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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

Final Draft
25 July 2005

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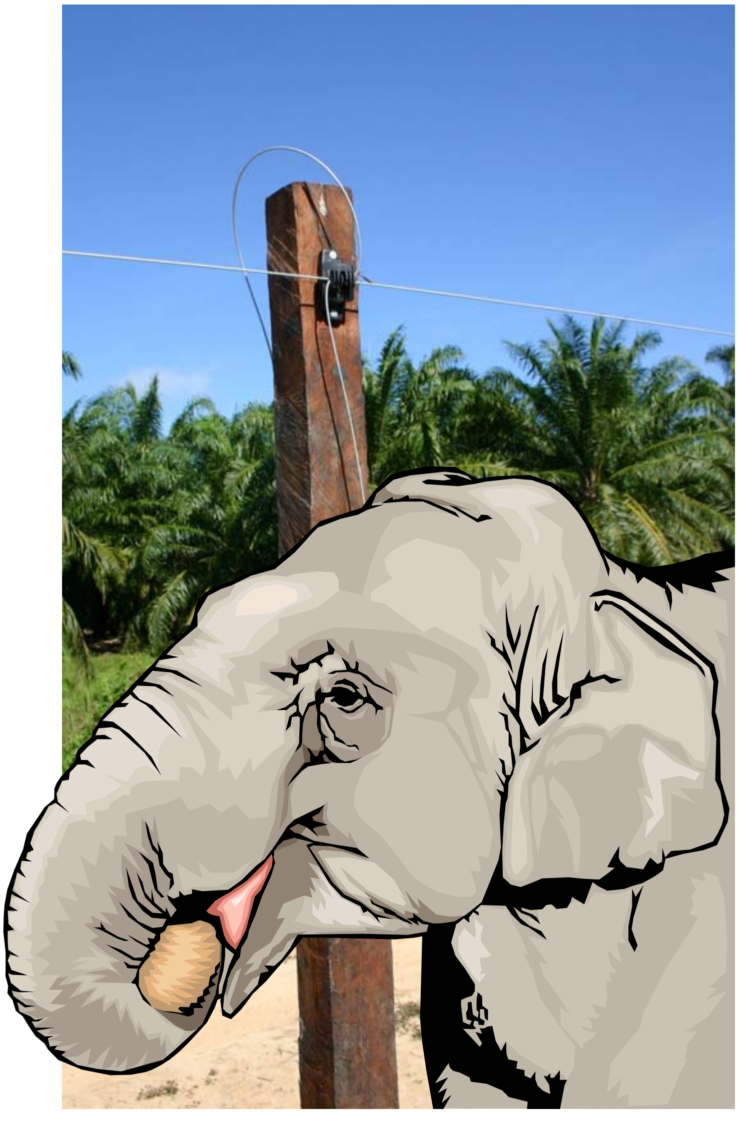

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1. Introduction

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 the African elephant which are recognized by the IUCN are the savannah or bush elephant *L. a. africana* and the forest elephant *L. a. cyclotis*, which some believe deserve to be classified as separate species. As for the Asian elephant, the three subspecies recognized by the IUCN are the Sri Lankan elephant *E. m. maximus*, the Indian elephant *E. m. indicus* which is not confined to India but also found elsewhere in mainland Asia, and the Sumatran elephant *E. m. sumatranus*. 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. Elephants 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 their drinking sites year after year. Elephants have traditional home ranges which they show high fidelity to.

Female elephants live in cow 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 and live solitarily or in small bull groups when they reach sexual maturity.

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 factor is probably food. Cow 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 shade. It is estimated that a herd of 200 elephants require 6,000 km² of roaming ground (Davies and Payne, 1982). It is believed that for a single population of elephants to be viable in the long term, 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. It uses its trunk for foraging and to sense danger. Elephants also have excellent hearing. Their large ears act as amplifiers and warn of possible dangers. Elephants are known to communicate via infrasonic waves. 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. It is illegal to kill elephants in Indonesia and Malaysia. Since 1931, the elephant has been protected in Indonesia, where it is illegal to hunt, trade, and keep elephant and elephant parts 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), which protects it from being shot, killed, or to be in possession without a licence, with 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 edge 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. From the elephant's perspective, HEC can be in the form of poaching and habitat encroachment.

