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Elephants in the farm – changing temporal and seasonal patterns of human-elephant interactions in a forest-agriculture matrix in the Western Ghats, India

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Accelerating levels of human-elephant conflicts (HEC) have become a topic of major concern in conservation efforts of endangered Asian elephants (*Elephas maximus*) throughout their range. Wayanad plateau (WP) is a key summer habitat of Asian elephants in the Brahmagri-Nilgiri Eastern Ghats elephant landscape (Nilgiris), harbouring the largest breeding population in Asia. With the increase in human population density and consequent forest loss, HEC amplified in frequency and intensity in Wayanad. We assessed the drivers of HEC in a temporal and spatial context by integrating questionnaire surveys, compensation claims for crop loss, and individual identification of crop-raiding elephants. The ordinal regression analysis showed that season and proximity to the forest boundary were the major drivers of conflict. The pattern of conflict is spatially heterogeneous, and there is peak crop depredation during the jackfruit and mango season (MayS-September), followed by paddy season (September-December). The conflict has resulted in the removal of jackfruit and mango trees from farmlands and stopped cultivation of several crops that attract elephants. This has impacted rural food supply, economic well-being, local biodiversity, and human-elephant coexistence. We discuss effective and locally appropriate conflict mitigation and management strategies which can apply in human-dominated landscapes.

KEYWORDS

***Elephas maximus*, human-elephant conflict, questionnaire survey, wayanad plateau, food security, elephant conservation**

1 Introduction

Conservation of threatened and conflict-prone large mammals is challenging in the Anthropocene because of increasing competition with people for space and resources (Dirzo et al., 2014). The Endangered Asian elephant (*Elephas maximus*) is no exception; it suffered a 95% reduction in the historical range and now lives in highly fragmented landscapes of tropical Asia (Sukumar, 2003; Williams et al., 2020). The species continues to be threatened by the loss, fragmentation, and degradation of habitat, poaching for ivory, and other related conflicts with humans (Menon and Tiwari, 2019; Williams et al., 2020). Currently, elephants and people coexist in various land uses and human population densities, where Human-elephant Conflict (HEC) is one of the most pressing threats to elephant conservation (Goswami et al., 2014; Shaffer et al., 2019). Local and marginalised livelihoods also suffer as HEC poses livelihood consequences, including crop raiding, infrastructure destruction, disruption of daily routines, impacts on psychological well-being of people, and even harm or death to humans, and elephants (Madhusudan, 2003; Barua et al., 2013; Sampson et al., 2021). Crop raiding and related risks to life and rural livelihood are major obstacles to public support for elephant conservation, and affected people respond to conflict by injuring or killing elephants or implementing management interventions to control elephant movement, such as fences and trenches (Obanda et al., 2008; Snyder and Rentsch, 2020). Consequently, elephant population is declining; thus, mitigating HEC is critical to the success of conservation efforts for elephants and well-being of local communities (Woodroffe et al., 2005; de la Torre et al., 2021).

HEC can occur for a variety of reasons, including behavioral traits of the species due to the polygamous mating system (Sukumar and Gadgil, 1988; Chiyo et al., 2011), inadequate conflict mitigation measures (Lenin and Sukumar, 2011; Shaffer et al., 2019), attraction to cultivated crops that are known to be richer in macronutrients and mineral salts than wild plants, the availability of water in farmlands adjacent to forests (Chiyo et al., 2005; Rode et al., 2006), nutritional stress caused by a decline in the quality and nutritive value of natural forage (Sukumar, 1989). All of these lead to increased encounters with elephants. Fragmentation and degradation of habitat and increase in elephant populations in response to protection, and their dispersal to new habitats are also major reasons for conflict (Chartier et al., 2011; Lenin and Sukumar, 2011). This is particularly true for India because the country supports about 60 percent of the wild population, and the remaining populations are mainly restricted to protected areas surrounded by agricultural landscapes (Karanth et al., 2010). Due to India's high population density (382 persons per square kilometre), even in rural areas, negative interactions between humans and large mammals are anticipated to worsen (Karanth et al., 2010; Prasad, 2012). In India, elephants are reported to kill over 400 rural people annually; conversely, around 100 elephants loose their lives due to continual conflicts. Hence, HEC remains a major hurdle in elephant conservation efforts and associated human life and livelihood loses.

Several traditional and advanced methods have been implemented to reduce and prevent HEC situations. commonly used traditional techniques range from crop-guarding, chasing elephants by making noise (shouting, drum-beating, fire-crackers), installation of physical barriers such as electric fences and elephant-proof trenches for physical exclusion, use of acoustic and light-based deterrents, use of agriculture-based deterrents, capture and relocation, and compensation and insurance schemes (Lenin and Sukumar, 2011; Shaffer et al., 2019). Technological advances have resulted in development of various other methods to address the problem such as early detection and warning, radio collaring of problem elephants to track their movement, cognitive IoT system with intelligence techniques, Wireless Integrated Sensor Network (WISN) based boundary intellect system (Kumar and Raghunathan, 2014; Anni and Sangaiah, 2018; Sangaiah et al., 2020). Studies also recommend incorporating individual variation, cognition, and behaviour into conflict resolution techniques (Mumby and Plotnik, 2018). However, there are significant differences in farming methods, resource availability, human-elephant interactions, environmental conditions, habitat characteristics, and elephant behaviour across the species' distribution range (Kumar et al., 2010; Karenina et al., 2018; de la Torre et al., 2021; Ram et al., 2021). Hence, the key questions that need to be answered to develop evidence-based HEC mitigation strategies appropriate for local circumstances are: what are the seasonal, spatial and temporal trend of HEC situations and the ecological and social drivers leading to it? What attracts elephants beyond park boundaries in different seasons? What methods do local people use to mitigate elephant impacts, and what their opinions about currently using and new mitigation methods to reduce conflict? However, landscape-specific information on specific scenarios of conflict, and the perception of people towards it is lacking in many regions which is a handicap to design locally appropriate and effective conflict mitigation strategies (Blake and Hedges, 2004; Thekaekara et al., 2021). Understanding people's perceptions towards elephants is also important for the assessing and restoring tolerance because social factors shape the attitudes and perceptions towards conflict and conflict animal at regional scales *viz.* ethnicity, values, shared history, and, cultural beliefs. Moreover, human-wildlife conflicts are often manifestations of underlying human–human conflicts, such as between authorities and local people, or between people of different cultural backgrounds and people's perceptions and attitudes towards landscapes (Dickman, 2010; Ghosal et al., 2015; Thekaekara et al., 2021). Hence, social scientists argue that effective approaches for managing human-elephant coexistence require interdisciplinary integration of social science expertise with conservation biology, which unfortunately is not the case (Thekaekara et al., 2021).

