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# The Economics and Efficacy of Elephant-Human Conflict Mitigation Measures in Southern India

THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY-INDIA INITIATIVE

FOREST

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- India Business and Biodiversity Initiative (IBBI)
- Conservation and Sustainable Management of Existing and Potential Coastal and Marine Protected Areas
- Himachal Pradesh Forest Ecosystem Services Project
- Access and Benefit Sharing Partnership Project

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# The Economics and Efficacy of Elephant-Human Conflict Mitigation Measures in Southern India

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# THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY-INDIA INITIATIVE

The Economics of Ecosystems and Biodiversity – India Initiative (TII) aims at making the values of biodiversity and linked ecosystem services explicit for consideration and mainstreaming into developmental planning. TII targets action at the policy making levels, the business decision level and awareness of citizens. TII has prioritized its focus on three ecosystems - forests, inland wetlands, and coastal and marine ecosystems - to ensure that tangible outcomes can be integrated into policy and planning for these ecosystems based on recommendations emerging from TII.

In addition to the existing knowledge, TII envisions establishing new policy-relevant evidences for ecosystems values and their relation to human well-being through field-based primary case studies in each of the three ecosystems. In response to an open call for proposals for conducting field-based case studies in the context of relevant policy or management challenges for conservation and the sustainable use of biodiversity and ecosystem services, over 200 proposals were received. A Scientific and Technical Advisory Group (STAG), comprising eminent ecologists and economists, appraised the proposals and recommended 14 case studies for commissioning under TII.

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## KEY MESSAGES

Elephants need large home ranges and have faced habitat loss, resulting in the raiding of nutritionally attractive crops, property destruction and human-elephant deaths. Electric fences and elephant proof trenches have been constructed to curtail increasing conflicts between elephants and humans in Kodagu district and Bannerghatta National Park (BNP). An economic valuation of losses incurred due to elephant raids reveals that the cost of barriers is worthwhile.

### FINDINGS

- Coffee plantations dominate the landscape of Kodagu district, forming **21%** of its **4,102 sq km** land cover.
- BNP is **261 sq km** and among the last remaining tropical dry thorn forests of peninsular India.
- The annual loss in earnings due to elephant-human conflicts is **₹1.59 million** (**US$ 26,500**).
- Since 2004, the Forest Department has spent **₹94.3 million** (**US$ 1.57m**) to erect **322 km** of electric fences in Kodagu.
- In BNP, the types of barriers include solar fence, elephant proof trench, rubble wall, concrete wall, wire mesh, concrete moat and spike pillar.
- The cost of resident relocation would be **₹72.3 million** (**US$ 1.2m**), and there is strong opposition in both Kodagu and BNP.
- To keep elephants at bay, the locals are willing to spend approximately **₹600,000** (**US$ 10,000**) each.

## RECOMMENDATIONS

- In both BNP and Kodagu, the benefit-cost ratios are high, indicating that the present barriers are useful mitigation measure.
- The barriers should be a long-term measure, continuously monitored and repaired in a timely manner when breaches occur.
- The cost effectiveness of the barriers should be evaluated based on their ability to reduce the probability of conflict. Effectiveness could be region-specific.
- The possibility of giving elephant-specific paths for movement in Kodagu district to maintain gene flow needs to be examined.
- Assess the potential of tourism in BNP to generate income.
- Cultivate crops which are not preferred by elephants (such as mulberry) in BNP.

*Photo: Nishant Srinivasaiah*

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## EXECUTIVE SUMMARY

# The Economics and Efficacy of Elephant-Human Conflict Mitigation Measures in Southern India

In many parts of the world, an increasing trend in wildlife-human conflict has made this an important issue in the conservation of wildlife. While there have been many definitions of the term "wildlife-human conflict", in this report we focus on situations where wildlife negatively impacts people and their activities. The nature of damage caused by wildlife includes livestock depredation and human deaths due to carnivores, crop raiding, property damage as well as manslaughter due to herbivorous animals, and the spread of zoonotic diseases. This is obviously a two-way interaction, with wildlife also suffering injuries, death, and loss or alteration of habitat and resources, as a result of human activities, which entail the threat of population reduction and local extinctions. However, this aspect, which has been addressed elsewhere by many conservation biologists, is not considered in this study. This study focuses on the economics of wildlife impacts on people and the mitigation measures in vogue to minimize such impacts. The causes of wildlife-human conflicts are rooted in a complex, interacting set of ecological factors that are not the subject of this investigation.

Elephants occupy a unique position in Asian tropical ecosystems, as a keystone species and a cultural icon. There are two chronic factors that bring elephants into direct conflict with people. First, elephants require large home ranges spanning hundreds of square kilometres and respond negatively to habitat loss and fragmentation. Second, they are versatile, generalist feeders that can easily supplement their natural diet with nutritionally-rich crops cultivated by people. The IUCN Asian Elephant Specialist Group defines Elephant-Human Conflict (EHC) as, *"any elephant-human interaction which results in negative effects on human social, economic or cultural life, on elephant conservation, or on the environment"*.

The intensity of elephant-human conflicts has been on the rise and the complexity of the conflict has now extended into various aspects of socio-economic life. The conflict itself is often magnified at localized scales. Elephant-human conflict causes distress to local communities and can manifest in various ways – crop raids, property destruction, and manslaughter. Crop raiding by elephants causes direct monetary losses to farmers, and associated indirect effects such as stress, fear and health costs, plus loss of income from guarding the fields at night. Since the nature of losses caused by elephants is not in the monetary realm alone, the measures needed to mitigate the conflict need to be sensitive to this fact.

The complexity of the problem of elephant-human conflict makes it necessary to bring together ecological knowledge and economic data in order to develop an effective multidimensional strategy to reduce the negative interaction between elephants and people, thereby promoting the conservation of elephants and natural areas, and improving quality of life for people who share space with elephants.

Mitigation measures implemented across Africa and Asia include traditional methods, such as crop-guarding, scaring elephants using drums and crackers, repellents like chilli and grease, and fire. These methods may offer temporary relief, but elephants are usually seen to quickly change their behaviour to overcome these. In India, there are some guidelines for managing elephant-human conflicts, but no clear policy framework to deal with this issue. The initiatives to reduce the conflict have tended to largely concentrate on physical (trenches, rubble walls) and psychological (electric fences, chemical deterrents) barriers, to keep the elephants from venturing outside their natural habitats and entering human settlements.

This study was carried out in two elephant regions of Karnataka state in southern India, viz. Kodagu district and Bannerghatta National Park. The common point in these two regions is the presence of elephant-human conflict, though to varying degrees. The ecological context, physical terrain and socio-economic conditions of both regions are vastly different, thereby allowing for the identification of measures that can be used across different terrains and those that cannot. Kodagu district is located in the vicinity of the Western Ghats in the southwestern region of Karnataka. Kodagu is dominated by coffee plantations, which form 21% of its land area. On the other hand, Bannerghatta NP is located only 25 km south of a rapidly expanding Bengaluru city. The park is small, narrow and highly irregular in shape, and is dominated by small peasant agriculture. It is necessary, then, when looking at the response to negative ecosystem services, like elephant-human conflict, to first recognise the broad economic and social features of the two regions. The census data for the specified villages provides the broad picture of the responses of the village to the conflict. This picture itself is to be viewed in the larger context of the demographic changes taking place in the region. There are also changes in factors, such as occupational structure, that result from the conflict in both Kodagu and Bannerghatta. While some of this information is available in the Census of India reports, the kind of details we need to capture ecosystem services required a separate household survey. Within each area, six villages were chosen based on two criteria: spatial spread and the intensity of conflict. Two villages were chosen from each zone, one in which conflict was high and the other in which it was low. The extent of conflict was derived from the data based on *ex-gratia* payments to those affected by elephant-human conflict.

As the intensity of conflicts in Kodagu and Bannerghatta increased in the 1990s, people felt it was necessary to adopt a preventive approach in addition to making *ex-gratia* payments to farmers for the damages incurred or loss of human life. This was attempted through the construction of physical barriers separating the forested and the non-forested areas in conflict-prone zones. The barriers currently being used are of two types: (1) Elephant Proof Trench (EPT), a V-shaped linear pit along the length of the boundary of the forest or protected area; and (2) high voltage fences, composed of three to five strands of wires stretched along the boundary, powered by a car battery to deliver a millisecond shock of over 5000 volts.

Within this larger goal, this study focuses on the efficacy of physical barriers, both in terms of reducing elephant-human conflict as well as its social and economic costs. The idea underlying the fixed barrier is to prevent elephants from entering areas where their actions are incompatible with human settlements. This strategy throws up a number of specific questions: Are the barriers effective in preventing elephants from entering land that is settled or cultivated by people? What are the costs of these barriers? Are these costs

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In order to see whether the costs of effective physical barriers are justified by the benefit of reduced elephant-human conflict, both the costs of physical barriers and the benefit from barriers preventing such conflict need to be estimated

justified in terms of the losses they actually prevent?

This study attempts to answer these questions using an approach based on the economic value of ecosystem services. Within framework, human-elephant conflict is understood as an unacceptable negative ecosystem service, which causes the loss of elephant as well as human lives. Initially, the total costs of ecosystem services due to elephant-human conflict are measured. The absence of these costs in an area can thus be seen as a benefit. The benefits of reducing conflict can thereby be compared to the costs of developing a specific mitigation measure. Since most strategy so far has been focused on the development of barriers, this study focuses on effective barriers. The following research questions emerge:

- How do we develop a framework to assess and evaluate the ecosystem services delivered by elephants and their habitats of various degrees of degradation?
- What is the ratio of benefits to costs in using physical barriers to reduce elephant-human conflict?
- Does this ratio differ substantially across geographical territories?

The strategy to mitigate elephant-human conflict has typically focused primarily on reducing the scope for incompatible actions. This was traditionally achieved by providing both people and elephants autonomous spaces. The current emphasis on physical barriers is a continuation of this approach to mitigating conflict. In order to see whether the costs of effective physical barriers are justified by the benefit of reduced elephant-human conflict, we need to estimate both the costs of physical barriers, as well as the benefit of avoiding the costs of elephant-human conflict that has been prevented by the barriers.

In calculating the costs of physical barriers, we first take into account the cost of constructing physical barriers. These costs will depend on a variety of factors, such as design (for instance, number of stands in an electric fence) and terrain (nature of soil and rock for excavating a trench), but an important consideration for us is the length of the barrier. However, the length alone does not serve as a useful indicator of the effectiveness of the barrier. The effectiveness of the barriers also depends on whether, and how frequently, they have been breached. A meaningful unit for measuring the value of physical barriers would then be not just the cost per kilometre of the barrier, but the cost of protecting a square kilometre of area. Based on patterns of conflict, a spatial map of the likelihood of conflict for the two regions was obtained, thereby generating the probability of conflict in Kodagu and Bannerghatta. Such probabilities are particularly useful to evaluate the effectiveness of physical barriers, as it takes into account the whole range of possibilities, from the impossibility of conflict to a very high probability. For comparison, probabilities were calculated separately for time periods before and after the construction of the barriers in Kodagu and Bannerghatta, respectively. Thus, the cost side of the benefit-cost equation is the total cost spent on construction of the fixed barriers divided by the area that the fixed barrier is expected to protect.

On the benefit side of the benefit-cost equation, there is a need to look beyond monetary indicators of the costs of conflict and emphasize the larger economic, social and cultural contexts. Thus, the evaluation of these benefits is in terms of a larger set of ecosystem services. This is of importance, as an emphasis is placed on the negative impact of elephant- human conflict on human well-being. Consequently, the removal or reduction of this conflict will be a positive ecosystem service. The task then is reduced to one of estimating the costs of elephant-human conflict and treats the reduction of these costs as a positive benefit that can be compared with the costs of creating physical barriers.

Total Economic Value is a method that can be used to provide the economic value of both the material and non-material elements of human elephant conflict. As this method takes the economic model beyond the material, it can identify different types of economic values neglected by the market. The advantage of using a valuation of ecosystems approach is that it helps assess overall contribution of ecosystems to social and economic well-being.

The Total Economic Value approach outlined by TEEB provides for a general method of evaluating these costs, which it achieves by taking into account both use values (for which market price exists) as well as non-use values (for which no market price exists). The actual use value is, in turn, of two kinds: direct and indirect. The direct use value relates to benefits obtained directly from the ecosystem service. Indirect use values are those values associated with regulating services provided by the ecosystem. A final distinction within the use value is a component termed as option value. Option values are values that may not currently serve any purpose, but utility may be derived from them in the future. In contrast to use values, non-use values are usually related to moral, religious or aesthetic properties, for which markets do not usually exist.

In considering the empirical reality of the field where the elephant-human conflict occurs, the above-mentioned variables can be modified to reflect the on-ground reality of the conflict. Thus, the factors that can be identified in the empirical reality of elephant-human conflict are: (i) damage to crops and property; (ii) reduced access to forest produce and forest water; (iii) change in land value; (iv) costs of access to spiritual elements within the forest; (v) costs of moving away from a preferred proximity to the forest; (vi) costs associated with overall health; (vii) fear of elephants (as a net effect of existence, bequest, altruistic values, as well as fear of elephants); (viii) abandonment of farming; (ix) change in soil fertility; (x) tapping of alternate sources of income. The total sum of all these individual variables per square kilometer is the total benefit that is to be obtained from reducing elephant-human conflict per square kilometer. But this is only the total value if the conflict were reduced to zero. Hence, only the proportion of conflict that has resulted from actual reduction is to be taken into consideration. The real benefit-cost ratio can be obtained through taking these variables into consideration and then multiplying them by the proportion of actual benefits of reduction in elephant-human conflict.

The final ratio obtained for the different regions highlights the specific localized nature of the elephant-human conflict. What emerges from the final ratios is the level to which the whole exercise is sensitive to the extent to which ecosystem services are accounted for. Observing the conflict in terms of material benefits alone does not justify the costs of the physical barriers. Savings on consumptive costs are then very small when compared to the costs per kilometre of effective physical barriers. However, once the ecosystem services are brought in, this gets dramatically reversed. From this, it can be inferred that the benefits from other ecosystem services per square kilometre due to reduction in elephant-human conflict is greater than the costs associated with construction of physical barriers. Such a conclusion, however, needs to be tempered by a more realistic consideration of which ecosystem services are meaningful in such evaluations, as well as more comprehensive cost analysis of the barriers themselves and their efficacy.

## 1. Introduction

Elephant-human conflicts have been receiving greater attention both because of their growing intensity as well as the complexity of their socio-economic impacts. Monetary losses because of elephants are generally lower than those caused by other crop-pests; however, they seem magnified at localized scales (Nelson et al. 2003), and a single event of crop damage by an elephant is generally perceived to be much greater than repeated damage by insects or even wild pigs. This perceived magnification of elephant-human conflicts makes it imperative to develop measures to mitigate them that are sensitive to the fact that the damage caused is not in monetary terms alone but in the larger context of the provision and negation of ecosystem services. This study aims to evaluate a particular mitigation measure – the implementation of physical barriers – within this larger context.

### 1.1. Wildlife-Human Conflict

Wildlife-human conflict has dominated the past few decades as one of the most relevant global conservation issues. Numerous case studies from around the world establish evidence for the severity of the problem (Sukumar 1994, Naughton-Treves et al. 1998, Woodroffe et al. 2005). Conflict between wildlife and humans is marked by an overlap for resource utilization; as overlaps in home ranges and food requirements increase, the possibility for conflict also increases. Unless these overlaps were to shrink altogether, wildlife-human conflict would be inevitable (Jackson et al. 2008). Potentially, any situation where human activities negatively impact wildlife, or vice-a-versa, qualifies as a case of wildlife-human conflict. A wide range of taxa, such as large and small mammals (both carnivores and herbivores), birds and reptiles, come into conflict with humans (Woodroffe et al. 2005), resulting in a suite of negative effects on both humans and wildlife (Hoare and Du Toit 1999).

Herbivores such as elephants, deer, wild pigs and monkeys, are known to raid cultivated crops, while carnivores such as lions, tigers, and leopard, prey upon domestic livestock (Sukumar 1994). Apart from crop raiding and livestock depredation, wildlife-human encounters also result in property damage and manslaughter, especially by large mammals such as wild elephants, tigers and bears. Similarly, costs are borne by wildlife species when injured or killed during conflict, or when their natural home ranges shrink owing to anthropogenic activities. Such interactions may also alter the natural population structures of wildlife species and result in their endangerment, and in severe cases, local extinctions.

