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Analysis Of Policy Options To Convert Human-Elephant Conflict Into Human-Elephant Harmony

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In Thailand the number of elephants are declining, and many of the remaining animals are protected in a network of wildlife sanctuaries. Unfortunately, elephants from these protected areas are coming into conflict with farmers. This human-elephant conflict (HEC) is causing crop damage. It is also leading to injury and loss of life amongst both farmers and elephants. Now a new EEPSEA study has looked at this problem and has highlighted a combination of policies that should help to reduce it.
The study is the work of Rawadee Jarungrattanapong, from the Ritsumeikan Asia Pacific University and Siriporn Sajjanand, from the Sukhothai Thammathirat Open University. It finds that improving the elephants' habitat, providing female elephants with contraception and using electric fences to keep elephants away from farmland would be the best combination of policies to mitigate HEC. It also finds that, in the long term, elephant relocation may be necessary in some areas.

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ANALYSIS OF POLICY OPTIONS TO CONVERT HUMAN-ELEPHANT CONFLICT INTO HUMAN-ELEPHANT HARMONY

Rawadee Jarungrattanapong

Siriporn Sajjanand

EXECUTIVE SUMMARY

The elephants in Thailand are Asian elephants (*Elephasmaximus*) and they are of cultural importance to Thai society. However, the total population of elephants in Thailand has been declining, except in some protected areas (e.g. KhaoAng Rue Nai [KARN] Wildlife Sanctuary) where local predators are extinct. Some of these sanctuaries have limited food and water sources for elephants, which leads to elephants venturing outside the sanctuaries into villages, resulting in human-elephant conflict (HEC). HEC causes damage to crops and property, human and elephant loss of life, and psychological stress.

The objective of this study is to conduct a cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) of human-elephant conflict mitigation options. The options considered were: 1) habitat improvement and female elephant contraception; 2) habitat improvement, female elephant contraception and land-use change; and 3) habitat improvement, female elephant contraception and the use of electric fences. A household survey was conducted in six villages to examine villagers' attitudes towards HEC, the extent of the HEC damage caused, and mitigation measures used to deal with HEC.

The household survey showed that the average HEC cost borne by households (crop loss, mitigation costs, and opportunity cost of time spent guarding crops) is THB 48,374 per household per year or USD 1,612 per household per year, which accounts for 26% of annual household income. Policy option 3, involving habitat improvement, female elephant contraception and the use of electric fences, shows the highest net present values (NPV) and is also the most cost-effective option. In the long run, however, experts suggest that relocation should be considered as an option for KARN, given its limited capacity to accommodate the growing elephant population.

1.0 INTRODUCTION

1.1 The Problem

Throughout Asian history the Asian elephant (*Elephasmaximus*) has been revered, worshipped, used as a warrior and even as a cultural ambassador (WWF, 2008). The elephant is a species that has special importance within Thailand's cultural heritage and in the past a white elephant sat right at the heart of the Thai flag. The Asian elephant is categorized as an endangered species by IUCN. In Thailand wild elephant populations and their habitats are protected by the National Park Act (1961) and by the Wild Animal Reservation and Protection Act (1960).There are thought to be around 2,500-3,000 elephants left in Thailand (Choudhury et al. 2008). According to interviews with experts, the population of wild elephants in Thailand has been decreasing, with the exception of some protected areas, e.g. KhaoAng Rue Nai Wildlife Sanctuary, where local predators are now extinct; in these places the elephant population cannot be controlled.

Human-elephant conflict (HEC) in Thailand has been reported since the late twentieth century when people encroached on elephant habitats in wetlands, lowland forests and uplands to grow rice and other crops for export (Srikrachang, 2008). Conflicts have been known to occur more frequently and with varying degrees of intensity. Using the number of deaths of humans and elephants as a criterion to evaluate human-elephant conflict, three protected areas, Salakphra Wildlife Sanctuary, HuaiKhaKhaeng Wildlife Sanctuary, and KhaoAng Rue Nai (KARN) Wildlife Sanctuary, have the most severe HEC problem in Thailand (Wonghongsa et al. 2006). The causes of human-elephant conflict in Thailand are as follows:

- the elephants learn that there are large patches of food in agricultural land adjacent to their park habitats and they conduct crop raids;
- the number of wild elephants is increasing in some severe conflict areas because of the extinction of important local predators, especially tigers;
- there is movement of elephants between habitats;
- and young male elephants that do not belong to the herd stray out of the forests (Srikrachang, 2008).

There are other economic costs associated with human-wildlife conflict, that can outweigh the direct costs of crop damage and may form a major element of the conflict as perceived by local people (WWF, 1997). The most extreme example of this is human death but other examples include restrictions on movement, competition for water sources, the need to guard crops and property (which may lead to loss of sleep), increased exposure to malaria, and psychological stress (Nelson et al. 2003).

There is little information available on the cost of damage due to HEC in Thailand. However, the Wildlife Conservation Society (WCS)[1] in Thailand conducted a survey in Kang Kra Jan National Park (KARN) from 1995 to 2003 and found that HEC events occurred approximately 29 times a month and that agricultural damage cost roughly 3.3 million THB (USD110,000[2]) a year.

[1] http://www.wcsthailand.org/main/elephant-project/elephant-conflict, 15 September, 2010
[2] USD 1 = THB 30

However, the key issue for the prevention of crop raiding by elephants is not whether or not it can be achieved, but rather how it can be implemented at a favorable cost-benefit ratio (WWF, 2008). To select the most effective method of alleviating the conflict between humans and elephants, a cost-benefit analysis (CBA) is needed. This research report is part of another project, a pilot project on Payment for Ecosystem Services (PES) for biodiversity conservation, which was conducted by Sukhothai Thammathirat, of the Open University, Thailand. In this project, KARN was ranked as having the most severe HEC problem in Thailand and so it was chosen as the study area. Due to budget constraints and limited human resources, the current mitigation activities undertaken by government agencies are not sufficient to reduce human-elephant conflict. Using the PES approach, where the service provider or farmer is rewarded for participating in mitigation activities, can alleviate the HEC problem. The private sector can act as a service provider. Some firms may choose to contribute to an environmental program in order to generate goodwill or to improve their reputation by using their corporate social responsibility (CSR) budget to provide the reward for farmers to generate a positive externality for HEC reduction. The pilot PES project has three components: 1) an estimation of the operating costs of the PES scheme, for example, the cost of the contracting process, evaluation, and so on; 2) seeking potential service buyers for PES; and 3) cost-benefit analysis of the proposed policy options. This proposal will focus on the third component of the PES pilot project. The results of this study will be input into the pilot PES project to select the policy intervention for the PES project in its second phase.

1.2 Research Objectives

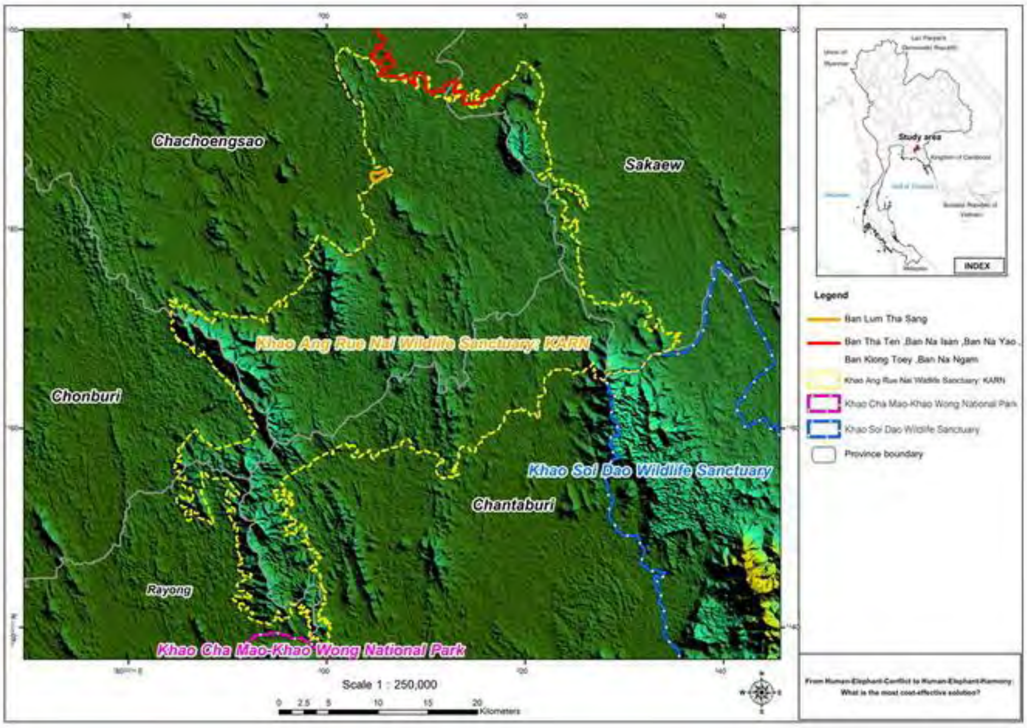
The general objective of this study is to conduct a simple cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) of ways to reduce human-elephant conflict. The options considered are: 1) habitat improvement activities and contraception of female elephants; 2) habitat improvement activities, contraception and land-use change; and 3) habitat improvement activities, contraception, and electric fences. These options will be compared with the status quo (more details of the status quo are described in section 1.3.2).

The objectives of the study are:

1. To determine what kind of measures households have taken to protect themselves and their crops from elephants.
2. To determine the attitudes of households towards the problem of HEC in the future.
3. To estimate the cost of damage/cost of protecting households/communities (crops and property) and human injury/death due to HEC, assuming that no additional mitigation activities are undertaken (the status quo).
4. To estimate the investment and maintenance costs of proposed mitigation measures.
5. To estimate the costs and benefits of proposed mitigation measures and to derive the net social welfare gains from each mitigation measure.
6. To estimate the net present values (NPVs) and cost-effectiveness ratio of the proposed mitigation options.
7. To determine the attitudes of local people towards participation in the proposed mitigation measures.

1.3 Description of the Study Area

The KhaoAng Rue Nai Wildlife Sanctuary (KARN) is one of seven protected areas in Thailand that harbor more than 100 elephants. There are no natural predators to the elephants, such as tigers, in KARN and this is an important contributing factor to the increase in the elephant population. Wanghongsa et al. (2006) reported that the wild elephant population was estimated at 136 in 2000, an acceleration of 9.83% per annum. KARN covers an area of 1,079 km^2 of lowland rainforests across five provinces (Chachoengsao, Chonburi, Rayong, Chanthaburi, and Sakaew provinces) in the East of Thailand (Figure 1). In 2007, the estimated elephant population in KARN was approximately 217 and the crude density was 0.2 elephant per km^{-2} (Wanghongsa et al. 2007).



Note: the red and orange lines illustrate the study areas (Ban LumTha Sang, Ban Tha Ten, Ban Na Isan, Ban Na Yao, Ban KlongToey, and Ban Na Ngam).

Figure 1. KARN wildlife sanctuary and the study areas

1.3.1 Impacts of HEC in KARN

There are only seven protected areas in Thailand where there are more than 100 elephants. Wanghongsa et al. (2008) reported that human-elephant conflict has taken place in 24 protected areas in Thailand. The areas range in size between 84 and 2915 km^2, encompassing between 5 and 350 elephants. Using the severity index of human-elephant conflict, KARN is one of two areas out of the 24 protected areas that were ranked at level 15[3], which is the most severe level. KARN is a lowland rainforest surrounded by farmland (Figure 2) and this makes it an area where elephants are keen to come out of their sanctuary to eat crops such as cassava and rice. Mr. Sawai Wanghongsa, the former head of the Chachoengsao Wildlife Research Station at KARN, explained that elephants like the taste of such foods. Some farmers have spent money on electric lights for their cassava farms, which they keep switched on the whole night in the hope that it will protect their farms from elephants. Some households in LumTha Sang village, who plant paddy rice, lost all their

[3]A severity index of level 15 equates to loss of property and human and elephant life.

income for the whole year when elephants raided their rice crop, which they can only plant once a year. The wild elephant habitat in KARN accounts for 36.63% of the 1,079 $km^2$of KARN. Therefore, the estimated elephant population living in the corridor between KARN and the surrounding farmlands is roughly 70-80. With a 9.83% growth rate in the wild elephant population in KARN (10.57% birth rate and 0.74% death rate), the number of elephants living in the corridor between KARN and farmlands will continue to increase and the HEC, both in terms of cropraiding and potential elephant and/or human deaths, will escalate in the near future.

Source: The Chachoengsao Wildlife Research Station

Figure 2. The lowland rainforest environment of KARN

Source: http://www.the-eastern-forest.org, 12 August, 2010

Figure 3.An elephant severely injured by a traditional trap

Source: http://www.the-eastern-forest.org, 12 August, 2010

Figure 4. A pregnant elephant electrocuted by farmers

Srisuk et al. (2010) reported that crop damage in Sub WuaDaeng (SWD) village, which is one of 90 villages surrounding KARN, cost approximately THB 100,000 for the 11 months of their survey, or approximately THB 109,000 (USD3,516) per year. Unfortunately, the SWD project did not collect data on household income that could be used to identify the magnitude of such damage by comparing the cost of crop damage to household income. However, the researcher in the SWD project emphasized that even though the cost of the crop damage is not large, it is significant compared to average household income. Such crop damage affects subsistence farmers through the loss of their primary food and cash resources (Osborn and Parker, 2003).

Apart from damage to agriculture, human death is another impact that is considered unacceptable. Between 1995 and 2009, 20 elephants were found dead outside the KARN boundaries. Five of them died of natural causes, 13 died of human-induced causes (Table 1.) and two died of unknown causes. Human-induced causes can be illustrated via three sub-categories of causes: conflict due to cropraiding by elephants (nine elephants); poaching for tusks (one elephant); and traffic accidents (three elephants). These figures show that human-elephant conflict due to crop raiding from elephants claims the greatest number of elephant lives. The human-elephant conflict in KARN not only affects wild elephants but injures and kills humans. Unfortunately there is no systematic data available on human injuries and death due to HEC. There are figures available on the number of human injuries and deaths caused by traffic accidents (Table 2). Furthermore, the KhaoAng Rue Nai Wildlife Sanctuary has reported that two men were found dead and one man was injured due to the conflict between humans and cropraiding by elephants in the past 12 months (October 2009-August 2010).

