FINDING SPACE FOR ELEPHANTS

An investigation into the socioecological factors influencing local perceptions of human-elephant conflict in relation to air photo analysis of deforestation and agricultural expansion around Shimba Hills National Reserve, Kenya

by

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ABSTRACT

Shimba Hills National Reserve (SHNR) in coastal Kenya is well known for it great biological diversity and large resident elephant population. However, there is concern that high rates of land use/land cover change (LULCC) around the reserve, combined with ecosystem destruction caused by the growing elephant population, have resulted in severe environmental degradation and loss of endemic species. Additionally, many elephants have developed a daily habit of searching for food outside of the reserve boundary, leading to high levels of human-elephant conflict. An electric fence was erected around the reserve in an effort to mitigate this conflict, but continuing reports of crop damage indicate the ineffectiveness of the fence in entirely preventing elephants from raiding crops around the reserve. This research project integrates air photo analysis and interviews with local residents to determine the rates of deforestation and agricultural expansion during the 1900s and the socioecological factors driving local perceptions of elephant threat. The analysis is based on visual interpretation of LULCC from a temporal series of aerial photos from 1991 and 1999 and interviews conducted around Shimba Hills National Reserve in 2005 and 2006.

The integration of household interviews with remotely sensed LULCC data greatly improves our understanding of the processes of land use patterns and local vulnerability. The results of the air photo analysis demonstrate a strong link between deforestation and agricultural expansion around SHNR. Dense forest cover decreased over 50%, from 31% in 1991 to 15% in 1999 while agriculture increased from 38% in 1991 to 54% in 1999. The analysis demonstrates how these two LULC categories are inextricably intertwined. Overall, the amount of bushland, open space, and developed land remained largely unchanged. The study found the four most significant socioecological factors influencing local perceptions of elephant threat were: 1) proximity to the reserve, 2) cultivation of cassava, 3) cultivation of coconuts, and 4) the ethnicity of the respondent. These variables were the strongest predictors of perceived conflict with elephants when multiple variables were included in the same statistical model. Local residents' perception of risk plays a major role in determining coping mechanisms and attitudes towards conservation programs. The results from this study demonstrate factors that shape vulnerability to elephant raiding around SHNR which is advantageous in the development of successful, long-term conflict mitigation strategies.

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CHAPTER 1

1.1 Introduction to conservation problems and human-wildlife conflict

Conserving biodiversity and mitigating human-wildlife conflict are prominent elements of global environmental programs (IUCN 2004). Effectively managing protected areas and wildlife populations in developing countries poses a seemingly endless challenge, due to widespread conditions of poverty, rapid population growth and political instability. Worldwide competition between humans and wildlife for land and resources is a historical phenomenon that is extensively documented (Bell 1984; Eltringham 1990; Naughton 1997). Therefore, while human-wildlife conflict is not a new dilemma for rural communities, population growth of approximately seventy-eight million persons annually is leading to escalating incidences of conflict, habitat fragmentation, and deforestation as progressively more land is converted from its natural state to agricultural land and human settlements (Cleaver and Schreiber 1994; Naughton 1997; Masunzu 1998; Soule and Terborgh 1999; Shemwetta and Kideghesho 2000; Smith and Kasiki 2000; Tilman, Fargione et al. 2001; United Nations Secretariat 2001; Rao, Maikhuri et al. 2002; Amos 2003; Georgiadis 2003; Sitati, Walpole et al. 2003; Madden 2004; Osborn 2004; Bulte and Rondeau 2005; Distefano 2005; CARACAL 2006; Treves, Wallace et al. 2006; Parker and Osborn 2007; United Nations Secretariat 2007). Habitat loss and destruction through cultivation, deforestation, overgrazing, pole cutting, blocking wildlife corridors, charcoal burning and other types of pollution all contribute to the rise of human-wildlife conflict (Shemwetta and Kideghesho 2000).

Despite rigorous efforts to maintain biodiversity, species continue to be lost at an alarming pace (Soule and Terborgh 1999). According to research based on the fossil record, human activities have stimulated a worldwide rate of biological extinction 50-100 times greater than the naturally expected pace, with the most rapid species loss occurring in the tropics where biodiversity is greatest (Stuart 1999; IUCN 2004). The principal strategy for conserving biodiversity is the establishment of protected areas (PAs) such as parks and reserves (Soule and Terborgh 1999). In an effort to impede the expansion of human development, many governments designate large tracts of land throughout their countries as protected areas. Historically, the aim of protected areas was to conserve the ecosystem, biodiversity and wildlife populations within their borders by excluding humans. This approach was favored by many conservationists due to the widespread belief in the inverse relationship between human actions and the well-being of the environment (Pimbert and Pretty 1995; Schwartzman, Nepstad et al. 2000). In Africa, the majority of protected areas were established by the colonial administration with little regard for the displacement of local communities (Gurung 1995).

However, this fortress approach began to give way during the 1980s and 1990s, with the recognition of indigenous ecological knowledge, appreciation for landscape level processes beyond the scale of parks, and the growing concern for local welfare. Traditional concentric-ring models of protected areas were criticized on account of the imposed separation and creation of hard boundaries between people and nature (Eltringham 1990; Soule and Terborgh 1999; Turner 1999; Zimmerer, Galt et al. 2005). As of today, more than 100,000 protected areas encompassing 17.1 million km^2 have been established worldwide, but the majority are too small to maintain biodiversity and are becoming increasingly fragmented and ecologically isolated due to mounting human development around their borders (Osborn and Parker 2003; DeFries, Hansen et al. 2005; Naughton-Treves, Holland et al. 2005; Zimmerer, Galt et al. 2005; Conservation International 2007).

Conservationists now recognize the need to work beyond protected areas if they are to sustain viable populations of wildlife and large-scale ecological processes (Turner 1999; Osborn and Parker 2003; Treves, Wallace et al. 2006). As an alternative to hard boundaries, many geographers support an approach that blurs rigid boundaries and addresses conservation at a broader, landscape level (Soule and Terborgh 1999). This concept embraces the idea of corridors and dispersal areas to create an interconnected landscape. Naughton has extensively researched the difficulties involved in attempts to create landscape conservation models that bring large wildlife in contact with high density populations and found that implementing integrated, landscape-level management is particularly challenging in such contexts (Naughton-Treves 1998; Naughton, Rose et al. 1999; Naughton and Salafsky 2005; Naughton-Treves, Holland et al. 2005). The challenge is to design strategies that not only ensure the long-term viability of species and ecosystems, but are also politically and economically acceptable to local communities and governments (Newmark 1993; Treves, Wallace et al. 2006). Caution must be taken not to implement regional analyses that exclude from consideration the ecological, sociological, and political factors that local studies identify as important (Turner 1999).

Ultimately, for both humans and wildlife to prosper and benefit simultaneously, conservationists must realize that utilizing protected areas as a means to separate humans from wildlife is often fraught with difficulties and must adjust their management strategies accordingly. A mutual bridge of understanding between all relevant parties is critical as environmental problems assume greater political significance and analytical approaches that integrate environmental and political understanding become more pressing (Bryant 1992). In many areas throughout Africa, humans and wildlife live in very close proximity to one another which tests the effectiveness of conservation and conflict mitigation strategies.

Shimba Hills National Reserve (SHNR)[1] in coastal Kenya, a site of great concern due to its high biological richness and status as an indigenous homeland, is a prime example of a location where well-intended management and conservation initiatives have led to even greater conservation dilemmas. Similar to other protected areas in Africa, the limited size of Shimba Hills cannot adequately sustain its rapidly growing resident elephant population as the extensive browsing behavior is destroying the existing ecosystem and extirpating endemic species (Armbruster and Lande 1993; Kiiru 1995; O'Connell-Rodwell, Rodwell et al. 2000; Kahumbu 2002). Additionally, elephants have learned to search for food outside of the reserve boundary leading to severe conflict between the elephants within the protected area and the farmers living near the reserve boundary (Kahumbu 2002; Knickerbocker and Waithaka 2005). The present situation illustrates the immense challenge of reconciling global biodiversity goals with local residents' concerns for economic development and security. Shimba Hills National Reserve is an archetypal model of how human-elephant conflict and subsequent mitigation strategies employed by park managers and conservationists can indirectly threaten biodiversity conservation.

[1] "Shimba Hills National Reserve" hereafter also referred to as: Shimba Hills or SHNR.

1.2 Research questions

This study integrates temporal air photo analysis and field interviews with local residents to determine the rates of deforestation and agricultural expansion during the 1900s and the factors driving local perceptions of elephant threat. The primary research questions investigate:

1) The intensity of human-wildlife conflict around Shimba Hills.

2) The socioecological variables associated with farmers' perceived rate of conflict with elephants and reported frequency of threat.

3) The total land use/land cover change (LULCC) around SHNR from 1991 to 1999.

4) Whether agricultural expansion occurred in all regions adjacent to SHNR between 1991 and 1999.

5) The manner in which LULCC differed between the four regions around SHNR (NW, NE, SW, and SE) where interviews were conducted.

6) Whether proximity to the park boundary played a role in rates of LULCC (in total and by region) around SHNR.

My overall aim is to contribute to the growing body of research on human-elephant conflict as well as to provide useful data to assist local managers with developing long-term conservation methods aimed at reducing ecosystem stress while simultaneously minimizing human-elephant conflict. To provide context for my research, I draw from three related fields of inquiry: 1) Human-elephant conflict mitigation strategies with an emphasis on crop raiding patterns and fences, 2) Wildlife corridors and dispersal areas, and 3) Air photo analysis of LULCC.

This paper is organized as follows: Chapter 2 outlines the existing literature and conceptual framework that play a role in this study. Chapter 3 describes the study site (Shimba Hills National Reserve, Kenya), gives an historical account of human-elephant conflict in this area and discusses wildlife corridors and dispersal areas in relation to SHNR. This section also documents past and present conflict mitigation methods employed by the Kenyan government and local residents living adjacent to the reserve. Chapter 4 summarizes the methodology, difficulties encountered, results and discussion of the air photo analysis of LULCC around SHNR. Chapter 5 provides a descriptive analysis of the characteristics of landowners around Shimba Hills. This chapter also explains the interview methods employed in the field, the data analysis procedures, and the results of the multivariate regression analysis which describe the factors contributing most significantly to perceived elephant conflict. Chapter 5 provides commentary on wildlife corridors and local conflict coping mechanisms and concludes with recommendations to managers on developing long-term conflict mitigation methods.

CHAPTER 2

2.1 Literature Review: Overview of elephant conflict mitigation strategies

Elephants, one of the greatest financially valuable species in terms of attracting international tourists to Africa, are also one of the most problematic species affecting the lives and livelihoods of rural residents (Gadd 2005). Incidences of crop raiding by elephants are prevalent throughout Africa and often lead to negative attitudes towards conservation as local residents view living with elephants as a liability (Masunzu 1998; Hoare and Du Toit 1999; O'Connell-Rodwell, Rodwell et al. 2000; Shemwetta and Kideghesho 2000; Hoare 2001; Distefano 2005; Gadd 2005; Sitati, Walpole et al. 2005; Parker and Osborn 2006; Sitati and Walpole 2006; Parker and Osborn 2007). Elephants negatively affect local food security when they damage crops in areas where farming yields are marginal (Hoare 2001). Due to widespread conflict, many local residents do not view elephants as an economic or social status advantage, but perceive elephants and conservation efforts as a contradiction to their socioeconomic endeavors (Shemwetta and Kideghesho 2000).

The economic and emotional costs of human-elephant conflict can be devastating at the household level because elephants are capable of damaging large areas of crops in a single raid, destroying property, and causing injury and death. (Smith and Kasiki 2000; Weladji and Tchamba 2003; Bulte and Rondeau 2005; Parker and Osborn 2007). In addition to the economic losses, negative social impacts of human-elephant conflict are vast. A tremendous amount of effort is required to protect crops and property. Many residents live in daily fear of injury or death, while loss of sleep and energy, restriction of movement between villages, poor employment opportunities, missed school, interference with the collection of fuel wood, psychological stress, and increased exposure to malaria due to guarding crops during the day and/or night are everyday perils (Hoare 2003; Parker and Osborn 2007). In Shimba Hills, Taita-Taveta and Narok, children are often unable to attend school because elephants block all possible routes (Kiiru 1995; Ngure 1995).

Developing effective conflict mitigation methods is a foremost concern for many conservationists. Based on vast research on methods that reduce crop-raiding, a number of "modern" mitigation methods have been introduced to high conflict areas (Masunzu 1998). However, these "modern" methods must often be financially sustained by donors and wildlife management agencies because they are relatively expensive and require resources and expertise that are not available in most rural communities (Sitati and Walpole 2006). Frequently, due to limited personnel and resources, rural communities living in close proximity to wildlife receive little support from the government (O'Connell-Rodwell, Rodwell et al. 2000). Therefore, out of necessity, rural communities living in close proximity to protected areas have developed numerous "local" or "self-defense" strategies for reducing conflict (Hoare 2001). Crop guarding in many regions of Africa primarily consists of inexpensive, low-tech methods implemented by farmers at the local level. Some traditional, relatively non-lethal techniques for scaring elephants away from crops include the following:

1) Noise: shouting, beating corrugated iron sheets, banging drums and metal tins, ringing bells, and cracking whips.

2) Passive barriers: digging ditches, moats, and pit traps, creating buffer zones by clearing areas around fields or planting unpalatable crops (e.g. tea, tobacco, timber, chili), creating hedges between crops, building fences of dry brush, poles, single strand wires, bark ropes, barbed wire, strings with tins/bells/cloth attached, and building stone walls.

3) Throwing objects: gravel, soil, rocks, and spears.

4) Fire/Smoke: lighting fires on the periphery of fields, waving or throwing fire sticks, burning chilies or dried elephant dung mixed with chilies, and burning tires.

5) Early warning techniques: watchmen, lookout platforms, watchtowers, whistles, torches, hanging tin cans, and hanging cowbells on string fences.

6) Decoys: decoy foods for elephants.

7) Dogs and scarecrows.

8) Olfactory (smell-based) repellants: chili sprays, chili bombs, and chili-based grease applied to simple barriers.

9) Obstacles: sharp stones or nails on elephant pathways, and sharpened wooden stakes surrounding fields.

10) Contacting a wildlife officer to come to farm and scare elephants away.

(Newmark, Manyanza et al. 1994; Masunzu 1998; Hoare 2001; Parker and Osborn 2006; Sitati and Walpole 2006).

Modern mitigation methods include the following:

1) Disturbance methods or animal scaring: firing weapons near elephants, setting flares or thunder flashes, firing blank shotgun cartridges, setting trip wire alarms, and elephant "drives" with aircrafts, vehicles or people.

2) Barriers: constructing electric[2] and solar powered fences (temporary and permanent).

3) Reduction of elephant populations: controlled shooting of problem elephants, culling elephant population, administering contraception drugs and translocating elephants to other locations.

4) Auditory (sound-based) repellants: broadcasting noises of people and livestock or elephant warning calls, and ultrasound alarm calls.

5) Community compensation schemes for lost crops.

(Newmark, Manyanza et al. 1994; Masunzu 1998; Hoare 2001; Parker and Osborn 2006; Sitati and Walpole 2006).

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[2] In this paper, "electric" powered fences refer to fences that are powered by generators or hooked up to the national power grid as opposed to electric solar power.

Animal scaring, controlled shootings of problem elephants, and electric fences tend to be the modern methods most preferred by local farmers (Weladji and Tchamba 2003). Wildlife barriers, such as electric fencing and moats, have met with success in protecting small areas or cash crops, but may be impractical for large-scale applications in developing countries unless funded by international aid agencies (Hoare 1995; O'Connell-Rodwell, Rodwell et al. 2000; Osborn and Anstey 2002; Hoare 2003). Contraception drugs have proved to have a wide range of physiological and behavioral side-effects that may prove to be damaging to the female and those around her, which makes this method undesirable for controlling the population (Whyte, van Aarde et al. 1998). Sitati and Walpole found thunder flashes repelled elephants for up to 2–3 weeks at a time, but concluded that this is not a viable long-term solution since thunder flashes are expensive and use is generally restricted to licensed personnel. Their research also found fences not powered by electricity were generally ineffective, whereas chili grease applied to rope barriers successfully deterred elephants (Sitati and Walpole 2006). The use of chilies as a deterrent warrants more extensive testing given its past successes (Osborn and Anstey 2002). However, even chili becomes prohibitively expensive if it is not grown locally (Parker and Osborn 2006).

Masunzu found that the more conscientiously farmers guarded and attended to their fields, the less crop damage they experienced. Crops that were consistently guarded also had higher yields those that were not defended as vigilantly (Masunzu 1998). Sitati and Walpole found that greater guarding efforts by some farmers increased the likelihood that elephants were detected prior to entry to fields and decreased the likelihood of successful crop raiding, as did the use of fire and noise. Farms were less likely to be raided when fires were lit and guards were stationed outside (Sitati, Walpole et al. 2005). Other studies demonstrate that active guarding and deterrent methods are largely superior to passive barriers alone, but several elephants were found to ignore fire displays and shouting during consecutive visits (Masunzu 1998; O'Connell-Rodwell, Rodwell et al. 2000).

Local mitigation methods are more sustainable than modern methods over the long-term for communities lacking financial resources. However, traditional methods often become less effective over time. Evidence suggests that local mitigation efforts may simply displace elephants to other farms in the short-term and elephants often habituate to false threats, rendering these methods ineffective (O'Connell-Rodwell, Rodwell et al. 2000; Hoare 2001; Bandara and Tisdell 2003). To overcome the problem of elephants becoming accustom to any single scare technique, it is recommended that a variety of methods are employed simultaneously (Osborn and Anstey 2002; Sitati, Walpole et al. 2005). Multiple tactics applied together ensures greater success (Hoare 2001; Madden 2004). For example, one study describes how the use of watchtowers and torches to provide early warning of approaching elephants enabled farmers to respond before elephants entered their farms, with a dramatic effect upon their ability to defend their farms (Sitati and Walpole 2006). These results suggest that a combination of early detection of elephants approaching fields, increased guarding efforts, and the use of active deterrents could form the basis of an effective mitigation strategy, regardless of location and the physical attributes of a farm.

2.1.1 Crop raiding patterns

Many cultivated food crops are more attractive to elephants than wild browse plants because selective crop breeding has increased their nutritional value and reduced their physical and chemical defenses, making them more palatable (Purseglove 1972; Sukumar 1990; Chiyo and Cochrane 2005). Overall, elephants appear to feed on virtually all cultivated grains, green vegetables and fruits as well as select portions of cash-crop plants (e.g. cotton and timber trees), preferring the mature growth stages (Hoare 1999).

Seasonal patterns of elephant crop raiding are common and may be triggered by a decline in the quality or availability of wild forage or by crop ripening (Kiiru 1995; Osborn 2004; Sitati and Walpole 2006). Elephants will choose the food source that offers the highest rate of nutrient intake at any given place or time (Osborn 2004). Studies demonstrate that elephants will raid crops during both wet and dry seasons, but raiding is usually seasonal, with increased raiding close to harvest time when cultivated crops are mature (Hoare 1995; Masunzu 1998; Hoare 1999; Hoare 2001). Elephants appear to select the maximum amount of highly nutritious food available to them throughout the year, as opposed to choosing the most available food (Osborn 2004; Sitati and Walpole 2006). This suggests that the time period when and the location where elephants will begin to raid can be predicted from the rainfall pattern and the pattern and rate of grass growth observed in the early-wet season (Osborn 2004).

Many factors influence the location and timing of conflict. A large percentage of crop raiding incidents affect farms with maize or millet, staple crops for many agriculturalists which negatively affects local food security. Besides the maturity of crops and the area of crops under cultivation, the distance of a farm from the boundary of a protected area plays a significant role in the likelihood of conflict (Parker and Osborn 2007). Studies have found that conflict tends to be either spatially clustered or unevenly distributed, which may be a result of variation in local physical or geographical factors, or may be due to individual farmer's efforts to defend their fields (Sitati, Walpole et al. 2005). Sitati and Walpole found that farms that were habitually raided in the past were more likely to be raided than those that were larger and bordered by hedges or fences (Sitati, Walpole et al. 2005). In Tanzania, conflict between wildlife and rural farmers appears to be related to human density, with a higher frequency of conflict with large species, such as elephants, reported in areas of low human density (Newmark, Manyanza et al. 1994). However, studies also demonstrate that conflict levels are also severe in areas where there are equally high human and elephant densities (O'Connell-Rodwell, Rodwell et al. 2000).

Resource use patterns and past interactions with wildlife and protected areas can influence people's attitudes to conservation (Newmark 1993). Intense human-wildlife conflict can undermine and negatively affect local support for conservation (Gadd 2005; Parker and Osborn 2007). Often, the public outcry over loss of crops has more to do with perceptions of potential risk and lack of control of the threat, than actual crop loss (Naughton 1997; Siex and Struhsaker 1999; Hoare 2001; Gillingham and Lee 2003; Madden 2004; Parker and Osborn 2007). However, studies have shown that compensation schemes to account for crops lost to wildlife are fraught with difficulties and often fail their ultimate goal (Rao, Maikhuri et al. 2002; Nyhus, Fischer et al. 2003; Weladji and Tchamba 2003; Bulte and Rondeau 2005). Therefore, establishing local threat perceptions and attitudes towards wildlife plays an important role when developing appropriate wildlife conservation policies and strategies (Hill 1998). Studies demonstrate that "local" and "modern" conflict mitigation techniques have both positive and negative results, and it appears difficult to determine which methods are most effective given the variety of environmental and socioecological variables at each study location. Thus, research as to which methods are the most effective and sustainable for the long-term is on-going.

2.1.2 Fences as conflict mitigation strategies

Many local communities experiencing high levels of wildlife conflict perceive fences as the most effective method for reducing crop and livestock losses (World Wildlife Fund for Nature 1998; Hoare 2003; Nelson, Bidwell et al. 2003; Witucki 2004; Gunaratne and Premarathne 2006). Fence materials range from cacti, thorn, stone, barbwire, and polywire to electric fences with high-tensile strands (Boone and Hobbs 2004). Physical barriers, such as fences, hold the promise of possessing the ability to control elephant movements and to reduce human-wildlife conflict.

Although those suffering from human-elephant conflict have developed a wide range of conflict alleviation strategies and deterrence techniques, including fences made from local materials, one “modern” strategy that is frequently preferred by local communities is the establishment of electric wildlife fences (Nelson, Bidwell et al. 2003). International support of electric fencing is extensive, since fences appear to be successful in controlling human trespass into protected areas while also defending residents from wildlife damage (Witucki 2004). Widespread local popularity and international funding helps to explain why a vast number of conservation areas in Africa have been partially or fully enclosed by fences in an effort to reduce human-elephant conflict. In 2004, Kenya alone possessed over 1,200 km of game-proof fences with plans to develop another 1,300 km in the future (Omondi 2004). However, electric fences have both positive and negative aspects (Sukumar 1990; Thouless and Sakwa 1995; O'Connell-Rodwell, Rodwell et al. 2000; Nelson, Bidwell et al. 2003; Boone and Hobbs 2004; Knickerbocker and Waithaka 2005).

Positive aspects of electric fences:

The main attractiveness of electric fences is the immediate decrease in human-wildlife conflict that occurs once they are constructed. If constructed properly, electric fences provide a strong physical barrier between wildlife living in protected areas and people residing nearby. In Zimbabwe, small community fences enclosing entire households and fields proved to be the most effective method of reducing wildlife damage to crops (Hoare and Mackie 1993). Another study suggests that small-scale fences that encircle irrigated crops or cash crops, such as cashews and bananas, are most likely to succeed (Osborn 1998). In Kenya, immediately after fencing was completed around Aberdares Conservation Area and Shimba Hills National Park, the frequency of elephant raids on nearby crops declined significantly (Witucki 2004; Knickerbocker and Waithaka 2005). In Namibia, one study that tested various elephant conflict mitigation methods found electric fencing to be the only strategy that reduced wildlife losses on a village-wide scale and had the potential for long term use (O'Connell-Rodwell, Rodwell et al. 2000).

Frequently, rural residents view elephants as government property, and this sentiment often leads to local resentment of elephants and imposed conservation initiatives (Hoare and Du Toit 1999; Smith and Kasiki 2000; Rao, Maikhuri et al. 2002; Treves, Wallace et al. 2006). Wildlife fences are politically popular because they help to alleviate tension between local communities and the government. Effective fencing decreases the need for farmers to guard their crops and fear for their lives. Therefore, the construction of electric fences may be viewed as a sign that the government is sympathetic to the recurrent elephant raids that local residents must tolerate. Electric fencing has the potential to reduce crop loss due to wildlife raids while helping to quiet local outcry about parks and alleviate objections to living alongside wildlife (Mburu and Birner 2002).

Fencing, as opposed to culling, is the preferred method of conflict mitigation in Kenya because of the local and international opposition to culling elephants. The Kenya Wildlife Service (KWS) conducts controlled shootings of problem elephants, when necessary, but considers large-scale culling to be undesirable for the following three reasons: 1) ethical considerations in regards to killing elephants, 2) disturbance to social structures and population dynamics, and 3) the negative impact on tourism (Kenya Wildlife Service 2007). Profit from tourism and funding from international conservation organizations provide the country with a considerable amount of income and resources. The introduction of culling projects would generate negative press and considerably jeopardize funding from international sources (Kenya Wildlife Service 2007).

Fencing protected areas potentially has additional benefits to biodiversity and natural resources, besides reducing wildlife access to crops. People living adjacent to reserve boundaries tend to depend partially on resources (i.e. wood, plants, grass, and wildlife) found within protected areas, and this may lead to over-exploitation. Wildlife fences restrict people from entering protected areas, therefore limiting protected resource use. Nairobi depends largely on water from the Aberdares, thus water utility favored fence construction to help protect this key source of water and hydropower while high levels of crop raiding also led to local support of the fence (Witucki 2004). This example demonstrates how fences may benefit the ecosystems within protected areas as well as help to mitigate conflict around their borders.

Negative aspects of electric fences:

Much of Africa's wildlife spends some portion of the year outside the boundaries of protected areas. Under natural conditions, elephants migrate throughout the landscape due to seasonal water distribution and forage quality. Their migration patterns often extend far beyond protected area boundaries, making it difficult to confine them to small parks (Western and Lindsay 1984; Douglas-Hamilton, Krink et al. 2005). As much as eighty percent of elephant range is found in unprotected land (Kimani and Pickard 1998; Hoare 1999; Blanc, Thouless et al. 2003). Wildlife populations that are restricted by fences become genetically isolated due to their inability to migrate across the landscape and lack of access to seasonal resources outside of fenced areas (Newmark, Manyanza et al. 1994; Boone and Hobbs 2004). Therefore, electric fences create hard boundaries that isolate protected ecosystems from the surrounding landscape and threaten their ecological integrity and biodiversity (Newmark 1996).

Fences erected around parks and reserves truncate migratory routes for wildlife that may spend only a portion of the year within protected areas and for species that traditionally traverse the area on their natural migration routes. Often, wildlife populations residing within the confines of fences increase to levels that are unsustainable for the environment which leads to overgrazing and over-predation inside the fence (Ben-Shar 1993; Newmark 1996; Kahumbu 2002; Boone and Hobbs 2004). Overpopulation of herbivores within confined areas also leads to vegetation degradation and in some areas has led to the extirpation of endemic species (Kahumbu 2002). Fenced areas essentially become ecosystem fragments within developed landscapes.

The results of fencing have often fallen below expectations because of the expense and effort required for continued maintenance (Hoare 2003; Nelson, Bidwell et al. 2003). Aside from ecological costs, electric fences are very expensive to construct and maintain (Hoare and Mackie 1993). Construction costs for electric fences in Kenya ranges from $2,000 to $10,800 (U.S. dollars) per kilometer and continued maintenance costs add to the overall expense (Thouless and Sakwa 1995; Smith and Kasiki 2000). For example, KWS budgets KSH 50,000 per km (~$700) annually for maintenance of the fence around SHNR in addition to the maintenance provided by local communities (Knickerbocker and Waithaka 2005). After construction of an electric fence is complete, it is very difficult for many countries to continue to fund the expensive fence maintenance that is necessary. Therefore, conservation projects involving electric fences are primarily funded by, and rely on, international donors such as USAID, Eden Wildlife Trust, World Bank and the European Union’s Biodiversity Conservation Fund (Georgiadis 2002; Knickerbocker 2002; Witucki 2004). Fence maintenance must be incorporated as a part of an integrated conflict management strategy in order to be successful against elephants (Sukumar 1990; Thouless and Sakwa 1995; Chiyo and Cochrane 2005).

One basic problem with fencing schemes is the communities' perceived ownership of the fence. Fence upkeep is vital for the long-term success and effectiveness of the fence, but maintenance problems are widespread (Hoare and Mackie 1993). If people do not perceive tangible benefits from living alongside elephants and view the prevention of crop raiding as the government's responsibility, local participation in fence maintenance is likely to be minimal. Often, initially there is enthusiastic local support for the construction of an electric fence in a conflict-ridden area (Witucki 2004). However, when future fence maintenance in not planned comprehensively or the role that local residents must play in fence upkeep is minimized during the initial fence design, the success of the fence is precarious. Studies have shown that the failure of electrified fences is most strongly related to the maintenance regime (Hoare and Mackie 1993; Thouless and Sakwa 1995; Nelson, Bidwell et al. 2003; Witucki 2004). In addition to the already intermittent solar power, uncontrolled vegetation growth which causes power leakages, delayed maintenance, and potential theft of fence components all lead to low or fluctuating fence voltage (Nelson, Bidwell et al. 2003). Without enforced, long-term fence maintenance regimes and the punishment of habitual elephant fence breakers, electric fences are unlikely to stop elephants from raiding nearby crops (Thouless and Sakwa 1995). Outcomes of the fence at Aberdares improved when KWS consulted with communities and drew up contracts clarifying expectations for communities, and for KWS, with regard to fence maintenance (Witucki 2004).

Additionally, elephants are a highly intelligent, adaptable species and have been known to use their tusks to destroy fences. Ivory is an excellent insulator which shields elephants from the electric voltage. Studies show that males may become habitual fence-breakers and crop raiders once they learn a fence’s weakness (Sukumar 1990). Elephants are also known to knock down wooden fence poles since the poles do not carry the electric current. After the poles are down, elephants are able to easily cross outside of protected areas through the gaps in the fence barrier (Knickerbocker 2002). At Shimba Hills, Kahumbu reports that elephants topple trees onto fences to break them and elder bulls ‘push’ younger elephants through the fence (Kahumbu 2005). Therefore, despite fences, farms adjacent to park boundaries are still vulnerable to elephant raids, especially during seasons when favored foods are at their optimal stage of growth.

It is especially important to integrate the effects of the fence on non-target species (i.e. baboons and monkeys) during the initial planning, layout, and design of wildlife fences. If these species are not taken into consideration, fences can unintentionally intensify human conflict with other wildlife species (Hoare and Mackie 1993; Nelson, Bidwell et al. 2003). For example, reported elephant conflict incidences decreased around Aberdares and Shimba Hills after the initial construction of an electric fence, but conflict with primates intensified and monkeys and baboons became the most frequently reported pests (Witucki 2004; Knickerbocker and Waithaka 2005). In these cases, farmers reported that the fence offered them security from elephants, but at the same time provided protection to primates that were raiding farms. When cornered in the fields, the monkeys used the fence posts to jump over the electric wires and escape their pursuers. On the other hand, residents' tolerance of primates may have decreased once conflict with elephants lessened. However, this case demonstrates how wildlife fences may initially provide tangible benefits by alleviating human-wildlife conflict with targeted species, but may also contribute to additional conservation problems by intensifying conflict with other species.

Another downfall of electric fences is that wildlife may become entangled in the wire from the fence or become electrocuted. Electric fences vary in voltage strength, number of strands, construction materials and price, but conventional wisdom presumes that the more expensive and stronger the fence, the more effective it will be in mitigating conflict (Hoare and Mackie 1993; Nelson, Bidwell et al. 2003). Counter-intuitively, a study in Kenya found no relationship between voltage and fence effectiveness by demonstrating that elephants will break through all fence types, including the most robust, if there is an adequate incentive on the other side of the fence, such as palatable crops (Kangwana 1995; Thouless and Sakwa 1995). In other areas, constant high voltage appears to deter most elephants, but low voltage, a common symptom of poor maintenance, renders the fence ineffective and affords elephants the opportunity to become skilled at breaking through the fence (Nelson, Bidwell et al. 2003). During a study in Mozambique, local people insisted that the fence kept the elephants within the reserve at one time, but later became ineffective. In this situation, the researcher believed that it was likely that the fence was unchallenged by elephants in the past due to adequate food, water and protection within the reserve, but once resources became limited, the fence was not a difficult obstacle for the elephants to overcome (Osborn 1998).

Protected area boundaries demarcate a zone where the use of natural resources is either controlled or forbidden, but people residing nearby often depend heavily on resources found within these areas (Witucki 2004; Naughton-Treves, Holland et al. 2005). Preventing or controlling access to resources such as wood, grasses, water, and grazing space may be beneficial to protecting the biodiversity within fenced areas, but may negatively affect residents’ livelihoods and sentiment towards conservation (Hart and O'Connell 1998). In one case, the construction of a game fence was popular among most community members as an effective barrier against elephant raids, but residents were known to take wire from the fence to make snares, thus compromising the effectiveness of the fence in reducing conflict (Sitati and Walpole 2006). This example reveals the heterogeneity of community perspectives on fences.