### 1.2. Elephant-Human Conflict

Elephants are the largest living terrestrial megafauna on Earth today and occupy a unique niche both as a keystone species in the tropical forest ecosystem and as a cultural icon in Asia. In the spheres of culture and religion, particularly Hinduism and Buddhism – the elephant-headed Ganesha in the former and the sacred white elephant as the Boddhisatva in the latter – a positive association between elephants and people has existed since ancient times. This connection is observed even today in the responses of several respondents who treat a visit to their farms by elephants as a visit by Lord Ganesha himself. Apart from playing a vital role in religious ceremonies and festivals, over the years, elephants have gained status as conservation symbols. In such ways, through culture, religion and conservation, people forge a positive interaction with elephants.

Elephants require large home-ranges, typically spanning a few hundred to over a thousand square kilometres, in order to sustain their natural life-cycles (Sukumar 2003). Elephants are versatile mixed feeders with a daily requirement of 8-10% of their body weight in the form of fresh forage; they supplement their natural diet opportunistically with nutrition-rich cultivated plants, such as cereals, fruits, palms, and other assorted crops (Sukumar 1989). These two factors often put them into direct contact with people both within and outside their normal home-ranges. The IUCN Asian Elephant Specialist Group defines elephant-human Conflict (EHC) as, *"any elephant-human interaction which results in negative effects on human social, economic or cultural life, on elephant conservation or on the environment".* Negative interactions between elephants and people are complicated by the different ways in which the elephant is viewed – an umbrella species, a flagship species, a source for revenue generation, and also a 'pest' that is responsible for much economic loss and social disharmony (Dublin and Hoare 2004, Fernando et al. 2005). Elephant-human conflict also exists, persists, and intensifies, when resource ranges of people and elephants overlap. Conflicts may manifest directly (physical damage, economic losses, human death and injury; habitat degradation, injury and mortality of elephants) (Figures 1-2) or indirectly (psychological, disturbance of normal day-to-day activities) (Nelson et al. 2003).

Elephant-human conflict has existed for centuries, though it has received attention from the scientific community only in the past few decades (Sukumar and Gadgil 1988; Sukumar 1989; Hoare 1999; Nelson et al. 2003). In Asia, references of crop-raiding are found in the Tamil Sangam literature (1st to 4th century CE) and in Sanskrit texts such as the *Matangalila* (c. 1000 years BP), derived from ancient elephant lore (*Gajasastra*), which can be traced back to fifth or sixth century BCE (Sukumar 2011). Elephant-human conflict is known to exist and persist throughout the ranges of elephants across Africa and Asia (Parker et al. 2007). The African Elephant Specialist Group (AfESG) of IUCN recognizes elephant-human conflict occurrence in as many as 37 countries of the African continent (Thouless and Sakwa 1995; Hoare 1999; Osborn and Parker 2002). Elephant-human conflict is also widespread in several Asian countries such as India (Sukumar 1989, Bist 2002), Sri Lanka (Fernando et al. 2005), Malaysia (Blair and Noor 1979), China (Tisdell and Zhu 1998, Zhang and Wang 2003), and Indonesia (Santiapillai and Ramono 1993). India, which is home to approximately 28,000 wild elephants (Bist 2002), reports cases of elephant-human conflict from almost all of the present elephant ranges. The problem has been documented in the states of Karnataka (Sukumar 1989, Nath and Sukumar 1998, Kulkarni et al. 2007), Tamil Nadu (Balasubramanian et al. 1995), West Bengal (Chaudhary 2004), Orissa (Sar and Lahiri-Choudhury 2009), Meghalaya (Williams and Johnsingh 1997) and Uttarakhand (Williams et al. 2001).

Elephant-human conflict causes distress to local communities (Osborn and Parker 2003) and can manifest in various ways, including crop raids, property destruction, and manslaughter. Elephant crop raids incur direct monetary losses to farmers and associated indirect effects, such as stress, fear, and health costs from guarding the fields at night. Bist (2002) calculated damage due to elephant-human conflict between 1991 and 2001 across different states in India and found that on an average, annually, 8-10 million hectares of land was affected, 10,000-15,000 houses damaged, 300 human and 200 elephant deaths reported, and the state's *ex-gratia* payments made to the victims were between Rupees 10-15 crores. The loss of human life often results in cascading financial, emotional and social impacts on the bereaved. There is also no market value for the fear that raiding elephants can cause. The other side of the coin deals with elephant deaths resulting from conflict and the associated ecological costs. Elephants are known to be one of the most important seed dispersers and contribute substantially to nutrient recycling. They are also known to influence forest structures (such as by opening up canopies). In the long run, the overall loss of biodiversity may result from drastic declines in elephant populations from unnatural causes. The effect of elephant-human interaction on local communities must then be seen in terms of ecosystem services as a whole, both positive and negative.

### 1.3. Mitigation Measures

Different mitigation measures have been developed and implemented across Asia and Africa to deter elephants from raiding crops and causing other damage. Crop-guarding, scaring intruding elephants by making noise (beating drums, bursting crackers), and using light (fire and flash lights), have been some of the traditionally adopted measures by communities. Farmers are also known to clear boundaries of agricultural fields to

**Figure 1: Paddy Field Damaged by Elephant**

**Figure 2: Areca Nut Plantation Damaged by Elephants**

create buffer zones and set up simple physical barriers, as well as place distracting food items elsewhere to lure the elephants away. More recent methods of mitigation include disturbance mechanisms (firing bullets, setting alarm bells); capturing, killing and translocating 'rogue' elephants; use of repellents (chili-tobacco grease barriers, oleo-resin capsicum sprays, playback of elephant distress calls); and construction of physical barriers (trenches, electrical and non-electrical fences, stone walls) (Nelson et al. 2003).

The themes that emerge out of current mitigation practices point out the following: most alleviation methods offer temporary relief (O'Connell-Rodwell et al. 2000); elephants adapt through novel behaviors to overcome barriers (Osborn and Parker 2003) or other mitigation measures; a medley of strategies works better than using any one mitigation measure; and, it is essential to involve local people for effective implementation of solutions (O'Connell- Rodwell et al. 2000, Osborn and Parker 2002). In fact, it is vital to not only employ active and passive mitigation measures, but to look at changes at the basic land-use and planning level. These would typically include decisions pertaining to the location of agricultural farms and the kind of crops cultivated (Osborn and Parker 2003).

### 1.4. Elephant-Human Conflict Policy and Management in India

Although general guidelines are available to manage elephant-human conflicts, there is so far no clear objective policy framework by the government to manage and mitigate this problem. The management initiatives towards reducing elephant-human conflict have tended to focus on physical barriers to keep elephants from entering human settlements. Trenches, fences, walls, and a combination of the three have been used, with varying degrees of success, to keep elephants from threatening the life and property of those living in the vicinity of elephant habitats. When a conflict does take place, *ex gratia* payments for loss to crops, property and human life are also being implemented by various state governments. The selective capture of elephants has also received endorsement from the state and central governments, as well as through a recent judgment of the High Court of Karnataka (in October 2013). There is evidence emerging that strategies built around the behaviour patterns of wild elephant can be used to reduce the interaction between the animals and humans. Plantations in Kodagu have found that greater control over crops the elephants seek, particularly jackfruits and bananas, does reduce the interest of the elephants to move into human settlements. There is also the possibility of altering behaviour norms within human settlements in ways that reduce the scope for conflict and destruction.

There is thus a need to evaluate the relative merits of alternative approaches to elephant-human conflict, ranging from ameliorative measures, such as *ex gratia* payments, to measures that reduce conflict; in particular, physical barriers, elephant capture, and behaviour-based initiatives to influence the movement of elephants away from human settlements. Such an evaluation will enable policy makers to make general decisions about which approach is more effective, as well as explore the possibility of implementing different approaches in different contexts. Of these alternatives, the most common strategy for the mitigation of human-elephant conflict has been the usage of fixed barriers, which prevent elephants from entering areas where their actions are incompatible with human settlements. This study focuses on the efficacy of physical barriers in reducing elephant-human conflict. Further, since the emphasis is on interventions by the government, it limits this focus to physical barriers set up by the Forest Department. The idea of physical barriers is to stop elephants from entering human settlements. This strategy throws up a number of specific questions: Are the fences effective in preventing elephants from entering land settled and cultivated by people? What is the cost of these fences? Are these costs justified in terms of the losses they actually prevent?

In addressing these questions, the importance of biodiversity for maintaining healthy elephant populations is obvious. Elephants spend 16 or more hours per day in foraging on a large variety of plant parts and plant species, estimated as well over 100 species in dry forests and perhaps up to 400 species in evergreen forests (Sukumar 1989). It is therefore important that their habitat stays healthy, so that they are less likely to come out of forests in search of food and water. A diverse tropical forest is more likely to support a healthy elephant population. Elephants also contribute to a more diverse forest (in terms of flora and fauna) through a number of activities, such as dispersing seeds of many large-fruited trees; breaking trees and branches, whose leaves are then available to a host of smaller animals for foraging; and digging for subsoil water on dry stream beds, which is subsequently utilized by other animals (Sukumar 2003). A comprehensive picture of elephant-human conflict would then have to consider the overall contribution of ecosystem services and treat conflict as a negative ecosystem service. How do we arrive at a comprehensive picture of losses from elephant- human conflict when we consider that the losses are not just economic, but also in terms of factors ranging from ecosystem protection to the role of the forest as a spiritual location? This question becomes particularly critical in light of the fact that the value of ecosystem services provided by Asian elephants has yet to be quantified, despite their considerable management implications.

This study attempts to answer these questions using an approach based on the economic value of ecosystem services. In this approach, human-elephant conflict is seen as a negative ecosystem service within which loss of elephant as well as human life is unacceptable. Initially, all costs of ecosystem services due to elephant-human conflict are measured. The absence of these costs in an area can thus be seen as the benefit. Thus, the benefits of reducing conflict can be compared to costs of developing a specific mitigation measure. Since much of the strategy thus far has been focused on the development of barriers, this study focuses on effective fencing. The results thus obtained could serve as pointers both to other measures that would reduce incompatible actions and to reducing conflict of interests between people and elephants.

### 1.5. Study Objectives

The complexity of the problem of elephant-human conflict makes it necessary to bring together ecological knowledge and economic data in order to develop an effective multidimensional strategy to reduce the interaction between elephants and human settlements, thereby minimizing the scope for human-elephant conflict, promoting the conservation of natural areas and improving quality of life for people. Within this larger goal, this study focuses on the efficacy of physical barriers in terms of reducing elephant-human conflict as well as its social and economic costs.

#### 1.5.1 Research Questions

- How do we develop a framework to assess and evaluate the ecosystem services delivered by elephants and their habitats at various degrees of degradation?
- What is the ratio of benefits to costs in using physical barriers to reduce elephant-human conflict?
- Does this ratio differ substantially across geographical territories?

### 1.6. Methodology

This study is being undertaken in two elephant regions in the state of Karnataka, in southern India: namely, Kodagu district and Bannerghatta National Park. While the two regions share the problem of elephant-human conflict, the intensity of the conflict as well as the ecological context, physical terrain, and socioeconomic patterns, are quite different. This approach allows us to identify measures that can be used across different terrains and those that cannot.

#### 1.6.1. Kodagu District

Kodagu district is located in the southeastern part of the state of Karnataka (Figure 3). Its western border runs along the crest line of the Western Ghats, and the entire district lies on the hilly terrain to the east of the Western Ghats. The district is divided primarily in two Forest Divisions, Madikeri Division and Virajpet Division. Nagarahole National Park, which is under the administrative control of Hunsur Wildlife Division, forms the southeastern tip of the district.

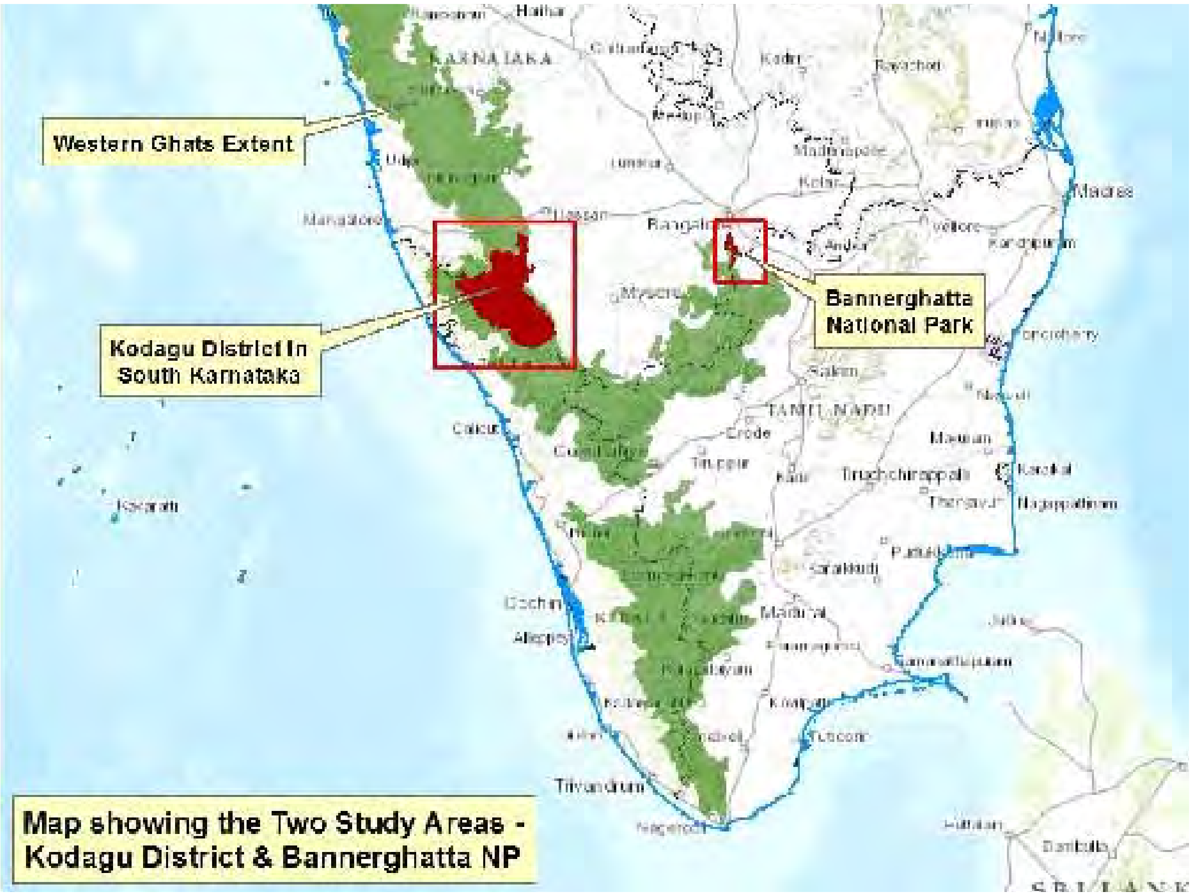
Kodagu is known as the coffee bowl of Karnataka. Its landscape is dominated by coffee plantations, which form 21% of its land cover. In the 19th and early part of 20th century Kodagu was a heavily forested district. Since that period a large percentage of the forest has been converted to plantations and agriculture. Even though Kodagu is the second smallest district in Karnataka, it records a high number of elephant-human conflict cases.

#### 1.6.2. Bannerghatta National Park (BNP)

BNP is located only 25 km south of a rapidly expanding Bengaluru city (Figure 3). The park is highly irregular in shape; it measures a maximum of 54 km in length, from north to south, and varies between 0.3 and 13.8 km in width, from east to west. Though administratively a small National Park in India, measuring 261 $km^2$ (until 2012, the park was only 104 $km^2$), the park is geographically contiguous in the south with the largest of the remaining tropical dry thorn forests in the country. There are 117 human settlements located less than 5 km from the boundary of the park, and 5 human settlements within the park.

The park has an average elephant population of 50-100 animals (78 reported in May 2012); however, forest staff involved in the elephant driving operations and farmers living adjacent to the park boundary have counted more than 200, with the "migratory" elephants that move in from the cropping season (July-November) until the end of winter (November-February). A comparative study in this park would provide a contrasting situation of conflict in an urbanizing landscape.

**Figure 3: Map Showing the 2 Study Areas – Kodagu District & Bannerghatta National Park**




## 1.7. Study Outline

In **Chapter 2**, we will describe the impact of elephant-human conflict in Kodagu and Bannerghatta National Parks. This will be attempted by first defining the boundaries of the areas that are expected to be protected by physical barriers. These boundaries will be arrived at by using evidence of conflict. It is now known that conflict, quite predictably, declines as we move away from the forest boundaries. The first points of zero conflict will be treated as the outer boundary of the area to be protected by the physical barrier. It is possible for the areas to be protected by two different sets of physical barriers to overlap. The data within the defined area will be interpolated to come up with the probability of conflict in each village.