Table 1. Deaths of wild elephants in KARN, 1995-2009

Causes of death	No. of deaths
1. Conflict from cropraiding	9
2. Natural deaths	5
3. Traffic accidents	3
4. Poaching	1
5. Reason unknown	2
Total	20

Source: ChachoengsaoWildlife Research Station

Table 2. Injuries and deaths from traffic accidents, humans and elephants, 2000-2008

	Injuries and deaths	
	Humans	**Elephants**
Injuries	11	4
Deaths	4	3

Source: ChachoengsaoWildlife Research Station

1.3.2 Current mitigation measures (status quo)

Local people and related government agencies have instigated mitigation measures to alleviate the impacts of HEC.

Traditional measures taken by households

Local people who have been affected by crop-raiding elephants have applied traditional crop-protection measures. The aim of traditional measures is to chase the elephants away. Examples of traditional measures are using firecrackers, planting plastic-bag flags, using hand-made lamps, using an elevated hut to keep watch over the farm, and using an electric fence (Figure 5).

Firecracker

Plastic-bag flag

Hand-made lamp

Elevated hut

Simple electric fence

Figure 5. Traditional mitigation measures taken by households

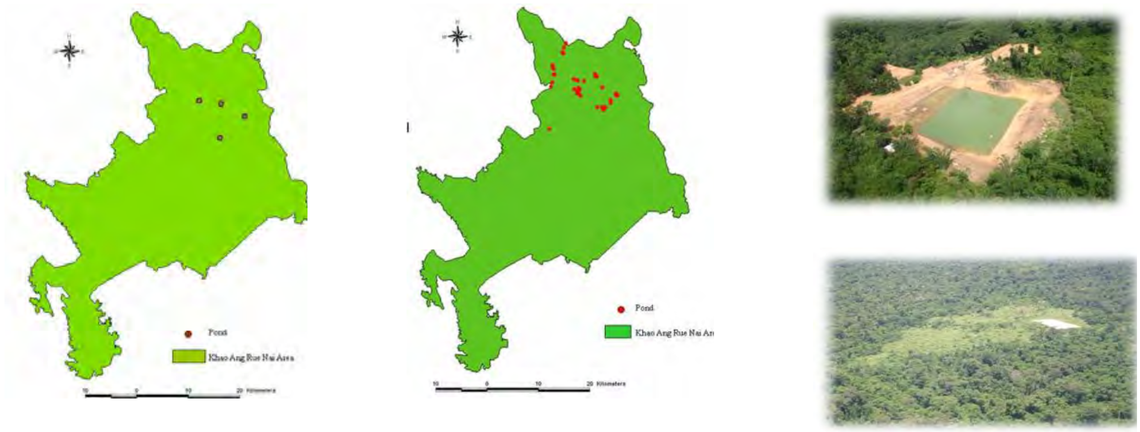
Existing measures taken by government agencies

Government agencies have taken some measures to alleviate HEC, such as artificial ponds (Figure 6), artificial salt licks (Figure 7), pilot ditches (Figure 8), road closure into KARN between 9 pm and 5 am (Figure 9), and compensation for damage to crops (Table 3).For existing measures to alleviate HEC, see Figure 10.

The elephant population in KARN is growing at 9.83% or approximately 10% a year so habitat improvement to provide supplementary food for elephants should be of the first priority; however, current measures in this area will not be able to keep up with the growth rate. Current measures include the provision of salt/mineral licks, which are a source of food for elephants and other wildlife. A salt lick is a salt deposit that animals regularly lick. Salt or mineral licks often occur naturally, providing the sodium, calcium, iron, phosphorus and zinc required in the early stage of life for bone, muscle and other growth[4].

Pilot ditches have been built as barriers to prevent elephants from entering farm areas. The collective length of the pilot ditches is approximately 16 kilometers and they cost about 2 million THB (USD 62,500[5]) in total. However, there is evidence to show that the pilot ditches do not prevent elephants from crossing into farm areas (Figure 8).Furthermore, since the road in front of the KARN office cuts through the sanctuary (Figure 9), it has caused loss of human and animal life. Wonghongsa et al. (2007a) reported that closing the roads saved approximately 60% of wildlife compared to not closing roads.

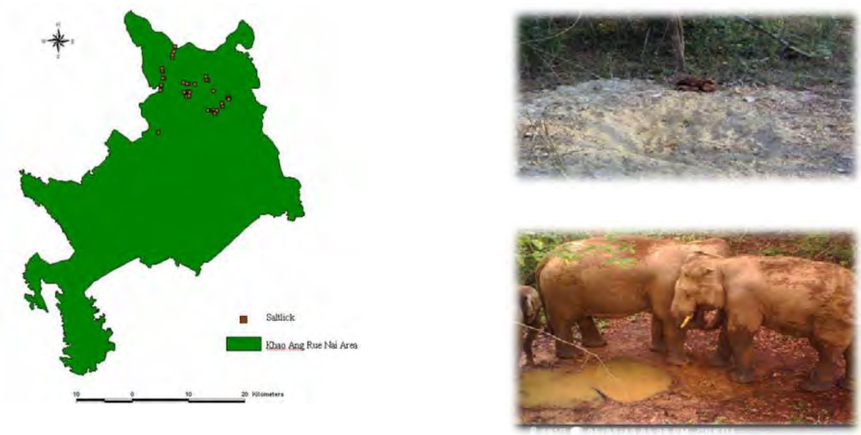
[4]http://en.wikipedia.org/wiki/Salt_lick 13 August, 2010
[5]Personal interview with Mr. SawaiWonghongsa, 19 January, 2011



Natural ponds Artificial ponds

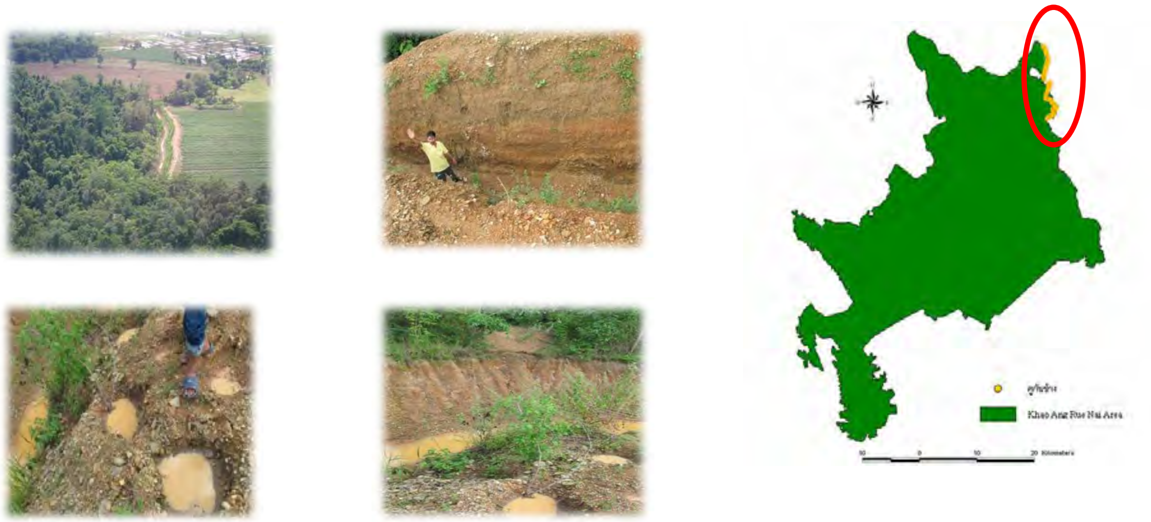
Source: The Chachoensao Wildlife Research Station

Figure 6.The location of natural and existing artificial ponds in KARN



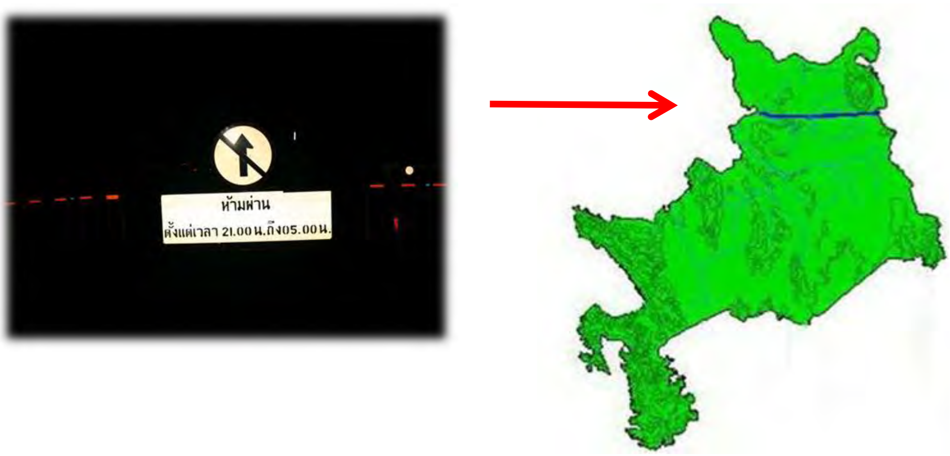
Source: The Chachoensao Wildlife Research Station

Figure 7.The location of existing artificial salt licks in KARN



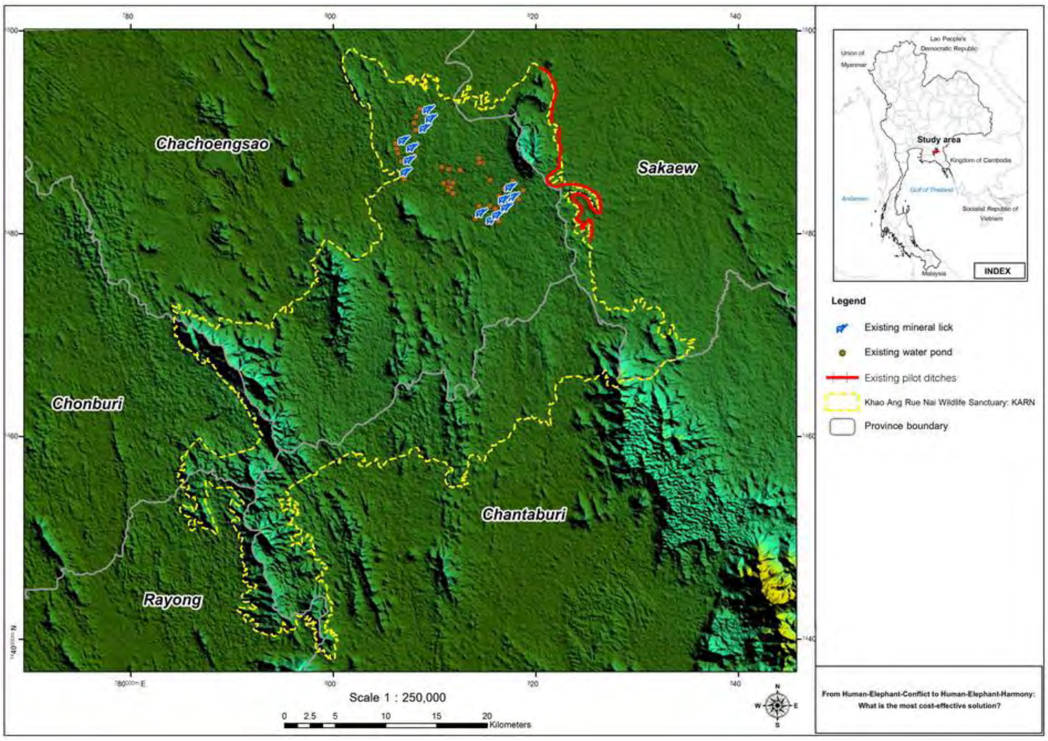
Source: The Chachoensao Wildlife Research Station

Figure 8.The location of pilot ditches in KARN



Source: The Chachoensao Wildlife Research Station

Figure 9.The location of road closures in KARN(in front of the KARN office)



Source: The Chachoensao Wildlife Research Station

Figure 10.Locations of existing habitat improvement activities in KARN

A government agency provides compensation for crop losses (Table 3) but the compensation rate (USD126-190 per hectare) is relatively low compared to the income loss suffered by households. For example, data shows that the cost of damage to SWD village was approximately USD649 per hectare in 2007. Compensation to farmers who made a claim for crop loss in the areas surrounding KARN in 2009 is shown in Table 4. In 2009 roughly 48,058 households registered for compensation due to crop raiding by elephants. The total area surrounding KARN that was affected by this problem was about 1,961 rai or 314 hectare in 2009. The total compensation for crop loss from crop raiding by elephants was approximately 1.5 million THB or USD 51,100 in 2009. However, this figure might be an underestimate because we found that the number of households who registered for compensation in Na Yao village (one of the study areas) was less than the affected households. Also, the compensation rate was estimated from production costs, not the market value of the crops. Some households even said that it was not worth going to register for compensation because the transportation costs of doing so might be higher than the compensation they would receive.

