EFFICIENCY OF MITIGATION MEASURES AGAINST CROP RAIDING WILD ANIMALS IN WAYANAD WILDLIFE SANCTUARY

By

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THESIS

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DECLARATION

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I, hereby declare that this thesis entitled **"Efficiency of mitigation measures against crop raiding wild animals in Wayanad Wildlife Sanctuary"** is a bonafide record of research work 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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Introduction

INTRODUCTION

In India, elephants are considered as a significant part of our culture and life. The diminishing forest habitats and the sport hunting activities at the time of British Raj dramatically reduced the elephant numbers and range which is now restricted to north-eastern, north-western, eastern and southern parts of our country. But still, it requires larger areas for its shelter and foraging. The enormous rise in the human population in the Asian countries has led to an accelerated conversion of forest areas into human settlements. The people's encroachment into the forest land coupled with the requirements of the wild creatures is what leads to crop raiding, injury or death of humans which ultimately leads to human-wildlife conflict. These incidents will have a significant consequence on the people's psychosocial wellbeing, food security and livelihood (Barua *et al.,* 2013). The post-independence development projects in India such as construction of dams, mining, and extensive agriculture accelerated deforestation and conversion of forest areas to commercial plantation or to agricultural land. Nearly 40% of original forest cover of Western Ghats was converted to plantations and agricultural land during 1920-1990. At that time, annual deforestation rate in Western Ghats was estimated to be 0.57%.

Conflict happens when the same physical space is shared by wildlife and humans. Identifying what drives conflict in an area is critical in determining how to resolve it. The human-wildlife conflict addresses situations ranging from grain eating rodents to man-eating tigers (Pimentel; *et al.,* 2005; Barlow, 2009). The species which are more exposed to conflict are more prone to extinction due to injury or death caused by humans accidently or intentionally (Ogada *et al.*, 2003).

If the elephants feed on crops opportunistically, then they can be deterred by any of the short-term measures such as guarding and electric fencing. However, if the elephants are forced to raid the crops for its survival, barriers are needed to stop them (Boominathan *et al.*, 2008). But, if these are successful, the future of elephants is

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threatened (Fernando *et al.*, 2005). The choice of intervention should not only depend on effectiveness but also sustainability (Treves *et al.*, 2006).

The people of Wayanad are predominantly agriculturists. Agriculture is characterized by a mixture of subsistence farming and mixed cash crops. Crop damage is a severe problem in most of the settlements. Wild boar, elephant, Indian-crested Porcupine, Sambar Deer, Spotted Deer, Common Langur and Bonnet Macaque are mainly responsible for crop damage problems among which elephants and wild boars tops the list. In a household survey by Easa and Sankar (2001), about 73.53% of respondents opined that crop damage was more in rainy season. Cattle lifting incidents are comparatively few and had occurred mostly in night. Human casualties by elephant is very common in Wayanad and mostly solitary tuskers were responsible. Crop damage by different animals estimated an economic loss of Rs. 42,43,203.47. Of this 88.89% was due to the damage by elephants alone (Easa and Sankar, 2001).

The straying of the wild animals outside the forest areas and thereby threatening the human life as well as causing damage to the crop fields and other properties are giving greater attention to the human-wildlife conflict. Kothari *et al.* (1995) have summarized the major reasons leading to human wildlife conflict in the Protected Areas in India. Irrationality in planning, curtailment of local community land and forest rights, access to natural resources inside Protected Areas, increase in the animal population due to increased protection offered by PAs and the urban industrial pressure for the resources are the major factors contributing to the human wildlife conflict.

Protected areas has become conservation islands surrounded by human-dominated landscape which leads to negative interaction between human and wildlife. Wildlife management which helps in the recovery of declining population of large mammals has also lead to increased conflicts (Saberwal *et al.*, 1994; Fall and Jackson, 2002; Vijayan and Patil, 2002; Woodroffe *et al.*, 2005). Human-wildlife conflicts mainly address the problems regarding injury and death of people, property damage

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and crop raiding by mainly elephants, livestock loss and threat to life by carnivores. There are many techniques which can be used for protecting livestock from wild animals (Miller *et al.*, 2016). Many of them are being used in India, such as feeding of livestock in stalls, housing small stock in predator proof enclosures at night and using guard dogs to protect livestock. In other countries, newer methods like fladry (coloured flags hung to fence to deter predators) and solar powered flashing lights are in use (Kermeliotis, 2013).

The elephants are also subject to human attack which causes danger to its life. Elephants are of prime concern when it comes to financial losses of the farmers. Farmers with small holdings is least able to withstand the risks posed by elephants (Nath and Sukumar, 1998), and in extreme cases they are forced to abandon their farms (Boominathan *et al.*, 2008).

The human-elephant conflict has become a serious issue faced by the elephant conservationists (Stephenson, 2004). A study by Sukumar and Gadgil (1998) on the gender differences of elephants in crop foraging has shown that pubertal and adult males incurred greater risk on foraging on cultivated crops than female herds. Grazing of livestock in forest lands reduces the forage available for elephants, and this also is a reason for human-wildlife conflict. Feeding of crops by elephants may be also a learnt behavior (Sukumar, 1985a). Calves may learn from the adults in the herd and the young bulls that disperse from the herd that have never fed on crops may learn by association with the bulls that do (Osborn, 1998).

The tolerance level of damages differs from communities to communities and from individuals to individual. And the repeated crop-raiding leads to the ill will against the elephants in many parts of India. The elephant killings which was practiced in colonial era is banned now, but shooting of rogue elephants is still in use by some state governments as a solution for elephant depredations. Thus, for successful conservation of elephants, measure for mitigating human-wildlife conflict is essential.

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For improving the co-existence of people and wildlife and to enhance the sustainability of conservation efforts, it is imperative to implement human-wildlife conflict mitigation measures. In India, preventing and mitigating human-wildlife conflict are a top conservation priority (Karanth *et al.*, 2013). Many measures are implemented for mitigating human-wildlife conflict. Almost all the mitigation measures adapted are concerned with crop raiding. Some may be of short-term solution, and some mitigation measures may be restricted to small-scale application due to its high financial requirements. There is no single management solution for all situations (Hoare, 2001; Osborn and Parker, 2002, Fernando *et al.*, 2008). State governments as well as the wildlife conservationists focus on identification of low-cost long lasting mitigation measures that will not harm elephants and humans. The mitigation measures need constant experimentation and innovation (Chong and Norwana, 2005).

Traditional methods encompass of all the self-defense measures practiced by local farmers for centuries to protect their farm from elephant damage (Hoare, 2001). It is still widely used due to economic reasons or when the modern methods are tested with little success. It ranges from chasing elephants with noise and fire, to collective prayer and magic (Tchamba, 1996), erection of human effigies (Thouless, 1994) and tying of clothes and rags on trees (De Boer and Ntumi, 2001). The more common techniques that have been practiced includes chasing away of elephants by creating loud sounds through shouting, beating drums, bursting fire crackers, and using powerful torches; constructing elephant-proof trenches and solar power fences; planting unpalatable crops to make the area less preferable to elephants; early warning communication system such as trip wire alarm system and satellite tracking; elephant mitigation squads with trained elephants (kumkies) to drive back the wild elephants from human habilitations; capturing and relocation of problem animals; relocation of people from elephant habitats; monetary compensation schemes for the victims of the crop-raiding, livestock loss and injury or loss of human life. In Kerala, indigenous

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animal deterrent methods such as traps, and fire crackers, and modern methods like elephant proof trenches, cracker lines, live wire fences, and electric fences are used for preventing crop raiding (Jayson, 1998).

The mitigation strategies will be location specific, that is, the techniques that reduce the problem in one area or one country may not be effective in another area or situation (Jasmine *et al.*, 2015). Manual guarding is reported to be the most widely used crop protection method followed by physical fences around fields (Sekar, 1998). Elephant-proof trenches are expensive to excavate and require regular maintenance (Nelson *et al.*, 2003) and the efficiency is negatively correlated to the age and number of roads and paths that crosses the trench (Fernando *et al.*, 2008). Stone walls are relatively expensive and most of the areas lack usable stones for construction. It also has a low environmental impact compared to trenches. In Indonesia, studies say that community-based guarding using conventional tools (eg. Noise makers) is useful in keeping elephants out of crops and chilly-grease fences do not add any significant deterrent effect (Hedges and Gunaryadi, 2010).

The mitigation measures which are expensive or affected by whether conditions are found to be unsustainable (Hans Enukwa, 2017). No method can be considered as a 'stand-alone' universal solution for human-wildlife conflict mitigation as each of the methods have its own advantages and disadvantages (Fernando *et al.*, 2008).

In Kerala, maximum crop damage is reported due to Asian Elephant and Wild Boar (Jayson, 1999). Asian Elephant is found to be involved in 47.7 percent of the human-wildlife conflict incidents, followed by Wild Boar (23.3 percent) and Bonnet Macaque (17.3 percent) (Shaji, 2018). It is also reported that 81 percent of these conflict incidents occurred in Forest Divisions towards the north of Palakkad gap on Western Ghats, which may be due to the high level of fragmentation of forest ecosystems, changes in cropping pattern, decreasing tolerance level of people towards wildlife, etc. 64 percent of the conflict incidents in Kerala is reported from three Forest

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Divisions of Wayanad. In Wayanad, more damage is caused by elephant and gaur (Easa and Sankar, 2001). The Kerala State Forest Department is practicing different mitigation measures such as elephant proof trenches, solar electric fences and elephant proof wall in Wayanad Wildlife Sanctuary. The conflict involving Wild Boar is spread throughout Kerala and Wayanad is one of the places where this problem is severe. Cai *et al.* (2008) has identified the main factors affecting the level of crop damage by Wild Boar and observed that all strategies employed by the local people to prevent crop raiding failed to work except human presence in the fields.

The mitigation measures incur considerable expenditure to the Government; not only at the time of installation of these mitigation measures as well as the cost of recurring maintenance too. For example, the cost of 1 kilometer Elephant Proof Trench, Solar Electric Fence and Elephant Proof Wall costs Rs. 8 lakhs, Rs. 1.9 lakhs and Rs. 1.3 crore respectively. However, no attempt has been made until now to evaluate the efficiency of these mitigation mechanisms to reduce the human- wildlife conflict. And hence the present study. The objective of the study is to map and document human-wildlife conflict mitigation measures being followed in Wayanad Wildlife Sanctuary. It is also proposed to examine the effectiveness of various intervention methods used in mitigating human wildlife conflict. The attitude, perception and suggestions on human-wildlife conflict mitigation measures of the individuals residing near to the forest fringes are also studied. It is expected to throw insights into the wildlife management interventions to mitigate the HWC in our protected areas.

Review of literature

REVIEW OF LITERATURE

2.1 Human-wildlife conflict:

Food, water and shelter are the most basic needs for both the humans and animals. Conflict arises when these basic needs are threatened. Habitat fragmentation and degradation due to developmental activities, land use transformation and human population explosion, lead to frequent conflicts between humans and wildlife (Distefano, 2005). Dutta *et al.* (2018) has identified 567 types of barriers such as roads, railway, reservoir and mines in 30 corridors in central India landscape consisting of 3,84,508 sq. km spread across 16 protected area in Madhya Pradesh, Maharashtra and Chhattisgarh. Bist (1996), and Santiapillai (1996) suggested control measures to overcome the problem of crop raiding.

The elephant crop-raiding is very much prominent in Asian and African countries and it has been reported from almost all elephant ranges in Asia where elephants survive in fragmented and disturbed habitats. Crop raiding by elephants has been identified to be the principal form of conflict (Johnsingh *et al.*, 2015). It is said that elephants damage around 0.8-1.0 million hectors of farm land annually in which at least 500,000 households are effected on top of causing millions of rupees' economic loss (Bist, 2002). Each year, about 400 people are reported to lose their lives in wild elephant encounters and about 100 elephants are killed as a result of human-elephant conflict (Datye and Bhagwat, 1995; Anon, 2010). The crop damage, quantified in terms of economic losses have been done in Palamau National Park (Mishra, 1971). Santiapillai and Ramono (1993) and Santiapillai and DeSilva (1994) concluded that the elephants are forced to raid crop as their habitat was degraded and lost. Habitat loss being the primary cause, other cause that attracts wildlife in crop raiding is the higher nutritive content and palatability of crops (Sukumar, 1990; 1991). Studies on crop raiding in continuous tracts of habitat have shown that not all the elephant individuals within a certain population are involved in crop raiding (Balasubramanian *et al.*, 1995;

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Williams *et al.*, 2001). Only in highly degraded landscapes, all individuals may resort to crop raiding and destruction.

A study in Assam, India habitat destruction, increasing monkey population and improper waste disposal are the major causes of human-monkey conflict (Devi and Saikia, 2008). Human-Rhesus monkey conflict was at Rampur was studied by Ahsan and Uddin (2014) and revealed that the Rhesus Macaques consumed plant parts of 10 different plant species and was found to be causing more damage to the betel leaves, followed by banana and vegetables.

Whenever opportunity arises, large carnivores attack people and domesticated ungulates (Karanth and Gopal, 2005). Wild ungulates, primates, granivores and frugivorous birds are often involved in raiding agricultural crops and fruit orchards which also damages young shoots of other crops (Jhala, 1993; Sekhar, 1998; Dave, 2010; Gubbi *et al.*, 2014). Among ungulates, elephants are the more studied one as it results in large scale damage of the crops (Gubbi, 2012). The replacement of agricultural crops with medicinal plants which are less preferable by the wildlife can be considered as an option in reducing the economic losses of the local communities (Rao *et al.*, 2002; Gross *et al.*, 2017). The implementation of mitigation strategies is vital for improving the coexistence of people and wildlife and it improves the attitude and tolerance of farmers towards wildlife as it reduces the crop loss, human death and injury as well as the elephant mortality due to human-elephant conflict (Jackson *et al.*, 2008). Even if crop raiding occurs throughout the year, it was observed that significantly higher damage occurred during the post monsoon period, and the damage was low during pre-monsoon and monsoon periods (Rohini *et al.*, 2016). As the wildlife are easily getting adapted to the mitigation measures used in defending the farms lands, management of the human-wildlife conflict issues is becoming a more challenging task. The evidence shows that the long term mitigation is challenging or seems to be practically impossible as the wild animals are easily getting habituated to these barriers. The conflict and the associated losses will negatively affect the public

support and it enhances the hatred towards the wildlife as well as the wildlife managers (Madhusudan, 2003; Ogra and Badola, 2008).

2.2 Human-wildlife conflict mitigation:

Different management tools are available to tackle the problem of human wildlife conflict. But most of them are site and species/genera specific and are not easily accessible. Preventive strategies such as artificial and natural barriers, guarding, alternative high cost livestock husbandry practices and mitigation strategies like compensation, insurance and incentive programmes, community based natural resource management schemes, regulated harvest and wildlife translocation can be adopted to deal with human wildlife conflict (Distefano, 2005).

In India, preventing and mitigating human-wildlife conflict are a top conservation priority (Karanth *et al.*, 2013). The mitigation strategies will be location specific, that is, the techniques that reduce the problem in one area or one country may not be effective in another area or situation (Jasmine *et al.*, 2015). In Asia, electric fences are the most commonly used physical barrier for mitigating human-wildlife conflict (Desai and Riddle, 2015). In Kerala, indigenous animal deterrent methods such as traps, and fire crackers, and modern methods like elephant proof trenches, cracker lines, live wire fences, and electric fences are used for preventing crop raiding (Jayson, 1998). However, elephant-proof trenches are observed to be most effective preventive measure when compared to ordinary fencing, guarding or using crackers (Easa and Sankar, 2001). Some of the other measures developed to tackle human-wildlife conflict are early warning alarm system through SMS to the forest officials for taking necessary action, bulk SMS to the villagers (Sugumar and Jayaparvathy, 2013). According to Sitati and Walpole (2006), the displacement of animal movement happens, not just because of the construction of the physical barriers, but due to the clubbed effect of the active involvement of the guards at the barrier as well. They

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conclude that the combination of early warning system, guarding and chilly grease deterrent is effective in controlling the human-wildlife conflict to a greater extent.

Traditional methods encompass of all the self-defense measures practiced by local farmers for centuries to protect their farm from elephant damage (Hoare, 2001). It is still widely used due to economic reasons or when the modern methods are tested with little success. It ranges from chasing elephants with noise and fire, to collective prayer and magic (Tchamba, 1996), erection of human effigies (Thouless, 1994) and tying of clothes and rags on trees (De Boer and Ntumi, 2001). Indigenous techniques, which comes under short term measures practiced in Rajasthan against blue bull are use of scare crows locally (known as Odaka), live fencing of thor (*Euphorbia neriifolia* L.) and *Prosopis juliflora* around their field boundaries, beating bells in the crop fields, use of animal excreta, especially blue bull excreta is a wonderful repellant for themselves, use of mixture of donkey excreta with cow urine and other wastes like rotten vegetable leaves which produces foul smell to allay blue bulls, use of crackers, use of forate insecticide granules and spray of phenyl solution as repellent and making fence of reels of shining tapes around the crop fields (Meena *et al.*, 2014). The elephants get quickly habituated to the human effigies (scarecrows), which is used in some places (Hoare, 2001).

Crop guarding is not considered to be a deterrence method. The crop guards sleeping on the watchtowers monitors the crop-raiding elephants and alerts the community with some signals (eg. Whistles). Platform at trees or huts at ground level are used as look-outs (Nelson *et al.*, 2003; Fernando *et al.*, 2008). Guarding and patrolling are the simplest and most effective means of crop protection (Desai, 2002). But, people endanger their lives by getting too close to elephants (Nath and Sukumar, 1998; Desai, 2002; Nelson *et al.*, 2003; Fernando *et al.*, 2008).

One of the other most common traditional strategy is to scare away the wild animals by making noises. The farmers living around the Maputo Elephant Reserve,

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Mozambique, used noise made by drumming on tins and pots to scare away the elephants, but only 52 percentage of people confirmed it as an effective method (De Boer and Ntumi, 2001). Imitation of gun fire using whip-cracking is used in both Asia and Africa (Hart and O'Connell, 1998; Hoare 1995; Nyhus and Tilson, 2000). The communities residing near to the Dzanga Sangha Reserve in the Central African Republic used to burn bamboos causing it to explode (Kamiss and Turkalo, 1999). The measures which are used repeatedly with little variation will eventually become ineffective as elephants get used to the measures that don't hurt (Nath and Sukumar, 1998; Hoare, 2001; Parker *et al.*, 2007).

The deterrent effects of fire can be enhanced using other additional materials. In the Democratic Republic of Congo, capsicum seeds are added to the fire (Kes Hilllman Smith *et al.*, 1995) where as in Zimbabwe, Briquettes of elephant dung mixed with ground chilies are used (Hoare, 2001; Osborn and Rasmussen, 1995). It is also found that Capsicum oleo-resin spray could be used as a short term repellent against African elephants (Osborn and Rasmussen, 1995). Farmers in Waza-Logone district of Cameroon believed that elephants dislike the burnt smell of sheep dung, but it was found to be ineffective (Tchamba, 1996).

The local people throws stuffs like sticks, stones, glowing tinder and spears on the wild animals which results in fatal incidents on both sides. Wounded elephants becomes more aggressive and it triggers attacks on human beings. The elephants may die because of infected wounds gradually (Tchamba, 1996; Thouless, 1994). Most of the traditional methods gives a temporary solution to the region or shifts it the problems to the neighboring areas (Kamiss and Turkalo, 1999; Nyhus *et al.*, 2000; Tchamba, 1995; Tchamba; 1996).

Jackson *et al.* (2008) have put an effort to understand the causes of the conflict by studying the factors underlying spatial use by elephants and people in Botswana, and found out that spatial use is a function of season and crop raiding by elephants is a

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function of season and social grouping. A quantitative assessment of the stakeholder's attitude through surveys and interviews could be helpful in developing management strategies (Decker *et al.*, 2012). Kansky and Knight (2014) have studied about the drivers of the conflict through meta-analysis of predicted variables. However, a single preventive measure may not be sufficient for deterring the wildlife (Sitati and Walpole, 2016). Even the combination of methods implemented which may found to be effective, becomes ineffective over time (Parker and Osborn, 2006). The crop raiding elephants learn to avoid crop protection measures and develops resistant against those measures (Bandara and Tisdell, 2002).

The study in Namibia by O'Connell-Rodwell *et al.* (2000) has shown that the early warning systems used for giving alert to the farmers when elephant approaches, is relatively successful in small-scale trials. Trip wire alarms are temporarily effective for individual small farms (O'Connell-Rodwell *et al.*, 2000, Nelson *et al.*, 2003; Sitati and Walpole, 2006). But, in high rainfall areas, electrical systems are difficult to maintain (Parker *et al.*, 2007). Osborn and Parker (2002) found that the time spend by the elephants in the crop fields can be reduced by using chilly sprays. The spray which contains atomized cloud particles floats in a cloud and can remain effective for approximately 20 minutes. In light wind, it can move to an effective distance up to 75 m and accidental exposure to people is considered to be a constant problem (Hoare, 2001). Chilly spray works by causing an irritation effect on contact with any mucous membrane. Chilly-based repellents have shown promise as deterrents against crop-raiding elephants in Africa. It was experimented in three sites in India- Buxa Tiger Reserve, Wayanad Wildlife Sanctuary and Hosur Forest Division. Efficacy of this method was significantly better in the low-rainfall regime relative to medium and high-rainfall regimes and a marked gender bias in repelling efficacy was observed (Chelliah *et al.*, 2010). They opinioned that it is found to be more effective for the female-led herds than the solitary males. In the case of Asian elephants, crop raiding effects of males were found to be five times that of the females (Sukumar, 1990; 1991), a

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discrepancy that is ascribed to a male strategy of risk taking that maximizes reproductive success through better nutrition (Sukumar, 1990; Sukumar and Gadgil, 1998). In Indonesia, studies say that community-based guarding using conventional tools (e.g. Noise makers) is useful in keeping elephants out of crops and chilly-grease fences do not add any significant deterrent effect (Hedges and Gunaryadi, 2010). Elephants easily bypassed a chilli fence once they learnt that it was of finite length (Sitati and Walpole, 2006). The same was found with an electric fence on the boundary of Tsavo East National Park, where conflict declined towards the centre of the fence but increased in farms at each end where elephants went around (Smith and Kasiki, 1999). Burning chilli laced briquettes to create pungent smell is practically difficult as it depends on the prevailing wind direction and dissipates quickly (Fernando *et al.*, 2008). The sensors at the trunk tip of the elephants help in detecting presence of chillies, and it may able to seal its trunk for shorter periods to prevent inhalation (Hoare, 2001; Rasmussen and Riddle, 2004).

"Probability of crop damage" and "area of crops damaged" by elephants were used as determinants of the effectiveness of the intervention method in a study conducted in Assam by Davies *et al.* (2011). Fences (chili and electric) were found as most effective followed by spotlights and fire. But when these methods were used in combination with noise their efficacy was compromised, with the most pronounced negative effect seen with fences and spotlights. The ineffectiveness of using Kumkies in preventing crop damage could be because of insufficient training of the elephants and mahouts used in these drives. Spotlights were found to be effective, which correlates with the findings of Sitati *et al.* (2005), especially when the lights were bright.

Barua *et al.* (2013) have studied the hidden dimensions of human- wildlife conflict which included health impacts, opportunity and transaction costs. Among the 13 reported mitigation measures practiced in the Western Ghats protected areas, no individual measure is associated with lowering the crop or livestock loss (Karanth *et*

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al., 2013). Significant determinants of fence performance in mitigating elephant crop-raiding are the location of fences in relation to landscape factors, maintenance of effective non-electrified fences and proximity of fences to areas of high elephant concentration (Kioko *et al.*, 2008). Santiapillai (1994) has correlated the man-elephant conflict with the attitude of the present-day people with man-elephant conflict and mentioned that the elephant tolerance of the settlers who came from towns is very poor. There is difference between the tribal and non-tribal people in tolerating the conflict (Nath and Sukumar, 1998).

In a study conducted in Royal Bardia National Park, Nepal, majority of the households have ranked guarding as the most effective measure against crop raiding due to lack of functioning of the preventive measures (Studsrod and Wegge, 1995). Manoa and Mwaura (2016) recommends that continuous maintenance of predator-proof bomas as a solution for livestock loss at night and close guarding of livestock by adults at day time.

Kumar (2007) has done an excellent review about the human-elephant conflict mitigation strategies in India and has evaluated their efficiency based on strengths, weaknesses, cost effectiveness and its long-term viability. He points outs that among the 75 publications, about 75 percentage of literature recommended mitigation measures, but only 16 percent of them evaluated or implemented any technique. The mitigation strategies that needs regular presence of people for its implementation and functionality tends to be tiresome and unsustainable because uptake of such methods would be low (Hans Enukwa, 2017).

Physical barriers are very popular wherever conflict is severe, as they separate people and wildlife, and the most commonly used types are elephant-proof trenches and electric fences. Barriers are effective when they do not deflect elephants to other areas, they do not cutoff their access to parts of their habitat and elephants are not crop-dependent (Chong and Norwana, 2005). Electric fencing is found to be successful by

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limiting the entry of pachyderms to the farm land in Coorg and Anamalai hills in Karnataka (Fernando *et al.*, 2008). According to Choudhury (2004), electric fencing may succeed initially, but it cannot to be used to eliminate human-wildlife conflict. Electric fencing was found to be successful and cost effective in preventing the entry of wild animals into the agricultural field, if maintained properly (Easa and Sankar, 2001; Hoare, 2003; Fernando *et al.*, 2008). Encircling fence is found to be better than a linear one which directs them t areas at either of the open ends (O'Connell-Rodwell *et al.*, 2000; Hoare, 2003; Kioko *et al.*, 2006). The method employed wont poses any threat to elephants will be unsustainable as the elephants become adapted to it (Hans Enukwa, 2017). In Gir National Park, Gujarat, fencing was not found to be economically feasible (Vijayan and Patil, 2002). Compared to government owned electric fence, privately owned electric fences gives better performance as the number of elephant crossing points per kilometer was found to be less (Rohini *et al.*, 2017; Parker *et al.*, 2007). Closer the electric fences to the human habitation, lesser are the probability of elephants to challenge the fences (Hoare, 2012). Once if the elephant breaches the electric fence, it gets habituated and will do it again (Chong and Norwana, 2005). So, fences implemented at natural week spots like swampy areas, streams or water bodies, tend to be a failure (Rohini *et al.*, 2017). Electric fencing can be successful and sustainable only through private sector participation and by educating the people about the importance of fencing (Hoare, 2001). The barriers suffer a high rate of failure as they are undermined by people who need access to the forest. They cut fence wires or creates bridges across trenches (Nath and Sukumar, 1998).

The local ecology and movement of elephants should be well-established before installation of fence, so that the ecological areas to which it needs access are not cut off (Kangwana, 1995; Hoare, 2003). A comparison of conflict levels before and after installation of fence indicated overall conflict levels remained same in the region in Kenya (Smith and Kasiki, 2000) or it leads to displacement of the conflict to adjacent areas where there may not have any conflict issues before the installation (Chong and

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Norwana, 2005; Barua, 1995; Blair *et al.*, 1979; O'Connell-Rodwell *et al.*, 2000). For the success of electric fence, it is critical to maintain its traditional routes (Gunaratne and Premarathne, 2005). The efficiency of the fence is also determined by the proximity of the forest where crop raiders can seek shelter, and which harbor a high elephant density (Kioko *et al.*, 2008).

Elephant proof trenches require huge investments for both construction and management (Nelson *et al.*, 2003). The elephant-proof trenches should be wide enough to prevent elephants from crossing over it (Fernando *et al.*, 2008). It is expensive to excavate and require regular maintenance (Nelson *et al.*, 2003). Elephants easily learn to kick the sides of the trenches and cross it (Rohini *et al.*, 2017; Hoare, 2003; Thouless and Sakwa, 1995b). In Karnataka, of 23 trenches examined, none was functional and half of the crossing points were made by people (Nath and Sukumar, 1998). It was also found ineffective due to either environmental factors or human error (Nath and Sukumar, 1998; Choudhury, 2004; Jayant *et al.*, 2007). The efficiency of trenches is negatively correlated to the age and number of roads and paths that crosses the trench (Fernando *et al.*, 2008). Several studies suggest that combination of trench and fence, if maintained good, will be one of the most efficient method for mitigating human-wildlife conflict (Sukumar 1985; Santiapillai and Jackson 1990; Bist 1996; Nyhus and Tilson, 2000; Desai 2002).

Stone walls are relatively expensive and most of the areas lack usable stones for construction. In Laikipia District, Kenya, it has shown varied success (Thouless and Sakwa, 1995b). Elephants are able to break it and another wall in the same place will be moderately effective. Thouless and Sakwa (1995b) suggest that the stone walls with concreted top or an electrified wire running along the top of them might be viable alternatives. It also has a low environmental impact compared to trenches.

In Kenya, beehive fences are more effective than thorn bush barriers for deterring elephants (King *et al.*, 2011). King *et al.* (2007) demonstrated that the

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elephants respond to the buzz of disturbed and aggressive African bees with alarm by moving away from the sound source. The beehive fences are found to be a viable tool for small scale farmers struggling with high levels of human-elephant conflict and were highly desired by the communities in southern Kenya (King *et al.*, 2017). Beehive fencing is more effective, if placed closer to each other.

Translocation of problem animals to adjoining forest areas is being practiced in various parts of India in order to mitigate the human-wildlife conflict. But in the case of carnivores, the translocation results in increase of the conflict incidents at the release site (Athreya *et al.*, 2011).

Bio-fences using thorny plants such as agave and cacti is being practiced in different places in India. The elephant's skin is impervious to these thorns and also elephants are recorded to feed on agave (Hoare, 2001).

Globally, many strategies have been developed to control wild boar population in order to reduce significant damage of crops such as chasing wild boar with dogs (Mcllroy and Saillard, 1989), trapping (Hone, 2002), hunting (Geisser and Reyer, 2004), and poisoning (Muthmainnah and Suardi, 1998). Hunting generally is not effective in reducing wild boar population as compared to poisoning with warfarin (Mcllroy and Saillard, 1989). But when compared to fencing, hunting is more effective in reducing damage by wild boars (Geisser and Reyer, 2004). In Europe, the most popular method to protect field crops from wild boar attack is electric fencing (Santilli and Stella, 2006). The use of odor repellents is also proven to be ineffective for protecting crops from wild boar damage (Schlageter and Haag-Wackernagel, 2012). Cai *et al.* (2008) has identified the main factors affecting the level of crop damage by wild boar and observed that all strategies employed by the local people to prevent crop raiding failed to work except human presence in the fields.

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In forest-farm ecotones, translocation of the macaques to adjacent areas may not end the crop damage but, may spread the problem from one place to another (Chakravarthy *et al.,* 2005). If the crop-raiding behavior in primates is once established, it is extremely difficult to change (Chakravarthy *et al.,* 2005; Hill, 2005). Honda *et al.* (2009) has specially designed an electric fence, which effectively exclude the wild animals, including the Japanese Macaque (*Macaca fusculata*). But it was uneconomical and impractical in rural areas where the problem was severe.

The migration and crop-raiding problem, due to elephants in Wayanad Wildlife Sanctuary was mentioned by Ramachandran (1990) and Gopinathan (1990). The incidences of loss of life and crop depredation due to wild animals in general and elephants in particular has been highlighted in the Management Plan for Elephant Reserves in Kerala (Easa, 1994). During 1985 and 1993, about Rs. 2,40,505 has been sanctioned for compensation for crop damage and Rs. 1,25,150 for human death and injury, which was registered as highest amount paid for compensation as compared to other Forest Divisions in Kerala (Veeramani and Jayson, 1995; Veeramani *et al.*, 1996). Since 1986, the compensation is on increase even after providing live wire fencing in some of the areas in Wayanad (Easa, 1994). These reports indicate the severity of the problem in Kerala especially in Wayanad.

Materials and methods

MATERIALS AND METHODS

3.1 STUDY AREA

3.1.1 Name, Location and Extent

Wayanad Wildlife Sanctuary was formed in the year 1973 by demarcating areas out of the Wayanad and Kozhikode territorial divisions. It is the second largest wildlife sanctuary in Kerala extend over an area of 344.44 sq. Km. with four ranges, two stations and 13 sections. The ranges are Sulthan Bathery, Muthanga, Kurichiyat 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 Wayanad Wildlife Division constituted in 1985 comprises of two discontinuous unit of the sanctuaries called WS-I (77.67 sq. km.) and WS-II (166.77 sq. km.). The larger units lie 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 latitude 11°50' N – 11°59' N and longitudes 76°02' E – 76° 7' E and fall in the Mananthavady taluk of Wayanad district.

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

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the age group of lower pre-Cambrian to Archaean. High rainfall prevalent in Western Ghats leads 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 50 to 100. 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 northeast monsoons 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°C to 19.4°C and monthly mean maximum and minimum temperatures range from 31.2°C and 15.0°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

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Puzha, Kurichiatu Puzha and Chedalathu Puzha are the other drainage systems in Wayanad WLS (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 into 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/C2)

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*,

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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.

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*,

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Themedatriandra and *Cymbopogan flexuosus* are found in open areas in the plantations. In Teak plantations, apart from a few deciduous tree species, *Helicteresisora* 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 problems occurring in the fringe villages of the sanctuary.

Table 1. 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

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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 Settlements

The zone of influence between the wildlife and human settlements in and around the sanctuary is unusually vast due to large number of human settlements within the protected area and lengthy, irregular, and discontinuous outer boundaries. The entire forest fringe is densely populated and paddy, other cash crops like banana, coconut, arecanut, coffee etc. contributes a major part of their cultivated area.

The Zone of influence areas outside the RFs, landscape wise, are not different from forest areas. The topography, climate, drainage patterns, land productivity, etc. are all similar. Majority of such cultivated/township areas except Pulpally were developed in to cultivated areas long back. These areas were occupied earlier by people belonging to Tribes, Wayanadan chetty, Jains and other communities. Pulpally area which is located in the North-west of WS-II was under private forests till early 1960's. These areas were under the ownership of Pulpally devaswam. At this period, the forests of WS-I and WS-II was having contiguity through these forests. There was a large scale migration of people from southern Kerala to these areas in the 1960's which resulted in destruction of more than 1300 Ha of forests in these parts and developing these areas in to agricultural areas. Later on the possession of some of the agricultural lands owned by tribes and other traditional occupants were transferred to the migrants either legally or illegally.