**Chapter 3** of the report will then go on to describe the status of physical barriers in Kodagu and Bannerghatta. This chapter will look at the cost-effectiveness of fencing. The difference in the probability of conflict before and after the barriers were built will allow us to calculate the effectiveness of the barrier as a proportion. When calculating the costs of the barrier per kilometre, the length of the barrier will be discounted by the proportion of effectiveness. For example, if we get an effectiveness of 0.75 for a barrier of 10 kilometres, the length of the barrier taken for calculating the costs per kilometre would be 7.5 kilometres.

**Chapter 4** outlines the ecosystem services approach to EHC. It goes on to outline the methodology that will be used to evaluate the economic value of ecosystem services.

**Chapter 5** will provide the economic valuation of the impact of EHC as a negative ecosystem service in Kodagu and Bannerghatta. This exercise will be conducted on the basis of the methodology outlined in Chapter 4. The survey will cover three villages affected by conflict and three villages that are not affected by conflict in the study areas.

**Chapter 6** will provide the main conclusions and alternative strategies for the mitigation of elephant-human conflict.

## 2. Impact of Elephant-Human Conflict in Kodagu and Bannerghatta National Park

### 2.1. Socio-Economic Impact of Elephant-Human Conflict

Peoples' responses to elephant-human conflict in different regions is not independent of their social processes. The overall responses depend a great deal on not just their fear or love of elephants but also on whether they have the economic and social ability to take steps to avoid that conflict. These differences become quite critical when we consider that the two areas under consideration in this study are very different socially and economically. Kodagu has been a plantation district, with place for coffee growers of all sizes, while Bannerghatta is close to the largest city in Karnataka, in a region that is dominated by small peasant agriculture. It is necessary then, when looking at the response to negative ecosystem services such as elephant-human conflict, to first recognise the broad economic and social features of the two regions. While some of this information is available in the Census of India reports, the kinds of details we need in order to capture ecosystem services needed a separate survey.

### 2.2. Sample Design

The sample was designed in a manner to be representative of the two areas the physical barriers were expected to protect, in Kodagu and in Bannerghatta. Within each area, six villages were chosen based on two criteria: the spatial spread, and the intensity of conflict. The area to be protected in Kodagu and Bannerghatta was first divided into three zones each. Two villages were chosen from each zone, one in which conflict was high and the other in which it was low. The extent of conflict was derived from the data based on compensation paid to those affected by elephant-human conflict. The villages with zero compensation claims were taken as 'low conflict villages', not 'zero conflict villages', for two reasons. First, these villages were within the broad area where elephant raids were known. Second, there were a large number of farmers who stated that the costs of getting ex-gratia payments were beyond their means. In other words, the transaction costs of getting compensation were too high. Within each village, thirty households were chosen for the survey. The effort was to pick the households through a sequential random sample. It must be mentioned that this method was easier to carry out in Bannerghatta, where the houses were clustered together. In Kodagu, where the houses were randomly spread over a wider area, the sequencing was more difficult. On the whole, 180 households were surveyed in each study area, a total of 360 households overall. In Kodagu, Hebbale, Bettageri and Badagabanangalawhile were chosen as villages with high intensity conflict, while Kottageri, Aruvathoklu and Nelliyahadikeri were chosen as villages with low levels of conflict. In Bannerghatta, Thoksandra, Bannimukodlu and Doddaguli were chosen as villages with high levels of conflict, while Kotekoppa, Ballagere and Bijjahalli were taken as villages with lower levels of conflict.

### 2.3. Elephant-Human Conflict and Demographic Patterns

The information for these villages has been gathered from two sources. Where the information required is available in the Census of India, that source has been taken. The survey has been used to gather information that is not available in the Census. The data from the Census provides a broad picture of the village response to elephant-human conflict in the affected areas. This picture has to be seen in the context of the wider changes taking place in the region where the affected area is situated. Bannerghatta, being in the vicinity of Bengaluru, has been affected by the attractions of a nearby metropolis. The possibility of migration to Bengaluru meant that the population growth in this region over the decade 2001 to 2011 was bound to be slow. But elephant-human conflict does seem to have had its impact as well. As can be seen in Table 1, the

> Peoples' responses to elephant-human conflict are related to their social processes. The overall responses depend on both their fear or love of elephants and whether they have the economic and social ability to take steps to avoid that conflict

growth in population in the villages with low intensity conflict in Bannerghatta was just 2.4%, but in the high conflict villages there were signs of an exodus, with the population of these villages declining by as much as 15.4 % over the decade.

The response in Kodagu does at first glance appear to be very different. The population of the villages with low intensity conflict in that district has grown by a noticeable 15.2%. Despite the forest department data on compensation pointing to an increase in the intensity of elephant-human conflict in Kodagu, the population of the villages with high conflict has grown, if somewhat slowly. It would, however, be a mistake to interpret these patterns as evidence of there being no change in village population in response to elephant-human conflict. It is quite possible that in these villages, in close proximity to the forest, those who have left have been replaced by new entrants from inside the forest. As Table 2 tells us, there has been a substantial increase in the tribal population in the villages affected by the conflict. The Scheduled Tribe population in these villages increased from 16.5% of the village population to well over a quarter of the village. This suggests an exodus of tribal populations from within the forest to the villages on the periphery that are typically more prone to elephant-human conflict. As this factor does not have the same role in the villages with low intensity conflict, which are typically away from the forest, the share of the Scheduled Tribes in these villages has remained largely stagnant.

**Table 1: Growth in Population in Sample Villages Between 2001 and 2011**

| | % Growth in population |
|---|---|
| Villages in Kodagu with high intensity conflict | 5.05 |
| Villages in Kodagu with low intensity conflict | 15.21 |
| Villages in Bannerghata with high intensity conflict | -15.35 |
| Villages in Bannerghata with low intensity conflict | 2.39 |

Source: *Census of India data from 2001 and 2011*

**Table 2: Tribal Population in the Sample Villages in 2001 and 2011**

| | % of ST population in 2001 | % of ST population in 2011 |
|---|---|---|
| Villages in Kodagu with high intensity conflict | 16.53 | 26.54 |
| Villages in Kodagu with low intensity conflict | 4.37 | 5.16 |
| Villages in Bannerghatta with high intensity conflict | 0.44 | 0.45 |
| Villages in Bannerghatta with low intensity conflict | 6.19 | 0.96 |

Source: *Census of India data from 2001 and 2011*

### 2.4. Calculation of areas affected and the associated probabilities

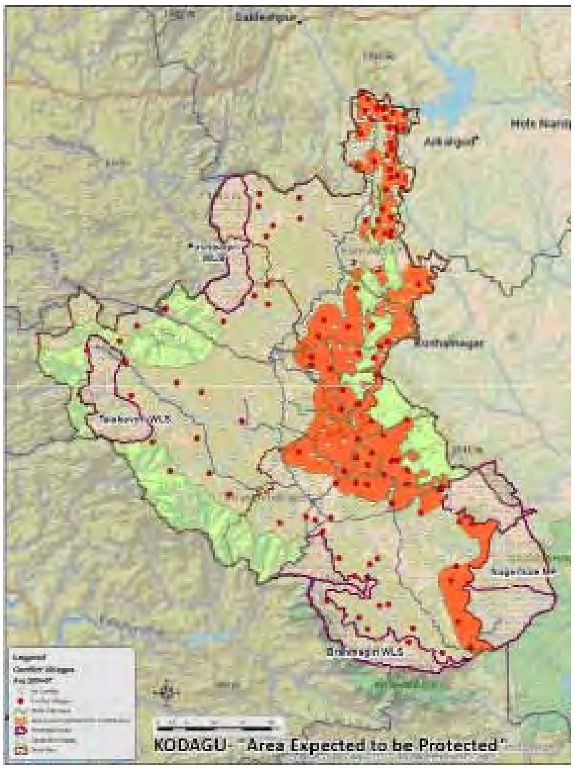
These boundaries of areas that are expected to be protected by physical barriers were arrived at by using evidence of conflict such as ex-gratia payments by the forest department to the farmers affected by crop raid. It is now known that conflict, quite predictably, declines as we move away from the forest boundaries and the intensity and frequency of crop raid incidents is more in farms that are closer to the forest boundaries.

For this project we took the first point of zero conflict away from the forest boundary as the outer boundary of the area that should be protected by the physical barrier. It is possible for areas protected by two different sets of physical barriers around forests to overlap. Below are the steps that were followed to arrive at the "area expected to be protected" for the Kodagu and Bannerghatta National Park study areas in ArcGIS, (a geographic information system software):

- We began with the whole area of Kodagu district, which is about 4,102 $km^2$.
- We then removed the area that is under reserved forest, national parks and wildlife sanctuaries; this left us with an area of 2,653 $km^2$.
- We overlaid the village locations (with or without conflict) for this area.
- Using spatial analysis tools in ArcGIS, we interpolated a surface using village points, with crop raid incident numbers for each village, during the years 2004-07. This is a representative period for incidents before the existing barriers (EPTs/solar fences) were put in place.
- The farthest point of a crop raid incident from the forest was taken as the limit of the "area expected to be protected". This also included, in some cases, villages that are closer to the forest but may not have had any crop raid incidents.

- For Kodagu, this area came to about 780 km$^2$ that should be protected by barriers along the western edge of the eastern stretch of reserved forests and protected areas. For this project, we did not consider the western side of the district because hardly any barriers have been constructed on that side since the conflict started (refer Kodagu barriers' map). So the area to be protected by barriers in Kodagu was also taken for the eastern side only. This is coming from the assumption that the eastern side barriers will not protect the western side conflict villages (Figure 4).
- For Bannerghatta National Park, we only took the western edge of the park and calculated the area that will be protected by the barrier. Due to the lack of consistent data on compensation claims, we relied on expert opinion to determine how far out of the park elephants go into agricultural areas – about 7 km. Hence, we created a buffer of 7 km around the park boundary on the western side (Figure 5). This area came to about 742 km$^2$.
- Probability models were only run on the villages that were inside these "areas expected to be protected". We selected 125 villages in Kodagu district and 133 villages around the western edge of Bannerghatta National Park.

**Figure 4: Map showing "Area Expected to be Protected" by Barriers in Kodagu**




After demarcating areas expected to be protected by physical barriers, the probability of elephant-human conflict occurring in any village on a given day was calculated. Probabilities were calculated for time periods before and after the construction of the barriers in Kodagu and Bannerghatta NP using the equation below:

$P_t = (T/2)/ (D)$

where

$P_t$ = Probability of occurrence of EHC in a village on any given day of the year for the designated time span 't'

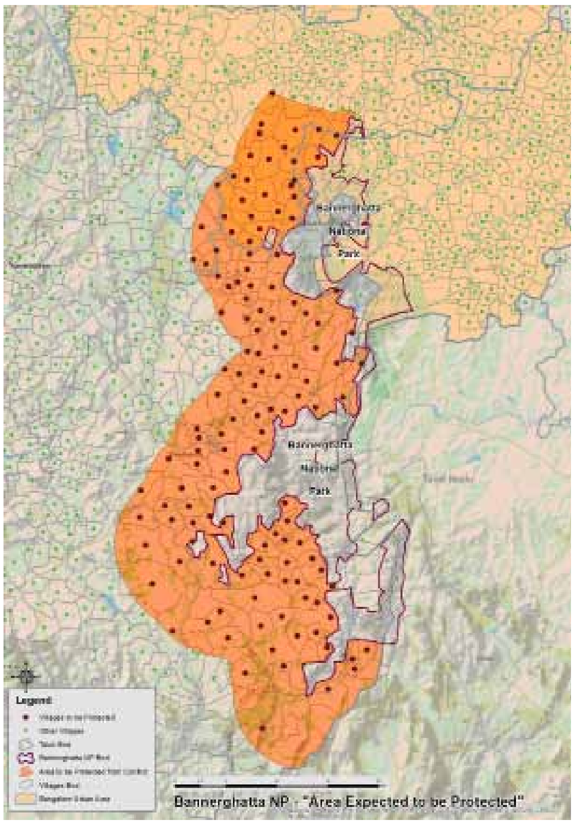
T= Total number of EHC cases for all villages in the defined area for the given time period

D = Total number of days in the given time period

N= Number of villages

For example, the total numbers of EHC cases for

**Figure 5: Map showing "Area Expected to be Protected" by Barriers Around Bannerghatta NP.**




Considering BNP's proximity to Bangalore the shortest straight-line distance between conflict villages and the outer edge of urban Bangalore is about 46 km the defined area in Kodagu between years 2004 to 2007 was 1792. The total number of villages in the defined area is 125. This is multiplied by the total number of days in 4 years (365*4). T has been divided by 2 to get the total number of unique 'conflict-days' across all villages in the area to be protected for the given time frame. This is to say that on a given day in any village more than one instance of elephant-human conflict is possible (and often happens). From field experience, and from long term compensation data, we have estimated that to be 2 raids per day per village. Therefore dividing 'T' by 2 gives us the number of unique conflict days. These values are incorporated into the equation above to calculate the probability – in this case, the probability of the occurrence of EHC in a given village lying within the demarcated area in Kodagu on a given day before the construction of barriers. Similarly, the probability is calculated for villages in Kodagu and Bannerghatta after the construction of barriers (Table 3).

### 2.5. Elephant-Human Conflict and the Occupational Structure

The period 2001 to 2011 presents an interesting picture in the working population of the sample villages. The impact of elephant-human conflict on working populations is not particularly significant. There is a marginal decline in the proportion of main workers to total population in both the high intensity conflict and low intensity conflict villages in Kodagu, and in the low intensity conflict villages of Bannerghatta (Table 4). The change in the high intensity conflict villages of Bannerghatta is also marginal, but in the opposite direction. The absence of a substantial variation between villages with high intensity conflict and those with low intensity conflict is also noteworthy. In the case of women workers in the high intensity villages of Kodagu, and the low intensity villages of both Kodagu and Bannerghatta, the difference is not insignificant. The proportion of women workers to female population declined noticeably in these villages between 2001 and 2011. The reasons for this significant shift in the gender ratios of cultivators cannot be determined from this data set. It could very easily be a part of a national trend in which female labour force participation is falling drastically in rural areas (Mammen and Paxson 2000, Thomas 2015). We must be open to the possibility that any difference between the villages with high intensity conflict and those with low intensity conflict is the result of factors other than elephant-human conflict.

The trends in the high conflict villages of Bannerghatta do not fit into this pattern. Though marginal, we must note that the changes are in the opposite direction to that of Kodagu (Table 4). In the villages with high intensity conflict in Bannerghatta there is, in fact, an increase in the proportion of main workers to the total population, an increase seen among women as well.

This pattern would have to be explained by factors outside this data set. We would have to take into account the fact that Bannerghatta is close to Bengaluru. Among the effects of this proximity is the possibility of living in Bannerghatta and working in Bengaluru. This could contribute to an increase in the proportion of main workers to total population. We could hypothesize that that the marginal increase in the

**Table 3: Probability of Occurrence of EHC in a Village on Any Given Day**

| | P(pre-barrier) | P(post-barrier) |
|---|---|---|
| Kodagu | 0.0049 | 0.0111 |
| Bannerghatta National Park | 0.0035 | 0.0035 |

**Table 4: Main Working Population in the Sample Villages in 2001 and 2011**

| | % Main workers to total pop. on in 2001 | % Main workers to total pop. in 2011 | % Female main workers to total pop. in 2001 | % Female main workers to total pop. in 2011 |
|---|---|---|---|---|
| Villages in Kodagu with high intensity conflict | 55.49 | 54.22 | 49.30 | 45.30 |
| Villages in Kodagu with low intensity conflict | 48.25 | 46.07 | 36.38 | 31.47 |
| Villages in Bannerghatta with high intensity conflict | 55.49 | 56.60 | 47.22 | 48.13 |
| Villages in Bannerghatta with low intensity conflict | 53.50 | 53.45 | 44.22 | 41.58 |

Source: *Census of India data from 2001 and 2011* proportion of main workers is due to this phenomenon. This and other similar arguments would, however, be beyond the scope of the data set we are operating with. It may be more prudent then to keep an open mind on the causes of this phenomenon.