Table 3. Compensation rate for damaged crops

Crop type	Totally damaged (USD per hectare)
Rice	126
Dry crops (e.g. sugarcane)	174
Horticulture (e.g. papaya)	190

Note: 1) 1 hectare = 6.25 rai and USD 1 = THB 30, 2) compensation rate for partial damage to all crops is approximately USD 60 per hectare
Source: The Chachoensao Wildlife Research Station

Table 4. Compensation to farmers in villages surrounding KARN for crop raiding by elephants, 2009

Affected areas by crop raiding	Total no. of villages	Total no. of HHs	Total HHs registered for compensation	Affected areas (rai)	Compensation (THB)
Chachoengsao Province					
KhlongTakrao SAO	25	7,147	2	17	14,379
ThaKra Dan SAO	23	6,620	NA	1,070	886,398
Sakaew Province					
PhraPhroeng SAO	19	4,207	NA	149	39,336
Wang Tong SAO	17	3,747	NA	236	197,586
Wang Mai SAO	14	4,122	48	300	230,390
Chantaburi Province					
Kun Song SAO	18	4,394	30	97	82,703
Pawa SAO	12	9,419	24	45.5	38,232
Tung Benja SAO	14	2,393	7	2.8	2,338
Rayong Province					
HuaiThap Mon SAO	8	3,063	2	NA	7,200
KhaoNoi SAO	5	894	4	39	29,871
Chonburi Province					
Ploung Tong SAO	7	2,052	2	5	4,560
Total	162	48,058	119	1,961.3 (314 ha)	1,532,993 (USD 51,100)

Note: 1. SAO = Sub-district Administration Organization;2. USD 1 = THB 30, 1 hectare = 6.25 rai

1.4 Review of Literature on the Mitigation of Human-Elephant Conflict

1.4.1 Africa and South Asia

Most HEC can never be completely eliminated; for this reason conflict reduction should aim to reach a local "tolerance level" toward elephants, rather than expect to eliminate the problem entirely (Dublin and Hoare, 2004). In Africa, the conflict between wild elephants and local people is central to wildlife management. Osborn and Parker (2003) reviewed the methods used to mitigate the conflict between humans and elephants in Africa. Current methods in use here can be categorized as two types: passive and active. The passive method tries to limit the movement of "target species" into farm areas by using wooden or stone fences, ditches and electric fences. Active methods attempt to drive elephants away by using noise (e.g. banging on tins or drums, shouting, and throwing objects) or fires. The success of passive methods depends on the material and design of the fence and the behavior of the elephants. The success rates of active methods are unclear since little published information is available. Furthermore, it is difficult to conduct experiments in the field and elephants can adapt their behavior. In addition, each site has specific characteristics so one model does not fit all situations. Osborn and Parker suggest that an integrated, community-based, low-tech approach, for example, modification of crops, farm location in relation to the movement pattern of crop raiding, a system of rotating guard duty etc., is the most sustainable response to HEC.

WWF (2008) reviewed the mitigation options for HEC in India and Sri Lanka. These options fall into seven categories; traditional crop protection (e.g. making noise, fires, etc.), elephant barriers, supplementary feeding (planting food for elephants), relocation, compensation and insurance, buffer crops and unpalatable crops, and land-use planning. The report describes the strengths and weaknesses of each option. For example, traditional crop protection by farmers, such as making noise and fires, tends to lose effectiveness over time because elephants become familiar with these techniques and learn that they do not pose a real physical threat. When these methods fail, animosity towards elephants begins to increase, resulting in the perception that cropraiding is significant. In addition, confrontational methods increase the risk of injury and death for farmers from elephants because if aggression levels rise on one side, then they rise on both sides. The use of tame elephants, known as*koonkies*, to chase away crop-raiding elephants is effective when raiding incidents occur in a small area so the *koonkies* can be stationed at strategic points. GPS satellite radio is another option for monitoring the movement of individual crop raiders; it can be used to issue warnings to villagers of a crop raider's presence in a particular location. However, this technology is very expensive (around USD5,000-8,000 per collar) and only has a lifespan of between one and two years. The benefit-cost ratio of this method is very low and cannot be applied to any area. However, using such collars in scientific studies to identify patterns of crop raiding and the effectiveness of preventive methods in different areas could provide helpful information that could be used to develop more effective mitigation methods for each area.

The use of electric fences can also alleviate the conflict between humans and elephants. Gunaratne and Premarathne (2006) assessed the effectiveness of electric fences in Sri Lanka by using several indicators, which are the number of human lives saved per year, the number of human injuries reduced per year, and the reduction in the incidence of property/crop damage per year. The treatment-control experiment procedure was adopted by comparing two groups between areas protected with an electric fence (with policy alternative) and areas not protected by an electric fence (without policy alternative). The study found that electric fences can help to alleviate HEC but do not completely eliminate the problem. Furthermore, an electric fence did not offer a "stand alone" solution but technical and socio-economic factors also played an important role in the success of each fence. The main factors affecting success were: good design, geographical variation, elephant migration patterns, the completeness of the fencing, and community support for fence maintenance.

1.4.2 Human-elephant conflict mitigation in Thailand

Two areas, KuiBuri National Park and Salakpra Wildlife Sanctuary, were reviewed regarding HEC mitigation in Thailand.

KuiBuri National Park

The KuiBuri National Park is located in PrachuapKhiri Khan Province. The human-elephant conflict in KuiBuri National Park began in 1994 (Chumnankid, 2007). In 2006, WWF staff conducted a household survey of the 25 communities living within three kilometers of the boundary of KuiBuri National Park, interviewing 758 households (Parr et al., 2008). The WWF project calculated that there were 268 km^2 (167,551 rai) of pineapple plantations located within three kilometers of the KuiBuri National Park boundary (based on satellite imagery). Villagers had land ownership documents for 205 pineapple fields situated right next to the National Park, covering 661.12 ha (4,132 rai); 179 fields encompassing 442.24 ha (2,764 rai) had no land titles, while 78 fields were rented. Out of the total sample of 543 agricultural fields, 217 fields (40%) had been recently raided by elephants. Of the farmers who were affected by crop damage, 66 reported that elephants came out of the forest more than 50 nights a year, while 22 farmers stated that elephants were in their fields between 200-365 nights per year. The peak months for intrusions were April, followed by February and then May. Most farmers observed elephants between 16.00-18.00 hr (34.3%). Thirty-four farmers were interviewed regarding the level of damage; 27 farmers estimated that the crop area damaged was less than 1.6 ha (10 rai); 15 farmers estimated the damage at less than USD250 (THB 10,000); 25 farmers estimated the damage between USD250 and 1,250 (THB 10,000-50,000), 11 farmers estimated the damage to be USD1,250-2,500 (THB 50,000-100,000), while seven farmers estimated damage at over USD2,500 (THB 100,000). Sixty-eight farmers reported that fireworks were the most effective way of discouraging wild elephants, while others used spotlights and gas lamps. Also, electric fencing was erected and some villagers burned tires to chase elephants away.

Regarding HEC mitigation at government level, under the royal-backed forest restoration and conservation project in KuiBuri, the 20,000-rai pineapple crop surrounding the protected area was expropriated to improve the habitat for wildlife. Examples of habitat improvement include water resource improvement, forest restoration, and the provision of supplementary food for elephants (WWF, 2009). Supplementary food for elephants was provided by villagers, who received payments from the project fund. This activity attracted the raiding elephants, thereby preventing raiding and reducing HEC.

Salakpra Wildlife Sanctuary

The Salakpra Wildlife Sanctuary is located in Kanchanaburi Province. Crop-raiding incidents were first recorded in 1982 (Sitati, 2007). Measures such as erecting bamboo fences or creating home-made alarm systems were taken by households. However, when crop raiding became more frequent and more intense, households tried to apply more effective measures such as simple electric fences, non-electric fences, watchtowers in tall trees, planting unpalatable crops, using torches and reflecting CDs, catapults and firecrackers and guarding crops at night (Sitati, 2007).

In 2007 the Elephant Conservation Network (ECN) started a crop protection trial, using trenches and electric fences (Ritthirat, forthcoming). In this project, the total length of the trench used was 3,867 meters and the construction budget was about THB 300,000 (USD 9,375), excluding rental of the heavy machinery, which was lent to the project by the Thai army based in Kanchanaburi. ECN staff collected information regarding crop damage by crop-raiding elephants in two periods, one year before the trench construction and one year after the trench construction (October 2006-September 2007 vs. October 2007-September 2008). The results showed that crop loss caused by raiding before the trench construction was THB 111,099 (USD3,703), as compared to THB 13,190 (USD440) during the post-trench period, or the losses had decreased by 88%. With regard to the use of electric fences, sites were selected for the trial that comprised both private farms and houses and also the entry and exit routes used by the elephants in the sanctuary. An electric fence was erected around a 20-rai sugarcane field. The trial area was monitored for 12 months (from March 2007-February 2008). Monitoring showed that there was a reduction in damage to crops, from THB 29,742 (USD991) to THB 5,316 (USD177) after the trial, or a decrease of about 82%.

1.5 Research Methods

1.5.1 Cost-benefit analysis

The cost-benefit analysis (CBA) will be used as a tool to compare three policy options over a 20-year period to deal with HEC in the study area. These scenarios are:1) habitat improvement activities and contraception for female elephants, 2) habitat improvement activities, female elephant contraception and land-use change, and 3) habitat improvement activities, female elephant contraception, and electric fences. Seven steps of CBA will be conducted.

Step 1:Defining the referent groups

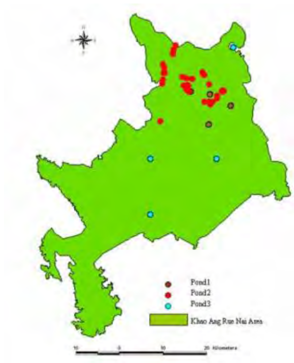
The referent group defines the group of individuals whose welfare will be accounted for when assessing the costs and benefits of the project. The reference group of this project is households affected by HEC whose crops are located near KARN.

Step 2: Identifying alternative methods of achieving the objectives

Even though local people and related government agencies have put some mitigation measures in place, they are not enough to eliminate the HEC problem. According to expert opinion, alleviating the HEC problem can be achieved by improving the level of the current mitigation activities (habitat improvement), combined with other options (contraception for female elephants, land-use change and electric fences). The alternative methods being considered are: 1) habitat improvement and female elephant contraception, 2) habitat improvement, female elephant contraception and land-use change and 3) habitat improvement, female elephant contraception and electric fences. These options will be compared with the status quo. The details of each policy options are as follows.

1. Habitat improvement and female elephant contraception

The former head of the Chachoensao Wildlife Research Station has suggested that an effective mitigation strategy is to keep the elephants within the sanctuary by improving the habitat for elephants to enable them to sustain life without raiding farms for food. Proposed measures include increasing the number of ponds, increasing the number of salt/mineral licks, and increasing the amount of grassland. The new water resources should be established in deep jungle to discourage elephants from leaving the sanctuary. The blue plots in Figure 11 show the location of additional ponds. Figure 12 shows the location of additional salt/mineral licks (the yellow plots). The widespread of alien plant species has negatively affected the amount of grassland in the sanctuary. In the deep forest, where sunlight cannot reach the ground, the grass cannot grow well. The amount of grassland could be increased by replacing alien species (e.g. the bitter bush) with native species of grass (e.g. wild sugarcane). This would increase the amount of food available for wildlife. Figure 13 shows the location of the proposed new grassland area. Birth control for female elephants will be introduced when the elephant population exceeds the maximum capacity level of 500 elephants.



The blue plots show the location of additional ponds

The yellow plots show the location of additional artificial salt licks

Source: The Chachoensao Wildlife Research Station

Figure 11. Proposed artificial ponds

Figure 12. Proposed artificial saltlicks

Bitter bush(alien species)

Grass cannot grow because sunlight cannot reach it

Proposed new grassland

Source: The Chachoensao Wildlife Research Station

Figure 13. Alien plant species, sunlight-poor areas of forest, and the location of proposed new grassland

2. Habitat improvement, female elephant contraception and land-use change

Habitat improvement and birth control for female elephants will be introduced at the same level as in scenario 1. The area within 0.5 km of the boundary of KARN is a high-risk zone for elephant crop raiding so usage will be changed from existing food crops to crops that are unpalatable to elephants.

3. Habitat improvement, female elephant contraception and electric fences

In this scenario habitat improvement and birth control for female elephants will be introduced at the same level as in scenario 1. In addition, electric fences will be erected in the risky area, which accounts for 220 km of the total 460-km boundary of KARN.

Step 3: Listing of outputs, impacts and potential impacts

The costs and benefits of each scenario are listed in Table 5. The avoided costs (cost of damage, cost of protection, and opportunity cost of time) can be viewed as the benefits of the project because the existing costs, currently borne by households, will be alleviated when the mitigation measures are implemented.

Step 4: Quantifying and monetization the outputs and impacts

Information on the costs of mitigation measures were obtained from reviews of documents, reviews of literature, and expert interviews. The benefits of the project are based on the field survey findings discussed in section 2 of this report. The technique for cost and benefit estimation and the sources of information are shown in Table 5.

Table 5: Categories of benefit and cost estimation

Categories	Technique used to estimate	Source of information
Benefits (avoided costs)		
1.1 Avoided cost of damage for households affected by crop raiding.	Market value	Field survey
1.2 Avoided cost of protection for households affected by crop raiding.	Market value	Field survey
1.3 Avoided opportunity cost of time spent guarding crops at night.	Market value (forgone income)	Field survey
Cost: Habitat improvement and contraception		
2.1 Investment and maintenance costs of mitigation activities (ponds, salt/mineral licks, grassland, etc.) to improve habitat in KARN.	Market value	Expert interview
2.2 Contraception	Market value	Expert interview
Cost: Habitat improvement, contraception and land use change		
3.1 Investment and maintenance costs of mitigation activities (ponds, salt/mineral licks, grassland, etc.) to improve habitat in KARN.	Market value	Expert interview
3.2 Contraception	Market value	Expert interview
3.3 The costs of forgone opportunities (the net present value of the next-best economic use of resources and land). In this case, it is the forgone income of changing existing food crops to crops that are unpalatable to elephants.	Market value	Field survey
Cost: Habitat improvement, contraception and electric fences		
4.1 Investment and maintenance costs of mitigation activities (ponds, salt/mineral licks, grassland, etc.) to improve habitat in KARN.	Market value	Expert interview
4.2 Investment and maintenance costs of electric fences.	Market value	Field survey

Step 5: Calculate net present value (NPV)

The values of the costs and benefits during the 20 years of the project period are discounted to get the present values by using 3%, 5% and 8% discount rates. Each rate indicates differences in time preferences for consumption now as opposed to the choice of delaying consumption to future periods. The NPV of the different scenarios are compared. In principle, all projects with NPVs > 0 are considered to have passed the NPV test since it is considered an improvement in social welfare.