The Western Ghats biodiversity hotspot harbours about 25% of the wild population of Asian elephants. The Ghats hold a minimum population of 10,000 elephants distributed in four landscape complexes (Baskaran, 2013). The Brahmagiri-Nilgiri Eastern Ghats elephant landscape (Nilgiris hereafter) supports over 57% of the elephant population in the Ghats, which is the largest single breeding population of the species at its highest density anywhere in Asia (Gajah, 2010). Nilgiris is prone to seasonal fluctuation in resource availability, where a large stretch of dry forests reduces the carrying capacity for elephants during the peak of the dry season (Sukumar, 2003; Anoop and Ganesh, 2020). Due to the distribution of swamps and perennial streams, the Wayanad plateau on the western side of the Nilgiris supports forage availability throughout the year. Hence the plateau is an important dry season refugia for elephants in the Nilgiris. However, around 70 percent of the plateau's forests have been lost to agriculture and settlement in recent decades, leading to a matrix of forest and agriculture. The remaining remnant in Wayanad is also degraded due to management activities and forestry operations by the state forest department, the spread of invasive plants, livestock grazing, and poor regeneration of native plants. Forest loss in Wayanad modifies the habitat heterogeneity in Nilgiris by reducing the size of the species' key dry season foraging area and disrupted several seasonal migration paths caused by human population growth, expansion of farmlands and other anthropogenic pressures (Nair et al., 1978). This has led to increasing use of human-developed landscapes in Wayanad further accentuating HEC (Anoop and Ganesh, 2020).

In the Western Ghats, Wayanad is an ideal location for an interdisciplinary understanding of HEC, which interaction is socio-ecologically prosaic due to the year-round availability of perennial, annual, commercial and non-commercial crops, various levels of habitat fragmentation and degradation, diverse human resource cultures, strict implementation of wildlife and forest protection laws, and a region of high human-elephant conflict. HEC here deserves an interdisciplinary inquiry because the region also has a long history of coexistence between people and elephants (Anoop and Ganesh, 2020; Jolly et al., 2022). To gain a comprehensive understanding of HEC in the landscape, this study integrated multiple methods such as semi-structured interviews with households and forest staff, information from compensation claims made by farmers for losses due to conflict, and the identification of individual crop-raiding elephants. Based on the above, we predict that (1) crop raiding patterns changed drastically in Wayanad in the recent past due to rise in elephant population, facilitated by legal protection and policy measures to prevent poaching, changing behaviour of elephants and people, and poor conflict mitigation measures (Sukumar, 2003; Münster and Münster, 2012); further that male elephants would mostly be involved in conflict due to sex-specific life-history strategies and adaptations to human-dominated areas (Srinivasaiah et al., 2019), (2) conflict will be high in areas close to forest boundaries, especially where it is difficult to raise barriers due to geographical constraints such as marshes and streams and therefore people living close to the forest boundary are more likely to encounter elephants, (3) the distribution of conflict is driven by the availability of highly attractive seasonal resources like jackfruit and mango in the agricultural landscape and conflict will be high during monsoon because the biomass and yield of many crops increase in this season (Rode et al., 2006) and easy for elephants to break any physical barriers because of damp soil (4) increasing conflict situation would seriously affect homestead farming and hence the food security, nutritional needs, and income of the villagers. The study contributes to growing body of knowledge on HEC in Asia, and its results have long-term implications for the landscape level management of elephants and mitigation of HEC in Wayanad and other elephant landscapes in Asia.

2 Materials and methods

2.1 Study area

The study was conducted from November 2019 to November 2021 in the Wayanad district of Kerala state, India. Wayanad is part of the Brahmagiri-Nilgiri Eastern Ghats elephant landscape of the Western Ghats and holds the largest contiguous population of Asian elephants globally that hosts around 8500 elephants (Gajah, 2010). The study areas include Wayanad Wildlife Sanctuary, Chetalayam, and Begur ranges (lies between north latitude 11° 34′ and 11° 59′ N and between east longitudes 75° 57′ and 76° 27′) that lies along the eastern boundary of Wayanad district, covering an area of 520 km^2 (Figure 1). Wayanad is a key dry season refuge for elephants in the Nilgiris due to its unique geographical features of low-lying swamps and numerous perennial streams (Nair et al., 1978; Easa, 1999). Wayanad is the least populated district in Kerala, with a population of 817420 and a population density of 384 persons per km^2. The massive influx of peasants to Wayanad from Travancore and Cochin princely states between 1930 and 1970s was the major driver of the demographic regime in Wayanad (George and Krishnaprasad, 2006; Anoop and Ganesh, 2020). There was a significant loss in forest cover from 1950 to 1980; where the total area of forest in the district in 1950 was 1816.5 km^2, but it reduced to 852.7 km^2 (113% reduction) by 1980 within 30 years (Anoop and Ganesh unpublished). The availability of fertile swamps and ample availability of water make was one of the major drivers of the immigration of paddy cultivators like Chetty and Kurumbas from other parts of southern India to Wayanad (Nair, 1911). Most of the land was appropriated by the 'upper caste' Nairs in the pre-colonial reign, then the British and later by the migrants and tribal eventually became landless and coolies in the farms (Kjosavik and Shanmugaratnam, 2021). Also, from the diversified annual cropping system (ragi, and paddy) by the local people in the precolonial and colonial reign, there was a sudden shift to perennial cash crop systems during the post-colonial time. Intensive agricultural development and rapid human population growth increased the potential for fragmentation and human-elephant interactions in Wayanad.

The study area is made up of a mosaic of moist deciduous, semi-evergreen forests in different stages of degradation intermixed with coffee and paddy-dominated cultivated land. The study area along the interstate border shares boundaries with the protected area networks of Karnataka (Bandipur and Nagarahole National parks to the east and Brahmagiri Wildlife Sanctuary to the West) and Tamil Nadu (Mudumalai National Park to the southeast). The weather is monsoonal and receives both southwest (June to September) and northeast monsoon (November-December) with heavy rains from June to September, a cool period from October to January, and a hot season from February to May. The average annual rainfall ranges between 1200-1700 mm with maximum precipitation from the

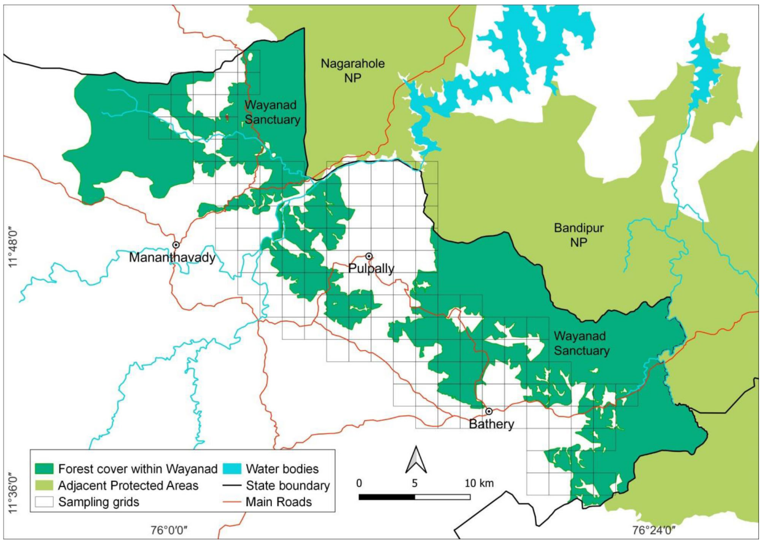

FIGURE 1
Map showing the study area and adjacent protected areas overlaid with sampling grids.

southwest monsoon, and the study area drains into the Kabini River (Supplementary Figure I). The entire area drains into the perennial Kabini River, and the study area has numerous perennial streams and around 250 artificial water holes.