The fact that there is a more dramatic change taking place in Bannerghatta than in Kodagu is confirmed when we look at the movement away from cultivation (Table 5). In the villages in Bannerghatta with high intensity conflict there has been a dramatic drop in the share of cultivators among the total main workers. In 2001, these villages were consistent with agrarian patterns in the region around them. They were dominated by small peasant agriculture, with cultivators accounting for nearly three-fourths of the main workers. Over the next ten years this proportion has dropped to just half the main workers. This sharp decline has been registered across both male and female workers. This pattern is consistent with a hypothesis that elephant-human conflict in these villages has forced workers to leave cultivation and seek work elsewhere, including, possibly, in the nearby metropolis. Such a hypothesis would require that, in areas with low intensity conflict, there should be no decline in the proportion of cultivators. In the villages in Bannerghatta with a lower intensity of conflict, the role of cultivators has not only remained dominant – it has increased. While this data is not sufficient for definitive conclusions, we cannot rule out the possibility of elephant-human conflict being a factor.

There is also a very significant shift in the gender equation: the share of male cultivators to total main workers has increased quite significantly, by 12%, while that of women cultivators has declined by just over 14%. As we have noted earlier, the data set is not sufficient to come up with definitive conclusions, since there is also a national trend of declining proportions of female workers. This would be particularly true in Kodagu, where the difference in reduction in female workers in villages with high intensity and low intensity conflict is not significant. In Bannerghatta, the national trend seems to be much stronger than in Kodagu, with a proportion of female cultivators to main cultivators in villages with low intensity conflict being 14.4% less than in 2001. However, the decline in villages with high intensity conflict is noticeably sharper, with the 2011 figure being almost 22% less than in 2001. This

**Table 5: Changing Proportion of Cultivators to Main Workers in Sample Villages 2001–2011**

| | % Cultivators to total main workers in 2001 | % Cultivators to total main workers in 2011 | % Male cultivators to total main workers in 2001 | % Male cultivators to total main workers in 2011 | % Female Cultivators to total main workers in 2001 | % Female Cultivators to total main workers in 2011 |
|---|---|---|---|---|---|---|
| Villages in Kodagu with high intensity conflict | 2.18 | 1.44 | 2.64 | 1.74 | 1.59 | 1.03 |
| Villages in Kodagu with low intensity conflict | 2.37 | 2.34 | 2.40 | 2.68 | 2.30 | 1.70 |
| Villages in Bannerghatta with high intensity conflict | 73.12 | 50.11 | 76.14 | 53.83 | 66.77 | 44.89 |
| Villages in Bannerghatta with low intensity conflict | 58.97 | 62.16 | 57.37 | 69.36 | 63.82 | 49.46 |

Source: *Census of India data from 2001 and 2011*

**Table 6: Proportion of Agricultural Labour to Total Main Workers in Sample Villages, in 2001 and 2011 (AL= Agricultural Labour, FAL= Female Agricultural Labour, MAL= Male Agricultural Labour)**

| | AL%0 1 | AL%1 1 | MAL%0 1 | MAL%1 1 | FAL%0 1 | FAL%1 1 |
|---|---|---|---|---|---|---|
| Conflict_Kodagu_Sum | 0.36 | 2.03 | 0.29 | 1.98 | 0.45 | 2.11 |
| Non-Conflict_Kodagu_Sum | 0.62 | 7.53 | 0.62 | 7.37 | 0.62 | 7.85 |
| Conflict_Bannerghatta Sum | 10.44 | 27.37 | 7.85 | 18.72 | 15.89 | 39.54 |
| Non-Conflict_Bannerghatta Sum | 10.31 | 29.20 | 9.01 | 20.46 | 14.24 | 44.65 |

Source: *Census of India data from 2001 and 2011*

suggests that the possibility of elephant-human conflict playing a role in keeping women away from cultivation cannot be ruled out.

In the plantation-dominated economy of Kodagu, the role of cultivators is of course marginal, accounting for just over 2% of the main workers in 2001. But even within these small numbers, the same patterns can be seen between 2001 and 2011. In the villages with high intensity elephant-human conflict, there is a decline in the share of cultivators among main workers, and this decline cuts across both male and female workers. In the villages with low intensity conflict, in contrast, the share of cultivators in main workers remains stagnant. There is also change in the gender ratios, with the share of male cultivators among total male main workers increasing, while that of female cultivators among total female main workers has declined (Table 6).

In understanding occupational shifts, and the possibility that these shifts are influenced by elephant-human conflict, in howsoever marginal a manner, it may be useful to make a distinction between two elements in the fear of elephants: fear of economic loss and the fear of loss of life. The fear of loss of life would contribute to a tendency to move out of the village and would be reflected in demographic changes. As we have noted earlier, the population in the villages in Bannerghatta with high intensity conflict declined quite sharply. The fear of economic loss would be seen in cultivators leaving their land fallow, even if that means they have to work as agricultural labour on other farms. And this is a factor that is quite substantial in both high intensity and low intensity conflict villages in Bannerghatta. The tendency towards an increase in the share of agricultural labour in total main workers is a little higher in the villages with low intensity conflict. This could be because those leaving cultivation in the villages with high intensity conflict may have used the option of moving out of the village altogether, rather than continuing to live in the village as agricultural labour.3.

## 3. Status of Physical Barriers & Their Cost Effectiveness

As elephant-human conflict escalated in Kodagu (Figure 6) in the late 1990s and in the early 2000s, there was need for a preventive approach, in addition to making ex-gratia payments to farmers for the damages incurred.

This was attempted through constructing physical barriers to separate the forested and the non- \forested areas in conflict-prone zones. The barriers currently in use are of two types (see photos below):

1) Elephant Proof Trench (EPT): A V-shaped linear pit (Figure 7) along the length of the boundary of the forest or protected area, with a three metres deep cross-section, two meters wide at the top and half a meter wide at its base.

2) High voltage electric fence: Three to five strands stretched across vertical posts (Figure 8) and powered by a car battery through an energizer to deliver high voltage (>5000 V) at a millisecond duration (usually about 1/1000 second). The battery is charged through the mains, or more typically using a solar panel.

Virajpet and Madikeri, territorial divisions of the Kodagu Forest Department, initiated the erection of high voltage fences in 2004, while the digging of EPTs started in 2006-07 along the eastern parts of Kodagu, an activity that still continues. Since 2004, the Forest Department has excavated 260 km of EPTs in Kodagu, and has erected 322 km of electric fences in the district (Figure 9) at the cost of ₹943 lakhs. Over the years, ₹123 lakhs have been spent as maintenance costs for these barriers.

We must mention here that costs incurred in additional structures, such as concrete dams and walls to plug gaps along streams, have not been obtained, and

**Figure 6: Average Annual Elephant-Human Conflict in Kodagu District during 2004-2014**

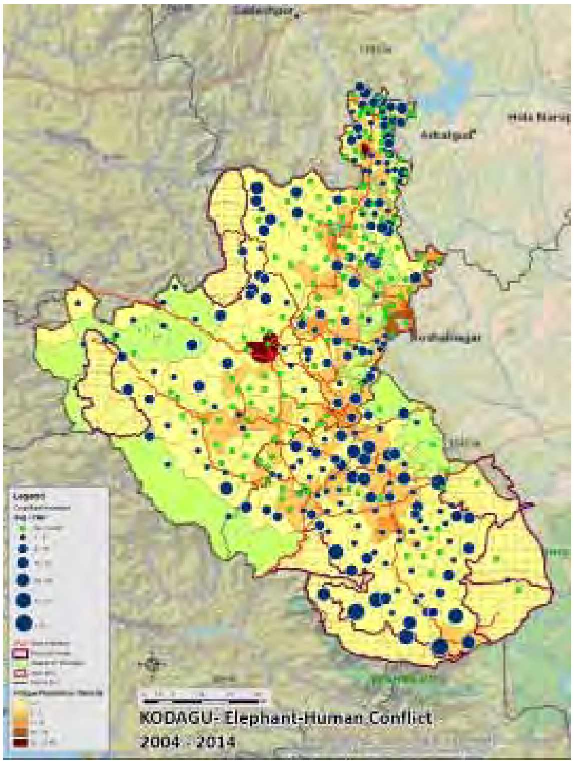



**Figure 7: Elephant-Proof Trench**

these could add to the overall cost of the barriers. Our barrier cost estimates are thus preliminary.

The efficacy of barriers has been mixed, as observed from the increase or decrease in the compensation paid by the Forest Department in areas where barriers have been implemented. There are several potential reasons for these barriers being ineffective, such as:

- Poor maintenance of EPTs and solar fences;
- EPTs are not conducive to high rainfall areas, where they routinely get filled up with rain water and many a time the sides collapse, creating tracks for elephants to easily cross over;
- Invariably, elephants attempt to push the side walls and fill up trenches, or have even learnt to slide down a trench and clamber across to the opposite side;
- Elephants have also figured out how to breach electric fences, by pushing trees and logs over the fences, or using their tusks and foot pads, which are poor conductors, to push and snap the wires.

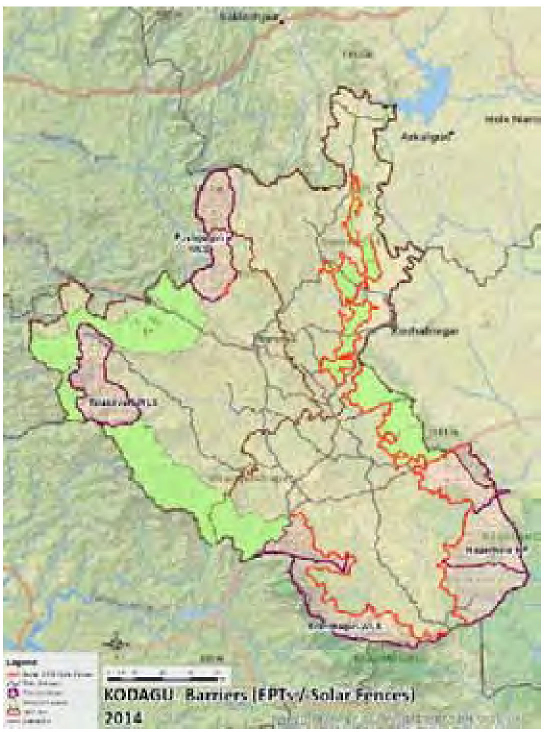
This has led the Forest Department to consider stronger barrier options, such as stone walls with spikes on them and barriers made out of discarded railway tracks. However, these are expensive propositions and are estimated to cost about ₹1.3 crore per running kilometer, as against ₹6.25 lakhs for EPTs and ₹2.6 lakhs for electric fences (based on the 2014-15 estimates).

In the narrowly-shaped Bannerghatta National Park (BNP) (close to Bengaluru city), the physical barrier option was explored as early as 1984, when rubble walls were constructed to mitigate the increase in elephant-human conflict. Since then, seven different types of barriers have been tried and built along the BNP boundary (see Varma et al. 2009 for a detailed account of conflict and barriers at Bannerghatta). Field surveys for assessment of barriers were conducted between November 2014 to January 2015 for a total of 101 km along the western and northwestern boundary of BNP.

**Figure 8: High Voltage Electric Fence**

Our survey period was commensurate with the end of northeast monsoon in the study area. A field team, comprising three to four research assistants trained a *priori* in the survey techniques, walked the boundary of BNP accompanied by the forest department staff on each particular beat. We defined each kilometre of the boundary as our spatial sampling unit. Within the sampling unit, we defined every 200 m of the barrier as a segment for recording data. The extent (Figures 10-12) of each of the barriers differs significantly. Electric fence spans 86.4 km of the 101 km surveyed, and has the highest span in the surveyed area of BNP. Elephant-proof trench (EPT) spans 77.2 km of the 101 km surveyed. The extent of rubble wall along the boundary is about 17.2 km. The extent of other forms of barrier is less significant and seems to be established more for reinforcing existing barriers in critical locations. Barrier-specific extent for the 100 km of the northern and western boundary of BNP is provided in the bar chart below (Figure 10) and some barrier specific maps (Figures 11-12).

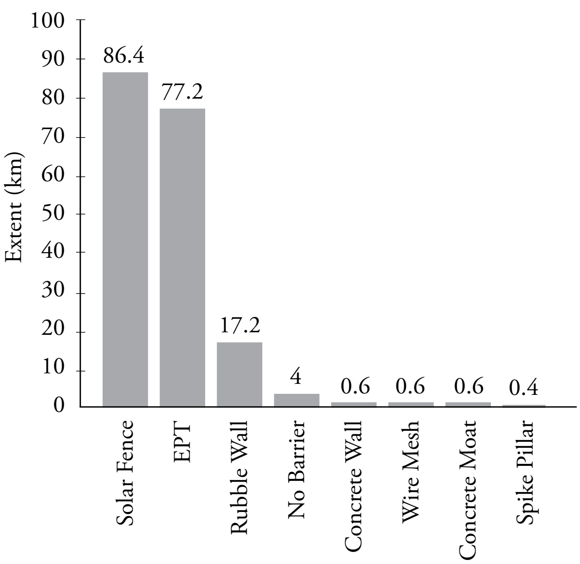
**Figure 9: Location of Physical Barriers (EPTs/Electric Fences) in Kodagu District**




In regions that witness high intensity elephant-human conflict, it is not uncommon for the management to maintain multiple layers of barriers. Factors such as substrate type, topography, ownership, annual precipitation, local density of elephants, local peoples' dependence on the forest, and other factors, may influence the type of barrier for a locality.

In BNP, seven types of barriers have been maintained. The layer of protection ranged from 0 (no barrier at all) to 4 (multiple layers of protection) (Figure 13). Breaches and breaks in physical barriers could potentially render them permeable to elephants, thus defeating their very purpose. Breaches in barriers are bound to occur due to a suite of induced and natural reasons. For effective management of EHC, we note that it is crucial to periodically assess the breaches in

**Figure 10: Types and Extent (km) of Barriers Maintained at Bannerghatta National Park**

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the barriers and mend them. Mending the breaches is easier and less of a strain on resources when attended to earlier.

In the surveyed stretch, EPTs have the highest number of breach locations (Table 7). Trails of cattle, elephants, people or even vehicles passing through the EPT were considered breaches. Similarly, caved-in earth and shallow moats were also considered breaches in EPTs. We recorded a total of 334 breaches in EPTs (Figure 14), which is over 80% of the total 415 breaches recorded in all barrier types. We note that even a 1 metre breach can be porous enough for the silent passage of elephants and, therefore, we recorded each such breach during the survey. Rubble walls contributed to 10% (n = 41) of the total breaches, while electric fence contributed to 8% (n = 30) of the total breaches.

**Figure 11: Extent of Electric Fencing at BNP**

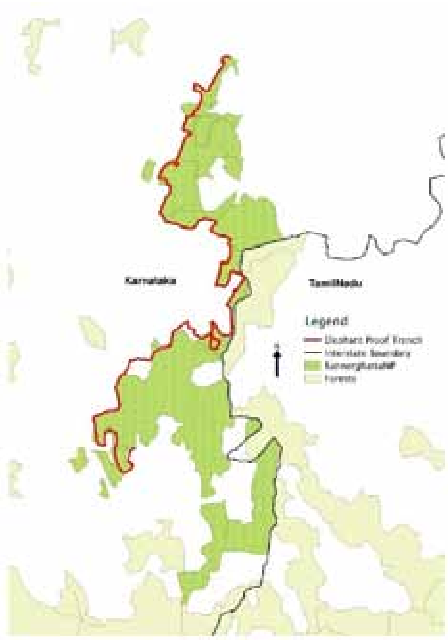



**Table 7: Frequency of Breaches for Each Barrier Type at Bannerghatta**

| Barrier type | Recorded breach locations | Number of breaches/km |
|---|---|---|
| Solar fence | 30 | 0.35 |
| EPT | 334 | 4.33 |
| Rubble wall | 41 | 2.38 |
| Others | 10 | 4.55 |

**Figure 12: Extent of EPT at BNP**


**Figure 13: Extent of Layers of Protection Through Barriers in Bannerghatta NP**

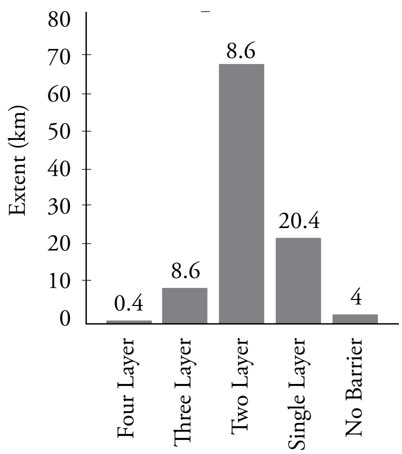
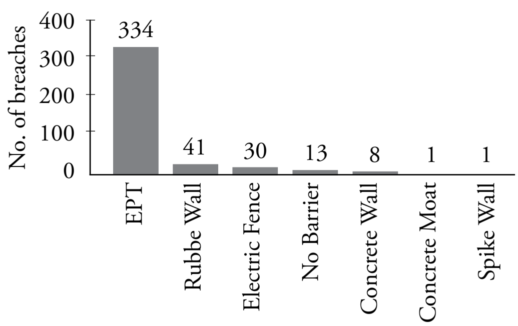



**Figure 14: Barrier-wise Number of Recorded Breaches**



## 4. Framework for Evaluation of Costs and Benefits of Barriers as a Measure to Mitigate Elephant-Human Conflict

The conceptualization of conflict tends to centre around two elements: divergence of interests and incompatibility of actions. The strategy to mitigate elephant-human conflict has typically focused primarily on reducing the scope for incompatible actions. The effort is thus primarily to reduce the scope for interaction between wild elephants and areas with human settlements. This was traditionally achieved by providing both people and elephants their autonomous space. The current emphasis on physical and psychological barriers (we must remember that the electric fence is only a psychological bluff) is a continuation of this approach to mitigating conflict. In order to see whether the costs of effective physical barriers are justified by the benefit of reduced elephant-human conflict, we need to estimate both the costs of physical barriers as well as the benefit of avoiding the costs of elephant-human conflict that have been prevented by the barriers.

