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Guidelines on the Better Management Practices for the Mitigation and Management of Human-Elephant Conflict in and around Oil-Palm Plantations in Indonesia and Malaysia

Version 1
29 July 2005

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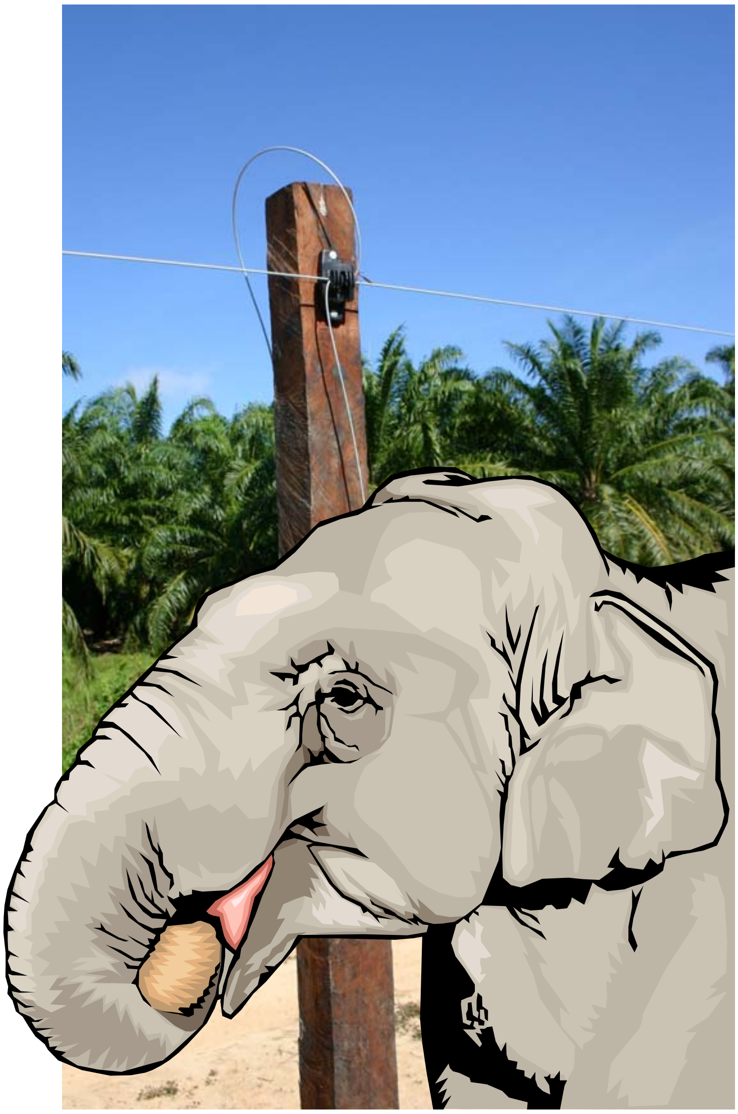

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Suggested citation:
Chong, D. K. F. and Dayang Norwana, A. A. B. 2005. Guidelines on the Better Management Practices for the Mitigation and Management of Human-Elephant Conflict in and around Oil-Palm Plantations in Indonesia and Malaysia, Version 1. WWF-Malaysia, Petaling Jaya.

Acknowledgments

The authors would like to thank the following individuals and organizations for their contributions to the development of this guide: Ahmad Zafir Abdul Wahab; Ajay Desai; Alexander Hastie; Bella Roscher; Brian Lee; Diana Anthony; Dionysius Sharma; Fiffy Hanisdah Saikim; Fitrian Ardiansyah; Gareth Goldthorpe; Geoffrey Davison; Hereward Corley; Ian Redmond; Ivy James; Junaidi Payne; Lee Shan Khee; Linda Giyung; Matthias Diemer; Mohd. Shariff Daim; Monica Borner; Nurchalis Fadhli; Preetha Sankar; Raymond Alfred; Shernytta Poloi; Suhandri; Surin Suksuwan; Tan Hui Shim; Teoh Cheng Hai; Tia Tzee Ling; Umi A'Zuhrah Abdul Rahman; Asiatic Development Bhd.; Avicess Sdn. Bhd.; Golden Hope Plantations Bhd.; Innoprise Corporation Sdn. Bhd.; IOI Corporation Bhd.; Kuala Lumpur Kepong Bhd.; Kulim (Malaysia) Bhd.; Kumpulan Guthrie Bhd.; Ladang Kinabatangan Sdn. Bhd.; Malaysian Nature Society; Malaysian Palm Oil Association; Malbumi Estate Sdn. Bhd.; Ministry of Tourism, Culture and Environment, Sabah; POIC Sabah Sdn. Bhd.; Pontian United Plantations Bhd.; PPB Oil Palms Bhd.; Roundtable on Sustainable Palm Oil; Sabah Forestry Department; Sabah Softwoods Bhd.; Sabah Wildlife Department; Sawit Kinabalu Bhd.; Tong Hup Enterprise Sdn. Bhd.; United Plantations Bhd.; WWF-Indonesia; WWF-Malaysia; WWF Nepal Program; and WWF-Switzerland.

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1. Introduction

1.1. Elephants

Elephants are of the order Proboscidae and the family Elephantidae, which has only two extant species, the African elephant *Loxodonta africana* and the Asian elephant *Elephas maximus*. The two subspecies of African elephant, recognized by the IUCN, are the savannah or bush elephant *L. a. africana* and the forest elephant *L. a. cyclotis* (although the latter is considered by some to be a separate species). There are three subspecies of Asian elephant: Sri Lankan *E. m. maximus*, Indian *E. m. indicus* (not confined to India), and Sumatran *E. m. sumatranus*. Furthermore, the elephants in Borneo, which have been found to be genetically distinct (Fernando *et al.* 2003), may represent a fourth subspecies, *E. m. borneensis*. As this guide is meant to cover Indonesia and Malaysia, the Asian elephant is the species of interest.

Asian elephants are able to adapt to a wide range of habitats, from thick jungles to grassy plains and usually gather where there are permanent water bodies and vegetation. Typically, elephants will rest in the shade during the day, or they will spray water and dirt to keep cool and clean. Elephants are known to have traditional drinking sites, returning to them year after year, and traditional home ranges to which they show high fidelity.

Female elephants live in herds usually consisting of related females and immature males. They are lead by the matriarch, the oldest and most experienced female. Males will eventually leave the group when they reach sexual maturity to live solitarily or in small bull groups seeking out herds during periods of sexual activity, known as musth.

Elephants spend most of their time feeding. They are generalists, consuming various types and parts of vegetation, which they gather with their long trunks. Their movements can be influenced by many factors but the most prominent is probably food. Herds may break into smaller groups for foraging and many groups may converge at water bodies during dry periods.

An elephant's habitat is limited to areas with access to food, water, minerals, and shelter. It is estimated that a herd of 200 elephants requires 6,000 km^2 of roaming ground (Davies and Payne, 1982). It is believed that for elephants to be viable, a population of at least 2,000 individuals needs to be reached (Jawatankuasa Pelan Induk Pemuliharaan Gajah, 1990). This is to maintain genetic diversity, which is important for the long-term viability of a population to evolve by natural selection.

Elephants have a highly developed sense of smell. The trunk of an elephant is an incredibly versatile organ and it contributes greatly to its olfactory ability, useful for both foraging and sensing danger. Elephants also have excellent hearing with their large ears acting as amplifiers to warn of possible dangers and to aid long-distance communication using infrasound. Their vision, however, is rather poor.

The Asian elephant is categorized as endangered in the IUCN Red List and is listed under the CITES Appendix I, which prohibits it from being traded internationally for commercial purposes. As protected animals, it is generally illegal to kill elephants in Indonesia and Malaysia. Since 1931, the elephant has been protected in Indonesia, where it is illegal to hunt, trade, or keep elephant without a licence. Offenders are liable to a fine of IDR2,000,000 and/or a minimum 5-year jail term. In Peninsular Malaysia, the elephant is listed under Part I of Schedule Two of the Protection of Wildlife Act 1972 (Act 76). This protects it from being killed or captured without a licence, carrying a penalty of up to MYR6,000 and/or a 3½-year jail term upon conviction, depending on the gender and age of the elephant. Similarly, the elephant is protected from unlicensed hunting under Schedule II of the Wildlife Conservation Enactment (WCE) 1997 in Sabah with offenders liable to a penalty of MYR50,000 and/or a 5-year jail term.