The South African experience with fencing offers some important lessons by depicting how fences directly caused great harm to wildlife in several regions by blocking migration as well as indirectly impaired conservation efforts by providing a superabundant source of wires for snares (Boone and Hobbs 2004). A more positive scenario comes from Kruger National Park where fences were the main component of a triage intervention during 1990s, but were later removed when conservation planning successfully incorporated adjacent to private lands (Maria 2005).

Finding a solution to mitigate human-wildlife conflict is complicated since the issue is complex and multifaceted, but many studies show that fences prove to be the most effective physical barrier against elephant crop raiders (Hoare and Mackie 1993; Osborn 1998; Nelson, Bidwell et al. 2003). The correct design, the consideration of geographical variation and elephant migratory patterns, the completeness of the fencing, and community support for fence maintenance appear to be crucial for fence success (Gunaratne and Premarathne 2006). Despite numerous difficulties, electric fences, with proper planning and forethought, may provide viable short-term solutions to human-elephant conflict. However, once elephant populations become too large and can no longer be sustained by protected area, other environmental issues arise. At the moment, fences are increasingly difficult to justify given the current emphasis in conservation ecology on connecting habitats at a landscape scale.

2.2 Literature Review: Wildlife corridors and dispersal areas

In many areas of Africa, traditional elephant migration routes have been cut off as a result of human population growth and agricultural expansion into areas that were previously elephant range (Kangwana 1995; Kabukuru 2007). With the high demand for agricultural land, farmers are encroaching into these previously avoided areas despite high levels of human-elephant conflict (Smith and Kasiki 2000; Kabukuru 2007). This agricultural expansion leaves numerous disconnected pockets of suitable wildlife habitat. As protected areas become progressively more fragmented and isolated from one another, landscape movements become more precarious for wildlife. Traveling from one adequate habitat island to another, wildlife are often exposed to predators, travel through areas without suitable resources, and risk getting lost and never finding another secure island with a suitable ecosystem (Tilman, Fargione et al. 2001). Landscapes require small natural-vegetation patches which serve as "stepping stones" between large habitat patches for a multitude of biological functions (Forman 1995). Therefore, vast interest in preserving and establishing wildlife corridors or dispersal areas, "Ecoregional" conservation, is taking main stage as a method for addressing these issues (Saunders, Hobbs et al. 1991; Harrison 1992; Center for Applied Biodiversity Science, Conservation International et al. 2000; Osborn and Parker 2003; Jenkins and Anderson 2006; Goldman 2007; Kabukuru 2007).

From a biological perspective, the principal goal of corridor planning is to maintain or restore connectivity across a landscape through the integration of populations into a single demographic unit (Horskins 2005). One potential means of reducing the rate of species loss and increasing the likelihood of species re-colonizing parks is to link protected areas with a system of wildlife corridors (Forman 1995; Newmark 1996). Corridor literature specifies that, in most cases, the ideal design consists of core conservation areas that are connected by secure buffered passageways, but corridors should ultimately be designed on a site-specific basis (Noss and American Wildlands 2004; Jenkins and Anderson 2006).

When creating corridor landscapes, it is important to incorporate animal behavior research. Establishing a "perfectly" constructed corridor ecosystem between one protected area and another does not guarantee that it will be utilized by elephants solely because it was created as a protected wildlife corridor (Douglas-Hamilton 2004; Douglas-Hamilton, Krink et al. 2005). When possible, elephants will continue to utilize ancient migration corridors despite high levels of human encroachment and settlement (Douglas-Hamilton 2004). Information regarding the location of resources is passed from generation to generation by the elephant matriarch, and elephants often follow the same paths year after year (Lenaiyasa 2004). Therefore, when ancient migration passageways are developed for agriculture, attempting to control elephant movements in an effort to prevent human-elephant conflict and crop-raiding is extremely difficult. Dissuading elephants from following their familiar migration paths requires major changes in infrastructure (i.e. fences or moats), significant manpower for monitoring elephant movements, and patrols for controlled shooting of problem elephants (Jivetti 2004; Kabukuru 2007).

Thus, the likelihood of corridor success may increase if a corridor is placed along a previously established migration route that it is still utilized by elephants. Studies show that the position of ancient wildlife corridors relates directly to present patterns of human-elephant conflict (Osborn and Parker 2003). Elephants follow the same routes throughout the year and raid crops in neighboring areas whenever food is available. One study in Kenya affirms that conflict could possibly be mitigated altogether if elephants were able to follow their traditional migration routes, but prevented access to crops near the corridors (Smith and Kasiki 2000). Along the same line of thought, conservationists in western Uganda are considering creating 'fenced corridors' to reconnect protected areas without exposing rural communities to elephant crop raiding (Naughton 2007).

When planning the creation or restoration of a corridor, a large amount of information regarding traditional migration routes may be obtained by consulting with local farmers. Community information is invaluable when planning the position of corridors, fences and other conflict mitigation measures (Smith and Kasiki 2000). With the growing human population and the expansion of agriculture, a strategy that integrates people and wildlife within the same environment is necessary in order to maintain biodiversity. However, both geographers and conservation biologists alike recognize the difficulties involved in implementing successful landscape-level conservation schemes. The complexity is exacerbated by the fact that countries which contain the most threatened species tend to be those that are least able to invest significant resources into conservation (IUCN 2004). Therefore, many large-scale corridor projects rely on the support of global political organizations, global treaties, and global conservation organizations, which introduces its own difficulties due to linking globalization and conservation (Zimmerer, Galt et al. 2005).

The establishment of wildlife corridors in areas developed as agricultural land or settlements brings to light a multitude of political complications in regards to local residents. In areas of East Africa, the intense focus on corridors by conservationists is preventing dialogue with local communities and may be detrimental to future conservation endeavours (Goldman 2007). Corridors may be perceived by local communities as modern 'land grab' schemes by conservationists and may backfire if communities respond by cultivating more land so as not to lose claim to land destined to be a corridor (Goldman 2007). Research on the rates and patterns of land use and settlement adjacent to parks is important since these factors affect the political and economic costs of establishing corridors (Newmark 1993).

Many biologists realize the long-term instability and ecological problems associated with species' genetic isolation and habitat fragmentation, and there is debate as to whether establishing corridors is appropriate (Simberloff and Cox 1987; Saunders, Hobbs et al. 1991; Plummer and Mann 1995). Some conservationists state that linking smaller reserves with other habitat patches via habitat corridors may alleviate the genetic problems associated with isolated populations and provide a solution to habitat fragmentation (Harris 1984; Newmark 1996; Center for Applied Biodiversity Science, Conservation International et al. 2000; Osborn and Parker 2003). Others have doubts about the effectiveness of corridors, believing that they may negatively affect the ecosystem by promoting genetic out-breeding depression and transmitting disease, predators, and noxious or exotic plants and animals (Simberloff and Cox 1987; Plummer and Mann 1995). Often, the debate over the value of corridors is stymied by vague or inconsistent definitions of biological corridors (Rosenberg, Noon et al. 1995; Goldman 2007). With regard to elephant conservation, the general consensus is that corridors are necessary to ensure long-term success. The majority of people-environment geographers and conservation biologists maintain, albeit with differing approaches, the overall proposal to abandon the notion that people and wildlife must live separately and embrace the notion of one intertwined landscape. Despite the misgivings regarding the function of corridors, it is clear that small, isolated ecosystems will certainly lose their biodiversity unless they are integrated into the surrounding landscape. Wildlife corridors may be one method for achieving the goal of landscape conservation.

2.3 Literature Review: Air photo analysis of land use/land cover change

Habitat loss and environmental degradation are the two factors that pose the greatest threat to wildlife populations worldwide (IUCN 2004; Jivetti 2004; Jenkins and Anderson 2006). Habitat loss, in the form of tropical deforestation, often leads to a decline in native plant species and soil degradation, which causes a negative ripple effect throughout the entire ecosystem (Olson 2004). Numerous studies have demonstrated that the effects of habitat loss on biodiversity are substantial, long-term, and consistently impact species richness, breeding success, growth rates, genetic diversity, and population abundance and distribution (Saunders, Hobbs et al. 1991; Fahrig 2003; Sanchez-Azofeifa, Daily et al. 2003). Single-factor causations, such as human population growth or shifting cultivation, are often disproportionately emphasized as the primary sources of tropical deforestation when instead, this phenomenon is best explained by multiple (economic, institutional, technological, cultural and demographic) factors and drivers that act synergistically (Geist and Lambin 2002). Taking this into consideration, the majority of studies conclude that the leading cause of regional tropical forest loss is agricultural expansion (Achard, Eva et al. 1998; Reenberg 2001). Therefore, up-to-date monitoring of the condition and increasing isolation of coastal forest habitats is crucial due to their high levels of endemism, biodiversity and species rarity (Matiru 1999).

The rates and spatiotemporal patterns of agricultural expansion differ due to variation in the biophysical, socioeconomic and political factors which drive land-use dynamics worldwide (Semwal, Nautiyal et al. 2004). In some instances, high demographic pressure is believed to lead to either agricultural extensification, the conversion of agriculturally marginal land to cultivation, or agricultural intensification, the increase in crop production often through the degradation and unsustainable use of existing fields (Reenberg 2001; Wood, Tappan et al. 2004). In forested areas of the tropics, agricultural expansion results in the extensive removal of native vegetation, resulting in fragmented patches of forest across the landscape. Ecosystem fragmentation causes significant biogeographic changes as well as notable modifications to the physical environment.

Currently, the most significant threat to coastal forest habitat in East Africa is the expansion, or extensification, of agriculture which has left only 10% of the original vegetation in pristine condition (Conservation International 2007). It is estimated that the coastal forests in Kenya decreased in area from over 50,000 km^2 in the early 1900s to approximately 650 km^2 in 2005 (Good 2005). Historically, when food security was threatened by population growth, a much larger amount of fertile land was available for expanding agriculture across the region; however these options are becoming limited or impractical (Wood, Tappan et al. 2004). In densely settled landscapes, rural farmers are turning to intensifying their agricultural production, resulting in both positive and negative environmental outcomes (Tiffen and Mortimore 1992; Wood, Tappan et al. 2004).

Deforestation to meet agricultural needs is ubiquitous at the borders of tropical forest protected areas (DeFries, Hansen et al. 2005). The removal of trees around the edge of forested parks and reserves isolates the ecosystems and creates perimeters of abrupt edges (Bulte and Rondeau 2005). Extensive ecological changes take place at forest edges which, depending on the size of the forest, may result in the inward collapse of the forest fragment (Gascon, Williamson et al. 2000). Edge effects are an important biological factor to consider when debating the establishment of “buffer zones”, transition areas between regions managed for different objectives (Martino 2001).

An ecological study in Costa Rica demonstrates that deforestation increases with distance from the border of national parks and biological reserves (Sanchez-Azofeifa, Daily et al. 2003). Similarly, in East Africa, research reveals that total deforestation tends to increase in relation to distance from protected area boundaries, but some of the highest *rates* of deforestation occur within 5 km of protected area edges (Plumptre, Masozera et al. 2002; Witucki 2004; Naughton-Treves, Holland et al. 2005). Beneficial to the forest ecosystem, electric fencing limits human resource use inside protected areas which shifts the extractive pressure to resources outside of the protected area (Witucki 2004). However, since fences inherently suggest increased security from wildlife raids, fencing protected areas may eliminate natural buffer zones and lead to the expansion of cultivation right up to the fence boundary. Some researchers (Soule and Terborgh 1999) see hard edges and isolation as evidence of the incompatibility of people and forest biodiversity, which reinforces their argument for strictly protected parks that are as large as possible. Others (Barraclough and Ghimire 2000; Vandermeer, Perfecto et al. 2005) see hard edges as failure of model and suggest landscape level integration.

Despite increasing concerns about the loss of biodiversity worldwide and new ideas about conservation strategies which integrate people into the landscape, some leading biologists still advocate preservationist approaches with a strong emphasis on island-like reserves that are theoretically capable of maintaining their biotic diversity (Eltringham 1990; Saunders, Hobbs et al. 1991; Soule and Terborgh 1999; Gaston, Pressey et al. 2002; Sanchez-Azofeifa, Daily et al. 2003; Semwal, Nautiyal et al. 2004). This strategy embraces the concept of interconnected, large, untouched, pristine core habitats and, in some cases, supports the establishment of "hard edges" (i.e. fences or barriers) as opposed to buffer zones

(Soule and Terborgh 1999). Studies indicate that larger forest remnants have bigger core areas that are unaffected by the environmental and biotic changes associated with edges (Saunders, Hobbs et al. 1991). Conservation biologists have found that rates of extinction of mammals in protected areas are significantly and inversely related to the park area, which suggests that the continued isolation of protected areas and the density of human population around parks have been significant factors in biological extinctions (Eltringham 1990; Newmark 1996; Woodroffe and Ginsberg 1998; Brashares 2003; Fahrig 2003; IUCN 2004). The inverse relationship between the rate of extinction and park area is consistent with MacArthur and Wilson's theory of "island biogeography" which supports the idea that habitat islands that were created when the continents fragmented lost species at a rate proportional to their size (MacArthur and Wilson 1967; Newmark 1996; Brashares 2003). However, most conservation biologists believe that human factors are directly compromising biodiversity in African forest 'islands' and loss of species is occurring at a rate far greater than that which can be attributed to purely natural losses associated with isolation (Brashares 2003; Newmark 2006).

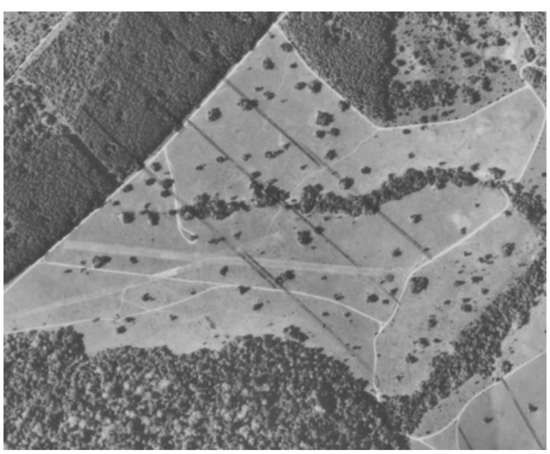
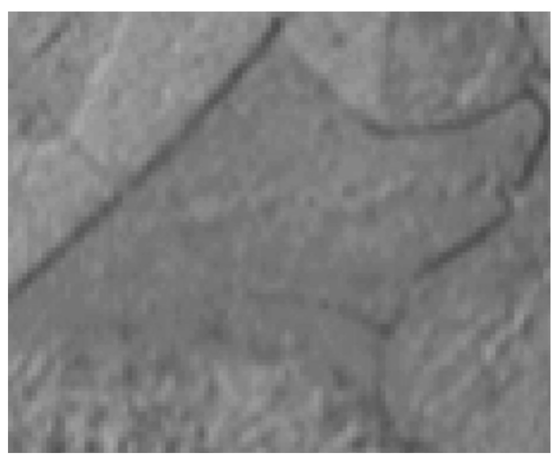
The consequences of isolated, fragmented forests extend beyond biodiversity and wildlife concerns. Forests provide many important ecological functions such as regulating the climate and water resources as well as serving as habitats for plants and animals. Disproportionately high demands for forest products and services place pressure on limited forests ecosystems and frequently lead to the conversion or degradation of forests into unsustainable forms of land use (Tomppo, Czaplewski et al. 2002). When forests are lost or severely degraded, their capacity to function as regulators of the environment is also lost, increasing flood and erosion hazards, reducing soil fertility and contributing to the loss of plant and animal life. As a result, the sustainable provision of goods and services from forests is jeopardized (Tomppo, Czaplewski et al. 2002).

On a local scale, rural communities living adjacent to forest ecosystems often depend on numerous resources found within the forest to fulfill or supplement resources required for daily life (i.e. wood for firewood and construction, grass for livestock, food, medicinal plants, etc.) (Arnold and Dewees 1997; Semwal, Nautiyal et al. 2004; Witucki 2004). Approximately 75% of Kenya's population live in rural areas; therefore the future of the forests is inextricably tied to the future of the local population and the conservation of the forests depends upon the sustainability of local rural livelihoods (Matiru 1999). In circumstances where forest resources are unavailable or restricted, many farmers plant and manage tree species on their own land to provide their own sustainable forest outputs (Arnold and Dewees 1997).

Ultimately, the park-preservation versus landscape-level-integration debate is limited by insufficient data on land use dynamics around protected areas and lack of attention to local socioecological context. Geographers and others who are conducting analyses of changes in land use and land cover play a vital role in understanding global environmental changes and contribute largely to land use management (Imbernon 1999). Most of the contemporary LULCC analyses feature satellite imagery, but air photo analysis remains a key method for historical analysis of land use change (Mertens, Sunderlin et al. 2000; Herold, Goldstein et al. 2003; Lambin 2003; Turner 2003; Turner, Hiernaux et al. 2005). Two leading realms of work in this research project are: 1) technological advances in orthorectifying air photo images and 2) combining interviews and field work with remote sensing to better understand causality.

With careful interpretation, air photos are an excellent source of spatial data for studying LULCC. Aerial photo analysis proves to be a powerful tool for assessing and quantifying broad changes in regional landscapes (Kahumbu 2002; Soini 2002; Witucki 2004). Similar to satellite images, aerial photographs serve to establish inventories of natural resources, reveal temporal assessment of land cover changes and provide quantitative information about changes between different land cover categories (Tekle and Hedlund 2000). Table 2.1 displays several characteristics that make aerial photo analysis valuable in comparison to satellite imagery analysis.

Table 2.1 – Advantages of aerial photos over satellite images
[Based on data from (Wheate 2007)]

<table>
<tr><th colspan="2">Advantages of aerial photos</th></tr>
<tr><td>Higher spatial resolution</td><td>3D stereo perspective</td></tr>
<tr><td>Both analogue photos and digital images</td><td>Easier interpretation</td></tr>
<tr><td rowspan="2">Higher understanding of landscape due to: size, shape, shadows, tone, texture, patterns, etc.</td><td>Lower cost of obtaining data</td></tr>
<tr><td>Ability to fly beneath clouds</td></tr>
<tr><td colspan="2">SHNR air photo (left) versus panchromatic 15-m satellite image (right) of same area: Scale 1: 6,279</td></tr>
<tr><td></td><td></td></tr>
</table>

When planning buffer zones, fences, and corridors, fine-scale spatially explicit analysis is needed. This is particularly true for elephant conflict circumstances because the nature of the conflict is often highly localized and unevenly distributed around protected areas (Naughton, Treves et al. 1998; Naughton-Treves 1998). Empirical evidence of land cover change, provided by an analysis of a time-series of aerial photographs, can greatly contribute to planning appropriate management of available resources, especially in developing countries, where other sources of background data are often lacking (Tekle and Hedlund 2000). The combination of interviews with local residents regarding land use change and aerial photo analyses provides complementary data sets which allow a greater understanding of the important drivers of change at various spatial and temporal scales (Mertens, Sunderlin et al. 2000; Kahumbu 2002). Integrating data from different sources is vital since relying solely on remote sensing analysis without incorporating social or ecological research may lead to erroneous conclusions about causality of environmental degradation (Fairhead and Leach 1996; Turner 2003).

Remote sensing technology plays an increasingly important role in understanding environmental change across landscapes and in developing management strategies that promote conservation and sustainable development. The use of remotely sensed digital data for mapping purposes has increased dramatically over the past 20 years along with the complexity of geocomputing and geospatial software capabilities (Camara, Souza et al. 2000; Sui and Goodchild 2001). Geotechnology is one of the three most important emerging and evolving fields in industrialized countries and consequently, computer mapping has become an enormously powerful decision-making tool (Gewin 2004). GIS technology can greatly facilitate the analysis and presentation of land use data classified from aerial photos (Tekle and Hedlund 2000; Gautam, Webb et al. 2003).

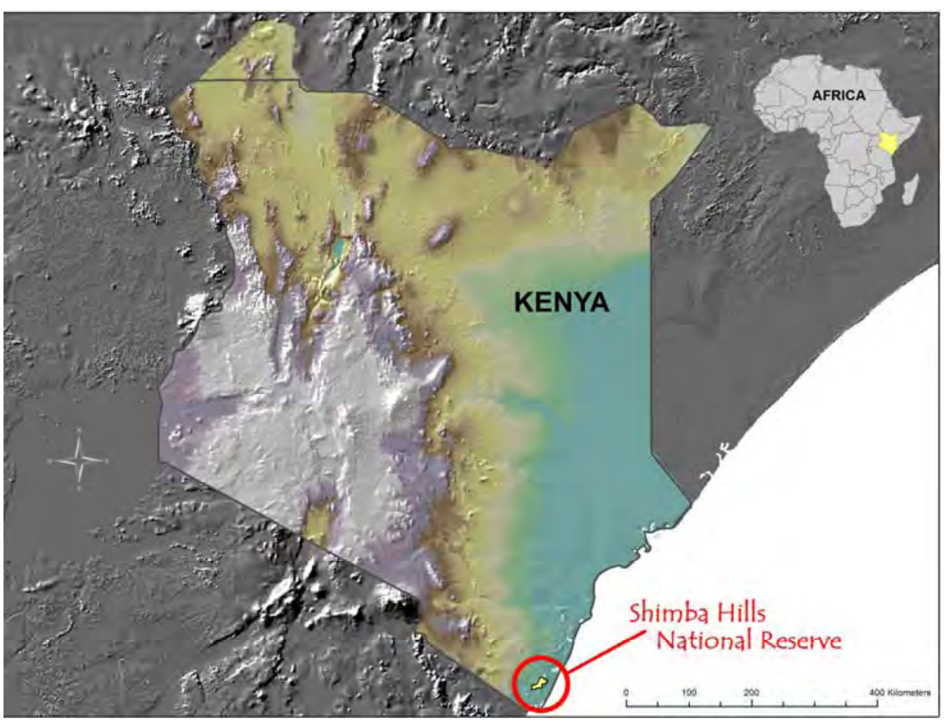
Digital photogrammetry and orthophotography are making significant impacts in the mapping sciences (Cowen 1994). Orthophotos are aerial photos that have been rectified such that they are equivalent to a map of the same scale and give an accurate representation of the earth's surface (Surveying Engineering Department 2006). Due to the differential rectification process that geometrically corrects for both relief and tilt displacement, orthophotos are unique from aerial photos because they may be used to measure true distances (Lillesand and Keifer 1994). Creating orthophoto mosaics is a process that has become quite common and widespread given that new software has made it possible for those who are not highly skilled photogrammetric technicians to create orthophotos (CHIPS Development Team 2000; Surveying Engineering Department 2006). OrthoMapper™, a robust softcopy photogrammetric software, provides a means for researchers to create orthophoto mosaics from multiple aerial photo images (Scarpace, Weiler et al. 2000). OrthoMapper™ software was instrumental in the analysis of temporal aerial photos for this research project.

CHAPTER 3

3.1 Study Site

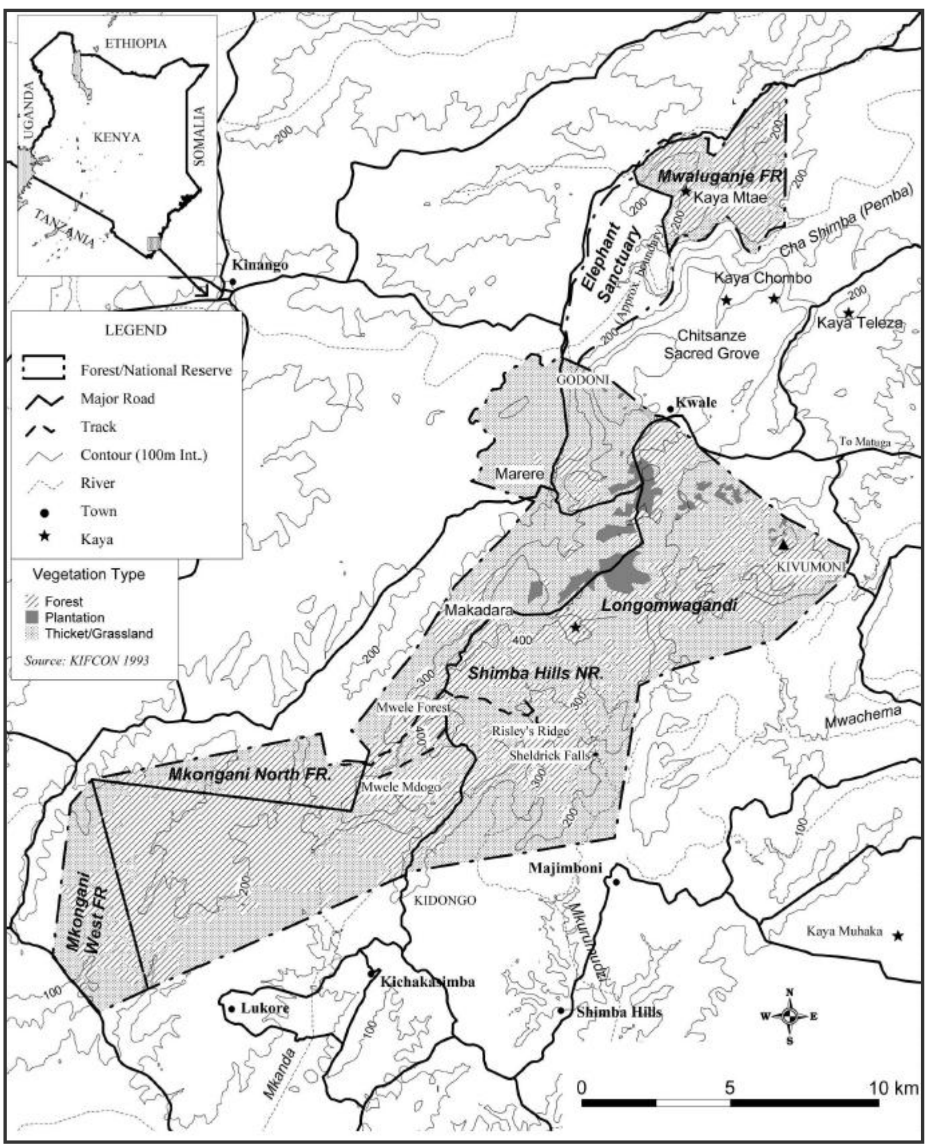
Shimba Hills National Reserve (SHNR) is a remnant coastal rainforest located 35 kilometers south of Mombasa, Kenya between 4º05'/-4º21'S and 39º15'/-39º30'E (Map 3.1) (Luke 2005). SHNR is situated in Kwale District within the Coastal Province and is composed of a low range of hills which rise to just over 400 meters along the coast of the Indian Ocean (Shimba Support Group 2007). The 253 km² Shimba Hills Conservation Area is comprised of Shimba Hills National Reserve (192 km²), Mwaluganje Elephant Sanctuary (MES) (36 km²), and Mkongani North (11 km²) and Mkongani West (14 km²) Forest Reserves (Map 3.2). SHNR, a Conservation International and World Conservation Union designated biodiversity hotspot, is jointly managed by the Kenya Wildlife Service (KWS), Kenya Forest Department (KFD), and the Mwaluganje Elephant Sanctuary Committee (Myers, Mittermeier et al. 2000; Burgess 2004; Conservation International 2007).

Map 3.1 Location of Shimba Hills National Reserve, Kenya
[Map created with data provided by (Environmental Systems Research Institute 2001)]



In the early 1900s, the British colonial administration realized the importance of the diverse Shimba Hills ecosystem and first established the area as a protected Forest Reserve (Glover 1968; Makin 1968). The region was subsequently gazetted as a National Reserve in 1968 by the Kenyan government. The Mwaluganje Elephant Sanctuary consists of a narrow (10 km) corridor of community-owned land that connects SHNR with the Mwaluganje Forest Reserve (MFR) to the Northwest (Map 3.2). The MES corridor was developed in 1995 to allow free movement of elephants between SHNR and the MFR and provide tourist income to community shareholders.

Map 3.2 – Map of SHNR and surrounding areas
(Luke 2005)



The climate in Kwale District ranges from humid, semi-hot equatorial to dry semi-hot tropical with bimodal rainfall (Kahumbu 2002). Monthly temperatures range from approximately 19ºC to 36ºC with July and August as the coldest months and February and March, the warmest (Jivetti 2004). Shimba Hills National Reserve is ideally located in the wettest portion of Kwale District and the hills are a primary water source for the area. The average annual precipitation varies between 500 and 1,500 millimeters with an average of approximately 1,200 millimeters of rainfall (Shimba Support Group 2007). The highest yearly precipitation occurs from March-June when the long rains take place and later in the year during the short rains of October and November. The lowest yearly precipitation occurs during January and February.

The area is composed of sedimentary rocks from the Duruma Sandstone series. The soil composition of the area is classified as Shimba Grit and Mazeras Sandstone from the Upper Triassic Age (200 million years ago) (Shimba Support Group 2007). The soil in Kwale has very poor fertility due to excessive leaching, high sand content, and low organic content (Makin 1968). The vegetation in and around Shimba Hills National Reserve creates an intricate montage of open grasslands, bushlands, woodlands, and forests. The mosaic of high-canopy forest, grass, deciduous forest and thicket provides ideal habitat for a diverse range of species (Kiiru 1996). The remnant humid tropical ecosystem contains endemic, threatened, and endangered flora and fauna and is home to the endangered sable antelopes and a large and rapidly growing population of African elephants (600+ elephants in 2005), which is three times greater than the optimal number for the ecosystem (Glover 1968; Cocheba and Ndriangu 2000; Knickerbocker and Waithaka 2005; Kenya Wildlife Service 2007). Shimba Hills arguably provides the highest biodiversity of plants and animals along the Kenyan Coast, composing one the few remaining important centers of biodiversity in East Africa (Engel 2000; Luke 2005). A study of the vegetation in the Shimba Hills ecosystem recorded a total of 1,396 plants that are indigenous to Shimba Hills and verified that the forest habitat holds more than half of Kenya's rare tree species (Luke 2005).

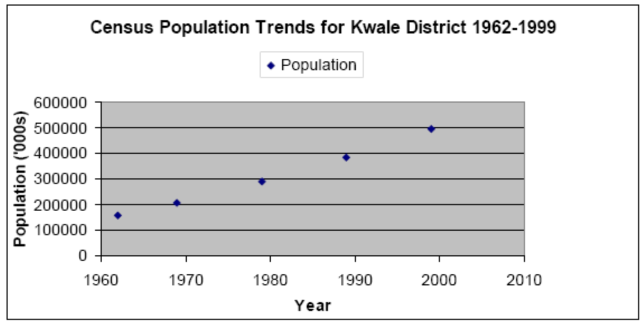
Realizing the great biodiversity and vulnerability of the Shimba Hills ecosystem, a surveyor of the area concluded in 1968 that, while still possible, a game corridor should be established from Shimba Hills across the Ramisi River and west of Mt. Jombo into Tanzania to facilitate the necessary wildlife movement to and from the reserve (Glover 1968). However, this corridor was never officially established and cultivation continued to expand into the proposed corridor area. In Kwale District, roughly 90% of the population lives in rural areas and small-scale agriculture is the most significant source of income, although 92% of the District is categorized as having low agricultural potential (Kahumbu 2002). Human settlement and development patterns around SHNR have reduced the forest habitat by separating it from the surrounding ecosystem which has led to species' genetic isolation and degraded wildlife habitat (Palmer 1971; Litoroh 2002).

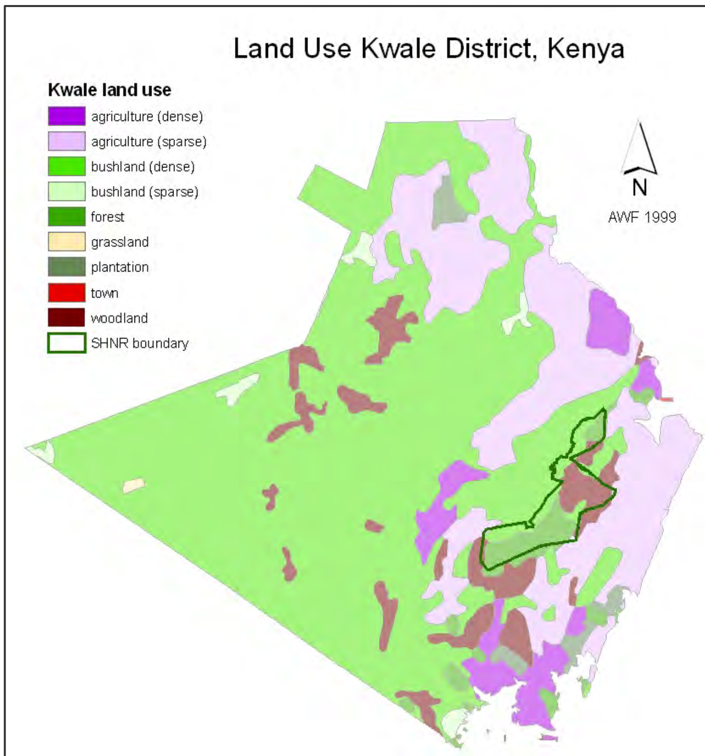
The Digo and Duruma, two of the nine subtribes of the Mijikenda group that migrated to Kenya in the early 17th century from southern Somalia, compose the largest populations in Kwale District (kenyaweb 2001). The Mijikenda tribes are now linguistically and culturally distinct and spread throughout the Kenya Coastal region. The 1999 Kenyan Census reported the population of Kwale District (5,160 sq. mi.) as approximately 500,000 of which about 50% identified themselves as Digo, followed by the Duruma who compose the second largest segment of the population (Knickerbocker 2002).