In calculating the costs of physical barriers, we need to first take into account the cost of constructing these barriers. These costs will depend on a variety of factors, such as design (for instance, number of stands in an electric fence) and terrain (nature of soil and rock for excavating a trench), but an important consideration for us is the length of the barrier. Our concern here is both the existence of the barrier and its effectiveness. The effectiveness of a barrier is not determined by its length alone. Some terrains may require a longer physical barrier to effectively keep elephants out of human habitations, while other terrains may be able to achieve the same result with shorter barriers. The effectiveness of the barriers would also depend on whether, and how frequently, they have been breached. The breaches need not be made only by elephants. Local people are often dependent on the forests for a variety of needs, from cattle grazing and firewood collection at one end and the pursuit of spirituality at the other extreme. People thus sometimes have reason to breach the barriers too. A detailed survey of breaches in barriers is in the process of being completed, but the evidence collected so far in this study suggests that breaches have a major role to play. A meaningful unit for measuring the value of barriers or fences would then be the cost per kilometre of the barrier as well as the cost of protecting a square kilometre of area.

The area that is to be protected by barriers in Kodagu and Bannerghatta has been defined and calculated in Chapter 2. Given this area, we need to recognise that even within this territory there will be a variation in the intensities of elephant-human conflict. Based on the patterns of this conflict so far, we have developed a spatial map of the likelihood of conflict, thereby generating the probability separately in Kodagu and Bannerghatta. Such probabilities are particularly useful in evaluating the effectiveness of barriers. Without such probabilities, we would have to stick to more absolute measures such as whether the area that has become completely conflict free after since setting up the barriers. But such measures tend to underestimate the effectiveness of physical barriers as they do not provide sufficient importance to a reduction in conflict, even when it is not stopped altogether. Barriers often have the effect of reducing conflict even when they cannot stop them altogether. The probability of conflict, in contrast, takes into account the whole range of possibilities from the impossibility of conflict to a very high probability. Based on our access to long-term data on conflicts, we have, in Chapter 2, calculated the probabilities of conflict in the villages in the defined area before and after the barriers were built. A comparison of these two probabilities gives us a clear idea of the effectiveness of a set of barriers. In making this calculation, it must be recognized that the level of elephant-human conflict is not static over time. Other factors, including the growth in the population of elephants and human encroachments into forests, also play their role. The relevant comparison after the barriers, then, is not with the levels of conflict before the barriers were put up, but with the levels of conflict that would have existed if no action was taken.

Thus, we need to first extrapolate trends in elephant-human conflict to the period after the physical barriers were created and then compare those



The cost of constructing physical barriers depends on a variety of factors, such as design, terrain and length. Its effectiveness depends on the length, terrain, and frequency of breaches. A barrier's value thus depends on both the costs of building and protecting it levels of conflict with what actually exists to capture the effectiveness of the barriers. This probability-based estimate of the effectiveness of the barriers can be used through what we call an efficiency variable. We would normally calculate the cost per square kilometre of the barrier as:

$T = C/A$,

where

T = cost of protecting a square kilometre of area
C = the total cost of building the barrier
A = the total area that is to be protected.

We can now add an efficiency variable, E, to the denominator, so that

$E = A^*(p_o - p_b)$

where

$p_o$ = probability of conflict in the year after the barriers were created, if there had been no physical barrier built
$p_b$ = probability of conflict after the barrier was built
A = the total area that is to be protected.
Adding E to the denominator we get
$T = C/(A + E)$

When the gap between the probabilities before and after the barrier is large, E will be large, thereby raising the denominator as a whole. This, in turn, would reduce the cost per square kilometre of area protected. In contrast, when there is no difference in the two probabilities, E will be zero, and there will be no efficiency contribution to the calculation of the cost per square kilometre of area protected from elephants.

$C/(A + E)$ will then be the costs side of our cost-benefit equation.

### The benefit of reducing elephant human conflict

We have already noted that IUCN defines elephant-human conflict (EHC) as, "any elephant-human interaction which results in negative effects on human social, economic or cultural life, on elephant conservation or on the environment". Implicit in this definition are two important pointers to the direction we need to take. First, it looks beyond simple monetary indicators of the costs of conflict and emphasizes the larger economic, social and cultural context. The evaluation of the benefits must then be in terms of a larger set of ecosystem services. There is thus a case for looking at the economic value of ecosystem services. Second, the definition stresses the negative impact of elephant-human conflict on human well-being. We can then treat elephant-human conflict as a negative ecosystem service. Consequently, the removal of this conflict will be a positive ecosystem service. Our task then is to estimate the costs of elephant-human conflict and treat the reduction of these costs as a positive benefit that can be compared with the costs of creating physical barriers.

When seen in these terms the benefit of preventing elephant-human conflict can be measured in terms of the costs that would have occurred if the conflict continued. Since our focus is on ecosystem services, we need a method of estimating costs that goes beyond its monetary elements. Total Economic Value is a method that can be used to provide the economic value of both the material and non-material elements of human elephant conflict. These values are of importance when making choices related to various strategies of mitigating conflict. It would help us make meaningful trade-offs during the allocation of the extremely limited resources available to address elephant-human conflict, thereby helping us to arrive at the most effective means of reducing this conflict. The economic idea of value has its roots in welfare economics, which advocates that economic value can be seen as an expression of the degree to which a good or service satisfies the preferences of an individual Thus, economic value is a reflection of people's choice and preferences. It is measured by the most somebody is willing to give up in other goods and services, in order to obtain a certain good or service. As this method takes the economic model beyond the material, it can identify different types of economic values neglected by the market. This is of relevance particularly when related to the environment, since many goods and services within an ecosystem have values that are not related to a direct use. The advantage of using a valuation of ecosystems is that it helps assess overall ecosystem contribution to social and economic well-being.

Ecosystem valuation thus involves the making of spending decisions that involve trade-offs in allocating resources. Ecosystem valuation has two major components: ecosystem functions and ecosystem services. Ecosystem functions are the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of an ecosystem. An ecosystem service is considered as any positive benefit that the ecosystem provides to people. Since we have categorized elephant-human conflict as a negative ecosystem service, our focus here is ecosystem services rather than ecosystem functions. The Millennium Ecosystem Assessment of the United Nations identifies four major categories of ecosystem services: provisioning services, or any type of benefit that can be extracted from nature; regulating services, or the benefit provided by an ecosystem process that moderates natural phenomena; cultural services, or non-material services that contribute to the development and cultural advancement of humans; and supporting services, or the fundamental underlying natural processes that sustain ecosystems.

In bringing this general method of evaluation into our study of elephant-human conflict, we have adapted the Total Economic Value method outlined by TEEB (Fisher et al. 2010). As can be seen in Chart 1, a major advantage of this approach is that it looks beyond market values. It does so by taking into account both the use values and the non-use values of ecosystem valuation. Use values are those values associated with goods and services for which market prices exist. These values can relate to those goods and services that currently have an actual value, as well as those that would result from options that are exercised in the future. The actual use value is, in turn, of two kinds, direct and indirect. The direct use value relates to benefits obtained directly from the ecosystem service. For example, with respect to the elephant-human conflict, access to forest produce such as firewood and fruit are benefits obtained directly from the ecosystem. Within the direct value, there is a further distinction, which is between consumptive and non-consumptive. Consumptive elements are those where, after use, the quantity of the good available is reduced. An example of a consumptive element is the damage to crops caused by the elephants. On the other hand, non-consumptive is when the quantity of the good remains the same even after use. An example of non-consumptive direct use values is the presence of the spiritual deity within the forest. Indirect use values are those values associated with regulating services provided by the ecosystem. For example, in the elephant-human conflict, soil fertility due to elephant presence is a regulating service provided by the ecosystem. A final distinction within the use values is a component known as option value. Option values are values that may not currently serve any purpose, but utility may be derived from them in the future. An example of option value is the use of coffee seeds in elephant dung as a special variety of coffee.

In contrast to use values, non-use values are usually related to moral, religious or aesthetic properties, for which markets do not usually exist. Non-use values are values that reflect the satisfaction that individuals derive from knowing that biodiversity exists. Hence, they are a reflection of experiences that occur in the valuer's mind (Christie et al. 2010). Examples of non-use values include the value of knowing that the elephant exists within the ecosystem, as well as the perception of the elephant on religious and cultural grounds.

In moving from the conceptual framework to the situation on the ground, we need to identify variables that capture these different elements. As can be seen from the details in the bottom-most row of Figure 15, there are six elements that contribute to the overall benefit from a reduction in elephant-human conflict: consumptive services, non-consumptive services, indirect uses, option value, bequest value, altruistic value, and existence value. It would be useful to first consider the existing situation before we look at options. At this stage, we can keep aside the variables related to future options and move on to find the empirical indicators of the remaining five ecosystem services.

In the empirical reality of the negative ecosystem services generated by elephant-human conflict there are five main components of consumptive services: damage to crops, damage to property, reduced access to forest produce, reduced access to forest water, and the change in land value. Elephants damage these crops either by trampling on them or by consuming them. Among the major crops damaged, especially in Kodagu, are paddy, coffee, banana, areca nut, cardamom, corn, jackfruit, pepper, sugarcane, sweet potato, and tamarind. This is the most common consumptive element within the elephant-human conflict. The extent of this damage can



There are six elements that contribute to the overall benefit from a reduction in elephant-human conflict: consumptive services, non-consumptive services, indirect uses, option value, bequest value, altruistic value, and existence value be estimated through the compensation amounts paid, which are documented by the forest department. The forest department also maintains records of claims made for property damages. Elephants often damage houses and more when they raid fields with crops in them. In our pilot study, conducted in Virajpet taluk of Kodagu district, it was clear that elephants routinely came very close to the houses. The forest department's records of *ex-gratia* payments can be used to estimate the costs due to these elements. It must be noted that this will be an underestimate of the actual damage to crops and property. This is because the compensation is linked to the ownership of land, and there is considerable lack of clarity about land ownership of the tribals. This was quite evident from conversations with tribals during our pilot study. Nevertheless in the absence of a better indicator of the extent of damage, we will need to stay with the forest department's estimates of compensation. In order to make this figure comparable to the effective costs of physical barriers, the compensation paid in the area that the physical barriers are designed to protect will be calculated per square kilometre of that area. To state it formally,

$C_d = C_p/A$

where

$C_d$ = Consumptive costs due to damage to crops and other property in the area, A

$C_p$ = Compensation amount paid in 2013-14 in area A

A = the total area that is to be protected.

Access to forest produce is known to be an important issue in elephant-human conflict. For each item of forest produce, there was a household survey to first find out the amount of each forest produce that has been reduced due to elephant-human conflict. On the basis of this data, we estimate the total reduction in each forest produce consumed in the six villages of our sample put together, and further, for the entire area that is to be protected by the physical barrier. This cumulative figure is then divided by the total area that is to be protected to arrive at the reduction in the consumption of that particular forest produce due to elephant human conflict. A monetary value can then be attributed to this reduction by using market prices in the case of products that are marketed. In the case of products that are not marketed, such as water, the monetary value is attributed in terms of the travel cost to the alternative source of that product.

Formally,

$d_i$ = Estimated reduction in the consumption of forest product i due to elephant human conflict in the total area to be protected

$r_i$ = price of forest product i in the case of marketed products and the shadow price of non-marketed products

A = the total area that is to be protected.

$D=\sum$ (i=1to n) $d_i r_i/A$ = monetary value of the total reduction in the use of forest products due to elephant-human conflict

The effect of elephant-human conflict on land values can be estimated through hedonic prices, that is, that part of land prices that can be attributed to this conflict. In order to estimate this impact, we compare the price of dry land in the high conflict villages with the price of the same quality of land in the low conflict villages. It is assumed that since the land belongs to the same area, all other factors will be the same, and the difference can be attributed to elephant-human conflict alone.

$L_c$ = price of land of average quality per acre in high conflict villages

$L_n$ = price of land of average quality per acre in low conflict villages

$A_c$ = cultivable land in the area to be protected

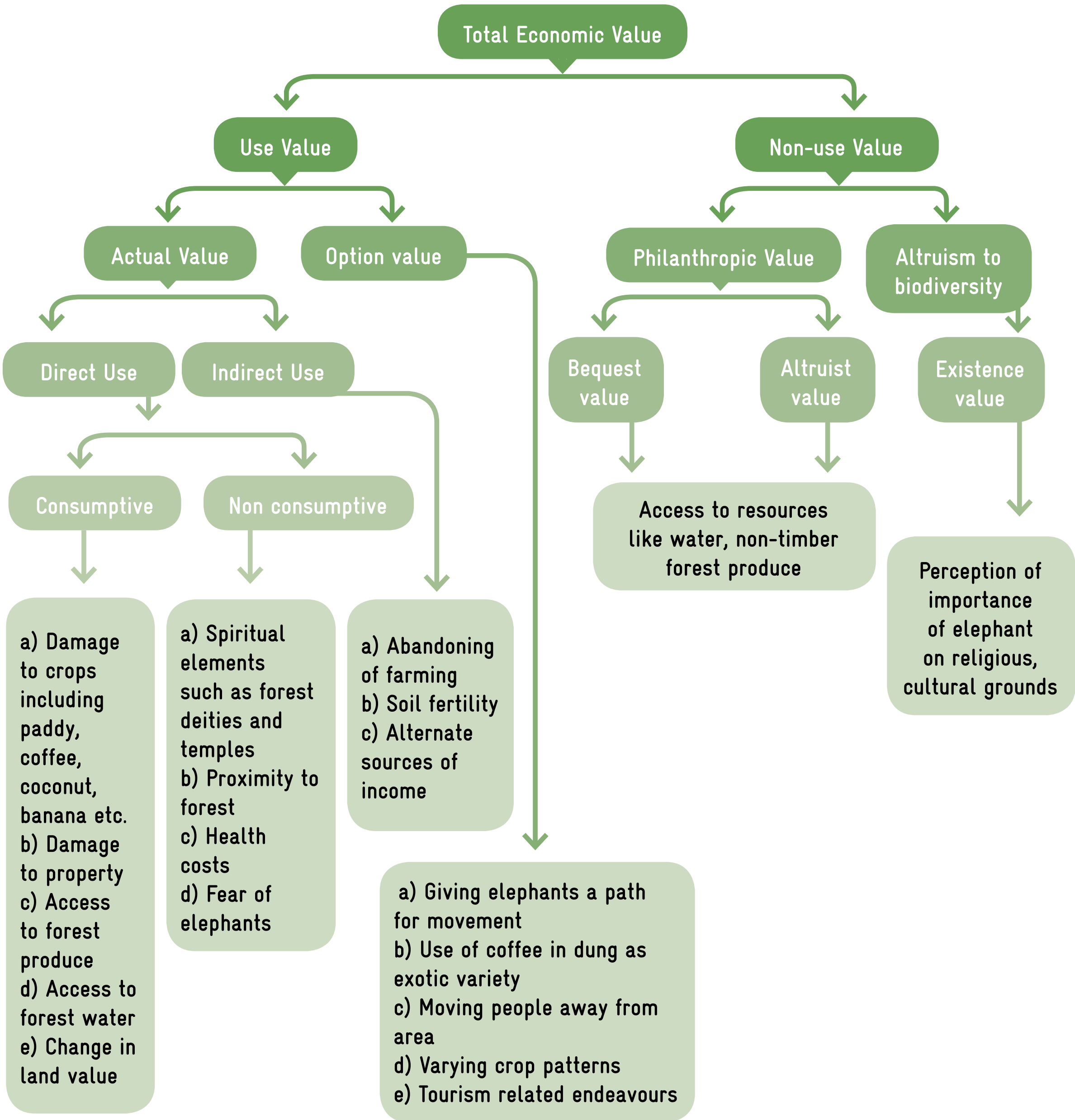
A = the total area that is to be protected

0.00404 is the conversion factor for acres to square kilometres

$L = [(L_n - L_c)^* A_c]^* 0.00404/A$ = loss of land value per square kilometre due to elephant- human conflict

The negative ecosystem service of elephant-human conflict is reflected in four factors: costs of access to spiritual elements within the forest, costs of moving away from a preferred proximity to the forest, costs associated with overall health of people, and fear of elephants. Spiritual elements as a non-consumptive element can be present in the form of a temple or a shrine within the forest. These shrines can be accessed individually or in groups. It is quite possible that the shrines that are accessed in groups are likely to continue being visited even in the presence of elephant-human conflict. The contingent valuation method is used in our study to estimate the number of persons who state their access to forest shrines has been affected by elephants, and the amount they are willing to pay to have uninterrupted access. Using population data for the village, we can first estimate how much the village as a whole is willing to pay for uninterrupted

Figure 15: Components of the Economic Value of Ecosystem Services




access to forest shrines. Population data can be used to further estimate the area to be protected. We can then calculate the amount that people would be willing to pay for uninterrupted access to forest shrines per square kilometre of the area to be protected.