The eastern parts of the PA are abutting to the protected areas of the adjoining states. The outer peripheral areas cover most of the western, northern and southern boundaries of WS-II and WS-I. The economies of the people in these tracts are predominantly agriculture based. Animal husbandry is also prevalent in these areas. There is abundance of road and transport infrastructure also.

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3.1.8 Enclosures

There are 57 enclosures within the outer boundaries of the sanctuary. The people in these enclosures are seen organized in separate socio-ethnic groupings (settlements). 107 settlements are distributed within these 57 enclosures. 44 settlements are located on the forest fringes and the remaining 63 are interior settlements and are distributed in either buffer or core zone of the PA. The list of enclosures is given in the Table 2

Table 2. Name of the enclosures in Wayanad Wildlife Sanctuary

Tholpetty Range

1. Neduthana
2. Cheriyanaikatty
3. Karamadu
4. Kottiyoor
5. Thirulkunnu
6. Begur I
7. Begur II
8. Begur III
9. Narumundakolly
10. Thetty road
11. Edakkode
12. Konavayal
13. Irumbupalam

Kurichiyat Range

1. Kurichiyat
2. Golur
3. Ammavayal
4. Vadakkanad
5. Chathalayam
6. 50 Acre
7. Kommenchery
8. Vengur
9. Puduveedu
10. Veettikutty
11. Manalimoola
12. Thenkuzhy

Sulthan Bathery Range

1. 1Puthur
2. Arakunji
3. Vellakkode
4. Pilakkavu
5. Kottangara
6. Kunduchira
7. Kolur
8. Muthanga
9. Alathur
10. Odappallam
11. Rampally
12. Kumbrankolli

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13. Kallumukku
14. Alumkalam
15. Marode
16. Ponkuzhy

Muthanga Range

1. Ponkuzhhy
2. Thakarappadi
3. Kalankandi
4. Kumizhy
5. Pankalam
6. Kalladikolli
7. Kolot
8. Ooankunnu
9. Njandankolli
10. Noolpuzha
11. Chittiyalathur
12. Muthanga
13. Mykkara
14. Malankappu
15. Kundur-Kappad
16. Konnamoola

3.1.9 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.

3.1.10 Human-wildlife conflict

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The forests of Wayanad are a transit path of elephants from the adjoining forest areas. After independence these paths existed earlier was disturbed by raising crops by local people. The total human population of the district is 8,16,558 (2011 census). The population around the forest and the adjoining villages are mainly agriculturists and agricultural labourers. The main source of income and livelihood of the local inhabitants in the district is agriculture. Most of the agricultural lands are surrounded by rich forests and it nourishes the fields by way of flowing humus and water. There was less conflict between man and animal in olden days. Expansion of agriculture, change in cropping pattern and increasing population made the situation difficult. Due to the interruption of elephant's corridor elephants are entering in to the agricultural land for food and water.

In summer season large number of elephants and other wild animals are migrating to this area due to scarcity of water and food inside the forest area. It leads destruction of a large extent of agricultural land by the elephants. Besides this, the forest fire reduces food availability in the forests and wild animals resort to crop raid for their food excessively. Fragmentation of forest area by the construction of road and residential buildings constructed in the corridors of elephants results in the isolation of elephants from one forest area to another. Moreover, the biological needs of elephants cannot be fulfilled due to the separation. It also creates cruelty to human beings. There is a regular raid by elephant in all adjoining parts of the forest area in the district. Cattle lifting by carnivores are also on the rise in recent future.

The role of human elephant conflict on inflicting mortality of elephants is not addressed properly. The visible manifestations of conflict on mortality are due to gunshot, poisoning, electrocution and use of explosives. Many times, elephants fall prey to illegal hunting methods such as live electric wires for killing wild animals for bush meat. Even spears or arrows were used to kill elephants to mitigate crop raiding.

The indirect impact of human elephant conflict on mortality of elephants needs to be studied in detail

3.1.11 Human-wildlife conflict mitigation

The forest department has brought up many possible mitigation measures, such as Elephant Proof Trenches, Electric/Solar power Fencing and Elephant Proof Wall and security guards are engaged to scare off the wild beasts. A Rapid Response Team has been constituted as per G.O (Rt) No. 408/2011/F&WLD dated 16.09.2011 for dealing with problematic wild animals straying into human habitations. The abstract of the mitigation measures constructed in the sanctuary is given in the Table 3.

Table 3. Mitigation measures taken in Wayanad Wildlife Sanctuary (as on 27/03/2019)

Sl. No.	Item of Work	Total extend done as on 31.03.12 (Km)	Work done during 2012-13 (Km)	Work done during 2013-14 (Km)	Work done during 2014-15 (Km)	Work done during 2015-16 (Km)	Work done during 2016-17 (Km)	Work done during 2017-18 (Km)	Work done during 2018-19 (27/3/19) (Km)	Total achievement (Km)
1	Elephant Proof Trench	161.344	25.600	35.260	8.560	1.050	3.290	1.240	3.972	240.316
2	Maintenance of Elephant Proof Trench	32.240	9.250	18.250	12.260	0.450	0.000	1.497	0.030	73.977
3	Stone-pitched Trench	0.033	0.358	0.210	0.169	0.675	0.021	0.013		1.479
4	Elephant Proof Wall	1.318	1.380	1.530	1.250	1.055	0.000			6.533
5	Solar Power Fencing	30.500	18.350	18.350	25.350	66.500	12.200			171.250
	Solar Power Fencing (NABARD)		10.25	11.82	15.35	45.98	35.25			118.650
	Solar fencing Total	30.500	28.600	30.170	40.700	112.480	47.450	0.000	0.000	289.900

Source: Kerala Forest Department

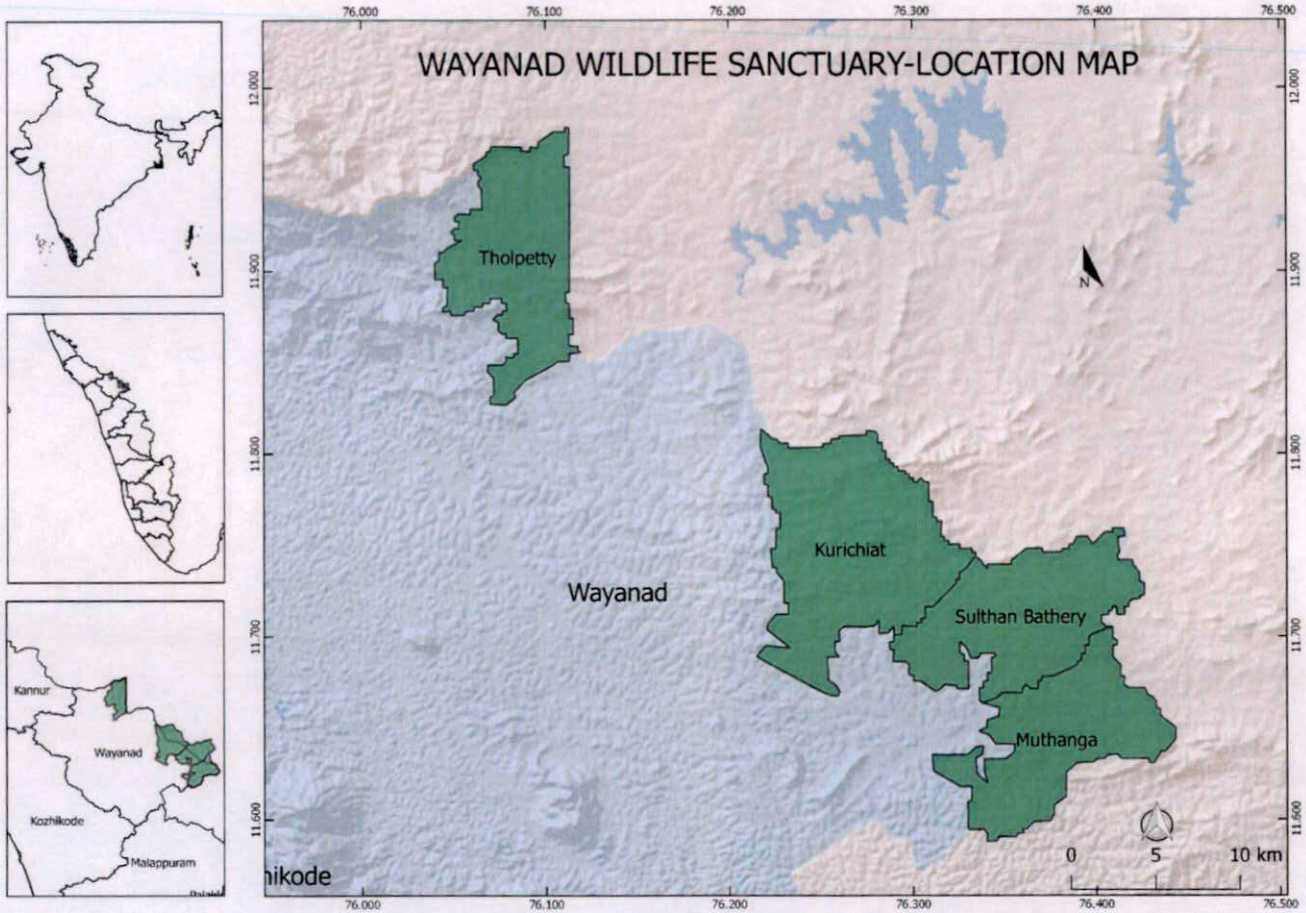

Figure 1. Location map of Wayanad Wildlife Sanctuary

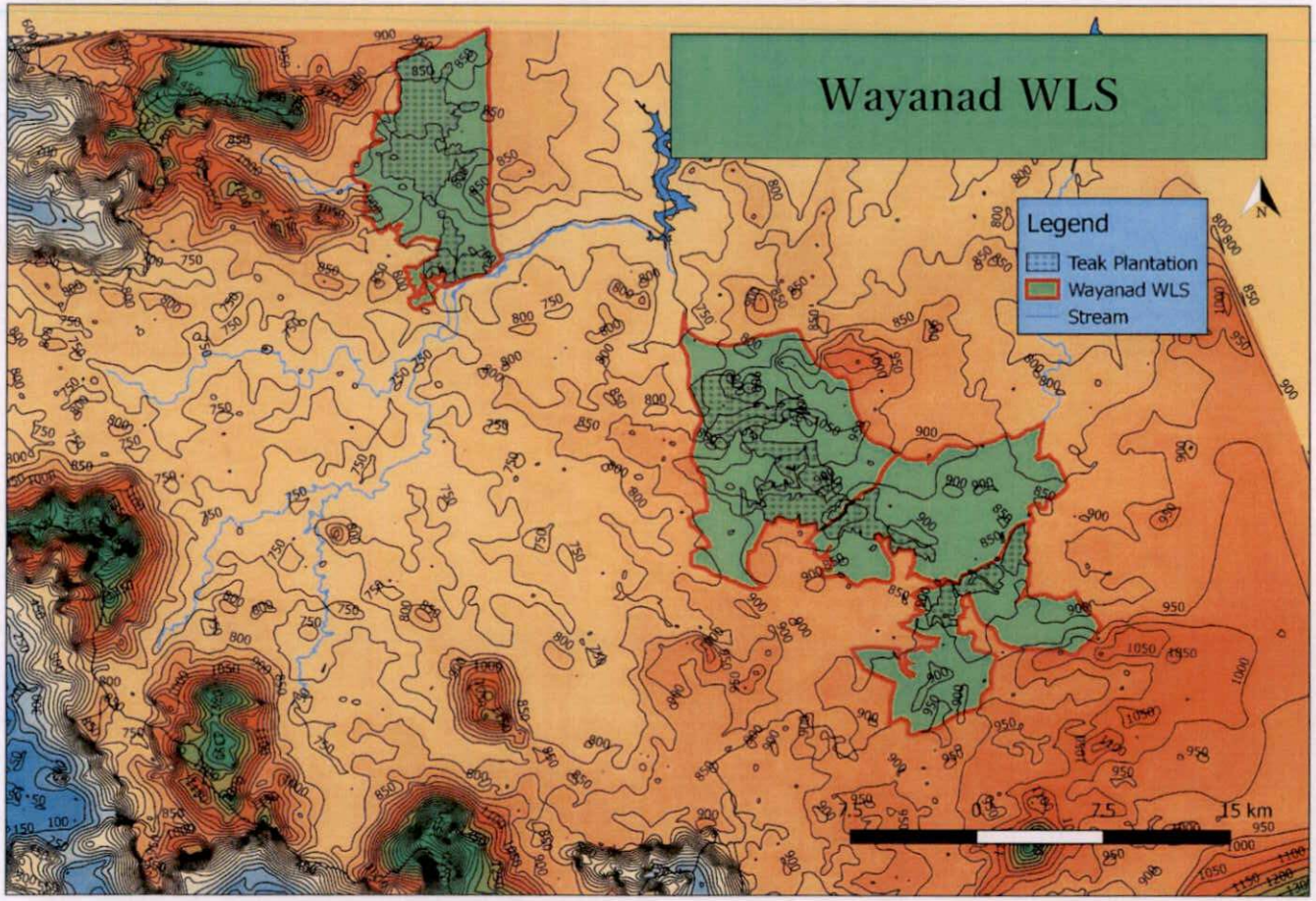

Figure 2. Contour map of Wayanad Wildlife Sanctuary

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The different vegatation types in Wayanad Wildlife Sanctuary are given from Plate 1 to Plate 7

Plate 1. Grassland (Vayal)

Plate 2. Natural Forest

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Plate 3. Bamboo brakes

Plate 4. Riparian forest

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Plate 5. Teak Plantation

Plate 6. Eucalyptus Plantation

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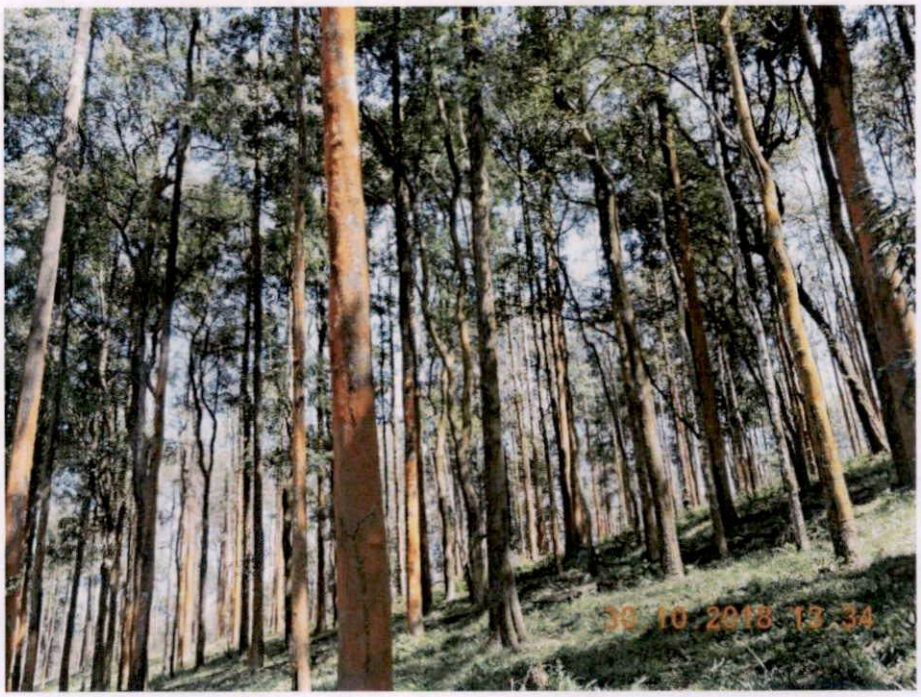

Plate 7. Silver oak Plantation

Major crops in Wayanad Wildlife Sanctuary are given from Plate 8 to Plate 12

Plate 8. Paddy field

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Plate 9. Coffee plantation

Plate 10. Arecanut plantation

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Plate 11. Arecanut, coconut and banana plantations

Plate 12. Rubber Plantation

3.2 METHODS

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3.2.1. Mapping of the mitigation measures

The human-wildlife conflict mitigation measures adopted in Wayanad Wildlife Sanctuary was identified by consulting forest department officials. The mitigation measures such as solar power electric fence, elephant-proof trench, and elephant-proof wall in all the four ranges were mapped. GPS readings were taken using the Locus free android app and Garmin GPS etrex 30x. Mapping was done using the software QGIS ver. 2.18.

3.2.2 Data collection

A detailed interview schedule was prepared to gather information from the respondents. Household survey was conducted using a structured interview schedule (Appendix No.1) to obtain data regarding the nature of human-wildlife conflict, attitude and perception of the individuals towards the human-wildlife conflict mitigation measures installed in their area. The interview schedule was designed under a total of 17 titles. Each of the sections were designed to describe various aspects concerned to the individual which includes personal details, nature of human-wildlife conflict, damage causing wild animals, seasonality of human-wildlife conflict incidents, attitude and perception of the people towards human-wildlife conflict mitigation measures, maintenance frequency of the mitigation measures, factors that has to be considered when implementing a mitigation measure in respondents point of view, opinion of respondents about the active involvement of government bodies in clearly communicating the problems and struggles faced by them, satisfaction of the respondents towards the compensation scheme and difficulties faced by the respondents in getting compensation for the wildlife damages.

The survey locations were decided with the help of the forest department officials. The purposive sampling consisted of 30 individuals from each range residing

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near the forest fringes, and the responses were subjected to various statistical analysis. The survey was conducted in areas such as Mundankolli and Mookkuthikkunnu in Muthanga range; Nenmeni, Odappallam and Noolpuzha Panchayat in Sulthan Bathery range; Chethalayam, Manpalloor, Malappadi colony, Poovanchi and Vadakkanadu in Kurichiyat range; Begur, Edakkode, Aranappara, Chakkaramukku, Pallimukku, and Puthiyoor in Tholpetty range.

3.2.2.1 Interview schedule analysis:

Each question in the questionnaire was assumed to be a category and the sub-questions were taken as subcategories. The responses were separately tabulated and was subjected to various statistical analysis such as association studies and correlation studies using SPSS software. Frequency of the response to a question and its percentage, Chi-square test, contingency coefficient, spearman rank correlation coefficient and Mann-Whitney U test were done.

Chi-square ($\chi 2$) test is one of the important non-parametric tests and one of the most commonly used tests of significance. P-values are used in hypothesis testing, which helps to figure out if the results are significant or not and it is a number between 0 and 1.

The contingency coefficient is a coefficient of association that tells whether two variables or data sets are independent or dependent of each other. It is a rough measure and doesn't quantify the dependence exactly. If the coefficient is near zero (or equal to zero) we can conclude that the variables are independent of each other; there is no association between them. It is a rough measure and doesn't quantify the dependence exactly. If the coefficient is near zero (or equal to zero) you can conclude that your variables are independent of each other; there is no association between them.

The Spearman rank correlation coefficient is defined as the correlation between ranks of individuals with respect to two characters. It is usually calculated on occasions when it is not convenient, economic, or even possible to give actual values to variables,

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but only to assign a rank order to instances of each variable. It may also be a better indicator that a relationship exists between two variables when the relationship is non-linear. It is a technique which can be used to summarize the strength and direction of relationship of two variables. Spearman's Rank correlation coefficient and lies between –1 and +1.

Mann-Whitney U test is the non-parametric alternative test to the independent sample t-test. It is a non-parametric test that is used to compare two sample means that come from the same population, and used to test whether two sample means are equal or not. Usually, the Mann-Whitney U test is used when the data is ordinal or when the assumptions of the t-test are not met.

3.2.3 Land use land cover change analysis

The Land Use Land Cover Changes (LULCC) were determined by using Geographical Information Systems (GIS) and remote sensing technology, both inside the Wayanad Wildlife Sanctuary and in a 5 km buffer area outside the sanctuary. The land use land cover data (250K) of Wayanad District during 2005-2006 and 2014-2015 were obtained from National Remote Sensing Agency (NRSA), Government of India, Hyderabad. The LULCC analysis was done to find out the change in the land use pattern before and after the establishment of the mitigation measures in the study area.

Results

RESULTS

4.1 Socio-economic studies in done in forest fringe areas of Wayanad Wildlife Sanctuary

The results of the socio-economic survey conducted among the stakeholders in the four ranges in Wayanad Wildlife Sanctuary are presented below.

4.1.1 Age class of the respondents at Wayanad Wildlife Sanctuary

Table 4 shows that in the Muthanga range, age class 30-50 years were dominating (46.67 percent), followed by age class 50-70 years (33.33 percent). In Sulthan Bathery range, the respondents belonging to the age class 50-70 is greatest (50 percent), followed by the age class group 30-50 years (33.33 percent). Similar to Muthanga range, in Kurichiyat range also the age class 30-50 years is dominating (13.33 percent). Similar to Sulthan Bathery range, in Tholpetty range, the age class 50-70 years dominates with 50 percent, followed by the age class 30-50 years (40 percent) and age class less than 30 years (10 percent). The respondents with age group of less than 30 years and age group 30-50 years was more in Kurichiyat. The number of respondents belonging to the age group 50-70 years is higher in Sulthan Bathery and Tholpetty. The respondents belonging to the age group more than 70 years is comparatively higher in Sulthan Bathery range.

Table 4. Age group category of the respondents of Wayanad Wildlife Sanctuary

	Muthanga		Sulthan Bathery		Kurichiyat		Tholpetty	
Age (years)	N	Percent	N	Percent	N	Percent	N	Percent
< 30	3	10.00	1	3.33	5	16.67	3	10.00
30 - 50	14	46.67	10	33.33	19	63.33	12	40.00
50 -70	10	33.33	15	50.00	4	13.33	15	50.00
> 70	3	10.00	4	13.33	2	6.67	0	0.00
Total	30	100.00	30	100.00	30	100.00	30	100.00

N- Number of respondents Percent- Percentage of respondents

4.1.2 Demography of the respondents at Wayanad Wildlife Sanctuary

The demographic condition of the respondents at Wayanad Wildlife Sanctuary is detailed in Table 5. It shows that in Muthanga range, the percentage of females surveyed was more than the males. In Sulthan Bathery and Kurichiyat ranges, the percentage of males surveyed was slightly greater than the number of females. Equal number of male and female respondents were surveyed in Tholpetty range. The number of male respondents is greater in Kurichiyat range and the number of female respondents is greater in Muthanga range.

Table 5. Demography of the respondents of Wayanad Wildlife Sanctuary

	Muthanga		Sulthan Bathery		Kurichiyat		Tholpetty	
Gender	N	Percent	N	Percent	N	Percent	N	Percent
Male	11	36.67	16	53.33	17	56.67	15	50.00
Female	19	63.33	14	46.67	13	43.33	15	50.00
Total	30	100.00	30	100.00	30	100.00	30	100.00

N- Number of respondents Percent- Percentage of respondents

4.1.3 Nature of residency of the people at the study site in Wayanad Wildlife Sanctuary

Table 6 shows the general trend of residency of the respondents of different ranges. In all the four ranges, majority of the respondents have been residing in the study area for more than 20 years. In Muthanga range and Sulthan Bathery range, 66.67 percent of the respondents were residing in the study area for more than 20 years and it is 80 percent in the case of Kurichiyat range and Tholpetty range.

Table 6. Nature of residency of the people at the study site in Wayanad Wildlife Sanctuary

	Muthanga		Sulthan Bathery		Kurichiyat		Tholpetty	
Duration	N	Percent	N	Percent	N	Percent	N	Percent
< 5 years	4	13.33	0	0	0	0	1	3.33
5-10 years	4	13.33	4	13.33	4	13.33	4	13.33
10-20 years	2	6.67	6	20	2	6.67	1	3.33
≥ 20 years	20	66.67	20	66.67	24	80	24	80
Total	30	100	30	100	30	100	30	100

N- Number of respondents Percent- Percentage of respondents

4.2 Human-wildlife conflict in Wayanad Wildlife Sanctuary

4.2.1 Nature of the human-wildlife conflict in Wayanad at the whole Sanctuary level

Table 7 and Figure 6 depicts that the major problem regarding human-wildlife conflict is crop loss (99.17 percent) followed by livestock loss (45.83 percent). Damage to human property due to Asian Elephant or Bonnet macaque was faced by more than 28 percent of the respondents.

Table 7. Nature of human-wildlife conflict in Wayanad Wildlife Sanctuary

Damage	No. of respondents	Percentage of respondents
Crop loss	119	99.17
Livestock loss	55	45.83
Injury or loss of human life	49	40.83
Damage to human property	34	28.33

4.2.2 Nature of human-wildlife conflict in Wayanad Wildlife Sanctuary at the range level

The details on the nature of the human-wildlife conflict is given in Table 8 and Figure 3. It shows that crop loss is the major problem faced by almost every respondent of all ranges. The number of respondents with livestock loss and threat to human life is more in Muthanga range, followed by Tholpetty range and Kurichiyat range.

Table 8. Nature of human-wildlife conflict in the different ranges of Wayanad Wildlife Sanctuary

	Muthanga		Sulthan Bathery		Kurichiyat		Tholpetty	
Damage	N	%	N	%	N	%	N	%
Livestock loss	20	66.67	9	30.00	10	33.33	16	53.33
Crop raiding	29	96.67	30	100.00	30	100.00	30	100.00
Injury and loss of life of human	17	56.67	8	26.67	11	36.67	13	43.33
Damage to human property	9	30.00	2	6.67	7	23.33	16	53.33

N- Number of respondents %- Percentage of respondents

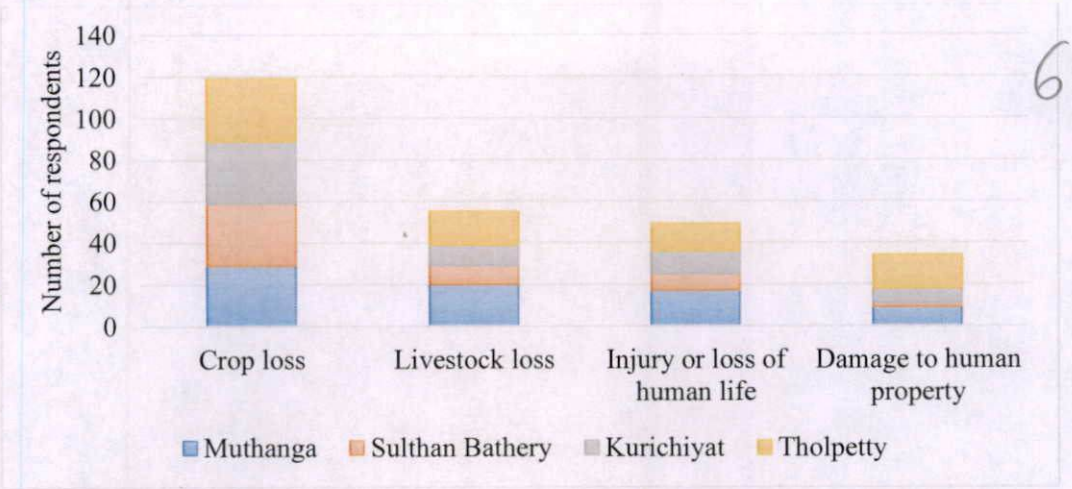

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Figure 3. Nature of human-wildlife conflict in the different ranges of Wayanad Wildlife Sanctuary

The number of respondents who suffers from damage to human property is greater in Tholpetty range. In all the ranges except Tholpetty, damage to human property was the lowest form of conflict reported, where as it was the 2nd most reported nature of human-wildlife conflict in Tholpetty range.

4.2.3 The major wild animals involved in the human-wildlife conflict in Wayanad at the whole Sanctuary level

Table 9 depicts that in Wayanad Wildlife Sanctuary, the human-elephant conflict is the most prominent issue that is faced by the respondents and almost every respondent (91.67 percent) are having some trouble due to elephants. 89.17 percent of the total respondents experienced crop loss due to deer and 87.50 percent of the respondents were having crop loss due to wild boar attack. 75 percent of the respondents has experienced crop loss and property damage due to monkey menace. Threat to life or livestock loss due to carnivores like tiger or leopard was faced by 41.67 percent of the respondents.

Table 9. Major wild animals involved in the human-wildlife conflict at Wayanad Wildlife Sanctuary

Wild animals	Frequency	Percentage
Asian Elephant	110	91.67
Spotted Deer	107	89.17
Wild Boar	105	87.50
Bonnet Macaque	90	75.00
Tiger	39	32.50
Malabar Giant Squirrel	32	26.67
Common Leopard	11	9.17
Indian Peafowl	7	5.83
Barking Deer	5	4.17
Sloth Bear	3	2.50
Indian Crested Porcupine	2	1.67
Civet	2	1.67

4.2.4 The major wild animals involved in the human-wildlife conflict in Wayanad at range level

The Table 10 and Figure 4 show the frequency of wild animals involved in human-wildlife conflict issues in each range. It can be observed that the conflict issues due to Asian Elephant, Spotted Deer and Wild Boar dominates in every forest ranges without much difference. The crop loss and property damage by monkeys are found to be comparatively less in Kurichiyat range, and the threat due to Tiger is more in Muthanga range (50% of the respondents), followed by Kurichiyat (30%) and Tholpetty ranges (30%). 50 percent and 16.67 percent of the respondents of Muthanga were having either livestock loss or treat to life due to tigers and leopards respectively. The crop damage due to Malabar Giant Squirrel is found to be so severe and it is damaging the coconuts at very early stages in Sulthan Bathery range. The damage due to Barking Deer, Indian Peafowl, Indian Crested Porcupine and civet is not very prominent.

Table 10. Major wild animals involved in the human-wildlife conflict in Wayanad Wildlife Sanctuary at range level

	Muthanga		Sulthan Bathery		Kurichiyat		Tholpetty	
Wild animals	N	Percent	N	Percent	N	Percent	N	Percent
Asian Elephant	26	86.67	27	90.00	29	96.67	28	93.33
Spotted Deer	26	86.67	29	96.67	24	80.00	28	93.33
Bonnet Macaque	25	83.33	29	96.67	9	30.00	27	90.00
Wild Boar	21	70.00	30	100.00	26	86.67	28	93.33
Tiger	15	50.00	6	20.00	9	30.00	9	30.00
Malabar Giant Squirrel	8	26.67	14	46.67	3	10.00	7	23.33
Common Leopard	5	16.67	0	0.00	0	0.00	6	20.00
Barking Deer	2	6.67	3	10.00	0	0.00	0	0.00
Indian Peafowl	2	6.67	2	6.67	1	3.33	2	6.67
Indian Crested Porcupine	2	6.67	0	0.00	0	0.00	0	0.00
Civet	1	3.33	0	0.00	0	0.00	1	3.33
Sloth Bear	0	0.00	0	0.00	2	6.67	1	3.33

N- Number of respondents

%- Percentage of respondents

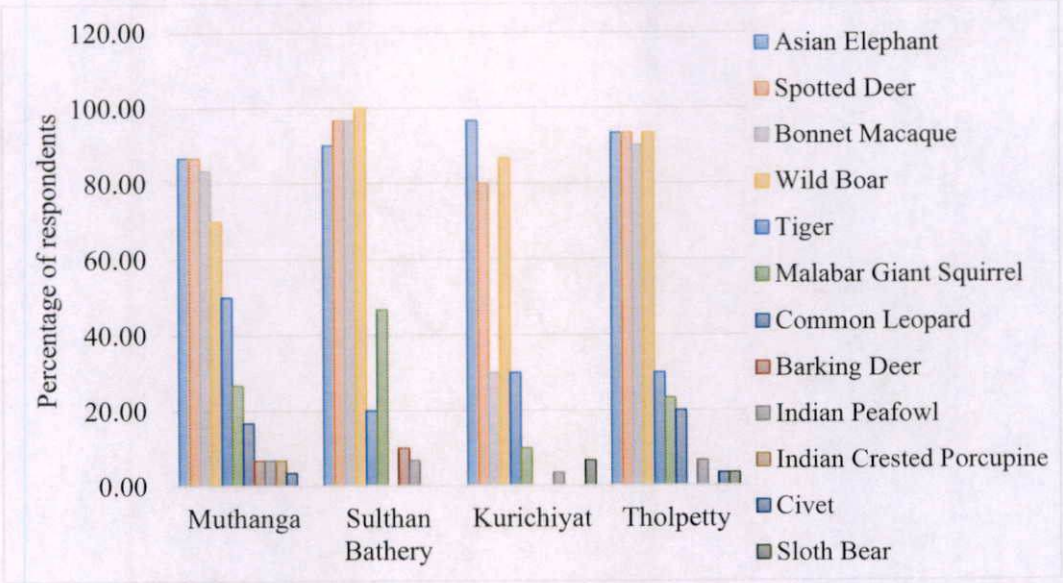

Figure 4. The major wild animals involved in the human-wildife conflict in Wayanad Wildlife Sanctuary

4.2.5 The social organization of the elephants involved in the human-wildlife conflict

Table 11 and Figure 5 show that in Wayanad Wildlife Sanctuary, most of the losses to the respondents is due to a single elephant bull (50.83%), followed by both single bull and herds (40%). In Muthanga range and Tholpetty range, most of the respondents are of the opinion that most of the losses encountered by them are due to both single elephant bull and elephant herds, followed by single elephant bull. In Sulthan Bathery range, majority of the respondents is of the opinion that most of the losses that are encountered by them are due to single elephant bull. In Kurichiyat range, 46.67 percent each of the respondents revealed that most of the losses that are encountered by them is due to single elephant bull and due to both single and herd of elephants.