Historically, the Mijikenda groups established nine fortified hill-top forest settlements, places of prayer called "kayas" in the area between Kilifi Creek and Shimba Hills. When Shimba Hills was gazetted as a National Reserve, people residing in the reserve were evicted (Knickerbocker and Waithaka 2005). Many Digo and Duruma settled around the boundary of the reserve where they subsist mainly as small-scale agriculturalists. Farmers cultivate numerous crops ranging from maize and beans to coconuts, cashew nuts and citrus crops (e.g. oranges and mangoes). In addition to the Digo and Duruma communities, more recent immigrants from other parts of Kenya, primarily from the Kamba group, also settled as agriculturalists around SHNR. There was an influx of immigrants to the SE region around Shimba Hills in 1969 when the government initiated the Shimba Hills Land Settlement Scheme. Large tracts of land (~ 20 acres), agricultural resources (i.e. seeds and fertilizer) and financial incentives were provided by the government to increase farming production in the area (Palmer 1971). This caused considerable ethnic friction because the Mijikenda considered the up-country people as equivalent to the colonial settlers who grabbed and settled their best land, leaving the indigenous people only the marginal areas of their homeland (Manundu 1997). The Shimba Hills Land Settlement Scheme was instituted to the southeast of SHNR which explains why this area has a higher concentration of agriculture when compared to other areas around SHNR (Map 3.3).

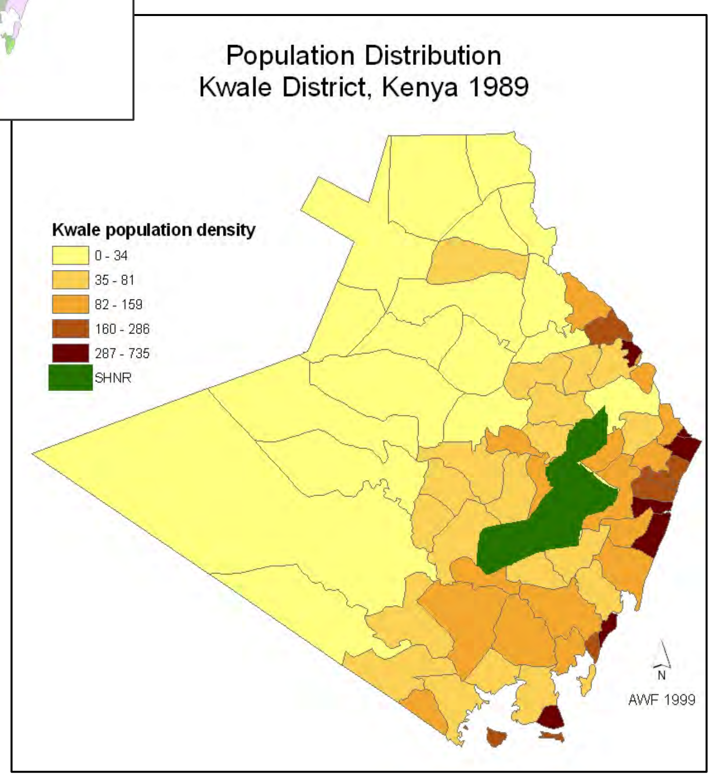
The human population and number of homesteads surrounding Shimba have grown rapidly over the past three decades (Table 3.1) (Knickerbocker 2002; Jivetti 2004). Between 1969 and 1999, the growth rate was consistently over 3% per year with the majority of the population dependent on subsistence cultivation of small-scale farms (Foeken and Owuor 2000).

Table 3.1 – Census Population Trends for Kwale District, 1962-1999
(Jivetti 2004)





Map 3.3 – Land Use Patterns in Kwale District, Kenya 1999
(Map created with GIS data provided by the African Wildlife Foundation, 2004)



Map 3.4 – Population Distribution, Kwale District, Kenya 1989
(Map created with GIS data provided by the African Wildlife Foundation, 2004)

3.2 Description and history of elephants and conflict around the Shimba Hills

Shimba Hills houses an elephant population that has grown to a level that is unsustainable for the ecosystem (Bryant 1992; Kiiru 1995; Kahumbu 2002; Litoroh 2003; Knickerbocker and Waithaka 2005; Kenya Wildlife Service 2007). The burgeoning elephant population has become comfortable with searching for food sources outside of the reserve, and this has led to a situation of conflict with the adjacent local agriculturalists. The effect of crop-raiding by elephants and other wildlife on the local population's livelihood is of special concern given that the survival of these low-income, politically marginalized peoples is, above all, dependent on their yearly agricultural yields. In addition to the conflict between elephants and farmers around Shimba, the fence-confined and rapidly growing elephant population has extirpated endemic plant species and greatly stressed the fragile ecosystem within the biologically diverse reserve (Kahumbu 2002).

Based on both local and international conservationists' interests and the government's political influence and agenda, there are three main factors driving conservation and policy in Shimba Hills: 1) maintaining the biodiversity and biological richness of the Shimba Hills ecosystem; 2) conserving and protecting the elephant population; and 3) reducing human-elephant conflict around the reserve.

International funding has allowed the implementation of large-scale projects aimed at mitigating human-wildlife conflict and conserving elephants in Shimba Hills. However, costly and dramatic conservation initiatives, while implemented with good intentions, run the risk of very short-term success as demonstrated in many areas of East Africa (Hoare and Mackie 1993; Newmark, Manyanza et al. 1994; Cocheba and Ndriangu 2000; Hoare 2000; Georgiadis 2003; Gutkin 2005). Unfortunately, many of the projects applied at Shimba Hills were only marginally successful in the long-term which may be because the project managers did not actively inform and integrate local residents living around the reserve in the various stages of the projects' design.

In the past, elephants were free to migrate out of the reserve to other protected areas, particularly west to Tsavo East National Park and south to Mkomazi Game Reserve in Tanzania, but intense poaching in Kenya and Tanzania in the 1970s and 1980s caused the elephants to seek refuge within SHNR (Litoroh 2003; Lenaiyasa 2004). While the elephants stayed within the safety of the reserve, human population growth and conversion of land to agriculture led to the increasing isolation of the Shimba ecosystem. After the Convention of International Trade in Endangered Species (CITES) ban on ivory trade in 1989, elephant poaching decreased significantly. Soon after, elephants felt safe enough to venture outside of the protected area in search of food, and ended up causing severe crop damage and threatening the lives of rural residents living in close proximity to the reserve borders (Kiiru 1995; Smith and Kasiki 2000; Litoroh 2003; Buya 2005). Protecting elephants in the Shimba Hills area is a top wildlife conservation priority, but elephants often threaten the security of local farmers who vary in their capacity to cope with crop losses to large wildlife (Naughton, Rose et al. 1999).

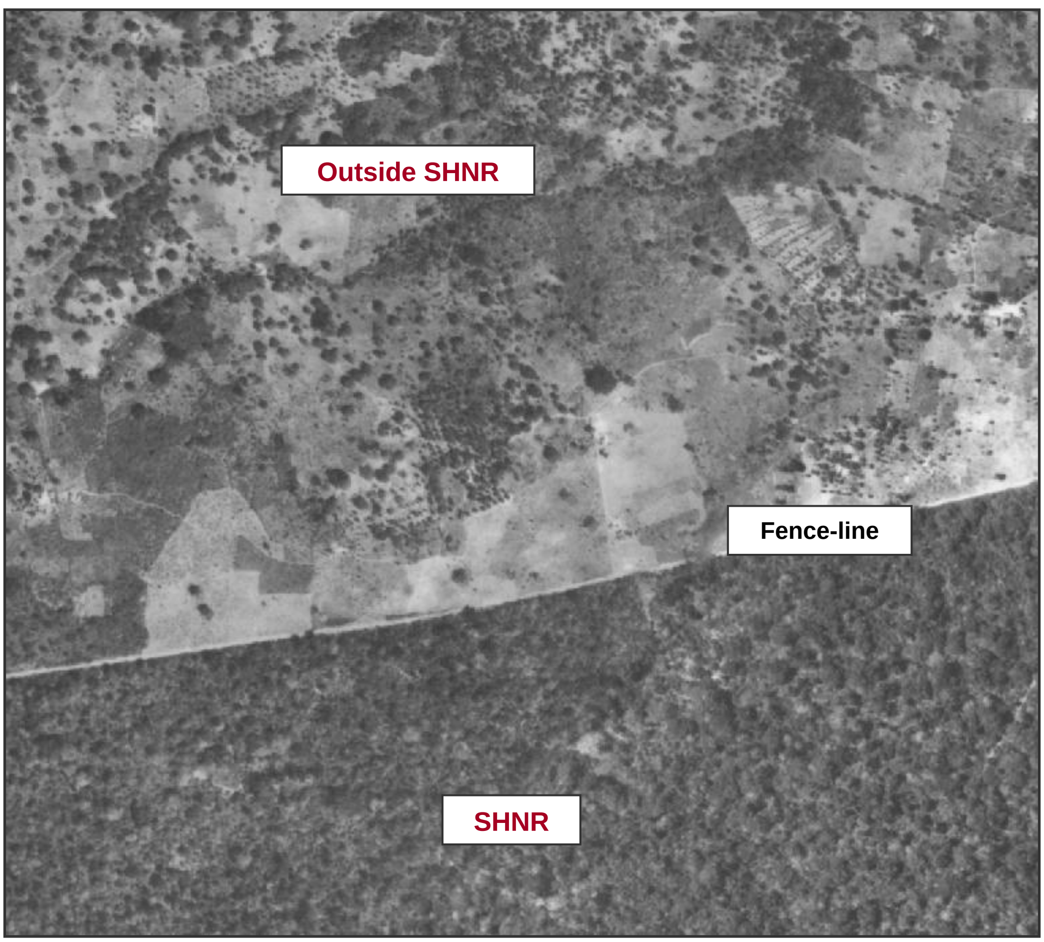
There is a long history of human-wildlife conflict around SHNR with the most severe conflict occurring between the farmers living adjacent or in close proximity to the reserve boundary and the resident elephant population. The conflict is due to the simultaneously growing human and elephant populations and the resulting high demand and intense competition for access to valuable land and diminishing resources (Kiiru 1996; Knickerbocker 2002). Many studies have documented Shimba elephants leaving the reserve at night to raid crops primarily in farms up to 3 km from the fence-line (Kiiru 1995; Waithaka and Mwathe 1995; Engel 2000; Kahumbu 2002; Litoroh 2003; Jivetti 2004; Knickerbocker and Waithaka 2005). In the 1980s and early 1990s, 2,171 cases of human-wildlife conflict involving crop and property damage, human deaths and injury as far as 15 km from SHNR were reported to the Kenya Wildlife Service, including more than 45 deaths (Waithaka and Mwathe 1995; Jivetti 2004). Incidences of elephants shot by KWS rangers and land owners in defense of human life or property increased yearly in the early 1990s (Kiiru 1995).

A study conducted in 1982 in Shimba Hills showed 40% of farms suffered from elephant damage at some time during the year (Ross 1982). The farms contiguous to the reserve had higher incidences of damage from elephants than those farther from the reserve (Ross 1982). From the mid-1980s through the 1990s, local Digo residents living adjacent to SHNR lost well over 75 percent of their coconut trees, and crop loss between 1990 and 1996 was estimated to be over 5 million Kenyan shillings, approximately $66,000 at the time (Knickerbocker 2002). It is difficult to assess the cost of crop devastation around SHNR because the value of subsistence agriculture cannot be measured purely in economic terms. However, crop damage assessments carried out in other areas of Kenya indicate that farmers experience serious economic losses due to elephants (Kangwana 1995; Kiiru 1995; Ngure 1995; Mburu and Birner 2002). A study near Tsavo National Park found that the annual expenditure of most households on material and services to reduce crop-raiding exceeded their average annual income (Smith and Kasiki 2000). The long-standing quandary is how to successfully establish a situation where people, agriculture, and elephants can simultaneously benefit and prosper.

Incidences where property and lives are lost to elephants hold weighty political significance because these highly symbolic animals are often perceived as ‘belonging’ to the government (Naughton 1997). Local outcry over lives lost and devastating crop damage around SHNR led the government to initiate various conservation techniques to alleviate the conflict. To reduce incidents of human-elephant conflict and simultaneously facilitate the conservation of elephants in this region, a high-tension electric wire fence was erected around Shimba Hills Reserve. The fence was erected after years of complaining and pleading for help by local people regarding the crop damage they sustained from elephants and other wildlife that routinely left the reserve in search of food in cultivated fields (Knickerbocker 2002). Construction began in 1994 and the fence was completed in 1999 with funding from various donors, including KWS, Eden Trust (UK), the European Union, and the World Bank (Jivetti 2004). The main intent of the fence was to contain the elephant population within the forest thus preventing them from raiding nearby farms and endangering local residents. Once wildlife managers constructed the electric fence, researchers described the project as a resounding success stating that the fence significantly decreased conflict between elephants and rural residents since reports of both crop destruction and humans injured or killed declined (Litoroh 2003; Knickerbocker and Waithaka 2005). According to the resident elephant researcher at SHNR, elephant conflict cases were reduced by 33% between 1995 and 2000 while elephant-induced human death and injury reduced by 70% during the same period (Litoroh 2003).

According to Knickerbocker and Waithaka, following the construction of the fence, local residents felt an increased sense of security from wildlife raids and expanded their cultivation and settlements right up to the fence perimeter, resulting in drastic changes to adjacent land use and settlement patterns (Knickerbocker and Waithaka 2005). Therefore, the construction of the fence added to the increasing isolation of the Shimba Hills ecosystem since the result of the fence construction was the agricultural development of the unofficially established "buffer zone" along the edge of the reserve. The agricultural development of this land negatively impacted the ecosystem and isolated Shimba's core habitat by creating a hard boundary between the forest and the surrounding agricultural land. The sharp edge between SHNR and the agriculture outside of the reserve is clearly defined on air photos (Figure 3.1).

Figure 3.1 – 1999 Air photo of SHNR boundary with subsistence agriculture along border



The electric fence initially proved successful in containing elephants within SHNR, but the subsequent consequences to the forest ecosystem were severe. Before the fence was constructed, tree damage by elephant browsing within the reserve was not at a critical level, but there was great concern that population increase would eventually have an immense impact on the habitat (Ross 1982). In the early 1980s, an aerial count estimated the Shimba resident elephant population at approximately 250, giving a high density figure of approximately one elephant per square kilometer (Ross 1982). Following the study by Ross and the reduction of severe poaching following the CITES ban, studies show that annual elephant growth consistently increased to greater levels, which were harmful to the diverse tree species and vegetation within the reserve (Kiiru 1995; Kahumbu 2002; Litoroh 2002). Extensive research in 2002 on elephant ecology at Shimba determined conclusively that the confined elephants are threatening the ecosystem and biodiversity of the forest by extirpating endemic species in the reserve (Kahumbu 2002).

The elephant population contained within the Shimba Hills fence has grown to between 650–800 individuals despite the fact that the Shimba ecosystem can ideally only support a total of 200-250 elephants in an environmentally sound manner (Kahumbu 2002; Kahumbu 2005; Knickerbocker and Waithaka 2005). It is very difficult to obtain an accurate count of the elephant population, but the high estimated population indicates that deforestation within SHNR and the potential for future conflicts are real and direct threats. The overpopulation of elephants in the reserve coincides with increased human activities in lands directly adjacent to the reserve and in lands that have traditionally offered elephants corridors into other habitats, such as the Abrabuko-Sokoke Forest (north of SHNR) and the Tsavo Ecosystem to the west (Kiiru 1995).

According to researchers, if elephant numbers in Shimba Hills are not reduced quickly, it is likely that food resources for the elephants will become scarce to the point that they will aggressively return to browsing outside of SHNR for their food despite the fence (Kahumbu 2005; Knickerbocker and Waithaka 2005). There is ample evidence that elephants have discovered ways of circumnavigating electric fences by pushing logs onto them or crossing under them where there is a ravine. (Thouless and Sakwa 1995; Kiiru 1996; Hoare 2001; Hoare 2003; Gunaratne and Premarathne 2006). Additionally, the Shimba Hills fence has not been maintained properly and the 120-km perimeter fence has been rendered nearly 60% ineffective with cases of human–elephant conflict again on the rise (Litoroh 2003). Since there is no compensation for crop damage by the government, most elephant cases go unreported unless someone is injured or killed. Despite the lack of compensation, over 200 cases of human–wildlife conflict were reported to the warden between 2001 and 2002, with elephants accounting for 84% of the incidents (Litoroh 2003). Depending on the severity of food and habitat shortages, this re-emergence of elephant conflict may pose an even greater threat to crops and human lives since the number of humans settling adjacent to the reserve has risen since the completion of the fence (Knickerbocker and Waithaka 2005).

3.2.1 Translocation and wildlife corridors

Given that the majority of the remaining elephant populations in Kenya are confined in protected areas bordered by human settlements and have lost access to traditional migratory routes, KWS must make decisive management decisions based on their understanding of elephants' ecological requirements and impacts (Waithaka 1997). The primary tactic for addressing human-elephant conflict around Shimba Hills was the construction of an electric fence. However, there is overwhelming evidence that the fence is not entirely successful in keeping the elephants within the reserve and exacerbated the internal damage to the reserve ecosystem by confining elephant browsing. In response, the Kenyan Wildlife Service (KWS) has taken measures to physically reduce the elephant population within SHNR through translocation (Knickerbocker and Waithaka 2005; Kenya Wildlife Service 2007). In 2005, the Kenyan government provided US$3.2 million to conduct a translocation project of over 400 elephants from Shimba Hills to Tsavo East National Park (Indakwa 2007). This constitutes the largest translocation of elephants ever conducted worldwide.

The aim of the translocation is to decrease the elephant population within SHNR to a more sustainable level for the ecosystem. Translocation, as opposed to culling, hunting, infertility drugs, moats, or wildlife corridors, is the preferred method of reducing elephant populations and conflict in Kenya for a number of reasons. Foremost, the Kenyan government receives substantial funding from international conservation organizations and donors who object to elephant culls. Kenya also earns substantial income from photographic tourism which warrants the need for a substantial elephant population. Therefore, while translocation efforts are often extremely traumatic for the elephants and difficult to implement efficiently, this conservation strategy is the current, internationally accepted and government-endorsed solution for simultaneously reducing ecosystem damage within SHNR and elephant conflict with the neighboring community (Dublin and Niskanen 2003). In conjunction with the mass elephant translocation plan, there are tentative plans to improve the electric fence around the reserve (Kenya Wildlife Service 2007).

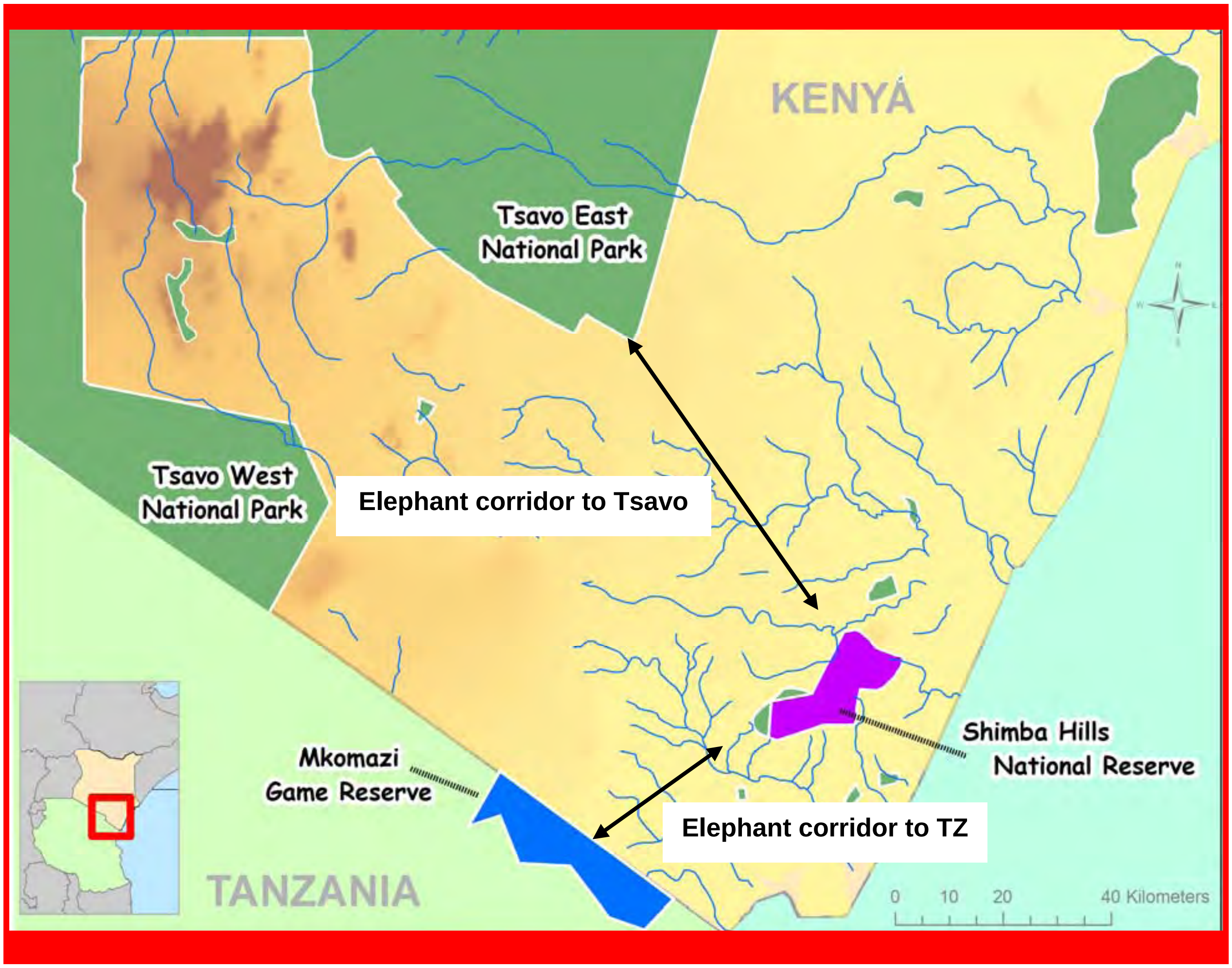
Translocations are very costly projects and KWS cannot solely meet the expenses of the recurrent expenditure. Therefore, the agency must continually seek additional donor support (Litoroh 2003). Translocation projects successfully reduce elephant densities, but have had very limited success in reducing conflict (Nelson, Bidwell et al. 2003). Evidence suggests that conflict is related more to individual elephant behavior than local density (Hoare 1999; Hoare 2000). Additionally, with the prohibitively high cost (often over US $2,500 per elephant) and the difficulties involved in a successful translocation, this strategy for reducing conflict does not appear to be a viable long-term solution (Nelson, Bidwell et al. 2003).

Alternatively, wildlife corridors which would allow Shimba elephants to disperse and migrate to other wildlife areas have the potential of greatly alleviating the current ecological stress produced by the high density of confined elephants. Elephants are an essential component of the broader ecosystem beyond protected areas, as they create habitats for numerous species by dispersing seeds and beneficially modifying the landscape for other species as they migrate (African Specialist Group 1996; Lenaiyasa 2004). A wildlife corridor that would allow safe wildlife movements between Shimba and another protected area would help alleviate the existing ecological stress in Shimba Hills and promote genetic diversity. This issue is quite complex because to be successful, the corridor must be planned and implemented without imperiling local communities' welfare and livelihood or exposing wildlife populations to risk (Naughton, Rose et al. 1999). Also, elephant migration to other areas may negatively affect tourism as visitors expect to see elephants while on safari.

Traditionally, elephants moved throughout Kwale District, migrating regularly along ancient routes from the Shimba Hills area to Mkomazi Game Reserve (GR) in northern Tanzania and Kenya's Tsavo National Park (NP), 40 km to the south-west and 60 km to the north-west, respectively (Map 3.5) (Glover 1968; Kahumbu 2002; Litoroh 2002). These ancient routes are no longer openly accessible to elephants due to the increase in human population density and agricultural intensification, but even so, these corridors may still be in active use. In order for conservation managers to establish appropriate wildlife corridors, they must be well-informed about the region's current elephant migration movements as well as changes in land use/land cover and human settlement patterns. Corridor conservation strategies must work to balance the food security and poverty alleviation of local communities with the biodiversity concerns of the international wildlife community. The establishment of a protected wildlife corridor as a management strategy would greatly benefit the conservation of the Shimba Hills ecosystem by helping to sustain its vast biodiversity by reducing elephant numbers. However, it is vital that the future establishment of a corridor is implemented in a manner that does not promote crop raiding and instead reduces the incentives that elephants have for frequenting local communities and agricultural fields.

Currently, there is no evidence to suggest that elephant migration to Mkomazi or Tsavo still exists (Litoroh 2002). However, elephants have remarkable memories that span their potential lifespan of over 60 years (African Specialist Group 1996; Lenaiyasa 2004). Information about water and food sources as well as migration paths is passed down through the matriarch from generation to generation (Milus 2001). For example, once when water was scarce, an elephant matriarch is known to have led her family unit back to a waterhole that she had not visited for over 20 years (Interdisciplinary Studies Core Seminar 2001).

Map 3.5 – Ancient elephant migration corridors
[Map drawn according to records and descriptions by (Glover 1968; Kahumbu 2002; Litoroh 2002)]



Elephants move along particular paths to specific resource locations based on knowledge passed down over many years. Biologists have found that elephants usually follow the same routes between patches of habitat, even paths that are many kilometers long or run through human developed areas, as long as they are available (Plummer and Mann 1995). The elephants' keen memory for locating resources supports the theory that elephants who are able to circumnavigate the fence may have returned to use these traditional corridors after many years of being forced to find resources elsewhere due to high levels of elephant poaching and the electric fence.

Prioritizing wildlife and biodiversity survival above human survival and livelihoods is a conservation dilemma in Kenya that is complicated from every perspective. My research will aid conservation managers by providing analysis on how the LULC adjacent to Shimba has changed spatially and temporally, which may be helpful if elephant corridor restoration becomes a future conservation management scheme for SHNR. Research conducted by outside sources often provides the evidence needed to initiate change since local voices and concerns frequently fall on deaf ears. This is particularly important given the marginalized status of the Digo and Duruma societies. I hope my work will also inform broader research efforts to understand human-wildlife interactions amidst rapid land use and social change.

CHAPTER 4

4.1 Air photo analysis of LULCC and deforestation around Shimba Hills

The analysis of land use/land cover change (LULCC) from a time series of aerial photos greatly aids the understanding of historical patterns and rates of agricultural expansion and deforestation leading to ecological isolation. Air photo analysis may be used in conjunction with information obtained from interviews with local farmers regarding land use change to establish the past and current LULC patterns around Shimba Hills Reserve. This research project applies remote sensing techniques to the question of LULCC through the analysis of aerial photos to investigate the following topics:

1. How has LULC around SHNR changed from 1991 to 1999?
2. Has agricultural expansion (indicated by reduced forest cover) occurred in all areas surrounding SHNR between 1991 and 1999?
3. How has LULC change differed between the four regions (NW, NE, SW, and SE) where interviews were conducted?
4. How has LULC change differed (in total and by region) in relation to proximity to the park boundary?

4.1.1 Methods of air photo analysis

Over three hundred aerial photos from 1965, 1991 and 1999, were obtained from Dr. Paula Kahumbu, a researcher who analyzed the hard copy photos to study vegetation change within Shimba Hills in 2002. Dr. Kahumbu acquired the black and white photos from the Survey of Kenya and Remote Sensing Technology (Kahumbu 2002). The 1991 and 1999 photos, of standard 9x9-inch air photo dimensions, had nominal scales of 1:25,000 with approximately 66% overlap between consecutive frames on each flight line and 33% overlap between adjacent flight lines. The time period between 1991 and 1999 was significant for Shimba Hills because this is the stretch of time when the electric fence encircling the reserve was erected (Knickerbocker 2002). This was also a period of rapid human and elephant population growth (Foeken and Owuor 2000). Regrettably, the 1965 photographs were of variable scales and quality and therefore could not be used, as was also the case for Dr. Kahumbu's study (Kahumbu 2002).

According to a study which utilized the same aerial photos to investigate vegetation within Shimba Hills National Reserve, forest cover remained remarkable constant between 1954 and 1999 except in the Northwest area and along the southern boundary where there was disturbance on the forest edges (Kahumbu 2002). Within the reserve, forest composition changed mainly due to commercial exploitation and elephant disturbance while subsistence hunting, timber and fuel-wood collection may explain the ragged forest edges near the reserve boundaries (Kahumbu 2002). Overall, the study found a 1.2% overall rate of forest decline per year within the protected area and mentioned that the aerial photos displayed dramatic changes taking place around the reserve (Kahumbu 2002).

The 1991 and 1999 air photos were first organized and arranged in four overlapping strips to discern the overall extent of the two photo mosaics. Each photo was scanned at 1000-dpi scale with an Epson 10000LX flatbed scanner to create digital images of the air photos. The images were converted to digital data to be compatible with the softcopy photogrammetry software (SurfaceMapper™ and OrthoMapper™) which was utilized to create orthophoto mosaics of each time period. OrthoMapper™ is a complex image processing software program that has the capacity to create digital orthophotos from images taken with metric and non-metric cameras when coupled with a digital elevation model (Scarpace, Weiler et al. 2000).

A 90-meter digital elevation model for Kenya, ArcView™ shapefiles of geographic and demographic features in Kwale District (provided by the African Wildlife Foundation in Nairobi), and a 15-meter panchromatic LandSat TM satellite image from 2000 (obtained from the Global Land Cover Facility, University of Maryland) were used in conjunction with the photogrammetry software to georeference and orthorectify each of the air photos individually.

4.1.2 Difficulties encountered when creating orthophoto mosaics

The ultimate accuracy of generated orthophotos is dependent on the accuracy of the existing data used to perform the photo orientation procedure (Scarpace, Weiler et al. 2000). Lack of camera calibration data, poor camera lens quality, inferior quality of the nitrate-based film, little or no GPS ground-truthing, physical damage or distortion of hard copy images, inherent errors introduced when scanning the aerial photos, human error during the orientation process, and limited geographic references for georeferencing the images are several problems that may affect the overall quality of the final orthophotos (Awwad 2003; Scarpace 2006). A number of these difficulties became apparent when attempting to create accurate orthophotos from the historical aerial photographs of SHNR.

Camera calibration

Typically, camera calibration information containing the focal length of the camera and the distances (in millimeters) from the camera’s optical center to the camera’s eight fiducial marks defines the frame of reference for spatial measurements made from the photograph is necessary for the creation of orthophotos (Lillesand and Keifer 1994). Camera calibration information is often not readily available unless it was provided in the initial contract for the aerial photo mission (Scarpace 2006). The calibration determines the vertical and horizontal scale which is especially important if the physical photos have become warped over time (i.e. due to humid conditions) which causes differential shrinking. The camera calibration information for the aerial photographs in this study was unavailable, but OrthoMapper™ incorporates a visual orientation method that allows users to create orthophotos with little or no camera calibration information (Scarpace, Weiler et al. 2000).

The process of determining the relationship between the rows and columns on digital aerial images and the photographic coordinate system without official camera calibration information is called the interior orientation process. The procedure involves simply clicking on the center of four of the fiducial marks to store the information that is used to determine the center of the image and the image coordinate system (Scarpace, Weiler et al. 2000). Observations indicate that with OrthoMapper™, the accuracy of the orthophoto is independent of the use of camera calibration information (Scarpace 2006).

Lack of previous orthophotos

Once the interior orientation was complete, an exterior orientation process was performed on each photo. The exterior orientation determines the camera position and orientation at the time the aerial image was acquired (Scarpace, Weiler et al. 2000). Often, orthophotos are created based on reference from previous orthophotos because this makes it much easier to georeference the images (Scarpace 2006). Georeferencing refers to the process of establishing the relationship between coordinates on a planer image and real-world, geographical coordinates (Lillesand and Keifer 1994). Typically, with a digital elevation model (DEM) and a previously constructed high-resolution orthophoto, OrthoMapper™ can facilitate the creation of orthophoto mosaics that are precise up to a few centimeters (Scarpace 2006).

