology, precision of study or actual variation in population, as can be observed from the studies cited above. In the present study, most transects were taken on trek paths and jeep roads. Varma and Sukumar (1995) had reported that density estimates along roads and specific paths could be significantly different from those in the interior of the forest. The results of the present study show that Wayanad Wildlife Sanctuary remains an important part of the elephant habitat of the Nilgiri Biosphere Reserve and Peninsular India.

5.1.2. Distribution and density of elephants in different ranges

The present study was conducted across the four ranges of the sanctuary, Muthanga, Sulthan Bathery, Kurichiyat and Tholpetty. Population density was highest in Sulthan Bathery (0.87 elephants/sq. km) and lowest in Tholpetty (0.58 elephants/sq. km), while Muthanga (0.65 elephants/sq. km) and Kurichiyat (0.61 elephants/sq. km) had almost similar density during the wet season.

In the dry season, the highest density was estimated in Muthanga (1.03 elephants/sq. km) while the lowest density was found in Sulthan Bathery (0.79 elephants/sq. km), while Kurichiyat and Tholpetty had densities of 0.92 elephants/sq. km and 0.84 elephants/sq. km respectively.

All the ranges except Sulthan Bathery showed an increase in elephant density in the dry season as compared to the first season. Easa (1999) reported that the seasonal density values recorded a uniformly higher value in the dry season in Southern Ranges of Wayanad (Muthanga) which is similar to the results of the present study. Such a change could be attributed to many proximate factors related to habitat and climate (Lamprey *et al.,* 1967; Dublin and Douglas-Hamilton, 1987). Another factor that could affect this decrease in elephant density in Sulthan Bathery range during the dry season could be because this particular range shares the least length of boundary between neighbouring protected areas like Mudumalai and Bandipur. Since most of the elephant movement occurs from these areas, the increase in population density in Kurichiyat and Muthanga ranges can be expected. Human factors may also play a role in this variation of elephant population density.

5.1.3. Distribution and density of elephants in different vegetation types

Wayanad Wildlife Sanctuary is primarily composed of three vegetation types, dry deciduous forests, moist deciduous forests and plantations. Transects were taken almost equally in dry and moist deciduous vegetation types in both seasons, while comparatively fewer transects were walked in the plantations since it is not considered an high density elephant habitat (Easa, 1999).

There was a clear difference between elephant densities in different habitats in both seasons, showing a pattern of distribution of elephants and habitat use by the elephants in the sanctuary. In the wet season, the dry deciduous habitat showed density of 0.86, while moist deciduous habitat gave an estimate of 0.52. The lowest elephant density was recorded in plantations with an estimate of 0.38. Encounter rates were 13.15, 9.78 and 7.6 in dry deciduous, moist deciduous and plantations respectively.

In the second season, the estimate of population density in dry deciduous habitat was 0.90, while moist deciduous habitat gave 0.86, and plantations gave a value of 0.77. It can be clearly observed that density in moist deciduous habitat and plantations showed an increase in values in the second season, while there was only a slight increase in the dry deciduous habitat.

The accurate area of dry deciduous and moist deciduous vegetation types were not available. The area of plantations given in the Management Plan of the sanctuary was used to calculate elephant distribution in plantations. The area of the other two vegetation types were combined and considered as natural forest. The spatial distribution was observed to be higher in natural forest in both the seasons, although there was an increase in elephant density in plantations during dry season.

The results of studies conducted by Easa (1999) in the same study area in 1994 showed that the elephant density in dry deciduous habitat was higher than both plantations and moist deciduous habitat in the dry season, but density decreased in dry deciduous habitat in the wet season and was less than both moist deciduous habitat and plantations. In 1995 also, similar results were observed with respect to distribution across habitats but there was a decrease in density in moist deciduous habitat. The pattern of population density in 1996 however followed similar patterns to 1994.

The present study shows contrasting results to the study by Easa (1999), since density in dry deciduous habitat did not decrease in the wet season as compared to the dry season. In the moist deciduous habitat and plantations, density of elephants was less in wet season as compared to dry season, which increases the contrast in results between both studies.

A contrast in both results could be due to a variety of reasons. Easa (1999) had cited the reasons for increase in density in moist deciduous habitat to fresh growth of grass and water availability. The increased invasive weed growth in the wet season in recent times could have prevented the fresh growth of palatable grass species in the moist deciduous habitat and plantations.

Fire could also play a role in the pattern of elephant density distribution (Easa, 1999). Fires that occurred in the dry season in Mudumalai, Bandipur and Nagarhole areas in the dry season of 2018 could have pushed the elephants towards Wayanad (Lokesh, 2017).

Study of elephant density in different vegetation types in Dindigul, Kodaikanal and Theni forest divisions (Kumaragru *et. al.*, 2010) also showed difference in distribution of elephants between different vegetation types. Elephant spatial distribution turned out to be higher in grassland, followed by teak plantations, dry deciduous forest and dry thorn forests.

Seasonal difference of elephant density between vegetation types was also reported by Sivaganesan (1991).

Encounter rates could be a function of visibility, which differs between different vegetation types (Kumaragaru *et. al.*, 2010). In the present study, it was observed that encounter rate is higher in dry deciduous than moist deciduous vegetation type. This could be because of higher chance of visibility due to sparse undergrowth in dry deciduous habitat. Hence, this could also affect the final estimate of elephant population density.

A comparison of the direct count and the dung count method was done by Varman *et. al.* (1995) in Mudumalai Tiger Reserve. They found that the direct count results in overestimation of elephant density since they got a result of 3.09 elephants/sq.km using direct count as opposed to 1.54 elephants/sq.km using dung count. This can also be observed in most of the census results published by the Forest Department which has been cited above. They have opined that dung count may be used to avoid this overestimation, but it can only be used when accurate data with respect to dung decay and dung defecation rates are available. These values may vary across different habitats. Dung count method used to estimate elephant density in Uttarakhand district by Varma and Sukumar (2012) gave a conservative estimate of 0.37 elephants/sq.km which is a predictable value for the northern populations of elephants. Such a survey can also indicate the areas that are mostly utilised by the elephants as opposed to areas which are rarely or never utilised. Barnes *et. al.* (1997) have also stated that dung count method is the most practical method for estimating elephant numbers in dense forest. They estimated forest elephant (*Loxodonta cyclotis*) numbers by stratifying the areas according to their distance from nearby roads. They could find more density of dung in areas that were farther away from roads. A comparison of conventional dung count method with fecal-DNA based Capture-Mark-Recapture method was conducted by Hedges *et. al.* (2012) in Asian Elephants of Lao PDR. They found that the fecal-DNA based method gave more precise estimates as well as additional information on the population structure.

5.2. Vegetation studies of the Asian Elephant habitat in Wayanad Wildlife Sanctuary

5.2.1. Density and abundance of tree species

A total of 600 quadrats were sampled for the vegetation studies in the habitat of the Asian Elephant in the Wayanad Wildlife Sanctuary. The quadrats were taken on the same transects as the dung count transects in the wet season of study (Oct-Nov). A quadrat was taken at every 100 m in the transect, giving a total of ten quadrats per transect. Same number of quadrats were sampled in dry deciduous and moist deciduous vegetation types, while a fewer quadrats were only sampled in the plantations.

The natural diversity of flora was studied and 67 species from 33 families were recorded. Species such as *Terminalia elliptica*, *Terminalia elliptica*, *Tectona grandis* and *Anogeissus latifolia* were found to have higher relative density. The number of species in dry deciduous habitat was 48, and number of species in moist deciduous habitat was 61. Only 21 species were recorded in plantations. The neighbouring Mudumalai Tiger Reserve was also found to have similar species diversity (Suresh *et. al.*, 1996). The study in Mudumalai was rather extensive with 19 one hectare plots taken for sampling between 1988-2000. Species greater than 1 cm dbh were sampled in these plots. Number of species recorded ranged from 62-71 during the sampling period from these plots. Families such as Labiatae (Lamiaceae), Combretaceae, Lythraceae, Tiliaceae etc. showed the highest density and basal area among the families recorded similar to the present study in Wayanad Wildlife Sanctuary. The species composition also composed mostly of species like *Tectona grandis*, *Terminalia elliptica*, *Lagerstroemia microcarpa*, *Anogeissus latifolia* etc. similar to the present studies conducted in Wayanad Wildlife Sanctuary. This comes as no surprise since Mudumalai-Wayanad-Bandipur-Nagarhole-Brahmagiri is a contiguous habitat of Asian Elephant with only slight variations in vegetation type and floral diversity and acts as one of the most important corridors for the elephants in the Nilgiri Biosphere Reserve.