Formally,

$S = s/A$

where

S = amount that people would be willing to pay for the uninterrupted access to forest shrines per square kilometre of the area to be protected.

s = amount people in the area to be protected would be willing to pay for the uninterrupted access to forest shrines

A = the total area that is to be protected

Households that have traditionally lived in close proximity to the forests may want to continue doing so. An increase in elephant-human conflict could exert pressure on the household to move away from the forest. This cost can be estimated using the contingent valuation method, whereby the head of the household is asked what monetary incentive they would require to move away from the forest. Based on the data from the sample households, we can estimate the average amount each household expects to receive in order to move out. This figure can then be multiplied by the total number of households in the area that is to be protected. While employing the contingent valuation method, there is the possibility of overestimating of the measure of the event. This is referred to as upward bias. The National Oceanographic and Atmospheric Administration's (NOAA) blue-ribbon panel recommendation suggested that hypothetical bids from surveys can be calibrated by using a 'divide by two' rule, particularly in cases where actual market data is unavailable (Arrow 1993).

Formally,

$F = (f/A)/2$

where,

F = amount that people would expect to be paid to movedaway from the forest, per square kilometre of the area to be protected.

*f*= amount that people would expect to be paid to be moved away from the forest

A = the total area that is to be protected

The cost of health is also affected by elephant-human conflict in two ways. There is the direct risk of injury from elephants, as well as the indirect effects on health through, say, staying awake at night to protect the land from raiding elephants. Even in cases where inhabitants are eligible for free medical treatment, costs can be incurred just in accessing medical facilities, which are at a considerable distance away from the village. Since the area to be protected is largely similar within the two regions, we can assume that the health risks and the responses to these risks are the same. The difference between the health costs of the villages with conflict and these costs in villages without conflict can then be attributed to the presence of elephant-human conflict. The hedonic price method can be used to determine what percentage of health costs can be attributed to elephant-human conflict. The household survey was used to collect this information. The question is asked only for the preceding two months in order to minimize the recall bias. This figure can then be multiplied by the number of households in the area to be protected. Dividing this amount by the area in square kilometres will give us the health cost due to elephant-human conflict per square kilometre of the area to be protected.

Formally,

$h_c$ = health cost per household in high conflict villages

$h_n$ = health cost per household in low conflict villages

o = number of households in the area to be protected

$H = [(h_n - h_c)*o]/A$ = health cost per square kilometre due to elephant-human conflict

We had earlier identified three major indirect use values that were impacted by elephant-human conflict: abandonment of farming, change in soil fertility, and the tapping of alternate sources of income. In terms of the effects on the family's income, the abandonment of farming and the tapping of alternative sources of income by those who have abandoned farming must be taken together. We need to then consider the net effect on family income of these two factors. The data to do so is generated from the household survey. First, the amount of land that has been left fallow due to the elephant-human conflict is obtained. The earnings from this the last time it was cultivated is the loss due to the conflict. Further, if the people working on the land have new occupations, that income is subtracted from the earnings of land abandoned to give us the loss per household due to the elephant-human conflict. We can then estimate the average loss or gain in earning per household as a result of elephant-human conflict. As done in the case of health costs, we can then estimate the costs, per acre of area to be protected, of the change in economic activity.

Formally,

a = earnings per household from land abandoned due to elephant-human conflicts the last time it was cultivated

g = earnings per household from new occupations of members of the household who were previously working on the land on which farming is now abandoned

$N = [(a - g_c)*o]/A$ = Loss or gain in earnings per square kilometre due to elephant-human conflict

Three factors are present within the non-use value element of ecosystem valuation. These are bequest value, altruistic value and existence value. Bequest value is a form of intergenerational equity concerns and involves knowing that individuals from future generations will have access to the benefits provided by the elephant and the ecosystem it lives in. On the other hand, altruistic value is a form of intergenerational equity concern that involves knowing that other people from the same generation have access to the benefits provided by the

Asking households 'If you have to spend your own money to keep the elephants away, how much would you be willing to pay?' allows estimation of average household willingess to pay for barriers

elephant and its ecosystem. Existence value is regarded as the satisfaction of knowing that the elephant and its ecosystem exist.

When capturing these values in a questionnaire, we must remember that while these three factors are conceptually separate, it will be difficult to expect the respondent to isolate each of them when using contingent valuation. The answer to the question of what cost a respondent will be willing to pay to be free of elephants will be a combination of all three. In addition, the answer to this question will also take into account the respondent's fear of elephants. While the bequest, altruistic and the existence values will be positive, the fear of elephants will have a negative effect. The contingent valuation will then be of the net effect of all these factors taken together. For example, the fear of the elephant may be so high so as to want to kill it, but the religious and cultural perception of the elephant will stop one from doing so.

Fear of elephants as a non-consumptive element is used to gauge to what extent the presence of elephants is seen as undesirable by the population. Direct quantitative data on the same is difficult to accept, and hence the contingent valuation method is used to put an economic value on the fear of elephants. The data is obtained using a household survey and the questionnaire frames the question as, 'If you have to spend your own money to keep the elephant away, how much would you be willing to pay?' Based on the data from the sample households, we can estimate the average amount each household is willing to pay. This figure can then be multiplied by the total number of households in the area that is to be protected.

Formally,

$G = g/A$

where,

G = amount people would be willing to pay to keep elephants away from their land per

square kilometre

g = amount that people would be willing to pay to keep the elephant away from their land

A = the total area that is to be protected

Once the above variables are calculated, it would be possible to arrive at the total benefits from the removal of elephant-human conflict. It must be remembered that these calculations derive the entire benefit possible if elephant-human conflict is reduced to zero. In reality, this is not the case. We must then only take that proportion of the benefits that would accrue to the area from the actual reduction in elephant-human conflict. We could calculate this reduction in terms of the probabilities of an incident of elephant-human conflict occurring on a particular day in a particular village in the region. Since the objective is a zero probability of elephant-human conflict, the task is to move from the probability before the fencing to a zero probability. As we had mentioned at the outset, since the levels of elephant-human conflict are not static, the relevant comparison is not with the probability before the physical barriers were constructed, but with the probability that would have existed had there been no physical barriers. The difference between this, extrapolated as if there were no physical barriers, and the probability after the physical barriers, as a fraction of the extrapolated probability, would give us an estimate of the proportion of the task that has been completed. This difference as a proportion of the extrapolated probability will give us the proportion of the benefits that must then be taken into account.

Formally,

$B = b^*[( po - pb)/ po]$

where

B = Benefits adjusted for changing levels of protection

b = Benefits if elephant-human conflict was completely removed = Cd+D+L+S+F+H+N+G

$p_o$ = probability of conflict in the year after the physical barriers were created if there had been no physical barrier built

$p_b$ = probability of conflict after the physical barrier was built

Based on these inputs we can now

Thus, as established before, we need to estimate whether

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the costs of effective physical barriers are justified by the benefit of reduced elephant-human conflict.

Formally,

(Benefits of reduced elephant-human conflict/ Costs of effective physical barriers) > 1

$\frac{B}{T} > 1$

Where

B = Benefits adjusted for changing levels of protection

T = the cost of protecting a square kilometre of area

Incorporating the formal element for each of these factors, we get

{(Cp/A)+(∑ (i=1to n) diri/A) +{[(Ln – Lc)* Ac ]* 0.00404/A}+(s/A)+(f/A)+ {[(hn – hc)*o]/A]}+ {[(a –gc)*o]/A}+(g/A)}/ {C/(A + A*(po – pb)}> 1

Where

$C_p$ = Compensation amount paid in the relevant year in the area, A

A = the total area that is to be protected

$d_i$ = Estimated reduction in the consumption of forest product i due to elephant-human conflict in the total area to be protected

$r_i$ = price of forest product i in the case of marketed products and the shadow price of non- marketed products

$L_c$ = price of land of average quality per acre in villages with elephant-human conflicts

$L_n$ = price of land of average quality per acre in villages without elephant-human conflicts

$A_c$ = cultivable land in the area to be protected

0.00404 is the conversion factor for acres to square kilometres

s = amount people in the area to be protected would be willing to pay for the uninterrupted access to forest shrines

f = amount that people would expect to be paid to be moved away from the forest

hc = health cost per household in villages with elephant-human conflicts

hn = health cost per household in villages without elephant-human conflicts

o = number of households in the area to be protected

a = earnings per household from land abandoned due to elephant-human conflicts the last time it was cultivated

g = earnings per household from new occupations of members of the household who were previously working on the land on which farming is now abandoned.

## 5. Benefit Cost Ratio of Barriers as a Means of Reducing Elephant-Human Conflict in Kodagu and Bannerghatta

In taking the framework outlined in the previous chapter to the reality in Kodagu and Bannerghatta, the calculation of the costs component of the Cost-Benefit ratio is relatively straightforward. The costs of fencing in both areas have been obtained from the forest department records. The area expected to be protected by the fences in the two areas have already been calculated in Chapter 2. That chapter also provided us with the probabilities of the occurrence of conflict on a particular day in a particular village in the two areas before and after the physical barriers. Chapter 4 also emphasized the need to compare the later probabilities with an extrapolation of the earlier probabilities so as to take into account the larger trends that would have occurred if the physical barriers had not been there.

In calculating the relevant probabilities, the first task is to estimate the value in the first year after the barriers were created as an extrapolation of the earlier trend. In Kodagu, the average of the growth rates in the three years between 2004 and 2007 was 0.887. Compounding this growth rate for 4 years we have an extrapolation of the probability of elephant-human conflict on a particular day in a particular village in the region for 2011, which is 0.431. The actual probability after the construction of the barriers in Kodagu was 0.029. Since the increase in the instances of elephant-human conflict in Bannerghatta in the years before the physical barriers were set up was marginal, the probability in the year before the barriers was taken to be the same as the probability in the year soon after the barrier was set up, that is, 0.00347. The probability after the creation of physical barriers was 0.00097.

We can now substitute the values in the equation

T = C/ (A + E)

For Kodagu,

The total cost of the physical barriers (C) = 94327000

Probability of conflict if barrier did not exist ($p_o$) = 0.431

Probability of conflict post-barrier ($p_b$) = 0.0288

Area to be protected in Kodagu (A) = 1096 sq km

Thus E= A*($p_o$ – $p_b$) = 1096(0.43149-0.02878) = 441.37 sq km

Therefore,

T= C/ (A+E) = 94327000/ (1096+441.37) = 94327000/1537.37= 61356.1 per sq. km for Kodagu

In the case of Bannerghatta,

The total cost of the physical barriers (C) = 59382000

Probability of conflict if barrier did not exist ($p_o$) = 0.00347

Probability of conflict post-barrier ($p_b$) = 0.00097

Area to be protected in Bannerghatta= 742

Thus, E= A*($p_o$ – $p_b$) = 742(0.00347-0.00097) = 1.855 sq km

T= C / (A+E) = 59382000/ (742+1.855) = 79830.1 per sq. km for Bannerghatta

Overall T= T (Kodagu) +T (Bannerghatta) = 61356.1+79830.1= 141186.2 per sq. km

### 5.1. Ecosystem services and benefits of reducing elephant-human conflict

The other side of the equation captures the benefits of reducing elephant-human conflict by estimating the value of ecosystem services delivered by elephant-human conflict. As the movement from a conceptual framework into an on-ground reality occurs, each of the variables that capture different elements of elephant-human conflict must be estimated. These variables have been defined in the methodology chapter and are calculated as follows:

#### 5.1.1. Consumptive costs due to damage to crops and property:

Consumptive costs, which are the most common type of damage incurred because of the conflict, are estimated using the records maintained by the forest department.

The formal method for estimating damage to crops is:

$C_d$ = Cp/A

$C_d$ = Consumptive costs due to damage to crops and other property in the area, A

$C_p$ = Compensation amount paid in 2013-2014 in the area, A

A = the total area that is to be protected

For Kodagu,

$C_p$ = 5930755

A= 1096 sq. km

**Table 8: Consumptive costs due to damage to crops and other property in the defined area**

| Area | Consumptive costs due to damage to crops and other property in the area (Cd) |
|---|---|
| Kodagu | 5411.3 |
| Bannerghatta | 213.5 |

Source: *Ex-gratia payment records of Karnataka Forest Department in 2013-2014*

Hence, Cd =5930755/1096= 5411.27 per sq. km

For Bannerghatta,

$C_p$ = 158415 (Source: Ex-gratia payment made by the forest department in the year 2013-2014)

A= 742 sq. km

Hence, Cd= 158415/742= 213.50 per sq. km

Thus, overall damage to crops in the two areas taken together,

$C_d$ (Total) = 3312.9 per sq. km

The results are as seen below: Table 8

The data obtained from the forest division of Kodagu and Bannerghatta shows that the consumptive damage per sq. km is more for the area under study in Kodagu than in Bannerghatta. This is largely because of the nature of damaged crops in Kodagu and Bannerghatta. The most commonly damaged crop in Kodagu is coffee, which is a cash crop, while the most commonly damaged crops in Bannerghatta are food crops. The ex-gratia payment for coffee is higher than for any of the other crops. The field study also shows that in Bannerghatta, larger swaths of land have been left fallow, as a result of which, claims for damage to crops in Bannerghatta will be lesser than in Kodagu.

##### 5.1.1.1. Access to forest produce:

This element estimates the reduction in the usage of forest produce as a result of elephant-human conflict. The reduction in forest produce usage is then multiplied with the cost price of the produce to estimate the total costs of reduction.

Formally,

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The nature of crops affects the consumptive damage per $km^2$. The consumptive damage was greater in Kodagu where primarily coffee (cash) crops were damaged, compared to Bannerghatta, where primarily food crops were damaged

Only the high conflict villages in Kodagu show reduction in use of forest produce as a result of elephant-human conflict. In Bannerghatta, where access to the forest in any form is completely illegal, there there was no change in the use of forest produce

$d_i$ = Estimated reduction in the consumption of forest product 'i' due to elephant human conflict in the total area to be protected

$r_i$ = price of forest product 'i' in the case of marketed products and the shadow price of non-marketed products

A = the total area that is to be protected.

D =∑ (i=1to n) $d_i r_i$/A = monetary value of the total reduction in the use of forest products due to elephant-human conflict

In Kodagu,

The only produce that is accessed from the forest is firewood. Based on the survey data, di= 1264369 kilos

$r_i$= ₹2 per kilo

A= 1096 sq. km

Therefore, D= (1264369.05*2)/1096= 2307.2 per sq. km

In Bannerghatta,

There is no forest produce accessed by the population, and as a result, di=0

**Table 9: Value of Total Reduction in Use of Forest Produce Due to Elephant-Human Conflict in the Defined Area**

| Area | Monetary value of the total reduction in the use of forest products due to elephant-human conflict (D) (in ₹/sq km) |
|---|---|
| Villages in Kodagu with high intensity conflict | 2,307 |
| Villages in Kodagu with low intensity conflict | 0 |
| Villages in Bannerghata with high intensity conflict | 0 |
| Villages in Bannerghata with low intensity conflict | 0 |

Source: *ANCF field survey, 2015*

Therefore, D=0

Therefore, the total reduction across both areas is,

D (Total) = ₹2,307.24 per sq. km

The results for individual regions are in Table 9.