Currently, agroforestry is a key feature of the study area where coffee, a major crop, is usually inter-cropped with pepper (*Piper nigrum*), Areca nut (*Areca catechu*), Coconut (*Cocos nucifera*), Banana (*Musa paradisiaca*), Jackfruit (*Artocarpus heterophyllus*) and Mango (*Mangifera indica*). In low-lying areas and swamps, paddy (*Oryza sativa*) and plantain are grown during the onset of the southwest monsoon and harvested during November-December (See crop calendar, Supplementary Figure II). Wayanad supports large herbivores like gaur (*Bos gaurus*), chital (*Axis axis*), sambar (*Rusa unicolor*) and large carnivores tiger (*Panthera tigris*), leopard (*Panthera pardus*), and Asiatic wild dog (*Cuon alpinus*) (Narasimen et al., 2013). Wayanad is also home to diverse ethnic, religious, and linguistic groups. The principal indigenous or 'Adivasi' groups in the area are Kurumbas, Paniyans, Kurichias, and Chettys. The region is also inhabited by other settlers viz. Hindus, Christians, and Muslims. Socio-economically marginalized Adivasi communities living close to the forest depend on nearby forests for fuelwood, fodder, grazing, wild tubers, and medicinal plants for subsistence.

2.2 Questionnaire survey

We interviewed 156 households between April and July 2021 to understand the conflict patterns and perceptions. The survey consisted of 44 questions in 30 sections. In order to conduct the survey, the study area, which includes all forest hamlets and a three km buffer around the forest boundary, was overlaid with 4×4 km grid cells. The size of the buffer area is fixed by considering the distribution and movement of elephants in the region (Anoop and Ganesh, 2020). The grids were again divided into 2 × 2 km grid cells. One to three households from each sub-grid were selected opportunistically for an interview and we made sure that these households were spatially apart and cultivated with different varieties of crops. To crosscheck any exaggeration by respondents about the number of visits by elephants in a grid, the number of elephants visits in each grid was confirmed by the forest watchers working in the area. We also conducted unstructured interviews with 15 forest watchers who were involved in HEC mitigation activities to gain their opinion about increasing conflict, the gender of elephants involved in the conflict, and change in elephant behaviour.

Before visiting households, the questionnaire was pre-tested on ten households to assess relevance of questions and improve time efficiency. On an average, the survey lasted 20-30 minutes per respondent, and the interviews took place in the respondents' homes or compounds. The main socio-economic activity of the respondents (96%) was farming. Respondents include farmers who own or rent land to raise crops, *viz.* paddy, coffee, areca nut, coconut, plantain, jack fruit, and mango trees, and have been living in the landscape for more than twenty years. The ages of the respondents ranged from 25 to over 73 years, with the 40 to 65 years range being the most common age bracket. Respondents were asked about the current and historical patterns of conflict, problems associated with conflict, their perception of conflict and elephant conservation, compensation claim, and suggestions to manage conflict. Further, the number of visits by elephants and the history of crop loss due to HEC in one year. Finally, the respondents were asked open-ended questions to explain the reason for the increasing HEC situation and what management actions, in their perspective, should be taken to mitigate HEC (Sampson et al., 2019; Milda et al., 2020).

2.3 HEC data from the compensation claims

Studies have used compensation claims made by farmers for the loss due to wildlife damage, to understand the pattern and intensity of human-elephant conflict over time and space in India (Gubbi, 2012; Karanth et al., 2018). In the study area, the compensation amount is reimbursed to individuals or their families who have experienced wildlife damage to crops, property, or bodily threats by wild animals. The current study collected information from forest department records regarding HEC incidents for two years, from 2017 to 2018. We restricted ourselves to these years because of the unavailability of complete records from previous years. The information collected from compensation claim forms includes the name and address of the claimant, survey number and GPS location of the depredated land, species involved in the conflict, extent of loss, date and time of the raid, and compensation amount paid. Additional information such as attacks on humans by elephants and the mortality of elephants due to the HEC situation.

2.4 Identification of crop-raiders and conflict pathways

The formation of several kilometres long paths (one and half two feet wide) due to continuous use by elephants is a noticeable feature in the study area during jackfruit and mango seasons from May and August. These paths pass through several kilometres inside the forest and farmland and are used by bull elephants (local knowledge of the forest watchers and community members and personal observation). Such paths are also created and maintained by African elephants to link their favourite sites, such as forest clearings, mineral licks, and fruit trees (Blake and Inkamba-Nkulu, 2004; Benitez and Queenborough, 2021). We tracked and monitored two heavily used paths (7.8 km) during 2022 in the Chethalayam range (Supplementary Figure III). We hypothesized that these paths lead to places with a high abundance of jackfruit and mango trees. To collect the data, two observers walked along these paths and information such as the number of jackfruits *Artocarpus heterophyllus*, *A. hirsutus*, and mango *Mangifera indica* trees that lay within 30 meters of either side of the paths were recorded. Trees smaller than the size at reproductive maturity were not counted. Also, we counted the number of dung droppings along these paths and assessed the presence of the seeds or fruit of jackfruit, mango, or any other species in the dung. Also, we deployed three Cuddebuck Capture 3.0 camera traps, fully automatic digital cameras with flash and 4 GB SD card, linked to passive infrared heat and motion detectors for four days (18 trap-days) paths to capture the images of elephants using these paths and entering villages. The traps were set between 6 pm to 7 am in the boundary of villages and checked on a daily basis, and the traps were set up at certain heights to get a frontal view of the individuals.

Additionally, a forest watcher who lives nearby was tasked with keeping an eye on the elephants' use of these paths, particularly the time of day and gender. To identify persistent crop-raiding elephants, their gender, and their age, we identified individuals involved in the conflict in the Begur, Tholpetty, and Chethalayam Ranges from 2020 November to 2022 June. The elephants were identified individually based on their external body characteristics, such as the pattern of tears, nicks, and holes in ears, the shape and size of tusks, tail morphology, and body scarring (Vidya et al., 2014). We used Canon EOS 60D DSL camera, Canon EF70-300 lens, and Sony HX400V Compact Camera with 50x Optical Zoom. We also gathered photographs of elephants taken by the forest department officials, villagers, and from newspapers. Individual identity code was generated for different individuals.