Table 11. Size of the elephant herd causing human-elephant conflict in Wayanad Wildlife Sanctuary

	Muthanga		**Sulthan Bathery**		**Kurichiyat**		**Tholpetty**		**Total**	
	N	%	N	%	N	%	N	%	N	%
Single elephant bull	11	36.67	25	83.33	14	46.67	11	36.67	61	50.83
Herd of elephants	1	3.33	2	6.67	2	6.67	1	3.33	6	5.00
Both	15	50.00	2	6.67	14	46.67	17	56.67	48	40
No elephant conflict	3	10.00	1	3.33	0	0	1	3.33	5	4.17

N- Number of respondents %- Percentage of respondents

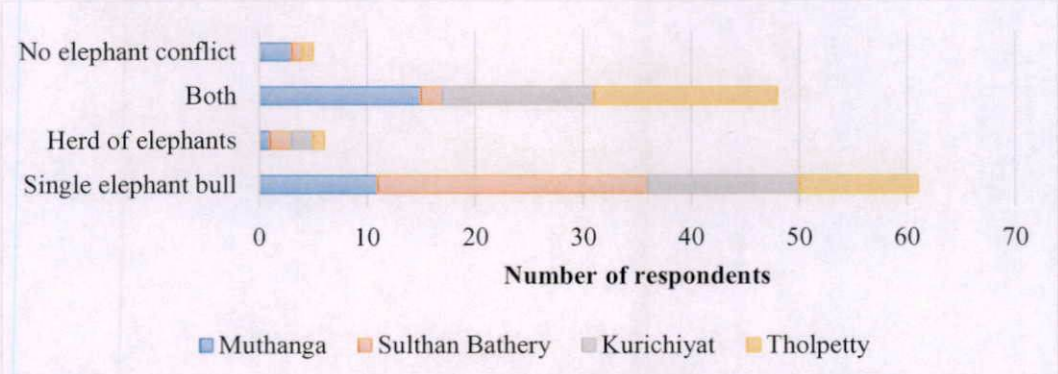

Figure 5. Size of the elephant herd causing human-elephant conflict in Wayanad Wildlife Sanctuary

Table 12 shows that majority of the respondents in Wayanad Wildlife Sanctuary were able to identify whether it is the same or different herd of elephants that visit their farm lands very often. The people were able to identify the elephants by the difference in its physical appearance. The respondents who were confident enough, revealed that mostly, it is the same elephant herd that frequently visits their farm, which indicates that the elephants are habituated to feed to crops in those areas. The crop land visitation by same elephant herds were said to be more in Sulthan Bathery range (58.62 percent), followed by Tholpetty range (45 percent) and Kurichiyat range (40 percent). However, in Muthanga range, the people who believes that different herds visit their farm is comparatively higher.

Table 12. Elephant herd responsible for the human-elephant conflict identified by the respondents in Wayanad Wildlife Sanctuary

	Muthanga		**Sulthan Bathery**		**Kurichiyat**		**Tholpetty**		**Total**	
	N	%	N	%	N	%	N	%	N	%
Same herd	8	29.63	17	58.62	12	40.00	8	27.59	45	39.13
Different herd	10	37.04	2	6.90	6	20.00	8	27.59	26	22.61
Cannot be ascertained	9	33.33	10	34.48	12	40.00	13	44.83	44	38.26

N- Number of respondents %- Percentage of respondents

4.2.6 The seasonality of human-wildlife conflict at Wayanad Wildlife Sanctuary

Table 13 and Figure 6 show that there is no seasonality for human-wildlife conflict issues. It can be observed that majority of the respondents in every range is facing human-wildlife conflict issues throughout the year.

Table 13. Seasonality of human-wildlife conflict at Wayanad Wildlife Sanctuary

	Muthanga		**Sulthan Bathery**		**Kurichiyat**		**Tholpetty**	
Season	N	Percent	N	Percent	N	Percent	N	Percent
Rainy season	4	13.33	3	10.00	12	40	4	13.33
Summer season	7	23.33	6	20.00	6	20	2	6.67
Throughout the year	19	63.33	21	70.00	12	40	24	80.00

N- Number of respondents

Percent- Percentage of respondents

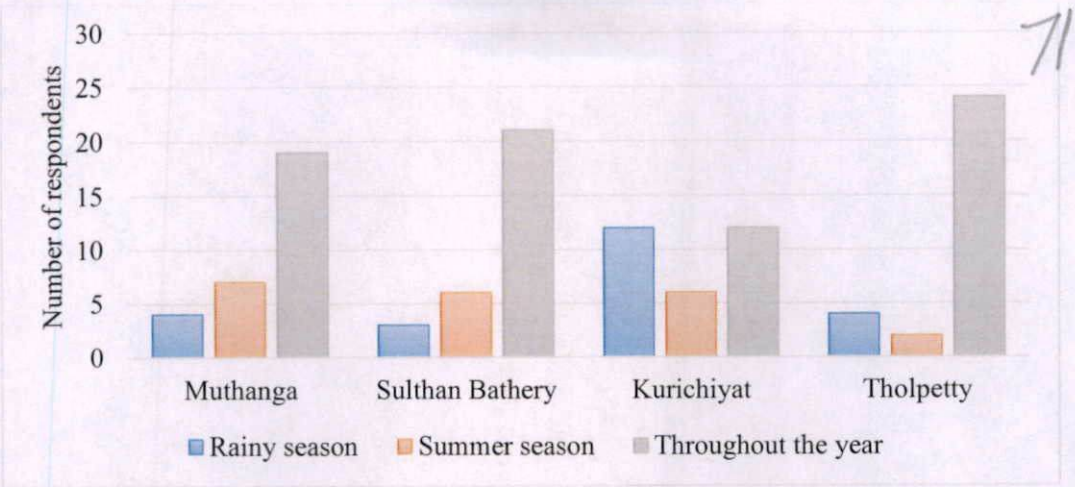

Figure 6. Seasonality of human-wildlife conflict at Wayanad Wildlife Sanctuary

The increased conflict issues during rainy season is due to the fruiting season of Jack and the local migrants from the adjacent protected areas can be the reason for increased conflict incidents during summer period.

4.3 Human-wildlife Conflict Mitigation

4.3.1 Maintenance frequency of the human-wildlife conflict mitigation measures at Wayanad Wildlife Sanctuary by the Kerala Forest Department officials

In Wayanad Wildlife Sanctuary, Solar Power Electric Fence, Elephant-proof Trench and Elephant-proof Wall are being used as a mitigation measure for human-wildlife conflict. The efficiency of the mitigation measures installed in a region is dependent on how well it is maintained. The maintenance work like deepening the elephant-proof trenches and clearing off the vines and undergrowth of electric fences are usually carried out with the help of local communities through Mahatma Gandhi National Rural Employment Guarantee Scheme (Thozhilurappu).

Table 14 and Figure 7 depicts that, the maintenance of the mitigation measures are fairly good in Muthanga range, when compared to all other ranges. In Kurichiyat range, the maintenance of the human-wildlife conflict measures is said to be very poor as 50 percent of the respondents revealed that the barriers are not frequently maintained and 30 percent says that there is no maintenance. Kurichiyat

was the only range where some people revealed that there is ultimately no maintenance after the construction of the mitigation measures in their region.

Table 14. Maintenance frequency of the human-wildlife conflict mitigation measures at Wayanad Wildlife Sanctuary by the Kerala Forest Department officials

	Muthanga		Sulthan Bathery		Kurichiyat		Tholpetty	
	N	Percent	N	Percent	N	Percent	N	Percent
Very often	3	10.00	0	0.00	1	3.33	1	0.00
Often	16	53.33	8	26.67	5	16.67	7	23.33
Sometimes	5	16.67	9	30.00	5	16.67	14	46.67
Rarely	6	20.00	13	43.33	10	33.33	8	26.67
None	0	0.00	0	0.00	9	30.00	0	0.00

N- Number of respondents

%- Percentage of respondents

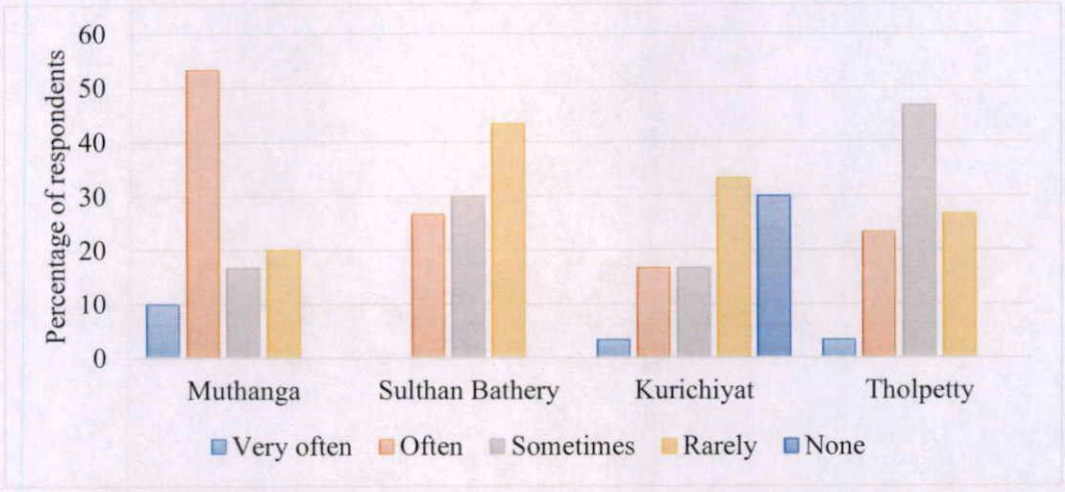

Figure 7. Maintenance frequency of the human-wildlife conflict mitigation measures at Wayanad Wildlife Sanctuary by the Kerala Forest Department officials

4.3.2 Maintenance frequency of the human-wildlife conflict mitigation measures at Wayanad Wildlife Sanctuary by the public

Table 15 and Figure 8 show that majority of the respondents were not regularly involved in maintaining the mitigation measures. In Muthanga range, the number of respondents involved in the maintenance activities are comparatively higher than the other forest ranges.

Table 15. Maintenance frequency of the human-wildlife conflict mitigation measures at Wayanad Wildlife Sanctuary by the public

	Muthanga		Sulthan Bathery		Kurichiyat		Tholpetty		Total	
	N	%	N	%	N	%	N	%	N	%
Very often	0	0	0	0	1	3.33	0	0.00	1	0.83
Often	3	10	1	3.33	1	3.33	1	3.33	6	5.00
Sometimes	3	10	1	3.33	1	3.33	3	10.00	8	6.67
Rarely	12	40	12	40	9	30	13	43.33	46	38.33
None	12	40	16	53.33	18	60	13	43.33	59	49.17

N- Number of respondents

%- Percentage of respondents

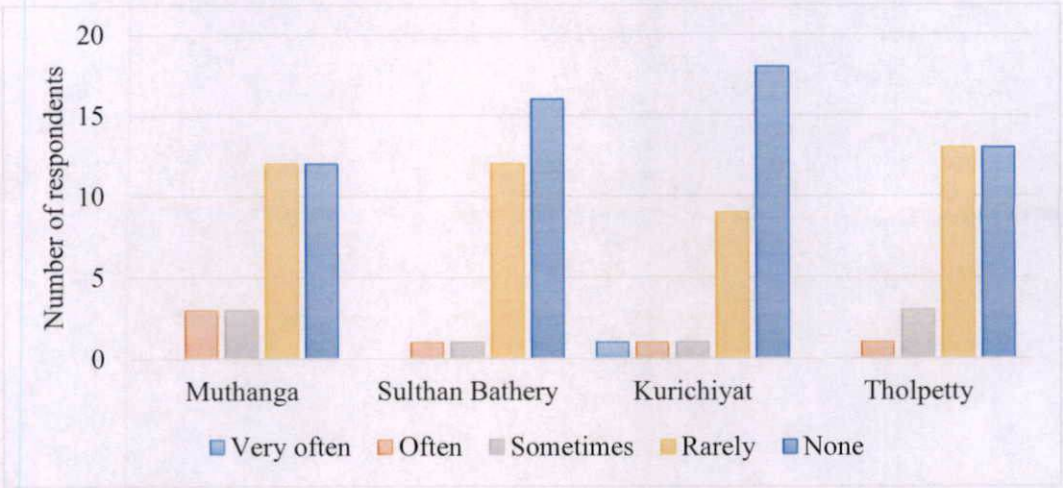

Figure 8. Maintenance frequency of the human-wildlife conflict mitigation measures at Wayanad Wildlife Sanctuary by the public

4.3.3 Role of the respondents in maintaining the mitigation measures in Wayanad Wildlife Sanctuary

The Government has some limitation in maintaining all the mitigation measures that are established in the sanctuary. The people residing near to the physical barrier should take some responsibility in the maintenance of the barriers, as they are benefiters. Table 16 shows that almost half of the respondents of Wayanad Wildlife Sanctuary (49.2 percent) are not involved in any maintenance activity of mitigation measures. 42.5 percent of the respondents are said to be taking some effort in reporting the condition of the mitigation measures to the forest department (KFD) whenever required. Only 8.3 percent of the respondents is involved in the physical maintenance. Physical maintenance by the respondents in

all the four ranges are very poor and it was comparatively higher in Muthanga range (16.67 percent).

Table 16. Role of the respondents in maintaining the mitigation measures in Wayanad Wildlife Sanctuary

	Muthanga		Sulthan Bathery		Kurichiyat		Tholpetty		Total	
	N	%	N	%	N	%	N	%	N	%
Timely reporting of the condition of mitigation measures to the KFD	13	43.33	12	40	11	36.7	15	50	51	42.5
Physical maintenance	5	16.67	2	6.67	1	3.3	2	6.7	10	8.3
None	12	40	16	53.3	18	60	13	43.3	59	49.2

N- Number of respondents
%- Percentage of respondents

4.4 Attitude and perception towards human-wildlife conflict mitigation measures in Wayanad Wildlife Sancturay

The attitude and perception of the respondents towards the human-wildlife conflict mitigation of all the four ranges are summarized below.

4.4.1 Attitude towards human-wildlife conflict mitigation measures in Muthanga range of Wayanad Wildlife Sanctuary

The Table 17 and Figure 9 depict the attitude of the respondents of Muthanga range regarding the human-wildlife conflict mitigation measures. 93.33 percent of the respondents agreed that wildlife should be controlled using non-lethal methods. 63.33 percent of the respondents have the opinion that conflict mitigation CESS should be collected from tourist people who visits the forest and wildlife, so that the fund shortage, if any, can be met. 50 percent of the respondents are of the opinion that adopting beehive fences will not reduce the human-wildlife conflict incidents. For about 30 percent of the respondents, this concept was totally new. 50 percent of the respondents are of the opinion that the animals get easily adapted to conflict mitigation measures. 43.33 percent of the respondents are of the opinion that the usage of ineffective preventive measures makes human-wildlife conflict more probable.

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Table 17. Attitude of the respondents towards human-wildlife conflict mitigation measures in Muthanga range (in percentages)

	S1	S2	S3	S4	S5
Strongly agree	40.00	23.33	0.00	0.00	6.67
Agree	53.33	33.33	20.00	50.00	43.33
Neutral	0.00	13.33	30.00	43.33	43.33
Disagree	0.00	10.00	20.00	3.33	6.67
Strongly disagree	6.67	20.00	30.00	3.33	0.00

S1: Wildlife should be controlled using non-lethal methods such as barriers, deterrents, and relocation.

S2: Tourists coming to see forest/wildlife should pay human-wildlife conflict mitigation CESS

S3: Adapting beehive fences is a good measure to reduce the conflict incidents

S4: Some of the barriers leads to the animals getting easily adapted to the mitigation measures

S5: Usage of ineffective preventive measures makes human-wildlife conflict more probable.

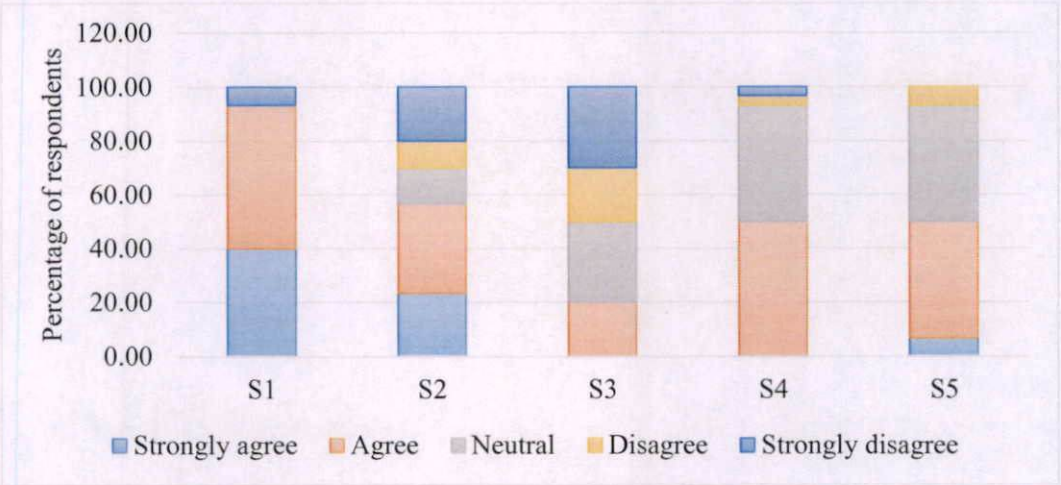

Figure 9. Attitude of the respondents towards human-wildlife conflict measures in Muthanga range

4.4.2 Perception towards human-wildlife conflict mitigation measures in Muthanga range of Wayanad Wildlife Sanctuary

Table 18 and Figure 10 show that in Muthanga range, the opinion of most of the respondents (70 percent) is that the lack of proper planning of the management interventions within the forest makes wildlife disturbed. About 33.34 percent of the respondents strongly believe that planting food plants inside the forest areas can bring down the conflict incidents, and 50 percent of the respondents

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considers it as purely impractical and useless effort. Majority (76.66 percent) of respondents are of the opinion that maintaining enough water source inside the forest does not bring down the conflict issues and they strongly believe that there is enough water sources inside the forest. Majority of the respondents (76.66 percent) disagrees that farming non-palatable crops in border areas of forest can reduce the crop raiding issues.

Table 18. Perception of the respondents towards human-wildlife conflict mitigation measures in Muthanga range (in percentages)

	S1	S2	S3	S4	S5	S6	S7
Excellent	0.00	6.67	0.00	0.00	36.67	20.00	3.33
Good	40.00	26.67	6.67	3.33	23.33	20.00	23.33
Fair	30.00	16.67	16.67	6.67	20.00	40.00	23.33
Poor	30.00	23.33	23.33	23.33	16.67	13.33	20.00
Very poor	0.00	26.67	53.33	66.67	3.33	6.67	30.00

S1: Lack of proper planning in management interventions like road construction/ barrier/ waterhole within the forests make wildlife disturbed

S2: Planting food plants inside the forest area brings down the conflict incidents

S3: Maintaining enough water sources inside forest reduce the conflict

S4: Farming plants containing capsaicin-like chilly and pepper/ non-palatable crops in border areas of the forest helps to avoid the wild animal attack of crops

S5: Physical barriers may shift the conflict from one site to another

S6: Official's quick interventions help in reducing human-wildlife conflict

S7: Wild animals have predictable behavioral patterns. We should understand this to construct proper barriers.

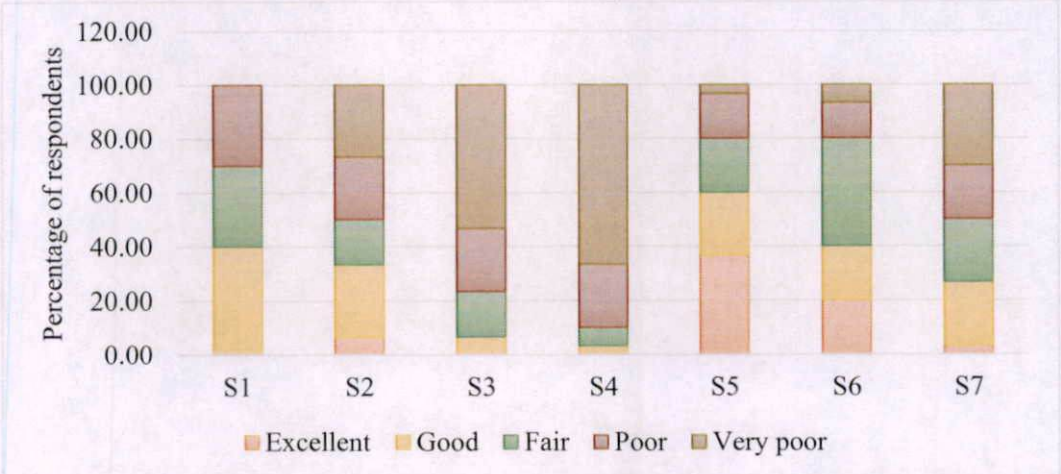

Figure 10. Perception of the respondents towards human-wildlife conflict mitigation measures in Muthanga range

About 80 percent of the respondents agreed that implementing the physical barriers shifts the conflict from one particular site to another, while 20 percent of the respondents opinioned that there will not be any shift in the conflict incidents as the animals are too intelligent to overcome the human-wildlife conflict mitigation measures. Half of the respondents is of the opinion that understanding of the behavioral patterns will not be helpful in building proper barriers and 80 percent of respondents is of the opinion that the quick interventions of forest officials can reduce the human-wildlife conflict and the rest of the respondents totally disagrees with the statement.

4.4.3 Attitude towards human-wildlife conflict mitigation measures in Sulthan Bathery range of Wayanad Wildlife Sanctuary

The Table 19 and Figure 11 depict the attitude of the respondents regarding the human-wildlife conflict mitigation measures. 96.67 percent of the respondents agreed that wildlife should be controlled using non-lethal methods. 26.67 percent of the respondents have the opinion that conflict mitigation CESS should be collected from tourists coming to visit the forest and wildlife, so that the fund shortage, if any, can be met and 60 percent of the respondents are of the opinion that there is no need of collection of such conflict mitigation CESS because it may negatively affect the tourism and they also opinionated that currently there is enough fund in the forest department allotted exclusively for the conflict mitigation strategies.

Table 19. Attitude of the respondents towards human-wildlife conflict measures in Sulthan Bathery range (in percentages)

	S1	S2	S3	S4	S5
Strongly agree	80.00	6.67	0.00	20.00	0.00
Agree	16.67	20.00	13.33	80.00	50.00
Neutral	0.00	13.33	46.67	0.00	40.00
Disagree	0.00	20.00	23.33	0.00	10.00
Strongly disagree	3.33	40.00	16.67	0.00	0.00

S1: Wildlife should be controlled using non-lethal methods such as barriers, deterrents, and relocation.

S2: Tourists coming to see forest/wildlife should pay human-wildlife conflict mitigation CESS

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S3: Adapting beehive fences is a good measure to reduce the conflict incidents
S4: Some of the barriers leads to the animals getting easily adapted to the mitigation measures
S5: Usage of ineffective preventive measures makes human-wildlife conflict more probable.

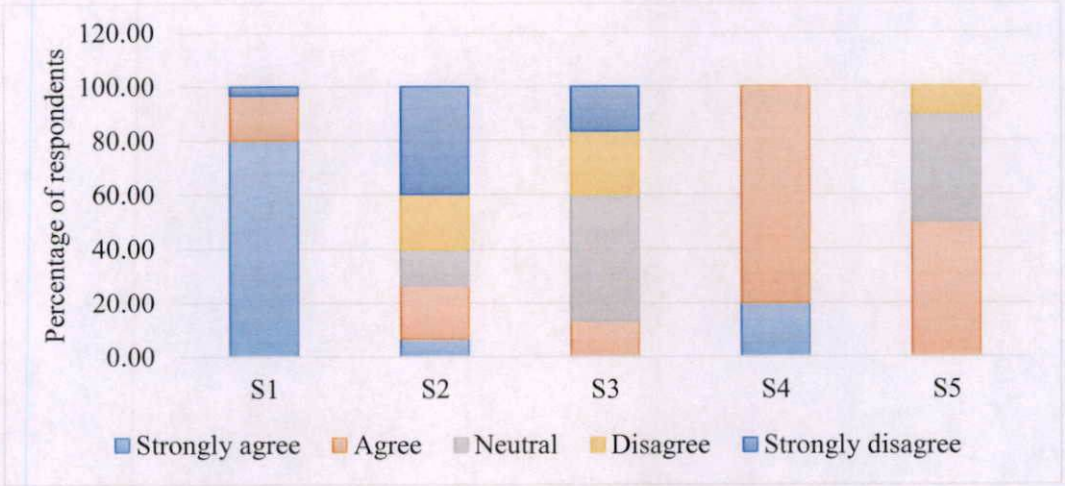

Figure 11. Attitude of the respondents towards human-wildlife conflict measures in Sulthan Bathery range

About 40 percent of the respondents were of the opinion that adopting beehive fences will not reduce the human-wildlife conflict incidents and 46.67 percent of the respondents were not having any opinion regarding the installation of beehive fences, as it was totally new for them. All the respondents have the opinion that the animals get easily adapted to conflict mitigation measures. 50 percent of the respondents are of the opinion that the usage of ineffective preventive measures makes human-wildlife conflict more probable.

4.4.4 Perception towards human-wildlife conflict mitigation measures in Sulthan Bathery range of Wayanad Wildlife Sanctuary

Table 20 and Figure 12 depicts that in Sulthan Bathery range, most of the respondents (76.67 percent) believes that the lack of proper planning in the management interventions within the forest makes wildlife disturbed. Majority of the respondents (53.33 percent) strongly believe that planting food plants inside the forest areas can bring down the conflict incidents. According to about 76 percent of the respondents, it is not the shortage of water inside the forest which is

increasing the conflict issues, and also farming non-palatable crops cannot help in reducing the conflict incidents (96.67 percent).

Table 20. Perception of the respondents towards human-wildlife conflict mitigation measures in Sulthan Bathery range (in percentages)

	S1	S2	S3	S4	S5	S6	S7
Excellent	6.67	20.00	3.33	0.00	80.00	16.67	0.00
Good	10.00	33.33	16.67	0.00	10.00	43.33	10.00
Fair	60.00	13.33	16.67	3.33	3.33	13.33	0.00
Poor	16.67	6.67	20.00	26.67	6.67	23.33	6.67
Very poor	6.67	26.67	43.33	70.00	0.00	3.33	83.33

S1: Lack of proper planning in management interventions like road construction/ barrier/ waterhole within the forests make wildlife disturbed

S2: Planting food plants inside the forest area brings down the conflict incidents

S3: Maintaining enough water sources inside forest reduce the conflict

S4: Farming plants containing capsaicin-like chilly and pepper/ non-palatable crops in border areas of the forest helps to avoid the wild animal attack of crops

S5: Physical barriers may shift the conflict from one site to another

S6: Official's quick interventions help in reducing human-wildlife conflict

S7: Wild animals have predictable behavioral patterns. We should understand this to construct proper barriers

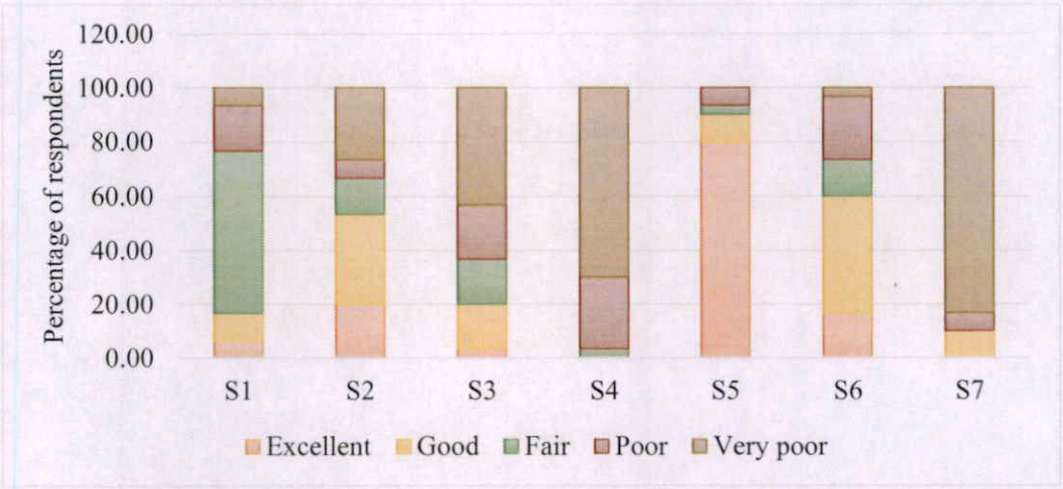

Figure 12. Perception of the respondents towards human-wildlife conflict mitigation measures in Sulthan Bathery range

Majority of the respondents (93.33 percent) agreed that implementation of the physical barriers shifts the conflict from one particular site to another. 90 percent of the respondents is of the opinion that understanding of the behavioral patterns will not be helpful in building proper barriers in a location. 73.33 percent

of respondents believe that the quick interventions of forest officials can reduce the human-wildlife conflict and the rest of the respondents disagrees with the statement.

4.4.5 Attitude towards human-wildlife conflict mitigation measures in Kurichiyat range of Wayanad Wildlife Sanctuary

The Table 21 and Figure 13 depict the attitude of the respondents of Kurichiyat range regarding the human-wildlife conflict mitigation measures. More than 96 percent of the respondents agrees that wildlife should be controlled using non-lethal methods. Half of the respondents have the opinion that conflict mitigation CESS should be collected from tourists coming to visit the forest and wildlife, so that the fund shortage, if any, can be met. About 20 percent of the respondents don't have an opinion about the collection of conflict mitigation CESS, and 30 percent of the respondents are of the opinion that there is no need of collection of such conflict mitigation CESS because it may negatively affect the tourism.

Table 21. Attitude of the respondents to human-wildlife conflict measures in Kurichiyat range (in percentages)

	S1	S2	S3	S4	S5
Strongly agree	10.00	10.00	0.00	46.67	0.00
Agree	86.67	40.00	13.33	46.67	16.67
Neutral	3.33	20.00	36.67	6.67	73.33
Disagree	0.00	23.33	13.33	0.00	10.00
Strongly disagree	0.00	6.67	36.67	0.00	0.00

S1: Wildlife should be controlled using non-lethal methods such as barriers, deterrents and relocation.

S2: Tourists coming to see forest/wildlife should pay human-wildlife conflict mitigation CESS

S3: Adapting beehive fences is a good measure to reduce the conflict incidents

S4: Some of the barrier leads to the animals getting easily adapted to the mitigation measures

S5: Usage of ineffective preventive measures makes human-wildlife conflict more probable.

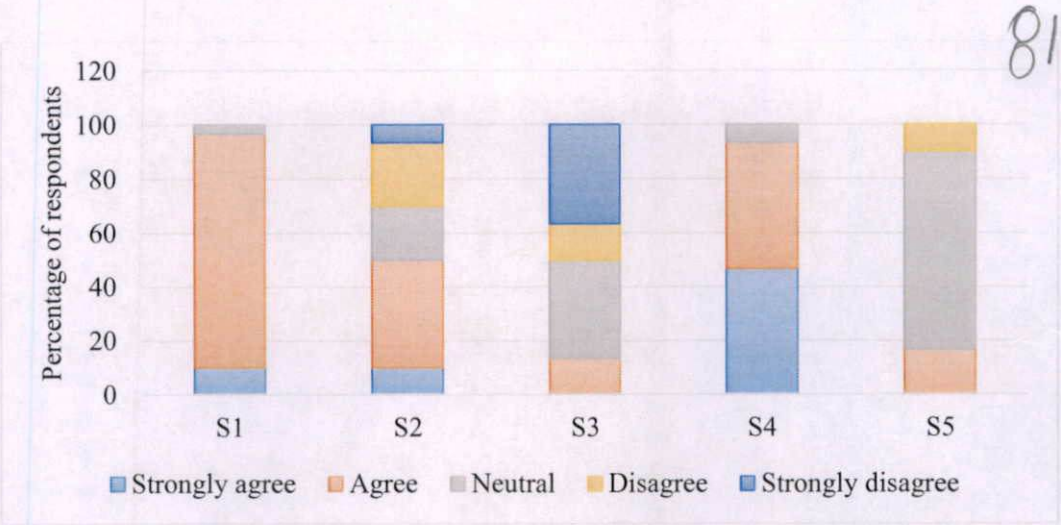

Figure 13. Attitude of the respondents to human-wildlife conflict measures in Kurichiyat range

Majority of the respondents (50 percent) consider beehive fences as an ineffective measure and for 36.67 percent of the respondents this concept was totally new. More than 93 percent of the respondents are of the opinion that the animals get easily adapted to conflict mitigation measures and none of the respondents disagreed with this statement.

4.4.6 Perception towards human-wildlife conflict mitigation measures in Kurichiyat range of Wayanad Wildlife Sanctuary

The Table 22 and Figure 14 depict that in Kurichiyat range, about 66 percent of respondents believe that the lack of proper planning of the management interventions within the forest makes wildlife disturbed. Some of the respondents (33.34 percent) strongly believe that planting food plants inside the forest areas can bring down the conflict incidents, and about 46.67 percent of the respondents considers it as a purely impractical and useless effort. Majority of the respondents (63.33 percent) is of the opinion that it is not the shortage of water inside the forest which is increasing the conflict issues. 96.67 percent of the respondents says that farming non palatable crops in border areas of forest will not help in reducing the crop loss and 73.34 percent of the respondents agreed that implementing the physical barriers shifts the conflict from one particular site to another. More than 73 percent of the respondents is of the opinion that understanding of the behavioral

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patterns will not be helpful in building proper barriers in a location. About 60 percent of respondents believes that quick interventions of the forest officials can reduce the human-wildlife conflict.