As the Table 9 shows, only the high conflict villages in Kodagu show reduction in use of forest produce as a result of elephant-human conflict. The only produce that is accessed is firewood and all the households that showed a reduction in the usage of firewood were tribal households. As has been established earlier, the presence of elephant-human conflict is pushing the tribals who were living inside the forest to the periphery of the forest, and these are the villages that have high levels of conflict. In Bannerghatta, on the other hand, the tribal population is very low, and access to the forest in any form is completely illegal after the declaration of Bannerghatta as a national park.

#### 5.1.1.2. Loss of Land Value

The hedonic pricing method can be used to gauge if the elephant-human conflict has any effect on the price of land. The data for the land prices is obtained from the sub-registrar's office for the particular area. The prices of dry land are compared in the villages with high conflict and low conflict. The total area under cultivation is estimated by averaging the total cultivable area for the households surveyed and multiplying that area with the number of households in the area to be protected.

Formally,

$L_c$ = price of land of average quality per acre in high conflict villages

$L_n$ = price of land of average quality per acre in low conflict villages

$A_c$ = cultivable land in the area to be protected

A = the total area that is to be protected

0.00404 is the conversion factor for acres to square kilometres

L = [($L_n$ – $L_c$)* $A_c$ ]* 0.00404/A = loss of land value per square kilometre due to elephant-human conflict

For Kodagu, $L_n$= 255000

$L_c$ =220000

$A_c$= 216229.5 sq. km

A= 1096 sq. km

Therefore, L= [(255000-220000) *216229.5 *0.00404]/1096= 27896.8 per sq. km for Kodagu

For Bannerghatta, $L_n$= 533333

$L_c$ = 533333

$A_c$= 86007 sq. km

A=742 sq. km

L= [(533333-533333)*86007.04*0.00404]/742= 0 for Bannerghatta

For the two areas defined taken together, L (Total) = 27896.8 per sq. km

The results tabulated region-wise are as follows: (Table 10)

The hedonic pricing method used for estimation of difference in land prices shows that in Kodagu, a part of the difference in land prices can be accounted for by the presence of elephant-human conflict. In Bannerghatta on the other hand, the data shows that no part of the prices of land can be attributed to the elephant-human conflict.

#### 5.1.1.3. Access to Shrines Within the Forest

The presence of shrines within the forest takes the form of a non-consumptive ecosystem service and the contingent valuation method can be used to estimate what costs are associated with continued access to the shrine.

Formally, S = s/A

Where,

S = amount that people would be willing to pay for the uninterrupted access to forest shrines per square kilometre of the area to be protected.

s = amount people in the area to be protected would be willing to pay for the uninterrupted access to forest shrines

A = the total area that is to be protected

In both Kodagu and Bannerghatta, there was no shrine accessed within the forest by the population. In Bannerghatta, all forms of access are illegal and hence nil. The field study shows that in Kodagu, also, there is no presence of a shrine or deity within the forest. Hence, the costs associated with this element in both Kodagu and Bannerghatta are zero.

Therefore, S=0 for Kodagu and Bannerghatta. Thus, S (Total) = 0.

#### 5.1.1.4. Proximity to Forest:

The presence of conflict is higher near the forest and begins to reduce away from the forest, but households that have traditionally lived in close proximity to the forests may want to continue doing so. The contingent valuation method can be used to estimate people's preference to stay in their current location.

**Table 10: Loss of Land Value Per Square km Due to Elephant-Human Conflict**

| Area | Loss of land value per square kilometre due to elephant-human conflict (L) (in ₹/sq Km) |
|---|---|
| Kodagu | 27,897 |
| Bannerghatta | 0 |

Source: *Data obtained from respective sub-registrar office*

Formally,

F = (f/A)/2

Where,

F = amount that people would expect to be paid to be moved away from the forest, per square kilometre of the area to be protected.

f= amount that people would expect to be paid to be moved away from the forest

A = the total area that is to be protected

In Kodagu,

The question involving proximity to the forest raised a lot of objections in Kodagu, as it was viewed by the people as an effort to relocate them from their land. In a majority of the households surveyed, the respondents said that they were unwilling to move. For the purpose of calculation, the unwillingness of the people to move has been taken as a high cost, viz. ₹2.5 crores.

**Table 11: Amount that People Would Expect to be Paid to be Moved Away from Forest in the Two Areas Defined**

| Area | Amount (in ₹) that people would expect to be paid to be moved away from the forest, per square kilometre of the area to be protected (F) |
|---|---|
| Villages in Kodagu with high intensity conflict | 106.8 crores |
| Villages in Kodagu with low intensity conflict | 346.2 crores |
| Villages in Bannerghata with high intensity conflict | 131.6 crores |
| Villages in Bannerghata with low intensity conflict | 138.1 crores |

Source: *ANCF field survey, 2015*

Thus, f = 4965618166883

A = 1096 sq. km

Therefore, F= ((4965618166883.28 /1096))/2 = 2265336755 per sq. km

In Bannerghatta,

There was an unwillingness to move in Bannerghatta as well by a majority of the households, so for the purpose of calculation, this has also been taken as ₹2.5 crores.

Thus,

f= 2001605546733

A= 742

Therefore, F= ((2001605546732.54 /742))/2 = 1348790800 per sq. km

For the region taken as a whole,

F (Total) = 1807063777 per sq. km

The differences between responses in the two areas in the high conflict and low conflict villages are as shown: (Table 11)

The single trend observed across regions and across both highly-conflicted and less -onflicted villages, was that there is a strong opposition to movement away from the current location. Thus, the costs associated with moving people away from the area are substantially higher. It is worth noting, however, that the two regions in consideration have shown declining trends in population, which means that there is movement away from the area. Thus, the people who wanted to move away have already done so, and the field study is largely focusing on people who do not want to move. It is observed that the costs of movement in the highly conflicted villages in Kodagu are substantially lower than that in the villages with low conflict.

If we were to consider variations within the conflicted villages, certain households are willing to move at no cost, and this can be attributed to the presence of conflict. The costs involved in moving people away from Bannerghatta are substantially lower than the costs involved in Kodagu. The census data for Bannerghatta has shown that there is movement away from high conflict villages to low conflict villages, and this is reflected in the difference in prices for high conflict and low conflict villages.

#### 5.1.1.5. Health Costs

Since the area to be protected is largely similar within the two regions, we can assume that the health risks and the responses to these risks are the same. The difference between the health costs of the villages with high conflict and these costs in villages with low conflict can then be attributed to the presence of elephant-human conflict. The hedonic price of human elephant conflict can then be calculated by taking the difference between the high and low conflict villages.

Formally,

$h_c$ = health cost per household in villages with high conflict

$h_n$ = health cost per household in villages with low conflict

o = number of households in the area to be protected

$H = [(h_n - h_c)*o]/A$ = health cost per square kilometre due to elephant-human conflict

After using the household survey to estimate the costs involved with health per household, a regression analysis was carried out, with presence of conflict as an independent variable, and health costs incurred as a dependent variable. The results of the regression are as follows: (Table 12)

From the regression analysis of the coefficients, we see that the regression is not significant in either Kodagu or Bannerghatta. Thus, no part of the health costs incurred can be attributed to the elephant-human conflict. The costs associated with health because of elephant- human conflict are taken as zero in Kodagu and in Bannerghatta.

As a result, the health costs in the overall area are also zero.

Abandonment of farming and alternate sources of income:

As an indirect effect of the elephant-human conflict, the loss of family earnings and the tapping of alternate sources of income are taken together to see what effect the conflict has on the household's overall income.

Formally,

a = earnings per household from land abandoned

No part of health costs incurred were attributable to the elephant-human conflict. The costs associated with health because of elephant-human conflict are taken as zero in both Kodagu and Bannerghatta

**Table 12: Regression Results of Health Costs and Intensity of Conflict**

| Area | Independent variable | Dependent variable | Beta value | Significance |
|---|---|---|---|---|
| Kodagu | High conflict | Costs incurred on health | -0.100 | 0.182 |
| Bannerghatta | Low conflict | Costs incurred on health | 0.062 | 0.409 |

Source: *ANCF field survey, 2015*

due to elephant-human conflicts the last time it was cultivated

g = earnings per household from new occupations of members of the household who were previously working on the land on which farming is now abandoned

o= number of households in the area to be protected

N = [(a $-g_c$)*o]/A = Loss or gain in earnings per square kilometre due to elephant-human conflict

For Kodagu, a= 5777.8

g= 3111.1

o= 50595

A= 1096 sq. km

N= [(5777.78-3111.11)*50595]/1096= 123102 per sq. km

For Bannerghatta, a= 25788.9

g= 0

A= 742

N= [(25788.88-0)*42368]/742= 1472488 per sq. km Thus, for the combination of the two areas defined, N (Total) = 667869

For a tabular form for individual areas, (Table 13)

The field study reveals that the loss in earnings per square kilometre due to the conflict is more in Bannerghatta than in Kodagu. Within Bannerghatta, even villages with lower intensities of conflict have suffered losses in earning due to the conflict. The field study also reveals that while there is some form of alternate income in Kodagu, no household has an alternate source of income in Bannerghatta. Large parts of land have been left fallow in Bannerghatta, but there is no movement away from agriculture. Another interesting aspect that emerged from the field study is that some villages in Bannerghatta that have high levels of conflict have shifted to Mulberry cultivation. This has happened over the last few years and has been attributed to the elephant-human conflict.

### 5.1.1.6. Fear of elephants

As described in a previous chapter, the contingent valuation method used to determine the fear of elephants will be a net effect of non-use values including altruistic, bequest and existence, along with the fear of elephants.

Formally, G = g/A

Where,

G = amount people would be willing to pay to keep elephants away from their land per square kilometre

g = amount that people would be willing to pay to keep the elephant away from their land

A = the total area that is to be protected

For Kodagu, g= 529054713

A= 1096

G= 529054712.7/1096= 482714 per sq. km for Kodagu

For Bannerghatta, g= 89679074.56

A= 742

G= 89679074.56/742= 120861.3 per sq. km for Bannerghatta

For the two areas taken together

G (Total) = 336634.3 per sq.km

The variations across regions are as shown below: (Table 14)

The data shows that the amount that people are willing to pay to keep the elephant away is substantially higher in Kodagu than in Bannerghatta. Within Kodagu and Bannerghatta, villages with higher levels of conflict

**Table 13: Loss in Earnings Due to Elephant-Human Conflict in the Areas Defined**

| Area | Loss in earnings (in ₹) per square kilometre due to elephant-human conflict (N) |
|---|---|
| Villages in Kodagu with high intensity conflict | 1.23 lakhs |
| Villages in Kodagu with low intensity conflict | 0 |
| Villages in Bannerghata with high intensity conflict | 10.2 lakhs |
| Villages in Bannerghata with low intensity conflict | 4.5 lakhs |

Source: *ANCF field survey, 2015*

Depending on village location and the intensity of conflict, people were willing to pay between ₹7,693 and ₹4.7 lakh to keep elephants from their land per km$^2$

are willing to pay more than villages with lower levels of conflict.

The localized nature of the elephant-human conflict and the distribution of households, particularly in Kodagu meant that within the villages, there was a stark contrast in the amounts that households were willing to pay.

### 5.1.2. Final Equation

After the calculation of each of the individual variables, the final equation takes the form of:

$$\frac{(Cd + D + L + S + F + H + N + G) * [( po - pb)/ po]}{T}$$

For Kodagu,

$$\frac{(5411.3 + 2307.2 + 27897 + 0 + 2265336755 + 0 + 123102 + 482714) * 0.9333}{61356.1}$$

Therefore, B/T= 34468

For Banneghatta,

$$\frac{(213.50 + 0 + 0 + 0 + 1348790800 + 0 + 1472488 + 120861) * 0.7204}{79830.1}$$

Therefore, B/T= 12186

Overall,

$$\frac{(3312.9 + 2307.2 + 27896.8 + 0 + 1807063777 + 0 + 667869 + 336634) * 0.9316}{141186}$$

Therefore B/T= 11923

The equation is sensitive to each of the factors, and the variable involving proximity to the forest has a tendency to scale up the numerator substantially. Considering that the people who wanted to move have already moved away from the villages, and that a majority of those who are left behind are unwilling to move, the equation can be modified by dropping the proximity-to-forest variable.

Thus,

For Kodagu,

$$\frac{(5411.3 + 2307.2 + 27897 + 0 + 0 + 0 + 123109 + 482714) * 0.9333}{61356}$$

Therefore, B/T= 9.75

For Bannerghatta,

$$\frac{(213.50 + 0 + 0 + 0 + 0 + 0 + 1472488 + 120861) * 0.7204}{79830.1}$$

Therefore, B/T= 14.38

Overall,

$$\frac{(3312.9 + 2307.2 + 27897 + 0 + 0 + 0 + 667869 + 336634) * 0.9316}{141186}$$

Therefore, B/T= 6.85

**Table 14: Amount that People are Willing to Pay to Keep Elephants Away in the Area Defined**

| Area | Amount people would be willing to pay (in ₹) to keep elephants away from their land per square kilometre (G) |
|---|---|
| Villages in Kodagu with high intensity conflict | 4.7 lakhs |
| Villages in Kodagu with low intensity conflict | 7,693 |
| Villages in Bannerghata with high intensity conflict | 1.05 lakhs |
| Villages in Bannerghata with low intensity conflict | 15,924 |

Source: *ANCF field survey, 2015*

## 6. Conclusions and Recommendations

In interpreting the Benefit-Cost ratios of barriers to keep elephants away from human settlements and agriculture, it is important to consider how sensitive the ratios are to the extent to which we are willing to take into account ecosystem services. If we were to go by the material elements alone, the benefits would be largely confined to the consumptive costs that would be saved. In such an equation the costs of barriers, even after adjustment for effectiveness, vastly exceeds the benefit in terms of savings due to a reduction in elephant-human conflict. The consumptive cost per square kilometre in the areas in Bannerghatta and Kodagu that were expected to be protected by the barriers was ₹3313. This entire figure cannot be taken as a benefit, as the elephant-human conflict has not disappeared. The saving on consumptive costs is then very small when compared to the costs per kilometre of effective physical barriers, ₹82,463. Once we take ecosystem services into account, the picture is dramatically reversed. It could be argued that this reversal has been driven by the very high values given to the proximity to the forest in the contingent evaluation, as people are not willing to move from the area. But even if we drop this variable, the benefit from other ecosystem services per square kilometre due to a reduction in elephant-human conflict is vastly greater than the costs.

The nature of the relationship between benefits and costs is also region-specific. The consumptive costs are much lower per square kilometre in Bannerghatta than in Kodagu. This is largely due to two factors, both related to the difference between a plantation crop and a crop that can be grown several times a year. First, in the case of long-lasting plantation crops, the option of responding to the threat of elephants by abandoning cultivation is minimal. The occurrence of some loss due to elephants year after year is then quite possible. The cultivation of rice and other crops, on the other hand, can be stopped more easily, and the land left fallow. In such cases, where there is no crop grown, there is no crop loss in terms of the payment of compensation. Second, the crops grown in Kodagu, particularly coffee, are more expensive. Thus, the loss in monetary terms of a raid by elephants would be higher.

The fear of elephants is also much greater in Kodagu than in Bannerghatta. People in the areas that the physical barriers were expected to protect in Kodagu were willing to pay a much higher price to be free of the possibility of an attack by elephants than those residing in a similar area in Bannerghatta. This could be because the intensity of conflict – as reflected in the probability of an incident with an elephant on a day in a village – is much higher in Kodagu than in Bannerghatta. This difference in the level of fear is also reflected in the willingness to move out of the region. A far greater number of respondents were willing to move out of Kodagu than Bannerghatta. This must of course also be seen in the context of the fact that Bannerghatta's proximity to Bengaluru would give respondents in that area a reason to take into account the possibility of an increase in real estate values.

Recommendations for mitigation of elephant-human conflicts should take into consideration the ecological basis of conflict as well as social, political and economic considerations. As the focus of this study is the economic dimensions of conflict mitigation measures, the following preliminary recommendations are confined to this aspect.

The benefits from ecosystem services due to reduction of elephant-human conflict are much greater than the cost of the barriers created for this purpose. Thus, there is a case to be made for increase in the presence of effective barriers as a long-term measure for mitigating elephant-human conflict. In both Bannerghatta and Kodagu, the benefit-cost ratios are high, thereby indicating that the presence of barriers is acting as a useful mitigation measure. However, in spite of this, it is useful to note the differences in the equation for Kodagu and Bannerghatta. This highlights that barriers themselves need to be looked at, keeping it area- or region-specific. In particular, the high failure rates of trenches in high rainfall areas, such as the Brahmagiris in the west (not covered in this study), and costs of maintenance could, lower the benefit-costs of this method. Concrete structures along trenches to plug gullies and streams would also push up the costs considerably and alter benefit-cost ratios; this factor could not be evaluated in this short study. Similarly, we



Reducing elephant-human conflict yields high benefit-cost ratios in both Bannerghatta and Kodagu. The presence of effective barriers may therefore be a useful long-term measure for mitigating elephant-human conflict

The cost of barriers should be looked at relative to their effectiveness in reducing the probability of conflict. Since the barriers are designed to protect a specific area, the area being protected should be the defining factor in judging their effectiveness

would caution against the large-scale adoption of the very expensive railway tracks as a mechanical barrier all across the region. The use of this barrier needs more observation and analysis and, to be profitable, may have to be confined to certain parts of Kodagu and to Bannerghatta NP, where it can be combined with high value tourism to enhance benefit-cost ratios.