2.5 Spatial pattern and drivers of HEC

Based on prior studies on Asian and African elephants (*Loxodonta cyclotis* Matschie, 1900 and *L. africana* Blumenbach 1797) and our own field observations and experience, we used a set of covariates for modelling the spatial aspect of HEC (Sitati et al., 2003; Buij et al., 2007; Tripathy et al., 2021). The information was gathered from multiple sources such as 1:50 000 Survey of India topographical sheets, and Google earth was used to prepare the forest boundary map of the area. A land-cover map prepared using Landsat satellite imageries, and human population density of villages was obtained from the 2011 population census report. The closest linear distance from the centre of each grid cell to the human habitation, distance to river, road, and towns were measured using QGIS Version 3.16. To examine how spatial variables affected reported patterns of conflict, we used the ordinal logistic regression (OLR) model. Seven independent landscape variables that might determine the spatial pattern of HEC were selected such as (1) distance from forest, (2) distance from towns, (3) distance from main roads, (4) distance from rivers, (5) human population density (6) perimeter of forest (7) area under forest (Sitati et al., 2003). The level of conflict (no conflict, less = up to 10 incidents/year, medium= 11-30 incidents, high= above 30 incidents) was used as a response variable and the other eight landscape predictors as explanatory variables (Table 1). Along with the spatial variables, we also included season (monsoon, post-monsoon, and summer) as an independent variable. To minimize problems associated with multicollinearity, we omitted variables that were strongly correlated with others (r>0.7). We used Akaike's Information Criteria (AIC) to evaluate the relative fit of each model *via* the calculation of Akaike weights (Burnham and Anderson, 2002), with the best models ($\Delta AIC \leq 2$) having the greatest weight. We conducted data analyses in the R statistical package v. 4.0.2 (R Core Team, 2020).

3 Results

3.1 Temporal and seasonal patterns of HEC, mitigation measures and people's perception of the impact of elephants

Most households (82.6%) reported some form of conflict with elephants, such as crop raiding, property damage, or injury from

TABLE 1 Prediction and candidate variables for analysing spatial patterns of crop-raiding in Wayanad.

Sl. No.	Variable	Predictions
1.	Distance from forest	HEC decreases away from forest boundary
2.	Distance from towns	HEC increases with distance from towns
3.	Distance from main roads	HEC negatively correlated with distance from roads
4.	Distance from rivers	HEC increases with closer to rivers
5.	Human population density	HEC increases in relation to human population density
6.	Forest perimeter	HEC increases with increasing forest perimeter
7.	Proportion of forest cover within sampling grids	HEC decreased with decreasing forest cover (grids that are far away from forest boundary with no forest cover will experience less HEC)

elephants, and local people perceived HEC as a major problem. In addition, 84% reported fear of encountering elephants in the landscape during evening and morning visits to market, relative's homes, or while sending their kids to schools. A total of 13 animal species were involved in conflicts in Wayanad, including elephant, tiger, leopard, gaur, chital, sambar deer, wild boar *Sus scrofa*, bonnet macaque *Macaca radiata*, Indian peafowl *Pavo cristatus*, Indian crested porcupine *Hystrix indica*, Asian palm civet *Paradoxurus hermaphroditus*, Indian muntjac *Muntiacus muntjak*, Malabar giant squirrel *Ratufa indica*. When asked to rank the most problematic species involved in crop-raiding, elephant (41.4%) was reported as the major species, followed by wild boar and elephant (29.9%), boar (8%), and (6.9%) reported elephant, monkey, boar and deer (See Figure 2). The most prevalent type of conflict by elephants across the landscape was crop-raiding (94.5%). Major crops that elephants reported to forage on were plantain (40%), coconut (32%), paddy (31%), areca (21%), and coffee (20.8%). All the households responded positively to elephant conservation but indicated that they would not support elephants threatening their livelihoods. Also, all respondents agreed that only a few elephants are involved in crop-raiding.

When people were asked about the temporal patterns of high intensity conflict, 22% reported that conflict increased over last 3 years, 46% said it increased between 6-10 years, 15% mentioned between 11 to 15 years, 7% said between 16-20 years and 7% said it has decreased over time and 1% said there is no change. However, all farmers cultivate same variety of crops for almost 20-25 years in the landscape. Fifty-four percentage households experience conflict in all months, and 100% reported that crop-raiding peaks in two seasons, viz. jackfruit and mango season (May to August), followed by the paddy season (June – December). According to 85% of households, only bulls engaged in crop raiding, while bull and family units accounted for the remaining 15%. Ninety-three % of households said crop raiding happened at night, and only 7% said it happened both at night and during the day (Figure 3).

According to forest watchers, conflict increased in the area over the last 10-15 years, and everyone claimed that bull elephant sightings have also increased over the previous 10 to 15 years in the area. HEC incidents showed an uneven spatial distribution, with conflict more frequently recorded in areas close to forest boundaries and fragmented forest areas. However, conflict is a recent phenomenon in and around the Chethalayam Range, where elephants are moving far into the croplands from the forest boundary (See Figure 4). All households and forest watchers in the Chethalayam range said there was no conflict in the region before 10-15 years.

When asked "have you stopped cultivating or removing any crops before maturing due to HEC?" 68% of households stated that they stopped planting crops palatable to elephants, and 52% reported that they harvested jackfruit and 7% harvested mangoes

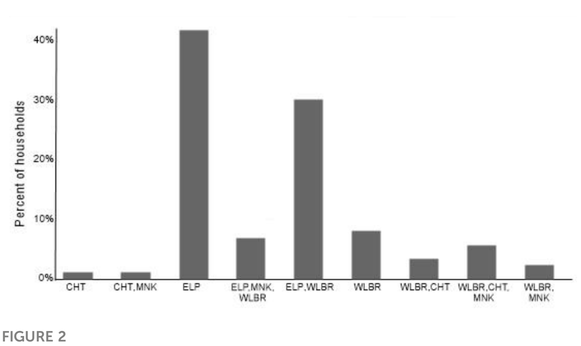

FIGURE 2
Percent of households that reported major species involved in conflicts in Wayanad (ELP, elephant; WLBR, wild boar; CHT, Chital; MNK, Monkey).

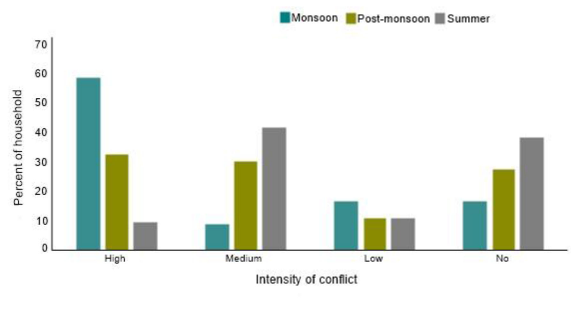

FIGURE 3
Extent of conflict in different seasons (summer – January to May 15, post-monsoon – September to December, and monsoon – May 15 to August) of 2019.

from trees before they ripened to keep elephants away from farm land. Additionally, 10% felled jackfruit trees from their fields due to conflict. When queried if they found any change in elephant behaviour in the recent past, 97% of households indicated that elephants have lost their fear and have become more aggressive, while the remaining 3% said that there has been no change. All households agreed that earlier elephants used to run away if they saw torch light or hear fire crackers or drums, but do not in the present. When asked how removing crop-raiding elephants from the forest may lessen the HEC problem, only 38% responded that it could, 48% said it would not, 12% said it might partially address the problem, and 4% were not sure. A majority of respondents (93%) said they are not getting adequate compensation for their losses, and 5% percent said they are not applying for compensation due to difficulty in pursuing related claims, 20% did not receive payment after submitting the application, and 2% were satisfied with the compensation amount. All respondents reported that the compensation process is cumbersome and slow.