1.2. Human-elephant conflict

Human-elephant conflict (HEC) occurs because humans and elephants have overlapping interests. The focal points of HEC are usually the edges of protected areas (Hart and O'Connell, 1998 in Nelson *et al.*, 2003). In most cases, the conflict is in the form of crop raiding and related activities. Other forms of conflict include damage independent of crop raiding, usually the effects of stampeding.

The underlying cause of HEC is habitat loss (Desai, 2002). Elephants tend to have large home ranges with traditional migration routes. When their home ranges are reduced by encroachment, they lose feeding grounds and these migration routes become disrupted. The conversion of natural forests to oil-palm plantations has contributed to the loss of elephant habitat and the situation is aggravated by the lack of integrated land-use planning which leads to forest fragmentation. This fragmentation of elephant habitat results in pocketed herds, which may have to depend on crop raiding for survival. If, as often happens, forest fragmentation continues in an area, resident elephants become squeezed into an ever decreasing forest patch, thereby increasing their density beyond the carrying capacity and placing a strain on the available resources. Furthermore, human activities, like logging, usually give rise to secondary vegetation which can attract elephants, so drawing them closer to human settlements.

In Peninsular Malaysia, the Jawatankuasa Pelan Induk Pemuliharaan Gajah (1990) identified forest conversion as the most serious threat to the survival of the elephant population. They reported that the estimated forest cover has been reduced from 84% in 1958 to 44% in 1990 and attributed the decline in the elephant population to forest conversion to monoculture plantations, especially oil palm, with the area earmarked for oil-palm plantations rising from 543,000 ha in 1960 to more than 1,625,000 in 1990. According to the Malaysian Palm Oil Board (MPOB), in 2003, the area planted with oil palm was 2,202,166 ha in Peninsular Malaysia and 3,802,040 ha in the whole of Malaysia, but not all of this expansion was converted from forests.

Some experts believe that elephant herds that raid crops do so out of necessity and that herds living in areas with sufficient natural resources will not raid crops even if they had the chance to do so (Desai, 2002). However, certain individuals, though usually not entire herds, may raid crops to supplement their diet even if there is no real need to do so (Desai, 2002). In this way, HEC is seen by some to be primarily an issue of habitual crop-raiders and the logical conclusion is that if these individuals are removed from a conflict area, crop-raiding events will cease. Field researchers, such as Nelson *et al*. (2003), however, argue that removal of such individuals will only provide temporary reprieve from HEC, as they will, over time, be replaced by new individuals with a taste for crops. As such, *the removal of targeted individuals is not a suitable long-term solution*, though may be necessary in certain situations, e.g., an individual which has overcome its fear of humans and become habituated to the usual protection measures.

The attraction of crops is that they are usually more palatable and have less secondary defences than wild plants (Sukumar, 1989 in Lee, 2002), and young oil palms, particularly between two and four years, are a favourite, (Blair and Nache, 1979a). Crops may also be more nutritious due to selective breeding. It has also been found that bulls are more likely to engage in high-risk activities like crop-raiding as a means of increasing their reproductive potential through better nutrition (Sukumar, 1991 in Nelson *et al.*, 2003). They are also more likely to break fences, including electric fences, as their tusks do not conduct electricity (Nelson *et al.*, 2003)

2. Managing human-elephant conflict

The main objective of this guide is to present ways for the mitigation and management of HEC through the adoption of better management practices (BMPs). This guide is not meant to be prescriptive, but some recommendations are given. *The BMPs on mitigating and managing HEC, as discussed in this guide, are not specific measures but rather a description of the manner with which HEC should be addressed and approached.*

It is important to understand that *as long as humans and elephants share the same landscape, HEC can never be eliminated*, only reduced. The objective of any HEC management plan should be to minimize the conflict and to ensure that the parties directly affected are able to tolerate any conflict that persists. From a conservation perspective, addressing HEC is important as it threatens to undermine the appreciation of the elephant within local communities. Communities facing HEC would usually be unable to appreciate elephants until the conflict can be minimised to a tolerable level.

Another important concept that must be grasped is that *the most important measure in managing HEC is the protection of elephant habitat*. No matter what types and combination of mitigation measures are employed, if there are insufficient natural resources for the elephants, they will, being intelligent and resourceful animals, overcome these mitigation measures. *It is only when there exists an alternative to crop raiding that the mitigation measures will be effective*.

One of the most important steps to take before implementing any HEC mitigation measure is to determine that it is indeed elephants and not other animals that are responsible for the damage. Visual detection is the best indication and verification method. In the absence of visual confirmation, other signs of elephant presence such as tracks, dung, and damage pattern should be verified by experts.

For new developments, it is recommended that the questions developed by Seidensticker (1984) are at least considered in an environmental impact assessment (EIA) before embarking on the project as they will help prepare for potential problems in the future (Box 1). Ideally, HEC management plans addressing the questions in Box 2, also quoted from Seidensticker (1984), should be drawn up for both new and existing developments in elephant-range areas.

Box 1. Questions to be addressed before embarking on a new plantation development.

- Are elephants present in the project area? If so, is their presence seasonal or continuous?
- How large an area necessary to elephants, will be influenced by the project, including their access to essential habitats?
- Will the project remove a significant portion of the elephant habitat in a region? If so, how much?
- How many elephants are involved in total, and more specifically, which clans and subgroups will be affected?
- Will the project isolate clans or subgroups from more continuous habitat areas during construction? Following project completion, will there be access to continuous tracts of suitable elephant habitat? The “pocketed herd” problem occurs where clans or subgroups become isolated, and frequently the only resources available to the herd are in the project production areas.
- Will the project block seasonal movements between feeding areas and other critical resources such as water sources and mineral deposits?
- Will the project alter the distribution, abundance, and predictability of food and other critical resources?

Source: Seidensticker, 1984

Box 2. Questions to be addressed in the development of an HEC management plan.

- How are elephants to be moved if they occur in production areas, or are cut off from areas of continuous habitat?
- What features in the project infrastructure can be adjusted, or what other actions can be taken to keep elephants out of production areas?
- How, where, and under what conditions should project infrastructure be modified to accommodate elephant movements?
- What mitigatory measures will ensure that elephant needs are met, if substantial habitat areas or critical resources are eliminated by the project? Can elephants be accommodated in parts of the project area such as catchments and banks of reservoirs?
- Who will monitor elephant responses to project activities, and how will new findings be addressed during project implementation? Who will carry out elephant management activities?

Source: Seidensticker, 1984

Box 3. The decision-making key for the recommended HEC mitigation measures.

1. Is the elephant herd pocketed?
- Yes: Go to 2.
- No: Go to 4.

2. Are there other elephants nearby?
- Yes: Go to 3.
- No: Go to 9.

3. Is it viable to establish a corridor?
- Yes: See measure A.
- No: Go to 4.

4. Is the terrain generally flat?
- Yes: Go to 5.
- No: Go to 6.

5. Is the climate very wet?
- Yes: Go to 6.
- No: Go to 7.

6. Can you afford electric fencing?
- Yes: See measure B.
- No: See measure C.

7. Is the soil type loose or prone to erosion?
- Yes: Go to 6.
- No: Go to 8.

8. Can you afford electric fencing and/or trenching?
- Yes: See measure D.
- No: See measure C.

9. Is there a suitable area to which you could translocate the entire herd?
- Yes: Go to 10.
- No: Go to 4.

10. Can you afford to translocate the entire herd?
- Yes: See measure E.
- No: Go to 4.

Measures

A. Establish corridor (§ 3.1.3).

B. Set up patrol squad (§ 3.4) and electric fences (§ 3.2.1.1).

C. Set up patrol squad (§ 3.4).

D. Set up patrol squad (§ 3.4) and trenches (§ 3.2.2) and/or electric fences (§ 3.2.1.1).

E. Consider translocating the entire herd (§ 3.6.1). If the wildlife authority has decided not to translocate, go to question 4.

It is important to have accurate information about when and where the conflict is occurring. This can be done through simple crop-damage monitoring schemes to gather relevant information. At the larger landscape level, the problem areas may be zoned, based on conflict intensity and quality of habitat, before decisions on mitigation measures are made. The intensity of the conflict should be evaluated before implementing any mitigation measure so that it is possible to gauge their effectiveness over time. This should take into account the distribution, frequency, and severity of the raiding (Hoare, 2001). It is also *important to determine if the elephants are dependent on raiding*. If these elephants have no choice but to survive on human crops, then purely passive protection will not work and measures have to be taken to reconnect their degraded habitat to a suitable tract of forest, or they will have to be translocated.