The NPV of a project is equivalent to the present value of the total benefits minus the total costs. Therefore, it assumes that at least one NPV is positive. If no NPV is positive, however, none of the proposed options are superior to the status quo. Then the status quo should remain in place. With the project time frame of this study being 20 years, the NPV is calculated using the following:

$$NPV = \sum_{t=0}^{19} \frac{B_t - C_t}{(1+r)^t}$$

Step 6: Performing sensitivity analysis

Sensitivity analyses are an essential stage of CBA, used to determine the sensitivity of the NPV given changes in a key parameter. The sensitivity parameters were discount rate, namely 3%, 5% and 8%, and the growth rate of crop-raiding damage, namely 5%, 10% and 15%.

Step 7: Compare NPVs and make recommendations based on the NPVs

The recommended option is the scenario with the largest NPV. The policy options should be ranked in order from the largest NPV to the smallest NPV.

1.5.2 Cost-Effectiveness Analysis (CEA)

The CEA compares options on the basis of the ratio of their costs but not on monetized effectiveness measure. The unit of output or the effectiveness measure can be derived from the objective the options are trying to achieve. In this case, the effectiveness is the area of crop saved from damage. The cost effectiveness ratios can be calculated from the following (Broadman et al., 2001):

where CE_i = Cost effectiveness ratio of policy i

C_i = Total costs of treatment or policy intervention

E_i = Effectiveness of the treatments = crop damage saved

The CE ratio can be represented as the average cost per unit of effectiveness. In general, the most cost-effective scenario has the lowest average cost per unit of effectiveness. The policy options should be ranked from the most cost-effective (the smallest CE ratio) to the least cost-effective (the largest CE ratio). The sensitivity tests were conducted in CEA. The sensitivity parameters were discount rate, namely 3%, 5% and 8%, and growth rate of crop-raiding damage, namely 5%, 10% and 15%.

1.6 Data Collection

Key informant interviews were arranged in order to get information on appropriate mitigation measures to deal with HEC and the cost of each mitigation option. A household survey was used to obtain information on the attitude of households towards the impact of HEC, crop damage by raiding elephants, and also mitigation measures taken by households. Information was also obtained from reviews of documents and literature. The household survey covered 200 households affected by HEC, across six villages.

2.0 Survey of Households Affected by HEC

Information gained from focus group discussions and key informant interviews, such as wildlife experts and the headmen in the study areas, was used to design the draft household questionnaire. A pretest was conducted to check that the questionnaire worked, with a total of 30 samples pretested. After the pretest, the questionnaire was revised. The household questionnaire comprises three sections: the first section covers socio-economic characteristics; the second section deals with the situations created by, and the impacts of HEC, in an effort to determine the extent and nature of the impact of HEC, including the frequency of crop-damage incidents and the cost of damage; and the last section investigates what households individually and collectively have done to deal with HEC, including assistance from external sources. This section also explores whether people affected by HEC plan to deal with it. The 200 households included in the sample were randomly selected. The survey was conducted in face-to-face interviews in March 2011 (Figure 14).

Figure 14.Conducting the household survey

2.1 Description of the Study Areas

The six villages adjacent to KARN, namely Na Yao, Na Isan, LumTha Sang, Tha Ten, Na Ngam, and KlongToey, were selected as the study areas (Table 6). These villages encounter the most severe HEC problems. In LumTha Sang village every household has been affected by crop raiding, whereas only some households in other study areas have been affected. Most crop types in the study areas, e.g. cassava, rice and corn, are cash crops that can be eaten by elephants. The villagers in the six study areas migrated from other provinces in the northeast region of Thailand to this area around 30 years ago. This could explain why most of them have dealt with the HEC problem individually, rather than as a group. The characteristics of the households and the cropsgrown in each area are shown in Table 6.

Table 6. Characteristics of households and damage information for each area

Characteristics	The study areas					
	Na Yao	**Na Isan**	**LumTha Sang**	**Tha Ten**	**Na Ngam**	**KlongToey**
Total no. of households (HH)	1,001	252	24	220	545	205
No. of HH affected by HEC	450	30	24	32	30	150
Crop type	Cassava, rice and rubber trees	Cassava rice and sugarcane	Cassava and corn	Cassava, rice, rubber trees and eucalyptus	Cassava and rubber trees	Cassava, rubber trees and rice
Sample size	50	47	13	32	20	38

Source: interviews with the headman in each study area

2.1.1 Na Yao

Na Yao is no. 15, ThaKra Darn sub-district, Sanamchai district, Chachoengsao Province. There were approximately 1,001 households in Na Yao in 2010. According to official records, 50 households registered for compensation following cropraiding in 2010. The crop types in this area are cassava, rice and rubber trees. According to in-depth interviews with the villagers, fields of crops adjacent to the park suffered more than ones located further away from the park. The villagers also mentioned that the elephants are quite clever. Before elephants enter a field of crops they will first make a noise to make sure there is no response from humans, and then they will enter the field. Sometimes, elephants do not eat the crops but simply play in the fields and this results in crop damage. In some households dogs try to protect crops by barking at the elephants but this makes matters worse because the elephants are frightened and so inflict more damage by trampling crops. Another impact of HEC in this area that can outweigh the economic costs of crop damage is human death. There has been one human death due to HEC in this area. Mrs. Malee Panongped lost her 30-year-old son last year during night-time crop guarding. Another example of impact due to HEC is the case of Mr.Sopa Klongsin (Figure 16). He and his two brothers have had to move to their fields to live amongst the crop, even though they have their own houses in the village. Mr Sopa said that guarding the crop at night leads to loss of sleep.

In the past traditional techniques such as shouting, drum-beating, noise-making, lighting firecrackers and bright lights were used to chase elephants away, however, an elephant is a highly adaptable animal. The elephants have become habituated to such measures and have learned that they pose no real threat. At present electrified fences are employed in some areas but they cannot completely eliminate crop loss.

The main damage from HEC is loss of crops, especially rice and cassava. Moreover, there is also property damage such as damage to guard huts (Figure 15). This type of damage places some households under stress because they have to borrow money to build a new hut.

Figure 15. Hut damaged by elephants

2.1.2 Na Isan

Na Isan is village no. 16, ThaKra Darn sub-district, Sanamchai district, Chachoengsao Province. There were 252 households in Na Yao in 2010. According to official records, 30 households registered for crop-raiding compensation in 2010. The crops in this area are cassava, rice and sugarcane.

Apart from individual mitigation measures, households act collectively to guard crops at night (Figure 16). Using radios to contact each other when they see elephants entering their fields, villagers act as a team firing guns into the air to scare the elephants.

Elevated observation hut at night

Guns

Figure 16. Collective action taken to guard crops at night

2.1.3 LumTha Sang

LumTha Sang is village no. 25, KlongThra Kao sub-district, Tha Ta Kiap district, Chachoengsao Province. There were 24 households in LumTha Sang in 2010. According to official records, 24 households registered for crop-raiding compensation in 2010 – meaning that all of the households in the village were affected by crop raiding. The crops in this area are cassava and corn. During focus group discussions, villagers said that human behavior can influence the elephants. For example over-ripe papayas that could not be sold were placed at the roadside as food for elephants. In the past elephants did not eat papayas but when they tasted them and realized they could digest them, they started to raid the papaya crop.

According to an in-depth interview with the ex-headman of LumTha Sang, his 20-rai corn crop was totally destroyed by elephants in 1980. After this happened he switched to growing chilli, eggplant and sesame instead. Even though elephants do not eat these crops, the crops were damaged because the elephants walked across the headman's fields searching for water and food. Mr. Ma Seedam was stabbed by an elephant's tusk while guarding his crop in 1995 (Figure 17). He showed us the scars from this attack, on his stomach, finger, and ear. The villagers reported that there are two elephants in particular that are persistent crop raiders – sometimes they even block the truck carrying sugarcane, in order to eat the sugarcane. The villagers called these elephants "*sugarcane robbers*". During the household survey, the research team found one of these two culprit elephants searching for food on the road (Figure 18).

Figure 17. Mr. Ma's scars, inflicted by an elephant's tusk in 1995

Figure 18.One of the two culprit elephants in LumTha Sang village

2.1.4 Tha Ten

Tha Ten is village no. 9, PraPhloeng sub-district, Kao Chakan district, SakaewProvince. There were 220 households in Tha Ten in 2010. According to official records, 30 households registered for crop-raiding compensation in 2010. The crop types in this area are cassava, rice, eucalyptus and rubber trees. Even though a government agency has already built pilot ditches in this area, the damage from crop-raiding has not lessened because elephants can cross the ditch (Figure 19). Some wildlife experts claim that the ditch was not constructed to appropriate specifications.

Figure 19.Elephants can cross pilot ditches

2.1.5 KlongToey

KlongToey is village no. 21, ThaKra Darn sub-district, Sanamchai district, Chachoengsao Province. There were 205 households in KlongToey in 2010. According to official records, 150 households registered for crop-raiding compensation in 2010. The crop types in this area are cassava, rice and rubber trees. Villagers claim that approximately 30-40 elephants entered the crop fields simultaneously last year. Collective action has been initiated by the headman and has been supported by the provincial administration and the sub-district administrative organization to grow food for elephants, e.g. banana and sugarcane, in the 50-rai area of the park (Figure 20). The villagers and students in the village have collectively contributed their labor, and some villagers have not only contributed labor but have also provided banana or sugarcane sprouts to plant in the park. This activity has taken place once a year since 2009 but villagers think this level of activity is still not enough.

Figure 20.Villagers from KlongToey plant food for elephants

2.1.6 Na Ngam

Na Ngam is village no. 19, ThaKra Darn sub-district, Sanamchai district, Chachoengsao Province. There were 545 households in KlongToey in 2010. According to official records, 30 households registered for crop-raiding compensation in 2010. The crop types in this area are cassava and rubber trees. Villagers explained that a lot of elephants (approximately 30-40) from the same herd enter their crop fields at the same time as they enter fields belonging to KlongToey because KlongToey is the neighboring village.

2.2 Results of the Household Survey

2.2.1 Socio-economic characteristics of the households

Table 7 summarizes the socio-economic characteristics of the households in the study areas. On average, there are four family members per household. The average agricultural area farmed by each household is roughly 33.6 rai or 5.4 hectares. The total agricultural area in LumTha Sang village is quite small (7.6 rai or 1.2 hectare per household) compared to other areas. The households in all the study areas are not made up of local people but of people who migrated from the northern region, so the average number of years each household has lived in the study area is approximately 21.6 years. The average annual income from agricultural is roughly THB 151,067 per household or USD 5,036 per household. The average total household income is approximately THB 183,950 per household or USD 6,132. However, the household incomes in LumTha Sang village (THB 80,398 per household or USD 2,680 per household) and Tha Ten village (THB 81,943 per household or USD 2,731 per household) are low compared to the other study areas.

Table 7.Socio-economic characteristics of households in the different study areas

Socio-economic characteristics	**Study areas**						
	Na Isan	**LumTha Sang**	**Na Yao**	**Tha Ten**	**KlongToey**	**Na Ngam**	**Total for area**
No. of people per HH	4.2	3.2	4.5	3.9	3.9	4.8	4.2
Agricultural area (rai)	28.2 (4.5 ha)	7.6 (1.2 ha)	44.3 (7.1 ha)	28.7 (4.6 ha)	41.1 (6.6 ha)	28.9 (4.6 ha)	33.6 (5.4 ha)
No. of years HH in study area	20.5	26.5	23.5	23.1	18.2	19.9	21.6
Annual agricultural income (THB/HH)	157,143 (USD 20,692)	44,797 (USD 1,493)	199,926 (USD 6,664)	58,415 (USD 1,947)	203,954 (USD 6,798)	123,872 (USD 4,129)	151,067 (USD 5,036)
Annual non-agricultural income (THB/HH)	20,692 (USD 690)	35,601 (USD 1,187)	46,097 (USD 1,537)	23,529 (USD 784)	28,579 (USD 953)	50,288 (USD 1,676)	32,882 (USD 1,096)
Annual HH income (THB/HH)	177,835 (USD 5,928)	80,398 (USD 2,680)	246,023 (USD 8,201)	81,943 (USD 2,731)	232,533 (USD 7,751)	174,161 (USD 5,805)	183,950 (USD 6,132)

Source: household survey, 2011
Note: USD1 =THB30
Note: 1 hectare = 6.25 rai
Note: all values are in 2010 prices

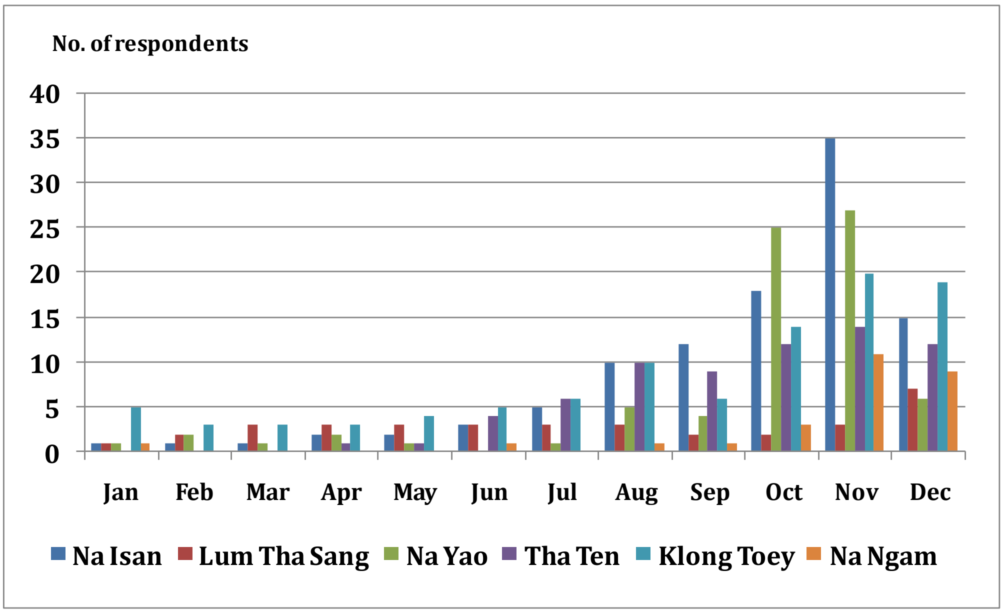
2.2.2 Situation and impacts from HEC

Households were asked when they were first affected by crop raiding. This information can be seen in Table 8 and it indicates that elephant crop raids have been increasing in frequency and in the number of locations affected. When asked which months saw an increase in the frequency of cropraiding, most households said that the worst period of the year was August-December (Figure 21), during the harvest. The rice harvest takes place October-December and the cassava harvest takes place September-December. Cropraiding incidents gradually increase in August, reach a peak in November, and then decline in December. None of the study areas have irrigated land so agricultural practices depend on the level of rainfall every year. This explains why farmers do not change their crop calendar even though they are aware of the crop-raiding period each year. The average number of crop-raiding incidents across all six study areas is approximately 25 incidents a month during the high frequency period (Table 9). There is no difference in the average number of crop-raiding incidents in each study area. On the other hand, the average number of crop-raiding incidents during the low-frequency period of cropraiding is approximately six per month. Therefore, the overall average number of crop-raiding incidents is roughly 15 per month. The average number of nights spent guarding crops across all the study areas is 212 nights per year (Table 10). While elephants do not eat rubber trees, some farmers mentioned that elephants play with them and damage them. Some households do not guard their crops because they are afraid that the elephants might hurt them.