Various types of mitigation measures have been used to reduce HEC in Wayanad by villagers and the forest department. Elephants entering villages were watched from elevated huts on trees and temporary shelters built inside the property. Also, forest watchers wait at strategic locations through which elephants enter villages during peak conflict season, and drive them back to forests. Once elephants enter or try to enter farmlands, they are usually driven back to forests through shouting, use of firecrackers, playing alarms, switching on high intensity torch light, use of catapults, and gun shots into the air. Bow (locally called kallamb) crafted out of bamboo is commonly used by the tribal to hit elephants using stone pebbles or mud balls made out of soil from termite hills. They target sensitive parts of elephant body (mainly on the face) to drive them back.

The primary conflict reduction strategy employed by the forest department in Wayanad is electric fencing and trenching. Thirty-nine percent of households indicated that this approach to reducing conflict is not effective, while 24% said it was 75–100% effective, and the remaining said its less than 75%. Conflict-affected households claim the failure to prevent conflict is poor maintenance of mitigation measures like trenches, which get earth-filled by humans and elephants, improper maintenance including of fences, and non-completion of trenches due to difficult terrain, stream, or swamp. Of the best methods to mitigate HEC, according to 102 households surveyed, 41% were for rail fence along with trench and electric fence, 27% mentioned rock wall with fencing, 14% preferred a combination of trench and fence, 7% opted for trench and hanging fence and 5% mentioned fence alone. Only 46 households were involved in guarding their crops during the night and all of them reported tiredness due to lack of sleep throughout the night and 67% were not able to go to work during the day due to lack of sleep. Fifteen percent reported that consumption of alcohol increased due to crop-guarding in the night. Seventy three percent respondents reported that the involvement of household members in driving away elephants from farmlands has reduced in the last ten years; 21% said it has not reduced and the rest of them offered no clear opinion. The reason for not participating in driving elephants is due to fear of attacks. Guarding crops from raids appears to have physical and mental health related consequences.

To examine perceptions of local people on wildlife management authorities in mitigating HEC, 37% claimed corruption among Forest Department officials is responsible for conflicts, 58% felt otherwise, and 5% said they are unsure. Corruption leads to the construction of poor-quality mitigation measures such as walls, fences, and trenches. 45% of respondents stated that the forest department does not assist efforts to lessen conflict. In comparison, 55% said the department does support efforts to drive elephants from farmland, provide firecrackers, or employ elephant watchers in high-conflict areas.

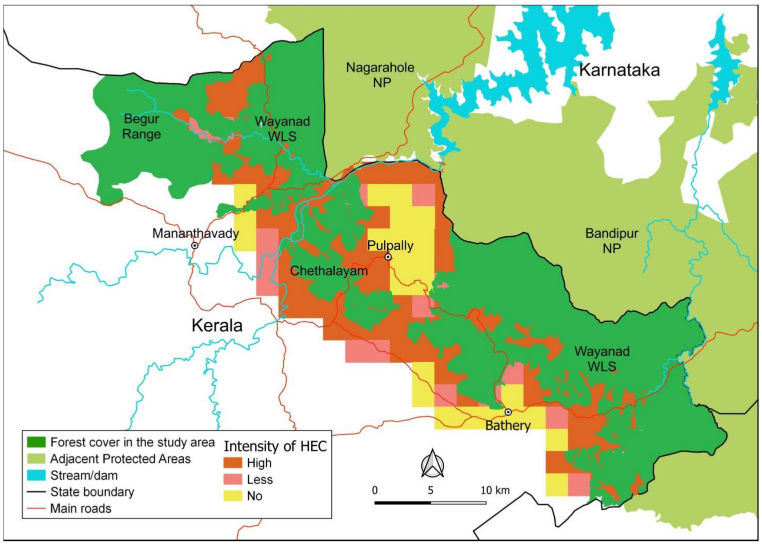

FIGURE 4
Map showing the spatial pattern of human-elephant conflict incidences in the study area.

3.2 Spatial aspects of conflict

Ordinal Regression analysis showed that the (1) probability of HEC is high in areas close to the forest boundary (2) conflict reduces when distance from towns and main roads increases and (3) conflicts reduce with forest cover decline and increase in human-population density. Also, season is the major driver of conflict where the best model shows that the medium to high level of conflict would be 8 times higher in monsoon than other seasons (Table 2).

3.2 Compensation payments

The number of conflict incidents is underestimated in the study area because of low reporting rates by the farmers due to difficulty in the process of claiming compensation, ineligibility of those without land records to apply for compensation, low payment amounts for the common and most-raided crops like paddy, absence of compensation for the loss of non-commercial crops like mango or jackfruit. During the 2-year duration of the study, 3584 conflict incidents (1733 in 2017 and 1851 in 2018) were reported for compensation in the study site. A total amount of US$ 259,083.8 was paid as compensation for crop and property loss. The data reveals that conflicts occurred year-round and crops were being damaged at all growth stages, but there was a peak during monsoon and paddy seasons (Figure 5). Major form of conflict was crop raiding (97.5%) and property damage was low (2.5%). Maximum number of crops raiding incidents in a month was 396 in 2018, July and minimum was 65 in January 2017 (149.3 ± 85.6 incidents per month). Plantain was the most raided crops accounting for 32.5% raiding incidents, followed by coffee (15.2%), coconut (14.4%), areca nut (13.8%), pepper (8.8%), and paddy (6.3%) (Figure 6). A total of 11 human deaths due to elephant occurred between 2017 and 2018. A total of 40 human deaths due to wildlife attacks were reported from three forest divisions of Wayanad district between 2009 and 2018. Elephants were responsible for maximum number of human deaths (67.5%) followed by snake bites (22.5%), tiger (7.5%) and 2.5% each by gaur and wild boar.

3.3 Formation of elephant trails and identification of crop-raiding elephants

A total of 7.8 km (7.7 km inside forest and 2.1 in farmland) survey was conducted along the elephant trails. Mean width of these trails are 45 cm, but it declined with distance from farmlands. During the survey, 72 fresh dung heaps (64 from forest and eight from farmland) were recorded (5.7 dungs/km), of which 45 dung heaps contained seeds of jackfruit or mango. No jackfruit trees were recorded within the forest, but two mango (0.25/km) and eight (1.03/km) wild jackfruit trees were recorded. However, in the 2.1 km survey in the farmland, 79 jackfruit trees (37.6/km), 48 mango trees (22.8/km), and four wild jack fruit (1.9/km) were recorded. These paths are exclusively used by bull elephants. A total of 16 individuals were found involved in crop-raiding in Tholpetty and Chethalayam Ranges during the study period (Supplementary Figure IV). Only adult bulls were found involved in conflict where the size of the bull group varies from one to seven.

4 Discussion

The results of our study suggest that HEC is both intense and widespread in Wayanad, which has severe direct and indirect consequences for both the local community and elephants. The elephant is the most troublesome species in the landscape, where crop raiding is the main form of conflict and seriously affects livelihoods and household food security. Both African and Asian elephants have been associated with damaging property (Choudhury, 2004; Matseketsa et al., 2019). However, while property damage by elephants is rare in Wayanad instead, it poses direct consequences on farming livelihoods. Conflict with elephants has caused many subsistence farmers to quit their settlements, and many have also stopped growing food crops like paddy and vegetables and started removing jackfruit and mango trees extensively from croplands. Elephants are also greatly feared by farmers because they are responsible for a significant number of cases of human injury and death (Dickman, 2010; Barua et al., 2013). Also, we noticed that to ensure better compensation for the loss, field officers help farmers by providing an exaggerated figure of the actual loss.