For most oil-palm plantations in Indonesia and Malaysia which are facing HEC, the mitigation measures recommended by this guide are based on the decision-making key in Box 3. However, it must be noted that *there is no one solution for all situations*. What works in one situation will probably not work to the same degree in a different situation. As such, *there has to be some degree of experimentation and innovation*. Consulting an expert is recommended.

The employment of only *one mitigation measure is rarely sufficient*, except in cases of low conflict, and some experts believe that employing many mitigation measures will tire the elephants and hence discourage them from crop raiding (Hoare, 2001). In this way, a synergy of various measures may result in an overall effectiveness that is greater than the aggregate of the effectiveness of each separate measure (Hoare, 2001).

It is also important to take other stakeholders' concerns into consideration, especially neighbouring plantations and villages, in an HEC management plan. This is especially important if barriers (§ 3.2) are to be put in place as these will restrict elephant movement and may channel them to neighbouring areas, e.g., in the Lower Kinabatangan region in Sabah, the employment of barriers by oil-palm plantations have led to an increase in conflict in the surrounding villages (Lee, 2002). A community-wide approach is always preferred to a unilateral approach and for most smallholders, collaborating with other smallholders may be the only feasible means to put any HEC management system in place. For larger plantations, it may be worthwhile to build the capacity of other stakeholders, to ensure a more effective community-wide approach.

Any good system should have a monitoring and evaluation component. As HEC will never be eliminated except, perhaps, in cases of removal of the entire elephant or human population, it is extremely important to have a monitoring system in place. Monitoring and evaluation may be performed by the company itself, but an independent third party should be able to provide a more objective outcome with much less bias.

3. Mitigation measures

The causes of conflict are often complex and difficult to resolve. There is a need for immediate, short-term measures to be taken in some areas, as the socio-political pressure to do so can be very high. However, if a lasting solution is to be found, it is important to address the underlying causes of the conflict. Successful mitigation and management of HEC will generally require a host of measures to be employed. The mitigation measures discussed here are divided into land-use changes, barriers, repellents, guarding, removal, and compensation and are a documentation of current knowledge and practices and

Table 1. A comparison of selected mitigation measures.

Measure	Advantages	Disadvantages	Recommendations
Land-use planning (§ 3.1)	• Addresses root cause • Long-term effect • Increases sustainability	• Larger landscape use depends on government decisions	Highly recommended for new developments
Protected areas (§ 3.1.1)	• Addresses root cause • Good for conservation • Long-term effect	• Depends on government decisions • Limits human use of the areas protected	Highly recommended but not usually applicable to existing plantations
Corridors (§ 3.1.2)	• Good for conservation • Long-term effect	• Limits human use of the corridors	Highly recommended where viable
Buffer zones (§ 3.1.4)	• Helps define scheme boundary	• Reduces area available for planting • Habituation	Highly recommended
Electrified fences (§ 3.2.1.1)	• Semi-permanent • Versatile	• Heavy maintenance • Expensive installation	Highly recommended
Trenches (§ 3.2.2)	• Semi-permanent	• Only suitable for flat and dry terrain • Heavy maintenance • Expensive installation	Recommended in flat and dry areas
Repellents (§ 3.3)	• Cheap	• Habituation	Experimentation recommended
Guarding (§ 3.4)	• Relatively inexpensive • Immediate effect	• Temporary effect • Dangerous	Highly recommended
Translocation (§ 3.5.1)	• Long-term effect if whole herd is translocated	• Temporary effect if only some individuals are translocated • Very expensive • Requires trained personnel • Dangerous • May be translocating problem • May distort elephant population	Recommended for pocketed herds with no chance of rejoining the main population

not necessarily recommended measures. Specific recommendations may be given for some measures. Table 1 compares selected mitigation measures discussed in this guide.

Mitigation measures can be either preventative or non-preventative. Preventative measures act to prevent intrusion by elephants while non-preventative measures are post-intrusion reactions. These reactive measures include chasing elephants out of the fields as well as compensation schemes. Preventative control is, of course, more effective in the long term.

Preventative measures may be in the form of active or passive protection and may be employed at a large-landscape level or at a local-community level. Active protection requires confrontation with elephants, e.g., guarding and removal. Passive protection does not entail direct confrontation but instead relies on land-use considerations and the use of barriers and repellents. Purely passive protection is rarely sufficient on its own.

Mitigation measures employed at the landscape level would typically consider land use and may employ elephant removal as a tool. At the local-community or plantation level, the mitigation measures used are typically guarding, barriers, and repellents. Land use is generally worth considering only at a much larger landscape level. The removal of elephants would have to be performed by or with wildlife authorities, whose decision to remove the elephants should have been based on large-landscape considerations.

Active protection tends to be more popular as it is cheap and gives immediate effect even though it may be only temporary. Some of these methods have proven to be successful in smaller plantations. Passive systems typically provide a longer-term solution. However, they require a full-time commitment, and are, therefore, more suited for larger plantations with the necessary resources. For instance, an electric fence requires a relatively high maintenance effort and is probably not feasible in communities where co-operation is low.

3.1. Land-use changes

Integrated land use is part of the solution to a broad spectrum of conservation and sustainability issues. There is currently a lack of integration and long-term consideration for conservation in the human land-use patterns in elephant-range areas of Indonesia and Malaysia. Wise land use would ensure an efficient and sustainable use of resources. Forest fragmentation is frequently a result of a lack of integrated land-use planning. For the purpose of HEC mitigation, it is useful to clearly define human-use and elephant-use areas with distinct boundaries. This would mean that in ideal situations, there would be large contiguous tracts of mostly forested areas for elephant use and clustered blocks of development, enforced with barriers, repellents, and patrol squads, strictly for human use. The idea is to enable the elephants to distinguish between the two types of landscapes and to instil in the elephants an appreciation of the boundaries. Opening new plantations adjacent to or within forested areas within elephant ranges is inviting trouble. Changing land-use patterns may require reacquisition, addressing compensation issues, land exchanges, and reforestation.

When it comes to land-use planning, high-conservation-value forests (HCVFs) should always be maintained. HCVFs are forests containing one or more high-conservation values (HCVs) as defined in Box 4. The HCVF concept is useful for a host of social and environmental issues including human-wildlife conflict. See Appendix I for more details.

3.1.1. Protected areas

Protecting elephant habitat is probably the single most important tool for elephant conservation and the reduction of HEC. Lee (2002) demonstrated a negative correlation between the size of forested areas utilized by elephants and the number of crop raids. Desai (2002) has stated that it is pointless to implement other mitigation measures if the issue of habitat loss is not addressed. The protection of large areas of natural forests within elephant home ranges will help ensure that the elephants will have adequate resources. These protected areas should take into consideration food, water, minerals, and shelter. Even production forests will suffice as elephants can make use of forests being actively logged, as long as there are large enough areas away from the logging compartments and related activities.

Box 4. Definition of high-conservation-value forests.

High-conservation-value forests are those that possess one or more of the following attributes:

- forest areas containing globally, regionally, or nationally significant concentrations of biodiversity values (e.g., endemism, endangered species, refugia) and/or large landscape-level forests, contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance;
- forest areas that are in or contain rare, threatened, or endangered ecosystems;
- forest areas that provide basic services of nature in critical situations (e.g., watershed protection, erosion control);
- forest areas fundamental to meeting basic needs of local communities (e.g., subsistence, health) and/or critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities).

Source: FSC Principles and Criteria for Forest Stewardship, April 2004

The establishment of protected areas entails a delineation of the area, gazetting, and subsequent enforcement by the relevant authorities. It is, therefore, outside the control of plantation companies. However, a plantation can set up unplanted "conservation areas". While these may be important for maintenance of HCVs, they do not contribute to HEC mitigation unless these conservation areas serve as corridors.

3.1.2. Corridors

Elephants typically require large areas to roam, especially if they need to migrate to seasonal feeding sites. Often, protected areas are too small to entirely support an elephant population. The strict protection of areas large enough for all elephant needs may be virtually impossible. The solution lies in linking separate protected areas with intact, forested corridors which are themselves afforded some form of protection from conversion. The establishment of corridors is also very important for maintaining gene flow between different populations.

Like protected areas, the establishment of corridors will usually be beyond the ability of an individual plantation as it involves larger landscape considerations. However, a few large plantations in the same area may be able to work together to establish a corridor if they are located between large forested areas. This would involve setting aside areas to be left unplanted or afforested and may require the setting up of barriers such as electric fences to firmly establish the boundaries.