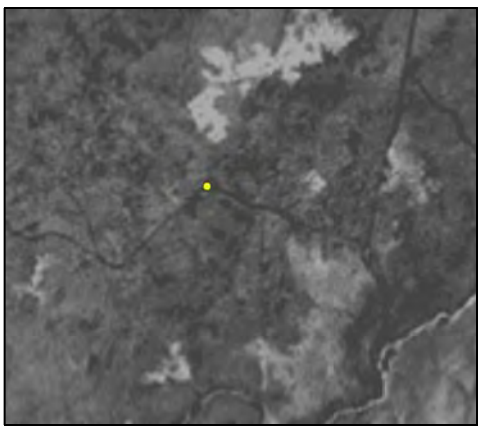
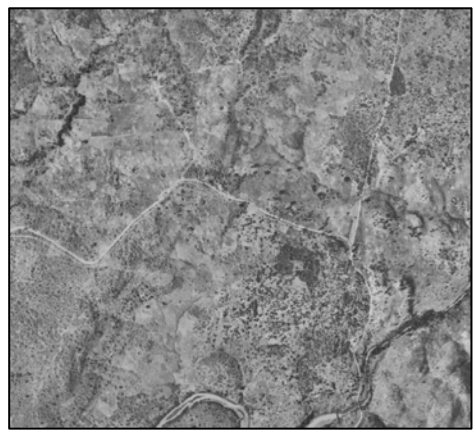
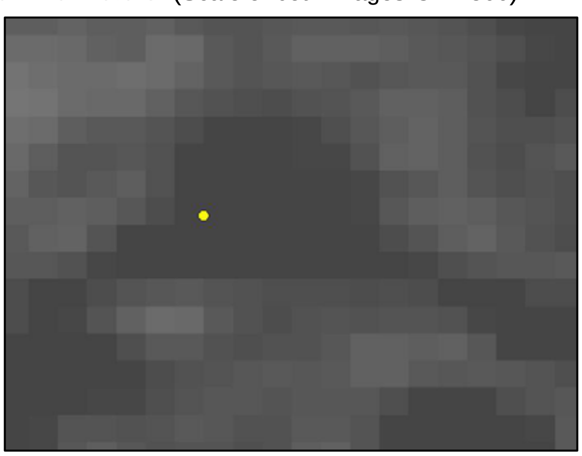
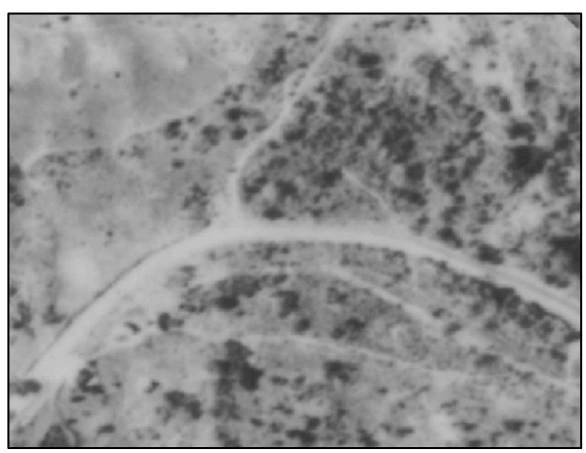
Due to the remote location of the study area and the lack of nationwide orthophotos for Kenya, previous orthophotos of SHNR were unavailable. Professor Frank Scarpace modified OrthoMapper™ to enable the software to accept a satellite image as a base to conduct the exterior orientation of the air photos as opposed to a previous orthophoto. The use of a satellite image for georeferencing was not ideal, since the resolution of the LandSat image was approximately 15 meters, but it allowed the software to successfully run the exterior orientation process. Georeferencing air photos in this manner allows accuracy of ±15-30 meters, at the best. Error is introduced when the user defines locations within the aerial photos and attempts to links them to locations on the already georeferenced image (orthophoto, or in this case, satellite image) to tie the aerial photo to a real-world geographic coordinate system. It was very difficult to find corresponding points, given the resolution of the SHNR images and the resolution of the satellite image (Table 4.1).

Ground control points

The exterior orientation/georeferencing of aerial images may also be accomplished through the use of GPS ground control points to tie the aerial images to a geographic coordinate system (Image Processing Software 2005). While in the field, a considerable amount of time was spent collecting GPS coordinates at prominent or distinct features, such as large road intersections. During the data analysis, it soon became apparent that due to the often indistinguishable terrain and minimal infrastructure around SHNR, the GPS data collected while conducting interviews was exceptionally difficult to work with. It was challenging to accurately identify the locations where the GPS points were collected on the ground with the same positions on the aerial photos and satellite image (Table 4.1).

The majority of the roads throughout the rural study area were very small dirt roads with countless intersections that were comparable to footpaths or livestock trails. Though obvious on the ground, these intersections were often indiscernible on the satellite image, making it problematical to determine the exact intersections where the GPS points were collected. There were a few landmarks that were clearly recognizable on the photos, but nearly all of the houses and buildings were extremely small and composed of materials that were practically indistinguishable from the surrounding environment on the photos.

Table 4.1 – Steps for collecting GPS ground control points for geo-referencing air photos

<table>
<tr><td colspan="2">Step 1: Drove the roads around SHNR and took a GPS points at locations that appeared to be distinct.</td></tr>
<tr><td colspan="2">Step 2: Took notes describing the locations for later reference (i.e. drew sketches of the intersection).</td></tr>
<tr><td>Step 3: Downloaded the GPS points and overlaid them on the georeferenced satellite image.
(LandSat image, 2000)
</td><td>Step 4: Found the same location on the aerial photo.(1991 air photo)
</td></tr>
<tr><td colspan="2">Step 5: Compared the satellite image and (overlapping) air photos to determine the exact location on each corresponding air photo of the GPS points shown on the satellite image. Accuracy was difficult because each pixel on the satellite image is 15-meters. An error of 3 pixels causes a miscalculation of ±45 meters. (Scale of both images is 1:1500)
 </td></tr>
</table>

This method of georeferencing air photos was tested for this study in Madison, WI before it was implemented in Kenya. Collecting ground control points in areas with easily defined infrastructure (i.e. wide, hard-surfaced roads and distinct, 90º intersections) and later associating the GPS data with the correct locations on base images is much easier because the roads appear clearly defined. In Madison, it was not hard to find the correct intersections and determine the exact locations (i.e. NW corner of the intersection where the GPS points were collected) because the roads are static, made of concrete, often have lines painted on them and have sharp corners, as opposed to small dirt roads (Scarpace 2006). Furthermore, it was much less problematic to identify buildings since they were larger, more uniquely distinct in shape or made of differing materials.

During the rainy season, it was extremely difficult to drive long distances around SHNR because the roads were quite rough and muddy due to daily precipitation. This resulted in an inadequate distribution of GPS points for georeferencing the 300+ aerial photos. Ideally, every third air photo in each strip of the final mosaics must have at least four recognizable GPS ground control points, one in each quadrant of the photo. This was impossible due to the location of traversable roads and high transportation costs, which restricted the amount of time for the fieldwork. There was a very limited budget for fuel and a short amount of time for both interviews with local farmers and GPS data collection. Additionally, one day it was raining heavily and the GPS unit was placed on the dashboard inside of the car. The position of the unit restricted its ability to pick up satellites and triangulate its exact location. All of these factors, among others, added to the difficulty of collecting high-quality GPS ground control data and subsequently the trouble in geo-referencing the aerial photos.

Order of air photo images

OrthoMapper™ is designed in a manner that makes it necessary for the user to enter all of the aerial photos files and their positional order within the project during the first few steps of creating a new orthophoto project. For example, if an analyst has 16 photos in four rows, it is necessary to indicate which photos are in each row and their exact order within the rows before beginning the process of creating the orthophoto mosaic. The air photos for SHNR were taken in opposite directions (within one strip) and on differing days, so the number of images in each strip varied. Therefore, Professor Scarpace modified OrthoMapper™ to allow the addition of photos to a larger project on an individual basis. This was a great help because it allowed for changes and modifications throughout the entire orthorectification process.

Orthophoto strips versus blocks

The bundle adjustment, a significant function within OrthoMapper™, is the automated method of populating photo blocks with Tie Points and Control Points to assure the creation of seamless orthophotos (Image Processing Software 2005). The user manually inputs points that "tie" the aerial photos to each other at 9-12 locations determined visually. The bundle adjustment joins all of the air photos together, despite as few as 2-3 ground control points on every third photo. Typically, photo blocks are created, but for this project, was easier to work with strips of photos instead of working with a block of images. Therefore, Professor Scarpace changed this feature in OrthoMapper™ to allow the software to first create orthorectified strips that could later be merged into one large, seamless block.

Scanning

Ultimately, the greatest difficulty in creating the orthophoto mosaics for this project stemmed from the initial scanning of the images. The scanner that was used to scan the images was defective, which led to disproportionate internal distortions in the digital images, which were imperceptible to the human eye. These unknown distortions made it impossible to create a seamless orthophoto mosaic using the correct procedures in OrthoMapper™ and were not detected until months into the project, after the orthorectification process was repeated numerous times. Once the distortion was discovered, all of the photos were re-scanned on a high resolution scanner. The internal and external orientation processes as well as the input of new ground control and tie points were completed once again. The photos were entered into OrthoMapper™ and the final orthophoto mosaics were created with approximately +/-45-meter (~3 pixel) accuracy (Figure 4.1 and 4.2).

Figure 4.1 – 1991 Air photo mosaic

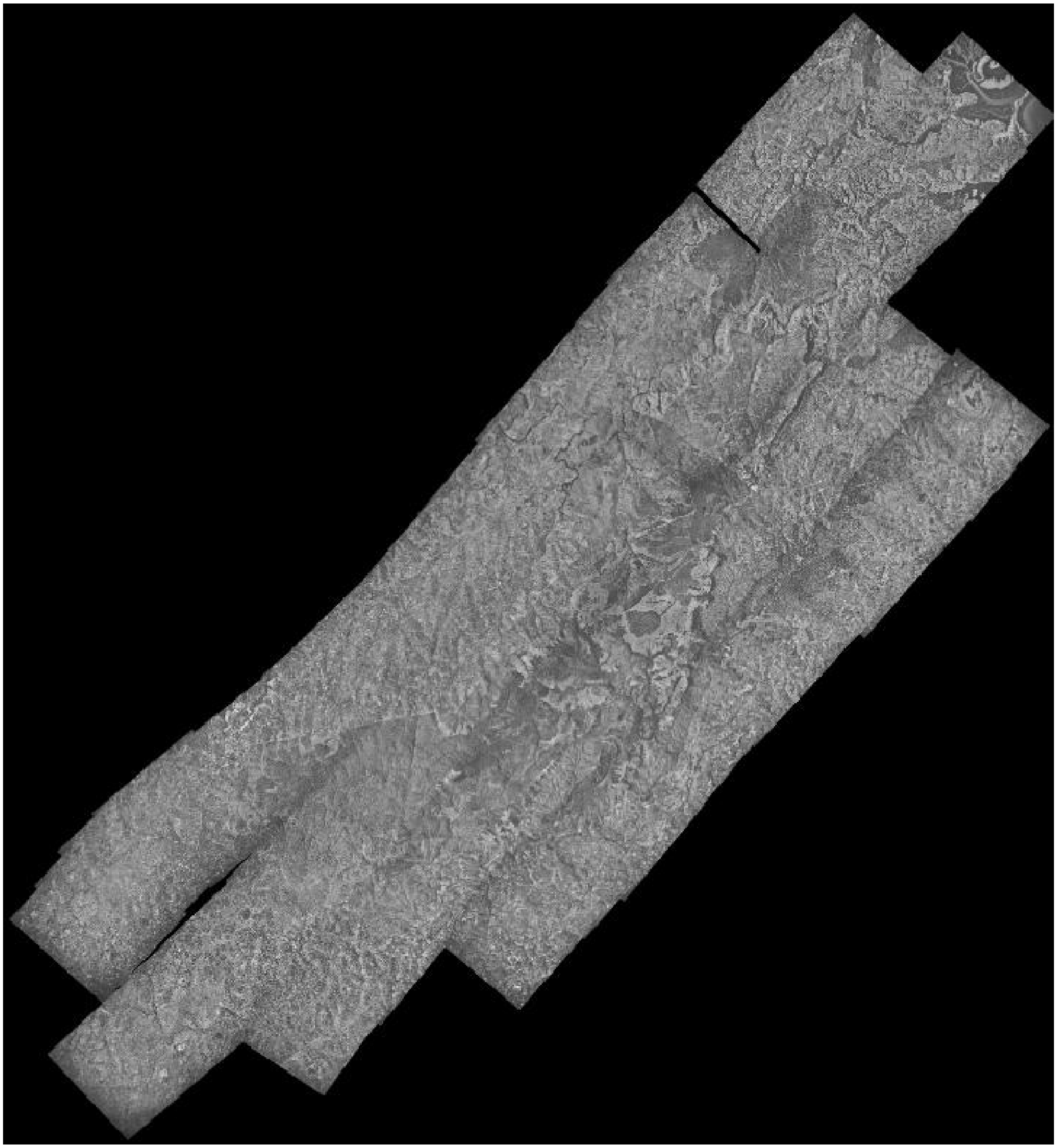
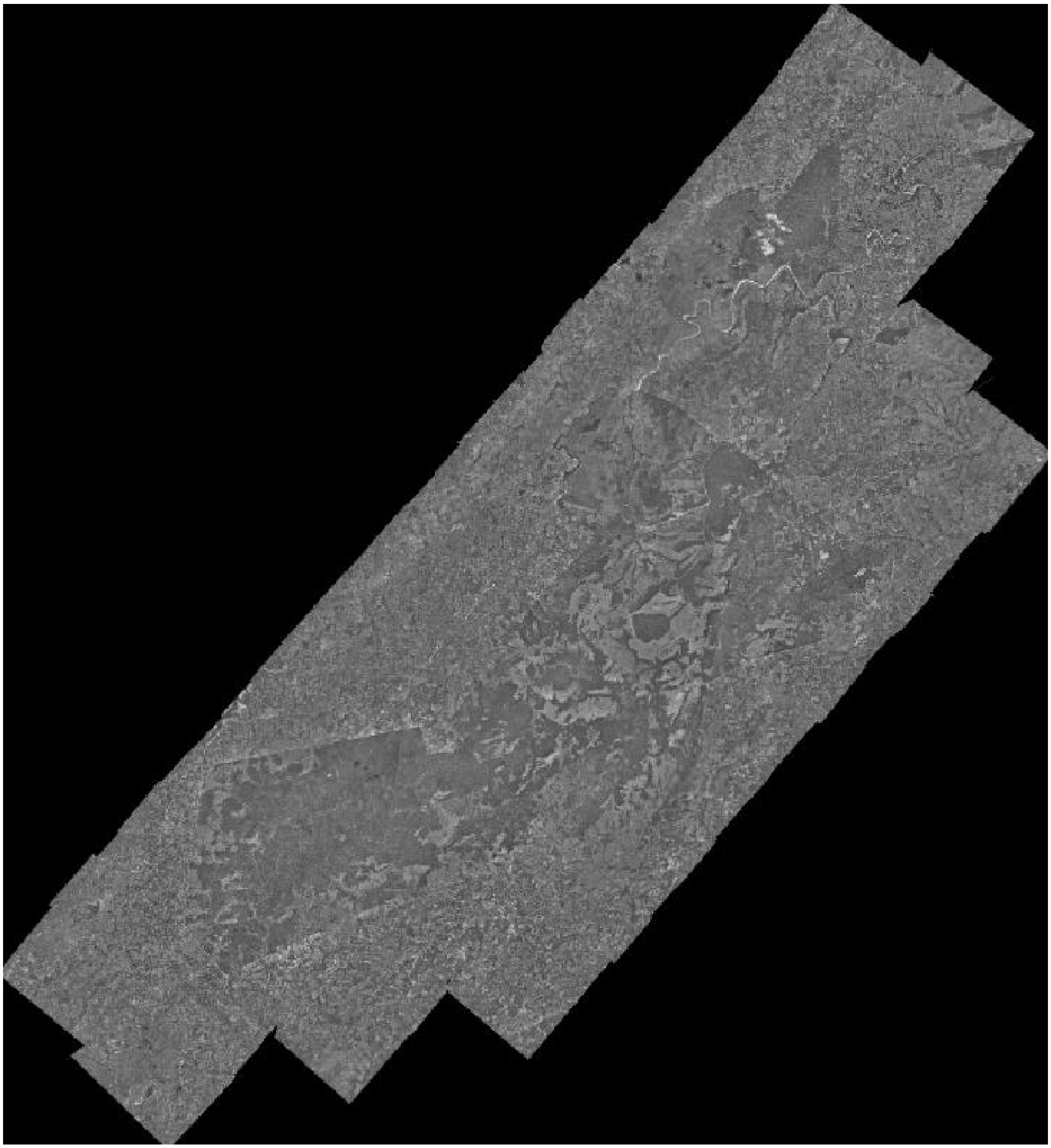


Figure 4.2 – 1999 Air photo mosaic



Prior to this study, the most accurate ArcGIS shapefile available for the SHNR boundary was generalized from a 1:100,000 scale map. During this study, the boundary was more accurately digitized, based on the boundary definition clearly visible on the air photo mosaics (Figure 4.3).

Figure 4.3 – Old and new SHNR boundary (including Mwaluganje)

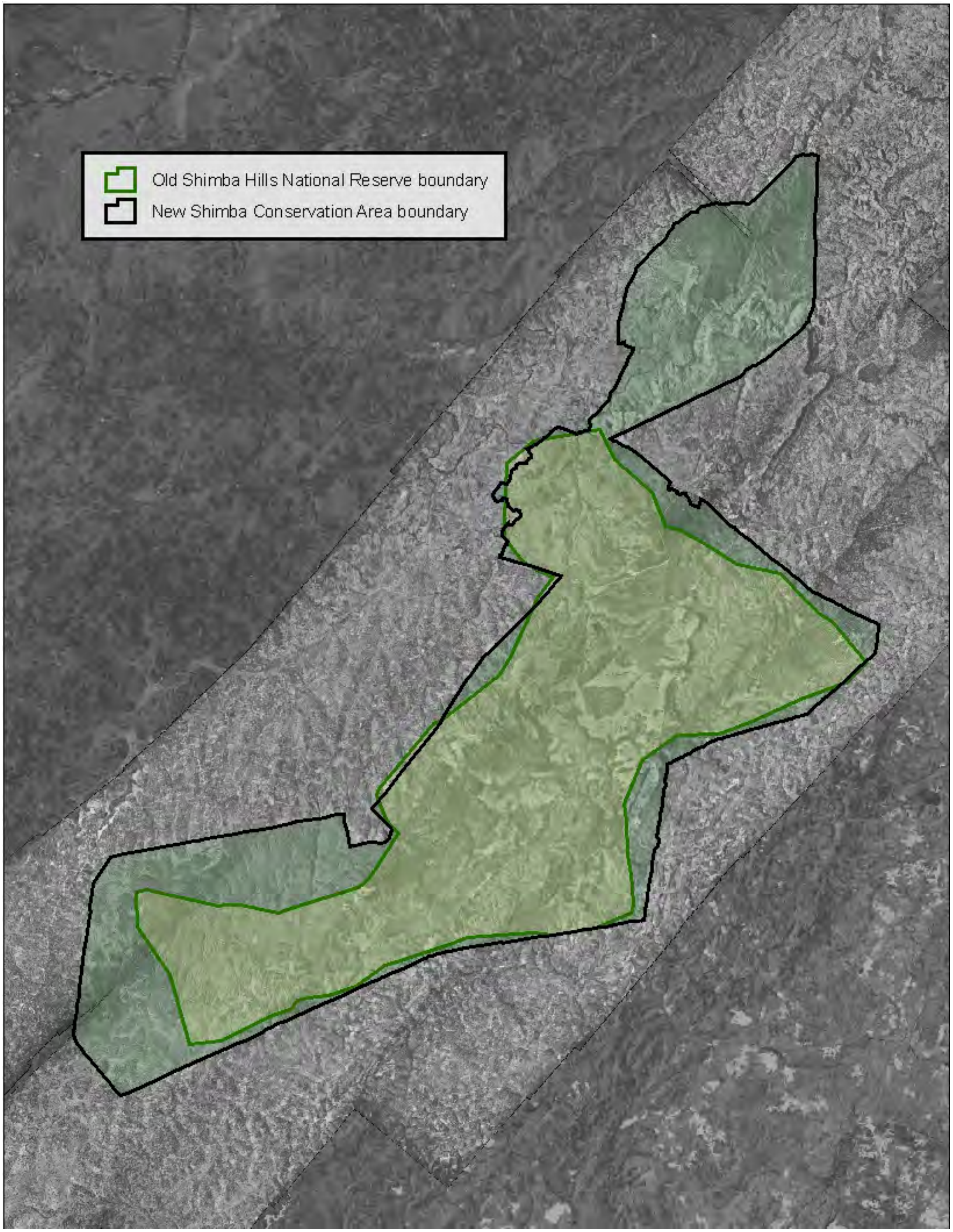


Figure 4.4 – Detail of SHNR boundary

Figure 4.5 – 1991 air photo mosaic overlaid on 2000 LandSat image with the SHNR boundary

Once the aerial photos from 1991 and 1999 of Shimba Hills Reserve and the surrounding area were in a digital format and successfully "stitched" together into a mulit-photo, orthophoto mosaic, another set of GPS ground control points was used to help in the visual classification of the different LULC categories on the air photo images. While conducting interviews with local residents throughout the study area, additional ground control points were collected in areas of specific land use (i.e. agriculture or developed) and distinct land cover categories (i.e. cornfields, cashew nut trees, orange trees, dense forest, brushland, etc.). This GPS data was helpful in the manual LULC classification. The ability to distinguish between various LULC types enables a more accurate temporal analysis of land use change. However, the quality and scale of the data derived from the images directly relates to the resolution of the available images.

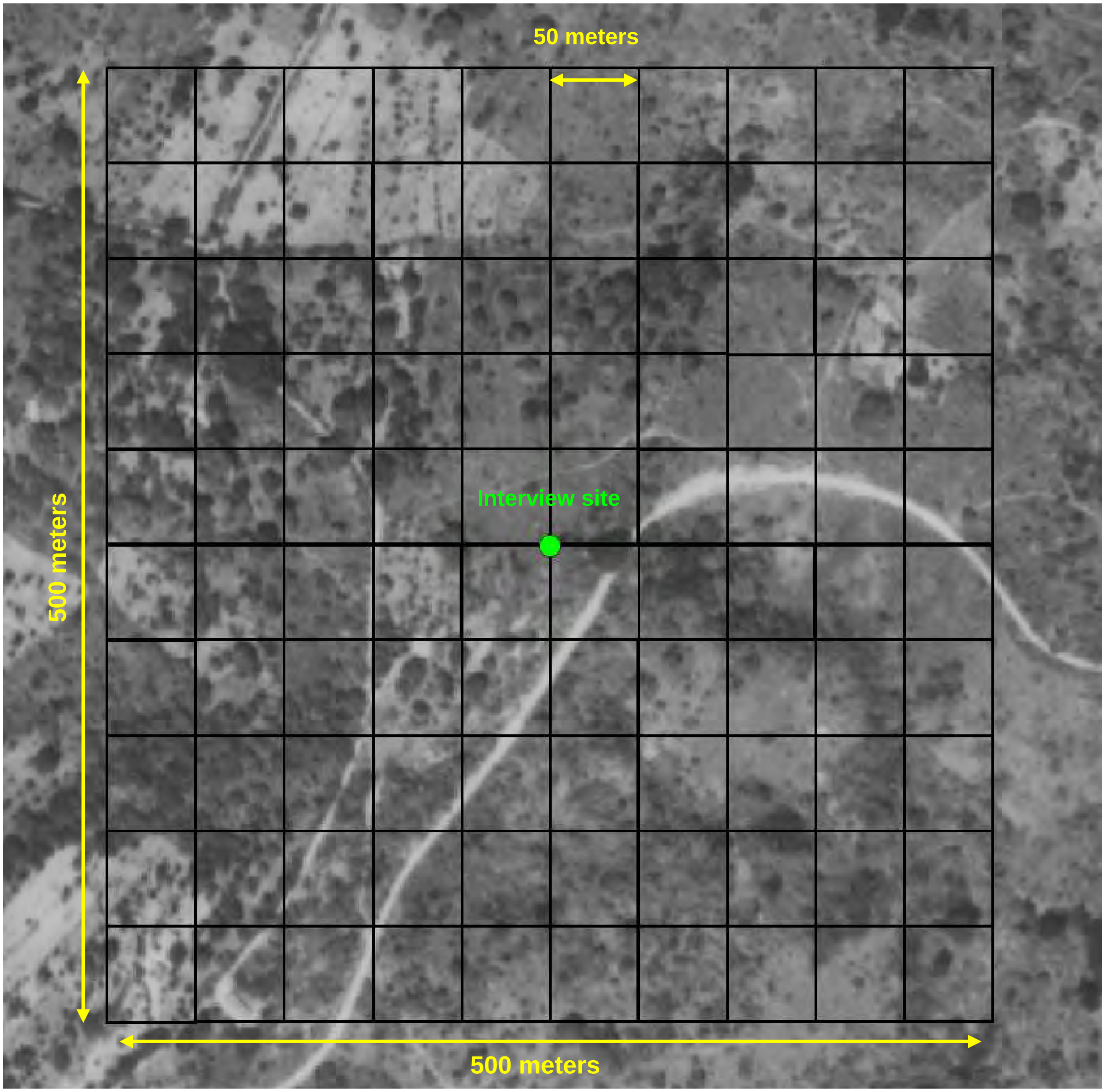
4.2 Land Use/Land Cover Change Analysis

A 25-hectare grid overlay was created in ArcGIS with 100 (50m by 50m) grid cells. Each grid was centered over the center of each respondent's farm and ArcGIS was utilized to classify the land use/land cover in each grid cell. A previous study regarding cultivation of maize and regional farming practices in Kwale District found that 7% of farmers own less that 0.1 ha of land, 70% own between 1.1-4.0 ha, 16% own between 4.1-8.0 ha, and 7% own more than 8.1 ha with the majority of farmers (80%) farming only a small portion (0.1 to 2.0 ha) of their land (Bonhof, van Huis et al. 2001). Based on these results, the average farm size for this study was defined as approximately two hectares, which is also the average farm size in Kenya (Kamau 2000; Nagayets 2005). A 0.25 hectare grid cell, one eighth the size of an average farm size, was chosen as the minimum mapping unit in this study to facilitate the LULC classification and enable noticeable change within a single farm.

Various other studies involving the classification of LULC categories from aerial photos were reviewed as a basis for developing an appropriate classification scheme for this study (Imbernon 1999; Matiru 1999; Tekle and Hedlund 2000; Soini 2002; Olson 2004; Soini 2005). Since it was impracticable to attempt to distinguish between all possible LULC classes on the aerial photos, some classes were combined into broader categories. The land use categories that pertain most directly to understanding conflict with elephants are agriculture and forest.

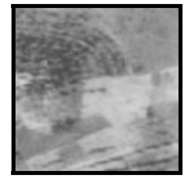
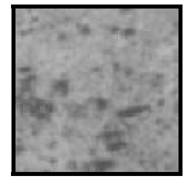
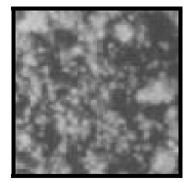
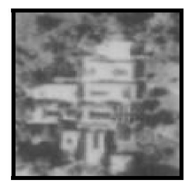
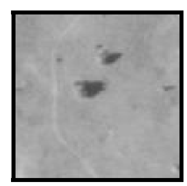
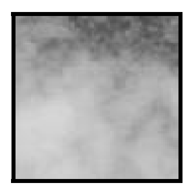
The grid overlay was centered over each interview location (Figure 4.6) and all grid cells were classified based on the majority LULC in the cell (Figure 4.7). All values in the analysis were rounded to the nearest whole number.

Figure 4.6 – 25 hectare grid overlay for LULC classification



The accuracy of the classification was verified partially through GPS ground control validation of known land cover types in field sites. The following six LULC categories (Table 4.2) were classified from the aerial photos for the landscape around each interview site using basic ground-truthing methods.

Table 4.2 – LULC classification

LULC Category	Description	Examples
Agriculture	Cultivated fields and areas that appeared to contain any of the following characteristics: cleared land in the shape of a field or crops visible in rows.	
Bushland or Few Trees	Areas of wooded grassland, bushed grassland, and bushlands, and trees that did not have a closed forest canopy.	
Dense Forest	Closed canopy rainforests (contiguous crowns of trees), commercial plantations, and private woodlots.	
Developed	Towns, roads, buildings, and settlements.	
Open Space or Sparse Bush	Areas with little or no vegetation (i.e. grass, meadows, pastures).	
Other or Obscured	Areas where LULC did not fall into any of the other categories (i.e. water) or areas where interpretation was difficult or impossible due to cloud cover, ripped photos, etc.	

Ten of the eighty total interview locations were revisited during the second field season to determine if seasonality played a role in interview responses. Therefore, a total of seventy sites around the reserve were used in the overall temporal LULCC analysis.

Figure 4.7 – Example of LULC classification method

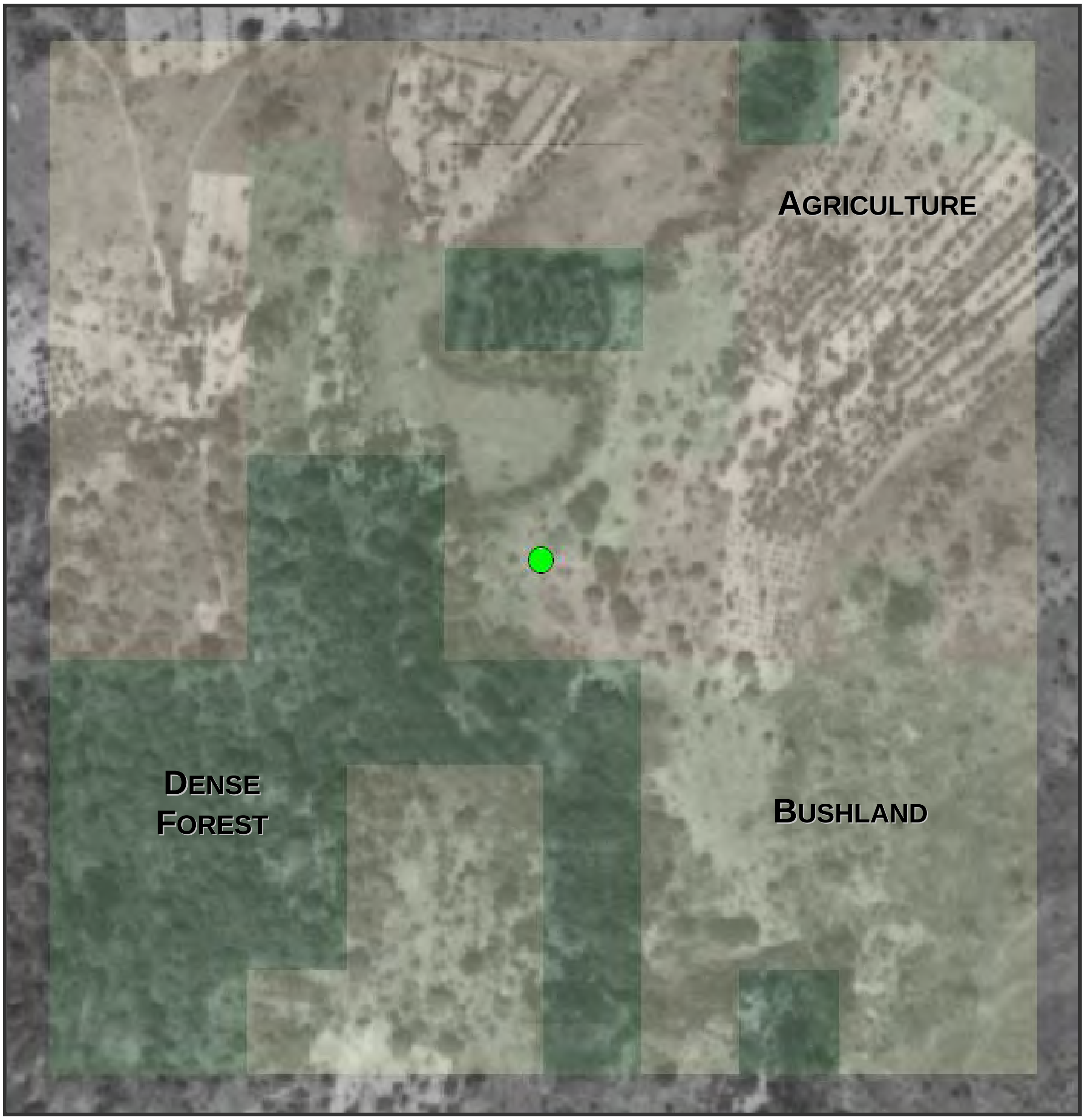
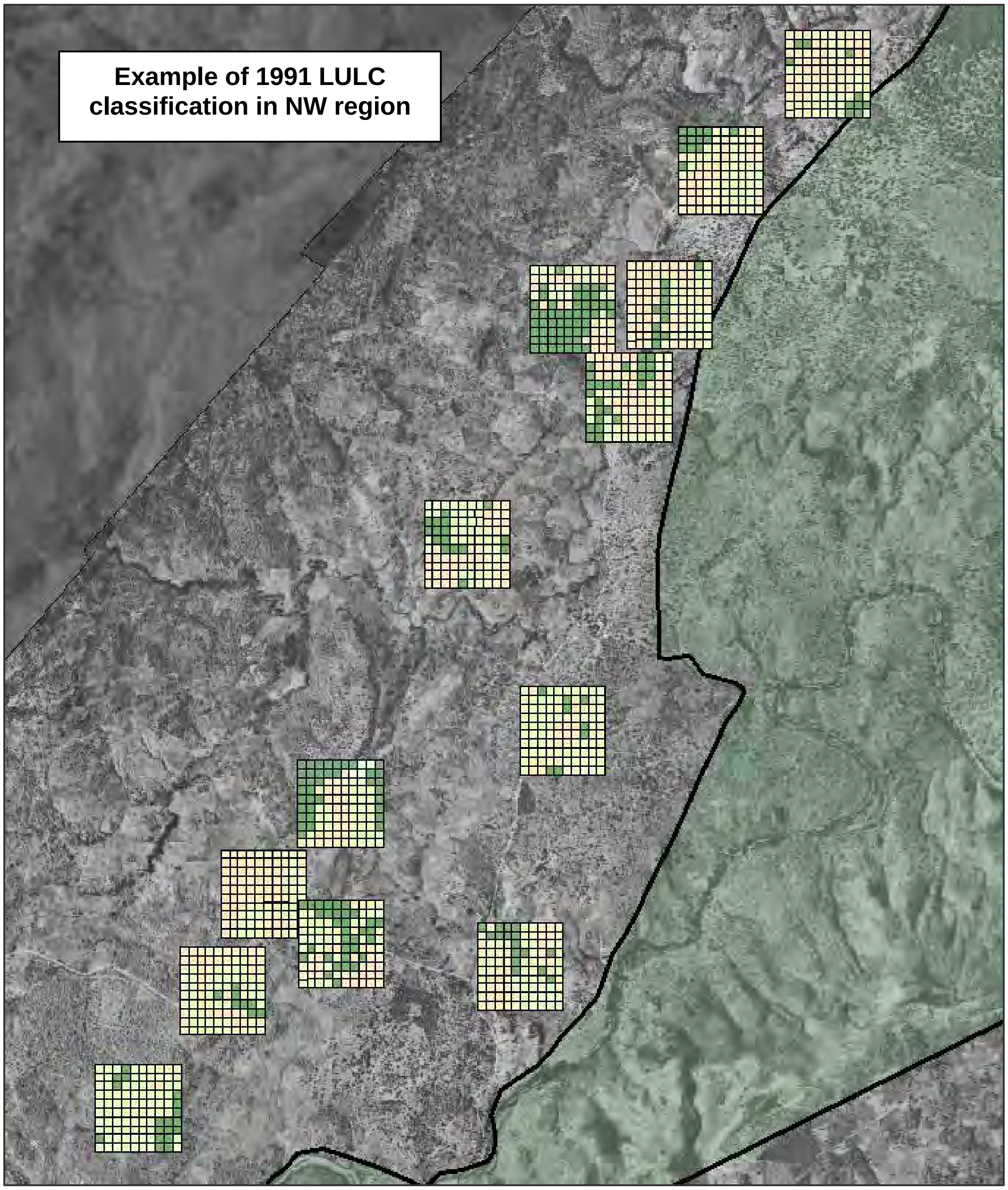