The underlying cause of HEC is habitat loss. Elephants have traditional home ranges, and when their home ranges are reduced by encroachment, they lose feeding ground and their migration routes are disrupted. The conversion of natural forests to oil-palm plantations have contributed to this loss of elephant habitat. The situation is aggravated by a lack of integrated land-use planning which leads to forest fragmentation. The fragmentation of elephant habitat results in pocketed herds, which may have to depend on crop raiding for survival. As forest fragmentation usually leads to even more fragmentation, the further decrease in habitat squeezes the elephants into the remaining forests, increasing the elephant density beyond the carrying capacity of the forests, putting a strain on the available resources. Furthermore, human activities like logging results in secondary vegetation, which elephants feed on, attracting them to these secondary forests, which may draw them closer to human development if such activities are carried out close 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. However, certain individuals may raid crops to supplement their diet even if there is no real need to do so, but usually, never entire herds. This has led to the belief that there are individual habitual raiders. Some think that if the habitual raiders are removed, the HEC problem will be solved. However, these removed habitual raiders may soon be replaced by other individuals (Nelson *et al.*, 2002). As such, *the removal of targeted individuals is not a suitable long-term solution*. However, persistent raiding individuals which have overcome their fear of humans and have become habituated to the usual protection measures may require separate management strategies, usually involving removal of these individuals.

The attraction of crops is that they are usually more palatable and have less secondary defences than wild plants (Sukumar, 1989 in Lee, 2002). Young oil palms are a favourite, especially those aged between two and four years (Blair and Nache, 1979a). Crops may also be more nutritious due to breeding and fertilization. Bulls are more likely to engage in high-risk activities like crop-raiding, which may be 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.

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 the manner 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 the appreciation of the elephant as a valuables species. 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 resources for the elephants, they will be able to overcome the mitigation measures, as they are intelligent and resourceful creatures. It is *only when there exists an alternative to crop raiding will the mitigation measures be effective*.

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

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

For new developments, it is recommended that the questions quoted from Seidensticker (1984) in Box 1 are at least considered, if not acted upon, before embarking on the project in order to prepare for potential problems in the future. 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 ele-

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 that you could translocate the entire herd to?
   - 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.

phant-range areas.

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 can be zoned based on conflict intensity and quality of habitat before decisions on which types of mitigation measures are implemented. The intensity of the conflict should be evaluated before implementing any mitigation measure so that it is possible to gauge the effectiveness of the implemented measures. The intensity of the conflict should be determined in terms of distribution, frequency, and severity of the raiding (Hoare, 2001). Studies have shown that the same fields are usually raided every year. It is also *important to determine if elephants are dependent on raiding*. If they 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. Some experts believe that employing many mitigation measures will tire the elephants and hence discourage them from crop raiding. 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 important to take other stakeholders' concerns into consideration, especially neighbouring plantations and villages, in an HEC management plan. This is especially important if barriers are to be put in place as these will restrict elephant movement and may channel them to neighbouring areas. For example, 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. For most smallholders, collaborating with other smallholders may be the only feasible means to put up 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 in cases of removal of the entire elephant or human population, it is extremely important to have a monitoring system in place. The effectiveness of mitigation measures employed should be monitored and evaluated based on the intensity of the conflict. Ideally, the distribution, frequency, and severity of the conflict should be determined before the employment of any mitigation measure and this information can be compared to the situation after the mitigation measures are put 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

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

The causes of conflict are often complex and difficult to resolve. There is a need for short-term immediate measures to be taken in some areas, as the socio-political pressure is 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. The measures in this section are a documentation of current knowledge and practices and 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 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. Guarding and removal are forms of active protection. Passive protection does not entail direct confrontation but instead relies on land-use considerations and the usage of barriers and repellents. Purely passive protection is rarely sufficient.

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 is 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 give a longer-term solution. However, they require a full-time commitment, and are, therefore, more suited for larger plantations. For instance, an electric fence requires a relatively high maintenance effort and is probably not feasible in communities where cooperation 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 in 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, there is a need to clearly define human-use areas and elephant-use areas with distinct boundaries. This would mean that there would be large contiguous tracts of mostly forested areas for elephant use and clustered blocks of development strictly for human use, which can be enforced with barriers, repellents, and patrol squads. 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, compensation, land swaps, 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, and minerals. 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.

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 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 creating forested corridors linking separate protected areas. These corridors would then have to be afforded some form of protection from conversion. The establishment of corridors is very important for 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.

Corridors can be established along rivers as elephants do travel along them. 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 resources is identified as a cause of HEC, then one method of mitigation that has been suggested is to supplement the resources that are lacking. Artificial waterways and salt licks may be established within forested areas. 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 relatively complicated, involving monitoring and maintenance, and would be carried out by the authorities and not by the plantations in most cases.