Landscape features that are used by the elephants, such as rivers, can be used to develop natural corridors. However, such corridors would have to be much wider than conventional riparian reserves. The minimum width required for a corridor would vary depending on factors like the quality of the forested areas connected by the corridor, the suitability of the corridor as elephant habitat, and the length of the corridor. Generally, it is expected that longer corridors would have to be wider. Corridors may have to be complemented by barriers and habitat enrichment.

3.1.3. Habitat enrichment

If a lack of natural resources is identified as a cause of HEC, then one method of mitigation that has been suggested is to supplement those resources. Artificial waterways and salt licks may be established within forested areas and elephant-food crops can be planted within forests to lure elephants away from plantations. Some lure crops that have been used include bananas (*Musa* spp.) and sugarcanes (*Saccharum* spp.). Habitat enrichment is, however, relatively complicated, involving monitoring and maintenance and would most likely be carried out by the relevant authorities rather than the plantations.

3.1.4. Buffer zones

Buffer zones are a land-use practice which helps define the boundary between plantations and forests whilst also acting as a psychological barrier. However, for buffer zones to be effective, they usually have to be rather large and used in conjunction with barriers or repellents.

The clearing of land for the establishment of buffer zones should always be on land within the plantations' boundaries and may be planted with low shrubs or left bare, either of which allows guards to spot elephants coming out of the forest. This risk of exposure often discourages elephants from leaving the forest. The grass *Imperata cylindrica*, known locally as *alang-alang* in Indonesia and as *lalang* in Malaysia, has been used as a cover crop for buffer zones as it is unpalatable to elephants. For buffer zones that are bare or planted with short plants, the minimum recommended width is 5 m. A road along the perimeter of the plantation can act as a buffer zone.

A buffer zone can also be a planted stretch between the forest and the crops to be protected, but such buffer zones have to be huge. An optimal buffer zone of this sort would comprise unpalatable crops planted next to suboptimal habitat (Osborn and Parker, 2003). For example, pulpwood plantations of *Acacia* spp. between forests and oil-palm plantations, if well maintained so that there is little undergrowth for food, have been observed to keep elephants away from the oil-palm plantations (Desai, 2002). The problem with *Acacia* is that it is an invasive exotic in this region. As such, safeguards have to be developed and put in place. Chillies (*Capsicum* spp.) are another exotic crop avoided by elephants. They are currently being tested as buffer crops and are reportedly good crops for both small-scale and commercial growers (Osborn and Parker, 2002), and can be used as a source of chilli to be used as a repellent (§ 3.3).

3.1.5. Alternative economic activities

In areas where HEC is severe, it may be easier and less costly to replace oil palms with another crop, or even a different industry. Alternative crops would have to be lucrative to growers and unpalatable to elephants. If elephants are particularly common in the area, it may even be possible to build an ecotourism industry around them. Elephants are a major ecotourist attraction in Africa and Asia. This may be a good option for some smallholders.

3.2. Barriers

Physical barriers are designed to keep elephants out by making it as difficult as possible for them to enter an area. It may be very expensive to construct barriers around the entire perimeter of a plantation, but this is usually the best thing to do if the financial resources are available. However, barriers have to be well-designed, with consideration given to the entire landscape in order to avoid diverting the conflict to neighbouring areas and cutting the elephants off from the rest of their habitat. Barriers can only be effective if the elephants are not dependant on crop raiding, i.e. there are large forested areas accessible to the elephants, and would usually have to be supported by active management. The most commonly used barriers are fences, trenches, and a combination of both.

3.2.1. Fences

3.2.1.1. Electrified

Electric fencing is considered by many plantation operators as the most effective method to deter most species of crop-raiding animals. In areas of moist non-rocky soil and high rainfall, electric fences (also called power or shock fences) are highly effective and can prevent stray livestock as well as wild animals such as elephants, gaurs, wild pigs, and deer from entering estates. Generally, an electric fence consists of wires carrying a pulsing electric charge supported by wooden posts. High-voltage intermittent pulses from the energizer send unpleasant but harmless electric shocks to animals (including humans) that come into contact with the electrified wires. See Appendix I for details on electric fencing.

The purpose of an electric fence is not so much as a physical barrier but more as a psychological one but it is important to remember that a determined elephant will usually get its way. A fully-grown elephant would have no problems pushing over a conventional electric fence if it is willing to endure the pain of the electric shock and larger elephants have been reported to push smaller elephants through electric fences to bring them down. Bull elephants have been observed to break electric fences with their tusks, which are good insulators. Thouless and Sakwa (1995 in Nelson *et al.*, 2003 and in Osborn and Parker, 2003) reported cases where electric fences were destroyed by elephants, despite modifications on the fences and concluded that resources should be invested in low-technology fences and active management rather than engaging in an "arms race" with the elephants. Such cases have shown that the effectiveness of an electric fence does not rely solely on its design, construction, and voltage but has to be complemented with active protection. This would mean that *patrol squads should be employed* (§ 3.4). Also, the fence would have to be *electrified every night from before dusk till after dawn*, as elephants would occasionally test the fences, and if the current is low or absent, they would break through. On overcast days, it may be necessary to electrify the fence all day. Once an elephant has breached a fence, it will try to do so again in the future, having lost its fear of electricity.

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Figure 1. An electrical fencing system with good space allocation for maintenance.

There are quite a few advantages in using electric fences. They do not harm the elephants. Other than a short electric shock, there is no known harm done to the elephants that come in contact with the electrified wires. The risk of injury to both humans and elephants is lower than non-electrified fences, especially barbed-wire fences. Fences are versatile with a variety of design possibilities. Furthermore, existing wire fences can be easily electrified, but *never electrify barbed-wire fences*, as this may lead to fatalities.

The major drawback generally associated with electric fences is the *need for regular maintenance*. In addition, the effective use of electric fences assumes a certain degree of technical sophistication on the part of the owner and the individuals responsible for regular maintenance, and technical support from the company which supplied the fence parts should be forthcoming when called for service.

3.2.1.2. Non-electrified

Non-electrified fencing is a common method used by farmers to keep crop raiders from entering their fields. These fences are usually built with wooden or steel poles or rail tracks driven vertically into the ground, with heavy gauge wire or cable strung between and drawn tight. While these sturdy fences do meet with some success, their effectiveness seems to vary between sites and they can be expensive to erect and maintain. Even multi-strand fences with stone posts have sometimes proven ineffective. In southern Africa, sturdy fences that have been built with several strong poles attached to the wires but not to the ground between fixed posts, making the fences flexible and less prone to breakage by elephants, have proven to be very effective (M. Borner, pers. comm.).

In some cases, simple string fences are constructed with nylon strings or ropes strung on poles along field boundaries and often bounded by buffer zones. These fences are not sturdy barriers but merely act as deterrents. In Africa, some farmers take the initiative to combine the fences with repellents by smearing the fence with grease, chilli powder, and other suitable repellents (§ 3.3). However, although the effect is immediate and cheap, this is not meant as a long-term solution.

Sturdy barbed-wire fences are quite popular and are useful where it is unsuitable to construct trenches (§ 3.2.2), such as across small patches of wet terrain. Another alternative is to use military-grade barbed-wire coils spread along the ground but this is not recommended as elephants (and other animals) may become entangled in them.

3.2.2. Trenches

Another barrier that has been used with some success is the elephant-proof trench. The aim is to create a trench that is wide and deep enough so that an elephant cannot step over it. Elephants are not able to jump. In some places, trenches are filled with pointed sticks to further deter elephants from crossing, but this is potentially harmful to the elephants and may also pose as a hazard to plantation workers and the local community and is thus discouraged. Trenches can be used in conjunction with electric fences, a combination which has worked well where both trenches and fences are well-maintained. See Appendix II for details on trench construction.

The major drawback with trenches is that they can be weakened through soil erosion, which, in turn, can provide elephants with a crossing point as the trench walls collapse and fill the trench. Elephants have been known to kick in the external wall to create steps and to dig their front feet into the internal wall to bring it down. This is especially easy if the soil is loose. Due to problems with erosion, trenches should not be used in sloping terrain, areas with very wet climate, or areas where the soil is prone to erosion. Establishing a cover crop may help strengthen trenches by binding the soil together. Trenches are also not suitable in wetland areas, as the trenches would have the tendency to be filled with water, enabling elephants to swim across.

Maintenance of trenches is mostly a matter of repairing the walls where it has eroded. The frequency of the maintenance is determined by the soil type, terrain, and rainfall.