Table 22. Perception of the respondents towards human-wildlife conflict mitigation measures in Kurichiyat range (in percentages)

	S1	S2	S3	S4	S5	S6	S7
Excellent	3.33	6.67	3.33	0.00	26.67	0.00	3.33
Good	23.33	26.67	16.67	0.00	46.67	60.00	6.67
Fair	40.00	20.00	16.67	3.33	6.67	23.33	16.67
Poor	33.33	20.00	40.00	20.00	16.67	13.33	36.67
Very poor	0.00	26.67	23.33	76.67	3.33	3.33	36.67

S1: Lack of proper planning in management interventions like road construction/ barrier/ waterhole within the forests make wildlife disturbed

S2: Planting food plants inside the forest area brings down the conflict incidents

S3: Maintaining enough water sources inside forest reduce the conflict

S4: Farming plants containing capsaicin like chilly and pepper/ non-palatable crops in border areas of forest helps to avoid wild animal attack of crops

S5: Physical barriers may shift the conflict from one site to another

S6: Official's quick interventions help in reducing human-wildlife conflict

S7: Wild animals have predictable behavioral patterns. We should understand this to construct proper barriers

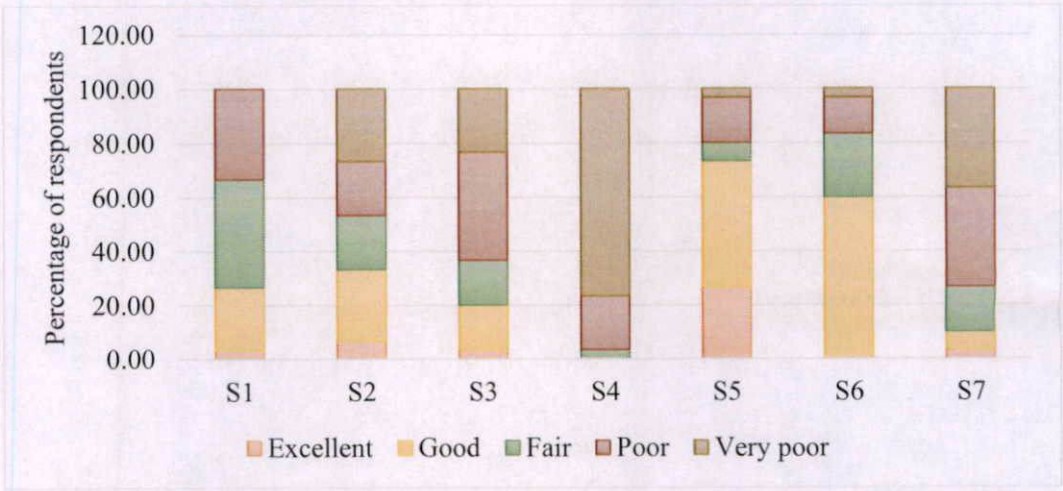

Figure 14. Perception of the respondents towards human-wildlife conflict mitigation measures in Kurichiyat range

4.4.7 Attitude towards human-wildlife conflict mitigation measures in Tholpetty range of Wayanad Wildlife Sanctuary

The Table 23 and Figure 15 depicts the attitude of the respondents regarding the human-wildlife conflict mitigation measures. Most of the respondents (96.67 percent) agreed that wildlife should be controlled using non-lethal methods. About 36 percentage of the respondents have the opinion that conflict mitigation CESS should be collected from tourists coming to visit the forest and wildlife, so that the fund shortage, if any, can be met. But, majority of the respondents (46.66 percent) are against this because they believe that it may negatively affect the tourism. Most of the respondents (56.67 percent) is of the opinion that beehive fences is not an effective tool for human-wildlife conflict mitigation and 30 percent of the respondents were not aware of beehive fences. All of the respondents agrees that animals get easily adapted to conflict mitigation measures and 40 percentage of the respondents are of the opinion that the usage of ineffective preventive measures makes human-wildlife conflict more probable.

Table 23. Attitude of the respondents to human-wildlife conflict measures in Tholpetty range (in percentages)

	S1	S2	S3	S4	S5
Strongly agree	70.00	10.00	6.67	80.00	0.00
Agree	26.67	26.67	6.67	20.00	40.00
Neutral	3.33	16.67	30.00	0.00	56.67
Disagree	0.00	23.33	10.00	0.00	0.00
Strongly disagree	0.00	23.33	46.67	0.00	3.33

S1: Wildlife should be controlled using non-lethal methods such as barriers, deterrents, and relocation.

S2: Tourists coming to see forest/wildlife should pay human-wildlife conflict mitigation CESS

S3: Adapting beehive fences is a good measure to reduce the conflict incidents

S4: Some of the barriers leads to the animals getting easily adapted to the mitigation measures

S5: Usage of ineffective preventive measures makes human-wildlife conflict more probable.

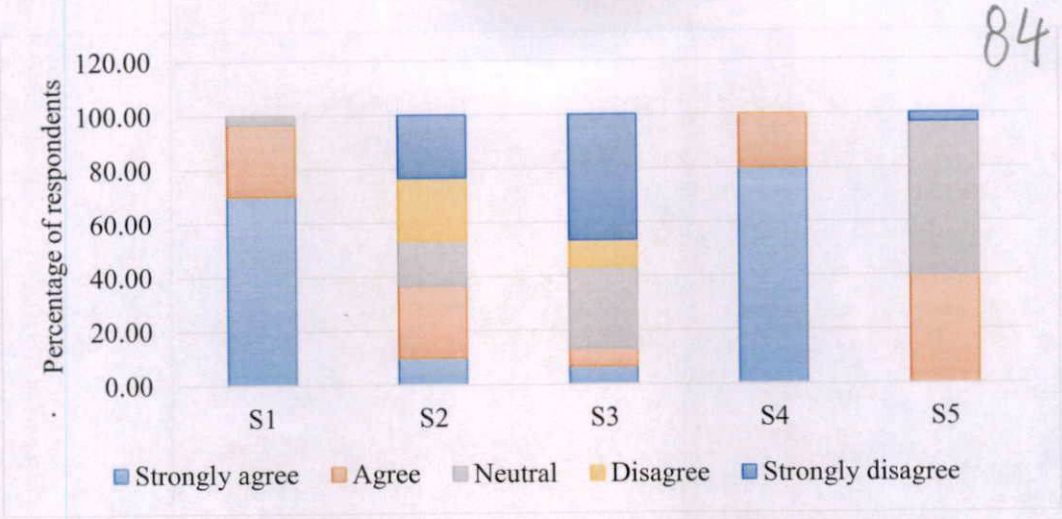

Figure 15. Attitude of the respondents to human-wildlife conflict measures in Tholpetty range

4.4.8 Perception towards human-wildlife conflict mitigation measures in Tholpetty range of Wayanad Wildlife Sanctuary

Table 24 and Figure 16 depicts that in Tholpetty range, 56.67 percent of respondents' is of the opinion that lack of proper planning of the developmental projects within the forest makes wildlife disturbed and 60 percent of the respondents strongly believe that planting food plants inside the forest areas can bring down the conflict incidents. Half of the respondents believe that the rise in the human-wildlife conflict is due to the shortage of water inside the forest. Most of the respondents (90 percent) says that that farming non-palatable crops in border areas of forest will not help in reducing the crop damages.

Table 24. Perception of the respondents towards human-wildlife conflict mitigation measures in Tholpetty range (in percentages)

	S1	S2	S3	S4	S5	S6	S7
Excellent	10.00	30.00	16.67	0.00	83.33	0.00	0.00
Good	16.67	30.00	26.67	6.67	10.00	56.67	10.00
Fair	30.00	20.00	6.67	3.33	6.67	43.33	10.00
Poor	43.33	6.67	16.67	13.33	0.00	0.00	16.67
Very poor	0.00	13.33	33.33	76.67	0.00	0.00	63.33

S1: Lack of proper planning in management interventions like road construction/ barrier/ waterhole within the forests make wildlife disturbed

S2: Planting food plants inside the forest area brings down the conflict incidents

S3: Maintaining enough water sources inside forest reduce the conflict

S4: Farming plants containing capsaicin-like chilly and pepper/ non-palatable crops in border areas of the forest helps to avoid the wild animal attack of crops
S5: Physical barriers may shift the conflict from one site to another
S6: Official's quick interventions help in reducing human-wildlife conflict
S7: Wild animals have predictable behavioral patterns. We should understand this to construct proper barriers.

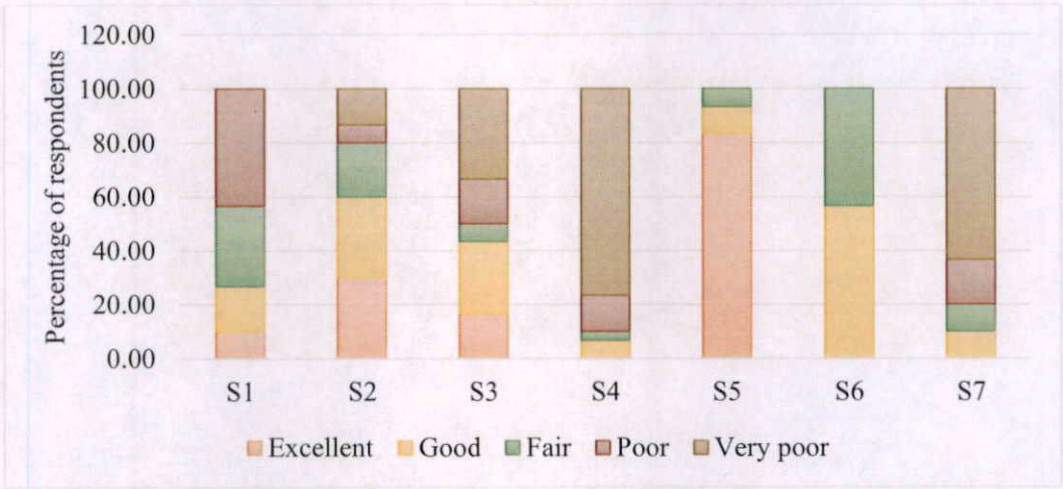

Figure 16. Perception of the respondents towards human-wildlife conflict mitigation measures in Tholpetty range

More than 93 percent of the respondents agreed that implementing physical barriers results in shifting of the conflict incidents from one particular site to another. About 80 percent of the respondents is of the opinion that understanding of the behavioral patterns will not help in building proper barriers in a location and 56.67 percent of respondents is of the opinion that the quick interventions of forest officials can reduce the human-wildlife conflict.

4.5 Factors that the respondents believe to be the most important when choosing a conflict mitigation scheme in Wayanad Wildlife Sanctuary

The factors that has to be considered when choosing a conflict mitigation scheme, according to the respondents of each range in Wayanad Wildlife sanctuary, is summarized below. Seven factors are selected and is numbered from S1 to S7. The factors are proven effectiveness (S1), low startup cost (S2), low maintenance cost (S3), low labor effort (S4), minimal negative effects on wildlife (S5), high level of acceptability to other people (S6) and fair level of compensation (S7).

4.5.1 Factors that the respondents believe to be the most important when choosing a conflict mitigation scheme in Muthanga range of Wayanad Wildlife Sanctuary

Table 25 represents the opinion of the respondents of Muthanga range regarding the factors that have to be considered when choosing a conflict mitigation scheme. All the respondents are of the opinion that the mitigation measure should be of proven effectiveness. Majority of the respondents did not give much importance to the startup cost, maintenance cost or the labor effort. According to 60 percent of the respondents, there should be only minimal negative effect on wildlife due to the conflict mitigation measures. But, 36.66 percent of the respondents do not bother about the negative effects on wildlife and 3.33 percent of the respondents are not having an opinion about the same. The acceptability of the physical barriers by the local people is considered to be important by 73.34 percentage of the respondents. Some of the respondents (13.33 percent) are of the opinion that a fair level of compensation should be sanctioned in case of crop raiding due to the failure of the mitigation measure, whereas 53.33 percent of the respondents are disagreeing with the statement and 33.33 percent of respondents refused to give opinion on this matter.

Table 25. Factors that the respondents believe to be the most important when choosing a conflict mitigation scheme in Muthanga range (in percentages)

	S1	S2	S3	S4	S5	S6	S7
Most effective	53.33	0.00	0.00	3.33	3.33	6.67	3.33
Effective	46.67	10.00	33.33	23.33	56.67	66.67	10.00
Neutral	0.00	16.67	3.33	23.33	3.33	23.33	33.33
Not much effective	0.00	46.67	36.67	26.67	33.33	3.33	20.00
Least effective	0.00	26.67	26.67	23.33	3.33	0.00	33.33

4.5.2 Factors that the respondents believe to be the most important when choosing a conflict mitigation scheme in Sulthan Bathery range of Wayanad Wildlife Sanctuary

Table 26 summarizes the opinion of the respondents of Sulthan Bathery range regarding the factors that have to be considered when choosing a conflict

mitigation scheme. All the respondents are of the opinion that the mitigation measure should be of proven effectiveness. Startup cost is given least importance, followed by labour effort and maintenance cost. About 20 percent of the respondents is of the opinion that there should be only minimal negative effect on wildlife due to the conflict mitigation measures. However, 26.67 percent of the respondents do not bother about the negative effects on wildlife that may occur due to implementation of the conflict mitigation measure and 53.33 percent of the respondents refused to give opinion regarding the same. More than half of the respondents (53.34 percent) are of the opinion that the mitigation measure which is to be implemented should be highly acceptable by the local people residing in that area. Majority of the respondents (86.67 percent) of the respondents was not having a positive nature towards the compensation scheme.

Table 26. Factors that the respondents believe to be the most important when choosing a conflict mitigation scheme in Sulthan Bathery range (in percentages)

	S1	S2	S3	S4	S5	S6	S7
Most effective	93.33	0.00	0.00	0.00	0.00	26.67	0.00
Effective	6.67	0.00	30.00	6.67	20.00	56.67	13.33
Neutral	0.00	3.33	3.33	0.00	53.33	6.67	0.00
Not much effective	0.00	20.00	26.67	13.33	20.00	0.00	10.00
Least effective	0.00	76.67	40.00	80.00	6.67	10.00	76.67

4.5.3 Factors that the respondents believe to be the most important when choosing a conflict mitigation scheme in Kurichiyat range of Wayanad Wildlife Sanctuary

The Table 27 shows the opinion of the respondents of Kurichiyat range regarding the factors that has to be considered in choosing a conflict mitigation scheme. All the respondents are of the opinion that the mitigation measure should be of proven effectiveness. The start-up cost, maintenance cost and the labour charges involved were given the least importance by majority of the respondents. More than 73 percent of the respondents is of the opinion that there should be only minimal negative effect on wildlife due to the conflict mitigation measures. But, 16.67 percent of the respondents does not bother about the negative effects on

wildlife that may occur due to implementation of the conflict mitigation measure and 10 percent of the respondents refused to give opinion about the same. The acceptability of the local people on the mitigation measure installed is accepted as a factor to be considered by 60 percent of the respondents. About 50 percent of the respondents did not consider fair level of compensation as an important factor to be considered in mitigating the human-wildlife conflict.

Table 27. Factors that the respondents believe to be the most important when choosing a conflict mitigation scheme in Kurichiyat range (in percentages)

	S1	S2	S3	S4	S5	S6	S7
Most effective	40.00	0.00	0.00	0.00	23.33	10.00	0.00
Effective	60.00	6.67	16.67	6.67	50.00	50.00	26.67
Neutral	0.00	36.67	20.00	66.67	10.00	26.67	23.33
Not much effective	0.00	30.00	33.33	3.33	16.67	0.00	3.33
Least effective	0.00	26.67	30.00	23.33	0.00	13.33	46.67

4.5.4 Factors that the respondents believe to be the most important when choosing a conflict mitigation scheme inTholpetty range of Wayanad Wildlife Sanctuary

Table 28 summarizes the opinion of the respondents of Tholpetty range about the factors to be considered when choosing a conflict mitigation scheme. All the respondents are of the opinion that the mitigation measure should be of proven effectiveness. Startup cost, labour effort and the maintenance cost are not given much priority by 96.67 percent, 93.33 percent and 86.67 percentage of the respondents respectively. Most of the respondents (96.67 percent) is of the opinion that there should be an only minimal negative effect on wildlife due to the conflict mitigation measures and 83.34 percent of the respondents has given much importance to the acceptability of the mitigation measures by the local people residing in that area. Only 30 percent of the respondents are of the opinion that fair level of compensation should be sanctioned in case of crop raiding due to the failure of the mitigation measure, whereas the rest, being unsatisfied, disagrees with it.

Table 28. Factors that the respondents believe to be the most important when choosing a conflict mitigation scheme in Tholpetty range (in percentages)

	S1	S2	S3	S4	S5	S6	S7
Most effective	60.00	0.00	0.00	0.00	16.67	36.67	10.00
Effective	40.00	3.33	13.33	6.67	80.00	46.67	20.00
Neutral	0.00	3.33	0.00	0.00	0.00	0.00	0.00
Not much effective	0.00	26.67	20.00	23.33	0.00	0.00	16.67
Least effective	0.00	66.67	66.67	70.00	3.33	16.67	53.33

4.6 Satisfaction of the respondents towards the active involvement of Government in tackling human-wildlife conflict issues

Table 29 and Figure 17 show that majority of the respondents were not satisfied with the involvement of the government bodies in clearly communicating the problems and struggles faced by them. In Sulthan Bathery and Tholpetty ranges, about 40 percent of respondents are satisfied with the approach of the government bodies in considering them and doing the needful. It is 36.67 percent in the case of Muthanga range and 33.33 percent in the case of Kurichiyat range.

Table 29. The opinion of respondents about the active involvement of government bodies in clearly communicating the problems and struggles faced by them

	Muthanga		Sulthan Bathery		Kurichiyat		Tholpetty	
	N	Percent	N	Percent	N	Percent	N	Percent
Strongly agree	2	6.67	0	0.00	3	10.00	3	10.00
Agree	9	30.00	12	40.00	7	23.33	9	30.00
Neutral	2	6.67	0	0.00	0	0.00	0	0.00
Disagree	13	43.33	8	26.67	11	36.67	11	36.67
Strongly disagree	4	13.33	10	33.33	9	30.00	7	23.33

N- Number of respondents

%- Percentage of respondents

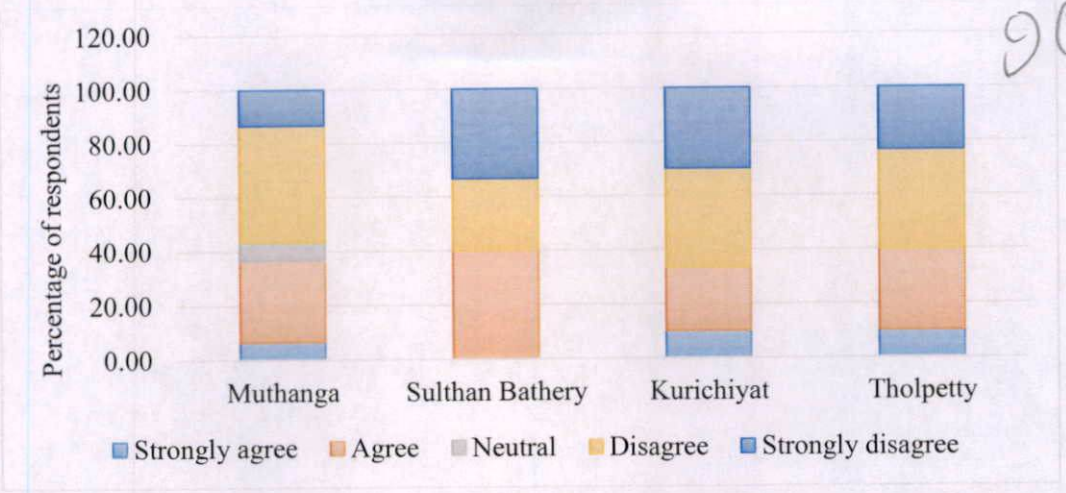

Figure17. The opinion of respondents about the active involvement of government bodies in clearly communicating the problems and struggles faced by them

4.7 Satisfaction of respondents with the compensation pattern of the government in Wayanad Wildlife Sanctuary

Table 30 shows the satisfaction of the respondents towards the compensation scheme is very poor in Tholpetty range where 90 percent of the respondents are not satisfied. It is followed by Sulthan Bathery and Muthanga ranges.

Table 30. Satisfaction of respondents with the compensation pattern of the government in Wayanad Wildlife Sanctuary

	Muthanga		Sulthan Bathery		Kurichiyat		Tholpetty	
	N	Percent	N	Percent	N	Percent	N	Percent
Strongly agree	0	0.00	0	0.00	0	0.00	0	0.00
Agree	5	16.67	6	20.00	7	23.33	3	10.00
Neutral	12	40.00	10	33.33	12	40.00	0	0.00
Disagree	8	26.67	4	13.33	3	10.00	13	43.33
Strongly Disagree	5	16.67	10	33.33	8	26.67	14	46.67

N- Number of respondents

Percent- Percentage of respondents

4.8 Difficulties faced by the respondents in getting compensation for the loss in Wayanad Wildlife Sanctuary

Figure 18 depicts that red-tapism is the major problem faced by the respondents of Wayanad Wildlife Sancturay. Only 8 percent of the respondents were not having much complaint regarding the compensation provided to them. 26

percentage of the respondents either did not give an application for getting compensation or were not eligible for claiming compensation. 91

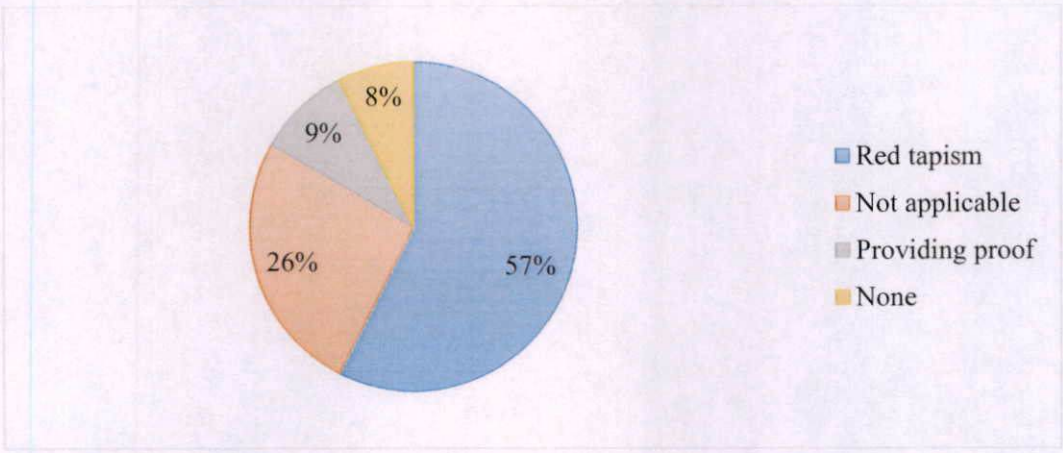

Figure 18. Difficulties faced by the respondents in getting compensation for the loss in Wayanad Wildlife Sanctuary

Table 31. Difficulties faced by the respondents in getting compensation for the loss in Wayanad Wildlife Sanctuary

	Muthanga		Sulthan Bathery		Kurichiyat		Tholpetty	
	N	Percent	N	Percent	N	Percent	N	Percent
Providing proof	4	13.33	4	13.33	0	0.00	3	10.00
Red-tapism	12	40.00	15	50.00	17	56.67	25	83.33
None	4	13.33	1	3.33	2	6.67	2	6.67
Not applicable	10	33.33	10	33.33	11	36.67	0	0.00

N- Number of respondents

Percent- Percentage of respondents

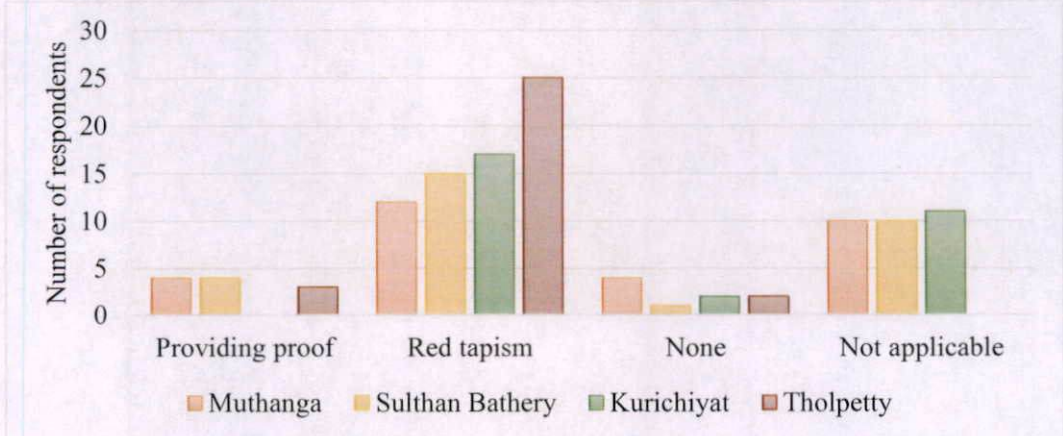

Figure 19. Difficulties faced by the respondents of each range in getting compensation for the loss in Wayanad Wildlife Sanctuary

Table 31 and Figure 19 show that 13.33 percent of the respondents in both Muthanga and Sulthan Bathery ranges are of the opinion that the proof of crop loss will not last long as weeds/ grasses grow over it, especially in the case of paddy and herbaceous plants. The number of non-applicants for compensation was more in Kurichiyat range (36.67 percent), followed by Muthanga (33.33 percent) and Sulthan Bathery range (33.33 percent).

4.8 Effectiveness of human-wildlife conflict mitigation measures implemented in Wayanad Wildlife Sanctuary

4.8.1 Effectiveness of human-wildlife conflict mitigation measures implemented in Muthanga range of Wayanad Wildlife Sanctuary

The Table 32 and Figure 20 depict that 36.67 percent of the respondents is of the opinion that the electric fences are effective and 21.43 percent of the respondents are of the opinion that the elephant-proof trenches are effective. Only 13.33 percent of the respondents are having an elephant proof wall and it is said to be effective. 63.34 percent of the respondents are of the opinion that the electric fences implemented in their residing area are not at all effective and 78.57 percent of the respondents are of the opinion that elephant-proof trenches are not effective. Only one of the respondents was having a wire fence in their location and it is said to be ineffective.

Table 32. Effectiveness of the mitigation measures implemented in Muthanga range of Wayanad Wildlife Sanctuary

	Electric Fence		Trench		Wall	Wire fence
	N	Percent	N	Percent	N	N
Most effective	3	10.00	0	0.00	1	0
Effective	8	26.67	6	21.43	3	0
Neutral	0	0.00	0	0.00	0	0
Not much effective	5	16.67	8	28.57	0	0
Least effective	14	46.67	14	50.00	0	1

N- Number of respondents

Percent- Percentage of respondents

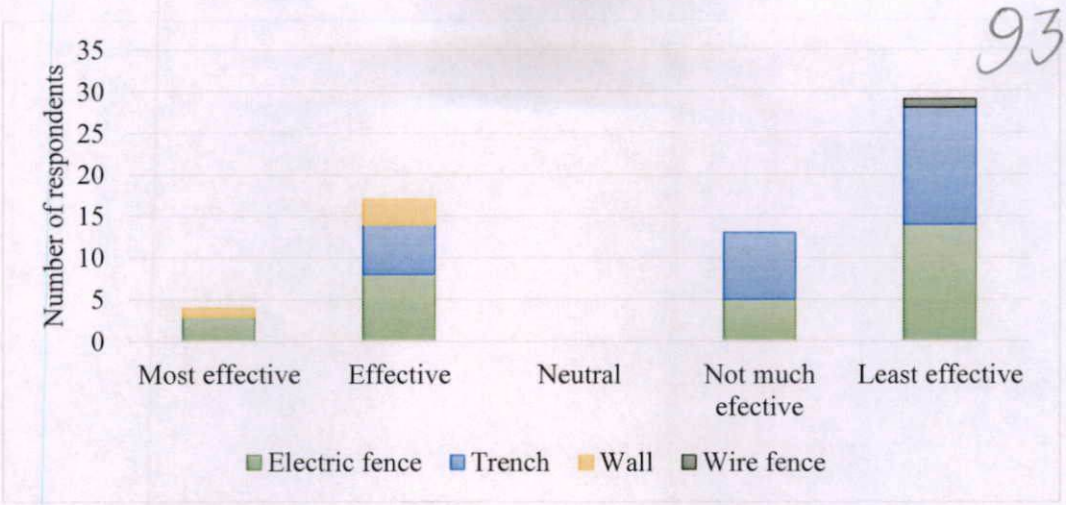

Figure 20. Effectiveness of the mitigation measures implemented in Muthanga range of Wayanad Wildlife Sanctuary

4.8.2 Effectiveness of human-wildlife conflict mitigation measures implemented in Sulthan Bathery range of Wayanad Wildlife Sanctuary

The Table 33 and Figure 21 depict that 28.57 percent of the respondents is of the opinion that the electric fences are effective and 36.67 percent of the respondents are of the opinion that the elephant-proof trenches are effective. Only 10 percent of the respondents are having an elephant proof wall and it is said to be effective. 71.43 percent of the respondents are of the opinion that the electric fences implemented in their residing area are not at all effective and 63.33 percent of the respondents are of the opinion that elephant-proof trenches are not effective. Only one of the respondents was having a wire fence in their location and it is said to be ineffective.

Table 33. Effectiveness of the mitigation measures implemented in Sulthan Bathery range of Wayanad Wildlife Sanctuary

	Electric fence		Trench		Wall	Wire fence
	N	Percent	N	Percent	N	N
Most effective	0	0.00	0	0.00	0	0
Effective	8	28.57	11	36.67	0	0
Neutral	0	0.00	0	0.00	0	0
Not much effective	5	17.86	4	13.33	1	1
Least effective	15	53.57	15	50.00	2	0

N- Number of respondents

Percent- Percentage of respondents

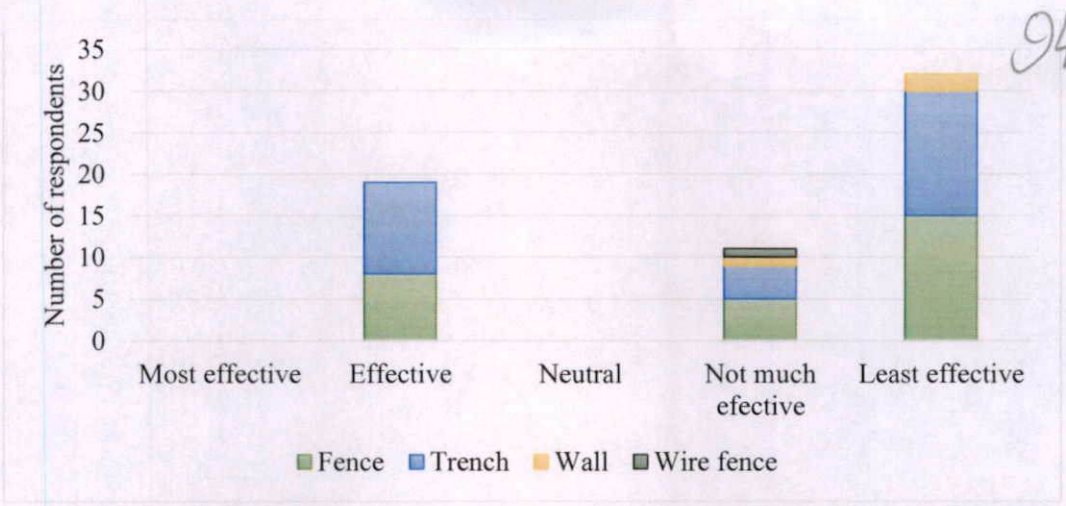

Figure 21. Effectiveness of the mitigation measures implemented in Sulthan Bathery range of Wayanad Wildlife Sanctuary

4.8.3 Effectiveness of human-wildlife conflict mitigation measures implemented in Kurichiyat range of Wayanad Wildlife Sanctuary

Table 34 and Figure 22 depicts that 16.67 percent of the respondents is of the opinion that the electric fences are effective and 33.33 percent of the respondents is of the opinion that the elephant-proof trenches are effective. More than 83 percent of the respondents is of the opinion that the electric fences implemented in their residing area is not at all effective and 66.67 percent of the respondents revealed that elephant-proof trenches are not effective. Only one of the respondents was having opinion about the biological fencing using agave, and it is said to be ineffective.

Table 34. Effectiveness of the mitigation measures implemented in Kurichiyat range of Wayanad Wildlife sanctuary

	Electric Fence		**Trench**		**Agave**
	N	Percent	N	Percent	N
Most effective	0	0	0	0	0
Effective	5	16.67	10	33.33	0
Neutral	0	0	0	0	0
Not much effective	6	20	5	16.67	1
Least effective	19	63.33	15	50	0

N- Number of respondents

Percent- Percentage of respondents

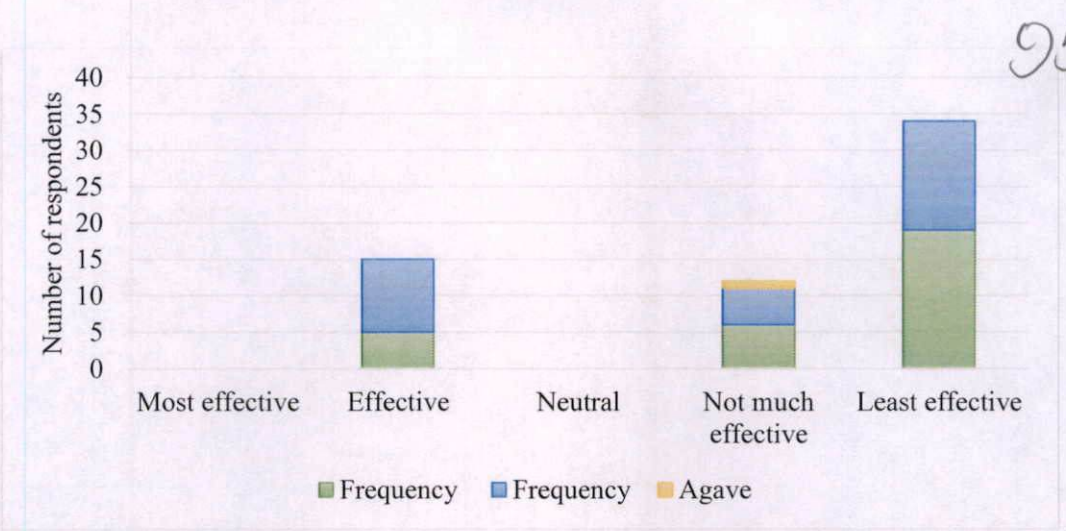

Figure 22. Effectiveness of the mitigation measures implemented in Kurichiyat range of Wayanad Wildlife sanctuary

4.8.4 Effectiveness of human-wildlife conflict mitigation measures implemented in Tholpetty range of Wayanad Wildlife Sanctuary

The Table 35 and Figure 23 depict that only 10.34 percent of the respondents is of the opinion that the electric fences are effective and 20 percent of the respondents are of the opinion that the elephant-proof trenches are effective. Only 3.33 percent of the respondents are having an elephant proof wall and it is said to be ineffective. Majority of the respondents are of the opinion that the electric fences (89.65 percent) and elephant-proof trenches (80 percent) implemented in their residing area are not at all effective. Only 10 percent of the respondents was having natural fence in their location and the effectiveness is yet to be studied properly.