Table 8.First incidents of cropraiding by elephants

Time period	No. of households affected by crop raiding	%
Before 1988	6	3.0
1988-1992	13	6.5
1993-1997	12	6.0
1998-2002	36	18.0
2003-2007	83	41.5
After 2007	50	25.0
Total	200	100.0

Source: household survey, 2011



Source: household survey, 2011

Figure 21. Number of crop-raiding incidents per month

Table 9.Frequency of cropraiding by elephants

Villages	Number of crop-raiding incidents per month		
	Min.	**Max.**	**Mean**
Na Isan	1	30	23.4
LumTha Sang	20	30	29.2
Na Yao	1	30	23.5
Tha Ten	1	30	22.7
KlongToey	3	30	26.2
Na Ngam	3	30	27.4
Total	1	30	24.6

Source: household survey, 2011

Table 10. Number of nights spent cropguarding per year

Study areas	**Number of nights spent crop guarding per year**
Na Isan	224
LumTha Sang	214
Na Yao	270
Tha Ten	234
KlongToey	167
Na Ngam	165
Average	212

Source: household survey, 2011

The average crop area damaged by HEC in 2010 was approximately 6 rai per household per year or 0.96 hectare per household per year (Table 11), which accounted for nearly 18% of the total crop area. The average total cost of damage due to HEC in 2010 was approximately THB 34,825 per household per year or USD1,161, which accounted for roughly 19% of average household income. Crop-raiding damage accounted for 99% of the total damage to crops. In absolute terms, the total cost of damage in the village of KlongToey was the highest. However, the damage cost in LumTha Sang ranked the highest in terms of the share of household income that damage to crops represented, which accounted for roughly 34% of the average household income. Furthermore, as mentioned in the previous section, HEC has caused not only direct costs, such as crop and property damage, but also a loss of life (as reported by one respondent in Na Yao village) and two injuries. Additionally, when asked whether they are worried about HEC, 89% of respondents reported that they are anxious that elephants might raid their crops, damage their property or harm them.

Table 11. Cost of damage due to HEC in 2010, classified by study area

Categories	Cost of damage due to HEC in 2010 (THB/HH)						
	Na Isan	**LumTha Sang**	**Na Yao**	**Tha Ten**	**KlongToey**	**Na Ngam**	**Total**
Crop-damaged area (rai)	4	3	6	3	10	9	6 (0.96 ha)
Cost of crop damage	24,357	27,677	34,293	17,709	57,805	48,074	34,582
Cost of property damage	221	46	679	-	59	-	243
Cost of treatment of injuries	10	-	38	-	-	-	12
Total damage cost due to HEC in 2010	24,578 (USD 819)	27,723 (USD 924)	34,971 (USD 1,166)	17,709 (USD 590)	57,864 (USD 1,929)	48,074 (USD 1,602)	34,825 (USD 1,161)
Total annual HH income	177,835 (USD 5,928)	80,398 (USD 2,680)	246,023 (USD 8,201)	81,943 (USD 2,731)	232,533 (USD 7,751)	174,161 (USD 5,805)	183,950 (USD 6,132)
Damage costs as a share of income (%)	14	34	14	22	25	28	19

Source: household survey, 2011
Note: USD1 =THB30
Note: 1 hectare = 6.25 rai
Note: all values are in 2010 prices

2.2.3 Mitigation strategies to deal with HEC

Table 12 presents existing mitigation strategies for dealing with HEC. These mitigation measures can complement each other and this would explain why every household applies more than one option. All the study areas are quite new communities and this would explain why most households have dealt with crop-raiding individually. Using fire crackers and catapults (Figure 22) are the most popular measures (55.2%). Almost one-third of respondents (29%) have also built a hut to guard their crops at night – this option has co-benefits such as households being able to take a rest in the hut after doing farm work. Unlike a normal hut (Figure 23), the main purpose of an elevated hut is to guard crops from crop raiding by elephants but only five households (1.8%) built an elevated hut in the trees for crop guarding. Households that did not apply this option said that they did not do so because they think it is dangerous to climb up and down the trees. Some households (6.5%) have built un-electrified or electrified fences around their crops (Figure 24). Some households use light to protect their crops by supplying electricity to their fields (1.8%) or using hand-made lamps (Figure 25) to light their crops (4.3%). When asked about the effectiveness of mitigation measures, all of the respondents thought that mitigation measures cannot eliminate the impact of HEC but they can lessen some of the impacts.

Table 12. HEC mitigation measures taken by households

Mitigation measures	Number of respondents*	%
1. Fire crackers and catapults	154	55.2
2. Un-electrified or electrified fences	18	6.5
3. Building a hut to guard crops	81	29.0
4. Light: supplying electricity to crop fields	9	3.2
5. Building an elevated hut to guard crops	5	1.8
6. Light: hand-made lamps set in the crops	12	4.3

Source: household survey, 2011
Note: * respondents indicated more than one choice

Figure 22.Fire crackers and catapults

Figure 23. A normal hut (left) and elevated huts (center, right)

Figure 24.An electrified fence (left) and an un-electrified fence (right)

Figure 25. Hand-made lamps in fields

Table 13 illustrates the cost of crop-raiding mitigation methods borne by households. The most expensive method is the electrified or un-electrified fence, which has an average cost of about THB 7,285 or USD243 per household. The second most-expensive option is the use of lamps (THB 5,353 or USD178 per household) because this method uses kerosene or gasoline as a source of energy. Fire crackers are not expensive, they cost about THB 5 per firecracker, but households need to use them every night. According to the household survey, households use roughly 13 firecrackers per night during the high frequency period of crop raiding and three firecrackers per night during the low frequency period. This explains why the firecracker option is the third most-expensive mitigation method, with an average cost of about THB 5,227 or USD174 per household. Supplying electricity to the crop fields to power lighting is another method of keeping away elephants, with an average cost of about THB 3,989 or USD133 per household. Building a hut or an elevated hut costs about THB 1,941 or USD65 per household, and THB 1,434 or USD48 per household respectively. Overall the average cost of mitigation measures borne by households is approximately THB 5,917 or USD197 per household per year.

The average number of nights households spend guarding their crops is approximately 212 nights per year. Average household income is THB 183,950 and the average number of people in each household is 4.2. Therefore, average per-capita income is roughly THB 43,798 per year or THB 120 (USD 4) per day. If we assume that the number of working hours is the same as the number of crop-guarding hours, then the opportunity cost of time for crop guarding would be THB 120 or USD4 per night. To use 100% of income as the opportunity cost is to overestimate because households just guard their crops, they do not work as in the daytime. Therefore, only 30% of household income is used as a proxy for the opportunity cost of time spent crop guarding at night. Consequently, the opportunity cost of time for nocturnal crop guarding is estimated to be THB 7,632 or USD254 per household per year.

The total cost of HEC borne by households included: the cost of damage (THB 34,825 or USD1,161 per household per year); mitigation costs (THB 5,917 or USD197 per household per year; and opportunity costs for guarding crops at night (THB 7,632 or USD254 per household per year). Therefore the total cost to households of HEC is approximately THB 48,374 or USD 1,612, which accounts for 26% of annual household income.

Table 13. Mitigation costs borne by households affected by HEC, 2010

Mitigation measures	**Number of respondents**	**Mitigation costs (THB per HH per year)**		
		Min.	**Max.**	**Mean**
1. Fire crackers/ catapults	152	500 (USD 17)	18,000 (USD 600)	5,227 (USD 174)
2. Un-electrified or electrified fences	18	222 (USD 7)	32,000 (USD 1,667)	7,285 (USD 243)
3. Building a hut to guard crops	81	86 (USD 3)	21,716 (USD 724)	1,941 (USD 65)
4. Light: supplying electricity to fields	9	700 (USD 23)	12,500 (USD 417)	3,989 (USD 133)
5. Building an elevated hut to guard crops	5	100 (USD 3)	4,200 (USD 140)	1,434 (USD 48)
6. Light: lamps set in the crops	12	60 (USD 2)	21,600 (USD 720)	5,353 (USD 178)
Average mitigation costs for all measures	200	0	36,914 (USD 1,230)	5,917 (USD 197)

Source: household survey, 2011
Note: 1 USD = 30 THB
Note: allvalues are in 2010 prices

When asked whether they have plans to deal with HEC in the future (Table 14), the majority of respondents (90%) have no plans for coping with the future impacts of HEC. However, some households (7%) plan to build a fence around their crops. Other mitigation measures that households plan include a switch to growing unpalatable crops (2%), changing to another occupation (0.5%), and making and placing battery lamps in crop fields (0.5%).

When asked whether they have dealt with HEC (Table 15) in a collective manner, about 28% of respondents said that they had taken collective action, including working as a team to grow food for elephants, sending out patrols to monitor crops at night, building fences or ditches, acting as a group to ask for help from government agencies, and holding meetings on how to deal with the HEC problem. On the other hand, 72% of respondents said that no collective action had been taken. Reasons given included the fact that they think it is better to work individually and that it is difficult to work together.

Table 14.Household mitigation plans to deal with HEC in the future

Mitigation plan	Number of respondents	%
No plan	180	90.0
Plan to change to grow unpalatable crops	4	2.0
Plan to build un-electrified or electrified fences	14	7.0
Plan to change occupation	1	0.5
Plan to set battery lamps in crops	1	0.5
Total	200	100.0

Source: household survey, 2011

Table 15. Collective action to deal with HEC

Collective action to deal with HEC	Number of respondents
Collective action	55 (27.5%)
Work as a team to chase elephants away, e.g. using fire crackers	34
Work as a team to build fences	2
Work as a team to build ditches	1
Act as a group to ask for help from related government agencies	2
Work as a team to patrol crops	3
Work as a team to grow food for elephants	11
Have a meeting on HEC mitigation	2
No collective action	145 (72.5%)
Reasons to have no collective action: Working individually is better	143
Too difficult to work together	2

Source: household survey, 2011

Most households (66%) did not receive any assistance from external sources (Table 16). Only 34% of respondents received assistance from both central and local government agencies in term of financial assistance and compensation for crop loss. One respondent from Na Yao who lost her son during crop guarding at night reported that she received financial assistance from her neighbors to help pay for her son's funeral.

Table 17 presents the proposed mitigation measures by households to deal with the crop-raiding problem, most respondents suggested using an elephant barrier, such as electrified or un-electrified fences, (32%) and ditches (15%). Some respondents recommended habitat improvement such as planting more food for elephants and increasing water resources for elephants (15%). Other measures were also proposed: supplying electricity to the fields at night for lighting (15%); working as a team to patrol crops at night (5%); and relocation (4%). Nevertheless, some respondents (4%) believe that there is no effective method to prevent crop raiding and some households (9%) have no idea of how to deal with this problem.

Table 16. Assistance from external sources

Assistance from external sources	**No. of respondents**
Did not receive any assistance	131 (65.5%)
Received assistance	69 (34.5%)
1. Central government agencies	16
• Governor's office, e.g. necessity bags and financial assistance	3
• KhaoAng Rue Nai Wildlife Sanctuary, e.g. compensation	4
• District office, e.g. compensation	5
• Five provinces bordering Forest Preservation Foundation, e.g. financial assistance	3
2. Local government agency	52
• Sub-district Administrative Organization, e.g. compensation	52
3. Neighbors, e.g. financial assistance for funeral ceremony of man who died from human-elephant conflict	1

Source: household survey, 2011

Table 17. Proposed mitigation measures to deal with HEC by households

Mitigation measures	**No. of respondents**	**%**
No effective method of protecting their crops	7	3.5
Do not know	17	8.5
Electrified or un-electrified fences	64	32.0
Ditches	30	15.0
Relocation	8	4.0
Planting more food for elephants/increasing water resources for elephants	30	15.0
Supplying electricity to crop fields at night to power lights	29	14.5
Working as a team to patrol crops at night	10	5.0
Other methods, e.g. change to growing crops unpalatable to elephants, female elephant contraception, elimination	5	2.5

Source: household survey, 2011

The majority (89%) of respondents think that the future impacts of HEC will be more severe than current impacts (Table 18) because of the increasing elephant population. Some people believe that elephants were released into the park and into SalakPra Wildlife Sanctuary by the Queen of Thailand. ECN staff explained that encouraging this belief is a strategy instigated by the park rangers because the villagers would not dare to harm elephants they believe to have been released by the Queen. Consequently, some villagers believe that they cannot do anything and the only solution is to relocate elephants to other areas. This belief can prevent households from employing mitigation options. However, some households (8%) believe that the impact of HEC will be the same in the future as the current situation, whereas few households (1%) think that the impact of HEC will be less severe in the future, because they believe the fences built by government agencies are effective.