3.2.3. Other barriers

Other forms of barriers that have been employed include loose-stone walls, earth bunds, log barricades, and moats. However, elephants can break down loose-stone walls and swim across moats (Nelson et al., 2003). Earth bunds, like trenches, are prone to erosion. Log barricades are not recommended, as it would require a large volume of logs, which would have to be cut from a nearby forest, further depriving elephants of their habitat. Based on experiences in zoos, Andau and Payne (1992) suggested the placement of sharp stones or bamboo shards protruding from the ground at intervals smaller than an elephant's foot in a band broader than an elephant's stride to prevent elephants from crossing. Another method is placing bamboo mats over shallow trenches, which act as a psychological barrier as elephants will sense that the ground ahead is not stable enough for crossing. Plants like *dedap* (*Erythrina* sp.) *Agave* spp., bamboos, and rattans (*Calamus* spp.) have been planted close together to form barriers known as biofences.

3.3. Repellents

Repellents are used to keep elephants away by causing discomfort to the elephants. Repellents can be a form of active protection, e.g., when guards carry the repellent-producing agents with them while patrolling, or a form of passive protection, e.g., when the repellent-producing agents are left along the perimeter of the plantation.

Noise is a commonly used repellent, as most wild animals would be scared off by loud noises. The most common noisemakers employed include firecrackers, pipe cannons or *ladum* using carbide, diesel, kerosene, or other types of fuel, thunderflashes, vehicle horns, shouts, rifle shots,

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Figure 2. Oil lamps used in conjunction with electric fencing and a moat.

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Figure 3. A pipe cannon.

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Figure 4. A mobile pipe cannon used by a patrol squad on elephant back.

and whip-cracking. Some estates install noise-making devices that produce sounds at fixed intervals. These generally work for a short time only as the elephants would soon become habituated with the tricks and simply ignore them. However, the use of noise may be quite effective when used in combination with other methods by patrol squads (§ 3.4) but should be limited to direct confrontation to avoid habituation by the elephants (Desai, 2002). There have been suggestions of using infrasonic recordings to deter elephants but a lot of research in elephant communication is still required.

Light is another common method used to scare away elephants. The most common practices are keeping oil lamps and fires burning along the perimeter of the plantation. Elephants habituate to oil lamps and fires quite quickly. There have been reports of elephants walking right up to the edge of the fire and even putting out fires by stamping or dousing with water. While lights on their own may not be very effective, it is helpful when used in conjunction with patrol squads, as it may help the guards see the elephants approaching and enables the elephants to see that the crops are being actively guarded.

Fires, in addition to being visual repellents, also double as olfactory repellents with their smoke. In areas where firewood is difficult to obtain, any substitute material that will smoulder (e.g., elephant dung) can be used. Burning old tyres is widely practiced but it is polluting and not encouraged. Noxious smoke from burning elephant dung with chilli seeds are presently being tested against crop-raiding elephants. Wind direction is a very important factor when smoke is used as a repellent.

Chemicals that have been suggested as repellents include lithium chloride, quinine sulphate, chloroquine hydrochloride, and tannic acid (Lee and Alfred, 2002). There have also been suggestions to use pheromones and other animal scents, but a lot of research is needed.

There is a commercially available capsaicin spray in Africa that has been reported to be effective (Osborn and Rasmussen, 1995). Capsaicin is an active compound derived from chillies and causes irritation to any mucous membrane it comes in contact with. The spray is relatively expensive and requires deployment at close range by trained personnel. Furthermore, they are wind dependent, which risks accidental exposure to humans and other non-target animals.

Similarly, chilli oil is being tested. This method helps to overcome the problems of airborne delivery but does require some sort of barrier on which to deploy it. Usually, simple string fences are put up and a mixture of chilli oil and grease for waterproofing are applied on the string. However, this method may not be suitable in very wet climate (Mohd. Shariff D., pers. comm.).

Aversive conditioning by leaving some oil palms unprotected that have been laced with an emetic (a vomit-inducing agent) has been suggested (I. Redmond, pers. comm.). The idea is that the elephants would learn to associate the discomfort caused by the emetic with oil palms and would pass this knowledge on to their offspring. This method has worked in protecting goats from wolves.

3.4. Guarding

The simplest and most basic measure to mitigate HEC is to actively guard one's crops. Crop-raiding can be unnecessarily severe simply because farmers do not appreciate that crop-guarding is integral to farming in elephant-range areas (Desai, 2002). The best way of guarding crops is with the use of night patrols along the perimeter of the conflict area, with access to a variety of active deterrents such as any of those described above.

A good road system along the perimeter would greatly ease patrolling and would enable the use of vehicles which, themselves can act as deterrents through the use of their headlights, horn and even engine noise. Patrolling can also be performed on elephant back (called flying squads in Indonesia), but this can be expensive. Patrolling can be complemented by watchtowers either on trees or as standalone structures protected by elephant-proof trenches. If well-designed trip-wire alarms are set up, it may not be necessary to patrol constantly. Trip-wire alarms can be very useful to small farmers as it allows them to sleep instead of keeping vigilant all night.

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Figure 5. Patrolling on elephant back.

Patrol squads are popular among both smallholders and large plantations facing HEC. It requires watchers or guards and a few unskilled labourers in groups of up to 20 people. The main function of the squad is to guard the crops, and if necessary, chase the herds of crop-raiding elephants back into the forest, using a combination of noise and lights. The most common way that guards or farmers attempt to chase elephants out of fields is by making loud noises. Farmers use a range of noisemakers, such as beating drums and tins, cracking whips in addition to yelling and whistling to chase off elephants. These noises are usually accompanied by fires, either located on the boundaries of the fields or as burning sticks, which the farmers carry with them. They may also throw rocks, burning sticks and occasionally spears. These methods have a varied range of effectiveness depending on how and when they are applied. These traditional methods for repelling elephants from fields tend to lose effectiveness after repeated exposure. Elephants are noted for the behavioural plasticity and some crop-raiding elephants quickly habituate to empty threats like drum beating and shouting. In some extreme cases, persistent bulls have not even been deterred by gunfire, including shooting one from the group (Hill *et al.*, 2002). Shooting or throwing objects which may harm the elephants is strongly discouraged.

A method commonly used to mitigate HEC is to drive the elephant herds back into the forests before they reach the fields. It involves teams of wildlife officers, plantation workers, farmers, or villagers waiting for elephants to come out of the forest and then chasing them back in. However, spots from which the elephants appear need to be identified. The effect is usually temporary, with the elephants returning within a few weeks.

3.5. Removal

The most intuitively effective method of reducing HEC would be the removal of elephants. While it is often true that only some and not all elephants in a herd will raid crops, removing the culprit will only have a short-term effect, as they will be replaced by other elephants (Nelson *et al.*, 2003). Furthermore, it is virtually impossible to pinpoint the culprit, as elephants tend to raid crops under the cover of darkness. The removal of elephants is only effective in the long term if the entire herd is removed and not individual culprits. Therefore, removal should be carried out only if the intention is to eliminate the local elephant population or to control the population size, whether by translocation or culling. An exception to this would be in situations where a serious and persistent crop-raider that has become habituated to all mitigation measures employed and overcome its fear of humans. Such animals often become aggressive and risk becoming killers. Removal of the problem individual, with a well-considered relocation plan (which may involve placing in captivity) will probably be beneficial in such a situation.

3.5.1. Translocation

Capture of elephants for translocation involves tracking and tranquillizing the elephants (using a dart gun), securing them with ropes and chains, and leading them to a specially modified truck, often with the help of domestic elephants. Only experienced and properly equipped personnel from the relevant wildlife authority are permitted to carry out such an operation. Immobilization of such a large animal is a very specialized and delicate process and the loading and transportation of the animal requires experience and organisation due to the potential risks to both the elephant and the public. A qualified vet is generally needed from start to end, including the journey to the release site for general husbandry and welfare considerations.

The costs involved in translocation are high (about USD8,000 per elephant in Malaysia) and available release sites are limited by both logistical and ecological considerations. Overall, it is a complex procedure which requires careful study and planning that takes into consideration a variety of factors such as herd size, sex ratio, and ranging patterns in both the points of capture and re-release. The receiving area has to be a large forested area with a low density of both elephants (to avoid displacement of resident herds) and people to ensure that while the elephants are translocated, the problems associated with the conflict are not. Translocated elephants may also find their way back to their original homes, making the translocation efforts futile. Mohd. Khan *et al.* (1992) concluded that for translocation to be viable, it has to be coupled with habitat conservation and long-term monitoring.