Table 35. Effectiveness of the mitigation measures implemented in Tholpetty range of Wayanad Wildlife Sanctuary

	Electric fence		Trench		Wall	Natural fence
	N	Percent	N	Percent	N	N
Most effective	0	0.00	0	0	0	0
Effective	3	10.34	6	20	0	2
Neutral	0	0.00	0	0	0	0
Not much effective	9	31.03	13	43.33	1	1
Least effective	17	58.62	11	36.67	0	0

N- Number of respondents

Percent- Percentage of respondents

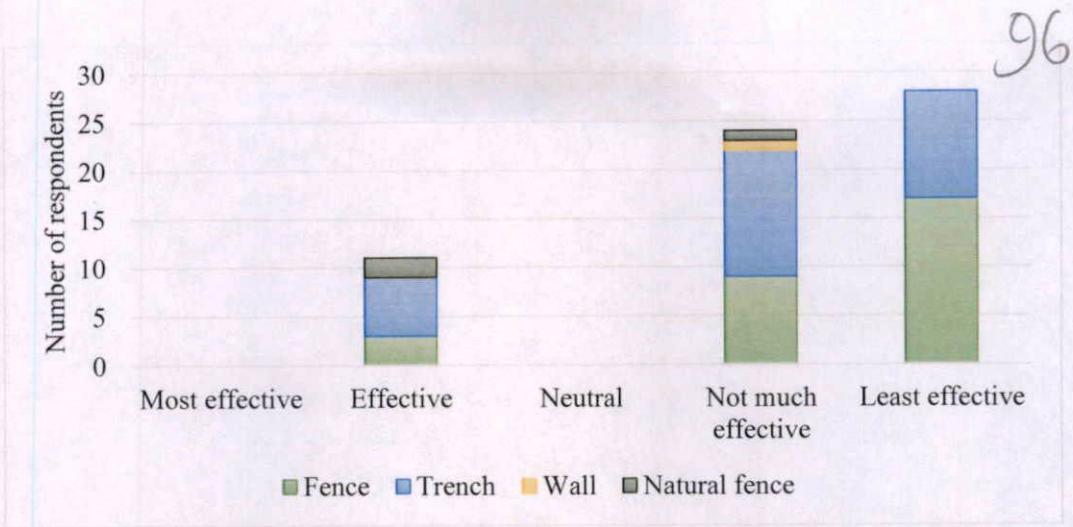

Figure 23. Effectiveness of the mitigation measures implemented in Tholpetty range of Wayanad Wildlife Sanctuary

4.9 People's perception on the mitigation measures

The peoples' perception on the mitigation measure that could be implemented in their own ranges are summarized in the Table 36 to Table 39. In Muthanga, 66.66 percent of the respondents is having their own opinion on the mitigation measure that should be implemented in their region. Table 36 shows that among that 50 percent of respondents preferred elephant proof wall and 15 percent preferred a combination of electric fence and elephant proof trench will be more effective. About 10 percent of the respondents hope that rail fence, which is relatively a new conflict mitigation strategy in Wayanad Wildlife Sanctuary will be helpful for reducing the conflict incidents.

Table 36. Suggestion of the mitigation measures that should be implemented in their area according to the respondents in Muthanga range

	Frequency	Percent
Elephant-proof trench	2	10
Wall	10	50
Rail fence	2	10
Steel net	2	10
Combination of electric fence and elephant proof trench	3	15
Combination of wall and elephant proof trench	1	5

In Sulthan Bathery, 96.66 percent of the respondents is having their own opinion on which mitigation measure should be implemented in their region. Table

37 shows that among them, 24.13 percent of the respondents hope that rail fence will be able to mitigate the human-wildlife conflict to certain extend. 17.24 percent of respondents preferred elephant proof wall and 17.24 percent preferred a combination of rail fence and electric fence.

Table 37. Suggestion of the mitigation measures that should be implemented in their area according to the respondents in Sulthan Bathery range

	Frequency	Percent
Electric fence	2	6.90
Elephant-proof trench	1	3.45
Elephant-proof wall	5	17.24
Rail fence	4	13.79
Steel net	1	3.45
Combination of electric fence and elephant proof trench	3	10.34
Combination of rail fence and electric fence	5	17.24
Combination of elephant-proof wall and electric fence	4	13.79
Rail fence with steel net	3	10.34
Biological barrier using agave	1	3.45

All the respondents of Kurichiyat range is having their own opinion on which mitigation measure should be implemented in their region. Table 38 depicts that among them, 43.33 percent of respondents preferred elephant proof wall and 20 percent preferred a combination of electric fence and elephant-proof trench. 13 percent of the respondents hope that rail fence, which is relatively a new conflict mitigation strategy in Wayanad Wildlife Sanctuary will be helpful for reducing the conflict incidents.

Table 38. Suggestion of the mitigation measures that should be implemented in their area according to the respondents in Kurichiyat range

	Frequency	Percent
Electric fence	1	3.33
Elephant-proof trench	3	10
A combination of electric fence and elephant proof trench	6	20
Elephant-proof Wall	13	43.33
Rail fence	4	13.33
Rail fence with steel net	1	3.33
Combination of rail fence and electric fence	1	3.33
Biological barrier using agave	1	3.33

In Tholpetty range, 86.66 percent of the respondents is having their own opinion on which mitigation measure should be implemented in their region. Table 39 shows that among that 19.23 percent of respondents preferred elephant proof wall and 23.08 percent preferred a combination of electric fence and elephant proof trench. About 46.15 percent of the respondents hope that rail fence, which is relatively a new conflict mitigation strategy going in Wayanad Wildlife Sanctuary will be helpful for reducing the conflict incidents.

Table 39. The suggestion of the mitigation measures that should be implemented in their area according to the respondents in Tholpetty range

	Frequency	Percent
Electric fence	2	7.69
Elephant-proof Wall	5	19.23
Rail fence	12	46.15
Combination of electric fence and elephant proof trench	6	23.08
Combination of rail fence and electric fence	1	3.85

4. 10 Association and Correlation studies in Wayanad Wildlife Sanctuary

The association of different variables describing the respondents to their responses on the attitude and perception on the aspects of human-wildlife conflict mitigation measures has been studied through Chi-square test. The variables chosen for the association study are age, duration of the residing period of the household members interviewed, satisfaction in compensation schemes and satisfaction of involvement of forest officials in understanding their problems.

4.10.1 Association and Correlation studies in Wayanad Wildlife Sanctuary

Table 40 shows the association study between the above-mentioned variables, i.e. age, gender and duration of residing period with attitude and perception of the respondents of the Wayanad Wildlife Sanctuary. From this table, the highest association (125.961, p value = 0.000) was observed for satisfaction of Government involvement x Perception. Contingency coefficient is used for finding the magnitude of this association and if the contingency coefficient value is closer to one, the two variables are highly associated. Based on the contingency

coefficient value, the satisfaction of Government involvement x Perception possesses higher association with a coefficient value of 0.716.

Table 40. Association studies in Wayanad Wildlife Sanctuary

Parameter	**Pearson Chi-square**	**P value**	**Contingency Coefficient**
Age x Attitude	113.354**	0.000	0.697
Duration x Attitude	75.521**	0.000	0.621
Compensation x Attitude	66.757**	0.000	0.598
Government involvement x Attitude	98.901**	0.000	0.672
Age x Perception	107.226**	0.000	0.687
Duration x Perception	58.819**	0.000	0.574
Compensation satisfaction x Perception	93.249**	0.000	0.661
Government involvement x Perception	125.961**	0.000	0.716

Table 41 shows the spearman rank correlation of the variables such as attitude, perception, age, duration, compensation satisfaction and satisfaction towards the involvement of Government officials in Wayanad Wildlife Sanctuary. It is evident from the table that all these parameters have a significant positive or negative correlation with attitude and perception.

Table 41. Spearman correlation studies in Wayanad Wildlife Sanctuary

	Attitude	Perception	Age	Duration	Compensation	Government involvement
Attitude	1					
Perception	0.61**	1				
Age	0.69**	0.79**	1			
Duration	0.45**	0.62**	0.64**	1		
Compensation satisfaction	-0.60**	-0.81**	-0.80**	-0.66**	1	
Government involvement	-0.62**	-0.82**	-0.78**	-0.72**	0.82**	1

So, all the 4 attributes are influencing the attitude and perception of the respondents residing in the Wayanad Wildlife Sanctuary. Age is having the highest positive correlation with both attitude (0.69) and perception (0.79). Satisfaction of

respondents towards the Government involvement has the highest negative correlation with attitude (-0.62) as well as with perception (-0.82).

4.10.2 Range-wise association and correlation studies in Wayanad Wildlife Sanctuary

The association study between the basic details i.e. age, gender and duration of residing period with attitude and perception was carried out in all the four ranges of the Wayanad Wildlife Sanctuary. Chi-square ($\chi 2$) test is one of the important non-parametric tests and one of the most commonly used tests of significance. Contingency coefficient is used for finding the magnitude of this association.

Spearman rank correlation studies of the variables such as attitude, perception, age, duration, compensation satisfaction and satisfaction of the respondents in the involvement of Government officials is done in all the four ranges in the sanctuary. It summarizes the strength and direction of the relationship between the two variables and Spearman rank correlation coefficient lies between -1 and+1.

Table 42 shows the association study between the basic details with attitude and perception of Muthanga range. From this table, the highest association (52.82, p value = 0.000) was observed for age x perception. Based on the contingency coefficient value, the age x perception possesses higher association with a coefficient value of 0.79.

Table 42. Association studies in Muthanga range of Wayanad Wildlife Sanctuary

Parameter	Pearson Chi-square	p value	Contingency Coefficient
Age x Attitude	49.99**	0.000	0.79
Gender x Attitude	11.76**	0.003	0.53
Duration x Attitude	27.35**	0.000	0.69
Age x Perception	52.82**	0.000	0.79
Gender x Perception	15.65**	0.001	0.59
Duration x Perception	18.60*	0.029	0.62

Table 43 shows the spearman rank correlation studies in Muthanga range. It is evident from the table that all these parameters have a significant positive or negative correlation with attitude and perception. Age is having the highest positive correlation with both attitude (0.88) and perception (0.92). Compensation satisfaction has the highest negative correlation with attitude (-0.86) as well as perception (-0.89).

Table 43. Spearman correlation studies in Muthanga range of Wayanad Wildlife Sanctuary

	Attitude	Perception	Age	Duration	Compe nsation	Government involvement
Attitude	1.00					
Perception	0.79**	1.00				
Age	0.88**	0.92**	1.00			
Duration	0.64**	0.66**	0.69**	1.00		
Compensation	-0.86**	-0.89**	-0.95**	-0.74**	1.00	
Government involvement	-0.76**	-0.84**	-0.85**	-0.83**	0.86**	1.00

Table 44 shows the association study between the basic details with attitude and perception of Sulthan Bathery range. From this table, the highest association (28.84, p value = 0.000) was observed for age x perception. Based on the contingency coefficient value, the age x perception possesses higher association with a coefficient value of 0.70.

Table 44. Association studies in Sulthan Bathery range of Wayanad Wildlife Sanctuary

Parameter	**Pearson Chi-square**	**P value**	**Contingency Coefficient**
Age x Attitude	23.280**	0.000	0.661
Gender x Attitude	6.857**	0.009	0.431
Duration x Attitude	3.000	0.223	0.302
Age x Perception	28.844**	0.000	0.700
Gender x Perception	20.206**	0.000	0.634
Duration x Perception	19.615**	.001	0.629

Table 45 shows the spearman rank correlation studies between the selected variables in Sulthan Bathery range. It is evident from the table that all these

parameters have a significant positive or negative correlation with attitude and perception. Age is having the highest positive correlation with both attitude (0.63) and perception (0.85). Satisfaction of respondents towards the Government involvement has the highest negative correlation with attitude (-0.55) as well as perception (-0.88).

Table 45. Spearman correlation studies in Suthan Bathery range of Wayanad Wildlife Sanctuary

	Attitude	Perception	Age	Duration	Compe nsation	Government involvement
Attitude	1					
Perception	0.45*	1				
Age	0.63**	0.85**	1			
Duration	0.3	0.78**	0.85**	1		
Compensation	-0.54**	-0.81**	-0.81**	-0.77**	1	
Government involvement	-0.55**	-0.88**	-0.86**	-0.77**	0.92**	1

Table 46 shows the association study between the basic details with attitude and perception of Kurichiyat range. From this table, the highest association (40.615, p value = 0.000) was observed for age x attitude. Based on the contingency coefficient value, the age x attitude possesses higher association with a coefficient value of 0.758.

Table 46. Association studies in Kurichiyat range of Wayanad Wildlife Sanctuary

Parameter	**Pearson Chi-square**	**P value**	**Contingency Coefficient**
Age x Attitude	40.615**	0.000	0.758
Gender x Attitude	4.156	0.125	0.349
Duration x Attitude	14.231**	0.007	0.567
Age x Perception	28.908**	0.001	0.701
Gender x Perception	30.000**	0.000	0.707
Duration x Perception	11.172	0.083	0.521

Table 47 shows the spearman rank correlation studies between the selected variables in Kurichiyat range. It is evident from the Table 47 that all these parameters have a significant positive or negative correlation with attitude and perception. Age is having the highest positive correlation with both attitude (0.65)

and perception (0.68 Satisfaction of respondents towards the Government involvement has the highest negative correlation with attitude (-0.53) and compensation satisfaction is having the highest negative correlation with perception (-0.83).

Table 47. Spearman correlation studies in Kurichiyat range of Wayanad Wildlife Sanctuary

	Attitude	Perception	Age	Duration	Compensation	Government involvement
Attitude	1					
Perception	0.51**	1				
Age	0.65**	0.68**	1			
Duration	0.48**	0.49**	0.72**	1		
Compensation	-0.50**	-0.83**	-0.82**	-0.70**	1	
Government involvement	-0.53**	-0.81**	-0.80**	-0.67**	0.93**	1

Table 48 shows the association study between the basic details with attitude and perception of Tholpetty range. From this table, the highest association (32.381, p value = 0.000) was observed for duration x attitude. Based on the contingency coefficient value, the age x attitude possesses higher association with a coefficient value of 0.720.

Table 48. Association studies in Tholpetty range of Wayanad Wildlife Sanctuary

Parameter	**Pearson Chi-square**	**P value**	**Contingency Coefficient**
Age x Attitude	19.714**	0.001	0.630
Gender x Attitude	11.333**	0.003	0.524
Duration x Attitude	32.381**	0.000	0.720
Age x Perception	19.527**	0.001	0.628
Gender x Perception	18.267**	0.000	0.615
Duration x Perception	12.955*	0.044	0.549

Table 49 shows the spearman rank correlation studies in Tholpetty range and it is evident from the table that all these parameters have a significant positive or negative correlation with attitude and perception. Age is having the highest positive correlation with both attitude (0.63) and perception (0.78). Satisfaction of

respondents towards the Government involvement has the highest negative correlation with attitude (-0.79) as well as with perception (-0.90).

Table 49. Spearman correlation studies in Tholpetty range of Wayanad Wildlife Sanctuary

	Attitude	Perception	Age	Duration	Compensation	Government involvement
Attitude	1					
Perception	0.65**	1				
Age	0.63**	0.78**	1			
Duration	0.41*	0.60**	0.64**	1		
Compensation	-0.66**	-0.76**	-0.95**	-0.62**	1	
Government involvement	-0.79**	-0.90**	-0.86**	-0.64**	0.85**	1

4.10.3 Comparison of the attitude and perception of the respondents between the different ranges of Wayanad Wildlife Sanctuary

Mann-Whitney U test is the non-parametric alternative test to the independent two-sample t-test. It is used to test whether two sample means are equal or not. In this study, the test was carried out to understand if there exist any relation between respondents of different forest ranges in their attitude and perception. The differences in the attitude of the respondents drawn from the four ranges towards human-wildlife conflict mitigation are outlined in the Table 50. The test statistics reveals that there is no significant difference between the attitudes of the respondents residing in the four different forest ranges.

Table 50. Comparison of the attitude of the respondents of different forest ranges using Mann-Whitney U Test

Attitude	**test statistic**	**p-value**
Muthanga x Sulthan Bathery	448	0.98
Muthanga x Kurichiyat	353	0.15
Muthanga x Tholpetty	418	0.63
Sulthan Bathery x Kurichiyat	348.5	0.13
Sulthan Bathery x Tholpetty	397	0.43
Kurichiyat x Tholpetty	399.5	0.45

Comparison of the perception of the respondents drawn from the four ranges towards human-wildlife conflict mitigation are outlined in the Table 51, it is evident that there is significant difference in the perception of the respondents between the ranges Muthanga and Tholpetty and Kurichiyat and Tholpetty.

Table 51. Comparison of the perception of the respondents of different forest ranges of Wayanad Wildlife Sanctuary

Perception	test statistic	p-value
Muthanga x Sulthan Bathery	409.5	0.55
Muthanag x Kurichiyat	444.5	0.94
Muthanga x Tholpetty	**312***	**0.04**
Sulthan Bathery x Kurichiyat	412.5	0.58
Sulthan Bathery x Tholpetty	346	0.12
Kurichiyat x Tholpetty	**300***	**0.03**

4.11 Mapping of the Human-wildlife conflict mitigation measures done at Wayanad Wildlife Sanctuary

The GPS reading of the human-wildlife conflict mitigation measures such as elephant-proof wall and the combination of solar power electric fence and elephant-proof trench established in all the four ranges of Wayanad Wildlife Sanctuary was taken and mapped using the software QGIS ver. 2.18. The solar power electric fence was established along with the elephant-proof trench. A total of 190.265 km of fence-trench combination that was erected at Wayanad Wildlife Sanctuary was mapped. The combination of solar power electric fence and elephant-proof trench was more in Muthanga range (56.535 km), followed by Kurichiyat range (46.626 km), Sulthan Bathery range (46.052 km) and Tholpetty range (41.052 km). Any of the elephant-proof wall erected at Wayanad Wildlife Sanctuary were of not more than 200 m and the total length of the elephant-proof wall that could be mapped was only 654.16 m. The maps of human-wildlife conflict mitigation measures are presented from Figure 24 to Figure 28.

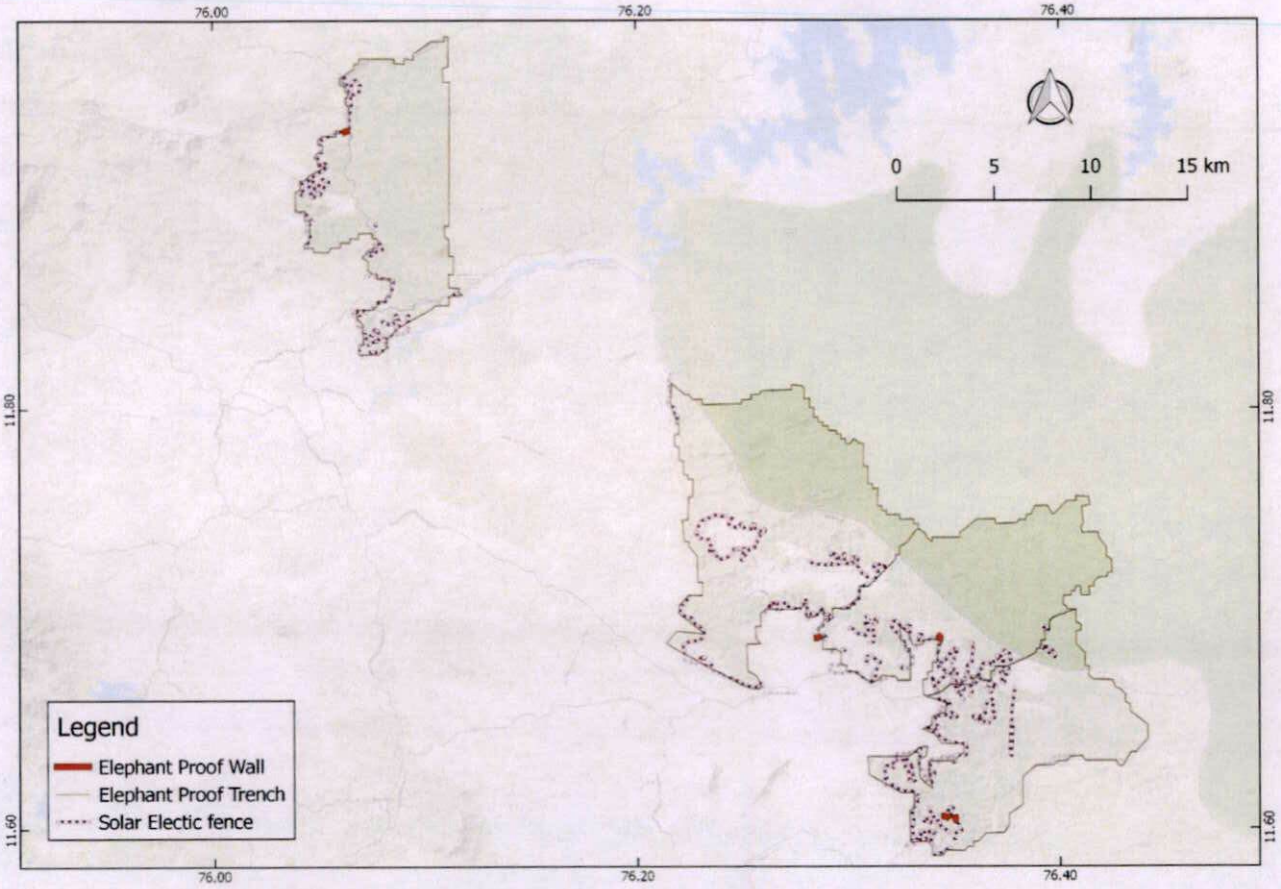

Figure 24. Mitigation measures established in Wayanad Wildlife Sanctuary

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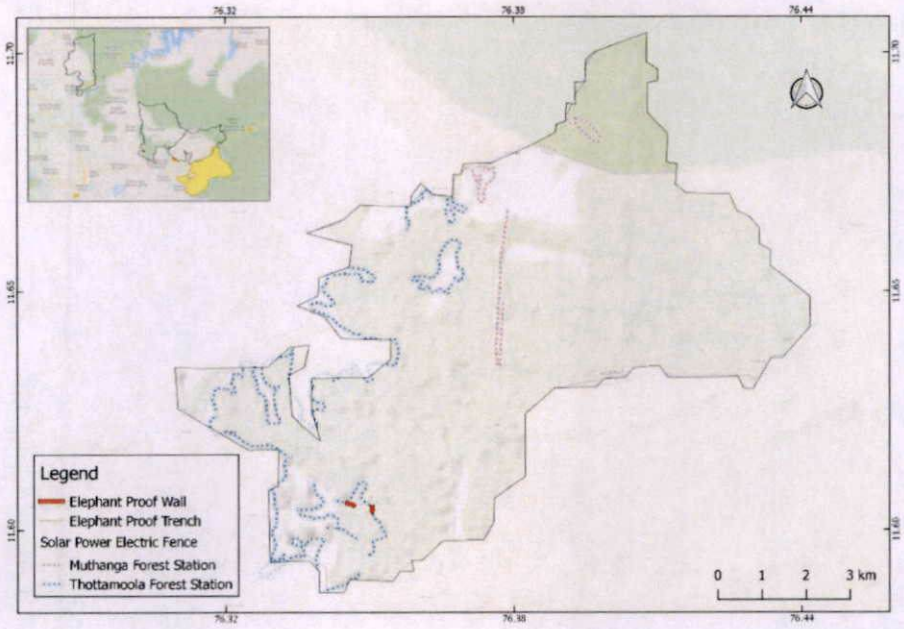

Figure. 25. Mitigation measures in Muthanga range of Wayanad Wildlife Sanctuary

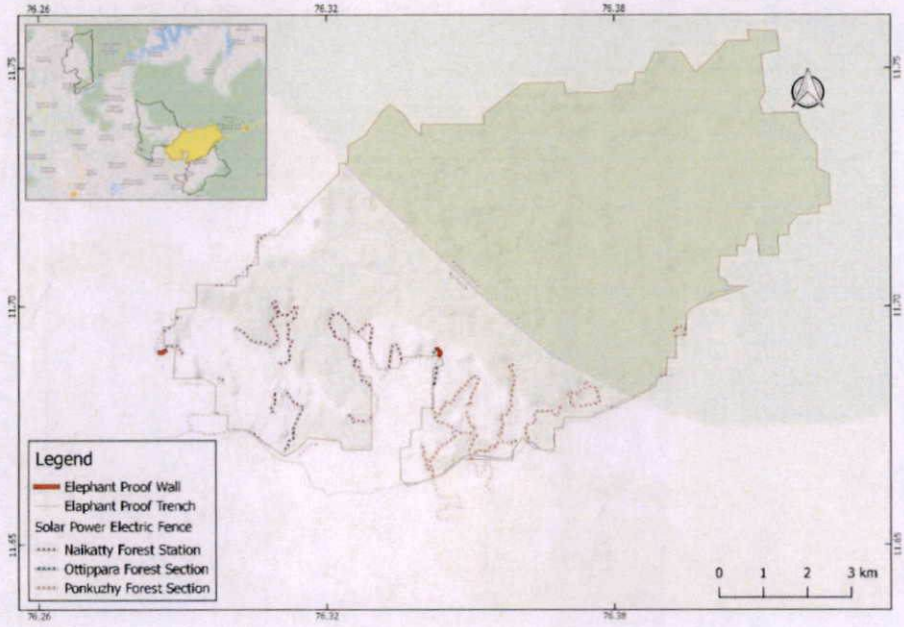

Figure 26. Mitigation measures in Sulthan Bathery range of Wayanad Wildlife Sanctuary

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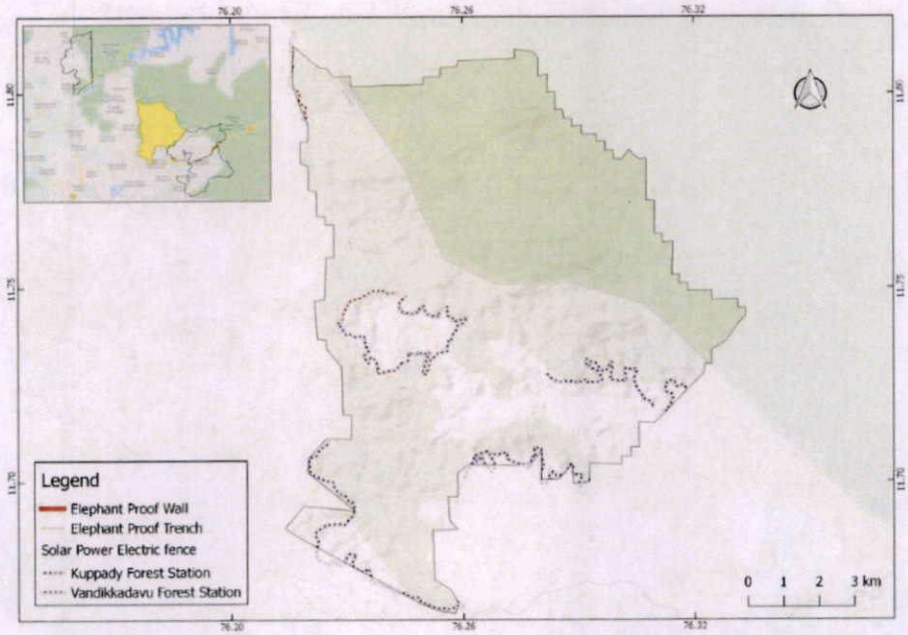

Figure 27. Mitigation measures in Kurichiyat range of Wayanad Wildlife Sanctuary

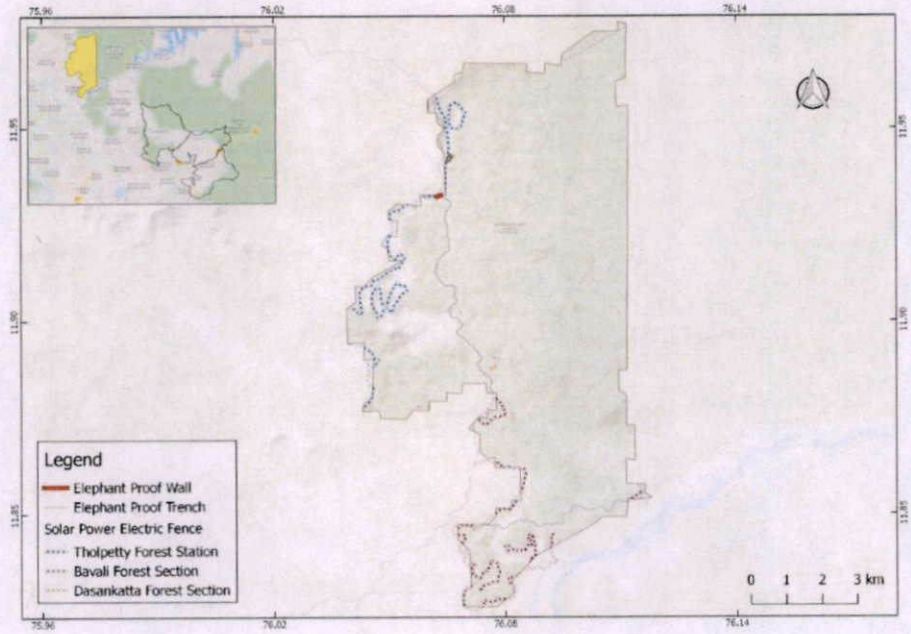

Figure 28. Mitigation measures in Tholpetty range of Wayanad Wildlife Sanctuary

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4.12 Land Use Land Cover Change Analysis

The enormous rise in the human population in the Asian countries has led to an accelerated conversion of forest areas into human settlements. The people's encroachment in to the forest land coupled with the requirements of the wild creatures leads to human-wildlife conflict.

Land use land cover change (LULCC) is a general term for the human modification of earth's terrestrial surface. It is an important measurement for assessing the spatiotemporal changes of the earth (Lambin, 1997). The temporal and spatial changes in an area can be studied using the remote sensing data. The land use land cover changes were determined by using remotely sensed data and Geographical Information Systems (GIS), both inside the Wayanad Wildlife Sanctuary and in a 5 km buffer area away from the sanctuary. On the basis of the interpretation of remote sensing imagery, the total study area was classified into 13 land use land cover classes. Built-up area is defined as the areas with construction, primarily building and houses. Kharif crops are crops which are sown during May-June and harvested in September-October. Rabi crops are sown during September-October and harvested during January-February. Zaid cropping are grown between Kharif and Rabi crop season from January-February to March April. The land use land cover maps pertaining to two different time periods were made to visualize the land use land cover change and it is quantified in the Table 52 and Table 53.

The Table 52 depicts the changes inside the sanctuary with in a time span of 10 years. It can be visualized that there is an increase in the built-up area by 35.12 ha inside the Wayanad Wildlife Sanctuary. There is a noticeable increment in the built-up area in Kurichiyat range, especially in the Kidanganad area (Figure 35 and Figure 36). In all other forest ranges, changes in cropping pattern can be observed. When sanctuary as a whole is considered, area under fallow land and wasteland has decreased by 713.89 ha (1.97% of the sanctuary area) the area under plantation and Kharif crops

has increased by 25.63 ha and 793.93 ha respectively. There is also a decrease in the area under double/triple cropping by 160.09 ha. This change in the cropping pattern from double/ triple cropping to Kharif/ Rabi/ Zaid crops may be due the more land availability for cropping due to the conversion of the fallow land and wasteland to agricultural fields. This shifts in the land use and land cover may be the reason for increased human-wildlife conflict incidents.

Table 52. Land Use Land Cover Change (LULCC) within the Wayanad Wildlife Sanctuary

Land Use Land Cover Classes	**Area (ha) 2005-06**	**Area (ha) 2014-15**	**LULCC (ha)**	**Percentage change in LULC**
Built-up	38.90	74.02	35.12	0.10
Kharif	63.61	857.54	793.93	2.19
Rabi	1.58	7.28	5.70	0.02
Zaid	0.00	14.55	14.55	0.04
Double/Triple	345.53	185.44	-160.09	-0.44
Current Fallow	763.24	77.82	-685.42	-1.89
Plantation	357.57	383.21	25.63	0.07
Evergreen Forest	579.70	579.70	0.00	0.00
Deciduous Forest	34064.25	34064.25	0.00	0.00
Degraded/Scrub	12.97	12.97	0.00	0.00
Wasteland	76.26	47.79	-28.47	-0.08
Waterbody Max	13.92	12.97	-0.95	0.00
	36317.54	36317.54	0.00	

(-) indicates decrease

The Table 53 depicts that the buffer area of 5 Km from Wayanad Wildlife Sanctuary has witnessed an increase in the built-up area by 213.26 ha. An enormous increase in the built-up area outside the Wayanad Wildlife sanctuary can be visualized at Sulthan Bathery area (Figure 33.and Figure 34). The built-up area is also increased in Irulam-Kenichira road, Thirunelli, Thrissilery, Aanappara and Tholpetty regions. The area under plantation has increased by 125.58 ha (0.32% of the total land area) and the agricultural area under Kharif, Zaid and Rabi cropping has increased by 520 ha, 83.18 ha and 26.01 ha during the interval of 10 years. The fallow land and wasteland

within the buffer area has decreased by 1639.56 ha (4.24%) and are converted to vegetated lands. The area under plantation crops has also increased by 125.58 ha. Double/ Triple cropping was found to be increased by 676.38 ha (1.75%).

Table 53. Land Use Land Cover Change in the buffer area of the Wayanad Wildlife Sanctuary

Land Use Land Cover Classes	**Area (ha) 2005-06**	**Area (ha) 2014-15**	**LULCC (ha)**	**Percentage change in LULC**
Built-up	70.01	283.27	213.26	0.55
Kharif	873.90	1394.84	520.94	1.35
Rabi	92.82	118.83	26.01	0.07
Zaid	0.64	83.83	83.18	0.21
Double/Triple	794.25	1470.63	676.38	1.75
Current Fallow	1625.11	211.97	-1413.14	-3.65
Plantation	2828.53	2954.11	125.58	0.32
Evergreen Forest	956.76	956.76	0.00	0.00
Deciduous Forest	30935.94	30935.94	0.00	0.00
Degraded/Scrub	14.77	14.77	0.00	0.00
Grasslands	80.29	80.29	0.00	0.00
Wasteland	280.70	54.28	-226.42	-0.59
Waterbody Max	136.82	126.86	-9.96	-0.03
Waterbody Min	0.00	4.18	4.18	0.01
Grand Total	38690.57	38690.57	0.00	

(-) indicates decrease

By analyzing the human-wildlife conflict incidents inside the sanctuary that have been reported in the Forest Department in the years 2007 and 2015, it was found that the conflict incidents have increased by 134 percent. So, despite of this much mitigation measures, there is no reduction in the overall conflict incidents. So, the unscientifically created physical barriers results in only fragmentation of forest. It may also change the behavior of the animals, which adds to conflict. The ecology and the movement pattern of the animals should be considered for implementing the physical barriers. The maps representing the intensity of conflict incidents during the years 2007 and 2015 are given in the Figure 41and 42.