The barriers should be continuously monitored and repaired in a timely manner when breaches occur. Barriers should not be looked at in isolation, but along with other mitigation techniques, such as elephant capture, translocation, etc.

The cost effectiveness of the barriers should be looked at relative to their ability to reduce the probability of conflict. Since the barriers are designed to protect a specific area, it is useful to view the area to be protected as the defining factor in judging their effectiveness. This also shifts the focus away from looking at the cost of the barrier in terms of the length of the barrier erected, to evaluating cost effectiveness in terms of the area to be protected. Thus, the probability of conflict in the specific area concerned before and after the erection of the barrier serves as a useful method of looking at the cost effectiveness of physical barriers. The probabilities of conflict and the cost effectiveness of the physical barrier are both area-specific and are subject to variation across the two regions.

The possibility of giving elephants specific paths for movement in the Kodagu district in order to maintain gene flow can also be looked at, along with the potential of tourism as an income-generating mechanism in the areas affected by conflict in this district.

A shift towards crops not preferred by elephants (such as mulberry) is an option that should be further explored with the help of agroeconomists. This was noticed particularly in Bannerghatta, where respondents from the villages with high intensities of conflict stressed that the shift to mulberry cultivation happened as a result of elephant-human conflict, and that mulberry leaves were not eaten by elephants. The household survey conducted tried to gauge the loss in earnings from agricultural land due to the elephant-human conflict. In Bannerghatta, large swathes of land have been left fallow as a result of elephant-human conflict and, in its place, mulberry cultivation is taking place on a small scale. Since elephants do not consume the mulberry leaves, the cultivation has continued unhindered. Respondents also said that since the mulberry is cultivated in one corner of the land, the elephants do not cause much damage by trampling on them either.

We will be continuing our more comprehensive studies on elephant-human conflicts that also take ecology and the direct ecosystem services provided by elephants and their natural habitats. These studies will be reported in future reports and journal papers. At the same time, our detailed boundary surveys, conducted to document precisely the locations of barrier breaches (data not presented here), will be provided to the state forest department for action, to enable the department to plug these gaps more effectively and contain the elephants within their natural forested habitats to the extent possible. We are also in the process of preparing a detailed landscape-level plan for the conservation and management of the elephants of these regions.

## REFERENCES


- Arrow, J.K., R. Solow, P.R. Portney, E.E. Leamer, R. Radner, and H. Schumand (1993). Report of the NOAA Panel on Contingent Valuation to the General Council of the US National Oceanic and Atmospheric Administration. Resources for the Future: Washington DC.
- Balasubramanian, M., Baskaran, N., Swaminathan, S. & Desai, A.A. (1995) Crop raiding by Asian elephants (*Elephas maximus*) in the Nilgiri Biosphere Reserve, South India. In: A Week with Elephants, pp. 350-367 (Eds. J.C. Daniel and H. Datye). Bombay Natural History Society and Oxford University Press, Bombay.
- Bist, S.S. (2002). An overview of elephant conservation in India. The Indian Forester 128, 121-136.
- Blair, J.A.S., Boon, G.L. & Noor, N.M., (1979). Conservation or cultivation: the confrontation between the Asian elephant and land development in peninsular Malaysia. Abstract of Land Development Digest 2(1), 25-58.
- Chaudhuri, K. (2004) Rapid survey of human-elephant conflict & elephant mortality in North Bengal. Wildlife Protection Society of India, New Delhi, India.
- Christie, M., de Groot, R. , Kumar , P , Sukhdev , P , van Beukering , P , Brander , L , Christie , M , Crossman , N , Ghermandi , A , Hein , L , Hussain , S , Pitt , D , van der Ploeg, S, Portela , R , Rodriguez , L & Kumar , P (eds.) (2010). The Economics of Ecosystems and Biodiversity: The Ecological and Economic Foundations (TEEB D0). Taylor & Francis. Chapter 5, pp 16.
- Dublin, H.T. & Hoare, R.E. (2004) Searching for solutions: the evolution of an integrated approach to understanding and mitigating human-elephant conflict in Africa. Human Dimensions of Wildlife 9, 271-278.
- Fernando, P., Wikramanayake, E., Weerakoon, D., Jayasinghe, L.K.A., Gunawardene, M. & Janaka, H.K. (2005) Patterns and perceptions of human-elephant conflict in old and new settlements in Sri Lanka: insights for mitigation and management. Biodiversity and Conservation 14, 2465-2481.
- Hoare, R. E. (1999) Determinants of human-elephant conflict in a land-use mosaic. Journal of Applied Ecology 36, 689-700.
- Hoare, R.E. & Du Toit, J.T. (1999) Coexistence between people and elephants in African savannas. Conservation Biology 13, 633-639.
- Jackson, T.P., Mosojane, S., Ferreira, S.M. & van Arde, R.J. (2008) Solutions for elephant *Loxodonta africana* crop raiding in northern Botswana: moving away from sympatric approaches. Oryx 42, 83-91.
- Kulkarni, J., Mehta, P., Boominathan, D. & Chaudhuri, S. (2007) A study of man- elephant conflict in Nagarhole National Park and surrounding areas of Kodagu district in Karnataka, India: Final Report. Envirosearch, Pune.
- Nath, C. D. and Sukumar, R (1998) Elephant-human conflict in Kodagu, Southern India: distribution patterns, people's perceptions and mitigation methods. Asian Elephant Conservation Research Center, Bangalore, India.
- Naughton-Treves, L. (1998) Predicting patterns of crop damage by wildlife around Kibale National Park, Uganda. Conservation Biology 12, 156-168.
- Nelson, A, Bidwell, P. & Sillero-Zubiri, C. (2003) A review of human-elephant conflict management strategies. People and Wildlife Initiative, Wildlife Conservation Unit, Oxford University.
- O'Connell-Rodwell, C.E., Rodwell, T., Rice, M. & Hart, L.A. (2000) Living with the modern conservation paradigm: can agricultural communities co-exist with elephants? A five year case study in East Caprivi, Namibia. Biological Conservation 93, 381-391.
- Osborn, F.V. & Parker, G.E. (2002) Community-based methods to reduce crop loss to elephants: experiments in the communal lands of Zimbabwe. Pachyderm 33, 32-38.
- Osborn, F.V. & Parker, G.E. (2003) Towards an integrated approach for reducing the conflict between elephants and people: a review of current research. Oryx 37, 1-5.
- Parker, G.E. & Osborn, F.V. (2001) Dual season crop damage by elephants in the Eastern Zambezi Valley, Zimbabwe. Pachyderm 30, 49-56.
- Parker, G.E., Osborn, F.V., Hoare, R.E. & Liskanen, L.S. (2007) Human-elephant conflict mitigation: A training course for community-based approaches in Africa. Participant's Manual. Elephant Pepper Development Trust, Livingstone, Zambia and IUCN/SSC African Elephant Specialist Group, Nairobi, Kenya.
- Santiapillai, C. & Ramono, W.S. (1993) Why do elephants raid crops in Sumatra? *Gajah* 11, 55-58.
- Sar, C. K. & Lahiri –Choudhury, D.K. (2009) Elephant - human conflict in Asia, Report on Orissa - India (Pt.-I), State Report (April 1992 – June 2000). Education Centre, Kolkata.
- Sukumar, R. & Gadgil, M. (1988) Male–female differences in foraging on crops by Asian elephants. Animal Behaviour 36, 1233–1255.
- Sukumar, R. (1989) The Asian elephant: ecology and management. Cambridge University Press, Cambridge, U.K.
- Sukumar, R. (1994) Wildlife-human conflict in India: an

ecological and social perspective. In: Guha R (ed) Social ecology. Oxford University Press, New Delhi, pp 303–317.

- Sukumar, R. (2003) The living elephants: evolutionary ecology, behaviour and conservation. Oxford University Press.
- Sukumar, R. (2011) The story of Asia's elephants. Marg Foundation, Mumbai.
- Thouless, C.R. & Sakwa, J. (1995) Shocking elephants: fences and crop raiders in Laikipia district, Kenya. Biological Conservation 72, 99-107.
- Tisdell, C. & Zhu, X. (1998) Protected areas, agricultural pests and economic damage: conflict with elephants and pests in Yunnan, China. The Environmentalist 18, 109-118.
- Varma, S., Anand, V.D., Gopalakrishna, S.P., Avinash, K.G. & Nishant, M.S. (2009) Ecology, conservation and management of the Asian elephant in Bannerghatta National Park, southern India. A Rocha India and Asian Nature Conservation Foundation, Bangalore.
- Williams, A.C. & Johnsingh, A.J.T. (1997) A status survey of elephants (*Elephas maximus*), their habitats, and assessment of the elephant human conflict in Garo hills, Meghalaya. Wildlife Institute of India, Dehradun.
- Williams, A.C., Johnsingh, A.J.T. & Krausman, P.R. (2001) Elephant-human conflict in Rajaji National Park, northwestern India. Wildlife Society Bulletin, 29(4), 1097- 1104.
- Woodroffe, R., Thirgood, S., & Rabinowitz, A. (eds.) (2005) People and wildlife: conflict or co-existence? Cambridge University Press, Cambridge, U.K.
- Zhang, L. & Wang, N. (2003) An initial study on habitat conservation of Asian elephant (Elephas maximus), with focus on human elephant conflict in Simao, China. Biological Conservation. 112, 453-459.
- http://www.interestingreads.org/wp- content/uploads/2012/12/Indias_Labour_Market_during_the_2000s.pdf
- http://www2.econ.iastate.edu/classes/econ321/orazem/mammon-development.pdf

## ANNEX I

# Data sources

- Spatial baseline data for District, Taluk, Village, Panchayat, Hobli boundaries and Highways for Kodagu district from KSCST (Karnataka State Council for Science & Technology), IISc, Bangalore. Original data source – Survey of India.
- Spatial data for Reserved Forests, Forest Division and Ranges, Protected Area boundary for Kodagu district from Office of Chief Conservator of Forests, Karnataka Forest Department (KFD),
- Spatial data for Villages in and around Bannerghatta national park, National Park (NP) boundary from FERAL (Foundation for Ecological Research, Advocacy and Learning). Original data source – Survey of India and Gazette notification
- Spatial data for Barriers (EPTs, solar fences, walls, etc.) for Kodagu district from Office of Chief Conservator of Forests, Kodagu Circle, Karnataka Forest Department and Surendra Varma (ANCF)
- Spatial data for Barriers (EPTs, solar fences, walls, etc.) for Bannerghatta NP area from FEP (Frontier Elephant Program) with volunteer support from AROSHA.
- Compensation data (ex-gratia payments) to farmers affected by crop raid for Kodagu from 2004 to 2014 from Office of Chief Conservator of Forests, Kodagu Circle, Karnataka Forest Department
- Compensation data (ex-gratia payments) to farmers affected by crop raid around Bannerghatta from 2002-03 & 2013-14 from Office of Deputy Conservator of Forests, Bannerghatta NP, Karnataka Forest Department

## ANNEX II

# Questionnaire for household survey

| | | | |
|---|---|---|---|
| Village | | Village code | |
| Person name | | Taluk | |
| Date of interview | | Household no. | |

### A1. House

| | | | | | |
|---|---|---|---|---|---|
| 1 | How long is family living in this village? | | | | |
| 2 | Is the house rented or owned? | | | | |
| 3 | Roof type of house | Thatched..1 Tile..2 RCC..3 Sheet…4 Others (Sp)… | | | |
| 4 | Nature of sanitation | | | | |
| 5 | Source of water | | | | |
| 6 | Caste | | | | |
| 7 | Caste category | SC..1 ST..2 OBC..3 Others..4 No caste/can't say | | | |
| 8 | Religion | Hindu..1 Muslim..2 Christian..3 Others (sp).. | | | |
| 9 | Family deity | | | | |
| 10 | Mother tongue | | | | |
| 11 | Native place | | | | |
| 12 | Cooking medium | LPG..1 Electricity..2 Kerosene..3 Firewood..4 others (sp) | | | |
| 13 | Diet (main staple) | Rice..1 Ragi..2 Jowar..3 | | | |
| 14 | Diet | Veg..1 Non-veg..2 | | | |
| 15 | Assets | Cycle | | Tractor | |
| | | Motorcycle | | Sheep | |
| | | Power tiller | | Cow | |
| | | Car | | Bull | |
| 16 | What is the total number of times people from your family have visited a doctor over the last two months? | If you have to spend your own money to keep the elephant away, how much would you be willing to pay? | | | |
| 17 | How much did each visit to a doctor cost? | | | | |
| 18 | Would you be willing to move away from the forest? | | | | |
| 19 | If not, how much money would induce you to do so? | | | | |
| 20 | If you have to spend your own money to keep the elephant away, how much would you be willing to pay? | | | | |
| 21 | Did your household use forest produce collected from the forest last year | | | | |
| 22 | Has the use of forest produce reduced due to elephants? | | | | |
| 23 | Reduction in the amount of each forest produce | Firewood: | | | |
| | | Water: | | | |
| | | Fruits: | | | |
| | | Others (specify): | | | |
| 25 | How many acres of land have you stopped cultivating because of elephants? | | | | |
| 26 | How much did you earn from that land when you last cultivated it? | | | | |
| 27 | What are the persons involved in cultivating that land in your family doing now? How much do they earn per year? | | | | |

**Section 1:**

| No | Relation to head of househ old (Q 200*) | Sex | Age | Marital status (Q 204*) | Highest edu (Q 205*) | Eco activity (Q 206*) | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Main | Sec | |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |

**Section 2: Compensation**

| Relation to land | Distance from forest | Acres | No. of times elephants entered the land last year | Amount of land which lies fallow because of elephants | Compensation claimed | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Crop 1 | | Crop 2 | | Damage to property |
| | | | | | Amt. | Compensation claimed | Amt. | Compensation claimed | |
| Owned/ operated | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
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| | | | | | | | | | |

| Out of village in last year | | | Do you enter the forest? | | | | | What amount would you be willing to pay for continued access to shrine? |
|---|---|---|---|---|---|---|---|---|
| Time | Where | Purpose | Water | Fire-wood | Fruit | Ever visited forest shrine? | Reduced due to elephants? | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
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**Codes**:

**Q200 Relationship to head:** Head -1; Wife/Husband -2; Married child-3; Spouse of married child-4; Unmarried child-5; Grandchild -6; Father/mother -7; Father in law/mother in law -8; Brother/Sister-9; Brother in law/Sister in law-10; Grandfather/Grandmother -11; Niece/Nephew -12; Other relative -13; Employee -14; Non-relative-15

**Q204 Marital status:** Never Married -1; Married-2; Widowed-3; Divorced/Separated -4

**Q205 Education:** Not Literate-1; Literate but below class 5-2; Class 5 to class 9-3; Class 10-4; Class 12-5; Diploma/Certificate course (ITI)-6; Graduate -7; Post graduate-8

**Q206 Main economic activity:** Agricultural labour-1; Other wage labour-2; Monthly salaried worker-3; Unpaid family worker in HH enterprise -4; Cultivator-5; Other own account worker -6; Employer-7; Renters,remittance recipients,pensioners -8; Did not work but seeking work -9; Student -10; Domestic duties including free collection of goods (firewood,cattle feed,etc)-11; Not able to work due to disability-12; Others

(including begging,etc)-13

## India a biodiversity hotspot

India is one of the megadiverse countries in the world. It faces unique circumstances as well as challenges in the conservation of its rich biological heritage. With only 2.4% of the world's geographical area, her 1.2 billion people coexist with over 47,000 species of plants and 91,000 species of animals. Several among them are the keystone and charismatic species. In addition, the country supports up to one-sixth of the world's livestock population. The rapid growth of her vibrant economy, as well as conserving natural capital, are both essential to maintaining ecosystem services that support human well-being and prosperity.

To demonstrate her empathy, love and reverence for all forms of life, India has set aside 4.89% of the geographical space as Protected Areas Network. India believes in "वसुधैव कुटुम्बकम" i.e. "the world is one family".

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