The advantages of translocation are that the elephants do not have to be killed and that the elephant population may be more viable in the translocated area. The disadvantages are high costs, the need for highly skilled personnel, the potential for disrupting population dynamics, the potential for transferring the original problem, and that translocated elephants may return to their original home. Due to the high level of uncertainty, translocation is only recommended for serious problem elephants and pocketed herds with no realistic chance of rejoining the main population.

3.5.2. Domestication

Domestication is an alternative to culling but it has little direct benefit to the conservation of wild elephants. However, domestication can benefit conservation causes through indirect avenues such as education, awareness building, and genetic storage. It would typically entail capturing the elephants and transporting them to an elephant-training facility. Domestication is very expensive as it is costly to maintain elephants and the capture and transportation would be like that of a translocation exercise (§ 3.5.1). Domestic elephants could potentially be used to give rides to tourists or as beasts of burden in local communities or logging operations, but careful studies would have to be carried out to look at the sustainability of domestication. Domestication is not recommended except as a last option for serious problem elephants which have become aggressive.

3.5.3. Killing

When it comes to human-elephant conflict, many people, especially those depending on their crops, see killing the problem elephants as the only way to reduce further and future crop damage. As a result, elephants are killed either by shooting or by poisoning. However, it is illegal to kill elephants in Indonesia and Malaysia unless performed or licensed by the relevant wildlife authority. After killing a problem elephant, there may be some temporary positive effect but in many conflict areas, other problem elephants continue to destroy crops without any decrease in their activity. Killing is not a remedy unless the purpose is to eliminate the entire herd (Desai, 2002) but this will have a negative impact on the already very low elephant populations in Indonesia and Malaysia. Killing is definitely not recommended.

The killing of these problematic elephants produces perceived immediate effects and, if carried out by the wildlife authorities, can provide good public relations in affected communities. However, it offers only a temporary reprieve from HEC, further decreases an already reduced elephant population, requires authorised and trained personnel, and it is very difficult to identify the culprit animals.

3.6. Compensation

Compensation is generally a non-preventive mitigation measure, and therefore does not usually lead to a reduction in crop-raiding. Compensation can be direct or indirect, monetary or non-monetary.

Box 5. Problems associated with direct compensation schemes.

- Inability to decrease the level of the problem because the cause of the problem is not being addressed.
- Reduction in the incentive for self-defence by farmers, which can even exacerbate the scale of the problem.
- Cumbersome, expensive, and slow administration because of the need to train assessors, cover large areas, have stringent controls, etc.
- High potential for considerable abuse or blatant corruption through bogus claims, inflated claims, etc.
- Absence of sufficient funds to cover all claims.
- The scheme potentially having no end point.
- Unequal disbursements (e.g., to only some victims), causing disputes or social problems.
- Inability to compensate for unquantifiable opportunity costs borne by people who are affected by the threat of problem elephants.

Source: Hoare, 2001

Direct compensation is not recommended under most circumstances as it does not address the cause of the problem and Hoare (2001) has identified several weaknesses associated with such compensation schemes that have been attempted in Africa (Box 5). These weaknesses probably hold true for most wildlife-conflict compensation schemes in most places.

Direct compensation does have advantages, such as potentially immediate relief for the victims and improved (if not exaggerated) reporting of events which can provide the authorities with a better understanding of the extent of the problem. Subsistence farmers may require direct compensation for survival but the amount compensated should not be the full amount lost, as this may encourage complacency.

Indirect compensation in the form of subsidies for crop protection may lead to the reduction of crop-raiding. It may also be possible to set up an insurance scheme against crop damage by elephants and such policies would typically require some responsibility on the part of the insured party for it to be worthwhile for both the insurer and the insured party to take up such a policy.

4. Conclusion

There is no one solution for all situations. Neither are there easy solutions. For most existing plantations facing HEC, the recommendation is to start by setting up clear buffer zones, employing patrol squads to guard the crops, and if financially possible, setting up electric fences and/or trenches, bearing in mind the possible negative effects to the local community, neighbouring plantations, and the elephants. The HEC situation should be monitored and if there is little or no improvement, assessments should be made to decide on modifications or changes to be made. No matter what measures are adopted, good maintenance is extremely important to ensure effectiveness.

This guide recommends that for new developments, and if the situation allows in existing developments, the first and best step to be taken is integrated land-use planning. If a long-term solution to HEC is to be found, the root cause must be addressed, and therefore, land use of the entire landscape must be considered. Clearly defined, clustered blocks of development for human-use should be made distinctly separate from large contiguous tracts of mostly forested areas for elephant use. All forests within elephant ranges that are still unprotected should be afforded protection against conversion. Corridors should be established to restore or maintain habitat connectivity. Corridors are also important for a host of other species besides elephants.

As land-use changes typically require long and complicated processes, usually beyond the control of plantations, stopgap measures have to be implemented. It is recommended that plantations facing HEC establish clear buffer zones and employ patrol squads. Larger plantations with more resources should set up well-designed electric fences or elephant-proof trenches, but these should still be complemented with patrol squads. The same measures are recommended for smallholders, but they would invariably require financial assistance. More studies have to be conducted to look into the means for smallholders to manage HEC.

For pocketed herds with no realistic chance of rejoining the main population, a study to consider translocation of the entire herd to a suitable location is recommended.

The development of the BMP for mitigating and managing HEC does not end with this guide. The guidelines outlined here should be field-tested and any suggestions and improvements should be incorporated into future versions.

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Appendix I. High-conservation-value forests

This section on high-conservation-value forests (HCVFs) was adapted from a WWF-Malaysia factsheet written by Stephen B. Jennings, Andrew S. H. Ng, and Daniel K. F. Chong.

Every forest has some environmental and social values that may include rare species, water catchments, resources harvested by local residents, or areas of cultural importance. Where these values are considered to be of outstanding significance or critical importance, the forest can be defined as an HCVF.

The HCVF concept was initially developed by the Forest Stewardship Council (FSC) for use in forest management certification and first published in 1999. It is a rational, comprehensive, and pragmatic way to think about conservation and sustainable natural resource use that is now widely used in several sectors. The concept focuses on identifying values that make a forest particularly important. Once identified, it is possible to make rational management decisions that are consistent with maintaining critical environmental and social values.

The key to the concept of HCVF is the identification of high conservation values (HCVs) as shown in Box 4 (p. 7). It is these values that are important and need to be protected. HCVFs are simply the forests where these values are found along with the wider area that needs to be appropriately managed in order to maintain or enhance the identified values. For example, one area may provide critical breeding sites for a rare species, with key feeding sites being found in a different part of the forest. If the species can only successfully move through forest, not plantations, the HCVF would be the breeding and feeding sites plus a green corridor of forest between the two.

An HCVF may be part of a larger forest, for example a riparian zone protecting a stream that is the sole supply of drinking water to a community or a patch of a rare limestone forest within a larger forest area. In other cases, the HCVF may be the whole of a large forest management unit, e.g., when the forest contains several threatened or endangered species that range throughout the forest. Any forest type — boreal, temperate, or tropical, logged or non-logged, natural or plantation — can potentially be an HCVF.

One particularly important issue is whether HCVF applies to existing plantations or only to new developments. In truth, HCVs are more likely to be found in areas that have not yet been converted, and in this context, HCVF can be a very useful tool in the deciding where to site new developments and which areas within new developments should be retained as conservation zones. However, HCVF can still sometimes be retained within existing land holdings, either within conservation zones or when part of the plantation retains an important function, such as an elephant migration route.

The integration of HCVF into the planning and implementation process for new plantations should not be a major hurdle under most circumstances where the oil palm industry claims it develops new plantations: heavily logged-over forests, *lalang* or *alang-alang* fields, or burnt-over areas. In fact, it would make the planning for *in situ* conservation and buffer zones more structured and purposeful.

The HCVs outlined in Box 4 (p. 7) are globally applicable. They need to be adapted to national conditions for a plantation company to implement them efficiently. Within Indonesia, there is a widely used toolkit that can be used to identify HCVFs (available from www.forestandtradeasia.org). Malaysia does not yet have any nationally agreed or implemented protocol, but WWF-Malaysia along with the Malaysian Palm Oil Association (MPOA) will be collaborating to initiate a national-level consultation process to develop such a protocol. Meanwhile, plantation managers can take advantage of the Global HCVF Toolkit, part of which is designed specifically for land managers who need to identify HCVFs in the absence of a national interpretation (Part 3 of the HCVF Toolkit, available from www.proforest.net). In addition, several HCVF assessments have already been carried out within the forestry sector in Malaysia and these can be used to guide local assessments. Further information on these assessments is available from WWF-Malaysia.