Density of tree species in natural forests (418 per ha) was found to be higher than density of tree species in plantations (288 per ha). The total density was about 420 trees per ha. The lower density in plantations did not affect overall density since only a few quadrats were taken there. In a similar study in Mudumalai Tiger Reserve neighbouring Wayanad Wildlife Reserve. a density of 350 trees per ha was recorded (Robert *et. al.*, 2002). In this study, positive density dependence in the mortality of large trees was also found in species

like *Anogeissus latifolia*, *Emblica officinalis* and *Terminalia elliptica*, which are species recorded in the present study as well. Detailed studies on density dependence of trees in mortality and recruitment of species in Wayanad could also yield interesting results. A similar study in Wayanad related to impact of invasive weeds also revealed a result showing density of 600 tree per ha (Angel, 2016). This study also recorded 22 invasive species in the study area, predominated by species like *Lantana camara, Chromoleana odorata* and *Mimosa pudica* which replaced the native grass species which raises concerns about the health of the forest. The study also found that density of invasive weeds was highest in teak plantations, followed by moist and dry deciduous forest although diversity of weeds was higher in the natural forests. Higher density of invasive weeds could explain the low density of elephants in this habitat as found in the present study. This can be further confirmed by a study in the neighbouring Mudumalai Tiger Reserve by Wilson *et. al.* (2014), in which the relationship between *L. camara* and grass cover was studied. It was concluded that *L. camara* was significantly associated with changes in grass species composition and density. It was associated with bringing about negative changes in some elephant browse species and grass cover in the deciduous forests. The tree density in grasslands or vayals was found to be comparatively low (270 per ha) in a study by Balan (2016) in the same study area.

Easa (1999) identified species such as *Grewia tilliaefolia*, *Bauhinia racemosa*, *Emblica officinalis*, *Kydia calycina*, *Shorea roxburghii* and *Tectona grandis* as primary species that are browsed by elephants. The present study has also recorded ample density of these species as well as other species which could be potentially utilized by elephants.

It was also observed that the bamboo brakes were very sparsely distributed and mostly they were seen in Thottamula Section of Muthanga range, where patches of dry evergreen forests are also present.

5.2.2. Girth class distribution of tree species

The girth at breast height of each tree had been recorded. Trees were classed into different girth classes of 10 cm interval. It was observed that more than 50% of individuals came under the girth class between 150-200 m. Trees having girth class less than 50 cm were very few showing that the regeneration was scarce within the sanctuary. Species like *Cassia fistula*, *Tabernaemontana heyneana*, *Anogeissus latifolia* etc had more trees in lower girth

classes. Regeneration of *Shorea roxburghii* with girth less than 10 cm were seen in Sulthan Bathery and Kurichiyat ranges. This is a good sign since this species is favoured by elephants as browse species (Easa, 1999). Lack of regeneration of abundant species like *Tectona grandis*, *Terminalia elliptica*, *Dalbergia latifolia* and *Terminalia elliptica* are a cause for concern.

The girth class distribution curve shows a skewed distribution. This indicates that the population of trees is not stable, since set of the future is extremely poor. Khan *et. al.* (1987) reported a similar pattern of girth class distribution in the disturbed forests of Northeast India An inverse J-shaped curve is essential to indicate a stable population having ample regeneration or recruitment (Sahu *et. al.*. 2012; Maiwada, 2014). The poor regeneration at Wayanad could be due to poor management practices being followed at Wayanad Wildlife Sanctuary. In the name of the vista clearing practice and to have an improved visibility for the tourists, extensive removal of the undergrowth is a regular activity at Wayanad Wildlife Sanctuary (Plate 1b). This practice combined with the heavy infestation of invasive weeds such as *Lantana camara*, *Chromoleana odorata*, *Senna spectabilis* etc. have been detrimental for the regeneration and thus the long term survival of the forests of Wayanad.

5.2.3. Diversity indices of the tree species in the habitat

The Shannon-Wiener index (H) (Shannon, 1948) and Simpson's Index (D) (Simpson, 1949) were used to understand the diversity of tree flora in the sanctuary. It was observed that both H and D values were higher in moist deciduous vegetation type with values of 1.34 and 0.92 respectively. Dry deciduous vegetation had H and D values of 1.13 and 0.87 respectively. As expected, plantations had a very low H and D value of 0.64 and 0.57 respectively showing very low diversity. Pearson's correlation between range-wise elephant density and range-wise tree species diversity showed that there was significant positive correlation between elephant density and tree species diversity (Shannon-Wiener index) during the dry season but there was no significant relation during the wet season. This could indicate that tree species diversity influences elephant movement and density during the dry season when food availability declines for the Asian Elephant. Since they are positively correlated, it is advisable to improve the tree species diversity of the sanctuary.

Diversity indices were calculated in deciduous habitats of Eastern Ghats by Sahu *et. al.* (2012). They obtained Shannon-Wiener index (H value) of 3.38 and Simpson's Index (D value) of 1.0. A study in dry deciduous forests of Chattisgarh by Negi *et. al* (2015) gave an H value of 3.35 and D value of 0.95. In the present study, it can be seen that both H and D values are less than the studies mentioned above in similar habitats. The very low value of Shannon index indicates the lack of evenness of tree species. The low diversity index in Wayanad Wildlife Sanctuary could influence the population density of elephants, and this may be the reason for the decline in the population density.

5.2.4. Important Value Index of families of tree species

The IVI of each family was calculated by adding Relative Density, Relative Frequency and Relative Dominance or Relative Basal Area of all families of trees. This revealed that families with very high IVI are Combretaceae, Lamiaceae and Fabaceae. This was similar in both dry and moist deciduous habitat. Plantations had higher importance value for Lamiaceae and Myrtaceae. Similar studies in Hudguru Reserve Forest in Karnataka also revealed high IVI for families Fabaceae, Combretaceae and Myrtaceae (Manohar, 2015).

Feeding behavior of elephants studied in Sri Lanka showed that among browse species, 25 per cent contribution was from trees of family Fabaceae (Samansiri and Weerakoon, 2007). Sukumar (2009) also recorded trees of family Fabaceae, Poaceae and Arecaceae as being important browse species. Easa (1999) studied the feeding biology of Asian Elephants in Wayanad and found that browse species consisted of species from Lamiaceae, Fabaceae and Tilliaceae families. The presence of the preferred plant species of Asian Elephants could be one of the reasons for the high density of elephants in Wayanad Wildlife Sanctuary.

5.3 Socio – economic survey done at elephant habitats in Wayanad Wildlife Sanctuary

5.3.1 Socio – economic survey conducted for local communities at Wayanad Wildlife Sanctuary

5.3.1.1 Basic Details of the respondents

A total of 30 individuals were interviewed of which 76.67% of the respondents were men. People interviewed were mainly between the age of 50 years and 70 years. More than 60% of the respondents were residing in the area for more than 50 years, a few families residing for more than 70 years. 96.66% of the villagers surveyed have received formal education. The level of education ranged from primary to the graduate level, among the educated respondents. Education plays a major role in deciding the attitude of people towards conserving elephants and tackling the risk of human- elephant conflict. The majority of the local communities (n=17) had their economic status below poverty line which indicates that a burden is placed on these families when the risk of crop raiding is increased. The major source of livelihood of the people were farming (53.33%) which is again an indication of economic burden when the yield is lost due to crop raiding by elephants. The number of members in each household varied from 3 to 9 with greater frequency of women in each household. Nearly 50% of the households had 5 to 7 members in each family which was also a reason for poor economic condition which is attributed by the fewer number of earners per household accompanied with less income which has to support more members.

5.3.1.2 Knowledge about Natural Resources and its Uses

The knowledge about natural resource and its uses were studied mainly under two categories, namely the changes in the area around the village and the change in the climate in the village which were to be answered on the basis of experience of past 10 years. The different variables under the category change in the area around the village were forest area, wild animals, domestic animals, water sources and agricultural land. The observed trend in the response of the people towards the change in these variables can be stated as increasing over the past years except for water sources. Ninety percent of the respondents stated that the water sources remained same for the past 10 years. This variation in attitudes is supported by the association study conducted between the age, occupation, education and the duration of residing period of the respondents with these variables. The positive association results indicate that the age of the respondent decides his/ her perception about the change in the area around the village along with their education level which plays a major role helping the

people understanding the actual situation which is further decided by the duration of the residing period of the particular respondent. These are further influenced by the occupation of the people based on which people can have an overestimation about these changes occurring around their village.

In contrast to the opinion made about the changes in the area, there was a uniformity in the response made by the respondents towards the change in climate. Irrespective of their age, education level, occupation and duration of residing period in the sanctuary, a 100% increase in the temperature has been reported. The disparity between the response of villagers about the changes in climate and the change in area indicating that there is a mismatch between the statement that the area under forest is increasing with an increase in the temperature of the area accompanied hot high velocity winds with a 75% stable rainfall pattern observed over the past 10 years.