3.1.4. Buffer zones

Buffer zones are a land-use practice which also function as psychological barriers. They help define the boundary between plantations and forests. For buffer zones to be effective, they 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. The buffer zone may be bare or planted. If it is bare or planted with short plants, it makes it easier for crop guards to spot elephants coming out of the forest. The exposure also 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 buffer zone can also be a relatively unattractive planted stretch between the forest and the crops to be protected. An optimal buffer zone of this sort would comprise unpalatable crops planted next to sub-optimal habitat (Osborn and Parker, 2003). 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 buffered by the *Acacia* (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).

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 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 cross these barriers. It may be very expensive to construct barriers around the entire perimeter of a plantation or village, but this is almost always the best thing to do. 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 without harming the animals. 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. A fully-grown elephant would have no problems pushing over conventional electric fences if it is willing to endure the pain of the electric shock. Larger elephants have been reported to push smaller elephants through electric fences to bring them down. A determined elephant would usually get its way. 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 (including 12-stranded ones) 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 have to be employed* (§ 3.4). Also, the fence would have to be *electrified every day 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.

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*. Also, 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. In addition, 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. Heavy gauge wire or cable is strung between the poles and drawn tight. While these sturdy fences do meet with some success, they can be expensive to erect and maintain. Nevertheless, the effectiveness of these fences varies with the case studies done in elephant countries. 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.).

Simple string fences are constructed with nylon strings or ropes strung on poles along field boundaries, often bounded by buffer zones. These fences are not sturdy barriers but merely deterrents. In Africa, some farmers take the initiative to combine the fences with olfactory repellent by smearing the fence with grease, chilli powder, and other suitable repellents (§ 3.3.3). However, although the effect is immediate and cheap, this is not meant as a long-term solution.

Barbed-wire fences are quite popular and are useful where it is unsuitable to construct trenches, such as across small patches of wet terrain. It consists of heavy timber supports wired together to form a triangular-shaped barrier. The posts, at least 15 cm in diameter, are covered with as much barbed wire as much as possible. Another alternative is to use army barbed-wire coils spread along the ground but this is not recommended as elephants (and other animals) may get entangled in them.

3.2.2. Trenches

Another barrier that has been used with some success is elephant-proof trenches. The goal is to dig a trench that is wide and deep enough 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 the plantation workers and the local community, and thus discouraged. Trenches can be used in conjunction with electric fences, a combination which has worked well if both trenches and fences are well-maintained. See Appendix II for details on trench construction.

The major drawback with trenches is that, if dug on a slope, they encourage soil erosion. Elephants usually cross trenches at weak points where the trench has eroded. 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 problem with erosion, trenches should not be used in sloping terrain, areas with very wet climate, or if the soil is prone to erosion. Establishing a cover crop may help. 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 would mostly involve fixing the trench in places 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.

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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.

3.3. Repellents

3.3.1. Light

Light is one of the most common methods used to scare away elephants. The most common methods are keeping oil lamps and fires burning along the perimeter of the plantation. In areas where firewood is difficult to obtain, any substitute material that will smoulder (e.g., elephant dung) can be used, but in such cases, it is the smoke that acts as an olfactory repellent and not the fire itself (§ 3.3.3). Burning old tyres is widely practiced but it is polluting and not encouraged.

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

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 also it enables the elephants to see that the crops are being actively guarded.

3.3.2. Noise

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, 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 became habituated with the tricks and simply ignore it. However, the use of noise may be quite effective when used in combination with other methods by patrol squads. The use of loud noises should be limited to direct confrontation with the elephants to avoid habituation (Desai, 2002). There have been suggestions of using infrasonic recordings to deter elephants but a lot of research in elephant communication is still required.

3.3.3. Chemicals

Fires, in addition to being visual repellents, also double as olfactory repellents with their smoke, especially if old tyres are burnt, but this is discouraged due to its toxic effects. 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.

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. Sprays are wind dependent, which risks accidental exposure to humans and other non-target animals.

Similarly, chilli oil is also 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 wet climate (Mohd. Shariff D., pers. comm.).

Aversive conditioning by intentionally leaving unprotected some oil palms which have been laced with a relatively harmless chemical that would make elephants very sick if they ingested it has been suggested (I. Redmond, pers. comm.). The idea is that the elephants would learn to associate the discomfort with oil palms and would pass this knowledge on to their offspring. This method has worked in protecting goats from wolves.

Other 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.