Figure 4.8 – LULC classification at interview locations (NW region)

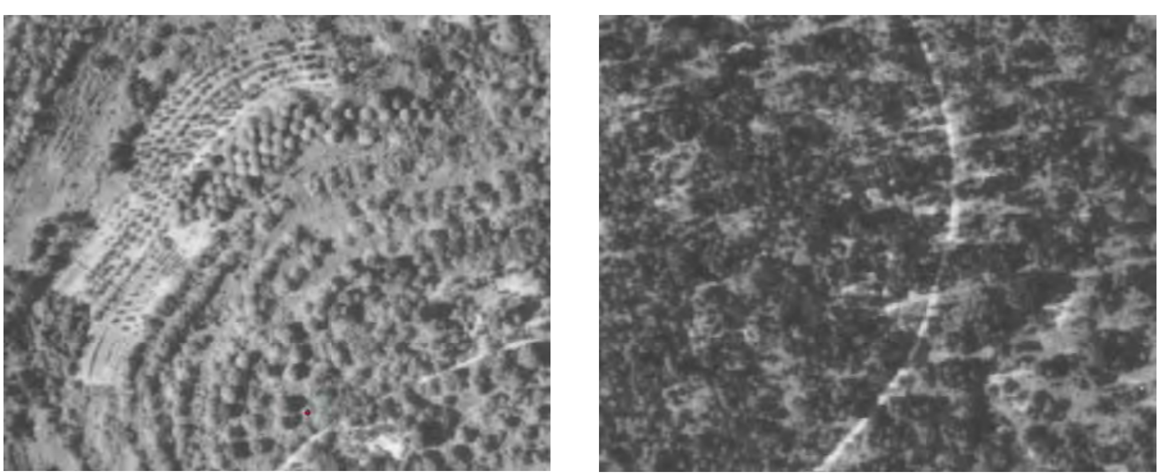


	Region				
	NW	**SW**	**NE**	**SE**	**Total**
LULC 1991	400 ha. 1,600 grid cells	425 ha. 1,700 grid cells	375 ha. 1,500 grid cells	500 ha. 2,000 grid cells	**1700 ha.** **6,800 grid cells**
LULC 1999	400 ha. 1,600 grid cells	425 ha. 1,700 grid cells	375 ha. 1,500 grid cells	500 ha. 2,000 grid cells	**1700 ha.** **6,800 grid cells**
Total	**800 ha.** **3,200 grid cells**	**850 ha.** **3,400 grid cells**	**750 ha.** **3,000 grid cells**	**1000 ha.** **4,000 grid cells**	**3400 ha.** **13,600 grid cells**

4.2.1 Difficulties encountered when classifying LULC categories

The most significant problem encountered when classifying the LULC categories was distinguishing agricultural areas composed primarily of agroforestry from dense forest or bushland. In these areas, cash tree crops such as cashews, mangoes, coconuts, oranges, bixa, and bananas are barely distinguishable from uncultivated bush and indigenous tree cover on the aerial photos. With such small fields interspersed among local bush and trees species, the land use/land cover was difficult to classify. Therefore, unless tree crops were planted in visible rows and easily identifiable as agricultural areas or ground-truthing confirmed the presence of tree crops (i.e. mixtures of coconuts, mangoes, cashews and oranges as shown in Figure 4.9), agroforestry was combined primarily with the bushland category, based primarily on the amount of tree canopy cover. Additionally, the interpretation of LULC was sensitive to errors in classification. In this study, LULC classification was performed solely by the researcher to keep subjectivity during the classification process constant and to a minimum. The category of "obscured" encompassed all areas that did not fall into other classes (i.e. locations where photos were damaged or regions where cloud cover made LULC impossible to distinguish).

Figure 4.9 – Easily identifiable cash tree crops versus harder to distinguish tree crops
(GPS ground-truthing confirmed tree crops in both locations)



4.3 Results of air photo analysis

The analysis of total LULCC around SHNR (Table 4.3) indicates that deforestation in areas of dense forest cover occurred at high rates during the 1990s. Dense forest cover decreased over 50%, from 31% in 1991 to 15% in 1999. The results of the air photo analysis demonstrate the strong correlation between the loss of dense forest and the increase in agricultural land use (Figure 4.10). Agricultural land use increased from 38% in 1991 to 54% in 1999. According to this data, the two LULC categories are inextricably intertwined. The amount of bushland, open space and developed land remained largely unchanged overall. The "developed" and "other/obscured" land use categories had negligible values and are consequently excluded from further discussion and analysis.

Table 4.3 - Total LULC change adjacent to SHNR (in hectares) from 1991-1999

	Agriculture	Open space or sparse bush	Dense forest	Bushland or Few trees	Other or obscured	Developed	TOTAL
1991	647	38	532	468	8	8	500 ha
	38%	2%	31%	28%	1%	0%	
1999	913	52	259	467	2	7	500 ha
	54%	3%	15%	28%	0%	0%	
Change	266	14	-273	-1	-6	0	
	+16%	**+1%**	**-16%**	**0%**	**0%**	**0%**	

Table 4.4 - LULCC matrix (forest versus agriculture)

Land use/land cover type	Year	
	1991	1999
Forest	**31%** (532 ha)	**15%** (259 ha)
Agriculture	**38%** (647ha)	**54%** (913ha)

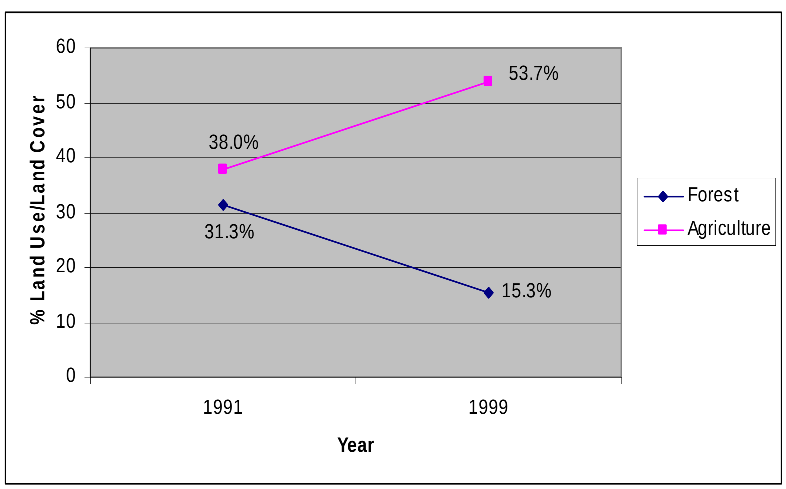


Figure 4.10 – Total change in agriculture and forest around SHNR from 1991-1999

The LULCC analysis of the period from 1991 to 1999 (Table 4.5) in the Northwest region around SHNR indicates that agricultural land use increased by 13% with a corresponding decrease in dense forest cover of 11%. This suggests that in this region, deforestation was occurring due to the expansion of agricultural land into densely forested areas. Figure 4.11 demonstrates an example of how agriculture increased in the NW region.

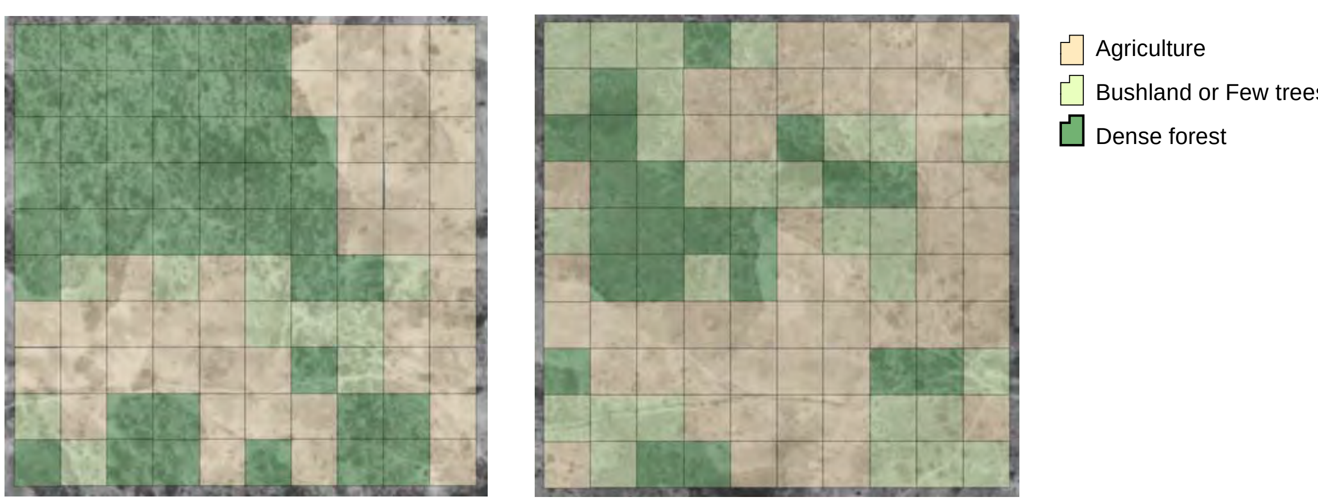
Table 4.5 - LULCC for Northwest region (hectares)

Northwest	Agriculture	Open space or sparse bush	Dense forest	Bushland or Few trees	TOTAL
1991	139	8	81	172	400 ha
	35%	2%	20%	43%	
1999	193	0	38	169	400 ha
	48%	0%	10%	42%	
Change	54	-8	-43	-3	
	+13%	**-2%**	**-11%**	**-1%**	

Table 4.6 - LULCC matrix for NW region (forest versus agriculture)

Land use/land cover type	Year	
	1991	**1999**
Forest	**20%** (81 ha)	**10%** (38 ha)
Agriculture	**35%** (139 ha)	**48%** (193 ha)

Figure 4.11 – Example of increase in agriculture and decrease in dense forest (NW, '91-'99)



The LULCC analysis of the period from 1991 to 1999 (Table 4.7) in the Southwest region around SHNR indicates a much greater increase in agricultural land use (22%) than the NW region, a significant reduction in dense forest (-19%) and a smaller decrease in bushland (-4%). In the SW region, a large amount of dense forest and bushland areas were converted to agricultural land use.

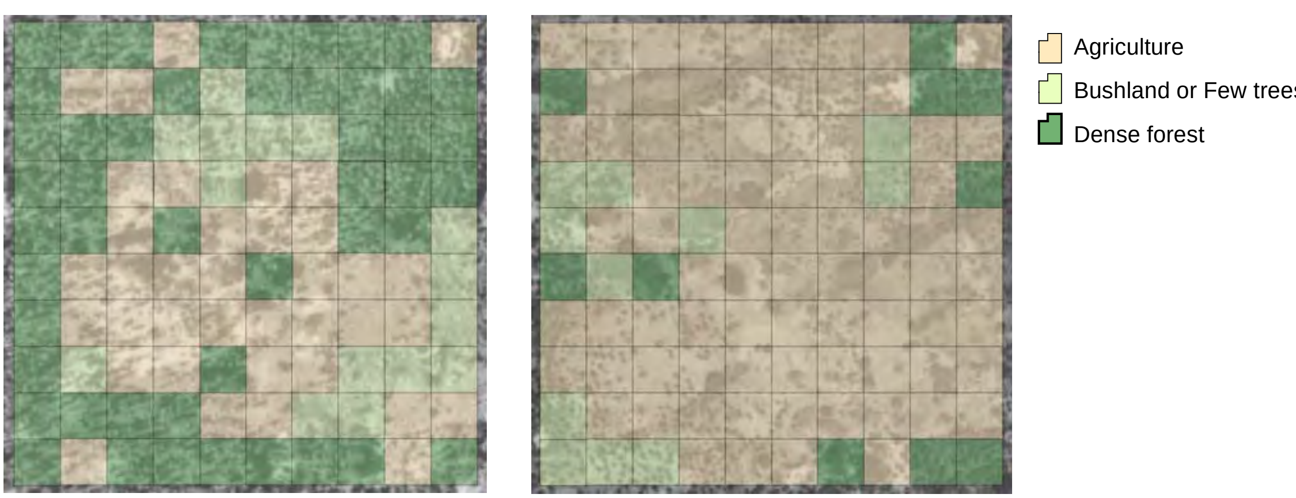
Table 4.7 - LULC change for Southwest region (hectares)

Southwest	Agriculture	Open space or sparse bush	Dense forest	Bushland or Few trees	TOTAL
1991	182	0	175	68	425 ha
	43%	0%	41%	16%	
1999	277	0	96	53	425 ha
	65%	0%	23%	12%	
Change	95	0	-80	-16	
	+22%	**0%**	**-19%**	**-4%**	

Table 4.8 - LULCC matrix for Southwest region (forest versus agriculture)

Land use/land cover type	Year	
	1991	**1999**
Forest	**41%** (175.3 ha)	**23%** (95.5 ha)
Agriculture	**43%** (181.8 ha)	**65%** (277.0 ha)

Figure 4.12 - Example of increase in agriculture and decrease in dense forest (SW, '91-'99)



The LULCC analysis of the period from 1991 to 1999 (Table 4.9) in the Northeast region around SHNR demonstrates a noticeable increase in agricultural land use (9%) and open space (5%). Dense forest decreased slightly (-3%), but the largest decrease was in bushland (-11%).

Table 4.9 - LULC change for Northeast region (hectares)

Northeast	Agriculture	Open space or sparse bush	Dense forest	Bushland or Few trees	TOTAL
1991	135	30	65	144	375 ha
	36%	8%	17%	38%	
1999	168	47	55	104	375 ha
	45%	13%	15%	28%	
Change	33	18	-10	-41	
	+9%	**+5%**	**-3%**	**-11%**	

Table 4.10 - LULCC matrix for Northeast region (forest versus agriculture)

Land use/land cover type	Year	
	1991	**1999**
Forest	**17%** (65 ha)	**15%** (55 ha)
Agriculture	**36%** (135 ha)	**45%** (168 ha)

The LULC analysis of the period from 1991 to 1999 (Table 4.11) in the Southeast region around SHNR shows a significant decrease in dense forest cover (28%) with an equivalent combined increase (28%) in agricultural land use (17%) and bushland (12%).

Table 4.11 - LULC change for Southeast region (hectares)

Southeast	Agriculture	Open space or sparse bush	Dense forest	Bushland or Few trees	TOTAL
1991	191	0	211	85	500 ha
	38%	0%	42%	17%	
1999	275	5	71	143	500 ha
	55%	1%	14%	29%	
Change	84	5	-140	58	
	+17%	**+1%**	**-28%**	**+12%**	

Table 4.12 - LULCC matrix for Southeast region (forest versus agriculture)

Land use/land cover type	Year	
	1991	1999
Forest	**42%** (211ha)	**14%** (71ha)
Agriculture	**38%** (191ha)	**55%** (275ha)

4.4 Land use/land cover change (LULCC) in relationship to SHNR boundary

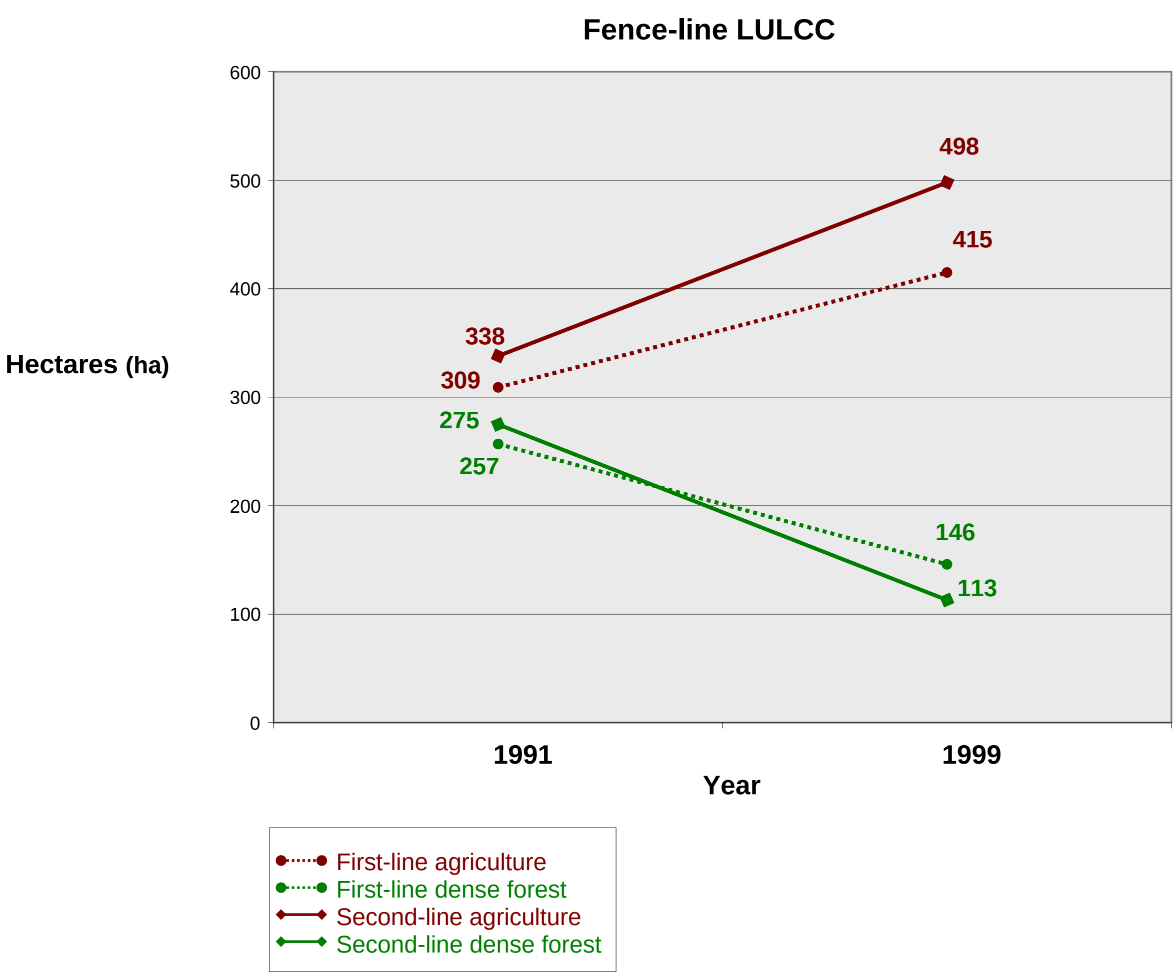
Results from the air photo analysis demonstrate how changes in LULC occurred throughout the 1990s in relation to proximity to the SHNR boundary. The electric fence construction began in the early 1990s and was complete by 1999 (Knickerbocker 2002). To examine the "fence-effect" question of whether agricultural expansion near the park boundary occurred as a direct result of the fence construction, LULC change was analyzed for interview sites along the fence-line (first-line) and for sites situated with at least one other farm between the interview site and the park boundary (second-line). The electric fence surrounding SHNR bordered at least one side of each first-line site.

When the air photos analysis of LULCC in proximity to the fence-line was expanded to generalize the overall change for the entire region around SHNR (Table 4.13), the results show a greater rate of deforestation (19%) throughout the second-line farm region than in the region adjacent to SHNR (13%). The rate of agricultural expansion in both regions closely follows the pattern of deforestation (Figure 4.13). In general, there was hardly any change in the amount of bushland both adjacent to and far from the fence-line. Open space increased slightly (2%) along the fence-line and change in the amount of developed land in the region around SHNR was negligible.

Table 4.13 - LULC change in relation to fence-line (first line/second line) around SHNR (ha)

Year	Fence-line	Agriculture	Open space/ sparse bush	Dense forest	Bushland/ Few trees	Total
Total 1991	**1**	309 (36%)	27 (3%)	257 (30%)	250 (29%)	850
Total 1999	**1**	415 (49%)	44 (5%)	146 (17%)	245 (29%)	850
Total 1st fence-line LULC change		**+12%**	**+2%**	**-13%**	**-1%**	
Total 1991	**2**	338 (40%)	11 (1%)	275 (32%)	218 (26%)	850
Total 1999	**2**	498 (59%)	8 (1%)	113 (13%)	223 (26%)	850
Total 2nd fence-line LULC change		**+19%**	**0%**	**-19%**	**+1%**	

Figure 4.13 – Graph: Change in agriculture and dense forest (first-line/second-line) from '91-'99



In the Northwest region, agriculture increased at a greater rate for second-line farms (18%) than first-line sites (8%) with a closely corresponding decrease in dense forest cover of 16% and 7% respectively. In the NW region, the greatest LULC change occurred in the second-line farmland (Table 4.14).

Table 4.14 - LULCC in relation to fence-line (first-line vs. second-line) for NW region (ha)

Region	Year	Fence-line	Agriculture	Open space/ sparse bush	Dense forest	Bushland/ Few trees	Total
NW	1991	1	69 (39%)	7 (4%)	25 (14%)	74 (43%)	175
NW	1999	1	83 (48%)	0 (0%)	18 (11%)	73 (42%)	175
LULC change			**+8%**	**-7%**	**-7%**	**-1%**	
NW	1991	2	70 (31%)	1 (0%)	57 (25%)	98 (43%)	225
NW	1999	2	110 (49%)	0 (0%)	20 (9%)	96 (42%)	225
LULC change			**+18%**	**0%**	**-16%**	**-1%**	

The Southwest region around SHNR showed a great increase in agricultural land use for both first-line (21%) and second-line (25%) sites (Table 4.15). The difference between the two areas is that along the fence-line, dense forest cover was reduced by 24% and bushland increased slightly (4%) to accommodate the agricultural expansion while in the second-line areas, dense forest cover and bushland decreased at more equal rates of 13% and 12%, respectively.

Table 4.15 - LULCC in relation to fence-line (first-line vs. second-line) for SW region (ha)

Region	Year	Fence-line	Agriculture	Open space/ sparse bush	Dense forest	Bushland/ Few trees	Total
SW	1991	1	93 (41%)	0	107 (47%)	26 (11%)	225
SW	1999	1	139 (62%)	0	53 (23%)	34 (15%)	225
LULC change			**+21%**	**0%**	**-24%**	**+4%**	
SW	1991	2	89 (45%)	0	69 (34%)	43 (21%)	200
SW	1999	2	138 (69%)	0	43 (22%)	19 (9%)	200
LULC change			**+25%**	**0%**	**-13%**	**-12%**	

In the Northeast region around SHNR, agriculture increased by 8% along the fence-line (Table 4.16). Throughout the first-line sites, the greatest changes in land cover were the reduction of bushland by 14% and the increase in open space by 9%. Deforestation along the fence-line was limited to a mere 4%. In the second-line areas, agriculture increased by a moderate 10% which corresponds closely to the combined decrease in bushland (6%), open space (3%) and dense forest (1%).

Table 4.16 - LULCC in relation to fence-line (first-line vs. second-line) for Northeast region

Region	Year	Fence-line	Agriculture	Open space/ sparse bush	Dense forest	Bushland/ Few trees	Total
NE	1991	1	60 (27%)	20 (9%)	47 (21%)	98 (44%)	225
NE	1999	1	79 (35%)	41 (18%)	38 (17%)	66 (29%)	225
LULC change			**+8%**	**+9%**	**-4%**	**-14%**	
NE	1991	2	75 (50%)	10 (6%)	18 (12%)	46 (31%)	150
NE	1999	2	89 (59%)	6 (4%)	17 (11%)	38 (25%)	150
LULC change			**+10%**	**-3%**	**-1%**	**-6%**	

The Southeast region demonstrated the greatest rate of deforestation with a reduction in dense forest of 36% for the second-line sites (Table 4.17). Along the fence-line, dense forest cover decreased by 19%. Agriculture increased at a greater rate away from the fence-line (21%) in comparison to the 12% increase in agriculture along the fence-line. In both areas, bushland increased as a result of the deforestation, while open space increased slightly.

Table 4.17 - LULCC in relation to fence-line (first line/second line) for SE region (ha)

Region	Year	Fence-line	Agriculture	Open space/ sparse bush	Dense forest	Bushland/ Few trees	Total
SE	1991	1	87 (39%)	0 (0%)	79 (35%)	53 (23%)	225
SE	1999	1	114 (50%)	2 (1%)	37 (16%)	72 (32%)	225
LULC change			**+12%**	**+1%**	**-19%**	**+9%**	
SE	1991	2	104 (38%)	0 (0%)	132 (48%)	32 (12%)	275
SE	1999	2	161 (59%)	3 (1%)	34 (12%)	71 (26%)	275
LULC change			**+21%**	**+1%**	**-36%**	**+14**	

Figure 4.14 – Bar Chart: Rate of LULCC in relation to fence-line (by region)

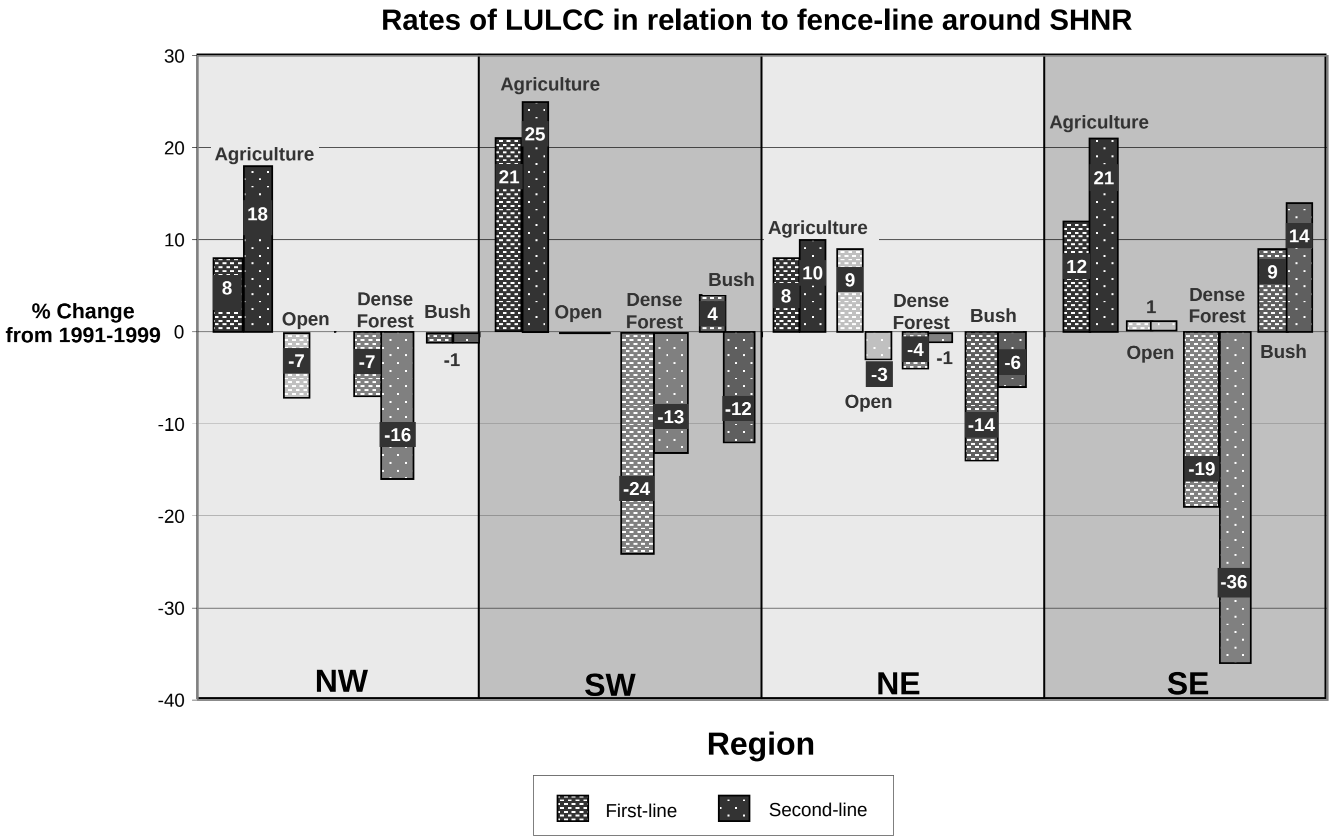
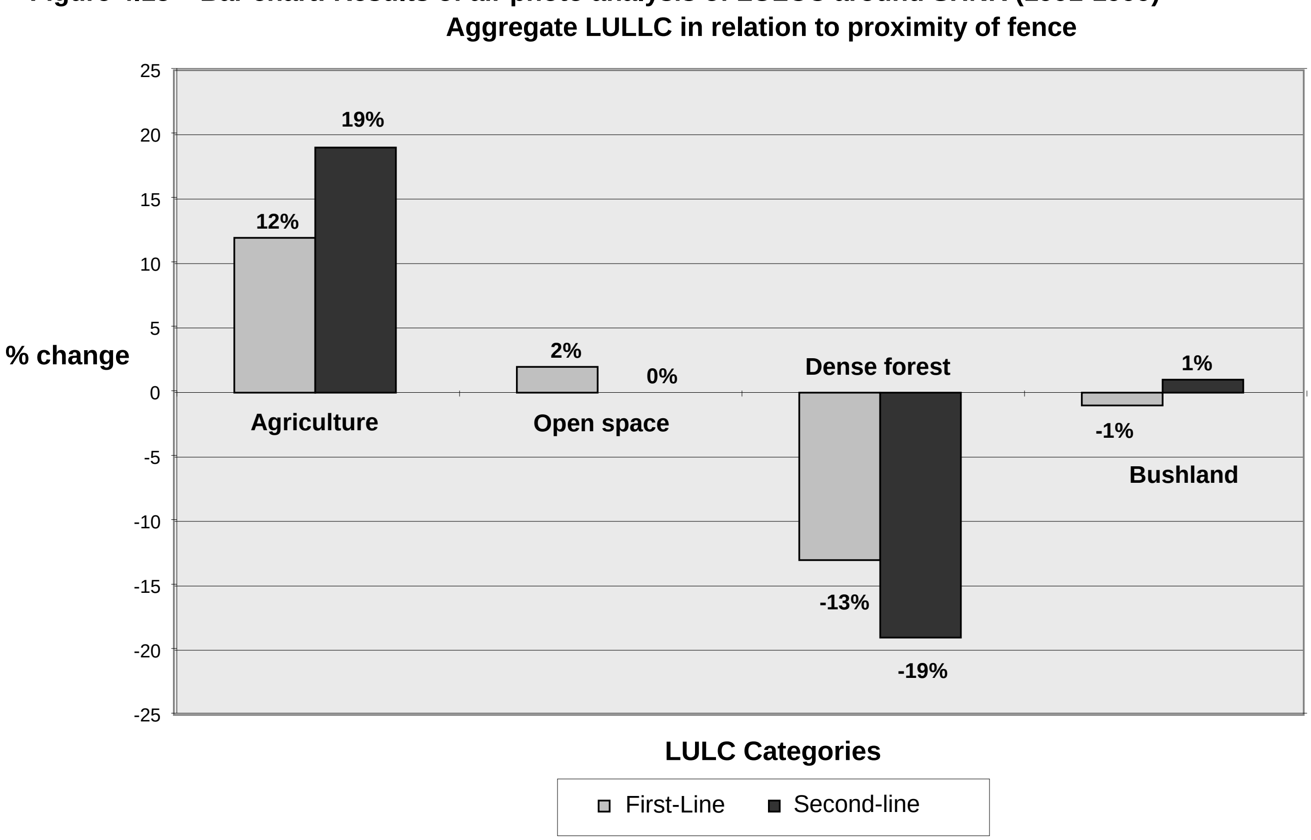


Figure 4.15 – Bar chart: Results of air photo analysis of LULCC around SHNR (1991-1999)



4.5 Discussion of aerial photo analysis

One of the most dramatic changes shown by the land use analysis is the gradual disappearance of natural vegetation. The results of the air photo analysis provide insight into the land use and cover changes that occurred around SHNR during the 1990s and present evidence to help explain landscape patterns and rates of change around the reserve. The investigation of LULCC in relation to region and proximity to the reserve is valuable for understanding the factors driving deforestation and agricultural expansion in this area.