5.3.1.3 Human-Elephant Conflict at Wayanad Wildlife Sanctuary

Fragmentation and depredation due to the dependence by the people in enclosures and fringes have contributed to the increased incidence of human-wildlife conflict. Information on various aspects of crop raiding would help in formulating suitable mitigative measures and policy decisions. The extent of the human elephant conflict was studied under different categories such as the problematic wild animals in the area, the most serious damage due to conflict, the most raided crops, the time of occurrence of damage, the damages encountered by the respondents and if the respondent were able to cope up the loss due to damage through the compensation. The survey results reveal that as far as the household members are concerned the most problematic wild animal in the area was elephant (90%, n = 27) followed by wild boar (n=15). The most serious damages were found to be crop raiding (n=24, 80%), property damage and human casualty. The prime agricultural crops raided by the elephants in the area as stated by the respondents were paddy, banana, areca nut, tapioca, coffee and jack. The time of occurrence of damage was mostly during night but considerable occurrence of damage was reported to occur in the dawn and any other time of the day. Numerous reports on crop depredation, livestock death and injuries and damage to properties due to elephants have also been made in African elephant ranges (Kiiru, 1995; Ngure, 1995; Tchamba, 1995; Barnes, *et al.*, 1995).

The respondents have stated an increased incidence of crop raiding and human injuries over past 5 years. Crop raiding and manslaughter by elephants have been reported

from different parts of its distribution ranges where elephants have been pushed to the fragments. Approximately 50% of the respondents have encountered the damages due to crop raiding and not all the parties have availed compensation. The respondents who have received compensation were not given sufficient amount to cope up their loss and the poor timeliness of availing compensation has increased the economic burden on the family. Even though most of them are aware of the compensation provisions, only a smaller proportion of the affected parties avail the facility mainly because of the procedural complexity. Lower income groups that generally get no incentives from the protected area are more likely to resist rules and regulations and continue to encroach upon wild life habitat (Kumssa and Bekel, 2014).

Human factors have also been observed to influence the movement of elephants as well as population density of elephants (Sukumar, 2003; Madhusudhan *et. al.*, 2015). The elephant population in the study area have also been observed to be influenced by certain human factors such as farming of tempting crops in the boundary of the forests and the overall close proximity of human settlements to forests. This has resulted in escalation of conflict in the ranges where farming is practiced very close to the sanctuary. The decrease in population density in Sulthan Bathery range could be a direct result of these human factors. A relatively lower percentage of farmers from among the respondents were observed in the Sulthan Bathery range, as well as lower percentage of farming households living within 100 m distance of the sanctuary (Table 49). This may correspond with the decrease in elephant population density in Sulthan Bathery range during the dry season as opposed to increase in density in the other three ranges. Trend of crop damage was also reported to increase by ah higher percentage of respondents in the three ranges, Muthanga, Kurichiyat and Tholpetty which also corresponds with increasing population density in these ranges. Hence, it can be observed that human factors may be influencing the movement of Asian Elephants in the study area.

Table 49. Range-wise classification of occupation, proximity and trend of crop damage of respondents in Wayanad Wildlife Sanctuary

Range	Percentage of farmers among respondents (%)	Percentage of respondents living within 100 m of the forest (%)	Percentage of respondents indicating increasing trend of crop damage (%)	Elephant Population (Number of individuals)	
				Wet	Dry
Muthanga	42.86	57.14	100	48	**75**

Sultan Bathery	25	50	50	75	66
Kurichiyat	88.88	55.56	77.78	65	97
Tholpetty	66.67	100	83.33	45	63

5.3.1.4 Prevention and mitigation measures to overcome the human wildlife conflict at Wayanad Wildlife Sanctuary

When the respondents were asked about the severity of human elephant conflict, majority of the respondents stated that it was as high as 76.67% for crop raiding, 40% for human injuries and 56.67% for property damage. This increasing trend has forced the forest department to take some preventive methods such as use of deterrents, establishing elephant squad, physical barriers, power fence, providing compensation and capturing the problem elephants in case of failure of all other measures. The extent of implementation of these measures have almost neared to 75 to 80 percent, but the study on effectiveness of these measures found to reveal that not all of these measures were effective. The respondents opined that elephant squads are the most effective preventive measure compared to all other measures which approximated nearly 50%. Measures like physical barriers mainly Elephant Proof Trenches (EPT) and capturing of problem elephants were also found to be effective to a certain extend. It can be drawn from these statements that measures suggested by the household members as effective to be implemented to its maximum which can help in better management and reduction of the risks of human elephant conflict.

5.3.1.5 Perception about human – elephant conflict and elephant conservation

When the respondents were asked about the causes of human elephant conflict they think to be exact, the major causes mentioned by them were the reduction in the availability of food and water within the sanctuary, the proximity of the households to the forest area and cultivation of tempting or palatable crops like paddy, banana etc. Of these only close proximity of the households to the sanctuary (Lahkar *et al.*, 2007; Nath *et al.*, 2009 and Das *et al.*, 2011) and palatability of the cultivated crops (Sukumar, 1990) have been reported in earlier studies conducted in various parts of India. Quick interventions by the officials, understanding the behavioural pattern of the wild animals, promotion of ecotourism and keeping distance from forest for farming were mentioned as effective measures to reduce the incidence of human elephant conflict. The people stated that the effectiveness of getting incentives was very poor to mitigate the risks of the conflict.

A survey was conducted to know the preference of actions to be taken for reducing human elephant conflict. More than 50% of the respondents claimed that support for permanent structures and support for alternative livelihood/ crops can greatly reduce the risks of human-elephant conflict. When 33.33% of them demanded the capturing and relocating of problem elephants only 13.33% demanded for relocation of all the elephants in the area. The response of a 16.67% of the respondents to kill the elephants shows the ignorance of the people about the role of elephant in maintaining a healthy and sound ecosystem and the possible consequences of killing an elephant.

5.3.1.6 Necessity for Human Elephant Coexistence

People were asked if they prefer to have human elephant coexistence in the study area. The response received was very interesting. Majority of the respondents (43.33%) preferred human elephant coexistence whereas 40% of them demanded for the relocation of the people to the buffer zone and 16.67% demanded for the relocation of the elephants.

5.3.1.7 Compensation

The majority of the respondents (76.67%) complained that they are not satisfied with the present policies of compensation, 6.67% were satisfied and 13.3% were partially satisfied. The dissatisfaction has occurred mainly because the compensation process by the forest department was slow and many have not received any compensation even after repeated follow ups.

5.3.1.8 Whom to take the responsibility to reduce the human - elephant conflict

With regard to who should be held accountable for the human – elephant conflict more than 50% of the respondents said it was forest department. It was surprising that the farmers claimed they are not accountable for human elephant conflict in spite of them being sheltered in the sanctuary. Lack of proper education can be a main reason for this negative attitude of the people about their responsibility to conserve elephants and minimize the risks of conflicts.

5.3.1.9 Awareness about Forest and Biodiversity Rules and Laws

The awareness of the people regarding the forest rules and laws, the schedule to which elephant belong to in the wildlife protection act and the definition of hunting as per the wildlife protection act, 1972 was seemingly very poor. Though 56.67% of the respondents

answered if hunting or poaching of elephant is allowed as per the act it is of great disappointment to mention that 43.35% of the respondents could not answer this question which throw light into the fact that the people are least aware of these general issues.

5.3.2 Socio – economic survey of forest officials at Wayanad Wildlife Sanctuary

5.3.2.1 Knowledge about Natural Resources and its Uses

A disagreement was observed in the opinion of forest officials about the change in area when compared to the statements made by the household members. While 66.6% of the household members stated that there is an increase in the forest area only 33.3 % of the officials stated that the forest area has increased. The percentage increase in the population of wild animals as stated by the officials was comparatively less than what was stated by the villagers. A hundred percent agreement to the increase in the temperature with increased hot winds of high velocity can be considered as a reason for the slow pace of increase in the forest area, with a considerable decrease in the rainfall pattern resulting a significant decrease in the availability of water.

5.3.2.2 Human- elephant conflict at Wayanad Wildlife Sanctuary

The forest officials mentioned that elephant being the most problematic animal in and around the periphery of the sanctuary and they also opined that a significant incidence of damage is reported due to wild boars and spotted deer. Although the preventive measures have achieved a hundred percent implementation which is in contrast to what the local communities have opined, the statement of elephant squad being the most efficient method was in agreement to the statement made by the local communities. They also mentioned that physical barriers were an effective measure for reducing the risks of conflicts.