When respondents were asked whether they would be willing to volunteer to work to improve the habitat for elephants in KARN (Table 19), 93% said that they would be willing to do so. The reason some respondents gave for volunteering, was that they have to pay for their own mitigation costs, therefore they are willing to do volunteer work in KARN. Some respondents stated that they might be willing to volunteer (1%) or that they were not sure about doing so (5%). People who were not sure about volunteering gave several reasons, such as the fact that they did not think the work would be effective, that they were not available, that they live too far away, or that they are too old to work. Nonetheless, only 2% of respondents said that they would not be willing to work in KARN. Reasons given included a lack of availability, living too far away, or being too old to work. Only one respondent said that working in KARN should be paid.

Table 20 shows household attitudes toward elephants in KARN. More than half of respondents (60%) stated that they did not hate the elephants but that they also did not want them to raid their crops, whereas 27% of respondents said that they are afraid of elephants harming them or their crops. However, 14% of respondents stated that they do dislike, hate or get angry with the elephants because they damage their crops. This information indicates that most households still do not hate the elephants, even though they have suffered from the impacts of crop losses for many years. These attitudes could be a good sign for possible future mitigation measures involving local households.

Table 18. Household attitudes towards HEC in the future

Reasons	**Attitudes towards HEC in the future**				**Total**
	The same	**More severe**	**Less severe**	**Do not know**	
Increasing elephant population	1	155	0	0	156
Decreasing food for elephants in KARN	1	5	0	0	6
Cannot do anything	6	2	0	0	8
Belief that the Queen released the elephants into the park	1	7	0	0	8
Government agencies have already erected a fence	0	0	2	0	2
Other reasons, e.g. the elephants are clever, the elephants are not afraid of humans anymore	1	5	0	0	6
Do not know	5	4	0	5	14

Source: household survey, 2011

Table 19. Household volunteers willing to work in KARN for habitat improvement

Reasons	**Are you willing to volunteer to work in KARN?**				**Total**
	Not willing to volunteer	**Willing to volunteer**	**Might be willing to volunteer**	**Not sure**	
If these measures are effective, I am willing to volunteer to work	-	168	-	-	168
We will not volunteer to work in KARN, we have mitigation costs	-	15	-	-	15
Willing to volunteer to work but do not think these measures are workable		3	-	1	4
Too busy/live too far away	1	-	2	5	8
Need to consult with neighbors about what they think	-	-	-	2	2
Too old	1	-	-	1	2
This work should be paid	1	-	-	-	1
Total	3(1.5%)	186(93.0%)	2(1.0%)	9(4.5%)	200(100.0%)

Source: household survey, 2011

Table 20. Household attitudes to elephants

Attitudes to elephants	**No. of respondents**	**%**
Do not hate elephants but do not want them to raid my crops	119	59.5
Fear of being hurt by elephants or fear of loss of crops	53	26.5
Dislike/hate/angry with elephants because they damage my crops	27	13.5
No comment	1	0.5
Total	200	100.0

Source: household survey, 2011

3.0 COST-BENEFIT ANALYSIS OF HEC MITIGATION STRATEGIES

3.1 Description of Alternative Scenarios

The cost-benefit analysis of HEC mitigation was examined in three policy options:1) habitat improvement and female elephant contraception; 2) habitat improvement activities, female elephant contraception and land use change; and 3) habitat improvement activities, female elephant contraception and electric fences. Each new policy option was compared with the status quo to see which course of action was preferable. The benefits and cost categories of each scenario are described in Table 21. The benefits for all the policies are avoided costs from the crop-raiding problem borne by households, which are the cost of damage, the cost of protection, and the opportunity costs of time spent crop guarding at night. The investment cost category depends on the mitigation activities of each scenario, which are habitat improvement activities, female elephant contraception and electric fences. Another cost category is payment using the weighted average crop return for rice and cassava in the study area as a proxy for farmers to convert traditional crops to unpalatable crops in the risky zone in policy 2. In addition, the residual costs for conversion from traditional crops to unpalatable crops are borne by households in policy 1 and policy 2 but not in policy 3.

It should be noted that the CBA conducted here underestimates the benefits of reducing HEC because the benefit does not value the lives of humans or elephants saved. The approach to value of life, namely the value of statistical life (VSL), by using the wage hedonic approach to estimate the tradeoffs of workers between wages and the risk of death on the job is still controversial, Taylor (2003) has mentioned two controversies regarding VSL estimation. First, there is a large variation in the VSL estimation so it is difficult to select which value is best for any specific policy option. Second, there is a concern whether a VSL estimation derived from studies of fatal workplace risks is appropriate for reducing the risk of death from illnesses because illnesses may reduce quality of life and/or involve pain. Besides the controversy of VSL estimation, another reason not to place the value of life in the analysis is that the inclusion of these values might have produced higher benefits but would not have changed the ranking of the policy options.

In addition, sensitivity tests were conducted. For each sub-scenario three discount rates were used in the calculation of NPV, namely 3%, 5% and 8%. The parameters for conducting sensitivity analysis for this study also include the growth rate of crop-raiding damage, namely 5%, 10% and 15% annually, because crop-raiding damage may increase above or below the growth rate of the elephants, which is approximately 10% annually.

Table 21. Benefits and cost categories for each scenario

Scenarios	**Benefits**	**Costs**
Status quo	-	Total cost of crop-raiding problem borne by households (cost of damage, protection costs, opportunity costs of time)
Habitat improvement and contraception	Avoided costs from crop-raiding problem borne by households	1. Cost of habitat improvement activities and contraception 2. Residual cost of crop-raiding problem borne by households
Habitat improvement, contraception and land use change	Avoided costs from crop-raiding problem borne by households	1. Cost of habitat improvement activities and female elephant contraception 2. Payment to farmers to convert traditional crops to unpalatable crops in the risky zone
Habitat improvement, contraception and electric fences	Avoided costs from crop-raiding problem borne by households	1. Cost of habitat improvement activities and female elephant contraception 2. Cost of electric fences 3. Residual costs of crop-raiding problem borne by households

3.1.1 The status quo scenario

The status quo scenario assumes that nothing will be done in addition to the mitigation efforts already in place. Costs occurred in this scenario are costs from the crop-raiding problem borne by households (cost of damage, protection costs, opportunity costs of time spent guarding crops at night). The details of cost estimations in each category follow.

Cost of crop-raiding damage borne by households

Assumptions based on scientific studies in KARN and expert interviews.

The area affected by cropraiding or the high-risk zone within 0.5 km of the KARN boundary (the area shown by the red line indicating the proposed electric fence in scenario 3,Figure 28), is about 220 km of the total 460-km boundary (KARN, 2010). The rest of the

240-km boundary is the mountainous area where the risk of crop-raiding by elephants is quite low. Therefore, the total area at risk is approximately 110 km^2 or 68,750 rai[6].

Based on the household survey, the unit cost of damage is THB 34,825 per household per year and the average agricultural area is 33.6 rai per household. Given these facts, the cost of damage to an average area borne by households accounts for 18% of the total agricultural area. This scenario assumes that the cost of damage also accounts for 18% of the area in the high-risk zone.

Based on the Wonghongsa et al. (2008b) study, the growth rate of the elephant population in KARN is 9.83% or approximately 10% a year. Therefore, this scenario assumes that damage costs increase in proportion to the growth rate of the elephant population or 10% a year for the whole period of the project. However, crop-raiding damage may increase by more than 10% or decrease below 10%. Therefore, a sensitivity analysis on the growth rate of crop-raiding costs was performed, namely 5%, 10% and 15%.

Protection costs borne by households

Assumptions are based on the household survey to calculate protection costs.

The unit cost of protection borne by households is approximately THB 5,917 per household per year, or USD 197 per household per year. This analysis assumes that the protection cost to households is constant for the whole period of the project, operating under the assumption that households cannot do anything more than they already do.

Opportunity costs of time spent crop guarding at night

Assumptions are based on the household survey to calculate the opportunity costs of time.

Average household income is approximately THB 183,950 per household per year and the average number of household members is 4.2 people. The average per capita income is THB 43,798 per year or THB 120 (USD 4) per day per person. The average number of nights spent crop guarding is approximately 212 nights per household per year. It is hypothesized that households' revealed value of time reflects the opportunity costs of time associated with an aspect of working (crop guarding) rather than resting (or sleeping), which measures the trade-off between work and leisure. However, households obtain benefits form crop guarding by reducing the cost of damage caused by crop raiding. Therefore, it might be an overestimation to apply the full wage rates of households as a proxy of the opportunity cost of time spent crop guarding at night. This analysis assumes that the opportunity cost of the time households spend guarding their crops, which leads to loss of sleep, is only 30% of the total household income.

This analysis assumes that only one family member guards the crops at night. This analysis assumes that the opportunity cost of time will be constant for the whole period of the project as households cannot do anything more than they already do and that they expect no increase in their wages or in the opportunity cost of time (because they are engaged in subsistence farming).

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[6] 1km^2 = 625 rai

3.1.2 Habitat improvement and female elephant contraception (HC)

In this scenario, habitat improvement activities (the construction of ponds and mineral licks, conversion of invasive alien plants into grassland, plantations for the supplementary feeding of elephants) and contraception for female elephants will be implemented. The NPV of this scenario is calculated from the following:

$$NPV = \sum_{t=0}^{19} \frac{B_t - C_t}{(1+r)^t}$$

where

B_t = (Avoided costs from the crop-raiding problem in the case of the status quo - Residual costs from crop-raiding problem borne by households)

C_t = Costs of habitat improvement activities and contraception

Avoided costs from crop-raiding problem in the case of status quo = Increase in harvests due to less damage inflicted by elephants + avoided protection costs + avoided opportunity costs of time

Residual costs from crop-raiding problem borne by households = residual damage costs, protection costs and opportunity costs of time

Assumptions are based on scientific studies in KARN and expert interviews.

Presently, only 36.61% of the total area, approximately 374 km^2, currently functions as an optimal forest habitat for elephants. Improving the degraded forest habitat, which represents about 63.29% of the total area, would increase the capacity of KARN, allowing it to support between 332 and 498 elephants (Wonghongsa et al., 2008b). Therefore, this analysis assumes that KARN's maximum capacity for elephants is approximately 500 elephants if the proposed habitat improvement activities are deployed.

With the habitat-improvement project in the Chachoensao Wildlife Research Station, the annual growth rate of the elephant population within the KARN boundary, which was surveyed via the dung count method from 2001 to 2007, was approximately 2.38%; therefore, the increasing elephant population (7.45% every year) extends forging into agricultural land (new dung-piles were detected near the periphery of the sanctuary, Wonghongsa et al., 2007b). The above information reveals that habitat improvement activities can accommodate roughly 2% of the 10% growth rate of the elephant population in KARN. Therefore, we can employ this information as an effectiveness indicator of habitat improvement activities, concluding that these activities can reduce crop-raiding damage by about 20%.

Given the 10% growth rate of the elephant population and the current elephant population in KARN, which is estimated to be 250 in total, the elephant population will exceed a sustainable level (500 elephants) in the next eight years. Therefore, birth control for 50 female elephants each year will be needed to control the herd size. Contraception allows the herd size to stabilize at a steady level. This means that residual damage will be kept at a constant level in the years after the contraception takes effect.

A monitoring procedure will be employed to check whether elephants come to use the ponds and mineral licks. If they do not, the reasons why they do not use these facilities need to be ascertained. It may be because ponds are inappropriately located or because mineral licks are made of improper component parts. If problems such as these were discovered, then the necessary changes could be made. The details of the costs of each activity follow.

Cost of habitat improvement activities and contraception

Details of these costs are summarized in Table 22.

Ponds

Five ponds will be constructed in the first year of the project. The construction cost of the ponds is approximately THB 50,000 (USD 1,667) per pond. The ponds will not require maintenance.

Mineral licks

Two-hundred-and-sixty mineral licks will be created in the first year of the project. This number of mineral licks need to be created because it is not known which licks the elephants will use. In the second year, the mineral licks (approximately 130) that are actually used will be developed into permanent mineral deposits for elephants and other animals. The construction cost of the licks and deposits are equal, which is approximately THB 2,500 (USD 83) per mineral lick.

Grassland conversion

An area of 30,000 rai or 48 km^2 of invasive alien plants will be converted to grassland by implementing change in an area of 3,000 rai or 4.8 km^2 each year (therefore, the 30,000 rai of grassland will be established in ten years). In the eleventh year, the first 3,000-raiplot to be converted will need to be reconverted to grassland again because the invasive alien species will have re-grown tore-cover the area. The second 3,000-raiplot that was converted will have to be reconverted to grassland in the twelfth year, and so on. Therefore, the cost of the conversion of invasive alien plants to grassland is roughly THB 3,180,000 or USD 106,000 per year. The unit cost of the conversion is THB 1,060 per rai or USD 22,083 per km^2.

Supplementary food for elephants

The provision of supplementary food, e.g. bananas, can attract crop-raiding elephants, keeping them in the park. The cost of establishing a supplementary feeding plantation is THB 2,500 per rai (or USD 52,083 per km^2). Therefore, the annual cost of a supplementary feeding plantation 500 rai or 0.8 km^{2}in area is approximately THB 1,250,000 per year or USD 41,667 per year. However, the supplementary feeding plantation needs to be replanted every two years.

Contraception or birth control

Contraception for female elephants will be introduced from the eighth year of the project, at the point at which the elephant population is no longer sustainable. The cost of contraception is approximately THB 50,000 (USD 1,667) per female elephant. According to an expert interview, 50 female elephants need to be exposed to contraception each year. Therefore, the annual cost of contraception is approximately THB 2,500,000 (USD 83,333). The contraception is effective for about ten years, therefore the contraception needs to be re-introduced every ten years.