Research questions:

1. How has LULC around SHNR changed from 1991 to 1999?

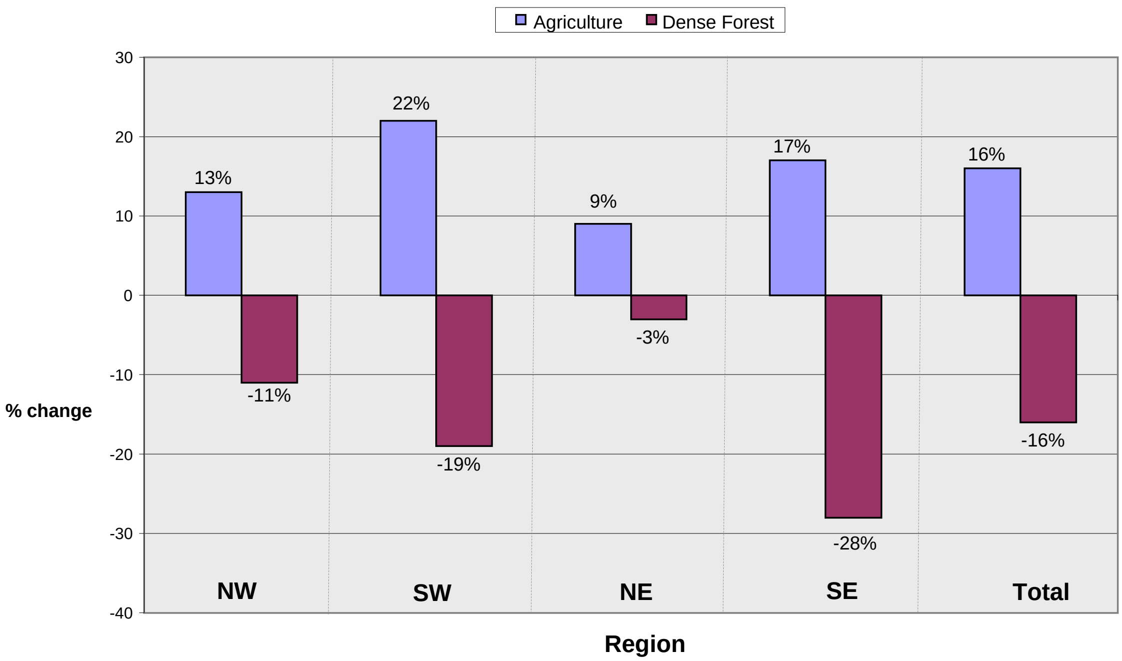
Agricultural expansion was significant around the reserve boundary (+16%) during the 1990s, particularly in the southwest quadrant which showed a 22% increase. The rate of agricultural growth occurred at the expense of closed canopy forest which revealed an overall decrease of 16%, creating an increasingly abrupt forest edge. Understanding the causal factors for this expansion requires turning to the field interview data. According to interviews with local farmers in this region, 65% reported that they have not changed their amount of cultivated land over the past decade. Of the 65% who reported changing the amount of land they cultivate, 69%, primarily living along the fence-line, stated that have reduced their cultivated land due to the seemingly futile fight against elephant raids and the resulting crop damage. At the time of the interviews, residents reported that people were presently moving out of the area due to problems with wildlife.

Since the majority of respondents reported that they had not expanded their fields nor opened new areas during the 1990s, the increase in agriculture during this decade suggests that a number of residents immigrated to SHNR during this time period. Information from interviews with residents living around SHNR overwhelmingly maintain the fact that the electric fence, which was started and finished in the 1990s, was initially very effective in reducing human-wildlife conflict. This supports the idea that when the fence was in the process of being constructed and was working effectively, there was incentive for people to move to this area, which resulted in the expansion of agricultural land use. Residents reported that the fence began to fail its purpose and became ineffective due to lack of maintenance and its conversion from electric power to solar power in the early 2000s. This history helps to explain why most respondents reported that they were presently reducing their agricultural fields and moving out of the area due to problems with wildlife.

2. Has agricultural expansion (indicated by reduced forest cover) occurred in all areas surrounding SHNR between 1991 and 1999?

According to the air photo analysis, agricultural expansion occurred at varying rates in all four regions around SHNR (Figure 4.16). The results clearly demonstrate how closely agricultural expansion and deforestation are related to one another. The rates of change in these two land use/land cover categories vary in direct relation to each other in each region around the reserve. In addition to deforestation of dense forest, the conversion of bushland to cropland also contributed to the amount of land available for agricultural expansion.

Figure 4.16 – Rates of agricultural expansion and deforestation around SHNR (by region)



3. **How has LULC change differed between the four regions (NW, NE, SW, and SE) where interviews were conducted?**

The results indicate that in the NW region, dense forest and open space were reduced to accommodate a moderate increase in agriculture of 13%. Whereas in the SW region, there was a much higher increase in agriculture land (22%) and a corresponding decrease in dense forest and bushland. The lowest percentages of agricultural expansion (9%) and deforestation (3%) occurred in the NE region where the large decline in bushland (-11%) played the most significant role and led to an increase in open space (5%) as well as agricultural land. However, agricultural land may have been unintentionally misclassified as open space, to some extent, due to the lack of crop growth observable in the air photos. The SE region demonstrated the most significant rate of deforestation (28%) to accommodate an increase in agriculture of 17% and bushland (12%). The discrepancy between the percentages of deforestation and agriculture expansion may be partially due to the misclassification of tree crops as bushland in this area.

4. How has LULC change differed (in general and by region) in relation to proximity to the park boundary?

The aerial photo analysis provides no evidence to suggest that fencing led to greater expansion of agriculture along the fence boundary than away from the boundary in the ling-term. Instead, the results from this study corroborate the results of Sanchez-Azofeifa's study in Costa Rica, and Wiens broader study where as distance increased from the reserve, total deforestation and deforestation rates also increased (Sanchez-Azofeifa, Daily et al. 2003). In East Africa, research demonstrates that total deforestation tends to increase in relation to distance from protected area boundaries, but some of the highest *rates* of deforestation occur within five km of protected area edges (Plumptre, Masozera et al. 2002; Witucki 2004; Naughton-Treves, Holland et al. 2005).

The results of the air photo analysis are interesting as they provide empirical evidence of land cover changes which may contribute positively to future management of available resources.

CHAPTER 5

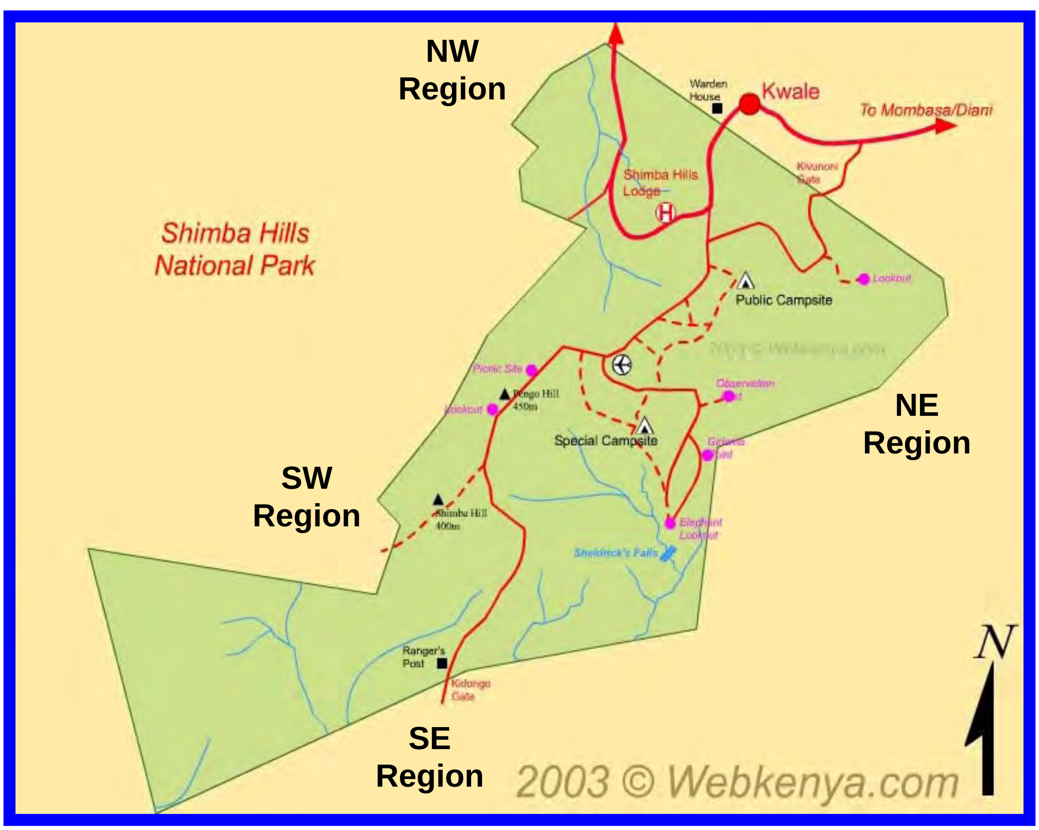
5.1 Interviews with Local Residents around SHNR

As stated in the introduction, my primary research objective was to further understand the socioecological variables driving human-elephant conflict around SHNR. I conducted personal interviews with local residents to reinforce my understanding of the LULCC interpreted from the air photo analysis and to gain a greater understanding of human-elephant conflict in the area around SHNR. In conjunction with remote sensing analysis, household-scale investigations of land use decisions are beneficial in revealing the socioeconomic causes of land use change (Mertens, Sunderlin et al. 2000; Olson 2004). The integration of household interviews with remotely sensed temporal land use/land cover data greatly improves our understanding of the processes of land use patterns (Maitima and Olson 2001).

Therefore, I explored the intensity of human-wildlife conflict, along with the various household-scale factors that influenced the severity of conflict, in the four pre-defined regions around Shimba Hills Reserve (NW, SW, NE and SE). I hypothesized that there were a number of interrelated factors which worked together to shape risk of elephant threat for local residents. To distinguish the elements significantly shaping perceived risk, I asked seventy households (n = 70) questions regarding crop threat by elephants and frequency of threat. I utilized analysis of the field interviews to answer my main study question: What are the specific socioecological variables associated with farmers' perceived rate of conflict with elephants and reported frequency of threat? My primary interest was to determine whether respondents perceived the severity of elephant threat differently throughout the region and, if so, the underlying reasons for the differences. I also examined patterns of LULCC at the local level.

I selected socioecological variables described in previous human-wildlife conflict studies (Newmark, Manyanza et al. 1994; Naughton-Treves 1998; Hoare 2000; Georgiadis 2003; Witucki 2004; Distefano 2005) as well as from conversations with local community leaders and KWS officials to investigate further. Literature on human-elephant interaction consistently points to hot spots of conflict. Therefore, one key variable to investigate was location. Some experts believe conflict hotspots are associated with elephant corridors, i.e. elephants repeatedly leave parks and reserves to follow ancient migratory paths (Smith and Kasiki 2000; Osborn and Parker 2003). Others posit that human planting activities or habitat disturbance attracts elephants to certain areas (Naughton-Treves 1997). KWS officials and local leaders at Shimba described marked spatial variation in conflict between various communities. I explored this geographic variation by partitioning my study region into four general quadrants, depicted in Map 5.1.

Map 5.1 – Four regions around SHNR where interviews were conducted
[Map provided by Webkenya, 2003]



To investigate my hypothesis and determine the factors shaping perceived risk of elephant threat by local residents, I asked 70 households whether they thought that their crops were currently threatened by elephants and inquired about the frequency of elephant conflict. Thus, the two dependent variables in my analysis are: 1) Are your crops currently threatened by elephants? (Y/N) and 2) Has your farm been raided by elephants in the past 6 months? (Y/N). Against these two dependent variables, I tested the following independent variables (Table 5.1).

Table 5.1 – List of independent variables

Variable Name	Variable Description	Responses*
Ethnicity	Tribe	- Digo - Duruma - Other (Kamba, Kikuyu, etc.)
Gender	Gender of respondent	- Male - Female
Family size	Number of family members on farm	- 1 - 40
Season	Interview season	- Wet season (May/June, 2005) - Dry season (January, 2006)
Land size	Size of farm	- Hectares
Fence-line	Proximity to reserve	- Along fence-line (first-line) - At least one farm between interview site and SHNR (second-line)
Cassava	Do you plant cassava?	- Yes - No
Coconut	Do you plant coconuts?	- Yes - No

* All questions included “no response” as a possible answer.

5.1.1 Field Activities

I was fortunate to have the opportunity to travel to Kenya to conduct interviews and collect GIS data during two separate field seasons. During my first field season, I was in Kenya for a period of approximately six weeks starting in the end of May 2005. I spent one week in Nairobi and Mombasa where I obtained research clearance from the government, coordinated final logistics with my research assistants, met with GIS experts at the African Wildlife Foundation's main office, and conducted additional background research.

At my study site, I was based in Kwale Town, which is adjacent to Shimba Hills National Reserve. Due to budgeting constraints in regards to transportation, I allocated just over one week to complete all of my field data collection, including interviews and GPS ground-truthing for the air photo analysis. Additional gathering of sources, contacting key players in conservation, writing, and data analysis was carried out for four weeks in Kenya after the fieldwork was complete. The second field season took place in January 2006 at the same study site location. During this two week period, I completed additional interviews with local residents regarding conflict and wildlife corridors. I was interested in establishing whether the elephant translocation effort which was scheduled to occur directly after my first field season made an impact on the perceived levels of human-elephant conflict reported around the reserve. I also used this opportunity to investigate elephant movements and wildlife corridors to a greater extent.

Permission to conduct my fieldwork around Shimba Hills was granted by Kenya's Ministry of Education, Science, and Technology (MOEST 13/001/35C 128/2), the Kenya Wildlife Service (KWS) Headquarters in Nairobi, the Kwale District County Council, and the

Shimba Hills National Reserve Warden. All of the interviews with local residents were conducted at the discretion of the informants.

To complete the field research in an efficient manner, I employed one Kenyan research assistant and two Digo field assistants for both field seasons. To navigate specific regions around SHNR, additional Digo and Duruma field assistants were hired intermittently to help with traversing certain areas and conducting interviews. The field assistants were fluent in the indigenous Digo and Duruma dialects of the Shimba Hills region as well as proficient in Swahili and conversational in English. My lead research assistant was fluent in both Swahili and English. I provided my assistants with short-term training in land cover analysis, GPS data collection, and interviewing techniques.

Figure 5.1 – Field assistants assemble air photos to determine traversable roads and potential interview locations

Figure 5.2 – Assistants collect GPS ground control points around SHNR

5.2 Methods for interviews about conflict

The first category of field data collection consisted of conducting interviews in four discrete areas bordering Shimba Hills Reserve. Prior to the field season, I developed an extensive questionnaire, based on human-elephant conflict and SHNR literature. Questions were modeled after the McCracken “Long Interview” method which combines the advantages of ethnographic style interviews with the benefits of a sharply focused, faster questioning strategy in order to reduce the redundancy and tangency of unstructured methods (McCracken 1988; Witucki 2004). To confirm the reliability of interview responses, one method of data triangulation was employed. Throughout the questionnaire, similar questions were asked in multiple ways to check for consistency in the responses (Fraenkel and Wallen 1996). For example, to check the reliability of responses, respondents were asked whether their crops were threatened by elephants and later asked which of their crops was most threatened by elephants. Ninety-nine percent of respondents provided consistent answers when they were asked questions designed to confirm the existence of elephant threat.

The aim of the questionnaire was to obtain demographic data, land use information and investigate the issues of wildlife damage and risk perception. In addition, the questionnaire included a wide range of questions pertaining to human-elephant conflict coping methods and mitigation strategies at the local level. A copy of the questionnaire follows in Appendix A. Once in the field, the questionnaire was modified slightly based on information gained from Participatory Rural Appraisals (PRAs). I met with three Kenya Wildlife Service officials (SHNR warden, KWS elephant research manager, and KWS employed ranger) and three local community leaders (Kwale District Officer and two village chairmen) to gain a greater understanding of the current conflict situation according to KWS officials and to obtain an alternate perspective from the local community leaders. The informal conversations with the KWS officials and local leaders helped greatly with modifying the questionnaire.

During the first field season in 2005, forty in-depth interviews were conducted. As an intermediate level Swahili speaker, I was able to introduce myself to informants and describe the purpose of the research. My field assistants asked the survey questions largely in Digo or Duruma, the main local languages. If respondents were immigrants to the area from other regions of Kenya, the interviews were conducted in Swahili. All data were first translated to

Swahili since my two field assistants who spoke the local languages were more comfortable explaining the responses in Swahili. Then, my Kenyan assistant, who was fluent in both Swahili and English, would help with the final translation into English. Interviews lasted approximately 40-60 minutes. All responses were recorded on the questionnaire during the interview.

Figure 5.3 – Conducting interviews in NE region around SHNR

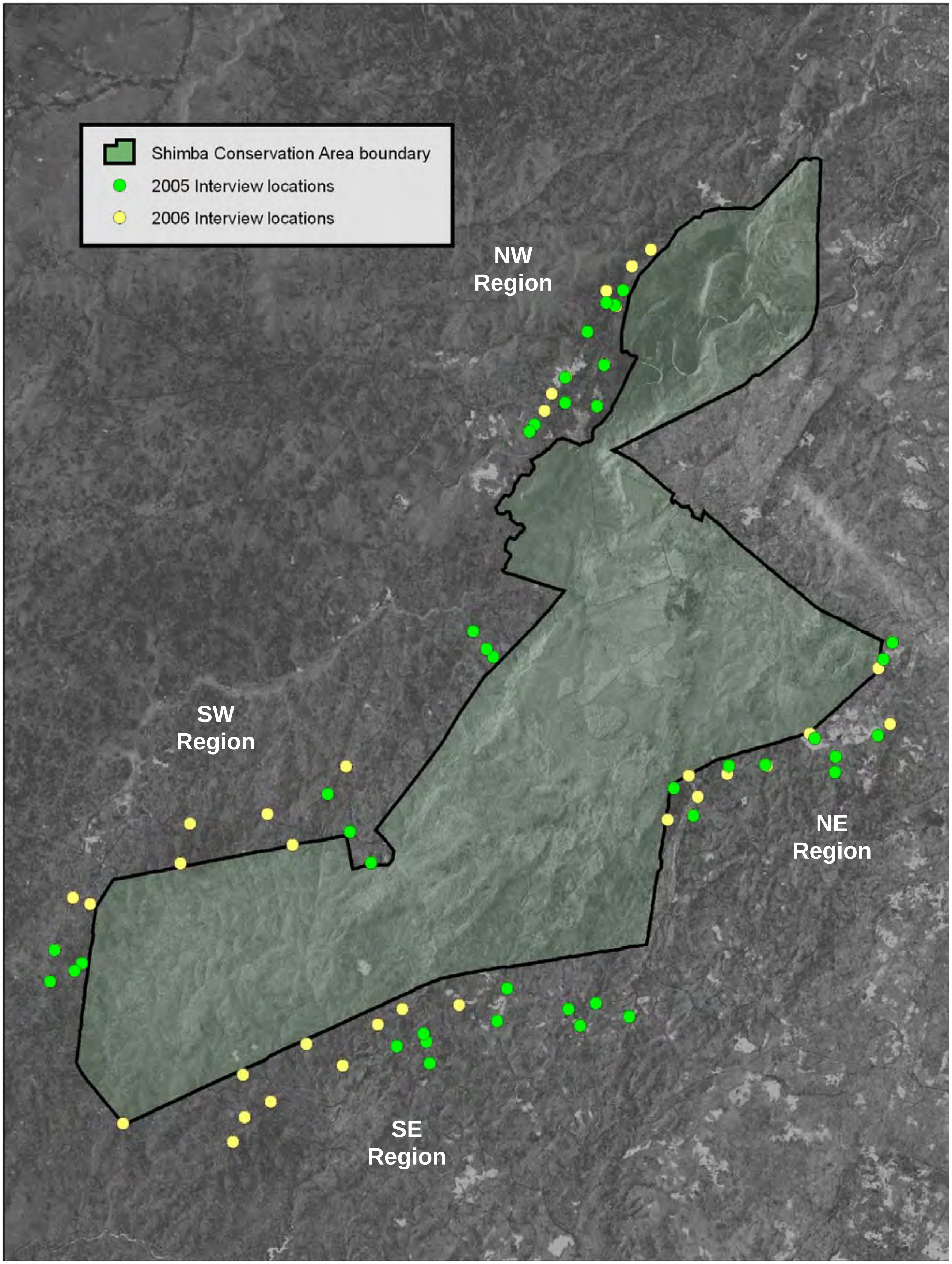
Figure 5.4 – Interviews with local residents around SHNR

The sampling unit was the individual household and the sampling design was a stratified random sample. The population of potential respondents was divided into four strata loosely defined by common land use practices, similar reports of elephant damage and general geographical location around the reserve: Northwest, Southwest, Northeast and Southeast. Due to its internal variability, "region" in terms of hotspots, was a common feature in the broader Shimba Hills area. Within each stratum, residents were randomly chosen with an effort to interview both farmers living along the reserve fence-line and those residing further from the fence boundary (Map 5.2, Table 5.2). This particular method of choosing respondents was employed in order to obtain a representative sample of residents both adjacent to and far from the fence boundary, given that proximity to the reserve was identified as a key factor shaping risk, both in literature and in pilot interviews with officials. Sampling in this manner is beneficial because combining data from each stratum enables an estimate that is expected to be more precise than that obtained from a random sample of the entire population (Trochim 2006).

I selected both men and women to interview on an opportunistic basis since I did not have the time or budget to return to site locations to seek out particular family members. I sought to interview the head of the household, usually the mother or father. Occasionally, a grandparent was interviewed when multiple generations shared the same land. If multiple elders were present, I interviewed the eldest family member at the residence, indiscriminate of gender because I sought a long-term perspective. Often, additional family members participated in the interview, which was helpful as they were able to add supplementary information (Figure 5.5). I interviewed residents in the location where I found them when I arrived at their farm, which meant that some interviews took place in the fields while others took place in or outside of the respondents' homes (Figure 5.4).

Figure 5.5 – Examples of interviews with family members from multiple generations

Map 5.2 – 2005 and 2006 Interview locations around SHNR



5.3 Data analysis

The responses from the interviews (n=70) were first entered into a spreadsheet and later transferred to the Statistical Package for Social Scientists (SPSS) PC version 12.0, where the data was organized, cleaned, and coded with the appropriate labels for each variable. I recoded my two dependent variables (reported risk) into dichotomous categories, for use in binary logistic regression models. Reported risk was determined by whether respondents felt their crops were threatened by elephants and the frequency of threat. Coding my categorical data into dichotomous variables allowed me to test my hypotheses with better accuracy for my study sample. I selected this type of analysis due to my relatively small sample size and to avoid problems caused by uneven distributions of the data.

I tested independent variables for collinearity using the Spearman rank analysis, Pearson r correlations, Likelihood Ratio, and Fisher's Exact Test, as appropriate. The Pearson Chi-square test was utilized for testing association between categorical variables. Any p-value < 0.05 was deemed significant. Univariate tests were conducted to ensure that the variables included in the logistic regression models were not highly correlated with each other so as not to bias the results. The relationships between underlying factors and farmers' perceived severity of threat and frequency of threat were examined individually using chi-squared tests for binary variables and *t*-tests for continuous variables, as well as in combination using logistic regression analysis.

5.3.1 Possible biases and limitations for interviews about conflict

Farmers living around Shimba Hills welcomed me as a researcher and residents were eager to sit down and take the time to answer my questions. Some studies have shown that farmers may reject and distrust research and researchers because answering questions and allowing outsiders to scrutinize their lifestyle has not led to tangible assistance (Treves, Wallace et al. 2006). However, the farmers around Shimba Hills were eager to help with this research project. Only one respondent refused to speak with us until her husband returned from the field. We attribute this more to the fact that one of my research assistants was wearing army pants and the woman was worried that we were KWS officials investigating the gathering of illegal firewood from the reserve. We have no evidence of any illegal activity, but my research assistants later informed me that they thought this might be why she was initially hesitant to speak with us. Once her husband returned, and we explained our purpose, they were both very helpful and answered our survey.

It was helpful that some of my research assistants were local residents from the area and were fluent in the indigenous Digo and Duruma dialects. Since I was not asking people to reveal illicit behavior, respondents were comfortable during the interviews. Also, by triangulating my questions, I was able to confirm that replies were consistent. I do not feel that respondents were exaggerating their risk or inflating their risk perception because there was no advantage to them to do so. At one location, I accidentally brushed the electric fence with my arm, and there was no current in the fence at all, indicating the fence's uneven effectiveness. Additionally, I saw elephant crop damage first-hand at multiple interview sites, interviewed farmers that were in the midst of guarding their crops, and directly observed the low power and damaged condition of the fence (Figure 5.6).

Figure 5.6 – Damage to crops and electric fence by elephants

However, there was some miscommunication or difficulty understanding a few of the questions in the survey. Consequently, a couple of questions were eliminated from the questionnaire when I realized that respondents found it difficult to answer them or understand their meaning. For example, a question that asked the respondents to determine what percentage of their crops was lost each year to wildlife was eliminated from the questionnaire because it was difficult for respondents to determine the percentages.

Due to knowledge gained during my first field season, the second time I returned to SHNR, I asked more specific questions and also included discussion of preliminary results. Thus, my sample size varies for some of the questions. However, the supplementary data were helpful in comprehensively understanding the conflict situation.

During the second field season, I was interested in investigating whether seasonality, in combination with the completion of the translocation of elephants from SHNR to Tsavo East National Park, played a role in risk perception or reported frequency of threat. My first field season took place during the rainiest period of the year (May/June) while my second field season occured during the dry season (January), a few months after the translocation project was scheduled to have been completed. My intention during the second round of interviews was to visit the same forty households throughout the four strata to evaluate differences between the seasons and to investigate whether the decreased elephant population affected perceptions of risk. However, after completing interviews with ten of the same households and learning that the elephant translocation project had been postponed due to severe drought; responses indicated that both seasonality and the translocation did not play significant roles in reported levels of human-wildlife conflict.

Therefore, instead of continuing to interview all of the same households twice, I decided to interview new households to increase my overall sample size. I completed an additional 30 interviews at new locations within the four strata. Combining field seasons, the final sample size for interviews and the subsequent statistical analysis was 70. A few questions were not answered by all respondents or were skipped when a respondent answered yes or no to a previous question that was related to the following questions. For example, if a respondent reported that they did not have any conflict with elephants; questions related to threat severity or conflict frequency were skipped. This accounts for the fact that the sample size differs for some questions in my statistical analysis. In regards to the households interviewed twice, I made the decision to use only the interviews from the second field season in my statistical analysis since the second season provided a more complete set of responses. A comparison of responses from each field season for these 10 interviews confirms that respondents remained consistent in regards to perceived risk and reported frequency of elephant threat.

Table 5.2 - Sampling design for interviews at Shimba Hills Reserve, Kenya

	NW Region	SW Region	NE Region	SE Region	Total
# of interviews	15 (21%)[a]	17 (24%)	18 (26%)	20 (29%)	70
Gender of respondents	8 male 7 female	10 male 7 female	10 male 8 female	13 male 7 female	41 male 29 female
Proximity to Reserve	40% First-line* 60% Second-line†	47% First-line 53% Second-line	44% First-line 56% Second-line	45% First-line 55% Second-line	44% First-line 56% Second-line

[a] % of total interviews
* First-line = adjacent to the fence around SHNR
† Second-line = second or third row farms

We did not offer monetary compensation for participation in our survey, nor did respondents ask for it. However, as a gesture of goodwill and thanks, we did provide residents with a small token of our appreciation (tea, sugar, milk and bread) for taking the time to answer our questions. This gift was not mentioned until the end of the interview so as to not interfere with, or bias, the results.

5.4 Results

5.4.1 Characteristics of Respondents

The four regions where interviews were conducted vary in numerous ways (Table 5.3). The table reveals the difference in the ethnic majority in the regions around SHNR. The NW, SW, and NE regions consisted mainly of indigenous residents, Digo in the NW and a Duruma majority in the SW and NE regions. Immigrant Kamba farmers composed the majority of the population in the SE region.

Out of all respondents in this study, 96% owned the land where we interviewed them (n=70). Four percent of respondents (all from the NE region) did not own the property, but borrowed land from kin or friends for farming purposes. Forty-four percent of respondents reported owning or borrowing more than one plot of land around SHNR. The majority (89%) of those with more than one plot (n=23) used their second holding for farming purposes as well, while 66% of the 'second plots' were located further from the reserve than the primary plot. The average farm size varied according to region as well, with farms averaging a larger size in the SE region (Table 5.3). The majority of respondents (87%) consistently planted maize as their staple food crop. Tree crops, such as coconuts, cashews and mangoes were the primary income crops in the SW, NE and SE regions.

Figure 5.7 – Varying SHNR landscapes: tree crops (SE region) vs. field crops (NW region)

Table 5.3 indicates that the variation between regions is significant in terms of socioecological variables.

Table 5.3 – Social and agricultural data from interviews

	NW Region	SW Region	NE Region	SE Region	Total	Significance
Ethnic composition (% within Area)	53% Digo 33% Duruma 13% Other (includes Kamba and Kikuyu)	65% Digo 18% Duruma 18% Other	22% Digo 72% Duruma 6% Other	15% Digo 5% Duruma 80% Other	37% Digo 31% Duruma 31% Other	Chi -Square χ^2 = 44.712 p = 0.000 n = 70
Average family size	14	8	10	8	10	Kruskal wallis χ^2= 10.803 p = 0.867 n = 68
Length of residence*	47% Born here 33% National immigrant 20% Local immigrant	41% Born here 35% National immigrant 24% Local immigrant	6% Born here 39% National immigrant 50% Local immigrant	15% Born here 75% National immigrant 10% Local immigrant	26% Born here 47% National immigrant 26% Local immigrant	Chi square χ^2= 21.704 p = 0.010 n = 70
Farm size† (Hectares)	48% Small 40% Medium 13% Large 0.4 – 24 ha (min-max)	75% Small 25% Medium 0% Large 0.4-8.1 ha (min-max)	67% Small 28% Medium 6% Large 0.40-12.14 ha (min-max)	5% Small 40% Medium 55% Large 1.21-18.62 ha (min-max)	46% Small 33% Medium 20% Large 0.4-24.38 ha (min-max)	Chi-Square χ^2= 30.180 p = 0.000 n = 69
Average # of crops	6.0	8.5	8.0	10.0	8.0	Kruskal wallis χ^2= 21.440 p = 0.123 n = 70
% of households w/ maize	93%	82%	83%	90%	87%	Chi square χ^2= 1.240 p = 0.743 n = 70
% of households w/ coconuts	27%	88%	56%	95%	69%	Chi square χ^2= 23.169 p = 0.000 n = 70
% of households w/ cassava	20%	59%	83%	70%	60%	Chi square χ^2= 14.926 p = 0.002 n = 70
Primary income crop type	47% Field crop 20% Tree crop 33% No income from agriculture	13% Field crop 87% Tree crop 0% No income	33% Field crop 61% Tree crop 6% No income	25% Field crop 75% Tree crop 0% No income	29%% Field 62% Tree crop 9% No income	Chi square χ^2= 22.892 p = 0.001 n = 68
Primary food crop	93% Maize 7% Other	88% Maize 12% No food crops on farm	67% Maize 22% Cassava 6% Other 5% No food crops on farm	95% Maize 5% Other	86% Maize 6% Cassava 4% Other 4% No food crops on farm	Chi square χ^2= 17.395 p = 0.043 n = 69

*Local immigrant = moved here from another area around Shimba Hills
National immigrant = moved to SHNR from another part of Kenya
† Small (≤ 3 ha), Medium (3-10 ha), Large (≥ 10 ha)

When respondents reporting serious elephant problems during the dry season were asked why they did not move somewhere wildlife conflict did not exist, 58% of respondents (n=40) said they would not move because they had spent too much time and money invested in their land or because this was their homeland and they could not leave. Thirty-three percent of respondents would move, but they did not have enough money or did not know where they would go. Fifty-eight percent of the immigrant Kamba respondents reported that they would not move because of the time and money invested in their land, 8% did not have the resources to move, and 25% would not leave due to sentimental reasons. Of the indigenous Digo and Duruma respondents, 23% of Digo and 13% of Duruma would not move because of the time and money invested in their land while 23% of Digo and 33% of Duruma stayed because they considered Shimba Hills their homeland. For the Digo, the majority (54%) would move if they had enough money and knew another place where they could buy land while 33% of the Duruma respondents would move, if possible. Interestingly, the indigenous respondents favored leaving the area while the immigrant respondents felt that they had too much time and money invested in the land to move.

Figure 5.8 – Reasons why residents do not move away from SHNR

	Reasons for staying in SHNR despite high levels of human-wildlife conflict		
Ethnicity	Too much time and money invested in their land	Sentimental feeling of a homeland they could not leave	Would move, but no money or no place to go
Digo	23%	23%	54%
Duruma	13%	33%	33%
Other (Kamba and Kikuyu)	58%	25%	8%
Total	**30%**	**28%**	**33%**

Few farmers around Shimba Hills (26%) reported receiving supplemental income from day labor or outside sources. Of those that did report some type of additional income besides farming, 39% earned money by raising and selling livestock or chickens, day labor (usually contributed to the family income by a member of a younger generation) contributed to 33%, and the remaining 28% supplemented their income through employment as teachers or local political positions. The lack of dependable supplementary income sources indicates high vulnerability since the farmers' ability to cope with risk is very low.

