Spatio-Temporal Effects of Land Use Changes in A Savanna Wildlife Area of Kenya

Enos E. Esikuri

Dissertation submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Fisheries and Wildlife Sciences

Dean F. Stauffer, Chair
Patrick F. Scanlon
Richard G. Oderwald
Steve L. McMullin
Randolph H. Wynne
Brian R. Murphy, Department Head

June 1998
Blacksburg, Virginia

Keywords: Kenya, Land Use, Elephants, Habitat Quality, Elephant Damage

Spatio-Temporal Effects of Land Use Changes in A Savanna Wildlife Area of Kenya

by

Enos E. Esikuri

Dean F. Stauffer, Chairman

Fisheries and Wildlife Sciences

(ABSTRACT)

Land use changes have been shown to have significant effects on wildlife species. Sixty three percent of the national Parks and Reserves in Kenya are located in the savannas. Because of the seasonality associated with savanna ecosystems, 75% of the wildlife species and numbers in Kenya occur in savanna nonpark areas. Therefore, conservation of wildlife in Kenya has to address the changes that are taking place in savanna areas outside parks. I studied land use changes and their effects on elephant habitat quality in Amboseli Basin, Kenya. I used visual interpretation to analyze land use changes from satellite images for 1975, 1988, and 1993. I determined that during the evaluation period, conversion of areas to agricultural land has been unidirectional. The hectarage under cultivation was 2,937, 10,950, and 24,476 for 1975, 1988, and 1993 respectively. Trend analysis seems to suggest that during the evaluation period, conversion of areas to agricultural land has followed an exponential function (R^2 = 0.99) in Amboseli Basin. The area under cultivation was 6.9% of the total area studied. This is small but significant considering that agricultural land was almost exclusively located in areas that form the dry season fall back areas. Such areas are important for the survival of elephants and other species during critical periods.

I developed a dry season habitat suitability index (HSI) model for the African elephant based on the density of acacia trees (# of trees > 5 cm dbh/ha) and distance (km) to natural sources of water in the basin. The amount of good quality habitat (i.e., HSI > 0.6) declined from 74,666 ha in 1975 to 54,890 ha in 1988, to 23,208 ha in 1993. This is a

drop of 51,890 ha (65.5%) of good quality habitat in the basin. On the other hand, low quality habitat (HSI < 0.2) increased by 272% between 1975 and 1993. The weighted HSI values in the basin showed a decline, as did the habitat units for the 3 evaluation years. The weighted HSI declined by 0.13 between 1975 and 1993, while the total habitat units (ha) declined by 40,567 ha during the 18 year period. It appears that elephant habitat quality has steadily declined in the Amboseli Basin during the period considered in this study.

The use of nonpark areas by elephants leads to direct interaction and conflicts with humans. Between June 1996 and July 1997, I recorded a total of 489 elephant damage incidents while the Amboseli National Park authorities recorded 143. The damage types were crops, livestock deaths, and human deaths and injuries. The majority of the damage cases involved crop depredation. The Amboseli National Park authorities significantly under-reported the number of elephant damage incidents in the basin ($P < 0.0001$).

ACKNOWLEDGEMENTS

I thank Dr. Dean F. Stauffer, Dissertation Committee Chair, for his support, advice, and friendship from the inception to completion of this study. I thank my Doctoral committee members, Drs. P. L. Scanlon, R. G. Oderwald, S. L. McMullin, and R. H. Wynne for their advice and support. I also benefited greatly from the advice of Dr. R. L. Kirkpatrick.

Financial support for this project was received from The Rockefeller Foundation, African Dissertation Awards, New York. Additional financial support was received from The World Wildlife Fund (WWF), Washington DC. I greatly appreciate this support. I gratefully acknowledge the financial support of The World Bank for my education in the USA. Without the financial support of the Department of Fisheries and Wildlife Sciences, Virginia Tech, I would not have been able to complete my studies.

This research received technical support from the Regional Center for Services in Surveying Mapping and Remote Sensing (RCSSMRS) and the Department of Resource Surveys and Remote Sensing (DRSRS), Nairobi, Kenya. I would like to acknowledge the help of the Fish and Wildlife Information Exchange (FWIE), Virginia Tech, especially Mr. Garrett Schairer for his assistance in the use of GIS facilities.

I thank the Kenya Wildlife Service, especially the staff at Amboseli National Park for making my fieldwork possible and exciting. The support of Dr. B. Wishitemi is greatly appreciated. My fellow graduate students have been fun to have around during the grind of graduate school. I thank the Departmental front office staff, especially Kathryn and Carol for guiding me through the administrative maze while at Tech.

Finally, special thanks to my family for the prayers, support, and love. You are the source of my happiness and, I would not have done it without you, thanks!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1. LAND USE AND WILDLIFE ISSUES IN KENYAN SAVANNAS

1.0. Introduction

The use of land to produce goods and services has been undertaken by humans around the world for most of the 10,000 years of settled agriculture (Houghton 1994, Vitousek et al. 1997). Expansion and intensification of agriculture is now recognized as one of the most significant human alterations of the global environment (Matson et al. 1997). Whereas land transformation for agricultural production has historic, economic, political and social justification, recent trends and rates of conversion of native habitats to croplands have been shown to be decisive factors in species extinction (Vitousek et al. 1997). For example, between 1700 and 1980, the total area of cultivated land worldwide increased by 466% (Meyer and Turner II 1992).

Even though recent figures show that global area under cultivation has declined (especially in Europe, North and Central America, former USSR), Africa has recorded increased area under cultivation while per capita food production has declined (World Resources Institute 1994). This situation creates conditions for extension of cropping activities into new frontiers. However, such changes cannot proceed indefinitely. In fact, global estimates show that the current area under cultivation accounts for 46% to 60% of all the lands suitable for agriculture (Houghton 1994).

Landscape characteristics such as vegetation cover are modified by land use activities. Such modification can lead to an increase or decrease in habitat quality and quantity for various species of wildlife native to an area. Experience shows that most land use activities encourage monocultures and thereby simplify the landscape. This can lead to a reduction in some species' ability to survive in such landscapes and may ultimately lead to local extirpation of some species. Current thinking in conservation identifies habitat conversion as the major threat to biodiversity (Dobson et al. 1997, Vitousek et al. 1997). The impact of anthropogenic activities on wildlife habitat and species will vary depending on the spatial and temporal scales considered and the persistence of the activities in the landscape.

It is important to recognize that land alterations do occur naturally by way of catastrophic events such as fires and climatic variations (e.g., severe droughts). However, because such changes tend to be temporally irregular and physically separate, ecosystems tend to recover from them. In contrast, human alterations of the land tend to have high degrees of persistence and consistency that minimize chances of ecosystems recovering as long as such areas are under continuous use by humans. Recent and current levels of human activities on savanna landscapes appear to be overriding the natural changes to ecosystems brought on by climate variations of the past several thousand years (Ojima et al. 1994, Turner et al. 1990, WCED 1987). Recognition of the effects of land use changes and their effects on ecosystems has led to efforts to understand the socio-political and bio-physical dynamics driving these processes.

1.1. Mainstream approaches to land use/land cover studies

Understanding land use change is rarely a straightforward exercise. First, we need to clearly define and understand what land use change means. Land use has been depicted theoretically as an equilibrating process in which land value is established by inherent characteristics (such as climate, soils), geographic location (especially with regard to market centers and transportation routes), and supply and demand (Birch 1968). Land use is a dynamic process that changes in space and time depending on the prevailing socio-economic and bio-physical conditions.

The distribution of land use types in the landscape produces a land use pattern. Generally, when mapping land use activities, it is the pattern that is observed, measured, and presented. Also, land use patterns are not static. The temporal changes in land use patterns yield what are referred to as trends. Analysis of land use patterns and trends can help in understanding the factors that influence the way land is used (World Resources Institute 1994). A clear understanding of factors driving land use requires integration of the social, economic and cultural causes of land transformation with evaluations of its bio-physical nature and consequences (Vitousek et al. 1997). Whereas economists have focused on the demand side of land value, geographers and planners have tended to focus on location and ownership issues (Houghton 1994).

Bio-physical, behavioral, cultural and political factors and the effects of observed land use changes have generally been neglected in land use studies. Hence, an interdisciplinary approach would seem to be more appropriate in understanding the land use dynamic. This interdisciplinary approach is essential but rarely has been achieved in most studies of land use land cover change. However, such an approach is essential to predicting the course of human-caused land use land cover changes. There are several approaches used to study land use and land cover changes. These methods vary in their accuracy, history of development, ease of data procurement and use, availability, reliability, technological sophistication, and coverage of potential geographic areas of study. Several of the mainstream approaches are briefly discussed below. The methods can be used in combination or alone depending on the objectives of the study and the availability of information.

1.1.1. Historical records and statistics

Croplands generally are well documented in census records in certain parts of the world (Richards 1990). Since the eighteenth and nineteenth centuries, land use statistics compiled at administrative districts of varying scales have been used to provide information on land use change. Where records are well kept and accessible, this approach can be quick to operationalize. This method has been used to estimate forest area lost to croplands in Latin America between 1850 and 1985 (Houghton et al. 1991). This approach may be limited by the fact that certain regions of the world have no or less than adequate censusing schedules.

Few developing countries have the resources to carry out thorough censuses, yet this is where the most rapid population and land use changes are taking place. Available information may thus be quite dated. For example, Kenya (population growth rate of 3.7%) has not had a successful census in the last 19 years (since 1979). Also, records may be inaccessible to researchers, missing, or incomplete. The net effect of such data gaps is to consistently underestimate (or in some cases overestimate) rates and magnitudes of land use/land cover changes. One needs to be aware of such limitations and assumptions before using this approach to analyze land use land cover changes. Consequently, results from such analyses should be interpreted cautiously.

1.1.2. FAO questionnaires to national governments

The Food and Agricultural Organization of the United Nations (FAO) compiles global data on land area and land use on a yearly basis. Land use data are provided to the FAO by national governments in response to annual questionnaires. However, definitions of land use categories may differ from country to country. The FAO therefore has to adjust some definitions in order to fit their definitional categories. Such revisions can have major influences on values reported for certain land use categories. For example, since 1985, the FAO has excluded from the cropland category land used for temporary cultivation but currently lying fallow (World Resources Institute 1994).

The information compiled by the FAO is widely used around the world by national and regional planners. This data source is periodically revised and kept up to date and widely distributed in FAO's *Production Yearbook*. Even though this is a reliable and accessible source of land use information, it has several limitations. First, the data are based on answers to questionnaires. The manner in which responsible government agencies respond to these questionnaires will depend on, a) how they interpret the questions, b) their knowledge of the issue, and c) the political agenda of the government.

Accuracy of the final data provided by FAO will only be as good as that achieved by the responding agency at the national level. Second, there is necessarily a high degree of data aggregation at national levels; various in-country changes that affect sensitive habitats (e.g., wetlands) may be overlooked for reasons of being smaller than the minimum mappable unit at the national level. Third, land use changes can reflect changes in data-reporting procedures and protocols as well as actual land use changes.

Hence apparent trends derived from this method also should be interpreted with caution.

1.1.3. Photogrammetry

The oldest approach in remote sensing of patterns in the landscape involves taking accurate measurements from aerial photographs (Campbell 1987). Since aerial photographs record complex detail of the varied patterns in any landscape, they are widely used around the world to study land use changes and have proven effective in planning activities. Even though they can serve as map substitutes or supplements, vertical aerial photographs have inherent positional or geometric errors that have to be corrected before the information can be used (Campbell 1987). Positional or geometric errors in aerial photos are due to optical distortions (due to camera lens, malfunction), tilt (displacement of focal plane from a truly horizontal position by aircraft motion), and relief displacement (objects appear to lean outward from the perspective of the camera). Fortunately, these errors are well known and can be corrected. Interpreters need to have the training and skills required to make the necessary adjustments in the photos.

This approach may not cover large areas with individual photographs. This means that for a large area to be covered, multiple photographs that ensure overlap have to be taken. This makes the process expensive and as a result, many institutions and countries cannot afford to keep their aerial photograph archives updated. One of the most sure ways to track changes in land use patterns is to continually, and at selected time intervals, survey the landscape. Once this dynamism is lost, then the ability to detect changes (if any) in land use (itself a dynamic activity), is impaired. For example, for the study area addressed in this research, the latest aerial photographs available were taken in 1967. This is well before immigration of people and sedentary agriculture were significant fixtures in this landscape. Therefore available aerial photographs of Amboseli cannot provide land use change information for the intervening period between 1967 and 1998.

1.1.4. Normalized Difference Vegetation Index

The National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) of the USA monitors vegetation using normalized difference vegetation index (NDVI) on a daily basis from satellites. NDVI data are composited or organized on a dekadal basis (i.e., every 10 days). The composite procedure is based on the NDVI, which is a ratio of the near-infrared (NIR) and red (R) radiances [(NIR-R)/(NIR+R)] for each pixel in the scene (Deering et al. 1975). This ratio yields a measure of photosynthetic capacity with high index values (shown as degree of greenness) indicating areas covered by green vegetation and low values indicating scantly-vegetated, unvegetated and cloud-covered areas (Sellers 1985, Townshend and Justice 1986). The fact that NOAA AVHRR data are collected daily gives this approach high temporal resolution. Because of its coverage of large areas, NDVI has been used on regional scales to monitor temporal variations in the areal extent of vegetation in the semi-arid Sahel of Africa (Tucker et al. 1986).

In some areas, vegetation coverage implies land use patterns and some studies have used NDVI taken at different time periods to identify and measure areas thought to have changed as a result of human activities. For example, for all of sub-Saharan Africa, forests and woodlands have been reduced by 44% due to human activities according to analyses based on NDVI comparisons (Houghton et al. 1993). Even though NOAA-AVHRR data are of low cost (Jeanjean and Achard 1997), this approach has the drawback of low spatial resolution (1.1 km^2 for NOAA-AVHRR data). This implies that certain changes will not be detected even if they were locally significant. For instance, a one square kilometer (100 hectares) swamp in the arid savanna may be critical for survival of particular wildlife species during the dry season. However, such an enclave will not show up on NOAA data whether it stays or is removed from the landscape through human activities. Hence, one needs supplementary information before using this approach, especially in areas where small areal changes may have larger impacts in the ecosystem.

1.1.5. Satellite Imagery

Since 1972, satellite information has been acquired and used in the measurement of land cover changes (Campbell 1987, Houghton 1994). Three satellite systems, the Multispectral Scanner (MSS), Thematic Mapper (TM), and SPOT (Systeme Polyvalent pour Observation de la Terre) have been used extensively in collecting land cover information. Collection of data using MSS has been discontinued and TM is currently the major system for resource sensing. TM is a multispectral sensor that collects data in 7 electromagnetic bands, from visible through the thermal infrared. These bands allow researchers to identify and classify surface features with a relatively high degree of accuracy. However, clouds, haze, and rain can obscure Landsat TM data. Also, images have to be taken during daylight. TM bands 4,5,7 (Red, Green, Blue) are used in studying land cover.

Landsat 5 is a TM satellite and was launched in 1984 (30 m spatial resolution, revisit time is 16 days at the equator - 9:30 a.m. equatorial crossing, 185 km swath) and is still healthy and continues to downlink data to EOSAT's Norman, Oklahoma, USA, ground station 3 times a day. It also downlinks daily to 15 other ground stations around the world. India's IRS-1B and IRS-P2 satellites also downlink data collected within the Norman reception area, and within India's reception area, on a daily basis. Landsat provides a regional perspective that affords researchers an understanding of the landscape's interaction with human activities and how this interaction leads to patterning and change in land use. SPOT multi-spectral 20-meter resolution 3 bands) satellite image can also be used for land use/land cover mapping. The SPOT satellite was launched in 1986 and is owned and operated by CNES, the French space agency.