Monitoring process

Habitat improvement activities (ponds and mineral licks) need to be monitored to make sure that elephants and/or other animals utilize them. Details of the technical equipment and human resources involved in the monitoring process follow.

- Ten monitoring cameras: the unit cost of a camera sited at ponds and mineral licks is approximately THB 12,500 (USD 417). Therefore, the cost of cameras for the first year will be THB 125,000 (USD 4,167). However, cameras need to be changed every five years. The battery cost of a camera is approximately THB 1,000 (USD 33) per year.

- Five handheld GPS receivers: the unit cost of a handheld GPS receiver is approximately THB 20,000 (USD 667). Therefore, the total cost for handheld GPS receivers is approximately THB 100,000 (USD 3,333). These five handheld GPS receivers can be used throughout the entire project period.
- Two notebook computers: the unit cost of a notebook computer is approximately THB 30,000 (USD 1,000). Therefore, the cost of computers for the first year will be THB 60,000 (USD 2,000). However, notebook computers need to be renewed every five years.
- Two staff members: the salary to hire wildlife technicians for the monitoring process is approximately THB 10,000 (USD 333) per month per person. The wage for a wildlife technician is approximately THB 240,000 (USD 8,000) per year.

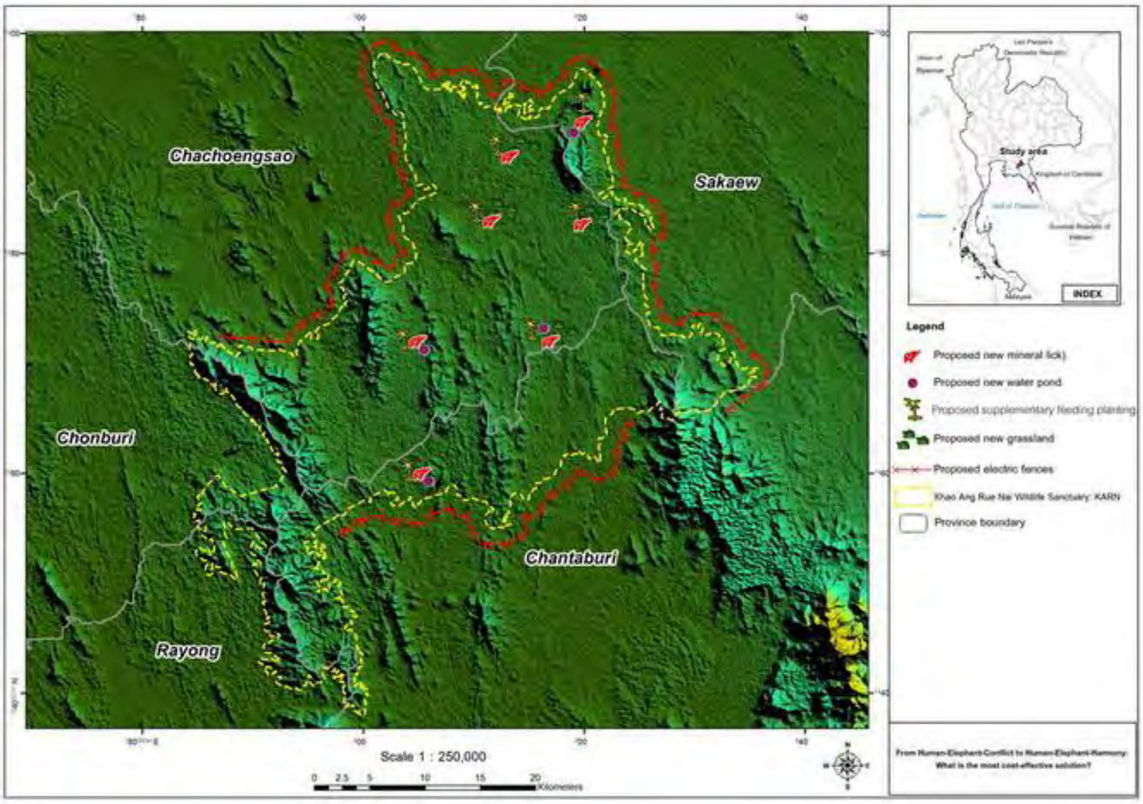

Figure 26. Locations of proposed habitat improvement activities and electric fences

Table 22. Cost of activities to alleviate HEC

Activities (unit)	**Cost per unit**	**Additional activities needed**
Habitat improvement and contraception		
Pond (pond)	THB 50,000 (USD 1,667)	Five ponds
Mineral lick (mineral lick)	THB 2,500 (USD 83)	260 mineral licks
Conversion of invasive alien plants to grassland (rai)	THB 1,060 (or USD 22,083/km^2)	30,000 rai or 48 km^2
Planting supplementary food for elephants (rai)	THB 2,500 (or USD 52,083/km^2)	500 rai or 0.8 km^2
Contraception or birth control (elephant)	THB 50,000 (USD 1,667)	50 female elephants for ten years, every ten years
Monitoring activities after implementation		
Handheld GPS receiver (piece)	THB 20,000 (USD 667)	Five pieces
Monitoring cameras at ponds and mineral licks	THB 12,500 (USD 417)	10 cameras
Notebook computer (per unit)	THB 30,000 (USD 1,000)	Two units
Staff for monitoring activities (THB/staff/month)	THB 10,000 (USD 333)	Two members of staff

Source: an interview with Mr. SawaiWonghongsa, the former head of Chachoengsao Wildlife Research Station, 19 January, 2011
Note: USD 1 = THB 30

Residual costs of crop-raiding borne by households

Crop-raiding costs borne by households include the cost of damage, protection costs and the opportunity costs of time spent guarding crops at night. Even when habitat-improvement activities and female elephant contraception are employed, the residual impacts remain. Such mitigation measures cannot eliminate all of the impacts of HEC but they can alleviate it. Assumptions for the calculation of residual impacts can be explained as follows.

As mention earlier, this analysis assumes that habitat improvement activities reduce crop-raiding damage by about 20%.Using this scenario, the residual damage costs of crop raiding will be increased until the ninth year of the project. Female elephant contraception will be introduced in the eighth year of the project but it may take one year before it becomes effective. Therefore, from the ninth year of the project until its end, the cost of damage due to crop raiding will be constant.

Regarding the protection costs and opportunity costs borne by households in this scenario, the estimation of these costs is based on the assumptions and information in the status quo scenario. Both the protection and opportunity costs for households were assumed to be constant for the whole project, under the assumption that households cannot do anything more than in the status quo scenario. No increase in wages or in the opportunity cost of time is assumed because households are engaged in subsistence farming, not waged income.

3.1.3 Habitat improvement activities, contraception and land use change (HCL)

In this scenario, habitat improvement and birth control for female elephants will be established within the same timeline as in the second scenario. Households within 0.5 km of the KARN boundary live in the high-risk zone (see the red line that indicates the proposed electric fences in Figure 26) and will be asked to convert their traditional crops to unpalatable crops (e.g. rubber trees, teak, etc.). Chong et al. (2005) recommend that buffer zones be planted with palatable crops at least 5 meters in width. However, Mr. Sawai Wonghongsa, the former head of Chachengsao Wildlife Research Station, recommends that these zones should be at least 0.5 km in width, which would be big enough for elephants to have no further need to search for food in villages. The implementation of habitat improvement activities would increase the amount of food available to elephants and would encourage them to return to the park rather than to walk to villages.

The NPV of this scenario is calculated from the following:

$$NPV = \sum_{t=0}^{19} \frac{B_t - C_t}{(1+r)^t}$$

where

B_t = Avoided costs from crop-raiding in case of status quo

C_t = (Cost of habitat improvement activities and contraception + Payment for farmers to convert from traditional crops to unpalatable crops)

Avoided costs from crop-raiding in case of status quo = Increase in harvests due to less damage inflicted by elephants + avoided protection costs + avoided opportunity costs of time

Assumptions to calculate the payment/compensation rate for land-use change can be described as follows.

The weighted average crop return in the study area (rice and cassava) is used to represent the opportunity cost of land use change to unpalatable crops, which is about THB 7,431 per rai[7] or USD248 per rai. The entire area of land use change is in the high-risk zone, which is approximately 110 km^2or 68,750 rai. The average area damaged by elephants accounts for 18% of the total area a household farms. In this scenario there is no crop loss from crop raiding by elephants because the high-risk area will be converted to unpalatable crops.

3.1.4 Habitat improvement activities, contraception and electric fences (HCE)

In this scenario, habitat improvement activities and contraception would be implemented on the same time scale as in the second scenario. In addition, electric fences would be erected at the edge of KARN in the risky crop-raiding areas (0.5-kmarea surrounding KARN, see red line in Figure 28) in the first year of the project period. On a field trip to the SalakPra Wildlife Sanctuary in Kanchanaburi Province, a park ranger

[7]The returns of rice and cassava in the study areas in 2010 were about THB 4,192 per rai and THB 8,820 per rai respectively. The areas of rice and cassava under cultivation are 1,671 and 3,897 rai respectively.

explained that fundamental rules for the installation of electric fences were needed to ensure that the fences were effective in containing elephants. The ranger suggested that fences should be about 2 meters above the ground, with posts 10 meters apart. The fences are maintained via a 24-hour duty cycle. A 3-meter area is needed on both sides of the fence, clear of the trees (Figure 27), to prevent elephants from putting trees on the fences and using the trees to cross. The voltage needs to be maintained at between 220 volts and 8,000 volts. The fence requires daily inspection for wire breaks, loosening, and current leakage from objects or plants touching the wires, for the replacement of damaged posts, and for power inspection.

Source: authors

Figure 27. Electric fences in the SalakPra Wildlife Sanctuary

The NPV of this scenario is calculated from the following.

$$NPV = \sum_{t=0}^{19} \frac{B_t - C_t}{(1+r)^t}$$

where

B_t = (Avoided costs from the crop-raiding problem in the case of the status quo - Residual costs from crop-raiding problem borne by households)

C_t = Construction and maintenance cost of electric fences

Avoided costs from crop raiding problem in case of status quo = Increase in harvests due to less damage inflicted by elephants + avoided protection costs + avoided opportunity costs of time

Residual cost of crop-raiding problem borne by households = residual damage costs, protection costs and opportunity costs of time

Assumptions to calculate the costs of electric fences and residual impacts can be described as follows.

According to the crop-protection trial project conducted by the Elephant Conservation Network (ECN), the construction and maintenance costs of electric fencing are approximately

THB 150,000 (USD 5,000) per kilometer and THB 15,000 (USD 500) per kilometer respectively (Ritthirat et al., forthcoming).The ECN's research found that electric fences could reduce crop-raiding damage by about 80%. Therefore we will assume that the estimation of the residual costs of crop-raiding borne by households (cost of damage, protection costs and opportunity costs of time spent crop guarding at night) will reduce by 80%. Some sections of electric fence will need to be reconstructed during the project period because it is possible that the fence will be stolen or destroyed by villagers who want to enter the park. Therefore, this analysis assumed that 40%, 30%, and 20% of the fence will need to be reconstructed in the 5th year, 10th year, and 15th year of the project respectively. It is assumed that the fence will need a decreasing rate of repair as villagers learn to understand the benefits of the fence and therefore will cease to damage it.

3.2 The Results of the Cost-Benefit Analysis

Table 23 illustrates the results of the CBA of HEC mitigation options. For each sub-scenario three discount rates are used in the calculation of NPV, namely 3%, 5% and 8%. Also, three different growth rates of crop-raiding damage, namely 5%, 10% and 15%, were used because crop-raiding damage may increase above or below the population growth rate of the elephants. The details of NPV estimations on the costs and benefits occurred in each year in each scenario are presented in Table A1-A36. The NPVs in each policy option will be used as a proxy to rank the preferable policy option. The NPVs for the status quo option are negative, which means in the "do nothing" option households will bear increasing costs as the elephant population rises. The NPVs in each policy option are sensitive to the rate of crop-raiding damage, especially policy 1 (habitat improvement and contraception). At a 5% crop-raiding growth rate, the NPVs of policy 1 for all discount rates are negative. This is because the lower the rate of crop-raiding damage, the lower the benefits from cropraiding saved, whereas the activity costs of mitigation measures are unchanged. Therefore policy 1 might be the only appropriate option at a certain level of crop-raiding damage.

Sensitivity tests were performed for the discount rate and the growth rate of crop-raiding damage. The NPVs of policy 3 (habitat improvement, contraception and electric fences) were the highest amongst all the options. Our research suggests that the greatest benefits are to be derived from the full-scale project, which comprises habitat improvement, contraception and electric fences. Policy 2 (habitat improvement, contraception and land-use change) ranks below the others even in the most favorable situation for crop damage but it is the cost of compensation that makes this option so negative. Furthermore, the costs of policy 2 would be even higher if the transaction costs of the negotiation process with farmers for crop conversion were included. However, the reason that policy 3 is preferable is because of the effectiveness of electric fences in protecting crops– they provide an 80% reduction in crop damage –and this drives the benefit of this option.

The results of NPV estimation tally with household attitudes towards crop-raiding mitigation measures. According to the household survey, most respondents (32%) think that the most effective way of dealing with HEC is to use electric or non-electric fences. Only one respondent thought that the most effective way of dealing with HEC would be a switch from traditional crops to unpalatable crops. If households compare policy 2 (habitat improvement, contraception and land use change) and policy 3, policy 3 is still more desirable because it is quite difficult to persuade households to change their land use. Households are likely to select their crop according to the market prices of crops. The results of the NPV estimation indicate that it would be more worthwhile for policymakers to apply policy 3.

4.0 COST-EFFECTIVENESS ANALYSIS OF HEC MITIGATION MEASURES

The cost-effectiveness (CE) of HEC mitigation was analyzed for the three policy options. It should be noted that the CEA focuses on the costs of policy intervention and ignores the residual impacts borne by households. However, CE estimation can provide the unit costs of effectiveness on each policy intervention, which can assist with decision making to select policy interventions.