3.4. Guarding

The simplest and most basic measure to mitigate HEC is to actively guard one's crops. The situation can be unnecessarily severe simply because farmers do not recognize crop-guarding as integral to farming in elephant-range areas (Desai, 2002). The best way of guarding crops is by patrolling along the conflict-area perimeter of the plantation throughout the night along with the use of repellents like powerful searchlights and pipe cannons if necessary.

A good road system along the perimeter would greatly ease patrolling and would enable the use of vehicles, of which the headlights as well as the sound of the engine and horn can function as repellents. Patrolling can also be performed on elephant back (called flying squads in Indonesia), but this is 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. Many authors have noted the plasticity of elephant behaviour. Some crop-raiding elephants quickly habituate to empty threats like drum beating and shouting, and in some cases, persistent bulls are not 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 by driving 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, studies need to be done in order to identify the spots from which the elephants appear. The effect is usually temporary, with the elephants returning within a few weeks.

3.5. Removal

The most apparent method of reducing HEC is 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 the removed culprits will soon be replaced by other elephants (Nelson *et al.*, 2003). Furthermore, it is virtually impossible to pinpoint the culprit as elephants raid crops under the cover of darkness. The removal of elephants is only effective in the long run 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 is if there is a serious problem elephant, which is a persistent raider that has become habituated to all mitigation measures employed and overcome fear of humans and may even have become violent. 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 is done by tranquillizing the elephants using a dart gun, securing them with ropes and chains, and leading them to the vehicle with the help of tamed elephants. Only experienced personnel from the relevant wildlife authority using the right equipment should attempt elephant capture. Immobilization of such a large animal is a very specialized process. This is followed by the considerable practical difficulty of raising the adult elephant off the ground and into the vehicle to transport it to a new destination safely and humanely without endangering people and traffic. Experienced personnel are advised to accompany elephants being transported over long distances as fighting may occur and further tranquillization could be necessary as well as for other general animal husbandry and welfare considerations.

The translocation cost is very expensive (about USD8,000 per elephant) and receiving areas available are limited by ecological size and accessibility to the heavy equipment needed. It is a complex procedure, which requires careful study and planning, with considerations on the herd size, sex ratio and ranging pattern of the herds in both the area of origin as well as the receiving area. The receiving area has to be a large forested area with a low elephant density. It also has to be free from any HEC and have a low HEC potential. This is 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 translocated do not have to be killed and that the elephant population may be more viable in the translocated area. The disadvantages are that it is very expensive, it requires highly skilled personnel, it may distort the elephant population structure, the problem may be translocated along with the elephants, and the translocated elephants may return to their original home.

3.5.2. Domestication

Domestication is an alternative to culling. It generally has no direct value to the conservation of wild elephants. However, domestication can benefit conservation causes through education, awareness building, and genetic storage. Domesticated elephants could potentially be used to give rides to tourists or for logging operations. It would typically entail capturing the elephants and transporting them to an elephant-training facility. The capture and transport process would be like that of a translocation exercise.

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 crop damage. Elephants are usually killed by shooting or poisoning. The operational cost for this method is relatively cheap and it is a quick control method. However, it is illegal to kill elephants in Indonesia and Malaysia unless performed by the relevant wildlife authority. Although it is technically possible to get permits from the wildlife authorities to kill elephants, it is not within their policy to do so. After killing a problem elephant, there may be some temporary effect but in many conflict areas, other problem elephants continue to destroy crops without any decrease in their activity. Killing is not an answer unless the purpose is to eliminate the entire herd

(Desai, 2002), but this is strongly discouraged as elephant populations in Indonesia and Malaysia are already very low. For serious problem animals, it has been suggested that trophy hunts can be organized by the wildlife authority and income derived from these organized hunts can be channelled to HEC management.

The advantages of killing are that it is cheap and quick to apply, the perceived effects are immediate, and, if carried out by wildlife authorities, it provides good public relations in affected communities. The disadvantages are that it further decreases the already low elephant population, it requires trained personnel, it is a dangerous exercise, it is very difficult, if not impossible, to identify the culprit animals, the effects are only temporary, and there is little deterrence on the other raiders.

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

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 either direct or indirect, monetary or non-monetary.

Direct compensation is not recommended under most circumstances, as it does not address the cause of the problem. Hoare (2001) noted that HEC compensation schemes in Africa suffered from a similar list of weaknesses and these are quoted in 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 and that most conflict cases will be reported, giving the authorities a better understanding of the extant of the conflict. 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 purchase an insurance policy 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 capable, setting up electric fences and/or trenches, bearing in mind the possible effects to the local community and neighbours as well as 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.