Since aerial photographs and other information sources traditionally used for land use mapping tend to become out of date quickly, satellite imagery provides continuity that is needed. Also, satellite imagery has been shown to be relatively easy to use and less expensive. For example, a single SPOT satellite image was used to capture the land use land cover conditions around The Great Dismal Swamp National Wildlife Refuge, VA, USA. The SPOT scene covered an area of 37 x 37 miles (876,000 acres). The total cost for the exercise was $5,000 (including image data, classification, and film products). Comparative area coverage with aerial photography (60 frames at a scale of 1:48,000) would have cost $14,000 (SPOT Image Corporation 1989). This does not include interpreting, classifying or digitizing costs. However, significant gaps in imagery archives occur since not all areas of the world are covered fully by these satellites. Also, trained expertise is required to interpret the imagery.

1.2. Conditions and Trends in Kenya

1.2.1. Land Scarcity

Kenya covers a land area of 582,646 km^2 with approximately 80% of this area being arid and semi-arid lands (ASAL) receiving < 700 mm of rainfall per year. The country is divided into 7 agro-climatic zones using a moisture index (Sombroek et al. 1982). The index used is annual rainfall expressed as a percentage of potential evaporation. Areas with an index > 50% have a high cropping potential and are grouped into zones I, II, and III. These account for 12% of Kenya's land area. Semi-humid to arid regions have moisture indices < 50%. These are classified into zones IV, V, VI, and VII. They are generally referred to as savanna rangelands and account for 88% of Kenya's land area (Leeuw et al. 1991).

About 80% of Kenya's (estimated 28 million) population is thus concentrated in only 10% of the land that is medium and high-potential agricultural land (Rutten 1992). The Kenyan economy is an agrarian one, and more than 70% of the population is engaged in some form of subsistence and/or commercial agricultural practices. Thus, a substantial amount of the country's land is tied up in agricultural activity compared to other countries (Table 1.1). The quality and quantity of land available for rain-fed agriculture are severely limited. As of 1988, landlessness in Kenya (31.8% of all rural households) was the highest in Africa (Rutten 1992). Also, the distribution of land among the group of owners is highly distorted. The gini-coefficient (a measure of inequality in land distribution, increasing on a scale from 0 to 1) for Kenya is 0.77. This is the second highest in Africa after Madagascar (Rutten 1992). Hence, land scarcity is a real problem to many Kenyan households.

Land scarcity in Kenya can be attributed to, 1) climatic constraints, 2) high gini-coefficient, and 3) inadequacy of nonagricultural options for the expanding population and labor force. The response of the agricultural sector has been predictable: expansion into the ASAL where there is low population pressure. Irrigation and draining of the few wetlands in these marginal areas have in part been the main facilitating actions leading to the expansion of agriculture into these ASALs. Key results of this response include irrigation, expansion into arid and semi-arid savannas, drainage of wetlands, farming along riverbanks and deltas, and conversion of forest into farmland.

Savanna areas have been most affected by this expansion. For example, in northern Kajiado District, the Kitengela wildlife dispersal area around Nairobi National Park has almost completely been occupied by farming, industrial, human and urban settlement activities in the last 10 years. Savannas make up 48.6% (27,682,000 ha) of Kenya's land area (56,969,000 ha) or habitat types (World Resources Institute 1994). The World Resources Institute (1994) estimates that between 1980 and 1989, Kenya lost 43% (11,903,260 ha) of savanna habitat types. Assuming uniform temporal pressure on savannas, this translates to an annual rate of loss of 4.3% or 1,903,326 ha/year for the 1980s decade.

The Kenya Wildlife Service (KWS) lists 54 National Parks and Reserves under its jurisdiction (KWS 1996). Of these 54 National Parks and Reserves, 63% (34) are located in the savanna rangelands. Hence the importance of savanna areas to wildlife conservation in Kenya cannot be overemphasized. Kenya has a very diverse species assemblage of plants and animals that use these parks. The loss of savanna habitats has major implications for most wildlife species in terms of both habitat quantity and quality. Zaire is the only country in Africa with more species of mammals and birds than Kenya (Table 1.2). This underscores the importance of Kenya as a region important for biodiversity conservation.

Kenya's amount of domesticated land is higher than most other countries due to much of the land being used by nomadic pastoral tribes (Table 1.1). However most of these groups are being forced to settle by environmental conditions, government policies, immigration by non-pastoralists due to overflowing densities in high potential agricultural areas, and internal demographic changes (some are abandoning pastoral lifestyles). All these factors come affect wildlife conservation in most parts of Kenya given the migratory nature of the wildlife and the seasonal nature of most parks.

1.2.2. Elephants in savanna habitats

Conventional wildlife management activities in Kenya have been concerned with the balance between wildlife preservation, habitat protection, and more recently, human concerns. However, most conservation efforts have targeted areas within protected area boundaries. The issue of wildlife use of nonpark areas has not been adequately addressed. Surveys done between 1977 and 1983 showed that 75% of wildlife occurred in nonpark areas (Andere et al. 1981, Kufwafwa 1985). The Amboseli Basin was among the areas with the highest wildlife densities outside protected area boundaries. Elephants in Amboseli spend most of the year outside the park. Evidence shows that food is the primary proximal factor determining elephant movement, distribution and use of space (Laws et al. 1975, Owen-Smith 1988). However, food availability in the arid and semi-arid savannas is a function of spatial and temporal pattern of rainfall (Leuthold and Sale 1973). Hence, dry season fallback areas in the savannas are critical for survival of elephant populations. The capacity of savanna areas to support elephant populations is influenced by rainfall patterns and amounts, availability of water, elephant population density, and human land use activities.

An increase in human land use activities (such as farming) will reduce both the quantity and quality of habitat available for elephant use and prevent migrations through what is referred to as ‘compression effects’ (Dublin and Hamilton 1987, Guy 1989, Lewis et al. 1986). Compression effects are usually observed when the usual dispersal routes of the elephant population are removed through such actions as farming and human settlements. The tendency is for the elephant population to experience an artificially high population density due to more individuals being confined, as it were, to a more reduced foraging area.

Elephants also affect their habitats. Elephants have been shown to cause major changes in their habitat and in most cases prevent the disturbed system from returning to its original state (Dublin et al. 1990, Lock 1977, 1993). Such drastic changes in habitat occur under ‘high’ elephant densities, arid and semi-arid conditions with low plant production, and land-use generated compression effects (Hoft and Hoft 1995, Jachmann and Croes 1991, Schmidt 1992). Leuthold and Sale (1973) showed that as habitat quality decreased, savanna elephants increased their mobility in search of food. But with increasing elephant mobility and increasing human land use activities, humans and elephants come into direct conflict. It is therefore important that habitat evaluation be undertaken to assess the capability of savannas to support elephant populations under different land use scenarios.

1.2.3. Human-elephant conflicts

The elephant population in Kenya declined (due to poaching and land use change) from 167,000 in 1969 to 20,000 in 1989 and has risen in the last 8 years (due to strict anti-poaching operations) to the current 26,000 individuals (KWS 1995, 1996). This represents an overall drop in numbers of about 84%. However, the frequency, variety and severity of human-elephant conflicts (i.e., elephant damage) seem to have increased in space and time. The ecological nature of savanna parks and the mobility of elephants will ensure that issues of elephant damage are not likely to decline and may in fact be intensifying as human population and land use changes expand into areas traditionally used by elephants and other wildlife.

It is important to point out that the *fact* of elephant damage has always been a fixture of rural areas where elephant conservation is practiced. Historical records show that elephants have been a problem to farmers in various parts of Kenya for a long time. For example, elephants were regarded as a problem to farmers in Laikipia by the 1920s. In 1934, 80 elephants were specifically shot for control by the Game Department in Laikipia (Kenya Colony 1935). So, the fact of elephant-human conflicts should not be in dispute; the intensification of the *effect* and pattern of such conflicts is what elephant managers and planners need to understand to minimize the conflicts.

From a survey of daily newspaper reports between January 1995 and July 1997, I established that elephants are a major problem in 26 districts representing 6 of the 8 provinces and composing > 60% of total land area in Kenya (Table 1.3). The elephant-human conflict problem is particularly acute where farmland borders conservation areas. Between 1989 and 1995, 272 elephants were shot for control while 148 people were killed and 48 others were injured in Kenya by elephants outside of protected areas (KWS 1996). In some areas, farmers have quit cropping due to constant elephant damage on their crops. In Trans-Mara District, elephants are reported to have developed a taste for human food and local women have had to finish their cooking before 6 p.m. because of night raids by elephants, which sometimes knock down the walls of houses in search of cooked food. In Mwea area, children can only go to school after 10 a.m. and have to leave by 3 p.m. to avoid elephants (other schools in unaffected areas start at 8 a.m. and stop at 5 p.m.). The fear these children experience, and the curtailment of school hours have seriously affected their learning attitudes. One must wonder why with the reduced elephant numbers there are such serious problems with elephants (c.f., in the US, deer problems have been attributed to overabundance in most places).

However for resource managers, I think this is not the right question to be asking especially in a variable landscape with a heavy human imprint. In my opinion, too much attention is being placed on whether or not biological carrying capacity has been attained. The more relevant question to be asking is whether Cultural Carrying Capacity (CCC) has been attained. CCC has been defined as the maximum number of animals that can coexist compatibly with local human populations (Ellingwood and Spignesi 1986, Ellingwood and Caturano 1988). This is a function of the local population's sensitivity and tolerance to elephant ranging and is dependent on local land use practices. Hence, agricultural damage complaints will probably indicate that CCC has been surpassed. It is important to note that even low elephant densities can overshoot the CCC; one rampaging elephant terrorizing a 90 km^2 farming community may be too many elephants.

1.3. Objectives

With the needs and challenges identified in the foregoing sections, this study seeks to further explore opportunities for elephant conservation in the savannas of Kenya within the following objectives.

1. To quantify and describe changes in the amount of land use cover types in Amboseli Basin from 1975 to 1993, with an evaluation of large scale effects on elephant habitat quality.
2. To develop and integrate models to evaluate potential quality of habitats for elephants, and to assess potential impacts of land use changes on the quality of elephant habitat.
3. To analyze in space and time, the effect of elephant foraging (damage) on land use types other than parks.

1.4. Study Area

Amboseli Basin is located in the southeastern portion of Kajiado District (Fig. 1.1). Kajiado District is located at the southern end of the Rift Valley Province. The Republic of Tanzania borders it to the southwest, Taita-Taveta district to the southeast, Machakos district to the east, Nairobi and Kiambu to the north, and Narok to the west. The district is situated between longitudes 36 degrees, 5 minutes and 37 degrees, 55 minutes East and between latitude 1 degree, 10 minutes and 3 degrees 10 minutes South. The physiography of Amboseli Basin is mainly flat to gently undulating plains with some uplands. The plains are situated in the basin within Oldoinyo Orok Hills in the west, Ilaingarrunyoni Hills to the north, and the slopes of Mt. Kilimanjaro to the south. The average altitude is 850-1340 meters above sea level.

The basin covers an area of about 5,726 km^2 and commonly has been referred to as the Amboseli Ecosystem (Western 1994). The geology of the area is of lacustrine ash deposits, olivine gneisses, and volcanic ash mixtures. The soil types that occur here are brown calcareous clay-loams, black clays, ash and pumice, and lava boulders (Kajiado District Atlas 1990). The basin falls within Agro-climatic zones V and VI (Sombroek et al. 1982) with the latter dominating the landscape. These zones form the arid and semi-arid lands. Zone V is rated as land with marginal to medium potential for agriculture. Livestock ranching and wildlife conservation are the major land use activities. Zone VI is classified as land with marginal agricultural potential with extensive pastoralism and wildlife conservation being the major favorable land use activities. Drainage is generally impeded and Lake Amboseli and several springs form the only sources of permanent water. During the wet season, area roads are generally impassable.

The eco-climatic, socio-economic and demographic aspects of Amboseli Basin (AB) have been described extensively elsewhere (Andere 1992a, Bekure et al. 1991, Berger 1993, KWS 1990, 1991, Lindsay 1987, Pratt and Gwynne 1977, Western 1982, 1983, 1989, 1994; Smith 1986, Touber 1983,). Natural vegetation comprises wooded-bush-shrub grassland (Pratt and Gwynne 1977) that supports a high density and diversity of wildlife. AB covers an area of 2,500 km^2 (Western 1983).

Amboseli National Park (ANP) covers an area of 392 km^2 and is only part of the ecosystem that large mammals use. They depend on a much larger area, without which their survival would be severely reduced. This is especially so for the water-dependent species such as elephant, wildebeest (*Connochaetes taurinus,* Burchell), zebra (*Equus burchelli*, Burchell), and African buffalo (*Syncerus caffer,* Sparrman) which move extensively within the basin between the wet and dry seasons. Western (1983) has estimated the foraging range (radius) for a male elephant to be as much as 30 km in this area. There are over 56 species of mammals in Amboseli Basin. More than 425 bird species have been recorded in this area (The World Bank 1993). Principal species and estimated numbers of wildlife within the basin are shown in Tables 1.4 and 1.5.

Amboseli Basin has a variety of habitats that are able to support a high diversity and density of wildlife. These are, 1) the seasonal lake, 2) alkaline plains, 3) *Acacia xanthophloea* woodlands, 4) *Acacia tortilis* woodlands, 5) swamp edge vegetation, 6) swamps, and 7) bushlands (see Chapter 2 for a description of these cover types). Open grassland and bush and woodland vegetation types (Western 1983) dominate the area. The area is arid and semi-arid with a bimodal rainfall regime. Mean annual rainfall ranges from 300 to 800 mm (Leeuw et al. 1991).

The areas around Lake Amboseli receive less than 400 mm of rainfall per annum (Kajiado District Atlas 1990). The first rains fall from October to December and the second rains fall from March to May with a short dry period during January and February and a long dry season from June to early October. Apart from wildlife, the area is used by the pastoral Maasai (Ilkisongo section) for grazing livestock. More recently (beginning early 1980's) sedentary farming and irrigation have become major activities in the more productive areas of the basin (Berger 1993, KWS 1990, 1991, Rutten 1992). There are significant resource use conflicts between farmers, pastoralists and wildlife and indications are that these are getting worse.

Table 1.1. Comparison of land area, population densities, and domesticated land for Kenya, Tanzania and USA

Country	Land area (1000 ha)	Population density, 1993 (per 1,000 ha)	Domesticated land, % of land area[a]
Kenya	56,969	458	71
Tanzania	88,604	325	43
USA	916,660	281	47

Source: World Resources Institute (1994).

[a] Domesticated land is the sum of cropland and permanent pasture. This has implications for wildlife dispersal, migration, use of nonparks, and human-wildlife conflicts.

Table 1.2. Threatened species of mammals and birds in 3 African countries and the USA[a]. The major threat is loss of habitat due to changing land use activities and patterns.