5.3.2.3 Perception about human – elephant conflict and elephant conservation

Multiple factors are involved in the crop raiding behaviour of elephants. Sukumar (1989), Balasubramanian *et al.*, (1995) and Kumar and Sathyanarayana (1995) have dealt with these factors while studying crop raiding by elephants. Sukumar (1989) enlisted these factors as those related to movement pattern, availability of water and food, reduction, fragmentation and degradation of habitat, and the difference in the palatability and nutritive value of crops compared to the natural food species. Regarding the perception of the officials about the conflict and conservation 90% stated the cultivation of tempting crops is the major

cause of conflict, 66.67% said that it was reduction in the availability of food and water in the sanctuary, 60% said that it was the lack of proper planning and 43.3% said that expansion of the human population into the wildlife habitats is the major cause of conflicts of which the latter is in disparity with the response of householders who said it was 6.67%. Sukumar (1988) reported that elephants' far ranging behaviour and larger requirement of the resources often lead them into contact with cultivation in the fragmented forests. Increased elephant population and local over abundance resulting in habitat degradation were also reported to lead to crop raiding by Desai (1997). This is in agreement with the results of the present study that an increase in the elephant density is observed during the summer season in the peripheral regions of the sanctuary, which can be a prime reason for the increased incidence of the crop raiding in the study area.

Ninety percent of the officials claimed that the quick interventions by the forest officials help in reducing the risks of human elephant conflict, while 72% of the officials said that the understanding of the predictable behavioral pattern of wild animals help in reducing the risks. 46.67% of the officials said that availing sufficient compensation on time have a significant role in reducing the risk of damage due to the conflicts.

When asked for the action needed in the present to mitigate HEC, 53.3% of the officials said that the local communities must be provided support for alternative livelihood/ crop and 43.3% said that capturing and relocating the problem elephants is the best measure to mitigate HEC.

5.3.2.4 Awareness about Forest and Biodiversity Rules and Laws

The forest officials of the highest rank were aware of all the forest rules and laws, and the related questions which were put forward during the survey. Few of the lower grade officials were unaware or not knowing these rules and laws and it was disappointing that at least all the forest officials are not aware that the hunting or poaching of elephants are not allowed to be hunted or poached as per the Wildlife Protection Act, 1972, which can be considered a bad indicator of poor management of these conflict by forest department to some extent.

5.3.2.5 Mann - Whitney U test to compare the response of household members with the response of forest officials

The test was conducted to study the relation between the response of household members and forest officials, if any existed. It was clearly understood from the test statistic that the difference between the response of the two groups regarding the change in climate and area of the Wayanad Wildlife Sanctuary is highly significant. There also exists a significant difference between the response of the two groups regarding their perception about conflict and conservation. This disparity in the response can be accounted to the education level of the respondents, poor status of awareness about Human-Elephant Conflict (HEC) by the local communities or even by the residing period of both the groups which can result in overestimation or underestimation of the actual situation regarding their perception about HEC. A further extensive study may be required to clear this disparity of response by the two groups.

Plate 6. Other mammals sighted during the study

Sloth Bear (*Melursus ursinus*)

Spotted Deer (*Axis axis*)

SUMMARY

SUMMARY

Asian Elephants (*Elephas maximus*) are the flagship species in many parts of India as well as South-East Asia. Habitat depredation and fragmentation has affected this majestic pachyderm and it is now an endangered species. The elephant is a core part of its habitat and influences the area in which it lives. Wayanad Wildlife Sanctuary forms part of the Wayanad Elephant Reserve and is one of the most stable abode of the elephant. It is also an important corridor for elephant movement between contiguous habitats and neighbouring reserve forests. It is also affected with habitat degradation due to human activities and invasive weed infestation. Human-elephant conflict is also a pertinent issue on the boundaries of the sanctuary.

The present study aims to study the population density of Asian Elephants, and its variation among different seasons, vegetation types and ranges. It also aims to characterize the habitat of the elephant and assess its condition with respect to the future of elephant population. Human-elephant conflict has also been studied to understand its impact. The methods employed to study the Asian Elephant and its habitat were, line transect dung count, quadrat survey for vegetation analysis, and interview schedule of local communities and forest officials. A total of 100 km of transects were walked, 600 quadrats of dimension 10m × 10m were sampled, and 30 households and 30 forest officials were interviewed. The salient findings are summarized as given below.

1. A total of 667 dung piles were recorded from 60 km of transect in season 1 (wet season) at an encounter rate of 11.12 dung piles per km. A total of 997 dung piles were recorded in season 2 (dry season) at an encounter rate of 24.75 dung piles per km.

2. The dung pile density was analysed from counts of dung turned out to be 1528.1 dung piles per sq. km in the first season. The population density computed from dung density was 0.68 elephants per sq. km which comes to a total population of about 233 elephants across the entire study area.

3. In the second season, the dung pile density was 2039.2 dung piles per sq. km and the population density was 0.87 elephants per sq. km. This comes out to about 301 elephants across the sanctuary during the second season showing a clear increase in elephant population from the first season.

4. The population density also showed variation between vegetation types across the two seasons. The density of elephants in dry deciduous habitat was higher in both seasons, although it remained almost the same across seasons. The density of elephants in moist deciduous forests and plantations showed marked increase in the second season but they were still less than density in dry deciduous habitat. It was also observed that elephants prefer natural forests over plantations from the high elephant density in dry and moist deciduous habitats over low density in plantations

5. The population density also varied considerably among the four ranges across the seasons. The highest population density was recorded at Sulthan Bathery in the first season, which decreased in the second season. In the second season, density in all three ranges other than Sulthan Bathery increased and highest was recorded in Muthanga.

6. The population studies show that seasonal movement of elephants does occur and elephants prefer Wayanad Wildlife Sanctuary more during dry season. This may be due to many proximate factors like availability of grass and browse, water, rainfall or even fires in the neighboring tiger reserves.

7. The vegetation study done through quadrat analysis recorded about 2525 trees from 60 quadrats of 10 m × 10 m area and their GBH and height were measured. A density of 420 trees per ha was calculated, wherein 418 trees per ha was the density in natural forests and 288 trees per ha in plantations. This shows a clear difference in density of trees among the two vegetation types.

8. The tree species such as *Terminalia elliptica*, *Tectona grandis* and *Anogeissus latifolia* were found to be the most dominant in dry deciduous habitat, whereas tree species like *Tectona grandis*, *Terminalia elliptica* and *Lagerstroemia microcarpa* were the most dominant in moist deciduous habitat.

9. The absence or scarcity of bamboo brakes in the sanctuary except for sporadic distribution in places like Thottamula was a a matter of concern, since it is a primary diet of the Asian Elephant.

10. The girth class distribution at an interval of 10 cm was plotted. The curve in all vegetation types as well as overall curve showed skewed distribution. This is not optimum for the stability of the habitat since it indicates that regeneration or recruitment of tree species is

not enough in the sanctuary to maintain the habitat in a wooded condition for the future. The Forest Department can perform some activities for improvement of regeneration of tree species like clearing of weeds and using tree guards to improve the set of the future in order to ensure habitat stability.

11. The diversity indices such as Shannon-Wiener index and Simpson's Index were computed. These reflect both the richness and evenness of tree species in a habitat. These were compared among all three vegetation types. It was found that moist deciduous habitat had highest values in both indices, followed closely by dry deciduous habitat while plantations performed abysmally low in this regard.

12. The correlation between range-wise elephant population density and range-wise tree species density was found to be significantly correlated during the dry season, indicating that tree species diversity can influence the elephant population density during the dry season, when scarcity of food resources may occur.

12. The Important Value Index was computed from relative density, relative frequency and relative basal area to show quantitative relationship among the vegetation and to highlight the importance of families of trees within a habitat. It was observed that Combretaceae, Lamiaceae and Fabaceae topped unequivocally in IVI values in both dry and moist deciduous habitat, while Lamiaceae and Myrtaceae topped in plantations due to higher density of teak and eucalyptus.

13. The high value of IVI of families of tree species preferred as browse by elephants and average diversity index is a good sign that the study area is still an optimum habitat for Asian Elephants. The pattern of girth class distribution of tree may be a cause of concern for the future of this habitat.

15. An interview schedule of local communities and forest officials in Wayanad Wildlife Sanctuary was prepared and survey was conducted for 30 household members and 30 forest officials to study the back ground, perceptions about conflict and consequences of human-elephant conflict.

16. The most important fact to be understood was that the tribal population in the sanctuary were less affected due to the risks or consequences of human- elephant conflict

when compared to the other communities residing in the sanctuary, and tribal people did not have negative perceptions about elephants.

17. The incidence of HEC such as crop raiding, property damage or human casualty has more probability to occur in areas proximal to the forests.

18. The expansion of human population to the wildlife habitats, reduction in the availability of food and water in the forest, cultivation of palatable crops in the surrounding agricultural lands, lack of proper planning in establishment of the preventive measures and inadequacy of compensation associated with the long term process for availing compensation are found to be the major causes for human elephant conflict.

19. The quick interventions by the forest officials, cultivation of repellent crops at greater distance from forests, and understanding the predictable behavioural changes of wild animals can help reduce the risk of human-elephant conflict to a great extent.

20. Creating awareness to the people about the forest rules and laws, ecological significance of elephants and the importance of conservation of elephants can further help reducing the risk of HEC.

21. Increased incidence of crop damage during summer can be an indirect indicator of movement of elephants into the sanctuary from the adjacent bordering protected areas, as well as presence of palatable fruit trees like Jack and Mango.