4.1 Spatial and temporal patterns and drivers of conflict

Crop raiding patterns may be influenced by a variety of factors, such as elephant density, the distribution of resources like water and forage, nutritional stress, the time of year, guarding intensity, human density, crop type, cultivation area, and proximity to forests (Graham et al., 2010; Guerbois et al., 2012). Consistent with our first prediction, the interview data suggests that the landscape's HEC situation has increased in the past 10-15 years. There are two seasonal peaks in conflict; during jackfruit (monsoon) followed by the paddy (October-December) season. These results are consistent with previous studies across Asia, and Africa, which reveal that HEC is strongly seasonal and correlated with rainfall patterns and cultivation cycles of local farmers (Bal et al., 2011; Chiyo et al., 2011; Goswami et al., 2015). Along with the availability of jackfruit in farmland, extensive crop raiding during monsoon attributes to risk avoidance behaviour since guarding crops is difficult during monsoon and hence less likely to be detected by farmers (Graham et al., 2009). Also, during monsoons, trenches are subtle to fail due to soil erosion, and elephants can easily use their front feet to dig the damp soil to fill in the trench and cross them or easily push the fence. A study from the coffee-dominant Coorg district of Karnataka state, adjacent to Wayanad, also reported a high level of conflict that coincides with more rainy days and during jackfruit, paddy and coffee fruiting season (Bal et al., 2011). We have also noted coffee beans in the elephant dung in large estates where elephants stay across the year;

TABLE 2 Parameter estimates of variables in the Ordinal Logistic Regression (OLR) to predict the drivers of different levels of conflict (No to High) in Wayanad between 2019 and 2020.

Model		β (SE)	t-value	P-value	OR	AIC	Delta AIC	Df	McFadden
Conflict ~ Disforest+ Town+ Road + River+Population +Season	Disforest	-1.344078e-03 (1.146245e-04)	-11.7	9.386776e-32	0.99	930.9		14	0.202
	Town	5.493311e-05 (6.478071e-05)	0.8	3.964459e-01	1				
	Road	2.635118e-04 (1.112862e-04)	2.4	1.789054e-02	1				
	River	-2.437863e-04 (8.450769e-05)	-2.8	3.916834e-03	0				
	Population	1.191894e-06 (NA)	–	–	1				
	Monsoon	2.097726e+00 (1.023024e-02)	205.05	0.000000e+00	8				
	Post-monsoon	1.053478e+00 (4.835106e-03)	217.8	0.000000e+00	2				
	No I Less	-9.936549e-01 (5.746155e-03)	-172.9	0.000000e+00					
	Less I Medium	9.901205e-01 (1.496311e-01)	6.6	3.663727e-11					
	edium|High	3.241718e+00 (2.140932e-01)	15.1	8.606426e-52					
Conflict~Disforest +Population +River +Season	Forest	-1.439938e-03 (9.978233e-05)	-14.4	3.312698e-47	0.9	939	8.196	10	0.192
	Population	-8.964892e-06 (-)	–	–	0.9				
	River	-2.195250e-04 (7.559979e-05)	-2.9	3.686900e-03	0.9				
	Monsoon	2.068784e+00 (8.205643e-03)	252.1	0.000000e+00	7.9				
	Post-monsoon	1.039700e+00 (7.325841e-03	141.9	0.000000e+00	5.9				
	No I Less	-1.739231e+00 (1.548318e-02)	-112.3	0.000000e+00					
	Less I Medium	1.938429e-01(1.042491e-01	1.8	6.296754e-02					
	Medium| High	2.389337e+00 (1.469169e-01)	16.3	1.801099e-59					
Conflict~Season + Forest	Monsoon	2.053638 (0.2463551)	8.3	7.678783e-17	7.8	942.883	11.983	6	0.185
	Post-monsoon	1.036792 (0.2340237)	4.4	9.410806e-06	2.8				
	Forest	-0.001483 (0.0001363)	-10.8	1.452363e-27	0.9				
	No I Less	-1.279469315 (0.1943009863)							
	Less I Medium	0.635723066 (0.1849235379)							

(Continued)

TABLE 2 Continued

Model		β (SE)	t-value	P-value	OR	AIC	Delta AIC	Df	McFadden
	Medium| High	2.812452338 (0.2397586909)							

Statistics include the coefficient or intercept value, standard error (SE), t-value, *P*-value, OR = odds ratio, model residual deviance B), Akaike Information Criterion (AIC), Delta AIC, and PsuedoR^2 value. **Disforest**: Distance from forest; **Town**: Distance from towns; **Road**: Distance from main roads; **River**: Distance from rivers; **Population**: Human population density; **Forest**: Proportion of forest cover within the sampling grid.

otherwise, elephants rarely eat coffee berries. Ordinal regression analysis shows that peripheral agricultural lands are prime for HEC where the probability of HEC is high in areas away from towns. Previous studies also suggest that conflict is generally highest in close proximity to protected areas that act as elephant refuges (de la Torre et al., 2022) and high level of conflict in areas with low human population density when compared to towns (Munyao et al., 2020). This finding implies that elephants view places farther from forest areas as increasingly risky (Chiyo et al., 2014).

Studies have reported landscape characteristics, the behaviour of elephants and people, bulls and female-led family groups are causing conflict (Chiyo et al., 2005; Graham et al., 2010). According to Sukumar, male elephants raid crops six times more than female elephants in the Western Ghats (Sukumar and Gadgil, 1988). Our study also found that bulls are primarily involved in conflict either singly or in small groups, but rarely do female herds also enter farmlands with less human disturbances, like large coffee estates adjacent to forest boundaries. Involvement of male elephants in crop-raiding is attributed to the risk-taking foraging strategy to improve their body condition prior to the sexually active musth period for reproductive success and also to reduce nutritional stress (Chiyo et al., 2011; Pokharel et al., 2018; Srinivasaiah et al., 2019). The timing of crop raids by elephants is often attributed to the unavailability of forage and water inside the forest (Sukumar, 2003; Osborn, 2004). Contrary to this, our study shows that crop-raiding in Wayanad is not related to the lack of resources inside the forest but rather to the presence of mature food crops and fruits in the farmlands. Because the quantity and quality of forage and water are high during monsoon and post-monsoon seasons when compare to the dry season in the study area (Sukumar, 2003).