Country	Mammals			Birds		
	All	Endemic	Threatened	All	Endemic	Threatened
Kenya	309	10	17	1067	7	18
Tanzania	306	13	30	1016	13	26
USA	346	94	27	650	70	43
Zaire	415	25	31	1086	23	27

Sources: World Conservation Monitoring Center, World Resources Institute (1994).

a The numbers refer to the total number of *known* species. Threatened species data are from 1990.

Table 1.3. Districts in Kenya with reported human-elephant conflicts, 1995-1997.

Province	Districts affected
Central	Nyandarua, Nyeri, Mwea, Kirinyaga..
Coast	Tana-River, Lamu, Kilifi, Taita-Taveta, Kwale.
Eastern	Kitui, Embu, Tharaka-Nithi, Meru, Isiolo.
North Eastern	Garissa, Marsabit.
Rift Valley	Samburu, Baringo, Elgeyo Marakwet, Laikipia, Bomet, Trans-Mara, Narok, Kajiado.
Western	Mt. Elgon, Trans-Nzoia.

Source: This study.

Table 1.4. The larger mammals of Amboseli Basin.

Herbivores	Carnivores
Elephant *Loxodonta africana*	Lion *Panthera leo*
Cape buffalo *Syncerus caffer*	Leopard *Panthera pardus*
Giraffe *Giraffa camelopardalis*	Cheetah *Acinonyx jubatus*
Hippo *Hippopotamus amphibius*	Spotted hyena *Crocuta crocuta*
Eland *Taurotragus pattersonianus*	Striped hyena *Hyaena hyaena*
Zebra *Equus burchelli*	Hunting dog *Lycaon pictus*
Wildebeest *Connochaetes taurinus*	Golden jackal *Canis aureus*
Hartebeest *Alcelaphus cokii*	Side-striped jackal *Canis adustus*
Waterbuck *Kobus ellipsiprymnus*	Bat-eared fox *Otocyon megalotis*
Oryx *Oryx b. callotis*	Aardwolf *Proteles cristatus*
Bushbuck *Tragephus massaicus*	Serval *Felis serval*
Lesser kudu *Tragelaphus imberbis*	Caracal *Felis caracal*
Bohor reedbuck *Redunca redunca*	African wild cat *Felis libyca*
Impala *Aepyceros melampus*	African civet *Viverra civetta*
Grant's gazelle *Gazella granti*	Honey badger *Mellivora capensis*
Thomson's gazelle *G. thomsoni*	Zorilla *Ictonyx striatus*
Gerenuk *Litocranius walleri*	Marsh mongoose *Atilax paludinosus*
Kirk's Dik-dik *Rhynchotragus kirki*	Dwarf mongoose *Helogale parvula*
	Grey mongoose *Herpestes pulverulentus*
	Slender mongoose *H. sanguineus*
	Large-spotted genet *Geneta tigrina*
	Small-spotted genet *Geneta servalina*

Source: Western (1983).

Table 1.5. The estimated numbers of the main animal species within Amboseli Basin.

Species	Estimated numbers
Elephant	1200
Ostrich	700
Giraffe	800
Buffalo	900
Eland	1000
Oryx	800
Kongoni	400
Grant’s gazelle	3500
Thomson’s gazelle	2000
Zebra	6000
Wildebeest	8000

Sources: DRSRS (1994), Western (1983).

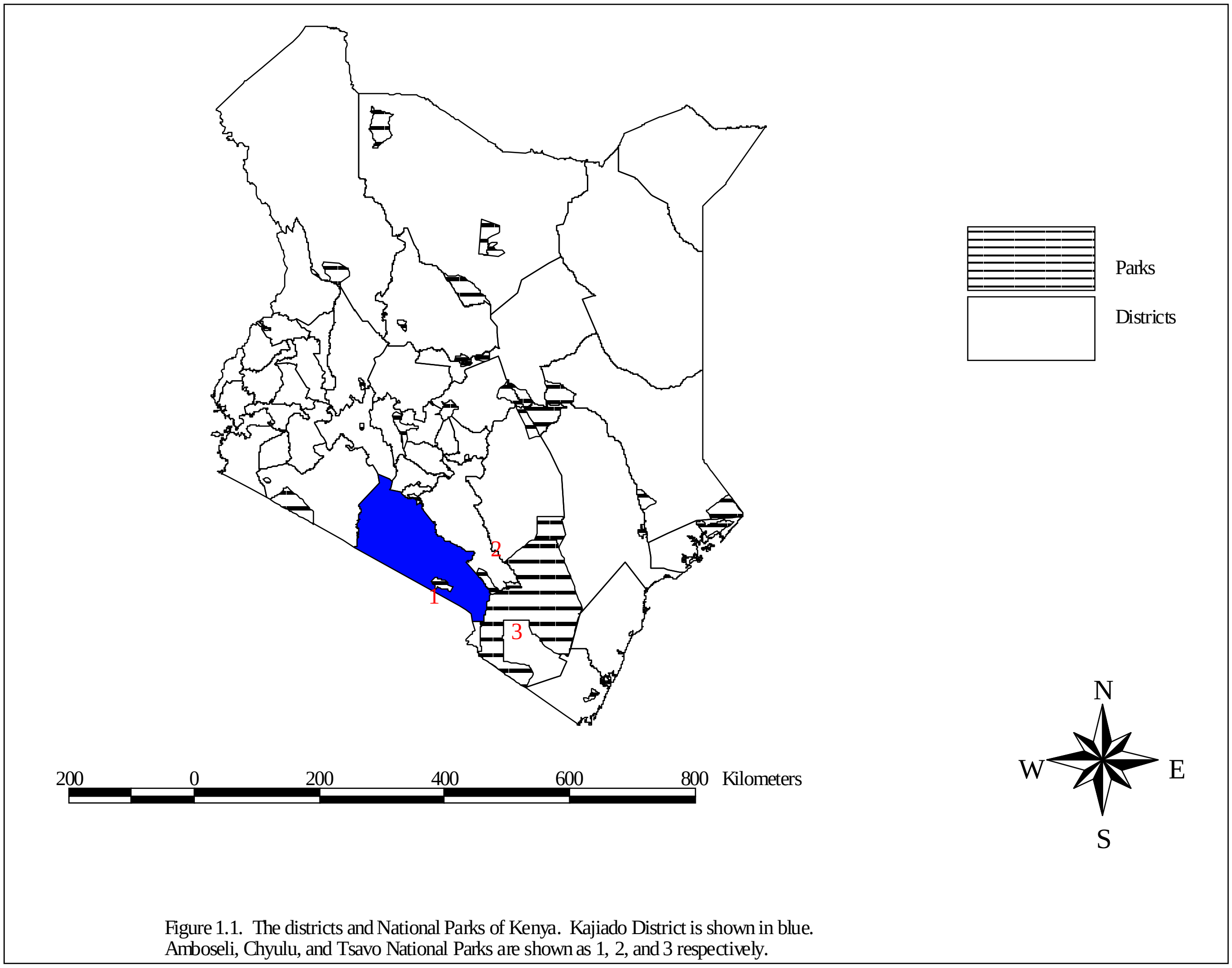

FIGURE 1.1. THE DISTRICTS AND NATIONAL PARKS OF KENYA. KAJIADO DISTRICT IS SHOWN IN BLUE. AMBOSELI, CHYULU, AND TSAVO NATIONAL PARKS ARE SHOWN AS 1, 2, AND 3 RESPECTIVELY.

Chapter 2. Quantification, Description and Evaluation of Land Use/Land Cover Changes in Amboseli Basin from 1975 to 1993.

2.0. Introduction

Over the past two decades, savanna rangelands in Kenya have experienced significant changes in land use patterns due to the increased human population. With the increasing land use activities in these savannas, there appears to be degradation of historically available wildlife habitat outside parks and reserves (World Bank 1993). Wildlife management systems in Kenya rely on savanna areas outside of parks, but the sustainability of these systems is threatened by expanding human activities in these areas. This chapter examines the current state of land use/land cover changes in Amboseli Basin, including the location, level, and rates of changes. The underlying causes of these changes are also reviewed.

It is important to point out that in the context of this study, land use changes are of interest *only* because they are indicators of potential environmental problems, viz. habitat loss, species loss, local watershed damage. Understanding the relationships between various land use changes and species-specific habitat losses in nonpark areas is necessary if appropriate remedial measures are to be taken, and environmentally sustainable economic and social policies are to be identified. An underlying assumption in this part of my study is that economic activities will continue to occur even in areas that are critical to species conservation. In other words, preservation of critical habitats outside parks will continue to be a less attractive option when local landowners consider other economic/subsistence options.

Any strategy to rationalize the development-conservation tradeoff in the savannas will need to be based on the best possible understanding of 1) the current magnitude of the land use change problem, 2) the underlying forces leading to the observed changes, and 3) the likely short-term and long-term environmental effects (externalities) such changes will have on wildlife. The challenge is to use the latest methodology in evaluating land use changes and to use the results to alert policy makers to the environmental consequences of these changes to savanna wildlife.

This chapter examines the land use land cover changes that have taken place in Amboseli Basin between 1975 and 1993 with an emphasis on human induced changes. I then proceed to evaluate the large scale effects of the observed changes on elephant foraging patterns in the basin.

2.1. Methods

2.1.1. Analysis Unit

The choice of Amboseli Basin as the basic unit of analysis was considered appropriate for several reasons. First, the area contains a major protected wildlife conservation area, Amboseli National Park. Amboseli National Park relies heavily on the surrounding nonpark areas for wildlife dispersal (Kufwafwa 1985, Western 1982, 1989, 1994; Western and Grimsdell 1979). Second, any potential to experience serious land use conflicts in this area will invariably involve wildlife as a key factor. Third, the area, like many other savanna rangelands in Kenya, has been undergoing major land tenure reforms since 1989. This is following a government directive to shift the tenure system from communal/group ownership to privately owned individual subdivisions. Fourth, the area has potential for wildlife conservation in a multiple land use system. This recognizes that wildlife conservation is not the only legitimate form of land use in this area. Hence the case study focuses on issues involving small-holder-irrigated agriculture, pastoralism, wildlife conservation, and subdivision of group ranches.

2.12. Evaluation Species

Since not <u>all</u> wildlife species (flora and fauna) could be studied under the present endeavor, the African elephant was selected as the evaluation species. The elephant is used because, inter alia, 1) it is highly visible nationally and internationally i.e., a large species that dominates the eye, 2) it presents great attraction to tourists, 3) it is water-dependent, very mobile and requires large areas and varied habitats to satisfy year-round needs, 4) elephants are known to cause serious damage to life and property outside Amboseli National Park, 5) they are in direct competition for space with other land uses, 6) they occur in large numbers (slightly over 1200 individuals as of July 1997) in the study area, 7) due to their size, savanna elephants can easily be counted during censuses, 8) Amboseli elephants have been intensively studied, and 9) therefore present the most challenges to wildlife managers and agencies (Berger 1993, KWS 1991, Western 1994). In other words, the elephant is an immediate 'high-stakes' wildlife species. Some consider this a keystone species and may therefore 'indicate' pressure on the overall ecosystem.

The elephant is also considered a megaherbivore, which can tolerate the low food quality of a large fraction of available savanna plant biomass, thereby being able to more evenly spread its use across the ecosystem resources (Owen-Smith 1988). Generally, if such a species cannot be sustained in the ecosystem, then it is not possible for the other smaller species to survive easily unless food and water are supplemented via pre-emptive management in order to avoid major die-offs during periods of droughts (Ottichilo 1987). Hence, I believe the elephant makes a good evaluation species.

2.1.3. Land Use/Land Cover Change Analysis

I used satellite image interpretation as the basic analysis tool. The use of remotely sensed information to describe and analyze wildlife-habitat relationships and general ecosystem changes has seen increasing application (Estes et al. 1982, Hepinstall et al. 1996, Hepinstall and Sader 1997, Mead et al. 1981, Pestana 1986, Sperduto and Congalton 1996). Odenyo (1979) used Landsat imagery for cover type mapping and assessment of range conditions in the savannas of Narok District, Kenya. Karime (1990) used both Landsat and SPOT images to identify and delineate cultivated areas and map cover types in areas adjacent to Maasai Mara National Reserve in Narok, Kenya. Andere (1992a, 1992b) used SPOT satellite imagery to map vegetation in Amboseli and Maasai Mara National Parks in Kenya. Ottichilo (1992) has used SPOT images to map large-scale wheat farming and Maasai settlements in Narok District, Kenya. In the savanna rangelands of Zimbabwe, Mushove (1994) used multitemporal satellite image analysis to monitor human encroachment on Mzola Forest Reserve. Results from these studies show that the application of this technology to analysis of land use land cover types in savannas can yield high quality results.

Multitemporal LANDSAT Multispectral Scanner (MSS) and Thematic Mapper (TM) scenes for the study area were acquired from EOSAT (Maryland, USA) through the Regional Center for Services in Surveying Mapping and Remote Sensing (RCSSMRS) and the Department of Resource Surveys and Remote Sensing (DRSRS) in Nairobi, Kenya. I acquired images from 1975, 1988, and 1993 for analysis of land use land cover types. The 1975 image was MSS with a ground resolution of 80 meters while the latter two were TM images with a ground resolution of 30 meters. The images were all taken in the dry month of February. The difference in ground resolutions was assumed be negligible for this study because the total land area converted at a landscape scale level was what I measured.

Landsat imagery acquisition dates (1975, 1988, and 1993) were selected so as to obtain the clearest separation of cover types and also because the precipitation (rainfall) between these 3 years was considered to be comparable**.** Exceptionally dry (drought) or wet years were avoided. In addition, these images were available in usable form; i.e., the cloud cover in the images was small enough to allow acceptable analyses to be performed. These images were used to delineate both land cover associations and changes in cover types/land use types over time and space. The photo-interpretation facilities at DRSRS and RCSSMRS were used in the production of the satellite photos and their interpretation.

The method of assessment of land use changes in Amboseli Basin over the 18-year (1975 - 1993) evaluation period was the "From-To" technique using visual interpretation of satellite images at a scale of 1:250,000. Analysis of Landsat photo products with visual interpretation techniques has been shown to produce quantitative results similar to digital processing of full-resolution data from TM and SPOT (Skole and Tucker 1993). The "From-To" method is a post-classification comparison change detection method (Skole and Tucker 1993). The analyst specifically selects classes of land use/land cover for analysis, which is totally driven by the study's objectives. The images are first classified independently into mappable land use land cover categories (e.g., agriculture, acacia woodland). The classified images can then be compared in a GIS.

An immediate and serious methodological issue is consistency in interpretation of cover types (e.g., shrubland, agriculture) within and between images. Operationally, I achieved consistency by going through 3 iterations. The first step involved the desk/laboratory interpretation of the images by comparing and cross matching them with the available vegetation maps of the area. In the second step, I randomly selected 10 sites (100x100 meters) in each cover type. These were carefully marked on the topographic map of the study area. I then visited each of the sites to check for consistency and to aid in amending the classification. Each site was scored (on a scale of 1 - 5, with 5 being in full agreement with the interpretation achieved in step one) with regard to how close it was to the assigned category.

The scoring was used in the third step, which involved returning to the image interpretation laboratory with the score tables and revising the initial classifications. This process was done twice during the dry months of August 1996 and February 1997. These dry months correspond to the dry period when the images used in the analysis were taken. Interpretation was performed by Mr. Hudson Mukanga (senior photo-interpreter, DRSRS, Nairobi), Mr. Edward Tishale (remote sensing analyst, RCSSMRS, Nairobi), and me.