5.4.2 Quantitative Results

Variables affecting respondents' perceived risk of elephant threat:

I found significance between various socioecological variables and respondents' *perceived* risk of conflict with elephants. Perceived risk (the dependent variable) was coded from the question "Are your crops currently threatened by elephants?" into a dichotomous variable: yes or no. Among the respondents, 64% indicated that their crops were currently (at the time of the interview) threatened by elephants while 36% perceived no current threat. Frequency of elephant threat was determined by whether or not elephants had raided crops in the past 6 months. A little over half, (57%) of the interviewees reported that they seldom experienced conflict with elephants (no raids of their farms in over 6 months) while 43% indicated that they frequently experienced elephant conflict by reporting a crop raiding rate that ranged from daily to once within the past 6 months. Univariate tests indicated that there was a strong relationship between the farmers who perceived their crops to be threatened by elephants and the frequency of conflict ($\chi^2=15.120$, $p\leq0.0001$).

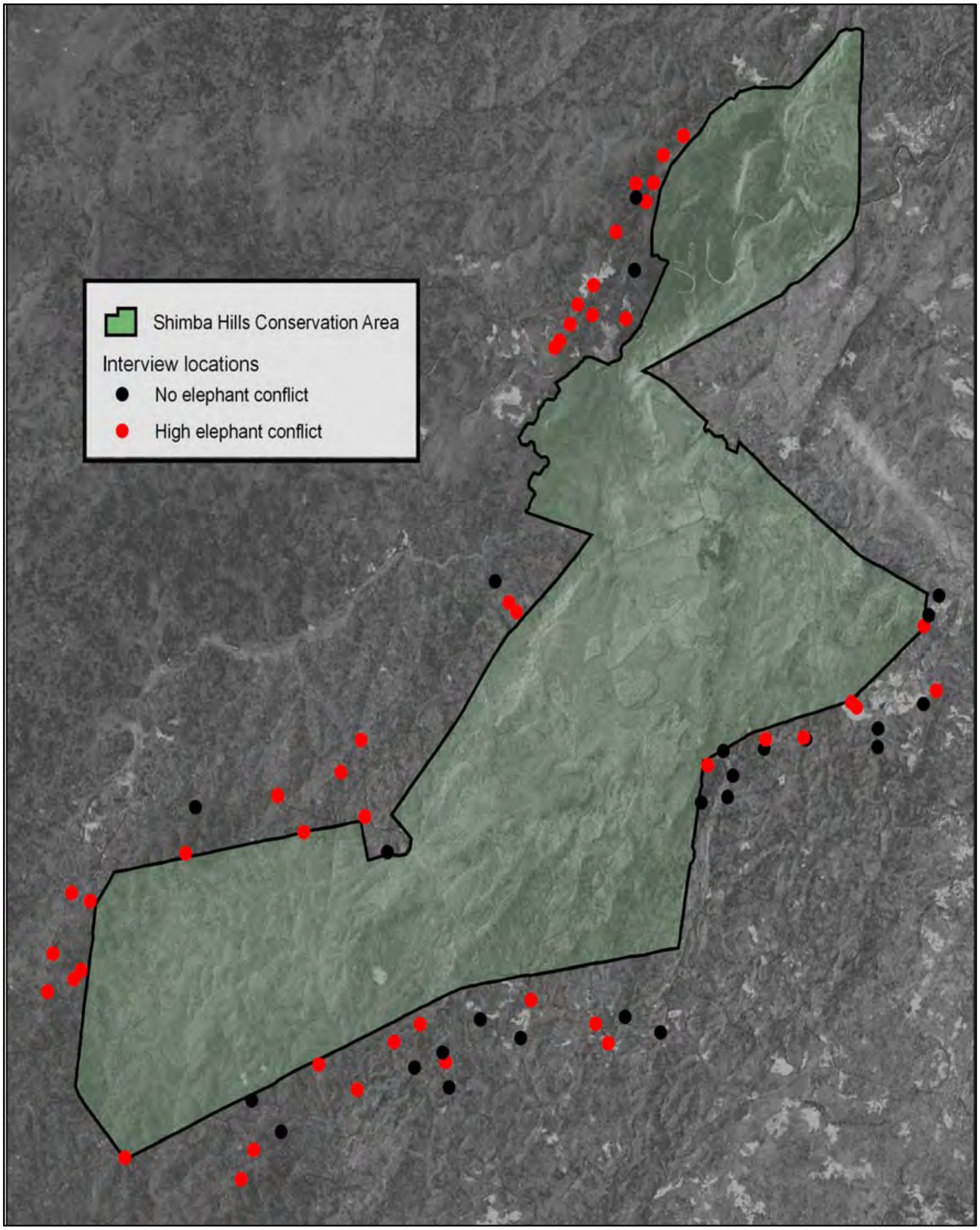
A Pearson chi-square test revealed that perceived risk varied significantly between regions, as measured by respondents who reported their crops currently threatened (χ^2=11.497, p=0.009). Therefore, perceived risk was highly associated with the region where farmers resided (Table 5.4, Map 5.3). Additional Univariate analysis showed that region was highly correlated with a number of other variables in the model (Table 5.3); therefore region was excluded from the multivariate binary logistic regression analysis. Rather, I explored household level and seasonal variables that might be associated with reported risk beyond the influence of region.

Table 5.4 – Univariate analysis (perceived crop threat vs. region)

Percentage of respondents reporting their crops were threatened by elephants vs. region

		Region				**Total**
		Northwest	**West**	**Northeast**	**Southeast**	
Respondents indicating their crops were currently threatened by elephants	Count	13	14	7	11	45
	% within Area	**87%**	**82%**	**39%**	**55%**	**64%**
Respondents indicating that elephants raided their farm in the past 6 months.	Count	9	9	8	4	30
	% within Area	**60%**	**53%**	**44%**	**20%**	**43%**
Total Respondents	Count	15	17	18	20	70

Map 5.3 – Map of perceived elephant threat around SHNR



5.4.3 Household level factors associated with perceived conflict

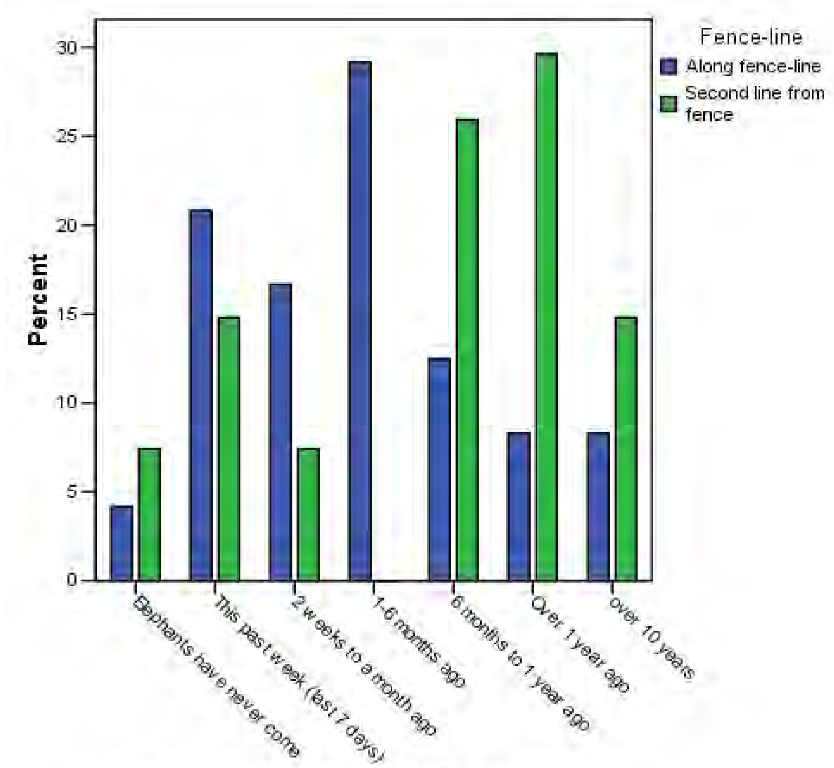
I next examined whether household level and seasonal factors were associated with the two reported measures of perceived intensity of conflict.

Size of farm and proximity to the fence-line (first-line versus second-line)

There was no correlation between the size of farm an individual owned and whether respondents perceived current elephant threat (Mann-Whitney U test: $z=-0.720$, $p=0.472$) or frequency of conflict with elephants (Mann-Whitney U test: $z=0.904$, $p=0.366$). However, distance to the fence-line and frequency of conflict were highly correlated ($\chi^2=7.720$, $p\leq0.005$). Sixty-one percent of respondents living along the fence reported experiencing conflict frequently while only 28% of respondent who lived far from the fence line reported a high frequency of conflict. Similarly, reports of current elephant threat were correlated to distance from the reserve border ($\chi^2=4.180$, $p=0.035$). Seventy-seven percent of residents living along the fence-line reported that their crops were threatened by elephants while 54% of residents far from the fence-line perceived elephant threat to their crops.

Almost all (96%) of respondents living next to the fence guarded their crops during the day as opposed to only 49% of respondents far from the fence ($\chi^2=15.749$, $p=0.000$). Thus, proximity to the park (fence-line) was a leading determinant of perceived conflict (Figure 5.9).

Figure 5.9 – Graph depicting perceived frequency of elephant threat in relation to fence-line



Last elephant raid

Perceived effectiveness of the fence and fence maintenance

Univariate analysis shows that the location around SHNR where farmers resided played a considerable role in perceived effectiveness of the fence. There was a significant difference in the percentage of respondents who felt that the fence did not reduce elephant threat based on the region where they lived. While 87% of farmers in the NW felt that the fence was ineffective in reducing threat, only 53% in the SW, 24% in the NE and 35% in the SE regions felt the fence failed its objective (χ^2=14.587, p=0.002). Out of all farmers interviewed, 47% responded that the fence did not reduce elephant threat (at the time of the interview) while 52% indicated that the fence did reduce threat to some extent. Univariate tests illustrate that people who believed their crops were threatened by elephants (65%)

strongly believed that the fence did not reduce elephant conflict, at the time of the interviews (χ^2=23.002, p=<0.0001). However, 79% of respondents reported that they felt the fence was previously successful in reducing elephant conflict, when the current was electric, not solar powered. Only 22% of respondents felt that the fence had never helped in reducing elephant threat to crops. Those farmers that believed the fence was never successful were much more likely to perceive elephant threat to their crops (χ^2=5.682, $p \leq 0.017$). The data provided no evidence to suggest that the people living adjacent to the fence and those living farther from the fence-line perceived the effectiveness of the fence in reducing elephant threat differently (χ^2=0.160, p=0.689). This is interesting given that fence-line was highly correlated with perception of elephant threat (χ^2= 4.180 p=0.041) and frequency of elephant conflict (χ^2= 7.720 p=0.005).

Univariate tests illustrated that those farmers who helped to maintain the fence at the time of the interviews (87%) were more likely to perceive that the fence helped to reduce elephant threat (χ^2=10.360, p=0.001). One hundred percent of residents who reported that they did not help with fence maintenance felt that the fence was ineffective while only thirty-five percent of residents who reported maintaining the fence felt that the fence did not reduce elephant raids. Fence effectiveness is highly correlated with region (χ^2=14.587, p=0.002) as is whether or not respondents participated in fence maintenance (χ^2=15.580, p=0.001). In the Northwest, only 50% of respondents participated in fence maintenance compared to 100% in the Southwest, 93% in the Northeast, and 95% in the Southeast region. This may help to explain why the highest percentages of perceived threat (87%) and frequency of threat (60%) were reported in the Northwest region. Farmers who planted mangoes (70%) were also more likely to perceive that the fence was successful in reducing crop raiding by elephants (χ^2=4.294, p=0.038).

Guarding crops and defense mechanisms

Farmers who believed their crops were threatened by elephants (65%) were more likely to guard their crops every night (χ^2=4.169, p=0.041). Out of the 80% of farmers who guarded their crops at night, 75% perceived a high threat from elephants (χ^2= 13.627 p=0.000). Additionally, frequency of elephant threat and whether farmers guarded their crops at night was correlated (χ^2=5.548, $p \leq 0.018$). Ninety-three percent of farmers who experienced a high frequency of elephant threat had family members guard their crops every night whereas 70% of farmers who experienced low threat guarded their crops at night. When asked their primary crop defense strategies, noise and shouting was reported first (63%), followed by fire (23%) and throwing sticks and stones (14%) (n=70).

Figure 5.10 – Local farmers guarding crops during the day around SHNR

Crop damage by elephants versus damage by other wildlife species

Past studies on human-elephant conflict demonstrate that farmers often complain bitterly about elephants because of the catastrophic damage they can inflict on a farm while disregarding the losses caused by other wildlife. It was interesting to note that when farmers where asked whether elephants or other wildlife were a bigger problem, not all farmers focused solely on elephant damage. Forty-four percent of respondents (n=70) felt that other wildlife species affected them more negatively than elephants. Farmers with greater perceived threat from other wildlife were disproportionately located in the NE and SE regions around Shimba (χ^2=20.586, p=0.000). The wildlife species that respondents reported as the most problematic were: bush pigs (57%), baboons (24%), monkeys (10%) and warthogs (10%) (n=54).

However, farmers who reported that elephants were a more severe problem than other wildlife were much more likely to perceive that their crops were threatened be elephants (χ^2=20.104, p=0.000). Eighty percent of farmers who experienced frequent elephant threat perceived elephants as a greater threat to their crops than other wildlife. Therefore, the likelihood that farmers who perceived elephants to be a greater threat than other wildlife was highly correlated with perceived frequency of elephant conflict (χ^2=12.550, p=0.000).

Crops cultivated

Maize, bananas, cashew nuts, pumpkins, sugarcane, sweet potatoes, carrots and onions are preferred food crops by elephants, with maize ranking high on the list (Kiiru 1995; Naughton-Treves 1998; Hoare 1999; Treves and Naughton-Treves 2005). However, Univariate analysis demonstrated no strong association between crops and perceived threat, except for farmers who planted cassava (Table 5.5). Farmers who planted cassava (64%)

tended to have a lower perception of elephant threat with 80% of farmers who cultivated cassava reporting no threat from elephants (χ^2= 6.481 *p*=0.011). Cultivating cassava and the frequency of elephant conflict were negatively correlated (χ^2=6.076, p≤0.014). Thus, the results indicate that crop type alone did not strongly affect perceptions of elephant threat.

Table 5.5 – Crops as predictors in Univariate analysis of perceived threat from elephants

Variable	**Perceived Elephant Threat** (current threat/frequency of threat)	**Pearson Chi-Square Value (χ^2)**	**p-value**
Maize	Current threat	0.026	0.594
	Frequency	2.391	0.118
Cassava	Current threat	6.481	**0.010**
	Frequency	6.076	**0.013**
Beans	Current threat	1.224	0.196
	Frequency	0.172	0.431
Bixa	Current threat	0.046	0.515
	Frequency	0.019	0.541
Bananas	Current threat	1.008	0.230
	Frequency	0.021	0.542
Sugarcane	Current threat	1.452	0.181
	Frequency	0.162	0.449
Mangoes	Current threat	0.074	0.504
	Frequency	0.278	0.398
Cashews	Current threat	0.006	0.582
	Frequency	0.093	0.487
Papayas	Current threat	0.033	0.530
	Frequency	0.044	0.515
Coconut	Current threat	1.326	0.188
	Frequency	0.088	0.483
Oranges	Current threat	0.001	0.585
	Frequency	0.021	0.542

While Univariate tests did not find cultivating coconuts significant in relation to perceived threat, planting coconuts was highly correlated with the region the farmers resided in (χ^2=23.169, p=0.000). Farmers who planted coconuts also tended to cultivate bixa (χ^2=13.303, p=0.000), bananas (χ^2=7.636, p=0.006), mangoes (χ^2=22.273, p=0.000), cashews (χ^2=14.643, p=0.000), and oranges (χ^2=24.135, p=0.000) on their property.

Ethnicity

Fifty-five percent of Kamba and Duruma respondents perceived high elephant threat to their crops as opposed to 81% of Digo respondents. Ethnicity did not significantly vary with the first measure of perceived elephant threat ("Are your crops threatened?" $\chi^2=4.895$, $p=0.087$), but did differ significantly with the second measure. Frequency of elephant threat was highly correlated to ethnicity ($\chi^2=8.265$, $p=0.016$). Disentangling the causality of the relationship is challenging given the strong correlation between ethnicity and region ($\chi^2=44.712$, $p=0.000$). This strong correlation precludes including both predictors (region and ethnicity) in a multivariate test.

Table 5.6 - Significant predictors in Univariate analysis of perceived threat from elephants

Variable (Responses)	Perceived Elephant Threat (current threat/frequency)	Pearson Chi-Square Value (χ^2)	P-value
Fence-line (first-line/second-line)	Current threat	4.180	**0.035**
	Frequency	7.720	**0.005**
Guard crops at night (Y/N)	Current threat	13.627	**0.000**
	Frequency	5.548	**0.017**
Tribe (Digo/Duruma/Other*)	Current threat	4.895	0.087
	Frequency	8.265	**0.016**
Land tenure (Rent / Borrow)	Current threat	5.520	**0.044**
	Frequency	2.413	0.174
Replant destroyed crops (Y / N)	Current threat	2.036	0.201
	Frequency	5.192	**0.037**
Cultivate cassava (Y / N)	Current threat	6.481	**0.010**
	Frequency	6.076	**0.013**

* Other = Kamba, Kikuyu, etc.

5.5 Multivariate Analysis

Univariate tests were conducted to eliminate variables with high collinearity so as not to bias the multivariate analysis. The following nominal logistic regression model (Section 5.5.1) illustrates the strongest predictors affecting the dependent variables: respondents' perception of elephant threat and perceived frequency of threat. Table 5.7 describes the eight possible predictors affecting the two dependent variables that were included in the logistic regression analyses.

Table 5.7 - Variables used in logistic regression analysis for perceived conflict

Variable Name	Variable Description	Responses*
Season	Interview season	- Wet season (May/June) - Dry season (January)
Ethnicity	Tribe	- Digo - Duruma - Other (Kamba, Kikuyu, etc.)
Gender	Gender of respondent	- Male - Female
Family size	Number of family members dependent on farm	- 1-40 individuals
Fence-line	Proximity to reserve	- Along fence-line - Second line from fence
Land size	Size of farm	- Hectares (farm size)
Cassava	Do you plant cassava?	- Yes - No
Coconut	Do you plant coconuts?	- Yes - No
* All questions included "no response" as a possible answer.		

5.5.1 Logistic regression models for perception of elephant threat

The following tables (Tables 5.8 and 5.9) show the final nominal logistic regression models with the strongest predictors for the two measures of perceived conflict: current threat and frequency of threat. The analysis demonstrates that several of the socioecological and seasonal variables work together simultaneously to shape risk perception.

Table 5.8- Final model with strongest predictors (for current threat)

	B	S.E.	Wald	df	Sig.	Exp(B)
Season	.598	.598	.998	1	.318	1.818
Ethnicity	-.855	.438	3.809	1	.051	.425
Family size	-.069	.050	1.896	1	.169	.933
Fence-line	-.750	.635	1.395	1	.238	.472
Land size	-.038	.063	.355	1	.551	.963
Cassava	-1.399	.694	4.066	1	**.044**	.247
Coconut	1.505	.733	4.212	1	**.040**	4.504
Gender	-.411	.695	.348	1	.555	.663

The final model for perceived current threat is significant and overall supported, evident by the Chi-square value (18.833) and p-value (0.016). The Cox & Snell R Square and Nagelkerke R Square tests indicate that between 25% and 33% of the variation of the dependent variable is explained by this model. In addition, the Hosmer and Lemeshow Fit test verifies that the model is a good fit by a p-value of 0.218.

Table 5.9- Final model with strongest predictors (for frequency of threat)

	B	S.E.	Wald	df	Sig.	Exp(B)
Season	.818	.620	1.739	1	.187	2.265
Ethnicity	-.906	.443	4.183	1	**.041**	.404
Family size	-.046	.053	.765	1	.382	.955
Fence-line	-1.343	.639	4.421	1	**.036**	.261
Land size	-.036	.064	.312	1	.577	.965
Cassava	-1.295	.622	4.335	1	**.037**	.274
Coconut	.318	.718	.196	1	.658	1.375
Gender	-.296	.731	.164	1	.686	.744

The final model for perceived frequency of threat is significant and overall supported, evident by the Chi-square value (22.467) and p-value (0.004). The Cox & Snell R Square and Nagelkerke R Square tests indicate that between 29% and 38% of the variation of the dependent variable is explained by this model. In addition, the Hosmer and Lemeshow Fit test verifies that the model is a good fit by a p-value of 0.764.

Univariate analysis demonstrates that many factors influence farmers' perception of elephant threat when analyzed individually (Table 5.6). However, the logistic regression analyses illustrate the four main factors that played the most significant role when multiple variables were included in the same statistical models: 1) proximity to the fence, 2) whether or not a farmer cultivates cassava, 3) whether or not a farmer cultivates coconuts, and 4) the respondents' ethnicity[3]. These four variables were the strongest predictors of perceived conflict with elephants around SHNR.

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[3] In this case, ethnicity may be a proxy for region since ethnicity and region were very highly correlated (χ^2=44.712, p=0.000)

5.6 Exploration of Wildlife corridors

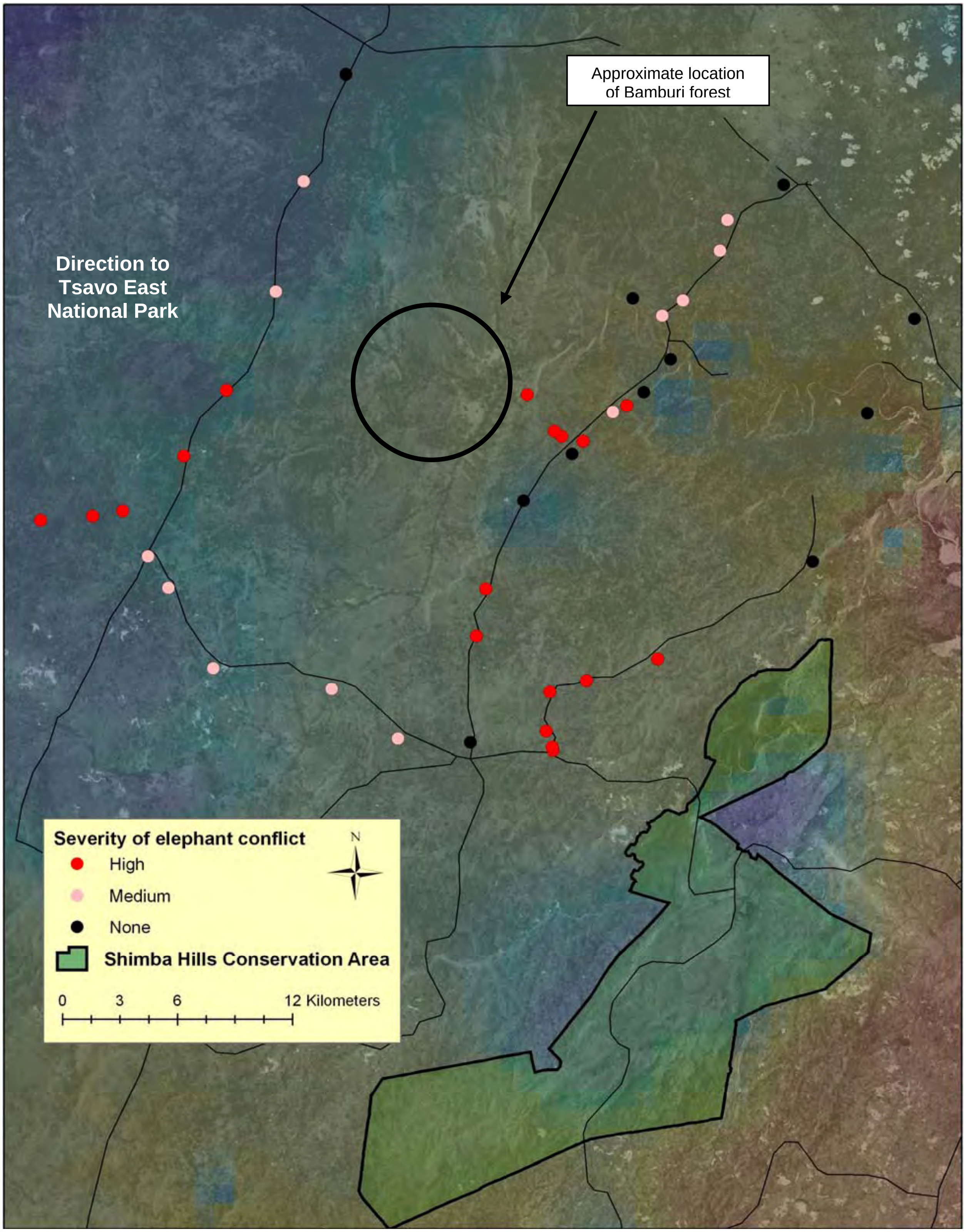
Unfortunately, inadequate data was collected during this research project to determine definitively whether elephants from SHNR were still using their ancient migration corridors and leaving the reserve for a portion of the year to find resources elsewhere. Seventy-four percent of respondents (n=70) around SHNR reported that elephants left the reserve at night to raid crops and then returned to the reserve in the early morning. These respondents did not feel that elephants were leaving the reserve for any other reason beyond searching for food in nearby fields. However, 21% of farmers reported that they thought elephants left the reserve most frequently to raid crops, but at times also traveled to other areas. Of interest is the fact that elder respondents who believed elephants were leaving SHNR for other areas indicated that they went either west or northwest, as opposed to south or southwest.

To investigate the question of whether or not elephants were leaving the reserve by means of ancient migration corridors, during the second field season, we spent two days conducting short interviews in the area to the Northwest and Southwest of the reserve, where elephants might travel if they were indeed traveling to Tsavo East National Park, Kenya or Mkomazi Game Reserve in Tanzania. Due to the rough terrain, we were limited mainly to traversing the roads. Eight-eight short interviews were conducted with residents along the way to learn whether they experienced elephant conflict in their location. Having previously spoken to the main elephant researcher at SHNR, who informed me that he had no knowledge of elephants ever leaving the reserve and moving to other areas, I did not expect to hear many reports of high elephant conflict once we crossed the 5-km radius from the reserve border. To my surprise, not only did we hear reports of elephant passing by various areas, but some people reported conflict as severe as that reported in the areas along the reserve boundary. Responses to the presence of elephants/elephant threat were coded into the following three general categories: High threat (indicated by reported elephant threat every day to within the past two weeks), Medium threat (indicated by elephant threat in the past year), and None (no threat from elephants) (Map 6.1).

The data suggest that some farmers perceived high elephant threat at distances up to and greater than 15-km from the reserve boundary. There is no evidence to determine conclusively whether these conflicts involved resident elephants of Shimba Hills or other families of elephants living outside the protected area. A few informants were sure that the elephants were originally from Shimba, but left the reserve once the fence was not longer powerful. These respondents were convinced that the elephants had found other, smaller patches of forest such as Bamburi forest (Map 6.1), where they now reside, crop raiding in the surrounding farms just as they did from SHNR.

Some residents indicated that there were very distinct paths that the elephant moved along when passing by their area. We were informed that these areas are very dangerous and given time and transportation constraints, we were unable to follow-up on these possible corridors. It would be very interesting to continue this study and investigate these paths for indicators of elephant presence.

Map 6.1 – Map showing perceived elephant threat in dispersal area NW of SHNR



5.6.1 Respondents coping mechanisms:

Differences in crops grown in various regions around SHNR may be due to variation in elevation, soil quality and rainfall as well as crops preferred by certain ethnicities. Approximately half (49%) of respondents (n=70) reported that they changed the amount of land that they cultivated over time with 35% reducing the amount of land that they farmed due to elephant damage. When asked which crops were perceived as most threatened, 38% cited coconuts, 29% thought maize, and 10% reported cassava (n=70). Sixty-three percent of respondents reported that they changed the types of crops that they cultivated, with 70% citing elephant damage as the primary reason. Interestingly, 45% of those who changed their crops stopped planting coconuts and 26% stopped planting cassava while only 1% stopped cultivating maize. This indicates that many farmers modified their crops to exclude those that they perceived were most threatened, except their staple crop of maize. Twenty-seven percent of respondents reported that they changed the types of crops they cultivated and 11% changed the amount of cultivated land due directly to the erection of the electric fence around the reserve. Some respondents mentioned that cultivating a second (or third) plot elsewhere was a way to reduce risk to elephants or other ‘pests’. While Hoare argues that crop raiding incidents are irregular and unpredictable (Hoare 1999), the results around SHNR indicate that farmers perceived high elephant threat to particular crops and modified their cultivation practices in relation to the intensity of threat they experienced.

Two noteworthy examples of social coping mechanisms were revealed during this study. In the Northwest region, respondents believed that cassava attracted elephants. Therefore, community members decided collectively to stop cultivating cassava. One respondent expressed irritation that a neighbor had not yet stopped planting cassava.

Accordingly, results pertaining to crops grown showed only 20% of farmers in the Northwest were still cultivating cassava as opposed to 59% in the Southwest, 83% in the Northeast, and 70% in the Southeast. Another social coping mechanism concerned guarding crops at night, a crop defense strategy conducted by 80% of respondents. Numerous farmers explained how residents living along the fence-line would indicate the presence of elephants by shouting or ringing bells. The noise was a means of scaring elephants away from the crops, but also served to warn other farmers that elephants were approaching.

My research assistants were sure that some farmers used arrows as well to scare elephants away from crops, but none of the respondents mentioned this, as it is illegal. Given the long list of local defense strategies listed previously in the literature review (Chapter 2), I am surprised that we did not hear of any other methods of defending crops. This indicates that residents around SHNR are not familiar about alternate defense strategies that have been successful in other high-conflict locations.

5.7 Discussion

The results from this study are advantageous in terms of developing conflict mitigation strategies around SHNR because they allow an investigation into the factors that shape perceived risk of elephant threat and vulnerability to elephant raiding. Understanding the nature and costs of human-wildlife conflict ideally includes the combined assessment of both the perceived and actual dimensions of the problem (Gillingham and Lee 2003). In Tanzania, Gillingham and Lee found a disjunction between the nature of wildlife crop damage as perceived by local villagers and the extent of actual destruction in the study area. Often, surveys of local perceptions of wildlife threat disagree with quantitative analysis of actual damage because local residents frequently exaggerate the threat that they perceive is the greatest (Bell 1984; Kangwana 1995). Research shows that local perceptions of crop damage tend to be disproportionately shaped by extreme damage events caused by wildlife such as elephants (Naughton 1997). Although this project did not systematically assess actual damage by elephants, I was able to illuminate distinct patterns regarding respondents' perceptions of risk and link these perceptions to socioecological factors in the regional context. I also compared respondents' perceptions to previous research on elephants at Shimba (Kiiru 1995; Kahumbu 2002). Moreover, respondents' perceptions on human-elephant conflict revealed underlying tensions in community-park relations at Shimba Hills.

As several studies document, elephants have the capacity to inflict catastrophic damage during one visit to a field (Smith and Kasiki 2000; Weladji and Tchamba 2003; Bulte and Rondeau 2005; Parker and Osborn 2007). Therefore, while elephant raids may occur less frequently than visits from smaller, less threatening wildlife species, elephants are still locally viewed as the foremost threat. Research has shown that unobtrusive wildlife, such as primates and rodents, or domesticated animals often cause a larger percentage of crop damage over an extended period without generating the same outcry for conflict mitigation assistance (Naughton 1997). This study suggests a similar pattern around Shimba Hills. Residents living in close proximity to SHNR indicated that they were able to cope with small daily losses and felt that their local crop defense strategies were relatively successful against wildlife other than elephants. However, respondents felt helpless against elephants and many reported that there was nothing they could do to stop elephant raids once elephants successfully entered their fields.

Many respondents reported that baboons were a serious nuisance because they were able to use the wooden fence posts to jump over the electric fence to raid crops. The baboons then used the fence as protection when farmers attempted to chase them out of the fields. This is similar to the situation found by Witucki around Aberdares (Witucki 2004). A Shimba Hills fence technician reported that a study was in progress along a sample portion of the fence to investigate whether wrapping the fence posts with wire was successful in keeping baboons in the reserve. This attempt to rectify one portion of the human-wildlife conflict is an example of KWS response to farmers' complaints.

Gillingham and Lee found widespread intolerance of wildlife in communities bordering Selous Game Reserve in SE Tanzania, with 59% of respondents advocating the killing of wild animals that caused crop damage (Gillingham and Lee 2003). Therefore, I was expecting to find similar negative attitudes towards elephants and wildlife around SHNR. However, when farmers were asked what should be done to control elephant raiding, 77% of respondents recommended increasing the power/reinforcing the electric fence or translocation while only 7% advocated culling the elephant population (n=70). These responses indicate that while farmers may be devastated by crop loss to elephants, they are not negative towards that species itself or the government's aim to conserve elephants. The farmers reported that their main concern was the protection of their crops, and the animosity that they did feel was directed at KWS for failing to keep the elephants in the reserve.