Like other elephant landscapes of Asia and Africa, the escalation of HEC in Wayanad has primarily been attributed to the increase in human population, expansion of agriculture and increase in elephant population (Baskaran, 2013; Goswami and Vasudev, 2017). The total area of forest in the Wayanad district in 1950 was 1816.5 km2, but it reduced to 852.7 km2 (113% reduction) by 1980 within 30 years (Anoop and Ganesh unpublished). The massive influx of peasants to Wayanad from the plains of Kerala between 1940 to 1970 was the critical driver of the demographic regime and habitat fragmentation in Wayanad (Anoop and Ganesh, 2020). Most land use changes have taken place in areas that where previously elephants dispersed, and resulted in interference of elephant migratory patterns (Nair et al., 1978). Other reasons of increasing conflict include; increase in elephant and human population, especially increased number of bull elephants in the Nilgiris due to habitat management approaches such as improving surface water availability and reducing selective poaching of bull elephants, banning the legal and illegal capture of elephants for domestic and international markets (Arivazhagan and Sukumar, 2005; Münster and Münster, 2012; Baskaran, 2013), dispersal of elephants to new habitats (Chakraborty et al., 2014), habitat degradation and reduction of forage within forest areas (Puyravaud and Davidar, 2013; Wilson et al., 2013), increased availability of palatable crops in the farmlands such as jackfruit, mango, areca nut, plantain, and coconut (Anoop and Ganesh, 2020), disruption of migratory paths due to expansion of agriculture (Goswami and Vasudev, 2017), poor conflict mitigation measures, and change in behaviour such as formation of stable, long-term all-male groups to survive in human-modified landscapes (Srinivasaiah et al., 2019) resulting in a further increase in HEC. Increased conflict is partly ascribed to the high level of protection afforded to the species, following the implementation of the Wildlife Protection Act in 1972, and the lack of authority of local people to manage elephants in farmlands (Münster, 2016). For instance, shooting animals that entered farmlands using locally

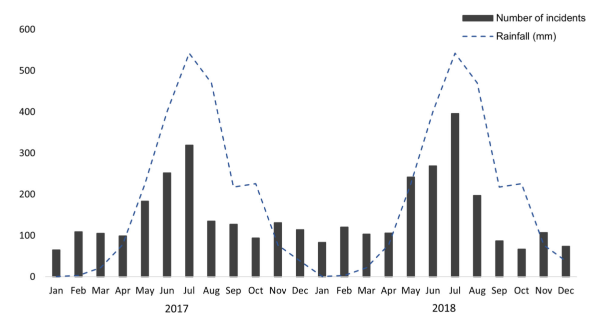

FIGURE 5
Temporal distribution of crop-raiding incidents by elephants between 2017 and 2018 in relation with rainfall pattern in Wayanad.

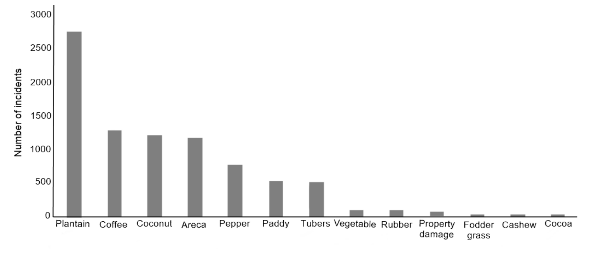

FIGURE 6
Frequency of different crops raided by elephants in the study area between 2017 and 2018 in Wayanad.

made firearms was Wayanad's most effective conflict management strategy until the late 1970s.

The highly fragmented Chethalayam forest Range is a major HEC hotspot in Wayanad. According to farmers and forest department officials, reduced man-made fires and grazing and hence the dispersal of elephants from Nagarahole and Wayanad Sanctuary have likely increased elephant numbers in Chethalayam. The increase in elephant numbers cannot be attributed to population growth alone but is likely to be the result of an influx of additional elephants from the degraded and fragmented habitat patches of the larger landscape (See Manakadan et al., 2010; Chakraborty et al., 2014). Hence, landscape connectivity, dispersal of elephants to new areas due to strict protection, and population growth of elephants also needs to be considered while devising conflict mitigation strategies in fragmented landscapes like Wayanad (See Goswami and Vasudev, 2017). Interview data suggest that increasing HEC in Chethalayam Range is a relatively recent phenomenon (around ten years). Hence, immigrant farmers who live around this range have little experience dealing with the issue. A study from the nearby Gudalur area also showed that the indigenous communities living in the landscape for a long time are best adapted and tolerant to elephants, but people who migrated recently are less tolerant of the species (Thekaekara et al., 2021).

The study found several movement paths in and around Chethalayam Range due to the continuous movement of bull elephants during jackfruit and mango seasons that extend deep into the farmlands (See Appendix image III). Of 72 fresh dungs recorded along these paths, 45 dungs contained seeds of jackfruit or mango, indicating that elephants extensively raid these fruits. When jackfruit and mango are in their later phenological growth stages, elephants may use a broader area than they do during other seasons to meet their nutritional needs (Sukumar, 1990). Studies from Afrotropical rainforests also reported the formation of permanent paths due to movement of African forest elephants *Loxodonta cyclotis* to access high-nutrient food resources like mineral licks and fruit trees (See Blake and Inkamba-Nkulu, 2004). Elephants are known to have excellent spatial memory, and olfactory capacity and are able to detect volatile components produced by plants over long distances and make preferential foraging decisions (Polansky et al., 2015; Schmitt et al., 2018). The jackfruit is a fleshy fruit, and the pleasant scent produced by it might be an evolved signal for olfactorily oriented mammal seed dispersers like elephants (Bal et al., 2011). Removal of trees or jackfruit at a young age to avoid elephant issues from peripheral areas of the forest might be a reason for elephants going far away from the forest boundary to farmland in search of jackfruit. Hence, the strategy to address HEC cannot be based on the removal of jackfruit trees but needs land use planning to ensure the coexistence of elephants and people without compromising the requirements of both (de la Torre et al., 2022). Also, elephants' olfactory and acoustic sensory strengths and spatial memory needs to be considered in conflict mitigation strategies in the future (Polansky et al., 2015; Ball et al., 2022).

Poor habitat quality due to extensive removal of a variety of fruit tree species, including mango, jackfruit, wild jack (*Artocarpus hirsutus*) and establishment of monoculture plantations as part of forestry operations, the spread of invasive plants, poor regeneration of bamboo and other native plants might affect the forage availability and nutritional requirement of elephants in Wayanad (Anoop and Ganesh, 2020). For instance, around 30% of Wayanad sanctuary is invaded by the invasive tree *Senna spectabilis*, which can seriously affect the carrying capacity of the habitat for elephants. However, habitat quality has been largely neglected while developing elephant conservation and conflict mitigation strategies. Hence, the formation of paths in Chethalayam to access seasonally available jackfruit and mango indicate that the agricultural landscape is also a prime habitat for elephants in Wayanad. A recent study from Peninsular Malaysia also shows that the areas of HEC incidents are of very high habitat suitability for Asian elephants and hence promoting human–elephant coexistence is key for elephant conservation (de la Torre et al., 2021; de la Torre et al., 2022). Previous studies reported that agricultural landscapes in the Western Ghats provide important effects on dispersal and metapopulation dynamics and hence may facilitate adequate protection of elephants in fragmented landscapes (Kumar et al., 2010; Bal et al., 2011). Thus, the paths in Chethalayam are also an indication of historical movement routes elephants used to move between the forest on the left and right banks of the Kabini River (Anoop and Ganesh, 2020). Hence, delineating elephant migratory corridors through agricultural landscapes is essential to develop strategies to develop coexistence and reduce conflict (Goswami and Vasudev, 2017).