The process of implementing the HCVF concept should be based as much as possible on existing information. Many organizations and governments have already identified particular areas of forest that are of critical importance for specific values. For example, the government may have defined critical watershed protection zones, a conservation NGO may have mapped rare forest types, or a social scientist may have studied customary land use in the region of a proposed plantation development. This existing information can be brought together and used to assess the presence of HCVs, reducing the need for field surveys.

As described above, the HCVF concept includes a range of different values. A range of knowledge is therefore required to implement HCVF identification and management. Few companies have personnel knowledgeable about field biology, environmental protection, social and cultural issues. This means that the process of identifying HCVs will usually include talking to experts (such as wildlife biologists) and consulting with local communities. Implementing HCVF, therefore, provides an excellent opportunity to develop new partnerships with other stakeholders.

As well as talking to people to gain the information necessary to identify whether HCVs are present on an individual land area, wider consultation is also an important part of the process. This is essential to ensure that the conclusions of the assessment are credible and that the company gains recognition for maintaining HCVFs. In addition, it promotes a process where due diligence to potential issues are systematically identified to be incorporated into corporate decision-making.

Appendix II. Electric fences

An electric fence usually consists of two to four wires fixed about 1' (0.3 m) apart to a height of around 5' (1.5 m) on posts about 30–60' (10–20 m) apart and delivers a pulsed 4,000–8,000 V electric shock if touched. Generally, a set-up of two strands of electrified wires at 1 m and 1.5 m high are sufficient to keep elephants out (Nelson *et al.*, 2003). More strands at different heights are required if the intention is to keep out other wildlife. For porcupines, the wire strand should be 10 cm above the ground surface, and 25 cm and 55 cm for smaller and larger wild pigs respectively (Duckett, 1989). A recently adopted method of reducing attacks on fence posts is to provide a few loops of electrified wire around the posts as well, an arrangement referred as to a “toupee”. The pulses of current in the wire are insufficient to kill animals (including humans) as they usually last for a very short time. However, if functioning optimally, they can act as a psychological deterrent to animals, preventing their entry into estates and crop fields.

The recommended placement of any fence is a minimum of 4 m from the forest edge. This is to avoid damage to the fence by elephants pushing over nearby trees as they search for entry points. All small trees taller than the distance to the fence should be cut down. All loose branches should be cleared. Having a clearing around the fence will also increase the psychological impact as the elephants learn to associate the shock with the plantation scheme.

The wires used should be of high-tensile, high-carbon galvanized steel (Blair and Nache, 1981) with a breaking strain of 250–300 lb (Duckett, 1989). The length of wire needed for a two-strand fence is about 2.5 times the length of the fence (Blair and Nache, 1981). During the set-up, the wires should be strained to 380–400 lb before being tied, after which they will settle to around 350 lb (Blair and Nache, 1981). Connections should be made using wire clamps, connectors, and good splices, as simply wrapping the wire loosely will cause corrosion, reducing the fences’ effectiveness. The posts should be of tropical hardwood with the minimal dimensions of 2" × 2" × 10' (5 cm × 5 cm × 3 m) for line posts and 3" × 3" × 12' (7.6 cm × 7.6 cm × 3.6 m) for corner posts (Blair and Nache, 1981).

Figure 6. A three-strand electric fence with the posts wired.

The energizer ensures continuous supply of electrical pulse. It sends high-voltage pulses along the entire length of the fence connected to it. Each pulse lasts for a very short time (approximately 500 µs) and is produced at 1-s intervals (McKillop *et al.*, 2003). The energizer is constantly switching on and off, and it is this characteristic which is responsible for preventing a fatality under normal operating conditions. Two wires exit through separate holes of the box: one is connected to the fence, the other one is connected to the earth ground stakes. It should be protected by housing it in a concrete or metal box within the


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Figure 7. An energizer powered by wet-cell batteries.

fenced area and well ventilated. Lead-out wires and jumper wires should be insulated to a minimum of 20,000 V, and never using regular insulated wires like Romex. The energizer should be placed as close as possible to the fence lines to be electrified.

In remote areas where there is no electricity supply, energizers can be powered by 12-V heavy-duty wet-cell batteries, the kind used for tractors (Blair and Nache, 1981). The batteries can be recharged with solar cells. The solar panel should be positioned where it does not get shaded at a north-south axis to enable all-day charging. Battery-powered energizers must also be placed at the centre of the fence to ensure maximum energy is transferred onto the fence. A second charged battery should be kept on standby in a dry and safe place. The spare battery will also come in handy on overcast days for solar-charged batteries. Where there is a choice, mains-operated energizers are preferable to avoid the problems of battery charging and maintenance.

For electric fencing to be effective, the conducting wires must be completely insulated and effectively isolated from the ground. The fence structure must be of sufficient strength and capacity to deliver an electric shock sensation to an animal when touched. The most commonly used insulator materials are ceramic or porcelain, rubber hose sections, and plastic (McKillop *et al.*, 2003).

To give an effective shock upon contact with the electrified wire, current must be able to flow through the animal's body to the ground. This can only happen by establishing a very sound earthing system, which must be connected directly to the energizer. The degree of shock experienced is directly related to the level of current, which can pass through the animal's body and the time it takes to do so. Studies have shown that a current of 5,000 V is sufficient for animals as large as elephants (Blair and Nache, 1981). Some plantations establish moats on the external (forest) side of the electric fence. The water helps in conducting electricity through the bodies of elephants that come into contact with the fence.

The earth stakes (usually iron pipes) form part of the total electrical circuit which begins at the live "fence" terminal on the energizer, follows the lead-out, then continues along the fence, through the animal, into the soil and back to the earth stakes and returns to the energizer. The stake and the wire connecting it to the energizer complete the circuit back to the earth terminal. If any part of this circuit is broken, no current will flow and the animal will not receive a shock. Most difficulties occur from the contact between the soil and the stake as there is often a high resistance between the stake and the soil.

Electrical resistance, which opposes the flow of current, regulates current level: the higher the resistance, the lower the current and the less shock sensation experienced. Earthing for the energizer is required to produce a ground resistance of less than 5 Ω and comprises lengths of ½" (1.27 cm) galvanized iron pipes joined to the energizer by galvanized iron wires (Blair and Nache, 1981). The stakes are driven not less than 1 m into the ground in a low-lying moist area (Blair and Nache, 1981). A study described by Lee and Alfred (2002) used three stakes which were set 3 m apart in an equilateral triangle. The stakes were then wired together, using hose chips to fasten the wires to the tops of the set stakes. Each stake should be placed at a distance equal to twice its length from all others. Earth stakes should not be installed within 50' (15 m) of a utility ground rod, buried telephone line, or buried water line to avoid picking up stray voltage (Lee and Alfred, 2002).

In areas with severe electrical storms, it is recommended that lightning arrestors be installed along the fence line at 1-km intervals, as lightning striking the live wire will cause a major voltage rise causing current to flow back to the energizer, damaging it. Each arrestor's negative lead is connected to an earth stake set in a nearby wet area while the positive lead is connected to a separate earth stake (Lee and Alfred, 2002). Arrestors should not be nailed to the fence posts as wires from the fence might get tangled with the arrestor's earth lead, risking zero voltage in the fence from that point on.

Gates should be constructed whenever the fence line crosses a road to assure uninterrupted flow past the gate. Underground cables are preferred to overhead wires because they are less susceptible to damage. The fence wire is routed underground through a double-insulated copper wire inside PVC tubing (Lee and Alfred, 2002). The zinc coating of the galvanized fence wire must be scraped off before joining it to the copper wire of the underground cable (McKillop *et al.*, 2003). The connection is then covered with flexible sealer (Lee and Alfred, 2002).

Streams and small rivers with rapidly fluctuating water levels present a problem which can be overcome with a simple design. Small streams, which carry little debris, are blocked with additional horizontal wires just set above the average high water level. The wires must be connected to the fence wires through knife switches to allow isolation if they are submerged. Another simple method is by attaching a wire to a floating device, which would ensure that the wire stays above the water level (Fig. 8). Small rivers which carry enough debris to snag a submerged wire can be blocked with a row of vertical wires suspended from a fence wire. The vertical wires must be connected to the fence wire through a switch.

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Figure 8. An empty plastic container used as a float to keep the electrified wire above the water.

Safeness of the fence and its surroundings must be taken into strict consideration when building electric fences. The fence must not be hazardous to humans and other animals. *Barbed wires should never be electrified*. If a person or animal is caught in it, it could result in fatality from the repeated electric shocks. Fences have to be well insulated, to prevent fence posts or other structures from becoming electrified. The power supply must always be disconnected before working on electric fences, including the maintenance spraying of herbicides. One should never connect more than one energizer to the same fence and never overcharge the battery. Warning signs must be visibly displayed, especially where there is public access.