The assumptions made in each scenario for estimation of the cost effectiveness ratio are similar to assumptions used in the cost benefit analysis. The difference in the cost effectiveness analysis is that the policy interventions have an effect on the areas of crop damage, not the cost of crop damage. Effectiveness can be measured by the crop area saved from crop-raiding. As mentioned earlier, the total area of the high-risk zone is about 110 km^2 or 68,750 rai. The average area of damage accounts for 18% of the total agricultural area, therefore the affected area is about 12,375 rai or 19.8 km^2. The parameters for conducting the sensitivity analysis for this study included discount rates, namely 3%, 5% and 8%, and growth rates for crop-raiding damage of 5%, 10% and 15%. The details of the effectiveness estimation in each scenario are shown in Table A37- A39.

4.1 Description of Alternative Scenarios

4.1.1 Habitat improvement and contraception

In this scenario, assumptions to calculate effectiveness can be described as follows.

Habitat improvement activities can reduce the annual growth rate of crop-damaged areas by about 20%. Birth control for female elephants will be initiated in the eighth year of the project so crop damage will be constant until the ninth year.

4.1.2 Habitat improvement, contraception and land-use change

In this scenario, assumptions to calculate effectiveness can be described as follows.

No crop is damaged in this scenario because all the crops in the high-risk zone will be converted to unpalatable crops.

4.1.3 Habitat improvement, contraception and electric fences

In this scenario, assumptions to calculate effectiveness can be described as follows.

Habitat improvement activities can reduce the annual growth rate of the crop-damaged areas by about 20%. Birth control for female elephants will be initiated in the eighth year, therefore the crop damage will be constant until the ninth year. Electric fences can reduce crop damage by 80%.

4.2 Results of the Cost-Effectiveness Analysis

The results of the CE ratios can be interpreted as the cost of a policy intervention to save one unit of crop area from crop-raiding elephants. The results of the CE ratios are illustrated in Table 24. The sensitivity tests on discount rates and growth rate of crop damage do not affect the ranking of policy options. The results of the CE ratios demonstrate that the CE ratio of option 3 is the most cost-effective, which agrees with the CBA results. Out of the three policy options, policy 2 is the most expensive; however, this option saves all of the crops from raiding (this is the expert view) so has no residual impacts. As mentioned earlier, the cost of compensation for crop conversion drives this policy and makes it less desirable. The CE ratios are also sensitive to the growth rate of crop-raiding damage. According to sensitivity tests of the growth rate of crop-raiding damage, the CE estimation shows that the higher the rate of crop-raiding damage, the lower the cost-effectiveness ratio. This is because the higher the rate of crop-raiding, the more crops are saved, whereas the activity costs of mitigation measures are unchanged for each rate of crop-raiding damage.

According to the household survey, the total HEC cost borne by households is about THB 48,374 (USD 1,612) per household and the average crop area is about 33.6 rai (0.05 km^2). Therefore, the average HEC cost borne per household is about THB 1,440 per rai. Comparing the HEC costs currently borne by households with the unit costs of the CE estimation and the unit cost of policy 3, against all the scenarios (which vary in cost between THB 132 and THB 599) it becomes obvious that the unit cost of policy 3 is lower than the current HEC costs borne by households. This information makes policy 3 more cost effective than doing nothing.

Table 23. Net present values of the net benefits of the three policy options (unit: million THB/million USD)

Scenarios	Discount rate								
	3%			5%			8%		
	Growth rate of crop-raiding cost			Growth rate of crop-raiding cost			Growth rate of crop-raiding cost		
	5%	10%	15%	5%	10%	15%	5%	10%	15%
Status quo	-582.5 (-19.4)	-786.9 (-26.2)	-1160.2 (-38.7)	-489.4 (-16.3)	-646.4 (-21.5)	-928.9 (-30.9)	-387.6 (-12.9)	-495.8 (-16.5)	-685.7 (-22.9)
Policy 1:Habitat improvement and contraception	-32.2 (-1.1)	97.8 (3.3)	373.9 (12.5)	-31.6 (-1.1)	65.6 (2.2)	270.2 (9.0)	-30.0 (-1.0)	34.0 (1.1)	167.0 (5.6)
Policy 2: Habitat improvement, contraception and land use change	-915.3 (-30.5)	-710.8 (-23.7)	-337.6 (-11.1)	-788.3 (-26.3)	-631.2 (-21.0)	-348.8 (-11.6)	-646.2 (-21.5)	-538.0 (-17.9)	-348.1 (-11.6)
Policy 3: Habitat improvement, contraception and electric fences	64.0 (2.1)	253.5 (8.4)	607.3 (20.2)	43.6 (1.5)	188.7 (6.3)	455.6 (15.2)	22.5 (0.7)	121.9 (4.1)	300.4 (10.0)

Note: USD 1 = THB 30

Table 24.Cost-effectiveness ratio of the three policy options

Options	Discount rate		
	3%	5%	8%
1) Habitat improvement and contraception			
Total cost of treatment (baht)	88,628,390	74,347,413	58,723,759
Total cost of treatment (USD)	2,954,280	2,478,247	1,957,459
1.1 At 5% growth rate of crop-raiding damage			
Total crop damage saved (rai)	40,687	40,687	40,687
Total crop damage saved (sq.km)	65	65	65
CE ratio (baht/rai)	***2,178***	***1,827***	***1,443***
CE ratio (USD/sq.km)	***45,381***	***38,068***	***30,069***
1.2 At 10% growth rate of crop-raiding damage			
Total crop damage saved (rai)	282,130	282,130	282,130
Total crop damage saved (sq.km)	451	451	451
CE ratio (baht/rai)	***314***	***264***	***208***
CE ratio (USD/sq.km)	***6,545***	***5,490***	***4,336***
1.3 At 15% growth rate of crop-raiding damage			
Total crop damage saved (rai)	376,090	376,090	376,090
Total crop damage saved (sq.km)	602	602	602
CE ratio (baht/rai)	***236***	***198***	***156***
CE ratio (USD/sq.km)	***4,910***	***4,118***	***3,253***
2) Habitat improvement, contraception and landuse change			
Total cost of treatment (baht)	1,497,783,885	1,277,655,527	1,033,816,161
Total cost of treatment (USD)	49,926,130	42,588,518	34,460,539
1.1 At 5% growth rate of crop-raiding damage			
Total crop damage saved (rai)	409,191	409,191	409,191
Total crop damage saved (sq.km)	655	655	655
CE ratio (baht/rai)	***3,660***	***3,122***	***2,526***
CE ratio (USD/sq.km)	***76,257***	***65,050***	***52,635***
1.2 At 10% growth rate of crop-raiding damage			
Total crop damage saved (rai)	708,778	708,778	708,778
Total crop damage saved (sq.km)	1,134	1,134	1,134
CE ratio (baht/rai)	***2,113***	***1,803***	***1,459***
CE ratio (USD/sq.km)	***44,025***	***37,555***	***30,387***
1.3 At 15% growth rate of crop-raiding damage			
Total crop damage saved (rai)	1,267,739	1,267,739	1,267,739
Total crop damage saved (sq.km)	2,028	2,028	2,028
CE ratio (baht/rai)	***1,181***	***1,008***	***815***
CE ratio (USD/sq.km)	***24,614***	***20,996***	***16,989***
3) Habitat improvement, contraception and electirc fences			
Total cost of treatment (baht)	195,186,181	170,123,972	142,365,545
Total cost of treatment (USD)	6,506,206	5,670,799	4,745,518
3.1 At 5% growth rate of crop-raiding damage			
Total crop damage saved (rai)	325,590	325,590	325,590
Total crop damage saved (sq.km)	521	521	521
CE ratio (baht/rai)	***599***	***523***	***437***
CE ratio (USD/sq.km)	***12,489***	***10,886***	***9,109***
3.2 At 10% growth rate of crop-raiding damage			
Total crop damage saved (rai)	609,590	609,590	609,590
Total crop damage saved (sq.km)	975	975	975
CE ratio (baht/rai)	***320***	***279***	***234***
CE ratio (USD/sq.km)	***6,671***	***5,814***	***4,865***
3.3 At 15% growth rate of crop-raiding damage			
Total crop damage saved (rai)	1,079,510	1,079,510	1,079,510
Total crop damage saved (sq.km)	1,727	1,727	1,727
CE ratio (baht/rai)	***181***	***158***	***132***
CE ratio (USD/sq.km)	***3,767***	***3,283***	***2,747***

Note: USD 1 = THB 30; 1 km^2 = 625 rai

5.0 CONCLUSIONS AND POLICY IMPLICATIONS

Elephants in Thailand are protected by the National Park Act of 1960 and the Wild Animal Reservation and Protection Act of 1961, and are also a cultural heritage species. However, the total population of elephants in Thailand has been decreasing, except in some protected areas (e.g. KhaoAng Rue Nai (KARN) Wildlife Sanctuary) where local predators are extinct. In KARN, the population of elephants exceeds the current capacity of the sanctuary. The problem of over-capacity in KARN leads to human-elephant conflict (HEC). The impacts of HEC are damage to crops, the endangerment of human and elephant life and various other impacts on the population living in the area. There are not enough sources of water and food for elephants in KARN and this is why they look for food and water in the surrounding villages. The current situation refers to the existing level of management that comprises largely traditional mitigation measures (e.g. making noise, lighting fires) by villagers and mitigation measures by related government agencies and organizations (e.g. increasing water sources, salt licks and digging ditches). However, the existing level of mitigation measures by government agencies is still not enough. Elephant experts suggest that habitat improvement in KARN could make the sanctuary more hospitable to the elephants and there would be less incentive for the elephants to leave the protected area and invade the villages. Therefore, habitat improvement would reduce HEC.

This study conducted a cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) of human-elephant conflict mitigation options. The options were as follows: 1) habitat improvement and female elephant contraception; 2) habitat improvement, female elephant contraception and land-use change; and 3) habitat improvement, female elephant contraception and electric fences. The results of the CBA and CEA will be used as an input to select which policy intervention to employ in the pilot PES scheme in the future. It should be noted that the CBA conducted here underestimates the benefits of reducing HEC because the benefit does not value the human or elephant lives saved. Value of life was not placed in the analysis because the technique to value life (value of statistical life, VSL) is still controversial and to include these values might have produced higher benefits but would not have changed the ranking of the policy options. This study also conducted a household survey in six villages affected by HEC around KARN, in order to examine household attitudes towards HEC, the impacts of HEC and the willingness of households to participate in working for free to alleviate HEC. Information from the household survey was used to calculate the impact costs borne by households.

The results of the CBA show the highest NPVs in option 3 (habitat improvement, contraception and electric fences). This means that full-scale option 3 provides the highest social benefits for HEC mitigation measures compared to the other options. Furthermore, a cost-effectiveness analysis (CEA) was performed to provide another criterion for decision makers. The results of the CBA and the CEA are consistent in that option 3 is preferable to other policy options. This result corresponds with attitudes expressed in the household survey, where most respondents said that they thought the most effective way of dealing with HEC is the use of electric fences or non-electric fences. Furthermore, household acceptability might be another factor in making policy 3 more practical. It would be difficult to persuade farmers to convert from traditional crops to crops unpalatable to elephants because a significant factor in a farmer's decision over which crops to plant is the market price of crops. According to the CE estimation, if we compare the HEC costs borne by households (THB 1,440 per rai) and the unit costs of policy 3, we find that the unit cost of policy 3 is lower than the unit cost currently borne by households. This information makes policy 3 the most desirable option.

After mitigation measures are implemented, HEC should be monitored and if there is little or no improvement, assessments should be made to decide on modifications. When the proposed mitigation measures are in place, it does not mean that HEC will be eliminated, as shown in the residual costs in the analysis, but the impacts will be lessened. The proposed mitigation measures should be complemented with traditional mitigation measures currently undertaken by households.

The household survey found that the average crop-damaged area of land is about 6 rai per household per year, which accounts for nearly 18% of the total crop area. The average annual cost of damage is THB 34,825 per household or USD 1,161 per household. Mitigation measures undertaken by households are complementary options. This explains why all the households have applied more than one option. The average annual mitigation cost is THB 5,917 per household or USD 197 per household. Another cost borne by households is the opportunity cost of time spent guarding crops at night. This study assumes that the opportunity cost of time accounts for 30% of household income. Therefore, the average opportunity cost of time spent guarding crops at night is THB 7,632 per household per year or USD 254 per household per year. Consequently, the average HEC cost borne by households is THB 48,374 per household per year or USD 1,612 per household per year, which accounts for 26% of annual household income.

In the household survey, the majority answer to the question "are you willing to work on mitigation measures, to install water holes, remove invasive plant species and build salt licks, for free" is revealing. The survey found that 93% of respondents are willing to work for free. This shows that households are rational because if the policy options are workable, households do not have to spend time protecting their crops – the opportunity cost of their time is effectively the time they would have spent guarding their crops. The opportunity cost of the time households would serve is a lower bound estimate of the costs of service providers in a PES scheme. This is an important finding with regard to future PES schemes.

Another observation is that human behavior can be a pull factor for crop-raiding elephants. For example, the elephants did not eat papaya in the past but papaya vendors threw over-ripe papayas on the road as food for wild elephants. The wild elephants have learned to eat the papayas and now raid the papaya crop. This example of giving food to wild elephants demonstrates the adverse consequences of changing the consumption behavior of the elephants. Therefore, education on not feeding wild animals is needed – people need to be provided with this kind of information so that they understand the consequences of feeding wild elephants. If people still keep on feeding the wild elephants, they may learn to eat other crops in the future.

Habitat improvement, female elephant contraception and electric fences are the medium-term solution. In the future, even though the habitat in the park will be improved to its full capacity potential, the park will still not be able to support the increasing elephant population, given the current growth rate. Chong and Norwana (2005) recommend that relocation of the entire herd to a suitable area should be considered. Therefore, the time may soon come when the relocation of the elephants should be discussed, however this idea is currently not acceptable to the Thai people. Providing information on both HEC and elephant relocation to the Thai people is essential if they are to understand that relocation may be a solution, for both elephant conservation and HEC in Thailand in the future.

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