The next task was to identify and classify the land use/cover types found in the study area. For land use/cover typing, I used the classification system advanced by Anderson et al. (1976) for the United States Geological Survey (USGS) as well as a hierarchical approach to vegetation classification in Kenya developed by Grunblatt et al. (1989). To identify the various land use/land cover types, we visually examined the images for color intensity, hue, pattern recognition, context, texture, and contiguity. Our knowledge of the area also was extensively used in the interpretation process.

I then delineated the different cover types from the satellite images onto transparent mylar paper. The delineated units were overlaid on a 1:250,000 topographic map of the area to obtain their proper locations and orientation. The 3 land use/land cover maps were then digitized separately using Arc/Info. The maps were then analyzed using Arc Info and Arc View. I obtained additional information on land use activities from the DRSRS and the local agricultural office at Kimana.

2.2. Results and Discussion

2.2.1. Characterization of Land Use/Land Cover Types

The final interpretation yielded 9 different cover types that were considered useful and spatially significant in the current analysis. The 9 'current' cover types in Amboseli Basin are Bare Grounds, Swamps, Wooded Grassland, Shrubland, Bushland, Forested Woodland, Riverine Vegetation, Agriculture, and Open Water (Table 2.1, Table 2.12). 'Current' refers to the latest available information from satellite images. For the purposes of this study, 'current' means 1993, which is the latest available satellite image of the study area. I assumed that the extent and location of the major land use/land cover types and changes have not changed greatly at this map scale (1:250,000) between 1993 and 1998. Figures 2.1, 2.2, and 2.3 show the extent and location of the different cover types for 1975, 1988, and 1993, respectively.

2.2.2. Land use land cover areas 1975, 1988, and 1993

My analysis suggests that between 1975 and 1993, Bare ground and Wooded grassland cover types have increased in extent while Shrubland, Bushland, Forested woodland, and Riverine vegetation have declined (Table 2.2). Open water cover type shows a dynamic but stable pattern. However, Agricultural land has increased tremendously.

The magnitudes of land cover changes for each cover type in hectares, between 1975 and 1988 (13 years), 1988 and 1993 (5 years), and 1975 and 1993 (18 years) vary (Table 2.3). Some cover types experienced losses in area while others showed gains in area (Table 2.3). As agricultural land increased, forested woodland and riverine vegetation declined in similar fashion in the Amboseli Basin (Table 2.3, Fig. 2.4). Bushland showed small declines between 1975-1988, but drastic declines between 1988-1993. Shrubland showed drastic declines between 1975-1988, but minimal changes between 1988-1993 (Fig. 2.4).

All 9 cover types have undergone changes in area to varying degrees. Savanna rangelands are extremely dynamic systems usually driven by rainfall amounts and distribution (Behnke and Scoones 1992, Coe 1985, Coe et al. 1976). The natural variability in these savannas produces significant oscillating changes in area of the different land cover types (Bie 1989). Thus, in cases where large variations in rainfall occur (i.e., droughts or extended wet season), certain cover types may decline or expand. Such changes are intrinsic to savannas and wildlife species living there have adopted different strategies for dealing with them.

In areas where significant populations of domestic livestock (extensive pastoralism) and wildlife occur, and when low rainfall leads to low plant production, overgrazing may occur. Such changes may fall within the cyclic pattern of changes common in savanna areas. These changes, especially when they involve decline in cover types, do not in themselves mean withdrawal of habitat from actual and potential elephant foraging. Since savanna vegetation is continuously disturbed (by fire, grazing, droughts), it has adapted to disturbance and in certain cases has the capacity to recover from disturbance (Behnke and Scoones 1992). Therefore, it is not always easy to distinguish between human-induced habitat loss, as opposed to rainfall-driven vegetation change (Tucker et al. 1986, 1991).

The initial challenge is to examine to what extent these changes indicate losses of habitat for elephant foraging outside Amboseli National Park (ANP). For purposes of this study, I considered degradation or loss of habitat in nonparks to involve the effective withdrawal of savanna areas for sedentary agricultural purposes. Therefore changes that were not associated with permanent cultivation and settlement activities were not considered to negatively impact elephant foraging outside ANP. It was not necessary to distinguish between crop types (perennial or annual) since the impact on elephant foraging and conservation will be similar. This approach excludes the potentially reversible vegetation changes that occur naturally, even if these lead to temporary declines in available elephant habitat outside ANP. Degradation assessment, as defined here, attempts to evaluate the capacity of Amboseli Basin to maintain those features of the natural environment that are essential for the survival of the elephant population in the short- and long-term periods.

2.2.3. Land use change and agriculture

Analyses of land use change, especially in these erratic savannas, may be of little interest to elephant managers unless it also provides reliable and consistent evidence of changes in habitats used by elephants in space and time. Conversion of cover types to agriculture is considered a land use activity that significantly modifies initial cover types and replaces natural vegetation (Matson et al. 1997, Wilson and Tupper 1982). The crops grown (Table 2.11) require close care and application of chemicals which ensures that any unwanted plants are completely removed from the crop farms. Since most cultivation in this area is based on irrigation (by gravity using water from natural springs), there is almost no fallow period that would allow abandoned land to establish pastures and other vegetation for possible use by elephants and other wildlife (Table 2.11). This implies that land converted to agricultural production is fairly 'permanent' and unavailable for elephant foraging throughout the evaluation period (18 years).

There was no observable reverse change involving conversion from agriculture to the other affected cover types (e.g., Riverine vegetation). This apparent permanence is what makes agriculture a critical factor affecting the functioning of this ecosystem. It can also be argued that since agriculture modifies both vegetation and soils, this human induced change is more severe than drought induced fluctuations. Of the 9 cover types analyzed, only 5 were affected by the conversion to agriculture (Table 2.4). These are Shrubland, Bushland, Forested woodland, Riverine vegetation, and Wooded grassland. From the 3 time periods considered, Bushland consistently contributed higher percentages to agricultural conversion than did the other cover types (Table 2.5).

Even though Bushland contributed the most area to agricultural conversion, the maximum pressure of agriculture on cover types appears to have been in the Forested woodland zone as indicated by area of each cover type converted to agriculture as a percentage of the 1975 areal extent of cover types (Table 2.5).

Thus of all the changes that occurred during the 18-year evaluation period, 8% of the area went into agricultural development. Indeed the growth in total area under agriculture appears to be appreciable during the evaluation period. At an aggregate level, net land conversion for agriculture was only 2.6% (1975-1988), 4.3% (1988-1993), and 6.9% (1975-1993) of the total land area studied. For each time period evaluated, these net conversions would appear to be insignificant at the outset. However, it is important to consider the location of these conversions to agricultural land in relation to key resource areas within the basin. These conversions have taken place to the east of ANP and mainly in areas formerly occupied by or close to riverine, swamp and springs, and forested woodland cover types (Figs. 2.1, 2.2, 2.3). This also happens to be the only area in the whole basin outside ANP, that has permanent sources of water.

The area affected thus is a critical dry season fallback zone for elephants. Hence in relation to the areal extent of the dry season fallback zones, the area converted to agriculture is significant. Any loss of area in this zone from elephant foraging means limiting the survival options of the elephant population and other mobile species in the Basin. Therefore, even though the actual area converted to agriculture is small compared to the whole basin, the withdrawal of these critical resource zones potentially affects the functioning of the whole system.

2.2.4. Estimates of Rates of conversion to agriculture

The area under agriculture increased by 273%, 461%, and 733% for the time periods 1975-1988, 1988-1993, and 1975-1993 respectively. From 1971 to 1989, land under cultivation in Kajiado District, within which AB occurs, expanded by about 800% (Kajiado District Atlas 1990). Therefore the rate of cultivated area increase in Amboseli Basin (1975-1993) compares closely with the rest of the District. The rates of change within the 3 evaluation time periods were: 1) 1975-1988, 616 ha/year; 2) 1988-1993, 2705 ha/year; and 3) 1975-1993, 1197 ha/year. It appears that the rate of change has steadily increased over the evaluation period. This potential to expand can only be realized by harnessing the limited water resources in this area for irrigation. Indeed most of the areas under cultivation are irrigated. However, rain-fed cultivation does take place in the higher altitude areas of the basin towards the slopes of Mt. Kilimanjaro.

The 1988-1993 time period had a steeper increase in cultivated land than the 1975-1988 interval (Fig. 2.5) with more land area per year being converted to agriculture during the 1988-1993 period. This period coincides with a government directive to subdivide and privatize the rangelands around ANP (Esikuri 1991). Originally this area was communally owned by the pastoral Maasai under the Group Representatives Act of 1969. The pressure to subdivide and privatize these rangelands may have led to the well-watered sections of Amboseli Basin being targeted first by land owners/farmers for clearing and cultivation. When the policy to privatize this area was introduced, more immigrants from agrarian communities in high population density areas were encouraged to move into this area and farm. Many of the immigrant farmers come from the non-pastoral Kikuyu, Kamba, Luo, and Luhya tribes of western and central Kenya. Tenant farmers from the Chagga tribe in Tanzania also moved in (Table 2.11).

The government has traditionally viewed extensive pastoralism as an activity that does not develop the land (Esikuri 1991). Areas used for extensive pastoralism have officially been viewed as open and unused. Therefore substantial efforts and resources (e.g., subdivision and privatization directive) have been put into strategies to settle the Maasai pastoralists by encouraging permanent cultivation. Hence the seemingly explosive growth in area under cultivation between 1988-1993 needs to be interpreted in this light.

2.2.5. Issues and assumptions in trend analysis

Trend analysis is important because it tends to depict the behavior of the phenomenon being measured through time. Figure 2.5 presents trend analysis of the conversion of area to agriculture with linear and exponential functions fitted to the trend line. The linear function had an R^2 value of 0.85 while the exponential function had an R^2 value of 0.99. Based on these values, the case can be made that the exponential function more accurately presents the trend in land conversion to agriculture. Indeed the rate of land conversion to agriculture between 1988-1993 increased by a factor of about 5 times that of 1975-1988. These values seem to support exponential growth in the area under cultivation. However, though this type of trend analysis is useful, it has pitfalls.

One of the potential problems is that trend analysis fails to take into account the underlying causes of the behavior being observed, and factors that might constrain it. Hence, any projection based on trend analysis must assume that the underlying forces that cause the trend remain largely unchanged during the projection period. Thus fitting an exponential function to the land use change data assumes that the percentage increase in land converted to agriculture is constant every year, so that the amounts converted to agriculture each succeeding year constantly increase. To justify such a projection, one would need to explain how new farmers cultivating land farther and farther away from limited sources of irrigation water would be able to irrigate their crops.

The type of irrigation practiced here is open furrow using the natural gradient of the land (gravity feed). Thus the farms have to be downhill from the springs and close enough so that furrows/dykes can supply water to them. Of course using open furrows in an area that has a very high evapotranspiration rate leads to losses through seepage and evaporation and has implications on the amount of water that effectively gets used for irrigation. According to the Kimana Area Agricultural Officer, water sharing is becoming a problem in some parts of the irrigated area (Mr. Kimani, pers. comm.). These limitations imply that the physical area that can be converted to agriculture is limited under current conditions.

I used distance (km) from water source to estimate the maximum area that could be converted to agriculture under current technological conditions (i.e., assuming open irrigation, no pumping of water) to be 60,000 hectares. It is important to point out that this is a liberal estimate that assumes that the current springs and seasonal streams have the capacity to provide adequate water for expanded irrigation. This may not be true. Of this potential area, 24,476 ha had already been put to agricultural production as of 1993. Hence, under a best-case scenario, only 35,524 ha remain for potential conversion to agriculture. The assumption of continued exponential growth in area under agriculture is untenable, at least on a priori grounds (Fig. 2.6). The exponential curve does indeed exceed the 60,000 ha line that represents the maximum possible area that could be converted to agriculture under current technological conditions. Also, trend analysis uses selected years (1975, 1988, and 1993) for evaluation which implies that conversion of land to agricultural production is a discontinuous point-process or 'event' taking place at a particular point in time. The reality is that land use change is a continuous process that is affected by factors external and internal to the process.

The comparison between two points in time (i.e., 1975-1988, 1988-1993, 1975-1993) gives a linear change. To be able to study the trends in the intervening periods, say between 1975 and 1988, more intensive temporal analyses are needed. The current analysis assumes that land cover conversion has taken place in a continuous manner from 1975 to 1993. It is not certain whether this change is a linear function or whether it follows some type of non-linear function. Ideally, it would be best to repeat the analyses on a yearly basis. But due to limitations of time and cost, it is difficult to achieve such temporal resolution by doing yearly analyses. However, even given the limitations and assumptions of the exponential trend, the evidence indicates strongly that growth of the area under agricultural production has been exponential, at least during the period of analysis. There is no evidence to contradict the exponential growth predicted in these analyses. However, it is likely that this growth will become asymptotic in the coming years as different constraining factors come to bear on the conversion process.

2.2.6. Indicators of real changes in land conversion pressure

Land use land cover maps can show the extent of anthropogenic factors in modifying habitat suitability and hence use by wildlife (Hepinstall et al. 1996, Sperduto and Congalton 1996). As pointed out, the savanna rangelands in AB have been used for centuries by the Maasai pastoralists. However, their opportunistic and extensive use of the savannas outside ANP has not had any noticeable negative effect on the elephant population. In fact, elephant numbers have continued to increase even as the number of livestock kept by pastoralists has increased. Indeed their extensive nomadic use of the savannas does not in itself change the way elephants and other wildlife use the rangelands. It is important that the indicators of real changes (i.e., changes that are aseasonal, unidirectional, and have low reversibility) be traced and monitored. Beginning in the early 1970's, there have been various pressures targeted at changing the land to a different resource use system. Some of the pressures that signify permanence and 'one-way' or unidirectional change in land use and possible withdrawal from elephant foraging are briefly presented below.

2.2.6.1. Agriculture

The major factor determining land use change is the growth of agriculture, mainly to the east of Amboseli National Park. The evidence from this analysis indicates that agriculture in this area continues to grow steadily (Fig. 2.5). Even stronger is the evidence that the change to agricultural conversion has been unidirectional. In the 18 years analyzed, no measurable area that had been converted to agriculture has been left to revert to any other cover type. The back and forth changes experienced in the other cover types was not observed in the 'agriculture' cover type. If more efficient irrigation methods are used, it appears more land will be put into agricultural production.

2.2.6.2. Livestock densities

The issue of why the livestock stocking rates in the arid and semi-arid pastoral savanna areas are so high has confounded range ecologists and policy makers for decades (, Behnke and Scoones 1992, Scoones 1993, Wilson and Macleod 1991, Wilson and Tupper 1982). The rangelands in Amboseli Basin have at different times experienced overstocking and overgrazing (Western and Finch 1986). The Kajiado District Atlas (1990) shows that the area to the east of ANP is overstocked more than 50% beyond the recommended densities. The persistence of high cattle, sheep and goat populations has been interpreted in terms of the exploitation of environmental heterogeneity at different spatial scales. The Maasai mainly achieve this through the nomadic herding strategies adopted. However, a combination of increased agricultural activities and high stocking densities can indirectly but severely affect savanna cover types, especially through overgrazing.