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Figure 9. A warning signboard for an electric fence.

Separate sections of the fence should be tested for voltage daily. Remote monitoring systems can be used for mains-powered fences, although this would be expensive. Vegetation and rust on the electric wires are the most common causes of voltage loss. Herbicides should be regularly applied under the fence. Any rusted wires should be replaced. Regular maintenance should include the clearing of undergrowth and fallen branches, ensuring that the insulators are not cracked and are well-sealed, mending or replacing broken wires, posts, and insulators, and ensuring that the battery, solar panels, and energizer are working optimally by testing the fence with a voltmeter. If the energizer stops working, check the fuses and replace them if required. Unhook the energizer from the fence line and use a tool to check for output when the unit is unplugged. If no power is detected, look for broken or cracked insulators. If there are no sparks when fence line is unplugged, send the energizer for repair. The fence inspection is a crucial role and it is recommended that full-time maintenance executives be employed.

Installation costs will depend on the topography, soil, and local material costs, ranging from about USD500 to USD2,000. In order to reduce costs, certain parts can be substituted with cheaper alternatives. These alternatives can be short lengths of rubber hosing instead of breakable ceramic insulators, existing large trees instead of new wooden posts, and recycled automobile batteries and chargers instead of expensive custom battery packs. Other methods of cutting costs include reducing the number of wires used and installing fencing only in areas of the property where elephants enter most frequently, but this has to be coupled with active guarding.

For further reading, McKillop *et al.* (2003) and Blair and Nache (1981) are recommended.

Appendix III. Trenches

Trenches should be constructed at least 6' (1.8 m) from the forest edge (Blair and Nache, 1979a). The recommended dimensions for trench construction are 8' × 6' × 4' (Blair and Nache, 1979b), which is 8' (2.4 m) wide across the top, 6' (1.8 m) deep, and 4' (1.2 m) wide at the bottom, with a vertical internal wall and the external wall sloping at about 56° (Fig. 10). The idea is to create a trench wide enough that the elephants cannot walk over and a bottom that is narrow enough so that the elephants cannot walk along the trench, as they will be more likely to find weak points along the trench in that way. A sloping external (forest-side) wall helps create an illusion of a higher internal (scheme-side) wall, prevent erosion, and it enables elephants that have entered the trench to get out. However, if the construction of a trench with one vertical wall and one sloping wall proves to be too expensive, a symmetrical trench with two sloping walls can be used as an alternative. An electrified fence may be erected on the scheme side of the trench to further enhance its effectiveness. To implement this recommended trench design, giving an allowance of 6' (1.8 m) for the spoil mound, up to 30' (9.1 m) of land may have to be left unplanted, depending on how close the forest edge is to the plantation boundary.

The deposition of the trench spoil can affect the effectiveness of the trench. The spoil should be deposited at least 2' (0.5 m) from the trench to prevent the spoil from being washed into the trench by surface runoff (Blair and Nache, 1979a). On sloping ground, the spoil should be deposited on the side of the trench with the lower elevation to prevent the spoil from washing into the trench and filling it up again (Blair and Nache, 1979b). If both the scheme side and forest side of the trench are on generally equal elevation, the spoil should be piled on the scheme side of the trench, to avoid the possibility of elephants kicking the spoil to fill up the trench. Also, a mound of spoil in addition to the near-vertical internal wall will seem like an even larger barrier to the elephants that are facing the trench. The spoil mound should be located at least 8' (2.4 m) from the planting site to ease maintenance works (Blair and Nache, 1979a). However, some think that the spoil should be placed on the forest side of the trench 4' (1.2 m) away (Blair and Nache, 1979b). This is to create a narrow space between the spoil mound and the trench. This narrow space will restrict the elephants' movements and prevent them from kicking in the external side of the trench to fill it up.

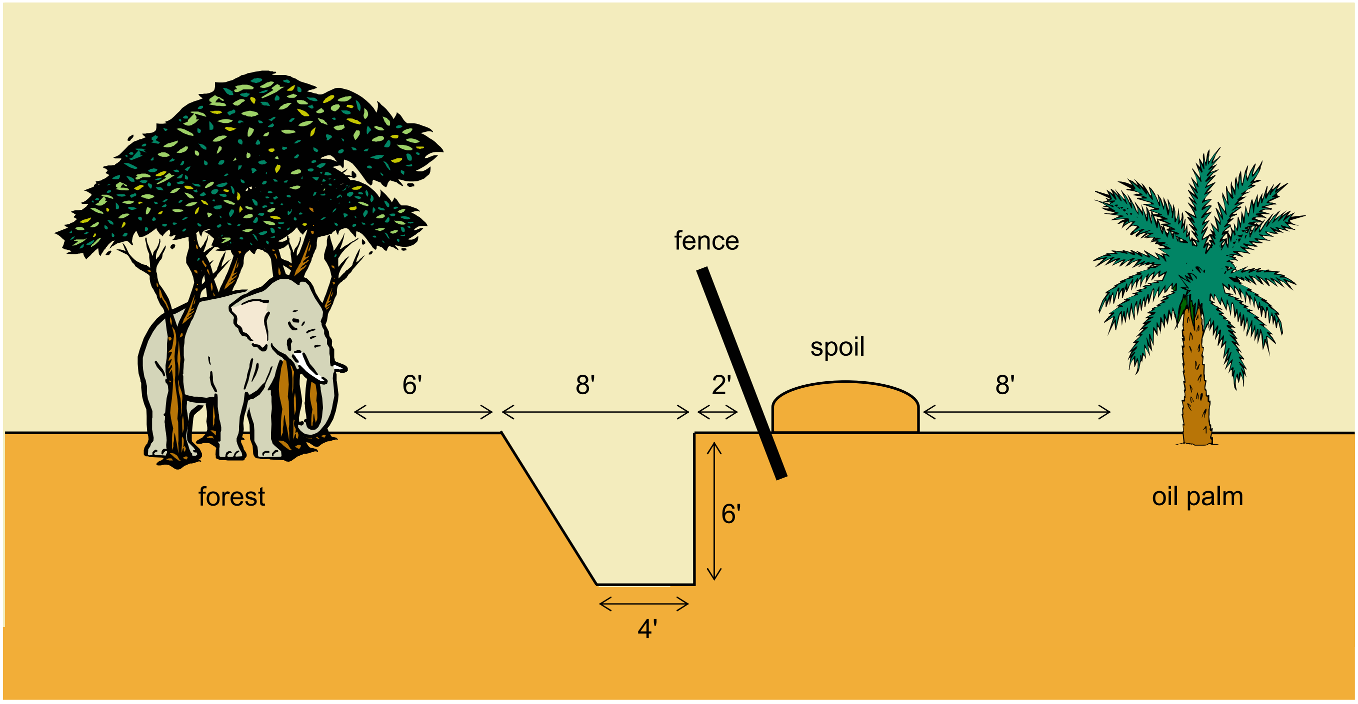

Figure 10. The recommended dimensions for trenching.

In building trenches, the type of machinery used can affect the condition and shape of the trench. Two choices have to be made: a vehicle can run on either a wheeled or a tracked chassis, and a trench can be dug either by backhoe or by dragline. Where logistically possible, a dragline on a tracked chassis is recommended (Blair and Nache, 1979b).

Roads are obstacles in trench construction. There are several alternatives to overcoming the problem. Suitable elephant-proof bridges can be designed and built. As roads cross the trench on the bridge, it is best to combine gate and bridge construction. The other alternative is to employ a patrol squad who would patrol the perimeter at night and drive off any elephants with noise and lights. Guards should be stationed at the weak points along the trench like roads.

It may be difficult to dig a trench following the boundary strictly, especially for existing plantation. In such cases, the trench may have to be rerouted, even if it means leaving areas unplanted or unprotected. Other obstacles to trenching are rocky areas, swamps, and small rivers. Blasting, minor rerouting or diverting the trench are some of the alternatives available to overcome such situations. Digging trenches in swampy or wetland areas are not recommended as these areas are prone to flooding, filling the trenches with water, thus providing access routes for the elephants. This can be overcome by terminating the trench and restarting it on the other side, and filling the trench gap by an alternative barrier, such as a fence.

For further information on trenching, read *Incompatible Neighbours: Proceedings of the Workshop on Elephant Damage Held at INPUT January 1979*, edited by J. A. S. Blair and Nache M. N.

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