22. Better implementation of the preventive measures can encourage the local communities residing in the sanctuary to ease the situation of human elephant coexistence.

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APPENDIX 1

GPS LOCATIONS OF WET SEASON TRANSECTS IN WAYANAD WILDLIFE SANCTUARY

Division	Range	Location	Vegetation	Date	Transect No.	Length of the transect (m)	Starting point Lat.	Starting Point Long.	Ending point Lat.	Ending point Long.
Wayanad	Muthanga	Kakkapaadam	Mixed moist deciduous	28-09-17	1	1000	11°39.984' N	76°23.436' E	11°39.747' N	76°24.001' E
Wayanad	Muthanga	Aimangalam 1	Mixed moist deciduous	07-10-17	2	1000	11°39.516' N	76°23.420' E	11°39.642' N	76°22.942' E
Wayanad	Muthanga	Forest station	Eucalyptus plantation	16-10-17	3	1000	11°40.054' N	76°22.294' E	11°39.711' N	76°22.715'E
Wayanad	Muthanga	Forest station	Eucalyptus plantation	16-10-17	4	1000	11°39.308' N	76°23.138' E	11°39.702' N	76°22.839' E
Wayanad	Muthanga	Maragatha	Mixed Dry deciduous	16-10-17	5	1000	11°38.711' N	76°25.954' E	11°38.425' N	76°25.640' E
Wayanad	Muthanga	Bajagatha	Mixed moist deciduous	17-10-17	6	1000	11°38.207'N	76°24.813'E	11°38.512'N	76°24.393'E
Wayanad	Muthanga	Mudumalakallu	Mixed Dry deciduous	17-10-17	7	1000	11°38.081'N	76°24.399' E	11°38.535' N	76°24.214' E
Wayanad	Muthanga	Nellore-Maragatha	Mixed Dry deciduous	17-10-17	8	1000	11°39.806' N	76°25.632' E	11°39.322' N	76°25.870' E

Wayanad	Muthanga	Ambazhankolli	Mixed moist deciduous	18-10-17	9	999.8	11º37.724' N	76º18.883' E	11º37.621' N	76º19.376' E
Wayanad	Muthanga	Kalkuttamchal	Mixed moist deciduous	18-10-17	10	1000	11º37.702' N	76º20.021' E	11º37.169' N	76º20.123' E
Wayanad	Muthanga	Mullankolli	Mixed moist deciduous	19-10-17	11	1000	11º36.333' N	76º21.102' E	11º36.377' N	76º21.574' E
Wayanad	Muthanga	Chettiyalathur	Mixed moist deciduous	19-10-17	12	1000	11º36.857' N	76º21.893' E	11º36.931' N	76º22.384' E
Wayanad	Muthanga	Cheeradankolli Junction	Mixed Dry deciduous	09-12-17	13	1010	11º38.952' N	76º23.186' E	11º38.467' N	76º23.413' E
Wayanad	Sulthan Bathery	Arakunji	Mixed Dry deciduous	06-10-17	15	1100	11º41.569' N	76º21.074' E	11º42.048' N	76º21.309' E
Wayanad	Sulthan Bathery	Kaithallam	Mixed Dry deciduous	21-10-17	16	1000	11º44.501' N	76º24.602' E	11º44.287' N	76º24.059' E
Wayanad	Sulthan Bathery	Kumizhallam	Mixed Dry deciduous	21-10-17	17	1000	11º43.968' N	76º23.534' E	11º44.509' N	76º23.346' E
Wayanad	Sulthan Bathery	Manjal	Mixed Dry deciduous	21-10-17	18	1000	11º43.009' N	76º22.594' E	11º42.501' N	76º22.510' E
Wayanad	Sulthan Bathery	Kallumukku	Mixed Dry deciduous	21-10-17	19	962.8	11º41.444' N	76º20.463' E	11º41.987' N	76º20.437' E
Wayanad	Sulthan Bathery	Karnataka border camp	Mixed Dry deciduous	25-10-	20	1000	11º44.297' N	76º20.459' E	11º44.396' N	76º20.991' E

				17						
Wayanad	Sulthan Bathery	Nallathanni	Mixed Dry deciduous	25-10-17	21	1000	11º44.164' N	76º20.987' E	11º43.917' N	76º21.458' E
Wayanad	Sulthan Bathery	Nallathanni to Kattichakulam vayal	Mixed Dry deciduous	26-10-17	22	1011	11º44.228' N	76º20.957' E	11º43.924' N	76º20.491' E
Wayanad	Sulthan Bathery	Erumachathakolli	Mixed Dry deciduous	26-10-17	23	1000	11º43.886' N	76º20.076' E	11º43.859' N	76º19.524' E
Wayanad	Sulthan Bathery	Kathiapalam	Mixed Dry deciduous	26-10-17	24	1000	11º42.946' N	76º19.359' E	11º42.466' N	76º19.523' E
Wayanad	Sulthan Bathery	Teak plantation Naikatti	Mixed Dry deciduous	26-10-17	25	1012	11º42.517' N	76º19.035' E	11º42.406' N	76º18.480' E
Wayanad	Sulthan Bathery	Mangamoola	Mixed Dry deciduous	27-10-17	26	1010	11º40.538' N	76º21.258' E	11º41.066' N	76º21.305' E
Wayanad	Sulthan Bathery	Ponkuzhi Border	Mixed Dry deciduous	07-12-17	27	1000	11º41.857' N	76º23.656' E	11º42.308' N	76º23.387' E
Wayanad	Sulthan Bathery	Thaalkolli	Mixed Dry deciduous	07-12-17	28	1010	11º42.601' N	76º23.177' E	11º42.829' N	76º22.683' E
Wayanad	Sulthan Bathery	Ottipara to Ponkuzhi	Mixed Dry deciduous	07-12-17	29	1010	11º43.307' N	76º24.135' E	11º42.799' N	76º24.184' E
Wayanad	Kurichiyat	Vadakkanad	Mixed moist deciduous	30-09-17	30	1100	11º42.472' N	76º17.436' E	11º42.995' N	76º17.416' E
Wayanad	Kurichiyat	Kalimala	Mixed	01-	31	1000	11º44.090'N	76º	11º44.571'N	76º 16.402'

			moist deciduous	10-17				15.922'E		E
Wayanad	Kurichiyat	Kuppady	Mixed moist deciduous	04-10-17	32	1000	11°41.443' N	76°14.465' E	11°41.399' N	76°14.915' E
Wayanad	Kurichiyat	Golur-Karnataka border	Mixed Dry deciduous	22-10-17	33	994.6	11°46.243' N	76°18.031' E	11°46.593' N	76°18.398' E
Wayanad	Kurichiyat	Thekkuvara	Mixed Dry deciduous	22-10-17	34	1000	11°47.159' N	76°17.608' E	11°46.732' N	76°17.387' E
Wayanad	Kurichiyat	Thekkuvara to Golur	Mixed Dry deciduous	22-10-17	35	1010	11°46.619' N	76°17.463' E	11°46.219' N	76°17.753' E
Wayanad	Kurichiyat	Mutharimala	Mixed Dry deciduous	23-10-17	36	1009	11°46.018' N	76°17.196' E	11°46.208' N	76°16.703' E
Wayanad	Kurichiyat	Bommadevar	Mixed moist deciduous	23-10-17	37	1000	11°46.596' N	76°16.424' E	11°46.884' N	76°15.904' E
Wayanad	Kurichiyat	Kazhukankolli	Mixed moist deciduous	23-10-17	38	1000	11°46.555' N	76°15.593' E	11°46.334' N	76°15.179' E
Wayanad	Kurichiyat	Poovanchi	Mixed Dry deciduous	23-10-17	39	1005	11°45.154' N	76°15.055' E	11°44.981' N	76°15.522' E
Wayanad	Kurichiyat	Kaatikolli	Mixed moist deciduous	23-10-17	40	1000	11°44.910' N	76°16.712' E	11°45.013' N	76°17.225' E
Wayanad	Kurichiyat	Ammavayal	Mixed moist deciduous	23-10-17	41	1000	11°45.061' N	76°17.837' E	11°45.431' N	76°18.178' E