There was a steady increase in the density of cattle, sheep and goats over the 1975-1993 period (Fig. 2.7). Between 1975 and 1988, both decreases and increases in stock numbers were recorded. However, after 1988, there appears to have been only increases well above the upper level densities that had been achieved before. In fact, beginning in 1988, there appears to have been an almost exponential growth in the number and density of sheep and goats combined. Growth in cattle density has not been nearly as dramatic. The growth in numbers of sheep and goats almost parallels the growth in area under cultivation. These persistent high densities are indicative of sustained grazing pressure in the basin and may lead to rangeland degradation. The supplementary data on stocking densities cannot be observed by satellite remote sensors.

2.2.6.3. Human population densities

Human population density increased in Kajiado District between 1969 and 1989 (Table 2.6). Loitokitok Division has an area of 5,726 km^2, basically forming the Amboseli Basin ecosystem. Population of this area in 1979 was 42,781 persons with a density of 7.5 persons per square kilometer. The 1990 projections for Amboseli Basin show a population of 75,138 persons with a density of 13.1 persons/km^2 (KDDP 1988). The population densities for Amboseli Basin are: 7 persons/km^2 for 1978, 12.5 persons/km^2 for 1988, 13.1 persons/km^2 for 1990, and 15 persons/km^2 for 1993 (Table 2.7). All the values for human density in Amboseli Basin are slightly higher than the values attained for the whole District.

There has been significant immigration by people from non-pastoral tribes. In a 1988 survey of farmers (n = 4,305) practicing both rainfed and irrigation farming in Loitokitok Division, Maasai accounted for 27%, Kikuyu accounted for 41%, and the other tribes (Kamba, Luhya, Luo) accounted for 32% (Kajiado District Atlas 1990). The migration of people from agrarian societies to this area has contributed to the growth of agricultural activities. The increase in migrant settlers in Amboseli Basin mirrors the same trend observed for the whole of Kajiado District between 1948 and 1989 (Table 2.8). The steady increase in the non-pastoral component of the population has significant influence on the rates and amounts of land use land cover change.

2.7. Effects on large scale elephant foraging in Amboseli basin

The ecological implications of the described changes on large-scale elephant foraging patterns are varied. The productivity of the basin during the wet season is adequate to provide for the elephant and other wildlife populations (Western 1983). The area converted to agriculture (21,539 ha) in the period 1975-1993, is very small relative to the whole area in the basin (309,119 ha) that was not under crops as of 1975. Thus the land use changes so far recorded probably have little or no effects on the wet season dynamics in the basin. However, the scenario is quite different in the dry season. Therefore, the ensuing discussion centers on the dry season dynamics.

Even if the total area converted to agriculture is small (6.9%) when compared to the area of Amboseli Basin, the effects of this change could significantly affect elephant ecology. The mobility of elephants has been presented as a strategy that enables them to exploit patchy resources at the landscape scale (Leuthold and Sale 1973, Tiezen et al. 1989). However, movement alone cannot guarantee survival and persistence of the elephant population. There has to be an array of resource areas that offer food resources within the landscape in which the movements occur. Spatial heterogeneity thus has an impact on the interaction between the elephant population and resources, at different levels in a hierarchy of scales.

It may be argued that persistence of the elephant population in Amboseli is assured by the expansion of the spatial range of resource use (through daily and seasonal movements) and through the exploitation of spatial heterogeneity and 'critical resource' patches in the basin. The critical resource patches in the basin are the riverine vegetation, swamps, and areas around lakes and springs (Western 1983). These key resource areas are the ones that have been under the most pressure from agriculture. Most of the area which is now under cultivation has been withdrawn from these critical resource patches to the east of ANP (Fig. 2.3). These fallback zones are critical in offsetting the dry season food constraints for elephants, other wildlife and pastoral livestock. During the dry season when most of the basin has very low forage quality, elephants move to these relatively small but critical areas of high vegetation production. Hence the withdrawal of these areas for agriculture has reduced the resources available to sustain elephants during the dry season.

The area currently under cultivation should be viewed as areas withdrawn from the critical dry season resource patches. In advancing this argument, I assumed that this area was available and accessible for elephant foraging prior to the current agricultural activities in this area. This is a valid assumption given the fact that there is no evidence, demographic or otherwise, to the contrary. Studies have shown that only pastoral Maasai used this area during critical periods (Kituyi 1989, Lindsay 1987, Western and Lindsay 1984, Western and Grimsdell 1979). Even though my study did not assess exactly how much dry season productivity has been lost, the frequent crop raiding behavior by elephants (Chapter 4) should be an indicator of increasing resource scarcity in the basin. Hence the main effect of land use changes has been to further compress the dry season area and resources available to elephants. Even though the actual areal extent of the cover types lost to agriculture is small, the capacity of the whole basin to support elephants and other animals during the critical dry periods is being progressively limited by the land use change activities.

Since farmers have taken over most of the swamps outside the park, pastoralists now drive their livestock into the park for water and grazing around the permanent swamps inside the park. This is illegal and is constantly straining the relations between the park authorities and the local Maasai. An additional effect of too many domestic livestock inside the park during the dry season is that cattle, sheep, and goats effectively compete with elephants and other wildlife for the extremely limited forage. This increases the pressure for the elephants to wander outside the park in search of food.

The number of patches of agricultural land increased between 1975-1988 then declined drastically between 1988-1993 as the actual area increased, and patches were combined (Table 2.9). This was due to the expanding farmlands coalescing into each other and forming a more uniform coverage of larger patches (Figs. 2.1, 2.2, and 2.3).

It is evident that agricultural land forms an almost continuous ‘barrier’ to the east of Amboseli National Park (Fig. 2.3). Movement of elephant herds between Amboseli, Chyulu Hills National Park, and Tsavo West National Park has been documented

(Western and Ssemakula 1981). The relative locations of Amboseli (392 km^2), Chyulu Hills (471 km^2) and Tsavo West National (9,065 km^2) Parks are in Figure 1.2 (Chapter 1). Both Chyulu and Tsavo West are larger and have a relatively richer vegetation component compared to Amboseli (Andere 1992b, The World Bank 1993, Sombroek et al. 1982). In fact, Chyulu is the main water catchment area for the Mzima Springs, which supplies water (by gravity) to Mombasa town (The World Bank 1993). Thus, Chyulu and Tsavo West have the capacity to provide an expanded resource base for Amboseli elephants.

The spread of agriculture to the east of Amboseli has probably impeded, to some degree, the movement of elephants between these conservation areas. A recent phenomenon has been the observation of Amboseli elephants moving into the Mt. Kilimanjaro area in Tanzania during the dry season. While hunting is banned in Kenya, Tanzania allows hunting. Some marked Amboseli elephants have been legally shot in Tanzania during the dry seasons in the last 3 years; and in 1995 and 1996, Kenya and Tanzania were involved in diplomatic disputes over the shooting of Amboseli elephants in Tanzania. The movement of Amboseli elephants into Tanzania could be explained by the withdrawal of critical dry season areas for cultivation in Kenya, and increasing disruption of their traditional movement routes by agriculture and settlements to the east of the park. The effect of agricultural expansion to the east of Amboseli seems to be the limitation of access to key resources in Chyulu and Tsavo West during critical periods.

Parker and Graham (1989) have estimated that in Kenya, elephants were excluded from highly fertile and high-rainfall agricultural areas by human activities at densities exceeding 82.5 persons/km^2. In Zimbabwe's less productive savannas, human densities over 18.9 persons/km^2 excluded elephants (Parker and Graham 1989). The arid and semi-arid savannas of Amboseli are more variable and even less productive and human population densities have doubled in the last 15 years (Table 2.7).

The human population density in Amboseli Basin was 15 persons/km^2 in 1993 which is close to the threshold estimate of 18.9 persons/km^2 in Zimbabwe. It is important to note that due to climatic constraints, distribution of population is clumped in areas where water is available. Therefore, densities within certain areas of the basin are higher than 15 persons/km^2.

2.8. Determinants of future pressures affecting land use changes

Future pressures to expand area under cultivation will reflect underlying socio-economic dynamics, government policy choices, and climatic constraints. The prevailing government policy is to encourage as much settlement and cultivation as possible regardless of the potential of the area to sustain cropping activities. Unless it is reconsidered, this generalized policy has, and will continue to encourage landowners to withdraw critical wildlife areas for cultivation.

Availability of water for irrigation and efficiency of utilizing the same will limit how much area can be brought under cultivation. It is doubtful that the exponential increases in area under crops realized in the past 18 years will continue unless new techniques of irrigating are adopted. According to the Area Agricultural Officer (Mr. Kimani), some of the techniques being considered presently include cementing the furrows so that water seepage is minimized.

Internal and external demographic forces (e.g., population growth, shifting from pastoral to agricultural lifestyles, immigration) will also have an impact. However, the major demographic factor, immigration, which has been driving agricultural growth seems to have slowed down. Most of the farmers in this area migrated from agrarian communities in high-density areas of Central and Western Kenya. The Kikuyu form the largest group of migrant farmers in Amboseli. As more land is withdrawn, less will be available for immigrants. Also, there has been unofficial but significant and sometimes violent political pressure to discourage people from the Kikuyu tribe from moving into certain areas of the Rift Valley, in which Amboseli Basin occurs. In fact, in some parts of the Rift Valley occupied by the Maasai (Narok District) the Kikuyu have been forcibly evicted from their farms by local Maasai (The Daily Nation 6/29/1996). These two factors will ensure that changes in the pool of potential migrants will continue to reduce the pressure to occupy land by people from purely agrarian societies.

2.9. Summary

This analysis has shown that despite the complex nature of interactions in the savannas of Kenya, many of the observed permanent changes in vegetative cover over time and space can be attributed to human acts. As these human acts are often influenced by public policies, it is possible to trace land use changes directly to a set of economic policies. For the case of Amboseli, the high market value of agricultural produce and public policy on land use, have together led to the current land use scenario. For the smallest farmer cultivating 0.2 ha (0.5 acres) in Amboseli during the 1996-1997 period, the returns on investment (in US dollars) were as follows: $160 for corn, $ 817 for onions, $ 1000 for tomatoes and $ 667 for cabbage. These figures were provided by the Kimana Area Agricultural Officer (Mr. Kimani) and were also confirmed by me at the local Kimana buying center.

These figures are high given the fact that per capita income in Kenya was $260 in 1997. On the other hand, returns from elephant conservation to the local farmers are nil; in fact, they represent a cost. Such economic realities will ensure that cultivation in this part Amboseli Basin continues even in areas that are critical to elephant foraging. This implies that agricultural expansion in this area will not come to an end by itself. There has to be intervention to alter local economic forces to ensure that elephant conservation goals are achieved in the short- and long-term.

Potential interventions may include land use zoning with the incentive that any one with land within a given critical resource area is compensated for not cultivating that area. The compensation rates could be worked out depending on the market value of the crops that would have been grown. At US $ 1500/ha/year, Amboseli National Park generates the highest wildlife-based tourism revenues in Africa (Child 1990). If these revenues are re-invested back into the area, it may be possible to reduce or stop the current agricultural activities.

The KWS needs to define its objectives with regard to wildlife use of nonpark areas. Upwards of 75% of wildlife uses areas outside parks. Indeed, Amboseli elephants spend most of their time outside the park boundaries. It is surprising that there is no particular strategy or policy that addresses the protection and management of wildlife habitat outside parks. Whereas laws protect elephants outside and inside parks, there is no demonstrated interest, commitment, and investment on the part of the government or KWS to conserve elephant habitat in nonpark areas. Specific strategies, informed by reliable land use change information, will need to be urgently devised and implemented in order to ensure adequate management of elephant habitat outside Amboseli National Park.

Table 2.1. General physiognomic description of the nine cover types used in habitat classification in the Amboseli Basin, Kenya.

Cover Type	Vegetation Association	General Remarks
Bare Ground	*Digitaria macroblephara, Pennisetum mazianum, Themeda triandra, Sporobolus fibriatus*	Mainly annual grasses and forbs that are grazed and dry out, leaving the soil exposed. Little or no forage during the dry seasons
Swamps	*Combretum, Acacia xanthophloea,* Hydrophytes such as reeds, *Cyperus papyrus*	Scattered in areas where springs occur. They are few and small in extent but critical in dry seasons.
Wooded Grassland	*Sporobolus fibriatus, Digitaria macroblephara, Ipomea kituensis, Acacia drepanolobium, A. seyal, Balanites aegyptiaca, Cymbognon pospischilli*	Grassland savanna with scattered trees. Very extensive in the Basin.
Shrubland	*Acacia nubica, A. tortilis, Commiphora africanus, Cenchrus ciliaris, Pennisetum strammineum, Cynodon dactylon, I. kituensis*	Shrub savanna with dense layer of shrubs. Offers both browse and grassy forage.
Bushland	*Commiphora africanus, Acacia mellifera, A. nubica, A. seyal, A. tortilis, Balanites aegyptiaca, Pennisetum strammineum, Cynodon plectostachyus*.	*Acacia-Commiphora* combination forms good browse while the understory provides grassy forage.
Forested Woodland	*Acacia xanthophloea, A. seyal, A. tortilis, A. seyal, Themeda triandra, Commiphora africanus, Combretum zeyheri, Chloris roxburghiana*	Important for dry season grazing, browsing, shade, and general cover for wildlife.
Riverine Vegetation	*A. xanthophloea*, reeds and other Hydrophytes.	Rivers are seasonal and the area covered is small but critical during dry seasons.
Agriculture	Corn, Onions, tomato, Cabbage, Irish potato, Banana, fruit trees such as Mango	Fallow lands and settlements are considered part of this category. Livestock husbandry is not part of this category.
Open Water	Open water that is permanent year-round.	Pools that form after rains are not included in this category.

Table 2.2. Land use/land cover areas (in hectares) in Amboseli Basin for 1975, 1988, and 1993. Values are based on interpretation of cover types for each year.

Cover type	**1975 coverages**	**1988 coverages**	**1993 coverages**
Bare ground	26,966	47,762	54,172
Wooded grassland	37,089	72,793	99,370
Shrubland	106,390	51,785	58,077
Bushland	107,526	99,818	57,473
Forested woodland	6,385	5,402	2,006
Riverine vegetation	22,821	18,931	14,548
Open water	1,942	4,615	1,934
Agricultural land	2,937	10,950	24,476
Total	312,056	312,056	312,056

Table 2.3. Magnitudes of land use land cover changes (in hectares) between 1975 and 1988 (13 years), 1988 and 1993 (5 years), and 1975 and 1993 (18 years).