Research shows that elephants will often eat any mature crops that are available to them as opposed to seeking out particular types of crops, which indicates mitigation strategies based solely on crop types may be uncertain (Osborn 2004; Sitati and Walpole 2006). However, Naughton-Treves and Sukumar report that elephants selectively forage various crops (Sukumar 1990; Naughton-Treves 1998). While some researchers argue that crop raiding incidents are irregular and unpredictable, the results indicate that farmers around SHNR perceive elephant threat to particular crops and modify their cultivation practices in relation to the intensity of threat they experience (Hoare 1999).

Proximity to protected areas is a risk factor that has been found to shape vulnerability differently based on the study location. A study by Smith and Kasiki in Taita Taveta, Kenya found significantly lower levels of human elephant conflict in areas bordering national parks (Smith and Kasiki 2000). They attribute their findings to the following three factors: 1) greater KWS involvement in elephant control along the national park border than further from the park, 2) farmers along the park border spent more time and effort defending their crops than those residing at a greater distance, and 3) many residents in Taita Taveta stopped growing crops that they believed attracted elephants such as sugar cane, mangoes and bananas (Smith and Kasiki 2000).

Several studies have revealed greater conflict closer to protected areas (Barnes, Asika et al. 1995; Bhima 1998; Naughton-Treves 1998; Hoare 2001; Parker and Osborne 2001) while others do not support the perception that crop damage is a function of proximity to protected areas (Sitati, Walpole et al. 2003). Rao found that the magnitude of crop yield losses varied significantly with the distance of agricultural fields from the forest boundary with the largest losses occurring near the forest edge (Rao, Maikhuri et al. 2002). Naughton found the same phenomenon around Kibale National Park in Uganda (Naughton 1997). The results from this study in Shimba Hills demonstrate a direct correlation between distance from the reserve and perceived elephant threat. Farmers along the fence-line perceived and reported experiencing higher conflict than those farmers whose land was situated with at least one farm between them and the reserve. The results from Shimba substantiate the need to focus conflict mitigation strategies in the area closest to the reserve border.

Smith and Kasiki (2000) found no significant difference between human elephant conflict prevalence before and after the construction of an electric fence in 1996 at Taita Taveta, Kenya. This is likely due to the limited length of the fence (30 km) in their study area. The fence did not encircle the entire protected area, which allowed elephants to walk around the ends. Previous work at Shimba Hills suggests that farmers thought the fence was initially very successful in reducing elephant threat (Knickerbocker 2002). It was only after the torrential El Niño rains in 1997, when a large portion of the electric fence around Shimba was destroyed and replaced with cheaper solar power, that residents reported that the fence was no longer successful in reducing elephant conflict (Gomez-Garcia 2002; Buya 2005). The fact that most farmers at Shimba perceived the fence as ineffective may be due to the fact that fence is better maintained in some areas around the reserve and therefore more effective in preventing elephant raids. One of the Shimba Hills fence technicians reported that the fence does not contain a continuous current throughout the day and night. The current is strongest during midday, when the sun is most intense, but loses much of its current as night approaches (Buya 2005). Considering that elephants primarily raid crops at night (Chiyo and Cochrane 2005), solar power, while sustainable and cheap, does not seem the best option for supplying adequate power to the fence. Additionally, residents around Shimba Hills have been known to steal various components of the fence and solar panels for their own use, decreasing the fence’s efficacy (Buya 2005). In Zimbabwe and Malawi, the conversion of wildlife proof fences to wire snares has proved a menace to wildlife (Bhima 1998; Hoare 2001).

Due to the fact that the translocation project was put on hold as a result of the drought and later torrential rains that took out many necessary roads, I was unable to ascertain any significant difference in conflict before and after the translocation. The few farmers that were interviewed twice reported the same amount of conflict during each interview. The only effect of the translocation project was noted in the Southwest where residents felt that conflict had actually increased, in the short-term, as a result of the translocation process. They felt that elephants in the Northwest were scared by the helicopters and trucks used in the translocation and fled to safety in the Southwest section of the reserve, increasing conflict in this area.

The proposed translocation of elephants by KWS demonstrates the interest that the government has in conserving the biodiversity within Shimba Hills and mitigating human-elephant conflict around the reserve boundary. However, translocation is often a temporary solution to a long-term problem. Fence repair was included in the translocation project design, but the primary emphasis was on the actual translocation. Decreasing the number of elephants in the reserve will help with conserving the ecosystem within SHNR, but without fixing the fence, and more importantly, introducing electric power instead of solar, the well-intended translocation will not be very successful in lessening human-elephant conflict.

One study shows that wealthier and better educated rural citizens may be more likely to report incidences of human-wildlife conflict (Treves, Wallace et al. 2006). When interviewing farmers around SHNR, 53% of respondents stated that they reported every incident of crop damage to KWS officials. Thirty-five percent occasionally reported loss of crops and 13% claimed that they never went to the KWS officials. When asked why crop damage was not reported to KWS or only communicated some of the time, 94% of respondents felt it did not benefit them to report damage to the wildlife officials. They felt that KWS officials were unable to help with crop damage. Respondents reported that when rangers did respond to elephant threat, they came during the day when elephants were in the reserve. Even if the rangers were successful in scaring away the elephants one day, they would return again to raid crops the following evening. For many farmers, too much time and expense was required to travel to the KWS main office in Kwale town when they received no tangible benefit for reporting the damage.

Accurately defining human-elephant conflict areas depends on whether or not crop damage is reported accurately and consistently. Effective management depends on evaluating threat and assessing damage. Therefore, reporting crop damage must be made more accessible to local farmers if it to help in monitoring damage and spatially defining locations to focus conflict mitigation strategies.

5.8 Recommendations for managers on possible strategies for mitigating conflict

When designing effective conservation schemes, protected area managers must carefully weigh the immediate resource needs of the often impoverished people that conduct precarious subsistence agriculture adjacent to the reserve borders against the ecological needs of the wildlife. In order to be successful, wildlife conservation strategies around Shimba Hills National Reserve must be long-term initiatives that promote the conservation of wildlife and biodiversity while concurrently benefiting the local residents who are forced to bear the brunt of living alongside wildlife. Often, these goals are not achieved when potential problems and future challenges are not considered in the project design and there is lack of sufficient follow-up.

In exchange for coping with the perils of living alongside wildlife, financial compensation schemes for wildlife damage were implemented in many locations where conflict is severe (Ngure 1995; Nyhus, Fischer et al. 2003; Bulte and Rondeau 2005; Treves, Wallace et al. 2006), but the information gained from respondents around Shimba Hills did not indicate a huge outcry for compensation. Naturally, farmers would appreciate any type of monetary compensation, but in general, respondents did not feel as though this was the best method for resolving the conflict issue. Most respondents seemed inclined to remain on their land, coping with wildlife as best as possible. As stated previously, many respondents were keen on relocating to low conflict areas, but did not have enough money to buy land or knowledge as to where they could move. With no option of relocation, they instead expressed hope that the government would listen to their problems and establish a successful method for preventing elephants from leaving the reserve. The majority of respondents that did comment on the Mwaluganje Elephnt Sanctuary's system of community shareholders earning income from entrance fees were not entirely positive. One frustrated respondent claimed that he received a minor sum of money the first year after he donated over half of his land to the sanctuary, but had not received any subsequent income.

Figure 5.11 – Shimba Hills elephants browsing in the reserve

Recommendations for alleviating human-elephant conflict around SHNR:

1) I support Hoare's view (Hoare 2001) that elephant damage is not consistent from year to year and data should be collected over a minimum of three years to be comparable to other studies. I recommend a long-term study that combines questionnaire-based interviews with quantifiable data on crop damage around SHNR to assess patterns of crop-raiding and elephant movement.

2) The conversion of the solar power to electric power, fence repair, and establishing provisions for continued fence maintenance should be foremost on the conservation agenda, along with the replacement of the wooden poles with concrete posts.

3) Farmers must be trained in fence maintenance and provided with the tools necessary to maintain the fence. While compensation for crop loss may lead to dishonesty, a system implemented by KWS, where farmers living adjacent to the fence boundary are held personally responsible for the portion of the fence along their land and receive financial compensation for maintaining their portion of the fence (with payments based on length of fence maintained and determined by weekly maintenance inspection by KWS), may be successful. Promoting fence maintenance by farmers through financial incentives will benefit the farmers along the fence-line as well as those living farther from the fence and will play a role in perceived threat by elephants. This system could develop into a community-wide project where farmers split the compensation based on the work they conduct.

4) There should be inquiry into whether cultivating medicinal plants that are high in value, but low in volume would be feasible around SHNR, as well as whether chili could be grown for profit and for use as crop-raiding deterrents.

5) Knowledge about effective local conflict mitigation methods utilized in other areas of high risk should be disseminated to local farmers around SHNR and farmers should be encouraged to work together utilizing various methods of conflict mitigation simultaneously.

6) Ultimately, the government must allocate a significant portion of tourist revenue towards financing continued fence maintenance and ensuring that the fence current is adequate (i.e. electric, not solar-powered). KWS must invest resources in educating local communities living in close proximity to SHNR about conservation and management projects.

7) While the establishment of wildlife corridors introduces a number of difficulties, fencing, though an answer to conflict in the short term, does not address the issues regarding protecting the endemic species and ecosystem within the reserve in the long-term. Extensive research should be directed towards the establishment of wildlife corridors, possibly fenced, along ancient migration routes. I firmly believe that wildlife corridors and dispersal areas are a form of long-term management of elephant problems around and within SHNR that should be considered as an alternative to depending on fencing and translocation, which both have negative aspects.

This research demonstrates the severity of human-elephant conflict around Shimba Hills National Reserve through the analysis of local farmers' perceptions of elephant threat. The results from the air photo analysis reveal the high rates of land use change, primarily in the form of deforestation to make way for agricultural expansion, leading to the ecological isolation of SHNR. Local support is crucial to the long-term success of environmental management programs. Enormous benefits are gained when humans are clearly integrated into the equation for conservation and sustainable development since the people who have resided in conflict prone regions for extended periods are often very knowledgeable about the local natural history (Meffe and Carroll 1997). This "indigenous knowledge" is beneficial as it adds an alternate perspective and aids in the development of reserve management plans. Conservation plans must be designed with participation and input from resident populations, otherwise conservationists risk creating 'paper buffer zones' that are infeasible to implement on a practical level (Naughton and Salafsky 2005). It is critical that protected area managers understand local attitudes towards wildlife in order to build strong alliances; otherwise they may alienate communities and turn people against the notion of conservation (Cocheba and Ndriangu 2000). The aspirations of local communities and other stakeholders are key elements of the conservation equation and are critical to ensuring the long-term sustainability of parks and reserves (Center for Applied Biodiversity Science, Conservation International et al. 2000). Collaboration between the Kenyan government and the public is critical if successful ecosystem management is to be ensured. Mitigating conflict and reducing ecosystem stress are daunting challenges, but by matching innovative conflict mitigation approaches with local knowledge, finding methods for resolving human-elephant conflict around Shimba Hills National Reserve is promising.

Appendix A - Questionnaire

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Questionnaire:
Factors driving local perceptions of elephant threat and LULCC around Shimba Hills National Reserve (2005-2006)

CODES:
-9 = Question not asked
99 = No response - (N/A)
-99 = Response not clear

Q0line	**Along fence-line or away?** 1 = Front-line (along fence-line) 2 = Second line (1 or more farm between fence)
Q0gender	**Gender of informant** 1 = Male 2 = Female
Q1code	**Area/Interview #** A = Northwest (Mulunganji) B = West C = Northeast D = Southeast
Q2wpt	**Waypoint #** ________
Q3loc	**Latitude** ____________________
Q3loc_b	**Longitude** ____________________
Q3loc_c	**Altitude** _________
Q3loc_d	**Name of area** (according to farmer) ______________________________
Q4date	**Date** ____________________
Q5tribe	**Tribe** 1 = Digo 2 = Duruma 3 = Kamba 4 = Kikuyu 5 = Other
Q6fam	**Family Size** (approximate # of people that depend on this farm) __________

Q7move	**Did you (personally/your immediate family – not parents) move to this location or were you born here?** 0 = Born here (did not move to this location) 1 = Moved here (moved here from another part of Kenya) 2 = Moved here (moved here from another location around SHNR) 3 = Do not live here, only use this land to farm
Q7move_b	**Why did you move here? (or use this land to farm?)** 1 = Farming opportunity/to own land 2 = To be with husband 3 = Shimba Hills Land Management Scheme 4 = Born here (no change) 5 = Other
Q8change	**If you changed your location around SHNR, why?** 1 = Better farming here 2 = Less wildlife conflict 3 = Inherited land 4 = Born here (no change) 5 = Other
Q8change_b	**Changed location from where?** 1 = Closer to fence/reserve boundary? 2 = Farther from fence/reserve boundary? 3 = Born here (no change) 4 = Do not know
Q9land	**Do you own, rent or borrow this land?** 1 = Own 2 = Rent 3 = Borrow
Q10size	**How large is your land?** (In acres: 1 hectare = approx 2.5 acres) 0 = Do not know Code = Number of acres
Q11othrland	**Do you own other land around SHNR?** 0 = No 1 = Yes
Q11othrland_b	**Do you rent or borrow other land around SHNR?** 0 = No 1 = Yes
Q11othrland_c	**Where is your other land?** 1 = Closer to fence 2 = Farther away from fence 3 = No other land 4 = Do not know

Q11othrland_d	**Why do you have other land?** 1 = Farming 2 = Later use 3 = Farm here and live on other land 4 = No other land 5 = Other
Q12chngsize	**Have you changed the amount of land that you cultivate over time?** (If no, skip to Q12chngsize_d) 0 = No 1 = Yes 2 = Do not know
Q12chngsize_b	**Why have you changed your amount of cultivated land?** (Answer 1) 1 = Need to farm more land to compensate for loss to wildlife 2 = Need to farm more land because family has gotten bigger 3 = Reduced amount of cultivated land due to elephants damage 4 = Changed amount of cultivated land because of fence (effectiveness) 5 = Drought 6 = Reduced capability to farm (age) 7 = Other 9 = No change
Q12chngsize_c	**Why have you changed your amount of cultivated land?** (Answer 2) Codes = See previous codes (1-7)
Q12chngsize_d	**Have you sold, bought or donated any of your land?** (=/- to this not land not another farm unless adjacent to property) 1 = Sold portion of farm/land 2 = Bought more land (adjacent) 3 = Donated land to MES (and is getting revenue) 4 = Donated land to MES (and is not getting revenue) 5 = No =/- to land (constant size)
Q13amount	**How much of your land is farmed?** (Approximately) 1 = 0-25% 2 = 25-50% 3 = 50-75% 4 = 75-100% 5 = Do not know
Q13amount_b	ELIMINATED FROM QUESTIONNAIRE **What types of crops do you have on your farm?** 1 = Field crops only (corn, cassava, beans) 2 = Cash crop trees only (cashew nuts, oranges, bixa) 3 = Both, majority of field crops 4 = Both, majority of cash crop trees
Q14maize	**Do you presently cultivate maize?** 0 = No 1 = Yes

Q15cassava	**Do you presently cultivate cassava?** 0 = No 1 = Yes
Q16legumes	ELIMINATED FROM QUESTIONNAIRE **Do you presently cultivate legumes?** 0 = No 1 = Yes
Q17beans	**Do you presently cultivate beans?** 0 = No 1 = Yes
Q18cowpeas	**Do you presently cultivate cow peas?** 0 = No 1 = Yes
Q19bixa	**Do you presently cultivate bixa?** 0 = No 1 = Yes
Q20banana	**Do you presently cultivate bananas?** 0 = No 1 = Yes
Q21sugar	**Do you presently cultivate sugarcane?** 0 = No 1 = Yes
Q22ggrams	ELIMINATED FROM QUESTIONNAIRE **Do you presently cultivate green grams?** 0 = No 1 = Yes
Q23mango	**Do you presently cultivate mangoes?** 0 = No 1 = Yes
Q24cashew	**Do you presently cultivate cashews?** 0 = No 1 = Yes
Q25papaya	**Do you presently cultivate papaya?** 0 = No 1 = Yes
Q26coconut	**Do you presently cultivate coconut?** 0 = No 1 = Yes
Q27orange	**Do you presently cultivate oranges?** 0 = No 1 = Yes

Q28spotato	**Do you presently cultivate sweet potatoes?** 0 = No 1 = Yes
Q29pump	**Do you presently cultivate pumpkin?** 0 = No 1 = Yes
Q30other	**Do you presently cultivate any other crops?** 1 – Passion fruit 2 – Jackfruit 3 - Pineapple 4 – Other
Q30other_b	**Do you presently cultivate any other crops?** **1 – Passion fruit** **2 – Jackfruit** **3 – Pineapple** **4 – Other**
Q31primcrop	**What is your primary crop for <u>income</u>?** 1 = Maize 2 = Cassava 3 = Legumes 4 = Beans 5 = Cow peas 6 = Bixa 7 = Bananas 8 = Sugarcane 9 = Passion fruit 10 = Mangoes 11 = Cashews 12 = Papaya 13 = Coconut 14 = Oranges 15 = Pineapple 16 = Pumpkin 17 = Other (jack, pineapple) 18 = None, no income from agriculture (subsistence) 19 = Do not know
Q31primcrop_b	**What is your primary crop for <u>food</u>?** Codes = See previous crop codes (1-19)
Q32income	**Do you have any other income besides farming?** 0 = No 1 = Yes 2 = Yes (but not receiving the expected money i.e. MES)
Q32income_b	**What is your other family income?** (Answer 1) 1 = Day labor 2 = Teacher 3 = Local political position (i.e. chairman) 4 = Community Conservation Program (i.e. MES) 5 = Livestock/chickens 6 = Other
Q32income_c	**What is your other family income?** (Answer 2) Codes = See previous codes (1-6)
Q33chgcrop	**Over the years, have you changed the types of crops that you cultivate?** (If no, skip to Q35) 0 = No 1 = Yes 2 = Do not know

Q33chgcrop_b	**Why have you changed your crops?** (Primary reason) 1 = Political reasons 2 = Changes in crop market prices 3 = Change in road access (to market) 4 = Community reasons 5 = Elephant damage 6 = Damage by other wildlife besides elephants 7 = Soil quality 8 = Other
Q33chgcrop_c	**Why have you changed your crops?** (Secondary reason) Codes = See previous codes (1-8)
Q33chgcrop_d	**If you stopped planting certain crops due to elephant damage, what crops do you no longer plant presently?** (Answer 1) Codes = See previous crop codes (1-17)
Q33chgcrop_e	**If you stopped planting certain crops due to elephant damage, what crops do you no longer plant presently?** (Answer 2) Codes = See previous crop codes (1-17)
Q33chgcrop_f	**If you stopped planting certain crops due to elephant damage, what crops do you no longer plant presently?** (Answer 3) Codes = See previous crop codes (1-17)
Q34fnccrop	**Have you changed the <u>types of crops</u> that you cultivate according to the effectiveness of the fence?** (Did you start planting different crops after the fence was built/working or did you plant different crops when the fence stopped working, etc?) 0 = No 1 = Yes
Q35fncland	**Have you changed the <u>amount of land</u> that you cultivate in response to the effectiveness of the fence?** (Did you plant on more of your land after the fence was built or have you reduced the amount of land that you cultivate because the fence stopped working?) 0 = No 1 = Yes
Q36market	**If you changed crops due to market prices, what crops?** (Answer 1) 1 = Maize 2 = Cassava 3 = Legumes 4 = Beans 5 = Cow peas 6 = Bixa 7 = Bananas 8 = Sugarcane 9 = Passion fruit 10 = Mangoes 11 = Cashews 12 = Papaya 13 = Coconut 14 = Oranges 15 = Pineapple 16 = Pumpkin 17 = Other (jack, pineapple) 18 = Have not changed due to market prices

Q36market_b	**If you changed crops due to market prices, what crops?** (Answer 2) Code = See previous crop codes (1-18)
Q36market_c	**How do you sell your produce?** 1 = We bring produce to the market 2 = Buyers come to farm, we do not go to the market 3 = Buyers come to the farm and we also go to the market 4 = We do not sell our crops
Q36market_d	**What is the distance of your farm from the nearest market to sell produce?** 1 = 0.0 – 0.5 km to market 2 = 0.5 – 1.0 km to market 3 = 1.0 – 2.0 km 4 = 2.0 – 3.0 km 5 = 3.0 – 4.0 km 6 = 4.0 – 5.0 km 7 = 5.0 – 6.0 km 8 = 6.0 – 8.0 km 9 = 9.0 – 10.0 km 10 = 10.0 + km
Q36market_e	**How do you transport your produce to the market?** (Answer 1) 1 = Truck comes to farms to pick up produce 2 = Rent vehicle 3 = Walk (produce on head) 4 = Carry on matatu 5 = Bike 6 = All transport methods 7 = Other
Q36market_f	**How do you transport your produce to the market?** (Answer 2) Codes = See previous codes (1-5)
Q37eles	**Are your crops presently threatened by elephants?** (ambiguous b/c of drought conditions) 0 = No 1 = Yes
Q37eles_b	**Which of your crops are most threatened presently?** (Answer 1) Code = See previous crop codes (1-17)
Q37eles_c	**Which of your crops are most threatened presently?** (Answer 2) Code = See previous crop codes (1-17) 18 = everything
Q37eles_d	**Which of your crops are most threatened presently?** (Answer 3) Code = See previous crop codes (1-17)

Q37eles_e	**When was the last time that elephants came to your farm?** 0 = Elephants have never come 1 = Yesterday 2 = This past week (within past 7 days) 3 = 2 weeks ago 4 = 1 month ago 5 = 2 months ago 6 = 3-6 months ago 7 = 6 months to 1 year ago 8 = 1 year ago 9 = 2-3 years ago 10 = 3-5 years ago 11 = over 5 years 12 = over 10 years 13 = before fence (ambiguous) 14 = last year (ambiguous)
Q37eles_f	**If previous answer was #13, years stated** 0 = No year specified 1 = over 10 years 2 = over 20 years
Q37eles_g	**Did the elephants destroy crops when they last entered your farm?** 1 = Yes 2 = No, they just passed by 3 = No, because we were able to deter them 4 = Other
Q38kws	**Is crop damage reported to KWS?** 0 = No, never 1 = Yes, sometimes 2 = Yes, always
Q38kws_b	**If crop damage is not reported or only reported sometimes to KWS, why?** 1 = No action by KWS/no compensation 2 = Reporting station is very far away 3 = Too expensive to travel to reporting station 4 = No time to report crop damage because I need to guard my crops 5 = Other reasons
Q39fnceles	**Is the part of the fence that is closest to your farm solar-powered or powered by electricity?** 1 = Solar 2 = Electric 3 = Do not know
Q39fnceles_b	**Does the fence currently help reduce the elephant threat on your farm?** 0 = No 1 = Yes 3 = Do not know (i.e. I am far from fence)

Q39fnceles_c	**Was the fence ever successful in reducing conflict with elephants on your farm?** 0 = No 1 = Yes
Q39fnceles_d	**If the fence does not help now, why not?** (Answer 1) 1 = Change from electricity to solar power, solar is not powerful enough 2 = Poles rot or elephants push down poles/fence 3 = Fence is down/broken (lack of maintenance) 4 = Other/do not know
Q39fnceles_e	**If the fence does not help, why not?** (Answer 2) Codes = See previous codes (1-4)
Q39fnceles_f	**If the fence does help now, why do you think it works to keep elephants out of your farm when it does not work in other areas around SHNR?** 1 = Fence solar panels are near my farm, so it works well 2 = We help to maintain the fence, so it works well 3 = I am far away from the fence, so the elephants go to farms closer to the Reserve 4 = Fence has always worked 5 = Other/do not know
Q40maint	**Do you (your family) help to maintain the electric fence presently?** 0 = No 1 = Yes
Q40maint_b	**Did you (your family) help to maintain the electric fence previously?** 0 = No 1 = Yes
Q40maint_c	**If you do help maintain fence presently, why?** 1 = Maintaining fence helps to keep elephants/wildlife out my farm 2 = Community obligation (organized maintenance) 3 = Other reason
Q40maint_d	**If you do not help to maintain the fence presently, why not?** 1 = Helped before when it was an electric fence, but not now because solar powered fence is not working, I (my family) does not help with maintenance 2 = Other people do not help, so we do not help either 3 = Fence maintenance should be done by people living along fence-line 4 = Would like to help, but I have no time 5 = I have not been asked to help 6 = Other people employed to work on fence
Q40maint_e	**How often do you work on the fence?** 1 = Every day 2 = Once a week 3 = Once a month 4 = 3-5 times a year (every 2-3 months) 5 = 1-2 times a year

Q40maint_f	**What do you do to maintain the fence?** 1 = Clear away grass/brush/trees 2 = Physically repair breaks in wire or logs 3 = Other
Q40maint_g	**Who organizes the maintenance of the fence?** 1 = Chairman (community/fence) 2 = No one organizes maintenance, we do it on our own 3 = MES, voluntary, but paid by day 4 = Do not know 5 = KWS
Q41season	**Elephants are the biggest problem for you during what season?** (Answer 1) 1 = Dry (summer) season (~ December through February) 2 = Long rains (~ March through June) 3 = Dry (winter) season (~ July through September) 4 = Short rains (~ October through November/December) 5 = All year long 6 = I do not know 7 = Elephants are not a problem
Q41season_b	**Elephants are the biggest problem for you during what season?** (Answer 2) Codes = See previous codes (1-6)
Q41season_c	**During the season that you have the worst problems with elephants, how often are elephants close enough to your farm/crops that you see them or hear them, and you have to do something to scare them/stop them from destroying your crops?** (The elephants are close enough that they are a direct threat to your personal crops, not to your neighbors) 1 = Every night 2 = around 5 times a week 3 = around 2 – 3 times a week 4 = around 1 time a week 5 = Less than 1 time a week 6 = Never 7 = I do not know
Q42month	**Is there any one month that elephants are a bigger problem than others?** Code = 1-12 (January – December) 13 = All year 14 = Do not know
Q43night	**Do elephants come to your farm during the day or night?** 1 = Day 2 = Night 3 = Both day and night 4 = Elephants do not come to my farm

Q43night_b	**During what time period are your crops most threatened?** (Answer 1) 1 = before 5:00 PM (kabla ya saa kumi na moja jioni) 2 = 5 PM – 8 PM (baina ya saa kumi na moja na saa mbili jioni) 3 = 8 PM – 12 midnight (baina ya saa mbili na saa sita usiku) 4 = 12 midnight – 4 AM (baina ya saa sita usiku na saa kumi usiku) 5 = 4 AM – 7 AM (baina ya saa kumi usiku na saa moja asubuhi) 6 = after 7 AM (baada ya saa moja asubuhi) 7 = Do not know
Q43night_c	**During what time period are your crops most threatened?** (Answer 2) Codes = See previous time period codes (1-7)
Q44receles	**Can you identify different groups of elephants from each other?** 0 = No 1 = Yes
Q44receles_b	**Can you tell the difference between male and female elephants?** 0 = No 1 = Yes
Q44receles_c	ELIMINATED QUESTION FROM QUESTIONNAIRE **Is this a photo of a male or female elephant?**
Q44receles_d	**When elephants come to your farm, do they usually come in groups or as single elephants?** 1 = Groups 2 = Single 3 = Do not know
Q44receles_e	**Do the same elephants (families/groups) come to your farm over and over again or do different groups come?** 1 = Only one group 2 = A few different groups come at different times 3 = New group each time 4 = Don't know 5 = Other
Q44receles_f	**When groups of elephants come to your farm, how large are the groups?** 1 = 2-5 2 = 5-10 3 = 10+
Q45wildlife	**Do you have problems with other wildlife besides elephants?** 0 = No 1 = Yes

Q45wildlife_b	**What other type of wildlife do you have problems with?** (Answer 1) 1 = Bush pig 2 = Baboons 3 = Monkeys 4 = Rats/rodents 5 = Birds 6 = Warthogs
Q45wildlife_c	**What other type of wildlife do you have problems with?** (Answer 2) Codes = See previous other wildlife codes (1-6)
Q46grdday	**Do you guard your crops during the day?** 0 = No (never) 1 = Yes (every day) 2 = Sometimes
Q47grdnight	**Do you guard your crops during the night?** 0 = No (never) 1 = Yes (every day) 2 = Sometimes
Q48grd	**How do you guard your crops?** (Answer 1) 1 = Noise/shout 2 = Make fires or throw/wave fire sticks 3 = Throw sticks or stones 4 = Burn Tires 5 = Other
Q48grd_b	**How do you guard your crops?** (Answer 2) Codes = See previous codes (1-5)
Q49loss	**What percentage of your all of your crops do you lose each year to all wildlife?** (loss of crops to both elephants and other wildlife) 1 = 25% 2 = less than 50 % 3 = over 50% 4 = over 75% 5 = Do not know
Q49loss_b	**What percentage of your crops do you lose each year to <u>elephants</u>?** (hard to determine) Codes = See previous codes (1-5)
Q49loss_c	**What percentage of your crops do you lose each year to <u>other wildlife</u>?** (hard to determine) Codes = See previous codes (1-5)
Q49loss_d	**Are elephants a bigger problem to you or are other wildlife a bigger problem?** (bush pigs, baboons, monkeys) 1 = Elephants 2 = Other wildlife 3 = Both elephants and other wildlife cause the same amount of damage 4 = Do not know

Q49loss_e	**If crop damage by elephants is a bigger problem than other wildlife, why?** 1 = When elephants come, they destroy/eat everything 2 = Elephants are dangerous (we can't scare them away) 3 = Elephants come at night so it is more difficult to see them or prevent them from entering the fields 4 = Other
Q49loss_f	**If crop damage by other wildlife is a bigger problem than elephants, why?** 1 = Other wildlife are small and hard to detect 2 = They use the fence as protection (raid and seek refuge behind fence) 3 = Many different kinds and number of wildlife so total damage is more overall 4 = Other
Q49loss_g	**If you lose a lot of you crops to wildlife and are not making enough money or food from agriculture, why do you stay here? Why don't you move somewhere else?** 1 = Too much time and money invested in land, so cannot move 2 = Unable to sell land 3 = Don't know where else to go, no other land to move to, no money 4 = Homeland/love area (sentimental reasons for staying) 5 = Think that the government will help to reduce the problem and things will get better 6 = Other
Q50replant	**Do you replant the crops that are destroyed by elephants/wildlife?** 0 = No 1 = Yes (all crops) 2 = Sometimes (certain crops)
Q50replant_b	**Why don't you replant the crops that are destroyed?** 1 = Too expensive to replant 2 = The crops will just be destroyed again so it is useless to replant 3 = I plant other crops that are less likely to be destroyed 4 = Other
Q51firewd	**Where do you get your firewood and building materials?** 1 = Inside SHNR 2 = Outside SHNR 3 = Both inside and outside SHNR
Q51firewd_b	**Why do you get firewood/building materials outside of SHNR?** 1 = Illegal to gather wood inside reserve 2 = Scared of elephants 3 = Both (illegal and scared of elephants) 4 = Other
Q52pplmovt	**Are people moving into or out of this area presently?** (near you) 1 = More people moving into area 2 = More people moving out of area 3 = People are not moving into or out of area 4 = People are both moving in and out of area 5 = Don't know

Q52pplmovt_b	**Why are people moving out of area?** (near you) 1 = Problems with wildlife 2 = Better farmland (soil) elsewhere 3 = Other reasons/Don't know
Q52pplmovt_c	**Why are people moving into this area?** 1 = Fence has reduced problems with wildlife 2 = Cheap land 3 = Land/place to farm 4 = Other reasons/Don't know
Q53elecntrl	**What do you think should be done to reduce problems with elephants?** (Answer 1) 1 = Re-build fence 2 = Increase fence power (electricity) 3 = Add wire mesh to keep smaller wildlife in SHNR 4 = Translocate elephants 5 = Cull elephants 6 = Nothing (no problems with elephants presently) 7 = Other solution
Q53elecntrl_b	**What do you think should be done to reduce problems with elephants?** (Answer 2) Codes = See previous codes (1-7)
Q53elecntrl_c	**What do you think should be done to control problems with other wildlife?** 1 = Add wire mesh to fence 2 = Shoot wildlife that enters farm 3 = Increase fence power (solar to electric) 4 = Prevent wildlife from using poles to jump over fence 5 = Do not know 6 = Other
Q54elemvt	**Do you think the elephants are leaving SHNR only to raid crops or are they moving to other areas/reserves?** 1 = Raid only 2 = Move to other areas 3 = Both raid and at times move to other areas
Q54elemvt_b	**If you think that elephants are moving to other areas, where are they moving to?** 1 = North 2 = Northwest 3 = Northeast 4 = South 5 = Southwest 6 = Southeast 7 = East 8 = West 9 = Circle around and return to SHNR 10 = Other 11= Do not know 12 = They are not moving/only raiding

Q54elemvt_c	**Do some of the elephants leave permanently?** 0 = No (they return after some time) 1 = Yes (some leave and do not return) 3 = Do not know
Q55trans	**Did you know that there is a plan by KWS to translocate (move) 400 elephants from Shimba to Tsavo and they have moved about 30 so far?** 0 = No 1 = Yes 2 = Heard something, but not sure
Q55trans_b	**Has this translocation helped to reduce your conflict with elephants?** (Have you had less conflict with elephants lately?) 1 = No (no difference) 2 = Slightly (a little less problems) 3 = Yes (a lot less problems) 4 = No, more problems (b/c elephants were scared in this direction) 5 = Do not know

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