Wayanad	Kurichiyat	Madapalli	Mixed Dry deciduous	24-10-17	42	1010	11º45.002' N	76º18.502' E	11º44.540' N	76º18.658' E
Wayanad	Kurichiyat	Manguvadi	Mixed Dry deciduous	24-10-17	43	1000	11º44.220' N	76º19.140' E	11º43.811' N	76º19.459' E
Wayanad	Kurichiyat	Odappalla, Kurichiyat	Teak plantation	24-10-17	44	1000	11º43.739' N	76º19.440' E	11º43.357' N	76º19.023' E
Wayanad	Kurichiyat	Chethalayam	Mixed moist deciduous	08-12-17	45	1020	11º42.059' N	76º14.397' E	11º45.408' N	76º14.785' E
Wayanad	Tholpetty	Dasangatta road	Mixed moist deciduous	01-12-17	46	1010	11º55.007' N	76º05.892' E	11º55.488' N	76º06.013' E
Wayanad	Tholpetty	Dasangatta APC	Mixed moist deciduous	01-12-17	47	1020	11º55.794' N	76º05.923' E	11º56.281' N	76º05.892' E
Wayanad	Tholpetty	Aralagadha road	Mixed moist deciduous	02-12-17	48	1000	11º53.286' N	76º05.147' E	11º53.621' N	76º05.487' E
Wayanad	Tholpetty	Bavali road	Mixed moist deciduous	02-12-17	49	1010	11º53.684' N	76º05.779' E	11º53.549' N	76º06.119' E
Wayanad	Tholpetty	Bavali road (2)	Mixed moist deciduous	02-12-17	50	1010	11º53.216' N	76º06.239' E	11º52.739' N	76º06.167' E
Wayanad	Tholpetty	Punchavayal	Mixed moist deciduous	02-12-17	51	1000	11º52.499' N	76º05.988' E	11º51.981' N	76º06.103' E
Wayanad	Tholpetty	Saambalam	Mixed moist	02-12-	52	1000	11º51.829' N	76º06.308' E	11º51.548' N	76º06.706' E

			deciduous	17						
Wayanad	Tholpetty	Tholpetty station road	Mixed moist deciduous	03-12-17	53	1015	11°57.279' N	76°05.238' E	11°57.309' N	76°05.757' E
Wayanad	Tholpetty	Gonipara	Mixed moist deciduous	03-12-17	54	1005	11°57.177' N	76°05.961' E	11°57.531' N	76°06.309' E
Wayanad	Tholpetty	Kaimaram	Mixed moist deciduous	03-12-17	55	1020	11°57.222' N	76°06.740' E	11°57.114' N	76°06.202' E
Wayanad	Tholpetty	Tholpetty station road (2)	Mixed moist deciduous	03-12-17	56	1010	11°57.199' N	76°04.908' E	11°56.898' N	76°04.440' E
Wayanad	Tholpetty	Thirulkunnu 1	Mixed moist deciduous	04-12-17	57	1070	11°54.218' N	76°03.674' E	11°53.711' N	76°03.575' E
Wayanad	Tholpetty	Thirulkunnu 2	Mixed moist deciduous	04-12-17	58	1030	11°53.616' N	76°03.471' E	11°53.510' N	76°03.075' E
Wayanad	Tholpetty	Thirulkunnu 3	Teak plantation	04-12-17	59	1020	11°53.574' N	76°02.782' E	11°53.869' N	76°02.426' E
Wayanad	Tholpetty	Lapwing watchtower	Teak plantation	05-12-17	60	1010	11°52.975' N	76°04.494' E	11°52.628' N	76°04.103' E

APPENDIX 2

GPS LOCATIONS OF DRY SEASON TRANSECTS IN WAYANAD WILDLIFE SANCTUARY

Division	Range	Location	Vegetation	Date	Transect No.	Length of the transect (m)	Starting point Lat.	Starting Point Long.	Ending point Lat.	Ending point Long.
Wayanad	Muthanga	Kakkapadam	Eucalyptus plantation	03-03-2018	1	1010	11º39.910' N	76º23.381' E	11º40.065' N	76º22.872' E
Wayanad	Muthanga	Noolpuzha Section	Mixed moist Deciduous	09-03-2018	2	1010	11º36.112' N	76º21.629' E	11º36.482' N	76º21.969' E
Wayanad	Muthanga	Cheeradankolli	Mixed moist Deciduous	09-03-2018	3	1020	11º36.986'	76º22.254'	11º36.964' N	76º22.715
Wayanad	Muthanga	Cheeradankolli to Mudumalakallu	Mixed Dry deciduous	09-03-2018	4	1030	11º37.404' N	76º22.827' E	11º37.925' N	76º22.822' E
Wayanad	Muthanga	Aimangalam	Mixed Dry deciduous	09-03-2018	5	1000	11º38.030' N	76º22.905' E	11º38.287' N	76º23.328' E
Wayanad	Muthanga	Way to Mudumalakallu	Mixed Dry deciduous	09-03-2018	6	1000	11º38.212' N	76º23.683' E	11º38.703	76º23.812' E
Wayanad	Muthanga	Mudumalakallu campshed	Mixed Dry deciduous	09-03-2018	7	1010	11º38.048' N	76º24.369' E	11º37.936' N	76º23.893' E
Wayanad	Sulthan Bathery	Teak Plantation, Naikatty	Teak plantation	30-03-2018	8	1010	11º42.425' N	76º18.634' E	11º42.535' N	76º19.149' E
Wayanad	Sulthan Bathery	Kathiapalam	Mixed Dry deciduous	30-03-2018	9	1000	11º42.671' N	76º19.468' E	11º43.118' N	76º19.410' E
Wayanad	Sulthan Bathery	Kurichiyat boundary	Mixed Dry deciduous	30-03-2018	10	1000	11º43.318' N	76º19.470' E	11º43.846' N	76º19.505' E

Wayanad	Sulthan Bathery	Erumachathakolli	Mixed moist Deciduous	30-03-2018	11	1010	11º43.842' N	76º19.802' E	11º43.904' N	76º20.323' E
Wayanad	Sulthan Bathery	Nallathanni	Mixed Dry deciduous	30-03-2018	12	1020	11º44.214' N	76º20.991' E	11º43.954' N	76º20.544' E
Wayanad	Sulthan Bathery	Near Kallumukku	Mixed Dry deciduous	30-03-2018	13	1000	11º42.352' N	76º19.553' E	11º42.034' N	76º19.954' E
Wayanad	Sulthan Bathery	Ponkuzhi border	Mixed Dry deciduous	01-04-2018	14	1000	11º42.060' N	76º23.507' E	11º42.498' N	76º23.274' E
Wayanad	Sulthan Bathery	Thaalkolli	Mixed moist Deciduous	01-04-2018	15	1000	11º42.683' N	76º22.835' E	11º43.123' N	76º 22.624' E
Wayanad	Sulthan Bathery	Kumizhallam	Mixed moist Deciduous	01-04-2018	16	1010	11º43.443' N	76º23.105' E	11º43.786' N	76º23,433' E
Wayanad	Sulthan Bathery	Kaithallam	Mixed moist Deciduous	01-04-2018	17	1000	11º44.160' N	76º23.876' E	11º44.480' N	76º24.302' E
Wayanad	Sulthan Bathery	OttIpara to Ponkuzhi	Mixed moist Deciduous	01-04-2018	18	1030	11º43.541' N	76º23.684' E	11º43.065' N	76º23.769' E
Wayanad	Sulthan Bathery	Moolahalla	Mixed moist Deciduous	01-04-2018	19	1050	11º43.354' N	76º24.513' E	11º43.382' N	76º25.070' E
Wayanad	Kurichiyat	Kamalapalam	Mixed moist Deciduous	08-03-2018	20	1010	11º46.415' N	76º16.501' E	11º46.044' N	76º16.258' E
Wayanad	Kurichiyat	St Br Vandikadavu	Mixed Dry deciduous	10-03-2018	21	979.7	11º47.729' N	76º14.509' E	11º48.205' N	76º14.557' E
Wayanad	Kurichiyat	Vandikadavu	Mixed Dry deciduous	10-03-2018	22	1010	11º47.931' N	76º13.434' E	11º 47.432' N	76º13.355' E
Wayanad	Kurichiyat	Waterfall	Mixed moist Deciduous	08-03-2018	23	1020	11º45.933' N	76º15.799' E	11º45.756' N	76º15.560' E
Wayanad	Kurichiyat	Nr Kurichiyat Clny	Mixed moist Deciduous	08-03-2018	24	1010	11º46.840' N	76º16.001' E	11º46.576' N	76º16.445' E
Wayanad	Kurichiyat	Kazhukankolli 2 sn	Mixed moist Deciduous	08-03-2018	25	1000	11º46.422' N	76º15.243' E	11º46.639' N	76º15.641' E