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. Corridors are recommended whenever it is foreseen to be useful.

Basically, this guide recommends that the first and best step to be taken in an ideal situation is integrated land-use planning, followed by the establishment of suitable protected areas, the establishment of suitable corridors, crop-guarding, well-designed electric fencing or trenching, and finally translocation if necessary.

Although the guide ends here for now, the BMP development does not. The guidelines outlined here should be field-tested and any suggestions and improvements should be incorporated into future versions. Also, more studies have to be conducted to look into the means for smallholders to manage HEC.

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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 S. Jennings, A. S. H. Ng, and D. 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 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 anomals, 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).

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 fenced area and well ventilated. Lead-out wires and jumper wires should be insulated to a mini-

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

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

mum 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 totally 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 (Lee and Alfred, 2002). If lightning strikes the live wire, the instantaneous major voltage rise may cause current to flow back to the energizer, damaging it (Lee and Alfred, 2002). Each arrestor's negative lead is connected to an earth stake set in a nearby wet area (Lee and Alfred, 2002). 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 are constructed whenever the fence line crosses a scheme road to assure uninterrupted flow past the gate. Underground cables are preferred than 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 wire must be scraped off before joining it to the copper wire (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.

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

Safety of the fence and its surrounding 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.

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.

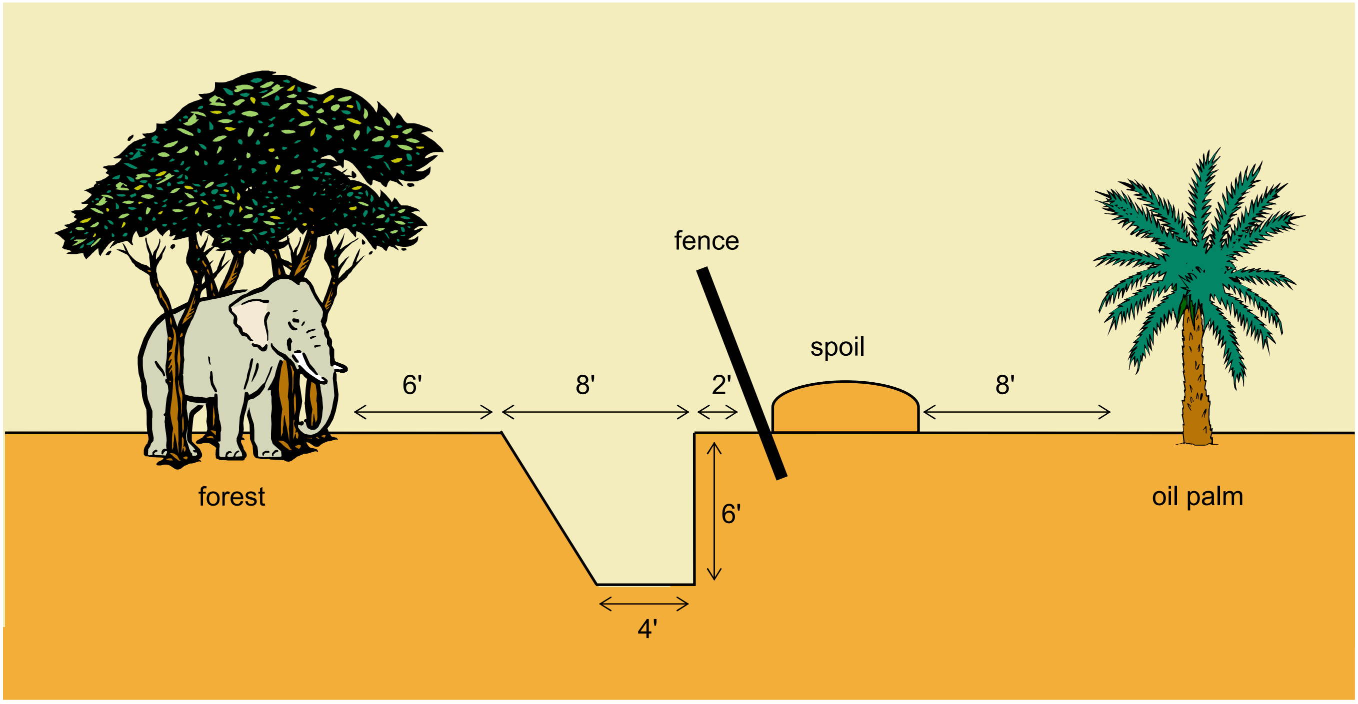

Figure 10. The recommended dimensions for trenching.

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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