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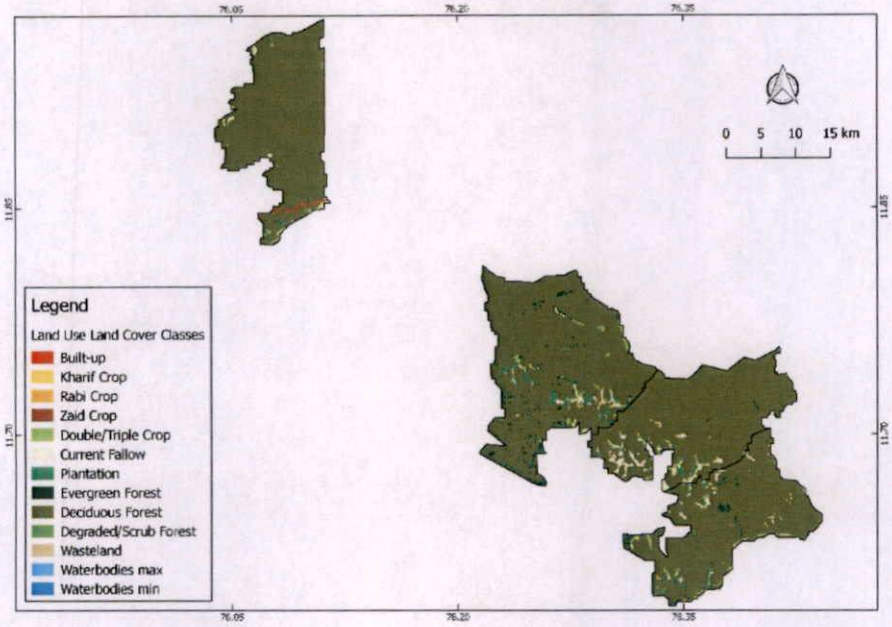

Figure 29. Land Use Land Cover of Wayanad Wildlife Sanctuary during 2005-2006

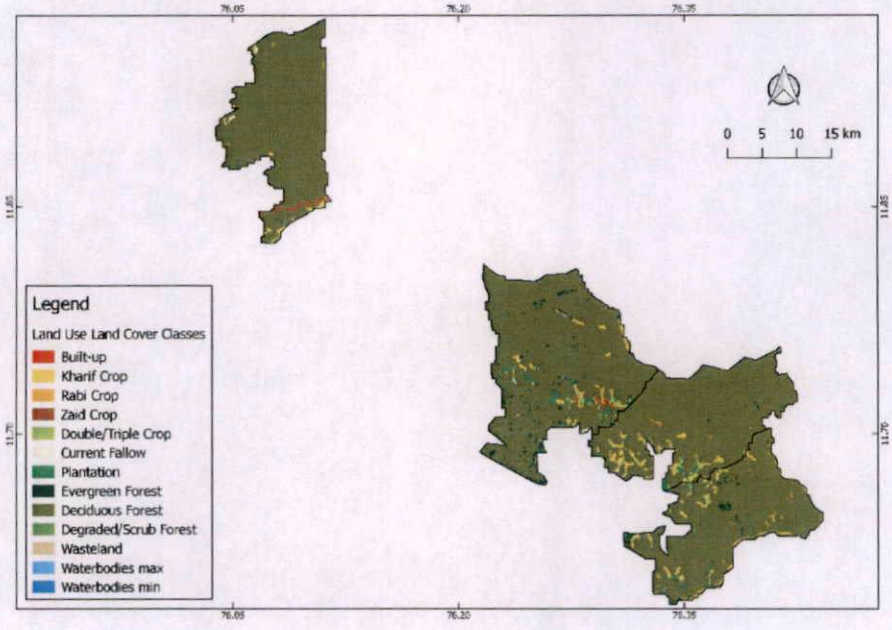

Figure 30. Land Use Land Cover of Wayanad Wildlife Sanctuary during 2014-2015

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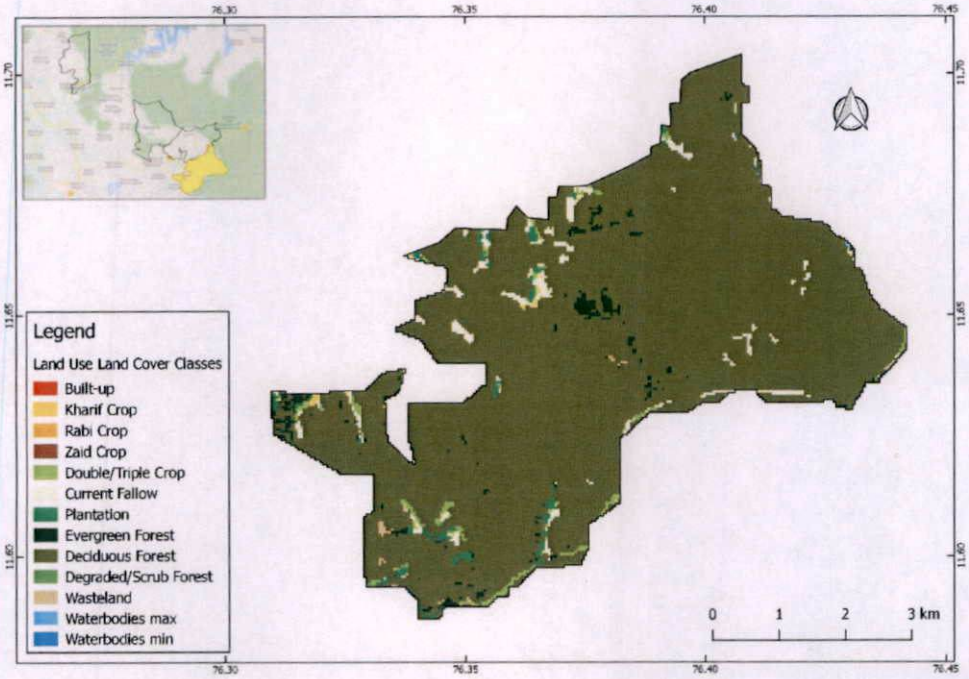

Figure 31. Land Use Land Cover of Muthanga range during 2005-2006

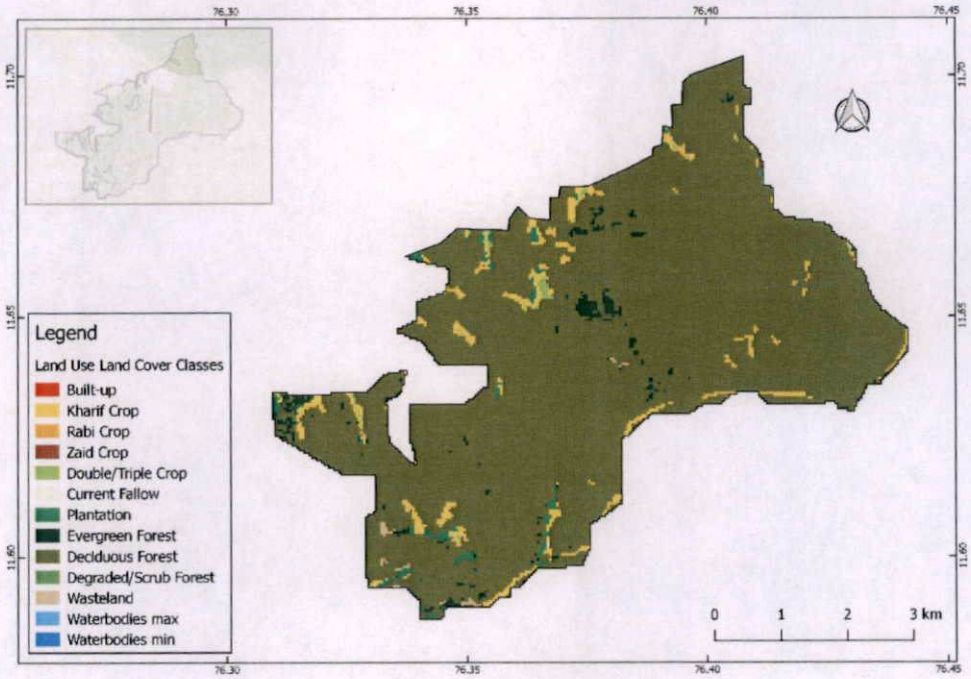

Figure 32. Land Use Land Cover of Muthanga range during 2014-2015

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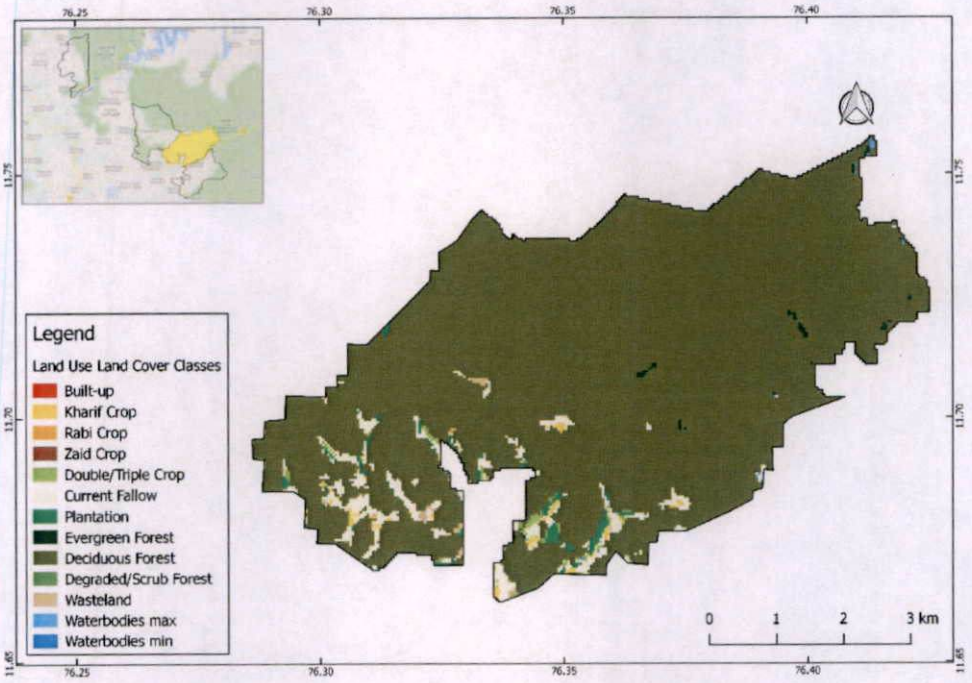

Figure 33. Land Use Land Cover of Sulthan Bathery range during 2005-2006

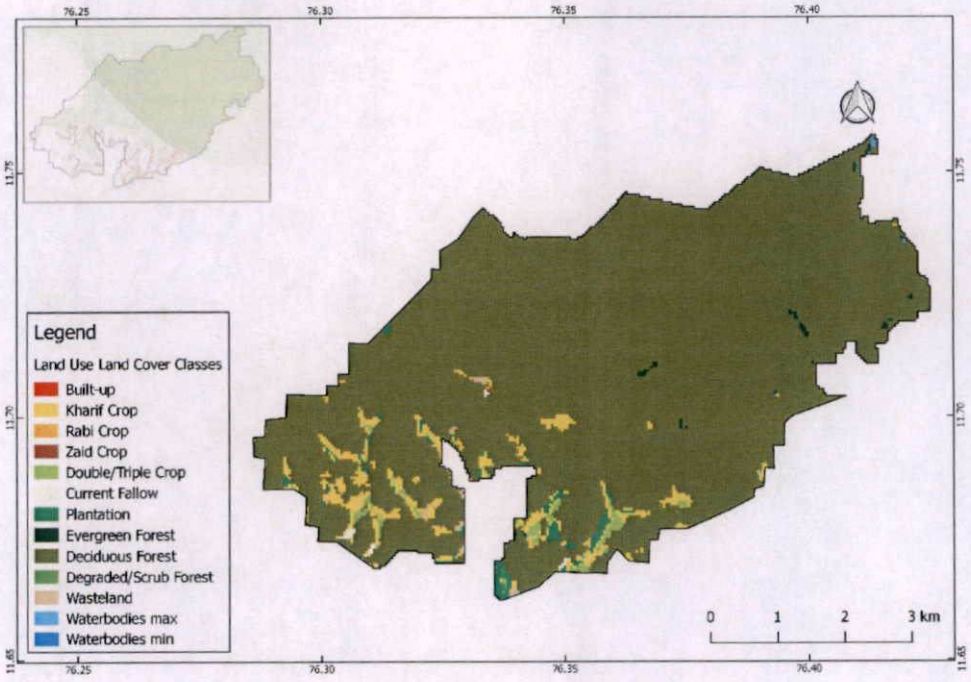

Figure 34. Land Use Land Cover of Sulthan Bathery range during 2014-2015

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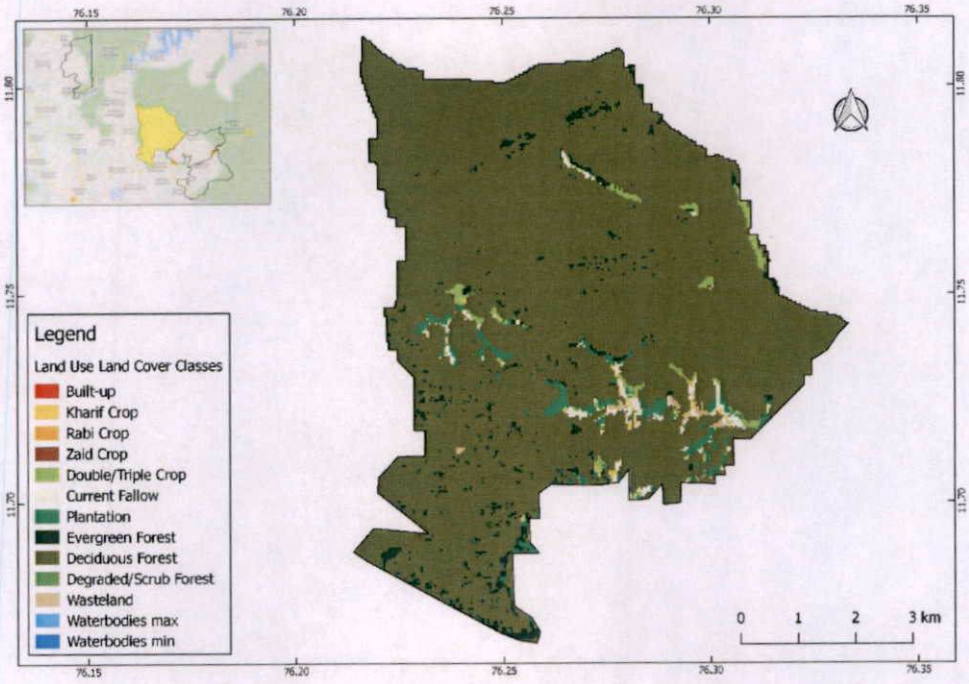

Figure 35. Land Use Land Cover of Kurichiyat range during 2005-2006

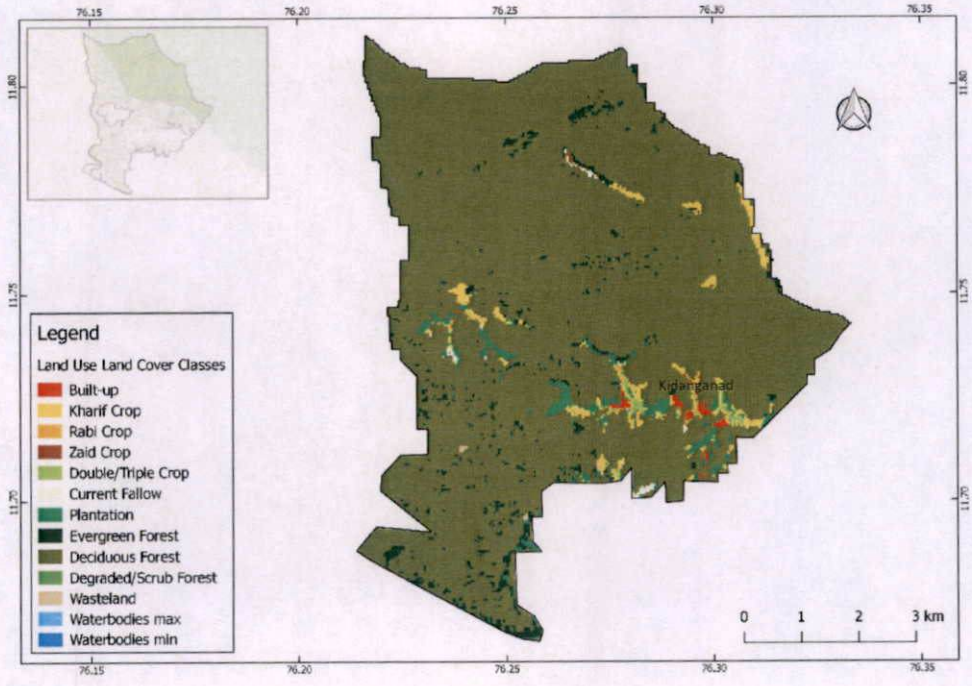

Figure 36. Land Use Land Cover of Kurichiyat range during 2014-2015

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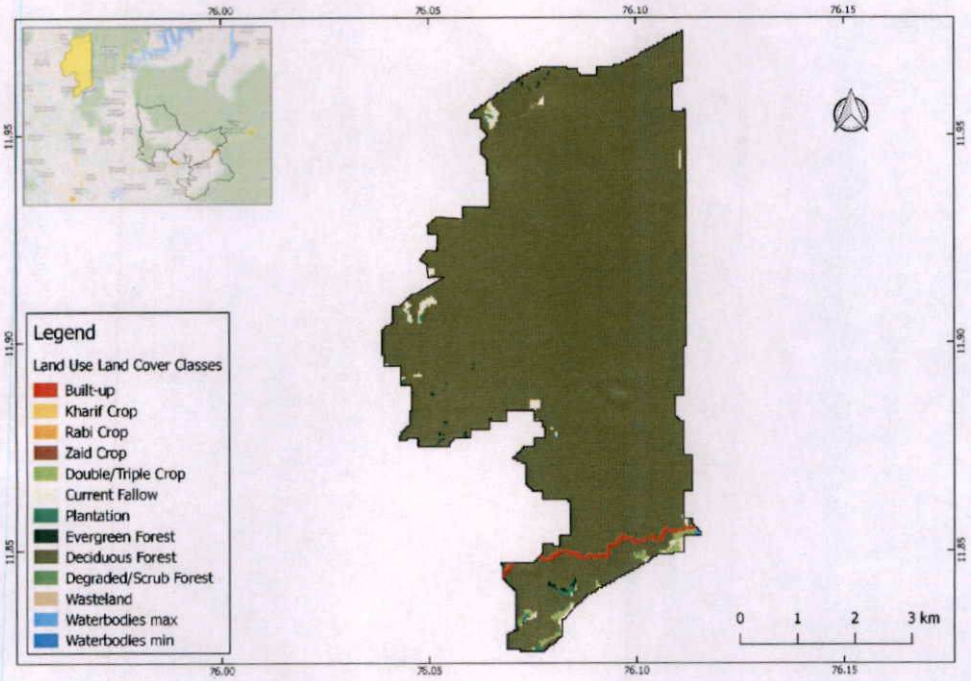

Figure 37. Land Use Land Cover of Tholpetty range during 2005-2006

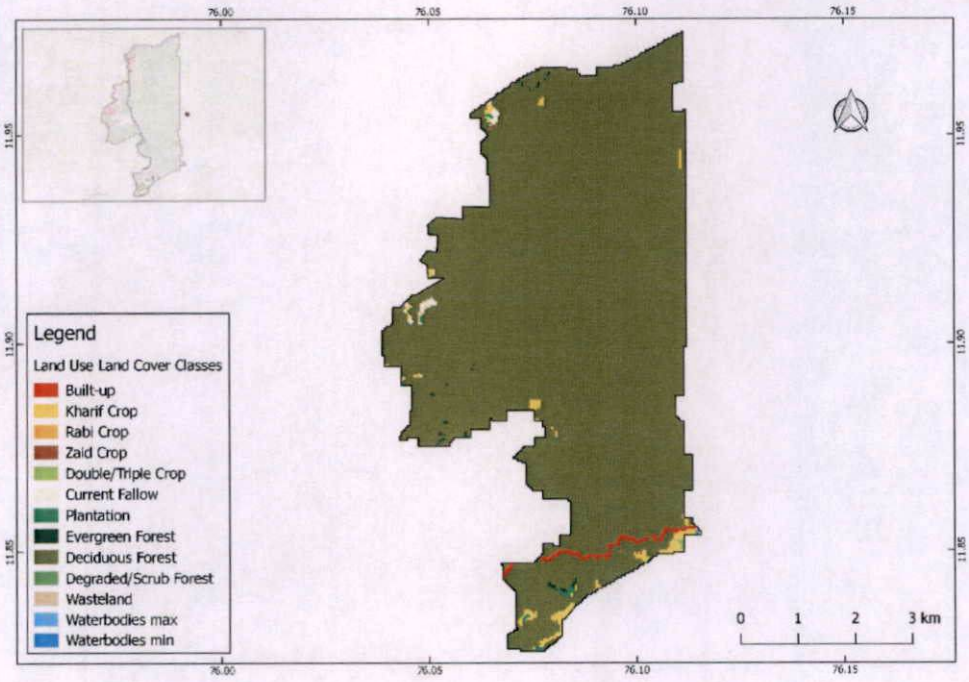

Figure 38. Land Use Land Cover of Tholpetty range during 2014-2015

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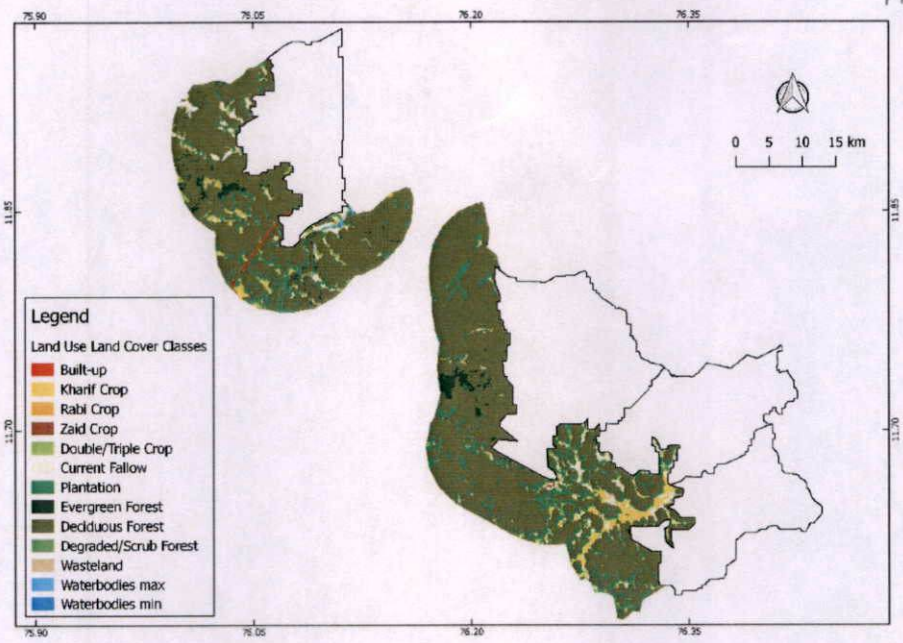

Figure 39. Land Use Land Cover of buffer area outside the Wayanad Wildlife Sanctuary during 2005-2006

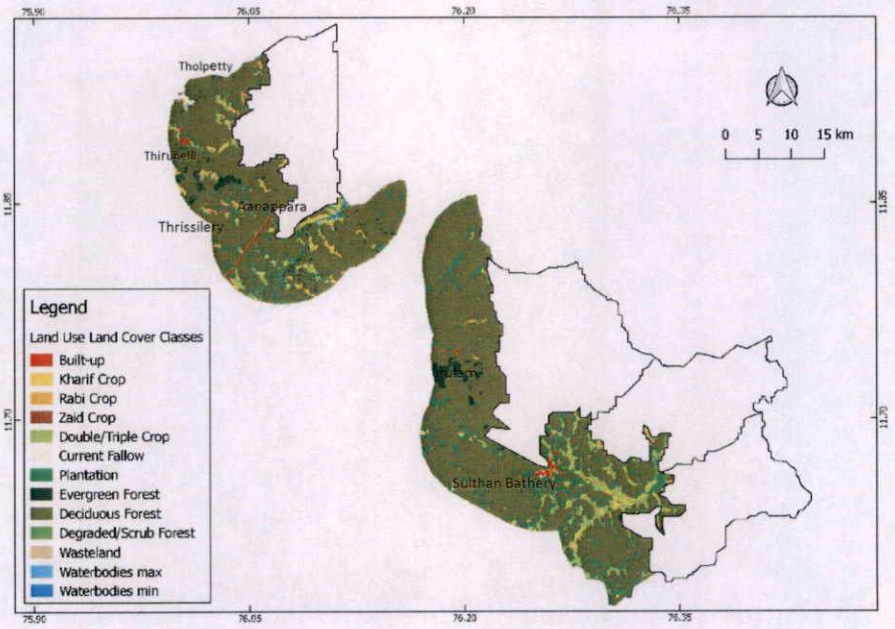

Figure 40. Land Use Land Cover of buffer area outside the Wayanad Wildlife Sanctuary during 2014-2015

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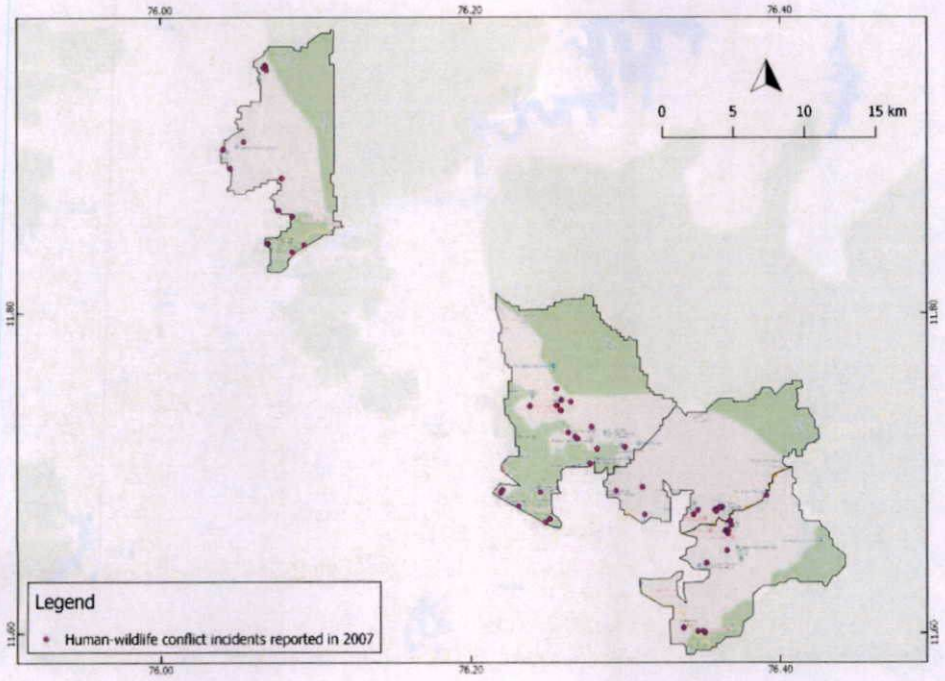

Figure 41. Human-wildlife conflict incidents reported in 2007

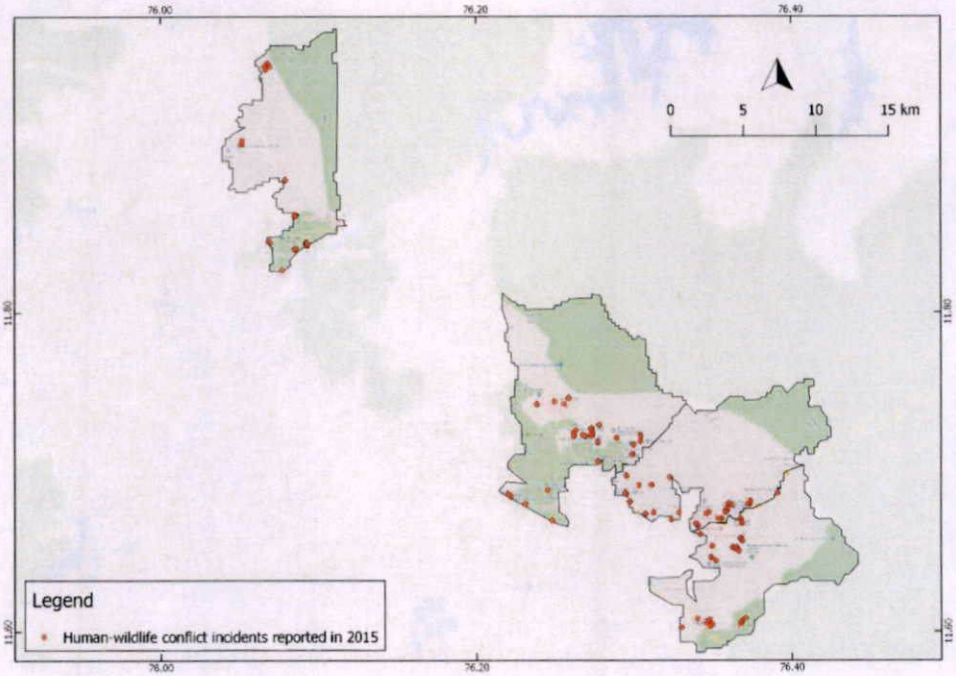

Figure 42. Human-wildlife conflict incidents reported in 2015

Discussion

DISCUSSION

5.1 Socio-economic survey done in forest fringe areas of Wayanad Wildlife Sanctuary

5.1.1 Basic Details of the respondents

A total of 120 individuals were interviewed (30 from each range) from the sanctuary of which 49.16 percent of the respondents were males. The people interviewed were mainly between the age of 30 years and 50 years (45.83 percent), followed by the age group 50 and 70 years. In all the four ranges, majority of the respondents were living in the same location for more than 20 years. More than 70 percent of the respondents of the sanctuary were residing in the area for more than 20 years.

5.2 Human-wildlife conflict at Wayanad Wildlife Sanctuary

Wayanad Wildlife Sanctuary is one such area which holds the highest elephant population in Asia. The destruction of agricultural crops by them is also very severe in the area, which leads to a negative attitude towards the wildlife. The encroachment of the wild habitat for agriculture as well as cultivation of edible crops adjacent to the forest boundaries attracts the wild animals towards the crop. The increasing crop damage by the wild animals has forced the respondents to abandon their crop fields.

According to the socio-economic survey conducted at Wayanad Wildlife Sanctuary, 99.17 percent of the respondents were the victim of crop damage, 45.83 percent of the respondents suffered from livestock loss and 40.83 percent of the respondents experienced threat to human life. Threat to life or livestock loss due to tiger attack was faced by 32.50 percentage of the respondents. It is reported that *in Nilambur, crop damage was the common type of conflict followed by property damage and injury and death by wildlife attack (Rohini *et al.*, 2016a). Poor visibility in the forest can be the reason for accidental encounters inside the forest (Datye and Bhagwat,

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1995; Sukumar, 2003). The elephant that may flee from a crop land, may become more aggressive and confident when encountered inside a forest (Hoare, 2001; Treves, 2007). Settlements and agriculture that block traditional routes can also lead to aggressive behavior in Elephants, leading to conflict issues (Naughton *et al.*, 1999).

The crop loss faced by the people in the sanctuary are mainly due to Asian Elephant, Spotted Deer, Wild Boar, Bonnet Macaque and Malabar Giant Squirrel. Human-elephant conflict is the most prominent issue that is faced by the respondents and almost every respondent (91.67 percent) were having some trouble due to elephants. Paddy cultivation is done extensively in Wayanad, and the damage on its vegetative phase is mainly due to trampling and the damage on its reproductive phase is by feeding (Easa and Sankar, 2001). Due to animal attack, the people of Wayanad are having difficulty in planting the traditional aromatic rice variety 'Gandhakashala' which has been registered with Geographical indication (GI) registry and certified under Protection of Plant Varieties and Farmers' Right Authority, Ministry of Agriculture. Trampling of the paddy field, uprooting of the trees, palms and plantain in the homesteads by the elephants is very common (Plate 13 and Plate 14).

About 89.17 percent of the total respondents experienced crop loss due to deer. Browsing and stripping of the bark are major problems caused by deer (Plate 15). According to 26.67 percentage of the respondents opinioned that the problem of Malabar Giant Squirrel is so severe and it is damaging the coconuts at very early stages by making holes in the endocarp, after removing the mesocarp (Plate 16 and Plate 17). Indian Crested Porcupine damages the basal portion of the coconut trees (Plate 18), which seriously affects the yield of coconuts.

According to 87.50 percent of the respondents were having crop loss due to Wild Boar attack. Wild Boar causes damage to the fallen coconut (Plate 19), pineapple plant (Plate 20); rhizome and fruits of plantain; and other tuber crops such as Colocasia, Elephant yam and Tapioca. It is also observed that the Wild Boar feeds on banana on

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its early stages after uprooting the plantain (Plate 21 and Plate 22). It also grubs the soil to feed on soil organism such as earthworms, especially in paddy fields and homestead areas (Plate 23). But, the extend of crop damage by Wild Boar, Gaur, Spotted Deer, Sambar Deer, Barking Deer and Bonnet Macaque is reported to be negligible when compared to that of Asian Elephants (Easa and Sankar, 2001).