Cover types	1988-1975	1993-1988	1993-1975
Bare ground	20,796	6,410	27,206
Wooded grassland	35,704	26,577	62,281
Shrubland	-54,605	6,292	-48,313
Bushland	-7,708	-42,345	-50,053
Forested woodland	-983	-3,396	-4,379
Riverine vegetation	-3,018	-4,383	-7,401
Open water	2,675	-2,681	-8
Agriculture	8,013	13,526	21,539

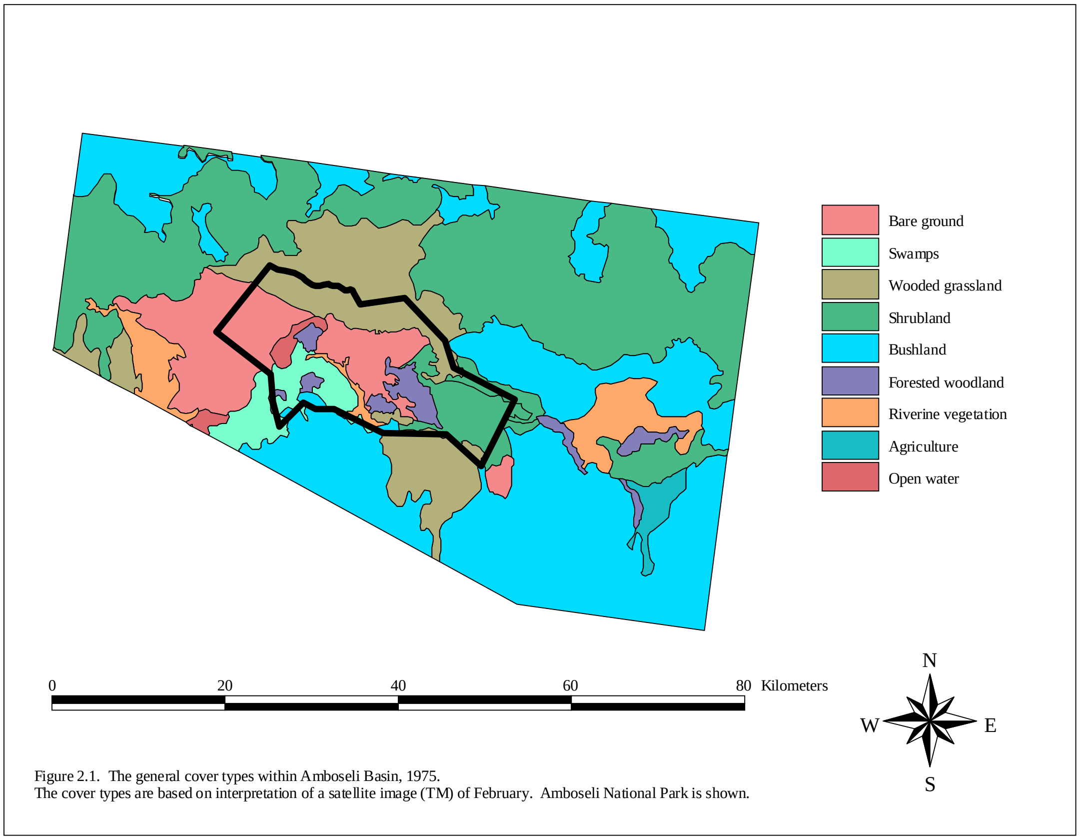

FIGURE 2.1. THE GENERAL COVER TYPES WITHIN AMBOSELI BASIN, 1975. THE COVER TYPES ARE BASED ON INTERPRETATION OF A SATELLITE IMAGE (MSS) OF FEBRUARY. AMBOSELI NATIONAL PARK IS SHOWN.

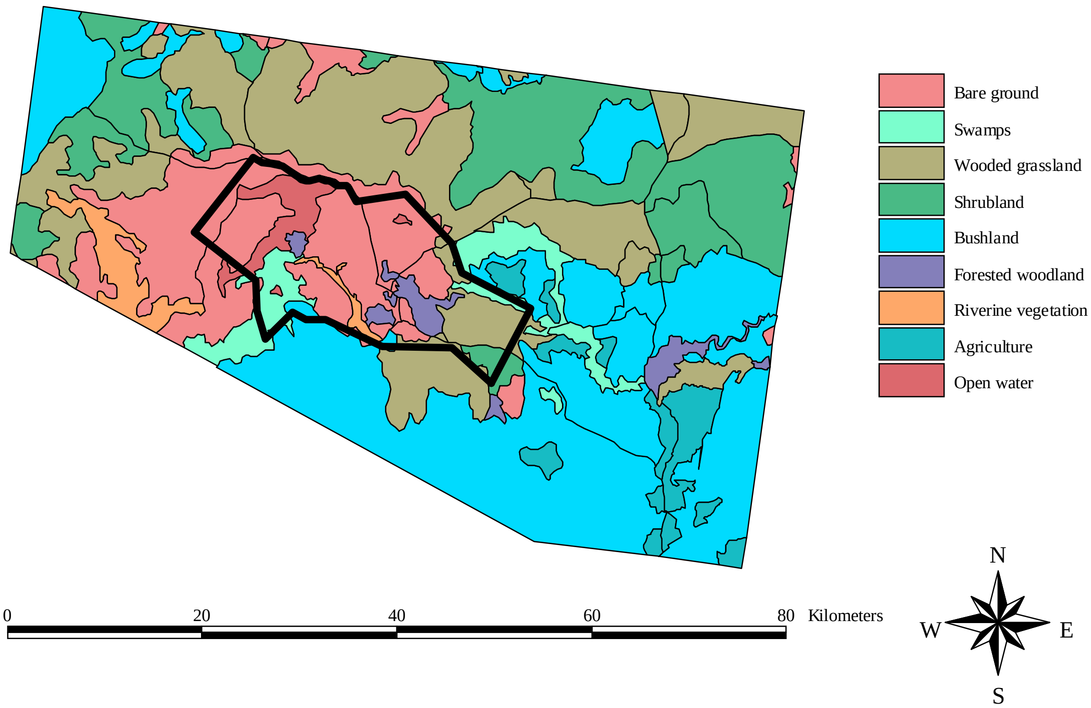

Figure 2.2. The general cover types within Amboseli Basin, 1988.
The cover types are based on interpretation of a satellite image (TM) of February. Amboseli National Park is shown.

FIGURE 2.2. THE GENERAL COVER TYPES WITHIN AMBOSELI BASIN, 1988. THE COVER TYPES ARE BASED ON INTERPRETATION OF A SATELLITE IMAGE (TM) OF FEBRUARY. AMBOSELI NATIONAL PARK IS SHOWN.

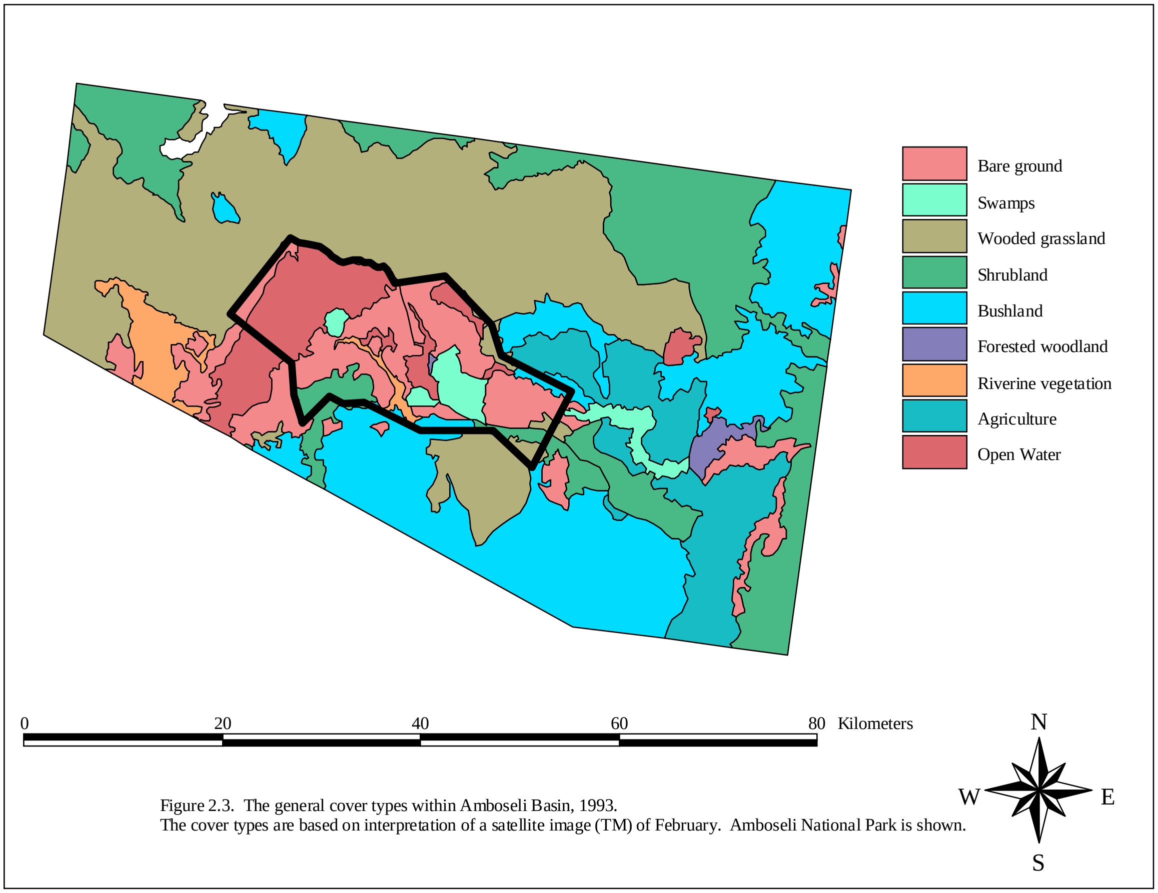

Figure 2.3. The general cover types within Amboseli Basin, 1993.
The cover types are based on interpretation of a satellite image (TM) of February. Amboseli National Park is shown.

FIGURE 2.3. THE GENERAL COVER TYPES WITHIN AMBOSELI BASIN, 1993. THE COVER TYPES ARE BASED ON INTERPRETATION OF A SATELLITE IMAGE (TM) OF FEBRUARY. AMBOSELI NATIONAL PARK IS SHOWN.

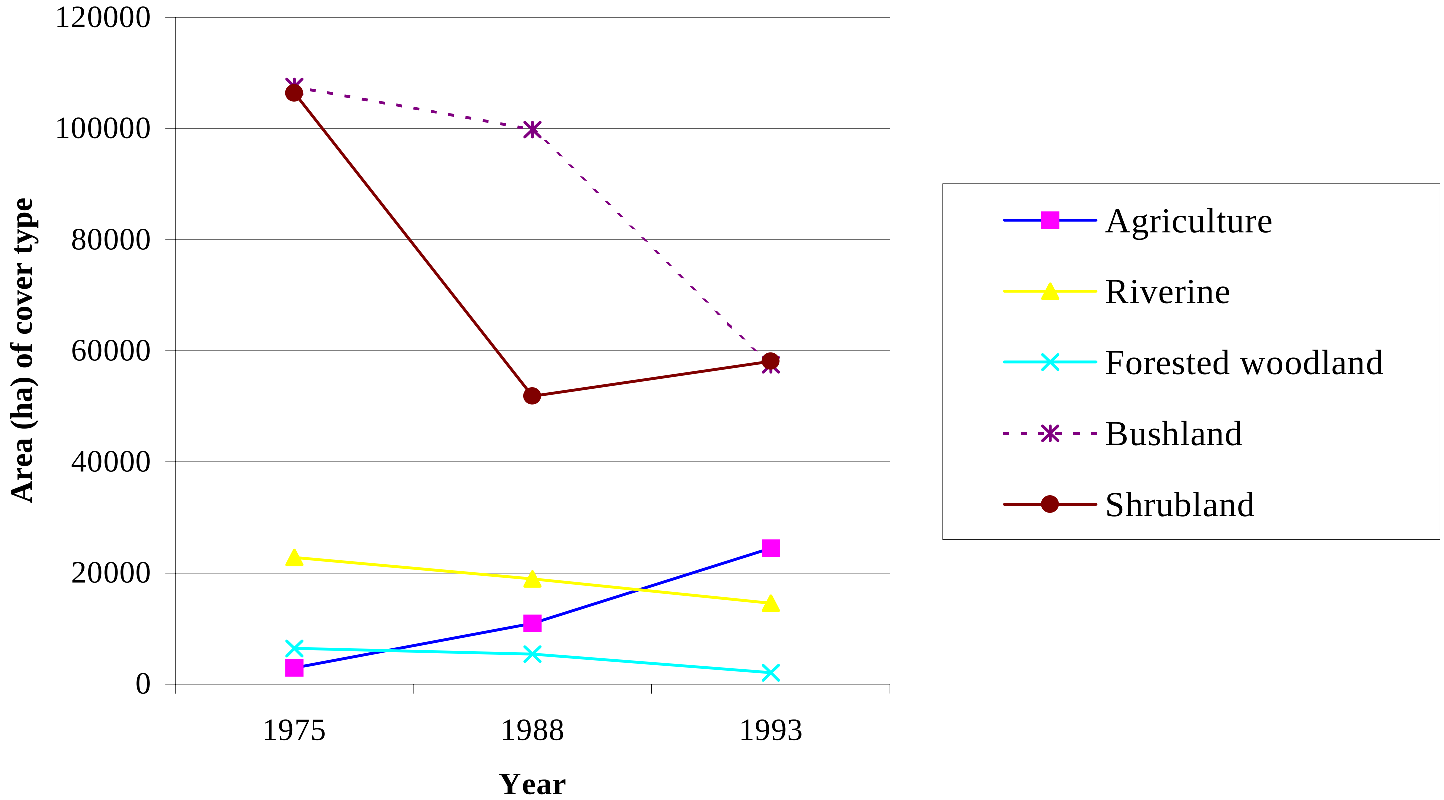

FIGURE 2.4. CHANGES (IN HA) IN AREAS FOR AGRICULTURE, RIVERINE, FORESTED WOODLAND, BUSHLAND AND SHRUBLAND COVER TYPES IN AMBOSELI BASIN BETWEEN 1975 AND 1993.

Table 2.4. Land use/land cover conversion to agriculture from cover types in Amboseli Basin 1975, 1988, and 1993.

Cover type	1975-1988		1988-1993		1975-1993 Cumulative change	
	Area (Ha)	**%**	**Area (Ha)**	**%**	**Area (Ha)**	**%**
Shrubland	2,056	26	----	---	2,056	9
Bushland	4,994	62	10,433	77	15,427	72
Forested woodland	571	7	532	4	1,103	5
Riverine vegetation	392	5	1,037	8	1,429	7
Wooded grassland	---	--	1,524	11	1,524	7
Total conversion	8,013	100	13,526	100	21,539	100

Table 2.5. Area converted to agriculture by 1993 as a percentage of 1975 area (ha) of cover types in the Amboseli Basin, Kenya.

Cover type	**Area (Ha) converted to agriculture, 1975-1993**	**Per cent of 1975 areal extent of cover type**
Shrubland	2,056	2
Bushland	15,427	14
Forested woodland	1,103	17
Riverine vegetation	1,429	7
Wooded grassland	1,524	4
Total conversion	21,539	8

Table 2.6. Human population in Kajiado District, Kenya, 1969 – 1989. Densities were calculated using the area of Kajiado District, which is 21,105 km^2. Values for population were extracted from the District Atlas (1990).

Year	**Population**	**Density (persons/km^2)**
1969	86,403	4.1
1979	149,005	7.1
1989	262,000	12.4

Table 2.7. Kajiado District population and ethnic composition, 1948-1989[a]

Year	Total Population	Maasai	%	Non Maasai	%
1948	28,234	25,748	91.2	2,486	8.8
1962	68,411	53,219	77.8	15,192	22.2
1969	85,903	58,961	68.6	26,942	31.4
1979	149,005	93,560	62.8	55,445	37.2
1989	262,585	148,462	56.5	114,123	43.5

[a]Sources: Kajiado District Atlas (1990).

Table 2.8. Population density in Amboseli Basin (Loitokitok Division), 1978-1993

Year	Persons/km^2
1978	7
1988	13
1990	14
1993*	15

Source: Kajiado District Atlas, 1990.

*- based on projections.

Table 2.9. Variation in the number of patches in each land use land cover category between 1975, 1988, and 1993.