Homestead farming is a common and age-old traditional practice by Wayanad's small and marginal farmers to manage household food security, nutritional needs, and income. Here, people mainly cultivate adequate nutritious and sustainable food to sustain a healthy life, and the gardens also support a variety of tree species, including jackfruit and mango. The home gardens are also the great reservoirs of biodiversity, and several species are peculiar to the region (Santhoshkumar and Ichikawa, 2010). Most of these crops are extensively raided by elephants, leaving people with an increased feeling of being marginalized and disempowered. Most interviewees confirmed having given up growing vegetables, fruits or tubers to avoid conflict with elephants and other animals. Additionally, they are forced to remove fruiting tree-like jackfruit and mango or the fruits at a very young age. Elephants can eat or trample huge quantities of crops in a single raiding event. Hence, people who are dependent upon a single livelihood strategy tend to be particularly vulnerable due to a lack of alternative income strategies (See Dickman, 2010; Shaffer et al., 2019). These findings demonstrate the urgent need for additional, in-depth research on the effects of elephant crop raiding on the food security and nutritional needs of the farming community in the HEC areas (Kaswamila et al., 2007). Based on the findings, we suggest innovative and participative land-use practices for reducing conflict. For instance, in Sri Lanka, farmers planted a local variety of orange (*Citrus sinensis*), which is not attractant to elephants, along with other crops; decrease crop raiding by elephants was a success in reducing conflict while also supplementing farmers' income (Dharmarathne et al., 2020). We also suggest that farmers plant several fruiting trees along coffee plantations that are not attractive to elephants, like avocado, lemon trees and other tropical fruits, by considering ecological suitability and market value (Parker and Osborn, 2006).

4.2 Conflict mitigation measures

Local farmers in Wayanad mostly use a wide range of comparatively cheap, non-fatal conflict mitigation techniques. These include active deterrent techniques like shouting, beating tin cans and drums, pelting stones, and setting fire close to farmlands as passive barriers. Also, the forest department uses methods like trenches, electric fencing, rock wall, and rail fencing. While some of these mitigations are only suitable for temporary fixes, others provide long-term advantages (Davies et al., 2011; Lenin and Sukumar, 2011). However, one of the oldest and most successful methods for reducing conflict is to guard their crop throughout night. People will constantly be vigilant and vigorously chase away elephants seen approaching the field using spotlights, fire crackers, and shouting. The entire village and its dogs will be involved in the process. Villagers and forest watchers reported that this method is becoming less effective because some elephants are bolder, more aggressive, have lost fear and are habituated to overcome all types of interventions. Based on long-term studies on individually identified elephants, it is evident that there is variation in behaviour at the individual level, and elephants can constantly learn, adapt, make decisions based on complex cognitive processes, and even teach each other. Hence, it is important to integrate behaviour, cognition, and ecology at the individual level to manage conflict in the future (Mumby and Plotnik, 2018; Ball et al., 2022). We also suggest using early warning systems against elephant intrusion to mitigate conflicts, and to avoid fatal encounters like Wireless Integrated Sensor Network (WISN) based boundary intellect system that incorporates multiple sensors to detect elephants (Anni and Sangaiah, 2018) and automatic acoustic and visual detection methods (Zeppelzauer and Stoeger, 2015), and use of network technology such as television cable network, and mobile phone coupled with active participation of stakeholders suggested by Kumar and Ganesh (2012). We also recommend that local communities vulnerable to elephants raids, be trained in adopting some of these technologies in mitigating raids.

Currently, an approach by the forest department to reduce conflict is capturing persistent crop-raiders and keeping them in captivity. Two adult bull elephants were captured from Wayanad Sanctuary in 2016 and 2019, and they are kept in captivity. However, our study showed that the conflict in the areas was not eradicated after their capture. Previous studies also suggested that translocation or capture of elephants will not solve the conflict issue because young raiders attaining a reproductive peak may engage in raiding due to energetic demands associated with reproduction (Chiyo et al., 2014) or other individuals at their reproductive peak will occupy the area. Also, since bull elephants have well-established social networks and hierarchies, hence capturing even a few individuals is likely to cause social disruption and genetic health of the population (See Evans and Harris, 2008; Saaban et al., 2020), thus threatening their conservation. Hence, novel solutions like capturing elephants to mitigate conflict may not represent a particularly effective or attractive management strategy (Fernando et al., 2012). A high number of elephant injuries from hostile human–elephant interactions has also been observed during our work in Wayanad (Anoop and Ganesh pers. Obs.). Hence, improving coexistence between people and elephants in fragmented landscapes like Wayanad is the better approach for the conservation of elephants and mitigation of conflict without incurring severe costs on either side (de la Torre et al., 2022).

The voluntary relocation of people from areas that have a high level of conflict can reduce conflict and enhance conservation (Harihar et al., 2014; Karanth et al., 2018). For instance, voluntary, participatory relocation of villages has been successfully carried out in Thirunelli-Kudrakote 'Elephant Corridor' by Wildlife Trust of India (WTI). It was successful in reducing conflict, improving economic wellbeing, enhancing accessibility of education and economic opportunity of people and facilitated habitat connectivity for elephants (Menon et al., 2020). However, the forceful relocation of people, especially tribals from forest areas is critiqued activists and social scientists because of socio-economic and cultural impacts (Rangarajan and Shahabuddin, 2006; Lasgorceix and Kothari, 2009). We suggest voluntary relocation in areas with high conflict in Wayanad only if procedural and distributive justice is ensured in relocation, and it benefits both people and elephants.

People's tolerance of elephants is important for any mitigation strategy and conservation of elephants (Dickman, 2010; Shaffer et al., 2019). If communities participate and benefit from elephant conservation and management on their land, this may help increase tolerance towards elephants and reduce human-elephant conflict (Cooney et al., 2016). Hence, along with well-made and regularly maintained barriers, implementing mechanisms for fair financial compensation for crop or property loss (Chen et al., 2013) can improve coexistence. Also, the creation of more employment opportunities, such as providing salary and insurance policies to farmers who guard their crops in their land, will reduce conflict and increase coexistence and financial opportunities. The impact of corruption on the increasing HEC situation is often ignored. We are convinced that departmental and administrative corruption is also one of the reasons for the increasing conflict situation in Wayanad, even as local people are not involved in the decision-making in forest management. Hence, we suggest a decentralised system or increasing local participation in forest management decision-making in the landscape, and providing opportunities in the governance of forest management is critical for successful conflict mitigation (Agrawal et al., 2008). The Forest Rights Act, and its commnity conservation clauses provides an institutional pathway for Adivasi and other long term forest dweller participation in forest management and conflict mitigation.

Data availability statement

The original contributions presented in the study are presented in the main text and appendix material. Further inquiries can be directed to the corresponding author.

Ethics statement

The study involving human participants were reviewed and approved by Ashoka Trust for Research in Ecology and the Environment (ATREE). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

This article is an output of NRA's PhD dissertation. NRA completed data collection, analysis, and manuscript writing with the guidance of TG and SK. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be constructed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcosc.2023.1142325/full#supplementary-material

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