Elephants not only feed on crops, but they also damage them by trampling. There are instances where the trampling has greatly exceeded the quantity actually consumed by the elephants (Wickramanayake *et al.*, 2004). Majority of the respondents (50.83 percent) opinioned that frequency of crop damage by single elephant bull higher than the elephant herds. Similar observation was reported by Easa and Sankar (2001). About 40 percent of the respondents experienced crop damage due to both the elephant bull as well as the herds. The Elephant bulls are more liable to feed on crops because of its availability in higher densities and higher nutritive value (Sukumar, 1985a; Sitati *et al.*, 2005; Chiyo *et al.*, 2005) and it is these few elephants that causes a bulk of damage. This nutritional advantage obtained from the crops helps the elephant bulls to sustain longer periods of musth (Seidensticker, 1984). It is said that a single Elephant bull is able to travel up to 6 km through cultivated fields in a single night (Sukumar, 1986) whereas the elephant herds eat crops opportunistically, not venturing more than 1 km from the forest boundary (Sukumar, 1989). Single elephant bull cause conflict throughout the year whereas the elephant herds are more likely to cause conflict only when the crops are ripe (Lahkar *et al.*, 2007). If undeterred, the Elephant bulls can become habitual crop-raiders (Boominathan *et al.*, 2008). The habitual crop raiders stay around the settlements and raids the crops irrespective of the mitigation measures employed (Easa and Sankar, 2001). About 37.5 percent of the respondents of Wayanad Wildlife Sanctuary believe that it is the same herd of elephants that comes to their fields and 63.33 percent of the respondents are suffering from crop damage throughout the year. In some areas, elephant herds are observed to cause more damage to the crops, when compared to single elephant bull (Smith and Kasiki, 2000;

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Williams *et al.*, 2001; Kumar *et al.*, 2004; Fernando *et al.*, 2005). In some parts of Southern India, this may reflect the dearth of adult bulls due to ivory poaching (Sukumar, 2003).

About 75 percent of the respondents in the sanctuary has experienced crop loss and property damage due to monkeys. They either consume or damages the fruits and pods of the plants. It is also observed to feed on paddy and till now, there is no proper solution to scare them away. In forest-farm ecotones, translocation of the macaques to adjacent areas may not end the crop damage but, may spread the problem from one place to another (Chakravarthy *et al.,* 2005). If the crop-raiding behavior in primates is once established, it is extremely difficult to change (Chakravarthy *et al.,* 2005; Hill, 2005). The translocation of the monkeys from the problems sites doesn't serve as a solution for the problem. Honda *et al.* (2009) has specially designed an electric fence, which effectively exclude the wild animals, including the Japanese Macaque (*Macaca fusculata*). But it was uneconomical and impractical in rural areas where the problem was severe.

Property damage due to wild animals was experienced by 28.33 percent of the respondents of Wayanad Wildlife sanctuary. In Wayanad Wildlife Sanctuary, there was incident where the Elephants were observed to feed on salt after destroying a small shop at road side. Elephants are reported to destroy the houses delibrately looking for salt, stored grain, home brewed alcohol, wheat and maize flour (Williams *et al.*, 2001; Lahkar *et al.*, 2007).

Another major problem regarding human-wildlife conflict is livestock loss by wild animals, especially in areas where the pastoralism remains the major source of livelihood. Patterson *et al.* (2004) have analyzed livestock attacks over a four- year period on two neighbouring arid-land ranches adjoining Tsavo East National Park, Kenya and revealed that lions were responsible for 85.9 percent of the attacks, followed by hyenas and cheetahs.

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The people in Wayanad Wildlife Sanctuary agrees that the major cause of livestock loss is due to the grazing inside forest. The heavy undergrowth in some road side areas are also a threat to humans as well as their livestock, as this undergrowth are being used as hides by the wild animals and 45.83 percent of the respondents in the sanctuary were victim of livestock loss (Table 7, Plate 24 and Plate 25). For claiming compensation, the people ties the unhealthy/diseased cattle in the forest fringes so that it will get easily attacked by tiger or leopard.

Plate 13. Damage to paddy due to elephants at Muthanga

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Plate 14. Trees uprooted by elephants in a homestead area at Muthanga,

Plate 15. Coffee plants debarked by deer at Kallumukku, Sulthan Bathery

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Plate 16. Coconut damaged by Malabar Giant Squirrel at Ponkuzhi, Muthanga

Plate 17. Closer view of coconut damaged by Malabar Giant Squirrel at Ponkuzhi, Muthanga

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Plate 18. Coconut palms damaged by Indian Crested Porcupine at Ponkuzhi, Muthanga

Plate 19. Coconut mesocarp removed by Wild Boar at Kallumukku, Sulthan Bathery

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Plate 20. Pineapple uprooted by Wild Boar at Kallumukku, Sulthan Bathery

Plate 21. Plantains uprooted by Wild Boar at Chethalayam, Kurichiyat

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Plate 22. Banana eaten by Wild Boar at Chethalayam, Kurichiyat

Plate 23. Soil grubbed by Wild Boar at Noolpuzha, Sulthan Bathery

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Plate 24. Cattle death at Chekadi, Tholpetty

Plate 25. Cattle death near RTO checkpost, Muthanga

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5.3 Human wildlife conflict mitigation

The increasing trend of the human-wildlife conflict has forced the forest department to take some preventive measures such as use of deterrents, establishing elephant squad, establishing physical barriers, providing compensation, and capturing the problem elephants in case of failure of all other measures. The efficiency of the mitigation measures installed in a region is dependent on how well it is maintained. 34.16 percent of the respondents is of the opinion that the mitigation measures are frequently maintained. But majority of the respondents (58.33 percent) revealed that the mitigation measures are only occasionally/ rarely maintained and 7 percent of the members says that there is ultimately no maintenance of the mitigation measures. The maintenance work like deepening the elephant-proof trenches and clearing off the vines and undergrowth of electric fences are usually carried out by the Kerala Forest Department by involving local communities through Mahatma Gandhi National Rural Employment Guarantee Scheme (Thozhilurappu).

The Government has some limitation in maintaining all the mitigation measures that are established in the sanctuary. The people residing near to the physical barrier should take some responsibility in the maintenance of the barriers, as they are benefiters. In Wayanad Wildlife Sanctuary; physical maintenance of the mitigation measures is carried out only by a few respondents (8.3 percent). Majority of the respondents do nothing for the maintenance and 42.5 percent of the respondents is said to take some effort in reporting the condition of the mitigation measures to the forest department whenever required.

5.3.1 Attitude of the respondents towards the human-wildlife conflict mitigation measures in Wayanad Wildlife Sanctuary

The attitudes of the respondents towards human-wildlife conflict mitigation measures of all the four forest ranges of Wayanad Wildlife Sanctuary were analyzed. Majority of the respondents (95.83 percent) agreed that wildlife should be controlled

using non-lethal methods. More than 44 percent of the respondents have the opinion that conflict mitigation CESS should be collected from tourists coming to visit the forest and wildlife, so that the fund shortage, if any, can be met. However, 41.66 percent of the respondents are against the statement, as it may negatively affect the tourism. They also added that currently there is enough fund in the forest department allotted exclusively for the conflict mitigation strategies.

Adaptation of beehive fences is not considered to be effective in mitigating the human-wildlife conflict by 49.16 percent of the respondents and more than 35 percent of the respondents were not having any opinion regarding the installation of beehive fences, as it was totally new for them. In Southern Kenya, beehive fences are found to be a viable tool for small scale farmers struggling with high levels of human-elephant conflict and were highly desired by the communities (King *et al.*, 2017). In Nepal also beehives along with the fences are tried (Kulkarni *et al.*, 2007). The efficiency is doubtful as the active elephant crop raiding occurs at night, when bees are inactive (Fernando *et al.*, 2008). More than 85 percent of the respondents agrees that the animals get easily adapted to conflict mitigation and around 40 percent of the respondents are of the opinion that the usage of ineffective preventive measures makes human-wildlife conflict more probable.

5.3.2 Perception about Human-wildlife conflict mitigation measures

When the respondents were asked about the causes and probable solutions of the human-wildlife mitigation measures 67.5 percent of respondents of the sanctuary were of the opinion that the lack of proper planning of the management interventions within the forest makes wildlife disturbed and 62.5 percent of the overall respondents were of the opinion that planting food plants inside the forest area brings down the conflict incidents. The habitat enrichment by regenerating bamboo along the stream was recommended by Sivaganesan (1995) and another recommendation was to cultivate "lure crops" such as banana and sugarcanes (Chong and Norwana, 2005).

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But, it is impractical to grow such crops in larger areas (Osborn, 1998; Kulkarni *et al.*, 2007).

Desai and Baskaran (1996) have suggested that manipulation of water resources can influence the presence of elephant. It is observed that the increase in the density of waterholes has led to shrinkage of home range of elephants in Kruger National Park (South Africa), Etosha National Park and Khaudum Game Reserve (Namibia) (van Aarde *et al.*, 2008). About 36.66 percent of the total respondents are of the belief that maintaining enough water sources inside the forest reduces the conflict incidents. Water provisioning in previously unused habitat will attract the wild animals, thereby resulting in its redistribution. But, it may result in unnatural increase in herbivore numbers, resulting in degradation of herbaceous plants (Walker *et al.*, 1987; Grant *et al.*, 2007). Majority of the respondents (93.33 percent) disagrees that farming plants containing capsaicin-like chilly and pepper/ non-palatable crops in border areas of the forest helps to avoid the wild animal attack of crops.

The displacement of conflict incidents does not give an overall reduction in the human-wildlife conflict issues. If better protection of some farm land simply displaces the problem to the neighboring areas, then these small-scale mitigation methods fails to reduce the overall levels of conflict incidents (O'Connell-Rodwell *et al.*, 2000). Majority of the respondents (83.33 percent) is of the opinion that there will be a shift of the conflict from one site to another when physical barriers are used. About 84.16 percent of the respondents believes that the quick interventions of the forest officials will help in reducing human-wildlife conflict and the rest of the respondents are of the opinion that the forest officials are doing all the that they could do in reducing the conflict issues. Majority of the respondents (73.33 percent) does not have the hope that studies on wildlife behavior can help in constructing the physical barriers more effectively.

5.3.3 Comparison of the attitude and perception of the respondents between the different ranges of Wayanad Wildlife Sanctuary

In this study, the Mann-Whitney U test was carried out to understand if there exist any relation between respondents of different forest ranges in their attitude and perception. It was found that there is no significant relation between the attitudes of the respondents residing in the four different forest ranges. And there is significant difference in the perception of the respondents between the ranges Muthanga and Tholpetty and Kurichiyat and Tholpetty.

5.3.4 Factors that the respondents believe to be the most important when choosing a conflict mitigation scheme in Wayanad Wildlife Sanctuary

All the respondents in Wayanad Wildlife Sanctuary prefers mitigation measure of proven effectiveness and it should be implemented regardless the other costs involved. Majority of the respondents has given lower priority to startup cost, labour effort and maintenance (95%, 83.33% and 76.66% of the respondents respectively). About 62.5 percent of the respondents is of the opinion that there should be only minimal negative effect on wildlife due to the conflict mitigation measures. But, more than 37.5 percent of the respondents does not bother much about the negative effects on wildlife. This shows the intolerance of some of the farmers at Wayanad Wildlife Sanctuary and they consider wild animals as the "Forest Department's animal". Santiapillai (1994) has correlated the man-elephant conflict with the attitude of the present-day people with man-elephant conflict and mentioned that the elephant tolerance of the settlers who came from towns is very poor.

Higher acceptability of the preventive measure by the local people is considered as an important factor to be considered for its effectiveness by 70 percent of the respondents. More than 20 percent of the respondents is of the opinion that a fair level of compensation should be sanctioned in case of crop raiding due to the failure of the mitigation measure, whereas 65 percentage of the respondents are disagreeing with the

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statement. The dissatisfaction is mainly because the sanction of the money will take a longer time and requires regular follow-ups which again leads to additional expenditure. Also, the compensation amount is highly inadequate to cover the loss they have undergone. So, some respondents also suggested apart from giving off compensatory amount, the forest officials can use it for proper construction or maintenance of the mitigation measures.

5.3.5 Opinion of the respondents about compensation pattern provided by the government in Wayanad Wildlife Sanctuary

Compensation scheme can reduce the impact of economic losses on agricultural crops due to wild animals but, do not reduce the human-wildlife conflict issues. There are some terms and conditions for availing the compensation. The people living in lease land are not eligible for applying for compensation. Assessment of the damage in the crop field is quite difficult. Most of the people are never satisfied by the amount sanctioned by the forest department. If crop losses are less at a single time, the farmers won't go for claiming compensation because of the extra expense involved in application procedures. Similar dissatisfaction towards the compensation was also reported by Rohini *et al.* (2016). About 57 percent of the respondents of sanctuary faced a long delay in claiming the compensation and 26 percentage of the respondents either did not give an application for getting compensation or were not eligible for claiming compensation. It can be also observed that, for claiming compensation people do unethical practices like tying the unhealthy/diseased cattle in the forest fringes so that it will get easily attacked by carnivores.

5.3.6 Association and correlation studies in Wayanad Wildlife Sanctuary

An application named IBM SPSS Statistics 25 were used for association and correlation studies. Association study was done between the basic details i.e., age, gender and duration of residing period with attitude and perception of the respondents in the sanctuary. Spearman rank correlation studies was carried out for the variables

such as attitude, perception, age, duration of residing period, compensation satisfaction and satisfaction of the respondents in the involvement of Government officials. Pearsons Chi square was used for testing the relationships between the categorical variables. Contingency coefficient is used for finding the magnitude of this association. The Spearman rank correlation coefficient indicates the strength and direction of the relationship between the variables.

In all the 4 ranges the variables such as age, compensation satisfaction and satisfaction of the respondents in the involvement of Government officials are having some association with the attitude and perception of the respondents. In the sanctuary, highest association (125.961, p value = 0.000) was observed for satisfaction of Government involvement x Perception. The parameters such as age, duration of residing period, compensation satisfaction and satisfaction of the respondents in the involvement of Government officials have a significant positive or negative correlation with attitude and perception. So, all these 4 attributes are influencing the attitude and perception of the respondents residing in the Wayanad Wildlife Sanctuary. Age is having the highest positive correlation with both attitude (0.69) and perception (0.79). Satisfaction of respondents towards the Government involvement has the highest negative correlation with attitude (-0.62) as well as with perception (-0.82).

5.4. Effectiveness of the mitigation measures implemented in Wayanad Wildlife Sanctuary

The elephant crop-raiding is very much prominent in Asian and African countries. Whenever conflict arises, establishment of physical barriers are the most popular method adapted as they are meant to separate the people and wildlife. But, as the wildlife are easily getting adapted to the mitigation measures used in defending the farms lands, management of the human-wildlife conflict issues is becoming a more challenging task. The evidence shows that the long term mitigation is challenging or

seems to be practically impossible as the wild animals are easily getting habituated to these barriers.

5.4.1 Traditional methods adapted in Wayanad Wildlife Sanctuary

The crop guards on the watchtowers monitors the crop-raiding elephants at night and alerts the community with some signals (eg. Whistles). Platform at trees or huts at ground level are used as look-outs (Nelson *et al.*, 2003; Fernando *et al.*, 2008). Guarding and patrolling are the simplest and most effective means of crop protection (Desai, 2002). The crop loss tends to be considerably less in the case of large extended families with enough man-power to guard crops, compared to individual nuclear families (Naughton *et al.*, 1999). But people endanger their lives by getting too close to elephants (Nath and Sukumar, 1998; Desai, 2002; Nelson *et al.*, 2003; Fernando *et al.*, 2008). The watchtowers are reported to be attacked by elephants, when annoyed by torch light or barking of dogs (Sukumar, 1989). In Wayanad Wildlife Sanctuary, due to the threat of single bull elephant attack, the watchtowers in the middle of the crop field were found to be shifting to the sides of the farm land (Plate 26). Due to the fear of their lives, some villagers in north Bengal have given up actively guarding their fields (Boominathan *et al.*, 2008).

The people of Wayanad Wildlife sanctuary have also tried hanging bottles and tin cans with pebbles in fence strings, so that they can stay alert and to divert the wild animals. (Plate 27 and Plate 28), but is found to be of no use. In Tholpetty range, a sound device system using crackers was in use (Plate 29). This kind of device allows farmers to sleep while maintaining vigilance (Nelson *et al.*, 2003; Chong and Norwana, 2005; Parker *et al.*, 2007). Even trip wire alarm has made no difference in overall conflict incidents (Nelson *et al.*, 2003). In some cases, bulls are found to be investigating the source of the sound, instead of fleeing from the field (Kulkarni *et al.*, 2007).

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5.4.2 Biological Barriers adapted in Wayanad Wildlife Sanctuary

Agave and cacti as barrier are found to be impractical and unsuccessful in Wayanad Wildlife Sanctuary. Agave is planted at the forest fringes, but was not compactly grown in most of the regions (Plate 30 and Plate 31). This idea was put forward in the belief that the spines of the modified leaves will not encourage the movement of wildlife across it. But these slow growing plants are difficult to maintain without gaps. It has already found to be ineffective in Sri Lanka as the elephant's thick hides are impervious to thorns (Fernando *et al.*, 2008). The people in Wayanad claim that these plants are not even bothered by the giant herbivores and even it has started feeding on Agave. Feeding on Agave by elephants is already reported in Africa (Hoare, 2001).

5.4.3 Physical Barriers adapted in Wayanad Wildlife Sanctuary

Plastic nets are commonly used in Wayanad Wildlife Sanctuary to protect their field against the deer and wild boar (Plate 32). Solar power electric fence is the most commonly employed barrier for deterring the wildlife from the agricultural lands. Kerala Forest department has taken great effort to construct it in the areas bordering forests. People living near the forest areas invest money for constructing the fences in their private lands and in areas where they are unsatisfied with the department's work (Plate33). The department is often blamed of using poor quality wires and batteries as well as poor maintenance. The people are reported to give mains AC power supply to the electric fences illegally, so that their farm lands remain protected.

When habitual elephant routes are blocked, the conflict mitigation barrier are more prone to failure (Sitati and Walpole, 2006). So, when electric fence was erected, the elephants innovated an intelligent way to break the fence posts by holding the top of the wooden posts by their trunk and breaking at the middle by gently pushing with their foot, this avoiding the live wires (Choudary, 2004). When compared to low voltage fence (poorly maintained), high voltage solar fence is able to keep out most of

the elephants, where the former ones merely irritate them provoking it to destroy the fence (Hoare, 2001). Neither of the simple fence or sophisticated 11 or 12 strand type are elephant proof (Thouless and Sakwa, 1995b). The policy of shooting fence-breaking elephants in Kenya, somehow made the electric fences effective for many years (Thouless and Sakwa, 1995b). It is said that due to this policy, even a simple fence encircling maize field in the middle of elephant corridor was effective for 10 years (Thouless and Sakwa, 1995a).

In Wayanad Wildlife Sanctuary, majority of the people reported that the electric fences (76.92%) as well as the elephant-proof trench (72.04%) implemented in their residing area are not at all effective due to poor maintenance. Only more than 6 percent of the respondents was having an elephant proof wall and half of them said it to be effective.

The mitigation will not succeed without cooperation within and between the communities. Most of the electric fences are in poor condition due to non-clearance of the undergrowth. Barriers suffer a high rate of failure as they are undermined by people who need access to forests. The people in Wayanad Wildlife Sanctuary residing near to the fences keep the fences alive only during their cropping season. The non-farmer residents are known to tie-up two wires of the solar electric fence, so that they can easily pass through without getting shock. In some parts in Wayanad Wildlife Sanctuary, these solar power electric fences are even used in drying up cloths (Plate 34) and to tie their cattle (Plate 35). Children take out the circular part used in fencing for making toys. Nath and Sugumar (1998) have reported that the people cut the fence wires or created bridges across trenches (Plate 36). It is also observed that the people are making steps for passing through the trench (Plate 37).

In Wayanad Wildlife Sanctuary, mostly, solar power electric fence is established along the elephant proof trench as a second line of defense. Even if the electric fence and elephant proof trench together are found to be effective, it failed to

deter the solitary elephants (Easa and Sankar, 2001). The natural week spots as well as the gateways created for passage of people and cattle are the main locations of elephant crossing points (Rohini *et al.*, 2017).

The trench works are either done with the help of local people through Mahatma Gandhi National Rural Employment Guarantee Scheme (thozhilurappu) or by using machines. The trenches made through man-power usually fails to be effective due to insufficient depth and width. It requires regular maintenance and it cannot be deployed in erosion-prone areas with loose soil. It is found to be established in many areas in the sanctuary where the soil is less stabilized, making it ineffective. Due to poor construction or maintenance, the soil on its sides easily slips into the trench, thus decreasing the depth of the trench (Plate 38) and the animals are also successful in doing so (Plate.39 and Plate 40). Asian Elephants and Wild Boar are very successful in creating a slope in the trench by shoving soil into the trenches, which allows them to cross it. It is also observed that the trenches made using JCBs lasts more. The soil can be stabilized by pitching stones or using concrete, but it increases the cost of construction considerably. In the sanctuary, only a few trenches are stone pitched (Plate 41). The efficiency depends on how often the elephant proof trenches are deepened and how often they are clearing off the plants growing in the trenches. In some areas, the trenches are very poorly maintained without clearing the undergrowth (Plate 42), and in some other areas it serves as a drainage canal of rainwater from both the forest areas and agricultural lands which results in the sedimentation of mud and soil and thereby decreasing the depth of the trenches (Plate 43). There are some trenches which are well maintained too (Plate 44).

Easa and Sankar (2001) has reported that in Wayanad, the elephant proof trenches are observed to be more effective, in the case of elephants. The low efficiency of these barriers to mitigate human-wildlife conflict is due to poor maintenance, natural causes, damage by the wild animals as well as due to human activities. It is observed that in Mysore Forest Division, the 59 percent of the causes that contribute to damage

of elephant-proof trenches are due to man-made activities, followed by natural causes (18%) (Varma *et al.*, 2011). It is also observed that the damage due to wild animals such as elephants and wild boar has contributed to only 13 percent of the breakage of the barriers. Varma *et al.* (2011) also revealed that the manmade causes are mainly responsible for the less efficiency of the electric fence (61%), followed by elephant and wild boar (26%).

Elephant-proof walls are made in short stretches in Wayanad Wildlife Sanctuary. It just shifts the movement of the wildlife. Elephants move along the walls until it finds a way out. Most of the walls are poorly made just for the sake of construction and the elephants are successful in damaging the walls so easily because of its poor strength (Plate 46 and Plate 47). The elephants damage the Elephant-proof walls by breaking the top portion of the wall (Rohini *et al.*, 2017). Repeated destruction of the Elephant-proof Wall constructed in elephant corridors is also observed, eventhough it is reconstructed (Plate 48). Even though it is much expensive, people demand that constructing walls properly in long stretches in the forest boundaries can bring down the human-wildlife conflict to a greater extend.

The implementation of the human-wildlife conflict mitigation measures for separating the man and wild animals is vital, for the safety of both. The mitigation measures have to be implemented wisely, after studying the topographical and geological aspect. It should be scientifically studied and make sure that it will not negatively affect our environment.

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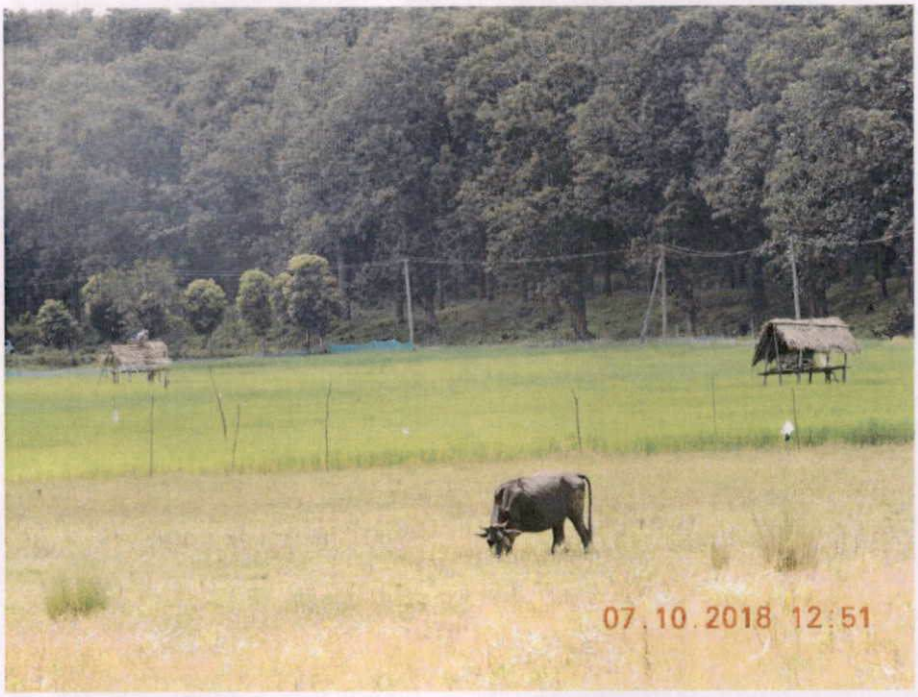

Plate 26. Shifting of watch-sheds from the middle of the farm due to threat by elephants during night at Thakarappady, Muthanga

Plate 27. Bottles tied to the wire fence at Golur, Muthanga

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Plate 28. Cans attached to the fence to scare away the wild animals at Golur, Muthanga

Plate 29. Sound device using stone to scare away the wild animals at Palvelicham, Tholpetty

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Plate 30. Agave as a biological barrier at Chethalayam, Kurichiyat

Plate 31. Cacti as a biological barrier at Begur, Tholpetty

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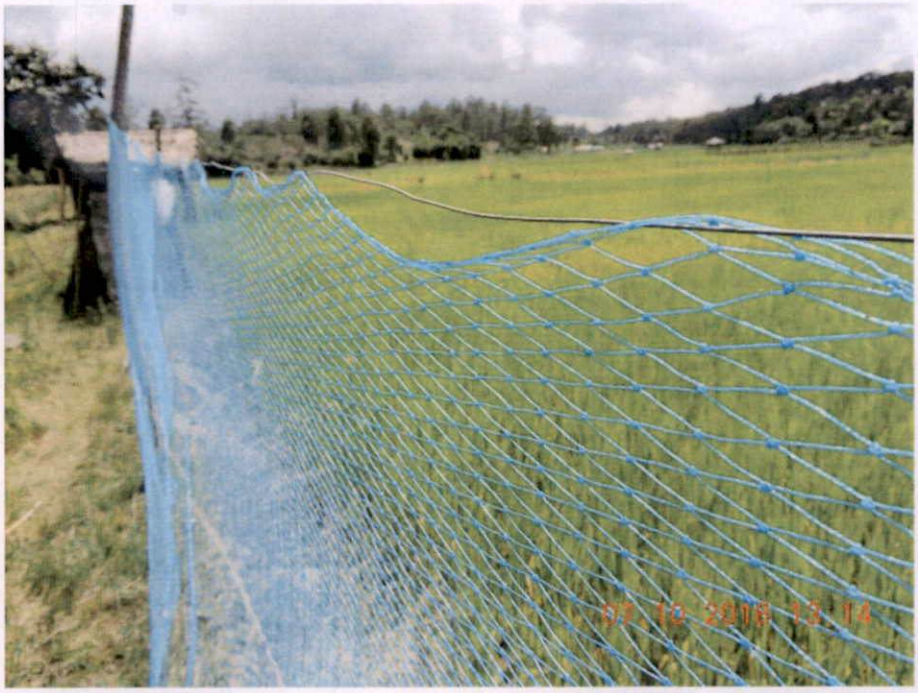

Plate 32. Plastic net used for protecting paddy field from Spotted Deer and Wild Boar at Thakarappady, Muthanga

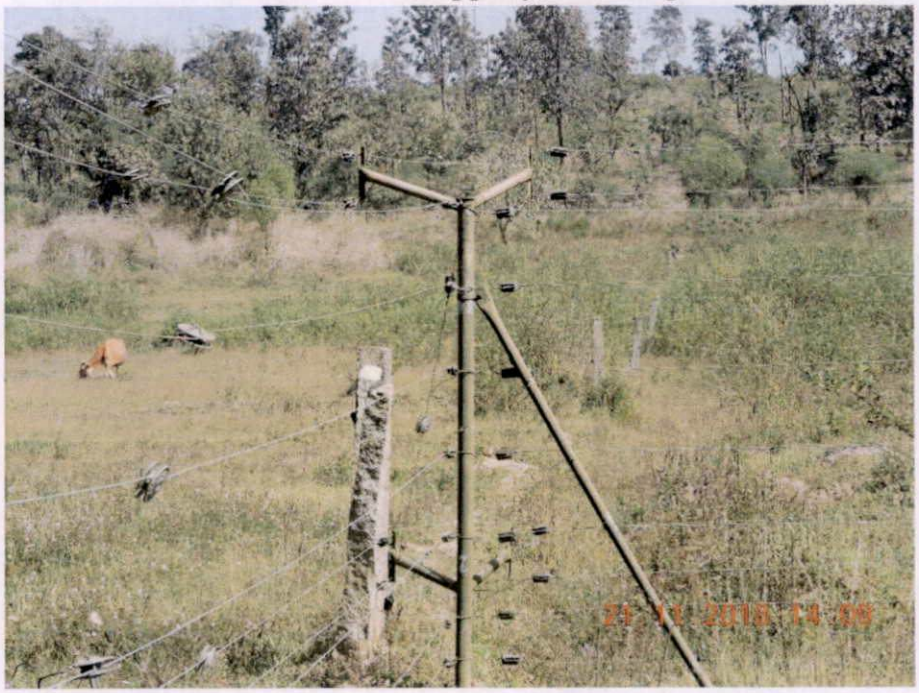

Plate 33. Well maintained private electric fence at Kallumukku, Sulthan Bathery

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Plate 34. Clothes hung on solar power electric fence at Kallumukku, Sulthan Bathery

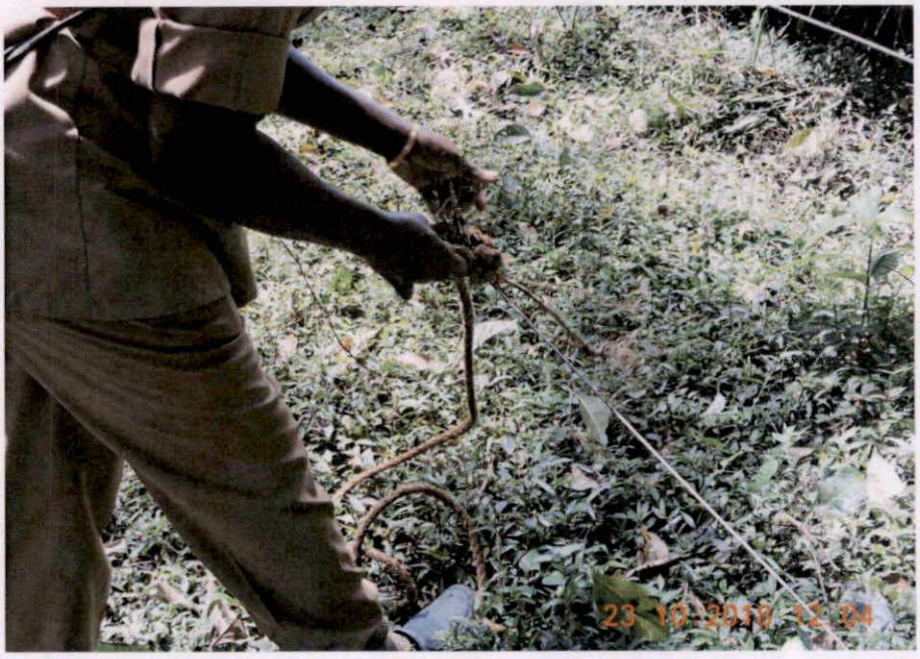

Plate 35. Forest watcher removing the cattle rope tied to the solar power fence at Noolpuzha, Muthanga

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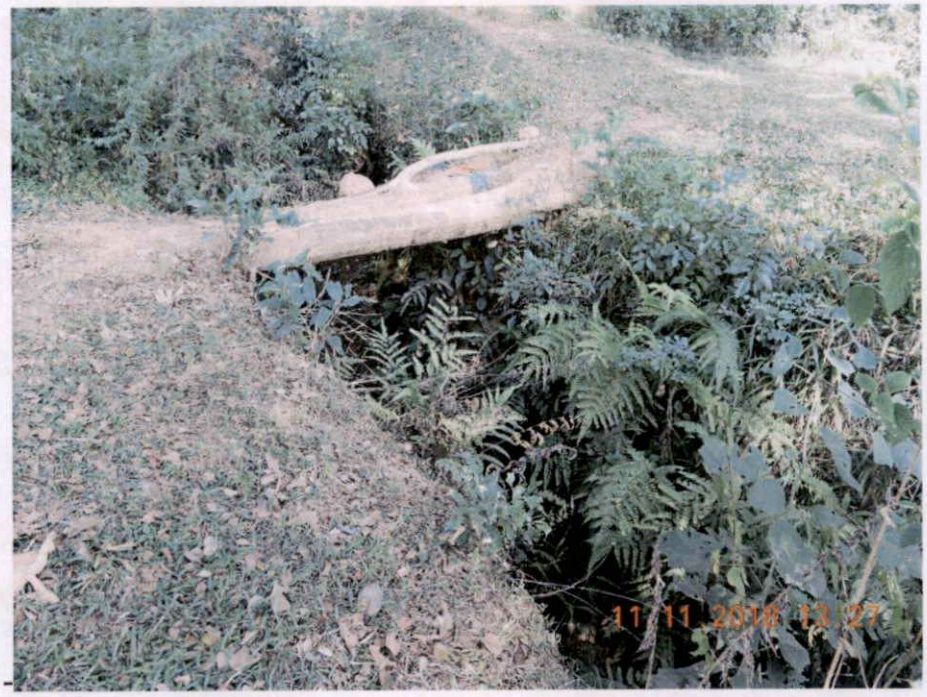

Plate 36. Bridge made across the Elephant-proof Trench at Chethalayam, Kurichiyat

Plate 37. Pathway through the Elephant-proof Trench at Begur, Tholpetty

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Plate 38. Elephant-proof Trench at Kallumukku, Sulthan Bathery

Plate 39. Elephant-proof Trench damaged by elephant at Golur, Muthanga

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Plate 40. Crossing point of deer through the Elephant-proof Trench at Golur, Muthanga

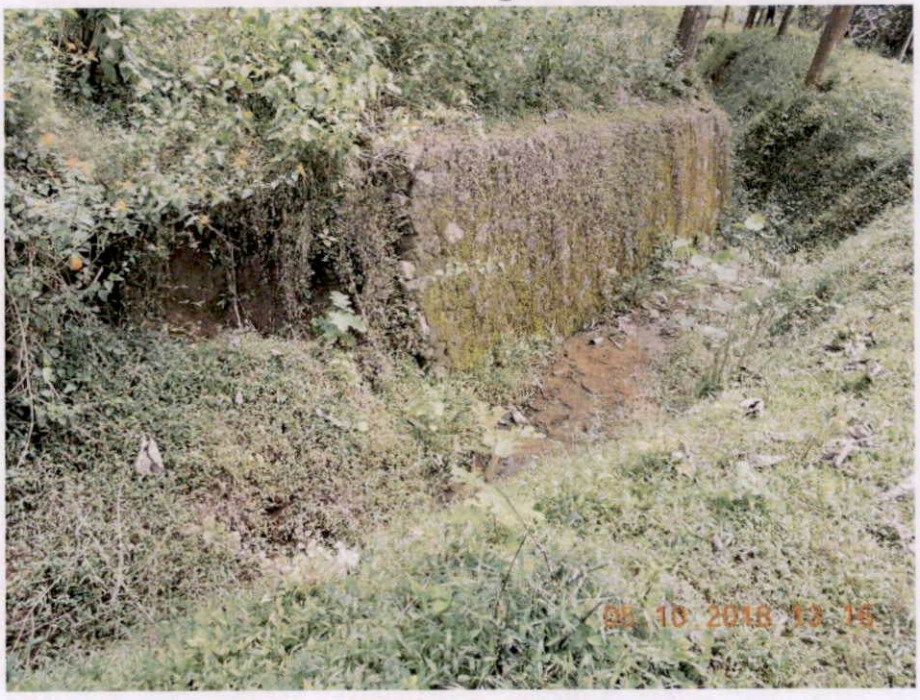

Plate 41. Stone pitched Elephant-proof Trench at Golur, Muthanga

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Plate 42. Poorly managed Elephant-proof Trench at Golur, Muthanga

Plate 43. Elephant-proof Trench at Thakarappady, Muthanga

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Plate 44. Elephant Proof Trench at Kallumukku, Sulthan Bathery

Plate 45. Combination of Electric fence, Elephant-proof trench and Elephant-proof Wall at Noolpuzha, Sulthan Bathery

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Plate 46. Elephant Proof Wall (with a week spot) separating forest and agricultural field at Noolpuzha, Sulthan Bathery

Plate 47. Elephant-proof Wall at Tholpetty

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Plate 48. Elephant-proof wall repaired after getting damaged by an elephant at Noolpuzha, Sulthan Bathery

Plate 49. Elephant-proof Wall under construction at Tholpetty

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5.5 Wild animal deterrent using lights

Light plays an important role in photoperiodic control of flowering in many plants and for short day plants, flowering occurs when the day becomes shorter. Dating from 17th and 18th centuries, there is an extensive literature on the effect of artificial manipulations of the light conditions on plants (Hunt, 1854; Darwin, 1881). Even short duration or low intensity light during night can have remarkable physiological effects (Smith, 1982).