Cover types	1975	1988	1993
Bare grounds	3	22	16
Wooded grassland	6	19	7
Shrubland	6	12	9
Bushland	10	17	9
Forested woodland	8	5	4
Riverine vegetation	8	6	4
Open water	2	3	4
Agricultural land	2	12	4

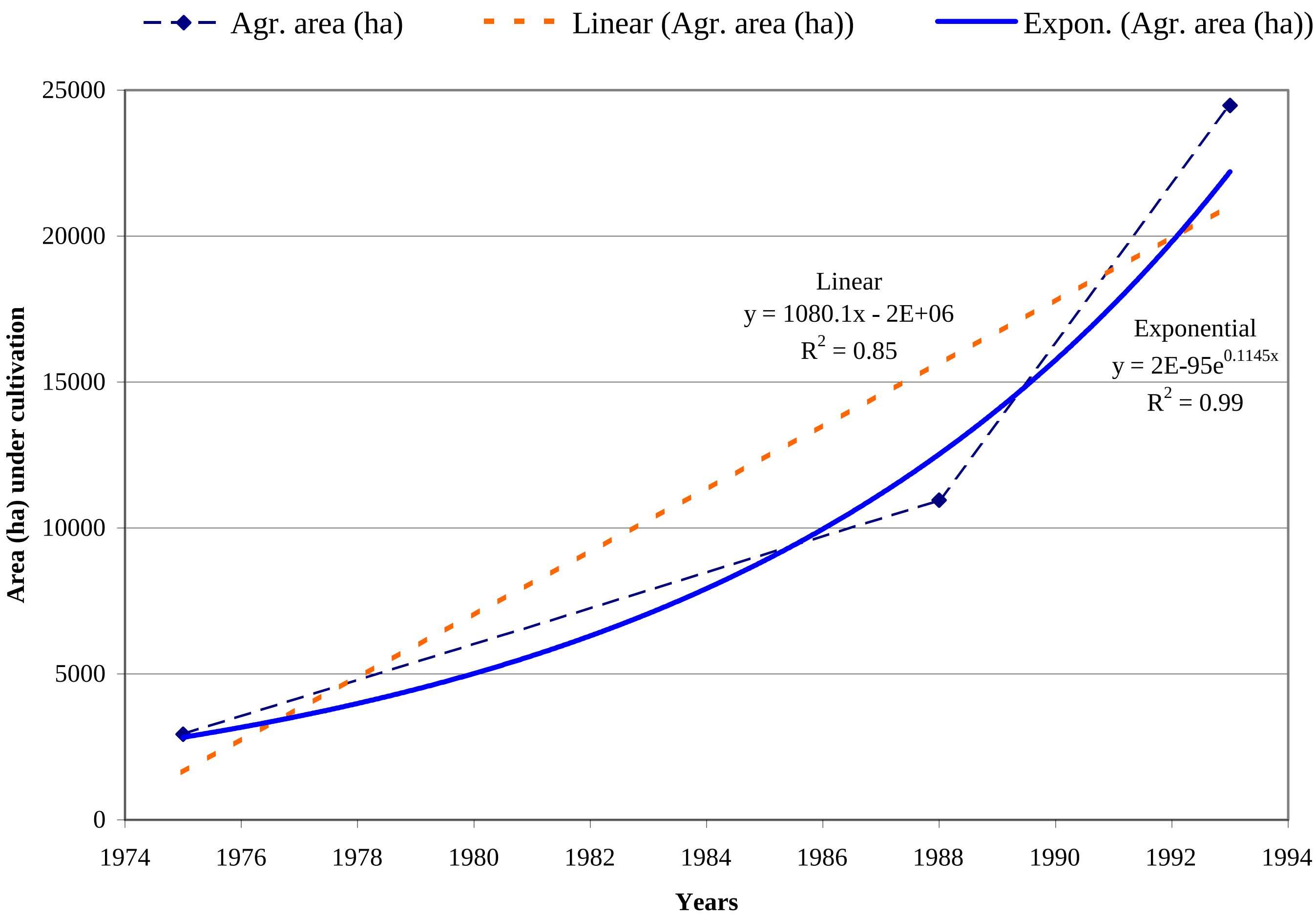

FIGURE 2.5. THE CHANGES IN AREA (HA) UNDER CULTIVATION IN AMBOSELI BASIN, KENYA, FOR THE PERIOD 1975 – 1993. LINEAR AND EXPONENTIAL FUNCTIONS ARE FITTED TO THE OBSERVED CHANGES IN AGRICULTURAL AREA.

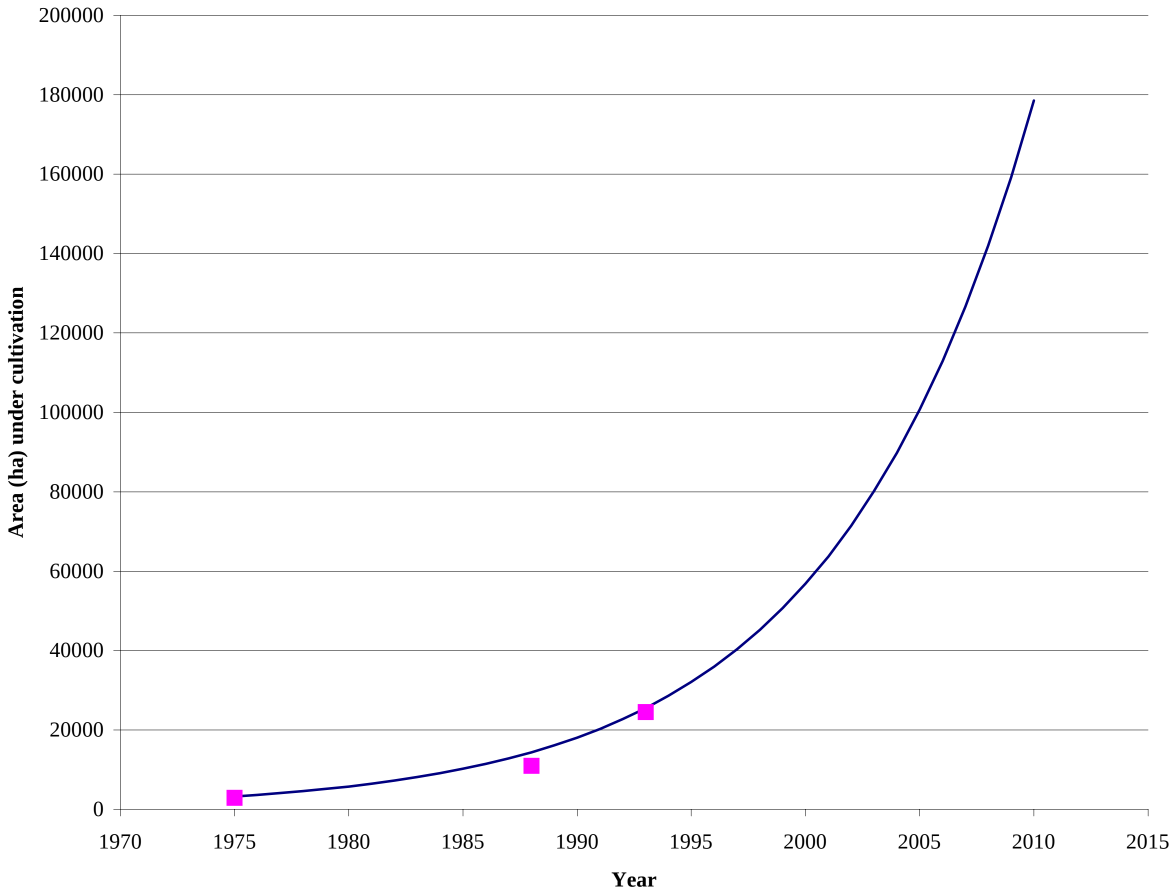

FIGURE 2.6. PROJECTIONS OF FUTURE CONVERSION OF COVER TYPES TO AGRICULTURE IN AMBOSELI BASIN, KENYA. THIS PROJECTION ASSUMES THERE ARE NO CONSTRAINTS ON AGRICULTURAL EXPANSION AND IS BASED ON THE OBSERVED TRENDS IN CONVERSION RATES FOR THE YEARS 1975, 1988, AND 1993.

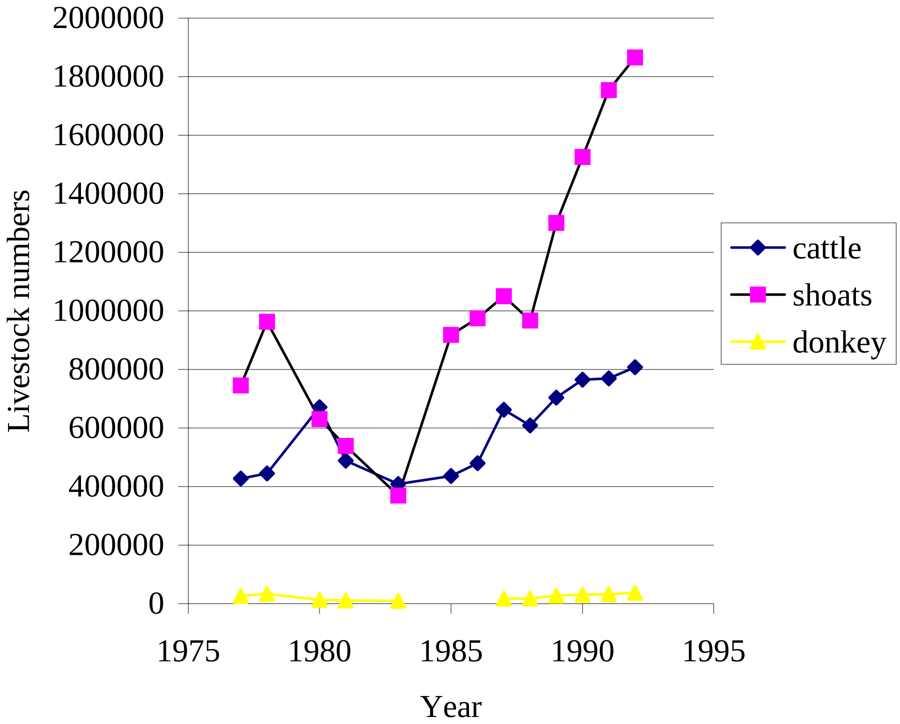

FIGURE 2.7. THE NUMBERS OF CATTLE, SHEEP AND GOATS (SHOATS), AND DONKEYS IN KAJIADO DISTRICT, KENYA, BETWEEN THE YEARS 1975 AND 1993. THE DATA WERE SOURCED FROM DRSRS.

Table 2.11. Irrigation locations in Amboseli Basin as of 1997. The main crops and ethnic groups are listed in order of declining importance for every irrigation location. The information was sourced from the Kimana Area Agricultural Office Records.

Irrigation location	**Water source**	**Main crops**	**Main ethnic groups**
Kimana	Kimana river and spring	onions, tomatoes, Asian vegetables, beans, cabbage, corn	Kikuyu, Chagga, Kamba, Maasai
Tikondo	Tikondo springs and Impiron river	onions, tomatoes, beans, cabbage, corn, bananas	Kikuyu, Chagga, Kamba, Maasai
Illasit	Kikelelwa and Mto wa Eliud rivers	tomatoes, onions, cabbage, corn, bananas	Kikuyu, Maasai, Luhya, Kamba, Chagga
Namelok	Ol Makau and Engumi springs	onions, tomatoes, corn, kales, cabbage	Maasai, Chagga
Isinet	Isinet river	onions, tomatoes, corn, cabbage, kales	Maasai, Kamba, Chagga
Impiron	Impiron river and other springs	onions, tomatoes, corn, peas, cabbage, citrus	Maasai, Kikuyu
Inkisanchani	Noolturesh Hills	onions, tomatoes, kales, corn, beans, peas	Maasai, Kamba, Chagga, Kikuyu

Table 2.12. Brief description of cover types in Amboseli Basin.

Cover type	Description
Bare ground	Occurs in the plains which have a shallow hard pan which tends to limit the depth to which roots can penetrate. There are no trees here. Forms dense grasses during rain season. The grasses usually get depleted after the beginning of the dry season.
Swamps, Open water, Riverine vegetation	Lakes are shallow and do support year round growth of grasses. Swamps support vegetation with the dominant grass being *Cynodon dactylon*. The most typical plants of swamps is the tall sedge, *Cyperus immuensis* and *C. papyrus*
Bushland	Generally contain more trees and bushes than other habitats in the basin. Acacia trees are found here in varying densities.
Forested woodland	Acacia xanthophloea and A. tortilis are the dominant features of the woodlands. These species are associated with a high ground water-table and are common around swamps and springs
Shrubland	This cover type is dominated by *Balanites* shrubs with dense mats of tall grasses.
Wooded grassland	Grasses dominate this cover type. However, various woody species are widely found in this cover type.

Chapter 3. Evaluation of habitat quality and quantity for elephants in Amboseli Basin

3. Introduction

In Chapter 2, I addressed the large-scale impacts of human actions on potential elephant habitat outside ANP, viz. withdrawal of areas for settlement and agricultural activities. In this section I select and quantify habitat variables that may be used in assessing the suitability of the habitat to elephants in the dry season.

The African elephant is a water-dependent, intermediate bulk feeder that is not very selective, preferring grazing to browsing (Van Soest 1982, Van Wijngaarden 1985). In addition to nutritional differences between grasses and browse, their spatial distribution differs, as grasses form dense mats of vegetation, while tree leaves, twigs and fruits (mainly *Acacia* seedpods) are more widely spaced (Beekman and Prins 1989). Elephants feed almost continuously over the 24-hour cycle because they are hind-gut fermenters and do not need to interrupt feeding bouts by ruminating (Beekman and Prins 1989, Owen-Smith 1988).

The time spent foraging has been shown to be independent of the time of the year. However, more time is spent grazing in the wet season while more time is devoted to browsing during the dry season (Beekman and Prins 1989, Barnes 1983). This shift in diet is related to changes in forage quality between the seasons (Coe and Coe 1987, Field 1971, Leuthold and Sale 1973). Leuthold and Sale (1973) showed that elephants may move considerable distances (85 km) within a few months in response to localized rainfall and food availability. This mobility is sufficient to allow elephants to exploit different habitat areas in different locations of their range (Tiezen et al. 1989).

Models depicting African elephant population dynamics have been developed (Croze et al. 1981, Fowler and Smith 1973, Hanks and McIntosh 1973). Recent elephant population studies have been dominated by the question of natural regulation of population size (Caughley 1976, Laws and Parker 1968, Sherry 1975) and poaching or predation by man (Kelso 1995). Few studies have looked at the issue of habitat quality in relation to elephant foraging patterns. Fowler and Smith (1973) developed their model to establish the elephant densities that would be compatible with 'normal environmental conditions' in the southern part of Murchison Falls National Park, Uganda. However, their study did not explicitly define what was considered normal environmental conditions.

The significance, if any, of anthropogenic land use changes on elephant foraging patterns, particularly in relation to accessibility, quantity, and quality of food resources, has not been given wide model and policy treatment and models of habitat suitability are lacking (Armbruster and Lande 1993). With the exception of Amboseli National Park, the other land uses in the basin (i.e., individual ranches, small holder farms, irrigation farming, pastoralism) present varying limitations to elephant foraging outside park boundaries. In particular, the growth of permanent cultivation (see Chapter 2) in areas formerly used for dry season foraging by elephants and other wildlife is a major concern. Hence, there is a need to consider land use change as a variable in models that depict potential elephant use of habitat in the basin.