Wayanad	Kurichiyat	Manivayal	Mixed moist Deciduous	08-03-2018	26	1010	11º45.572' N	76º15.054' E	11º45.214' N	76º14.695' E
Wayanad	Kurichiyat	Trb Colony n Teak	Teak plantation	10-03-2018	27	1020	11º47.289' N	76º13.333' E	11º47.137' N	76º13.826' E
Wayanad	Kurichiyat	Vandikadav u 2	Mixed Dry deciduous	10-03-2018	28	1050	11º47.792' N	76º13.574' E	11º47.854' N	76º14.132' E
Wayanad	Kurichiyat	Vandikadav u Br 2	Mixed Dry deciduous	10-03-2018	29	1010	11º47.745' N	76º14.716' E	11º47.758' N	76º15.235' E
Wayanad	Kurichiyat	Vandikadav u Br 3	Mixed Dry deciduous	10-03-2018	30	1010	11º47.762' N	76º15.287' E	11º47.567' N	76º15.747' E
Wayanad	Tholpetty	Aralagadha	Mixed Dry deciduous	04-04-2018	31	1010	11º 54.067' N	76º05.629' E	11º54.554' N	76º05.716' E
Wayanad	Tholpetty	Dasangatta section	Mixed Dry deciduous	04-04-2018	32	1000	11º55.968' N	76º05.903' E	11º56.422' N	76º05.940' E
Wayanad	Tholpetty	Bavali road 2	Mixed moist Deciduous	04-04-2018	33	1030	11º53.258' N	76º06.173' E	11º52.817' N	76º06.184' E
Wayanad	Tholpetty	Bavali road	Mixed moist Deciduous	04-04-2018	34	1030	11º53.624' N	76º05.606' E	11º53.638' N	76º06.148' E
Wayanad	Tholpetty	Punchavaya l	Mixed moist Deciduous	04-04-2018	35	1030	11º52.474' N	76º05.998' E	11º51.988' N	76º06.075' E
Wayanad	Tholpetty	Dasangatta road	Mixed Dry deciduous	04-04-2018	36	1030	11º54.850' N	76º05.857' E	11º55.361' N	76º05.889' E
Wayanad	Tholpetty	Aralagadha road	Mixed Dry deciduous	04-04-2018	37	1030	11º53.226' N	76º05.119' E	11º53.664' N	76º05.324' E
Wayanad	Tholpetty	Tholpetty CP	Mixed Dry deciduous	03-04-2018	38	1020	11º56.852' N	76º04.392' E	11º57.152' N	76º04.839' E
Wayanad	Tholpetty	Sambalam	Mixed moist Deciduous	04-04-2018	39	1020	11º51.807' N	76º06.325' E	11º51.562' N	76º06.747' E
Wayanad	Tholpetty	Dasangatta interior	Mixed moist Deciduous	03-04-2018	40	1020	11º55.473' N	76º05.184' E	11º55.811' N	76º04.968' E

APPENDIX III

INTERVIEW SCHEDULE FOR HOUSEHOLD SURVEY REGARDING HUMAN-ELEPHANT INTERACTION

1. Basic Details

(a). Household particulars:

A. Date B. Forest Range C. Location

D. Name & Address Household members

Male: Female: Children: Total:

F. Community G. Occupation H. Age

I. Education J. Economic Status (APL/BPL/Other)

K. How long have you been living here? ..... years

(b). Main sources of livelihood and season of the activity:

Livelihood	Seasons		
	Summer	Monsoon	Winter
Agriculture			
Livestock			
Wage Labour			
Forest Products			
Other			

(c). Has your traditional livelihood changed?

2. Natural resource knowledge and use

(a). Do you think areas around your village have changed over the last 10,20 or 30 years. Yes/no. If yes please specify:

Particulars	15 years	30 years
Forest Area		
Wild Animals		
Domestic Animals		
Water Sources		
Agricultural Land		
Cropping Pattern		

(b). Do you think the climate has changed over the last 10, 20 or 30 years? Yes/No. If Yes, please specify.

Climatic condition	15 years	30 years
Temperature		
Wind speeds		
Rainfall pattern		
Water availability		

(c) How often do you access the forest? Occasionally/Often/Always
What is the purpose of visit?

3. Human-Elephant conflict

(a). What are the problematic wild animals in your area?

Most problematic animals	Relatively problematic animals	Animals with little or no problem

(b). What are the most serious problems caused by wild elephants (in order)?

(c). What are the most raided crops (in order)?

(d). What is the time of day the damage by elephants most likely to occur (Dawn, Morning, afternoon, dusk, night)?

A. Crop damage: **B. Property damage:** **C. Human casualty/injury:**

(e). How do you see the trend of elephant damage over the last five years?

	Highly increased	Increased	Stable	Decreased	Highly decreased
Crop damage					
Property damage					
Human casualty/injury					

(f). Have wild elephants caused any damage to you and your family (people living with you in your house) over the last five years?

A. Crop damage (Estimated loss: Rs. .....); Type of damage:
B. Property damage (Estimated loss: Rs. .....); Type of damage:
C. Human casualty/injury (Injured: ....., Killed :.....)

(g). Have you got relief/compensation of the losses from elephant damage?

A. Crop damage (Compensation: Rs. .....)
B. Property damage (Compensation: Rs. .....)
C. Human casualty (Treatment cost: Rs. ....., Relief: Rs. .....)

4. Prevention and mitigation measures

(a). What are the measures taken for minimizing human-elephant conflict in your area? (Tick only the methods practiced so far)

A. Deterrents (Noise, fire crackers)

B. Elephant squad

c. Physical barriers (Trench, fence)

D. Power fence (electric, solar)

F. Compensation/Relief

G. Capturing problem elephants

(b). How do you rate the effectiveness of the methods practised so far to minimize damage by wild elephants? (Rate between 0 to 4 where 0 is never effective , 1 is rarely effective, 2 is effective about half the time, 3 is mostly effective, 4 is always effective)

SN	Methods	Effectiveness rating				
		0	1	2	3	4
1	Deterrents(Noise, fire crackers)					
2	Elephant squad					
3	Physical barriers (Trench, fence)					
4	Power fence (electric, solar)					
5	Compensation/Relief					
6	Capturing problem elephants					

(c). Is the compensation/relief adequate? (Please tick one)

Very adequate	Adequate	Partially adequate	Inadequate	Completely inadequate

(e). Are you getting compensation/relief on time?

Always/Mostly/Usually/Sometimes/Rarely

If no, what should be the time frame?

5. Perception about conflict and conservation

SL NO:	Statements	Excellent perception	Very good perception	Fair	Poor	Very poor
i	Human population expanding into wild animal habitats is the main cause of human elephant conflict.					
ii	Reduction in the availability of natural food and water sources in forest leads to elephants raiding crops in farms and residential area.					
iii	Lack of proper planning in developmental projects like road construction through the forest area makes elephants disturbed.					

iv	Poaching, hunting, illegal activities inside the forest, etc make human elephant conflict more probable.					
v	Keeping some distance from forest for farming and residing helps to reduce conflict.					
vi	Farming plants containing capsaicin like chilly and pepper in border areas of forest helps to avoid elephants raiding crops.					
viii	Sufficient compensation related to crop damage helps to cope up with financial losses.					
ix	Timely compensation can be an effective way to reduce villagers' suffering due to human-wildlife conflict.					
xi	Ecotourism is one of the major preventive measures. It helps in conservation of wildlife and it also increases the employment opportunities of local people.					
xii	Official's quick interventions help in reducing human elephant conflict.					
xiii	Wild animals have predictable behavioural patterns. If we understand this, we can reduce human wildlife conflict.					
xiv	Tempting crops like mango and jack being cultivated in summer season, easily cause elephant raids					

6. Approximate elephant population in your range

7. Do you think elephants should be protected?

	Yes	No
Why		

8. What should be done to minimize conflict between people and elephant in this area?

a. Capture and relocate problem elephant
b. Kill the problem elephant
c. Capture and relocate all the elephants
d. Support to construct permanent houses
e. Support for alternative livelihood/ crops

9. Who should take responsibility for reducing conflict with wildlife?

SL NO:	Stakeholders	Most effective	Effective	Neutral	Not much effective	Least effective
i	Farmers					
ii	Villagers					
iii	Forest Department					
iv	Agriculture Department					
v	Revenue Department					
vi	Non-Governmental Organizations (NGO's)					
vii	Local administers					
viii	Tourists					
ix	People's representatives					

9. Do you want human-elephant coexistence in this area? a. Yes b. No

If no, what should be done?

A. Kill the elephants
B. Relocate elephants
C. Relocate people

If relocate people, where?
A. Within buffer zone
B. Outside buffer zone

If relocate elephant, where?

10. Awareness about Forest and biodiversity rules and laws

Question	Not answered	Correct	Incorrect
Name the forest related rules and laws that you are aware of.			
Elephant belongs to which schedule in Wildlife Protection Act 1972			
As per the Wildlife Protection Act 1972, what is hunting?			
Is hunting or poaching of Elephant allowed as per Wildlife Protection Act 1972?			

APPENDIX IV

INTERVIEW SCHEDULE FOR FOREST DEPARTMENT OFFICIALS REGARDING HUMAN ELEPHANT INTERACTION

1. Basic Details

(a). Household particulars:

A. Date B. Forest Range C. Location

D. Name & Address

G. Occupation H. Age

K. How long have you been living here? ..... years

L. GPS Location: .....N .....E

2. Natural resource knowledge and use

(a). Do you think areas around your village have changed over the last 10,20 or 30 years. Yes/no. If yes please specify:

Particulars	15 years	30 years
Forest Area		
Wild Animals		
Domestic Animals		
Water Sources		
Agricultural Land		
Cropping Pattern		

(b). Do you think the climate has changed over the last 10, 20 or 30 years? Yes/No. If Yes, please specify.