The people at Tholpetty range have tried to protect the paddy fields from wild animals by lighting incandescent bulb during night. Being a short-day crop, the harvest maturity of the paddy in lighted region is delayed due to the effect of the light during night time (Plate 50).

Plate 50. Bulb fixed at the paddy field at Palvelicham, Tholpetty

Plant response to light can be sensitive to the wavelength and it has been identified that extreme red portion of the spectrum is associated with flowering and the

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blue light induces germination of the seeds, independently of the broad spectral range of the light associated with photosynthesis (Hunt, 1844; 1844a). Even brief exposure to red light at night can interrupt the detection of an unbroken dark period, and prevent flowering in short day plants (Borthwick *et al.*, 1952). Ishikawa *et al.* (2009) has found that flowering in rice is suppressed with increased supply of light intensity.

5.6 Tentacle fence

The tentacle fence, installed in Gudalur dump yard, Tamil Nadu was visited during the study period. The 4-acre dump yard which usually is a mix of fruits, vegetables and plastics was a host of wildlife including elephants, leopards, deer etc. and served as a quick meal for them. Ordinary solar power fence of 300 m failed to keep the wild animals off the garbage dump yard, especially, the elephants. The 500m fence cost two Lakh and was funded by Gudalur municipality. Galvanized iron wire, 10 KV DC current, 100-mAh battery, 10 KV energizer and 100 W panels was used for the construction of the fence. A fence monitoring system with IR sensor and siren is also installed to monitor whether the battery is discharging power, and also in monitoring the voltage of solar panels and ground conductivity.

The tentacle fence was designed after studying the camera trap video of an elephant breaking a normal fence established there before, with the involvement of WWF. It was designed in such a way that the interval between the tentacles is 75cm, which is lesser than the size of the elephant head. The length of the protruding tentacles is fixed as 1.5m, which is lengthier than the elephant tusk. This dimension is supposed to prevent the attempt of breakage of the fence by the giant herbivores and is found to be effective for the last two years. There is no need of construction of an additional mitigation measure such as elephant-proof trench along with the tentacle fence and so, it is economically feasible too. A similar kind of tentacle fence is also established in Kothagiri, Tamil Nadu recently.

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Plate 51. Gudalur dump yard, Tamil Nadu

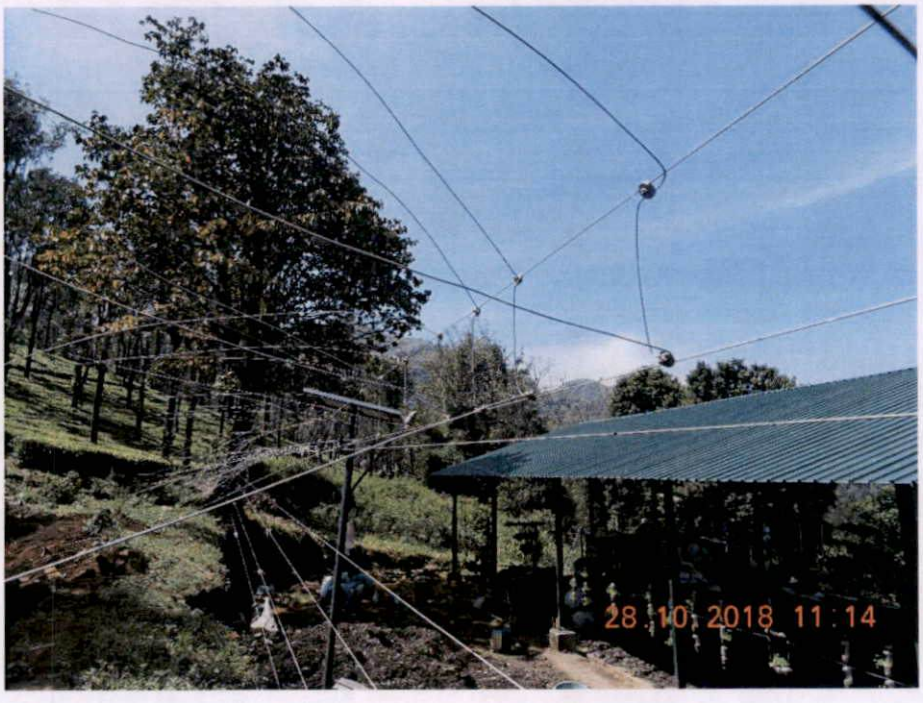

Plate 52. Tentacle fence established to prevent wild animals from entering the dump yard

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Plate 53. Gate with tentacle fence at Gudalur dump yard

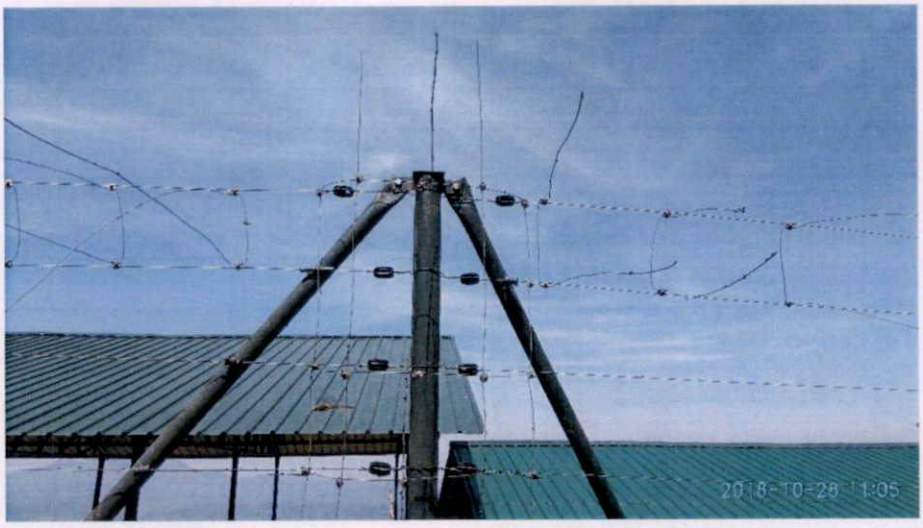

Plate 54. Pole of the tentacle fence protected from all sides at Gudalur dump yard

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Plate 55. Electric fence to protect the dump yard with tree as support at Gudalur dump yard

5.5. Land Use Land Cover Change Analysis

The Land Use Land Cover Changes were determined by using remotely sensed data and Geographical Information Systems (GIS), both inside the Wayanad Wildlife Sanctuary and in a 5 Km buffer area away from the sanctuary.

Based on the interpretation of remote sensing imagery, the total study area was classified into 13 land use land cover classes. It was found that there is an increase in the built-up area inside the Wayanad Wildlife Sanctuary, especially in Kidanganad area of Kurichiyat range. Increment in the built-up area is found to be more in the buffer area (213.26 ha). Change in the cropping pattern can be noticed in all the four ranges with in a time span of 10 years. The area under fallow land and wasteland inside the sanctuary has decreased by 713.89 ha (1.97% of the sanctuary area) and the area under plantation and Kharif crops has increased by 25.63 ha and 793.93 ha respectively. There is also a decrease in the area under double/triple cropping by 160.09 ha. This change in the cropping pattern from double/ triple cropping to Kharif/ Rabi/ Zaid crops

may be due the more land availability for cropping due to the conversion of the fallow land and wasteland to agricultural fields. This shift in the land use and land cover, especially, the increase in cropped area may be the reason for attracting the wild animals, which in turn, increases the human-wildlife conflict incidents.

The fallow land and wasteland within the buffer area has decreased by 1639.56 ha (4.24%) and are converted to vegetated lands. The area under plantation and Kharif crops has increased by 125.58 ha and 520 ha respectively. The area under plantation has increased by 125.58 ha and the agricultural area under Kharif, Zaid and Rabi cropping has increased by 520 ha, 83.18 ha and 26.01 ha during the interval of 10 years. Double/ Triple cropping was also found to be increased by 676.38 ha (1.75%).

There is an overall increase in the cropped area and it may be of the belief that the solar power electric fence and elephant proof trenches established around the settlements will reduce the crop damage due to the wild animals. The increase in the agricultural land area near the sanctuary may be one of the reasons for the rise in human-wildlife conflict issues, as the palatable crops becomes readily available to the wild animals in large quantities. The establishment of the human-wildlife conflict mitigation measures such as solar power electric fence and elephant proof trenches in the boundaries of Wayanad Wildlife Sanctuary may have decreased the conflict issues initially, but the problem is increasing day by day and the farmers are being reluctant to do cropping in their farmlands.

Summary

SUMMARY

The enormous rise in the human population in the Asian countries has led to an accelerated conversion of forest areas into human settlements. The people's encroachment in to the forest land coupled with the requirements of the wild creatures leads to human-wildlife conflict. Wildlife management which helps in the recovery of declining population of large mammals has also led to increased conflicts. Human-wildlife conflicts mainly address the problems regarding injury and death of people, property damage and crop raiding by mainly elephants, livestock loss and threat to life by carnivores. For improving the co-existence of people and wildlife and to enhance the sustainability of conservation efforts, it is imperative to implement human-wildlife conflict mitigation measures. In India, preventing and mitigating human-wildlife conflict are a top conservation priority. State governments as well as the wildlife conservationists focus on identification of low-cost long-lasting mitigation measures that will not harm elephants and humans. The mitigation strategies will be location specific, that is, the techniques that reduce the problem in one area or one country may not be effective in another area or situation. The mitigation measures need constant experimentation and innovation.

The present study aims to map and document human-wildlife conflict mitigation measures being followed in Wayanad Wildlife Sanctuary. The effectiveness of various intervention methods used in mitigating human wildlife conflict is also studied. The attitude, perception and suggestions of the individuals residing near to the forest fringes are also studied.

The Land Use Land Cover Changes (LULCC) were determined by using Geographical Information Systems (GIS) and remote sensing technology, both inside the Wayanad Wildlife Sanctuary and in a 5 km buffer area outside the sanctuary. The LULCC analysis was done to find out the change in the land use pattern before and after the establishment of the mitigation measures in the study area.

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The human-wildlife conflict mitigation measures such as elephant-proof wall and the combination of solar power electric fence and elephant-proof trench established in all the four ranges of Wayanad Wildlife Sanctuary was mapped using the software QGIS ver. 2.18. The solar power electric fence was established along with the elephant-proof trench, as a second line of defense.

The salient findings are summarized below,

1. A total of 190.265 km of fence-trench combination that was erected at Wayanad Wildlife Sanctuary (WWS) was mapped
2. The combination of solar power electric fence and elephant-proof trench was more in Muthanga range (56.54 km), followed by Kurichiyat range (46.63 km), Sulthan Bathery range (46.05 km) and Tholpetty range (41.05 km).
3. The elephant-proof wall erected at WWS were of not more than 200 m.
4. The total length of the elephant-proof wall that could be mapped at WWS was only 654.16 m.
5. The physical barriers were implemented along the administrative boundary of the WWS, and also between the ranges. This unscientific construction leads to fragmentation of forest.
6. Based on the socio-economic survey conducted at WWS, 99.17 percent of the respondents were the victim of crop damage, 45.83 percent suffered from livestock loss and 40.83 percent experienced threat to human life.
7. The crop loss was primarily caused by the Asian Elephant (91.67%), Spotted Deer (89.17%), Wild Boar (87.50%), Bonnet Macaque and Malabar Giant Squirrel (26.67%) at WWS.
8. Both the single elephant bull and the herd were responsible for the crop damage. However, the single elephant bull was responsible for majority of the crop damage than the herds.

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9. 75 percent of the respondents in the sanctuary had experienced crop loss and property damage due to monkeys. They either consume or damages the fruits and pods of the plants. It is also observed to feed on paddy.
10. 28.33 percent of the respondents of WWS experienced damage to their properties due to Asian Elephants or Bonnet Macacque.
11. The major cause of livestock loss is due to the grazing inside forest. 45.83 percent of the respondents in the sanctuary were victim of livestock loss.
12. For claiming compensation, the people tie the unhealthy/diseased cattle in the forest fringes so that it will get easily attacked by a large carnivore
13. The heavy undergrowth in some road side areas are also a threat to humans as well as their livestock, as this undergrowth are being used as hides by the wild animals.
14. The efficiency of the mitigation measures installed in a region is dependent on how well it is maintained. 58.33 percent of respondents revealed that the mitigation measures were occasionally/ rarely maintained and 7 percent of the members says that there is ultimately no maintenance of the mitigation measures.
15. 49.16 percent of the respondents disagrees with the statement that adopting beehive fences will reduce the human-wildlife conflict incidents.
16. 35.83 percent of the respondents were not having any opinion regarding the installation of beehive fences, as it was totally new for them.
17. 67.5 percentage of respondents of the sanctuary were of the opinion that the lack of proper planning of the developmental projects within the forest makes wildlife disturbed.
18. Majority of the respondents (93.33 percent) disagrees that farming plants containing capsaicin-like chilly and pepper/ non-palatable crops in border areas of the forest helps to avoid the wild animal attack of crops.

19. 83.33 percent of the respondents is of the opinion that there will be a shift of the conflict from one site to another when physical barriers are used.
20. 84.16 percent of the respondents believes that the quick interventions of the forest officials will help in reducing human-wildlife conflict and the rest of the respondents are of the opinion that the forest officials are doing all the that they could do in reducing the conflict issues.
21. The people of WWS prefer human-wildlife conflict mitigation measures with proven effectiveness and irrespective of the cost involved, it should be implemented, if found ecologically viable and effective.
22. The efficiency of the preventive measures is directly dependent on the acceptability by the people, since they are having a good involvement in damaging them.
23. Majority of the people are unsatisfied with the compensation scheme of Government, due to insufficient fund and inordinate delay
24. The parameters such as age, duration of residing period, compensation satisfaction and satisfaction of the respondents in the involvement of Government officials are influencing the attitude and perception of the people residing in WSS.
25. Age is having the highest positive correlation with both attitude (r_{sp}= 0.69) and perception (r_{sp}= 0.79). Satisfaction of respondents towards the Government involvement has the highest negative correlation with attitude (r_{sp}= -0.62) as well as with perception (r_{sp}= -0.82).

    r_{sp}: Spearman correlation coefficient
26. Agave and cacti as barrier are found to be impractical and unsuccessful in Wayanad Wildlife Sanctuary.

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27. In Wayanad Wildlife Sanctuary, majority of the people reported that the electric fences (76.92%) as well as the elephant-proof trench (72.04%) implemented in their residing area are ineffective due to poor maintenance.

28. The physical barriers face high rate of failure of the physical barriers are due to man-made reasons and adaptability by animals

29. The people residing near to the fences keep the fences alive only during their cropping season.

30. The non-farmer residents are known to tie-up two wires of the solar electric fence, so that they can easily pass through without getting shock.

31. The solar power electric fences were even used in drying up cloths and to tie their cattle.

32. It is also reported that children take out some part of the electric fences for making toys.

33. The depth of the trenches is found to be decreasing due to the sedimentation of mud and soil from the drainage of rain water from the forest as well as agricultural land, due to poor maintenance.

34. Some of the elephant-proof walls are made in short stretches in Wayanad Wildlife Sanctuary, which just shifts the movement of the wildlife. Elephants move along the walls until it finds a way out.

35. The elephant proof wall was found to be highly in effective and the elephants are found destroying them easily

36. Despite of a huge implementation of the mitigation measures, not only that there is no reduction in the overall conflict incidents, but there is a substantial increase to the tune of 134% in HWC in 8 years.

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37. Specially designed tentacle fence in Gudalur, Tamil Nadu is found to be effective for the last two years, which doesn't require any additional mitigation measure.

38. Based on the Land Use Land Cover Change analysis, it was found that there is an increase in the built-up area inside the Wayanad Wildlife Sanctuary, especially in Kidanganad area of Kurichiyat range, within a time span of 10 years. Increment in the built-up area is found to be more in the buffer area (213.26 ha).

39. Change in the cropping pattern can be noticed in all the four ranges with in a time span of 10 years. The area under fallow land and wasteland inside the sanctuary has decreased by 713.89 ha (1.97% of the sanctuary area) and the area under plantation and Kharif crops has increased by 25.63 ha and 793.93 ha respectively.

40. The fallow land and wasteland within the buffer area have decreased by 1639.56 ha (4.24%) and are converted to vegetated lands. The area under plantation and Kharif crops has increased by 125.58 ha and 520 ha respectively. The area under plantation has increased by 125.58 ha and the agricultural area under Kharif, Zaid and Rabi cropping has increased by 520 ha, 83.18 ha and 26.01 ha during the interval of 10 years.

41. The increase in the agricultural land area near the sanctuary may be one of the reasons for the rise in human-wildlife conflict issues, as the palatable crops becomes readily available to the wild animals in large quantities.

42. The establishment of the human-wildlife conflict mitigation measures such as solar power electric fence and elephant proof trenches in the boundaries of Wayanad Wildlife Sanctuary may have decreased the conflict issues initially, but the problem is increasing day by day and the farmers are being reluctant to do cropping in their farmlands.

43. The Land Use Land Cover Change analysis, show that there is an increase in the built-up area as well as cultivable area inside the Sanctuary as well as in the fringes, just outside the sanctuary, over the last 10 years.
44. Increment in the built-up area is found to be more in the fringe area (213.26 ha)
45. The increase in the agricultural land area near the sanctuary may be one of the reasons for the rise in human-wildlife conflict issues, as the palatable crops becomes readily available to the wild animals in large quantities
46. The implementation of the human-wildlife conflict mitigation measures for separating the man and wild animals is vital, for the safety of both. The mitigation measures have to be implemented wisely, after studying the topographical and geological aspects of the area as well as taking into account the biology and ecology of the wild animals.

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Appendices

APPENDIX I

INTERVIEW SCHEDULE FOR STUDY ON HUMAN-WILDLIFE CONFLICT MITIGATION MEASURES IN WAYANAD WILDLIFE SANCTUARY

College of Forestry, Vellanikkara

Interviewer name: **Date:**

Name of the Forest Range:

1) **Personal details**

Name of person interviewed:

Age:

Sex: Male ☐ Female ☐ Transgender ☐

How long have you been living in this location?

Less than 5 year ☐ 5-10 years ☐ 10-20 years ☐ More than 20 years ☐

2) In your opinion, what are the major outcomes of human wildlife conflict in this area?

☐ Livestock loss ☐ Damage to human property
☐ Crop raiding ☐ Destruction of habitat
☐ Injury and loss of life of humans and wildlife
☐ Others- specify: _____

3) Which wild animals are causing damages/loss to you?

☐ Deer ☐ Monkeys ☐ Elephant ☐ Wild Boar
☐ Gaur ☐ Malabar Giant Squirrel ☐ Others- specify: _____

4) In which season the conflict incidents are more prominent?

☐ Rainy season ☐ Non-rainy season ☐ Throughout the year

5) The conflict or the crop damage raises mainly due to

☐ Single elephant bull ☐ Herd of elephants ☐ Wild Boar
☐ Others- specify: _____

6) Are the conflict incidents are caused by the same herd of elephants?

☐ Yes ☐ No ☐ Cannot be ascertained

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7) Attitudes to human-wildlife conflict mitigation measures

Sl. No:	Statements	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
i.	Wildlife should be controlled using non-lethal methods such as barriers, deterrents and relocation					
ii.	Tourists coming to see forests/wildlife should pay human-wildlife conflict mitigation CESS					
iii.	Adapting beehive fences is a good measure to reduce the conflict incidents.					
iv.	Some of the barrier leads to the animals getting easily adapted to the mitigation measures					
v.	Usage of ineffective preventive measures makes human wildlife conflict more probable					

8) Perception towards Human-Wildlife Conflict mitigation measures

Sl No:	Statements	Excellent perception	Very good perception	Fair	Poor	Very poor
i.	Lack of proper planning in developmental projects like road construction/barrier/ waterhole etc. within the forests make wildlife disturbed					
ii.	Planting food plants inside the forest area brings down the conflict incidents					
iii.	Maintaining enough water source inside forest reduce the conflict					
iv.	Farming plants containing capsaicin like chilly and pepper/non-palatable crops in border areas of forest helps to avoid wild animals attack in crops					

v.	Physical barriers may shift the conflict from one site to another					
vi.	Official's quick interventions help in reducing human wildlife conflict					
vii.	Wild animals have predictable behavioral patterns. We should understand this to build/produce proper barriers					

9) What factors do you believe are most important when choosing a conflict mitigation scheme?

Sl. No:	Statements	Most effective	Effective	Neutral	Not much effective	Least effective
i.	Proven effectiveness					
ii.	Low startup cost (financial)					
iii.	Low maintenance cost (financial)					
iv.	Low labor effort					
v.	Minimal negative effects on wildlife					
vi.	High level of acceptability to other people					
vii.	Fair level of compensation					

10) What are the preventive measures under taken in your area? Are they effective?

Sl. No:	Preventive measures	Most effective	Effective	Neutral	Not much effective	Least effective
i.	Natural fencing (thorn bushes, stone walls)					
ii.	Wire fencing					
iii.	Electric fencing					
iv.	Trenches					
v.	Strobe Lights					
vi.	Ecotourism					
vii.	Others					

11) How often the mitigation measures are maintained?

☐ Very often ☐ Often ☐ Sometimes ☐ Rarely ☐ None

12) Have you take part in maintenance of these mitigation measures?

☐ Very often ☐ Often ☐ Sometimes ☐ Rarely ☐ None

13) What is your role in maintenance of these mitigation measures?

☐ Timely reporting of the condition of mitigation measures to the forest department

☐ Physical maintenance ☐ Others ☐ None

14) Are you satisfied with the compensation pattern of government?

☐ Strongly agree ☐ Agree ☐ Neutral

☐ Disagree ☐ Strongly disagree

15) What kinds of difficulties are usually seen in getting compensation for the loss?

☐ Incomplete or inaccurate documents ☐ Red tapism ☐ Bribery

☐ Providing Proof as victim of conflict ☐ Others: _____

16) Do you feel the government bodies and other agencies clearly communicate with your problems, struggles and suggestion?

☐ Strongly agree ☐ Agree ☐ Neutral

☐ Disagree ☐ Strongly disagree

17) Opinion/ constraints and problems about human-wildlife conflict mitigation measures

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APPENDIX II

Metadata of LULC Map of India 2005-06

I. Data Identification Information

1.	Name of the Dataset	LULC Map of India 2005-06
2.	Theme	Land Use Land Cover
3.	Access Constraints	As per NRSC Data Dissemination Policy
4.	Use Constraints	As per NRSC Data Dissemination Policy
5.	Purpose of creating data	The project focuses on generating information on Net Sown Area (NSA) at the end of the season and to prepare LULC map at the end of each year using multitemporal IRS P6 AWiFS data.
6.	Data Type	Raster
7.	Edition	First
8.	Status	Completed

II. Geographic Location

1.	Spheroid / Datum	GCS, WGS-1984

III. Citation

1.	Data Prepared by	National Remote Sensing Centre, Hyderabad.
2.	Original Source	LULC AWiFS Project
3.	Source Scale and Date	1:250,000 and 2005-06
4.	Lineage	All toposheets of India on 1:250,000 scale
5.	Corporate Name	National Remote Sensing Centre, ISRO
6.	Corporate Address	Balanagar, Hyderabad, India

IV. Dataset Topic Category

1.	Data Identification topic category	Land Use Land Cover Data

V. Abstract describing the data

1.	Data Identification abstract	The map service is on Land use/Land cover map of India on 1:250,000 scale and published under Bhuvan-Thematic Services of NRSC, ISRO. The LULC maps are generated using multi-temporal satellite data of IRS AWiFS sensor for year 2005-06 .

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VI. Data Quality

1.	Process Description	The data was classified following a hybrid approach (Decision Tree - See5 or Supervised MXL or both). The selection of a classifier is dependent on the number of temporal datasets available during the season, freedom from cloud/haze, complexity of the terrain and temporal registration errors etc., The classification procedure followed is as per the guidelines given in LULC manual. In North Eastern states, Jammu & Kashmir, Tamil Nadu, and Karnataka the required temporal registration was found to be a limiting factor due to complexity of the terrain. In these states the cropped areas were extracted using the individual months and combined with the other LULC information.
2.	Source contribution attribute accuracy report	The accuracy was assessed at state level (India administrative unit).Stratified random points generated were used to assess the accuracy of classification. The number of sample points for each strata for selected based on the proportion of the area. However, a minimum of 20 sample points were considered for each class to estimate the accuracy of the classified output. Ground truth data, legacy maps, and multi-temporal FCC have formed the basis for assessment and generation of Kappa co-efficients. The overall classification accuracy is found to be 90.07 % with a range of 86 to 95 % in different states.
3.	Horizontal positional report accuracy	For products covered in the plain terrains second order polynomial method was used and accuracy of one pixel was achieved. In the products of hilly terrains, TIN based model was used against an Area of Interest (AOI). By this method an accuracy of 2-3 pixels is achieved in hilly terrain.

APPENDIX III

Metadata of LULC Map of India 2014-15

I. Data Identification Information

1.	Name of the Dataset	LULC Map of India 2014-15
2.	Theme	Land Use Land Cover
3.	Access Constraints	As per NRSC Data Dissemination Policy
4.	Use Constraints	As per NRSC Data Dissemination Policy
5.	Purpose of creating data	The project focuses on generating information on Net Sown Area (NSA) at the end of the season and to prepare LULC map at the end of each year using multitemporal IRS P6 AWiFS data.
6.	Data Type	Raster
7.	Edition	First
8.	Status	Completed

II. Geographic Location

1.	Spheroid / Datum	GCS, WGS-1984

III. Citation

1.	Data Prepared by	National Remote Sensing Centre, Hyderabad.
2.	Original Source	LULC AWiFS Project
3.	Source Scale and Date	1:250,000 and 2014-15
4.	Lineage	All toposheets of India on 1:250,000 scale
5.	Corporate Name	National Remote Sensing Centre, ISRO
6.	Corporate Address	Balanagar, Hyderabad, India

IV. Dataset Topic Category

1.	Data Identification topic category	Land Use Land Cover Data

V. Abstract describing the data

1.	Data Identification abstract	The map service is on Land use/Land cover map of India on 1:250,000 scale and published under Bhuvan-Thematic Services of NRSC, ISRO. The LULC maps are generated using multi-temporal satellite data of IRS AWiFS sensor for year 2014-15

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VI. Data Quality

1.	Process Description	The data was classified following a hybrid approach (Decision Tree - See5 or Supervised MXL or both). The selection of a classifier is dependent on the number of temporal datasets available during the season, freedom from cloud/haze, complexity of the terrain and temporal registration errors etc., The classification procedure followed is as per the guidelines given in LULC manual. In North Eastern states, Jammu & Kashmir, Tamil Nadu, and Karnataka the required temporal registration was found to be a limiting factor due to complexity of the terrain. In these states the cropped areas were extracted using the individual months and combined with the other LULC information.
2.	Source contribution attribute accuracy report	The accuracy was assessed at state level (India administrative unit).Stratified random points generated were used to assess the accuracy of classification. The number of sample points for each strata for selected based on the proportion of the area. However, a minimum of 20 sample points were considered for each class to estimate the accuracy of the classified output. Ground truth data, legacy maps, and multi-temporal FCC have formed the basis for assessment and generation of Kappa co-efficients. The overall classification accuracy is found to be 90.07 % with a range of 86 to 95 % in different states.
3.	Horizontal positional report accuracy	For products covered in the plain terrains second order polynomial method was used and accuracy of one pixel was achieved. In the products of hilly terrains, TIN based model was used against an Area of Interest (AOI). By this method an accuracy of 2-3 pixels is achieved in hilly terrain.

EFFICIENCY OF MITIGATION MEASURES AGAINST CROP RAIDING WILD ANIMALS IN WAYANAD WILDLIFE SANCTUARY

By

WAHIBA IRSHAD HUMAM
(2017-17-002)

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE IN FORESTRY

Faculty of Forestry

Kerala Agricultural University

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2019

ABSTRACT

A field study was conducted to map and document the human-wildlife conflict (HWC) mitigation measures being followed in Wayanad Wildlife Sanctuary and to examine the effectiveness of the various intervention measures used in mitigating the human-wildlife conflict at WWS. The study was conducted from September 2018 to May 2019 in all the four ranges of Wayanad Wildlife Sanctuary *viz.*, Muthanga, Sulthan Bathery, Kurichiyat and Tholpetty. The mitigation measures such as Solar Power Electric Fence, Elephant-proof Trench and Elephant-proof Wall were mapped using the software QGIS ver. 2.18. Sanctuary level and range-wise maps were prepared. Socio-economic survey of the local communities residing near the forest fringes was also conducted for understanding the extent of human-wildlife conflict, conflict mitigation measures and their effectiveness, attitude and perception of the people towards the HWC mitigation measures etc. The Land Use Land Cover Change (LULCC) analysis was also carried out by using Geographical Information Systems (GIS) and remote sensing technology, both inside the Wayanad Wildlife Sanctuary and in a 5 km buffer area outside the sanctuary during 2005-2006 and 2014-2015.

The solar power electric fence was established along with the elephant-proof trench. A total of 190.265 km of fence-trench combination that was taken at Wayanad was mapped. The combination of solar power electric fence and elephant-proof trench surveyed was more in Muthanga range (56.535 km), followed by Kurichiyat range (46.626 km), Sulthan Bathery range (46.052 km) and Tholpetty range (41.052 km). The elephant-proof wall erected at Wayanad Wildlife Sanctuary were less than 200 m and the total length of the elephant-proof wall that could be mapped was only 654.16 m.

According to the socio-economic survey that is conducted at Wayanad Wildlife Sanctuary, 99.17 percent of the respondents were the victim of crop damage, 45.83 percent of the respondents suffered from livestock loss and 40.83 percent of the

respondents experienced threat to human life. Human-wildlife conflict was more due to Asian Elephants (91.67%), followed by Spotted Deer (89.17%) and Wild Boar (87.50%). 75 percent of the respondents has experienced crop loss and property damage due to Bonnet Macaque. Threat to livestock loss due to tiger/leopard attack was faced by 32.50 percent of the respondents. 26.67 percent of the respondents opined on that the damage caused by the Malabar Giant Squirrel on coconuts.

In Wayanad Wildlife Sanctuary, mostly, a combination of elephant proof trench and solar power electric fence were established. The trenches and the electric fences are poorly maintained and thus they are less effective. The barriers also suffer a high rate of failure as people deliberately break them for accessing the forests for various reasons. Elephant-proof walls cause major ecological challenges, as it completely fragments the habitat and even affect the ecology and behaviour of several non-target species of wild animals too. Moreover, it has also been found to be highly ineffective as in almost all the sites the Elephant-proof walls were broken by the elephants. Biological barriers were also found to be ineffective to mitigate the human-wildlife conflict. Despite of a huge implementation of the mitigation measures, the overall conflict incidents has increased substantially.

Based on the Land Use Land Cover change analysis, it was found that there is an increase in the built-up area inside the Wayanad Wildlife Sanctuary, especially in Kidanganad area of Kurichiyat range over the 10 years. Increment in the built-up area is found to be more in the buffer area (213.26 ha). There is a significant increase in built-up area and cropping area within and on the fringes of the sanctuary. This change in land use has been done primarily by the conversion of the natural *vayals* in and around sanctuary. This change in the land use pattern and the increase in the agricultural land area could be one of the reasons for the increased human-wildlife conflict incidents in Wayanad Wildlife Sanctuary.