Climatic condition	15 years	30 years
Temperature		
Wind speeds		
Rainfall pattern		
Water availability		

3. Human-Elephant conflict

(a). What are the problematic wild animals in your area?

Most problematic animals	Relatively problematic animals	Animals with little or no problem

4. Prevention and mitigation measures

(a). What are the measures taken for minimizing human-elephant conflict in your area? (Tick only the methods practiced so far)

A. Deterrents (Noise, fire crackers)

B. Elephant squad

c. Physical barriers (Trench, fence)

D. Power fence (electric, solar)

F. Compensation/Relief

G. Capturing problem elephants

(b). How do you rate the effectiveness of the methods practised so far to minimize damage by wild elephants? (Rate between 0 to 4 where 0 is never effective , 1 is rarely effective, 2 is effective about half the time, 3 is mostly effective, 4 is always effective)

SN	Methods	Effectiveness rating				
		0	1	2	3	4
1	Deterrents(Noise, fire crackers)					
2	Elephant squad					
3	Physical barriers (Trench, fence)					
4	Power fence (electric, solar)					
6	Compensation/Relief					
7	Capturing problem elephants					

(c). Is the compensation/relief adequate? (Please tick one)

Very adequate	Adequate	Partially adequate	Inadequate	Completely inadequate

(e). Are the victims getting compensation/relief on time?

Always/Mostly/Usually/Sometimes/Rarely

If no, what should be the time frame?

5. Perception about conflict and conservation

SL NO:	Statements	Excellent perception	Very good perception	Fair	Poor	Very poor
i	Human population expanding into wild animal habitats is the main cause of human elephant conflict.					
ii	Reduction in the availability of natural food and water sources in forest leads to elephants raiding crops in farms and residential area.					
iii	Lack of proper planning in developmental projects like road construction through the forest area makes elephants disturbed.					
iv	Poaching, hunting, illegal activities inside the forest, etc make human elephant conflict more probable.					
v	Keeping some distance from forest for farming and residing helps to reduce conflict.					
vi	Farming plants containing capsaicin like chilly and pepper in border areas of forest helps to avoid elephants raiding crops.					
viii	Sufficient compensation related to crop damage helps to cope up with financial losses.					
ix	Timely compensation can be an effective way to reduce villagers' suffering due to human-wildlife conflict.					
xi	Ecotourism is one of the major preventive measures. It helps in conservation of wildlife and it also increases the employment opportunities of local people.					
xii	Official's quick interventions help in reducing human elephant conflict.					

xiii	Wild animals have predictable behavioural patterns. If we understand this, we can reduce human wildlife conflict.					
xiv	Tempting crops like mango and jack being cultivated in summer season, easily cause elephant raids					

6. Elephant population dynamics in your range

7. Do you think elephants should be protected?

	Yes	No
Why		

8. What should be done to minimize conflict between people and elephant in this area?

a. Capture and relocate problem elephant
b. Kill the problem elephant
c. Capture and relocate all the elephants
d. Support to construct permanent houses
e. Support for alternative livelihood/ crops

9. Who should take responsibility for reducing conflict with wildlife?

SL NO:	Stakeholders	Most effective	Effective	Neutral	Not much effective	Least effective
i	Farmers					
ii	Villagers					
iii	Forest Department					
iv	Agriculture Department					
v	Revenue Department					
vi	Non-Governmental Organizations (NGO's)					
vii	Local administers					
viii	Tourists					
ix	People's representatives					

9. Do you want human-elephant coexistence in this area? a. Yes b. No

If no, what should be done?

A. Kill the elephants
B. Relocate elephants
C. Relocate people

If relocate people, where?
A. Within buffer zone
B. Outside buffer zone

If relocate elephant, where?

10. Awareness about Forest and biodiversity rules and laws

Question	Not answered	Correct	Incorrect
Name the forest related rules and laws that you are aware of.			
Elephant belongs to which schedule in Wildlife Protection Act 1972			
As per the Wildlife Protection Act 1972, what is hunting?			
Is hunting or poaching of Elephant allowed as per Wildlife Protection Act 1972?			

HABITAT CHARACTERISATION OF ASIAN ELEPHANT (*Elephas maximus*) IN WAYANAD WILDLIFE SANCTUARY, KERALA

By

ASHWIN S (2016-17-009)

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree

MASTER OF SCIENCE IN FORESTRY

Faculty of Forestry

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VELLANIKKARA

THRISSUR, KERALA

2018

ABSTRACT

A field study was conducted to characterise the habitat of the Asian Elephant (*Elephas maximus*). The study was conducted from September 2017 to April 2018 in Wayanad Wildlife Sanctuary, Kerala.

A total of 100 transects were walked randomly across different vegetation types of Wayanad Wildlife Sanctuary to obtain elephant population density through dung count method across two separate seasons, wet season (Oct-Nov) and dry season (Mar-Apr). Vegetation parameters of these areas were also recorded in a total of 600 quadrats of size 10m × 10m. Socioeconomic survey of local communities around the sanctuary and forest officials was also conducted through an interview schedule to understand the perception towards human-elephant conflict.

Seasonal movement of Asian Elephants was observed in the sanctuary as characterised by the difference in population density during the wet season (0.68 elephants/km^2) and the dry season (0.87 elephants/km^2). Elephant density was higher in the dry season. There was also variation in density of elephants between different ranges across the two seasons. Sulthan Bathery recorded highest elephant density of 0.87 elephants/km^2 in the wet season, while Muthanga recorded highest elephant density of 1.03 elephants/km^2 in the dry season. All ranges except Sulthan Bathery recorded increase in elephant density during the dry season.

Elephant population density also varied between different vegetation types. Density was highest in the natural forests, consisting mainly of mixed moist deciduous habitat and mixed dry deciduous habitat in both seasons. Percentage distribution of elephants was found to be higher in natural forests (84.26% and 74.09% in wet and dry seasons respectively) than in plantations (16.74% and 27.91% in wet and dry seasons respectively). Therefore, it can be deduced that elephants prefer natural forests over plantations. Hence, the declining area of natural forests could be a cause of concern for long-term conservation of the Asian Elephant in Wayanad. This could also be a reason for the escalating incidence of human-elephant conflict in the area.

Vegetation studies using quadrat surveys showed a total of 67 species of trees within 33 families. The density of trees was calculated to be 420 trees/ha. Density of trees was slightly higher in plantations (432 trees/ha) than in natural forests (418 trees/ha). Tree species such as *Terminalia elliptica*, *Tectona grandis*, *Anogeissus latifolia*, and *Lagerstroemia microcarpa* were found to be the most abundant in the sanctuary. Girth class distribution of tree species followed a skewed distribution indicating that the habitat is not in a stable condition due to lack of regeneration. Restoration efforts should be done to ensure the long-term survival of the forests of Wayanad Wildlife Sanctuary.

Diversity indices such as Shannon-Wiener Index and Simpson's Index showed an rather low diversity of tree species in the sanctuary, with higher diversity in natural forests than plantations. Correlation between elephant density and tree species diversity was found to

be highly significant only during the dry season. This could imply that tree species diversity influences elephant distribution during the dry season. The Important Value Index was computed from relative density, relative frequency and relative basal area to show quantitative relationship among the vegetation and to highlight the importance of families of trees within a habitat. Important Value Index (IVI) values shows that the most important families of trees in the sanctuary are Combretaceae, Fabaceae, Lamiaceae and Lythraceae, which include trees preferred by the elephants as browse species.

Interview schedule of local communities and forest officials shows that that there is a highly significant and strong relation between the response of the two groups (local communities and forest officials) towards their perception about the change in land-use systems, change in climate, and factors related to human-elephant conflict and conservation strategies.

The expansion of human population to the wildlife habitats, reduction in the availability of food and water in the forest, cultivation of palatable crops in the agricultural lands surrounding the sanctuary, lack of proper planning in establishment of the preventive measures and inadequacy of compensation associated with the long term process for availing compensation were found to be the major causes for human elephant conflict. Increased incidence of crop damage during summer can be an indirect indicator of movement of elephants into the sanctuary from the adjacent bordering protected areas, as well as presence of palatable fruit trees like Jack and Mango. Proximity of farming areas among respondents to the forests were recorded at a higher percentage in Muthanga and Tholpetty range, which could influence elephant movements into these areas during the dry season.

The quick interventions by the forest officials, cultivation of repellent crops at greater distance from forests, and understanding the predictable behavioural changes of wild animals can help reduce the risk of human-elephant conflict to a great extent. Better implementation of the preventive measures can encourage the local communities residing in the sanctuary to ease the situation of human elephant coexistence.