Quantification of the amount of habitat withdrawn from elephant foraging at landscape scale (Chapter 2) does not offer complete information to estimate quality of the same for elephants. Elephants shift diets between seasons mainly due to changing food quality (Owen-Smith 1988); hence models that predict the potential quality of habitat during the limiting season for the elephant population in AB need to be developed to help guide habitat management. Food in East African savannas has been shown to be strongly influenced by the interaction between mean annual rainfall and soil fertility (Bell 1986). In arid and semi-arid areas (such as Amboseli Basin) receiving between 300 to 800 mm of annual rainfall, the total herbivore density can be predicted from a rainfall/biomass regression (Coe et al. 1976). The temporal variability in rainfall and the distribution of plant-available moisture close to the soil surface creates spatially discrete distributions of vegetation that will influence foraging movement and patterns by elephants if the area is not intensively used by humans.

Habitat quality is a continuous characteristic which refers to the ability of the environment to provide conditions appropriate for individual and population persistence (Hall et al. 1997). Generally, the value of a habitat to a species of wildlife can be described by a set of habitat variables that are important to that species. Habitat quality can be expressed in the form of a Habitat Suitability Index (HSI) (Anderson and Gutzwiller 1994). HSI models use habitat features of an area to yield an index of habitat suitability that is assumed to represent the capacity of that area to support a given species. Even though they eesentially represent working hypotheses, HSI models have been shown to be appropriate for evaluating species-specific habitat quality at a variety of scales (Allen 1987, Anderson and Gutzwiller 1994, Cooperrider 1986). Hence, my objective in this section is to develop a large-scale HSI model to evaluate quality of habitat for elephants in Amboseli Basin and to evaluate changes in habitat quality over the 1975-1993 analysis period.

3.1. Methods

I developed an Habitat Suitability Index (HSI) model (USFWS 1980a, 1981a) for the African elephant in Amboseli. HSI models synthesize in simple form the environmental factors (e.g., mean height of deciduous shrub canopy, percent shrub crown cover, tree density) thought to most affect presence, distribution, and abundance of a wildlife species (Cooperrider 1986, Allen 1987). HSI models are developed by using existing data, literature, and expert opinion (Cooperrider 1986). Such models produce an index of habitat quality scaled from 0.0 to 1.0, with 0.0 indicating no habitat value and 1.0 optimal habitat for the species in question. HSI models relate habitat variables (e.g., percent canopy cover of trees) to life requisites (e.g., food) and cover types (e.g., wooded-shrubland) (Allen 1987). Evaluation of the habitat was only done for the dry season since this is considered the most limiting for elephants.

I used the strip quadrat or belt transect method (Hays et al. 1981) to estimate the density of acacia trees in the basin. A total of 7 sites randomly located around the park was sampled. Each site had 10 transects, for a total of 70 transects. The transects were 130 meters long and 8 meters wide. At each site, the first transect was established at 1 km distance away from Amboseli National Park boundary. If there was considerable human activity (e.g., settlement) at the initial 1 km distance, the location of the first transect was moved farther from the park boundary. The transects were spaced at 1 km intervals and their orientation was random. Bare grounds, swamps, agriculture, and open water cover types (see Chapter 2) generally do not have acacia trees growing in them; hence I assumed that they had a tree density of 0. I did not sample these cover types even though in some places they may have residual trees growing.

Because a rectangle tends to cut across clumps of individual species, strip transects have been found to be more efficient in estimating density than square or circular plots (Hays et al. 1981). After the transects were randomly established, I recorded the number of individual acacia trees that were > 5 cm DBH within the strip. I did not differentiate between the acacia species since I assumed that elephants browse equally on all the 6 species occurring in the basin. The resulting acacia densities were applied to the cover types for all the 3 evaluation years and the acacia-based dry season food suitability index (SI_{Food}) for the basin determined. This yielded maps of SI_{Food}.

I used both distance from free water and density of springs in the basin to assess habitat suitability with regard to water. I put a 0-5, 6-10, 21-40, >40 km zones of influence around all the free water sources and assigned respective suitabilities. Swamps and open water were considered for this analysis. I excluded water and water points that tend to collect/form only during periods of significant rainfall. Only natural water sources were considered since the man-made structures are usually out of operation most of the time due to mechanical and budgetary problems. The water-based dry season suitability indices (SI_{Water}) were applied to the study area. This yielded a map of SI_{Water}.

To obtain the HSI values for the basin, I combined the dry season acacia-based SI_{Food} with the distance to water source SI_{Water} using a geometric mean (i.e., $[SI_{Food} * SI_{Water}]^{1/2}$). The geometric mean was used because it weights the most limiting variable. The multiplicative function was performed in ArcView.

Also, the weighted HSI for the whole basin was calculated using the formula,

$$\sum_{i=1}^{n} \frac{HSI_i A_i}{A}$$

Where,

n = number of cover types in the assessment;

HSI_i = HSI of the cover type i;

A_i = area of cover type i.

3.2. HSI model development

3.2.1. Habitat Suitability Index Model for the African Elephant in Amboseli Basin

The model considers the dry season ability of the habitats within Amboseli Basin (AB) to meet the food, cover, space, and water needs of the elephant as an indication of overall habitat quality/suitability. Adult elephants are known to have large home ranges (mean of 350 km^2 in Tsavo West National Park and 1,580 km^2 in Tsavo East National Park) (Leuthold and Sale 1973). If home range is viewed as a reservoir of resources, then the quality of the habitat is paramount in determining home range size (Leuthold 1977). An area with low rainfall and wide fluctuations in local environment will compel elephants to forage widely to satisfy their needs. Cover and food needs are met by similar habitats, namely woodland and wooded grassland. Water is considered to be a limiting factor. Human influence by way of land use change is considered to constrain the other factors (via competition for water, food and space) and therefore impacts the elephant.

Laws et al. (1975) noted that diurnal behavior of elephants is modified by climate, season, and habitat type. Within a habitat type, shade, food and water availability were the most important variables determining elephant activity patterns. Hence, holding other factors (e.g., climate and season) constant, a workable index of habitat quality can be developed from information on vegetation (density of acacia trees), water presence, and the degree of human disturbance or modification of the habitat (agriculture and settlements). The spatial arrangement of these factors also affects how elephants use habitat.

3.2.2. Dry season foraging habitat suitability

Evidence shows that food is the primary proximal factor determining elephant movement and distribution (Leuthold and Sale 1973). Open woodland, secondary forest or disturbed vegetation tend to attract elephants more than pure grassland or closed forest (Nummelin 1990). Elephant habitat preference appears to be strongly related to seasonal changes in food quantity and quality (Kabigula 1993, Lewis 1986).

Even though they are bulk feeders, elephants tend to shift diets (from grass to browse) in response to seasonal changes in food quality (Miller and Coe 1993). Browsing occurs mainly in woodlands and shrubby areas. Observations throughout the savannas of Africa show that elephants prefer acacias over other woody species as a source of browse during critical dry periods (Coe and Coe 1987, Dublin et al. 1990, Gwynne 1969, Hoft and Hoft 1995, Jachmann 1989, Jachmann and Croes 1991, Lock 1977, 1993; Mwalyosi 1990, Owen-Smith 1988). Therefore the density of acacia trees in Amboseli Basin was considered important.

I assumed that the 6 acacia species (*Acacia seyal, A. xanthophloea, A. mellifera, A. drepanolobium, A. tortilis, and A. nubica*) in Amboseli Basin were equally used by elephants for food and cover. During dry seasons when forage quality and quantity drop, elephants tend to shift diets toward more browse and especially acacia seedpods. Because it was not easy to directly measure the quantity of acacia browse and seedpods produced, an operational variable used in this study that is easy to measure in this environment is the density of acacia trees with > 5 cm diameter at breast height (dbh). Density of acacia trees will indirectly reflect the abundance of browse and seedpods.

Two factors that are important in the nutritional value of a plant are morphology and nutrient composition (Reed 1983). The preference for acacias shown by elephants can be attributed to these factors. Acacias form the most dominant woody plants in many of the wooded grasslands, woodlands, and bushed grasslands of East Africa (Gwynne 1969, Reed 1983). The characteristics of the various acacia species occurring in the study area have been described elsewhere (Bogdan and Pratt 1974, Reed 1983).

Elephants consume acacia seedpods and browse during the dry season when other food sources are scarce (Coe and Coe 1987, Gwynne 1969, Miller and Coe 1993). Acacia seedpods are dehiscent (can self-disperse assisted by wind, water and gravity) or indehiscent (do not split and remain on the tree until removed by wind, senescence, rainfall, or browsers). Adaptations of the acacia seed pods (especially the indehiscent type) such as nutrient content, strong attractive scent, and rounded form (as described by Gwynne 1969) attract elephants. There are several reasons why elephants prefer acacias. The high levels of nutrients and low levels of secondary phytochemistry result in in acacias being highly palatable (Gwynne 1969, Jachmann 1989). The evidence shows that acacias have much higher food quality than grasses during the dry seasons (Tables 3.1, 3.2). Reed (1983) has shown that polyphenolic compounds are important inhibitors in most browse plants on Kenyan savanna rangelands. Also, the small tap root and dominating meristem may make acacia highly vulnerable to elephant attack (Jachmann 1987) and the strong scent of acacia seedpods attracts elephants (Gwynne 1969).

In turn, acacia seeds benefit by enhanced germination for those that survive gut passage (the hard and rounded form of acacia seeds enables them to survive) and improved dispersal (Gwynne 1969). Acacia seeds are shade intolerant and rarely germinate under parent canopy (Mwalyosi 1990). Gwynne (1969) showed that only 2% of ingested acacia seeds were damaged by the initial mastication by ungulates and that further damage due to remastication affected not more than 20% of the seeds. This implies that a substantial number of acacia seeds are dispersed in good condition, thus ensuring germination where possible. Given the wide-ranging patterns of elephants, wide dispersal is assured.

The mean crude protein content for the assessed acacias is 13.68 while that for grasses is 6.1 (Tables 3.1, 3.2). Acacias seem to provide a higher quality food resource than grass. It appears that the relatively high food quality of acacias is consistent within and between species and areas of the East African savannas (Table 3.2). The dry matter content (DM) is consistently high for seeds and pods in all species from all 3 sites which have low rainfall. Seeds have much higher crude protein (CP) (all above 20%) than pods or seeds and pods combined. The nitrogen free extract (NFE) (carbohydrates) appears to be relatively high in all pods, seeds and pods and seeds combined for all species. Thus, acacia leaves, seeds and pods provide a high quality digestible food source for elephants.

The first variable I selected to reflect habitat quality for elephants was acacia tree density. I assumed that the quality of habitat decreases with declining acacia tree density. Acacia tree densities >140/ha are considered optimum habitat for elephants (Cynthia Moss, Amboseli elephant research team, pers. comm., Jachmann and Bell 1985). Tree densities < 80/ha were considered sub-optimal while densities < 1 tree/ha were considered to have suitability of 0.0 (Fig. 3.1). I used a step function (histogram) in the development of the suitability curve for tree density because I considered my sampling to have been done at very coarse levels.

3.2.3. Dry season water requirements habitat suitability

Elephants need large quantities of drinking water daily. Hence availability of free water is important (Jachman and Croes 1991). It has been estimated that adult elephants consume up to 50 gallons (225 liters) of water every day (Sikes 1971). Elephants water twice daily (Leuthold and Sale 1973). Water also is used for skin hygiene and elephants have been shown to suffer acutely from prolonged periods without the opportunity to bathe and wallow (Sikes 1971). Laws et al. (1975) determined that the rate of feeding by elephants declined significantly during the dry season since movements to and from water took most of the time. Such movements were not noted and did not significantly affect feeding rates during the wet season when water sources were abundant. Also, in arid and semi-arid areas such as Amboseli, proximity of food plants to water sources appears to be important in determining vegetation use by elephants (Ben-Shahar 1993). Hence, availability of drinking water is a critical factor for elephant survival (Sikes 1971).

In the HSI model, this variable can be expressed as distance to free water or density of springs (Cooperrider 1986). A 5-km radius around water sources is considered high (optimum) quality habitat since elephants expend less energy trekking in search of water (Cynthia Moss, Amboseli elephant research team, pers comm., Wyatt and Eltringham 1974). Food within a distance of 6-10 km to an accessible water source is considered good habitat and this distance was assigned a suitability value of 0.8. I assumed declining habitat quality with increasing distance from a water source, with areas > 40 km from water having minimal value to elephants (Fig. 3.2).

3.2.4. Combining food and water components

The food and water suitability indices were combined by means of a geometric mean to provide the overall HSI values for any particular parcel in the basin. The equation used is:

$$HSI = (SI_{Food} * SI_{Water})^{1/2} .$$

Using a geometric mean in the aggregation equation allows the more limiting (lower value) habitat component to exert more influence on the final HSI value. This is considered conservative in estimating the quality of habitat for elephants.

3.3. Results and Discussion

3.3.1. Habitat suitability in Amboseli Basin

The most visually dominant of the acacias during dry season was *Acacia nubica*, and *A. tortilis* in the woodland/bushland cover types. *A. xanthophloea*, *A. seyal* , *A. drepanolobium* occurred in woodland and grassland cover types, while *A. mellifera* occurred in the bushland cover type. The highest density per transect was 144 while the lowest was 0.00. The mean density across all sites was 80 (se = 5.26) trees per hectare. For the cover types that I sampled, forested woodland had the highest density while wooded grassland had the lowest (Table 3.3). The evidence from 6 sites seems to suggest that the density of acacia trees increases as one moves away from ANP boundary (Figures 3.3 to 3.11). This is more evident to the east of the park. However, the southeastern site on Olgulului Group Ranch (Fig. 3.8) did not show a similar pattern.

It also appears that the increase in the number of acacia trees seems to start declining at about 8 km away from the park boundary (Fig. 3.11). This leaves a pattern of low density near the park and low density far away from the park. The latter may be attributed to human activities (e.g., charcoal burning, livestock grazing, farming) while the former can be attributed to heavy elephant browsing. The findings show that there is increased density of acacia trees as one moves away from the park boundary. This implies that habitat quality (as a function of acacia trees) is better away from the park and as a result, elephants spend more time out of the park foraging.

The amount of good quality habitat (i.e., HSI > 0.6) declined from 74,666 ha in 1975 to 54,890 ha in 1988, to 23,208 ha in 1993 (Table 3.4). This is a drop of 51,890 ha (65.5%) of good quality habitat in the basin. On the other hand, low quality habitat (HSI < 0.2) increased by 272% between 1975 and 1993 (Table 3.4). The weighted HSI values in the basin showed a decline, as did the habitat units for the 3 evaluation years (Table 3.5). The weighted HSI declined by 0.13 between 1975 and 1993, while the total habitat units (ha) declined by 40,567 ha during the 18 year period. It appears safe to say that elephant habitat quality has steadily declined in the Amboseli Basin during the period considered in this study (Figures 3.12, 3.13, 3.14).

3.3.2. Effect of elephant foraging on habitat quality

I assumed in the model application that the density of elephants did not have an effect on habitat quality. However, elephants may impact their habitats significantly. Elephants, in combination with other factors such as fire or drought, can cause major changes in natural vegetation (Dublin et al. 1990, Lock 1977, 1993; McNaughton and Sabuni 1988, Pellew 1983, Rues and Halter 1990). Elephants have been shown to significantly slow or inhibit natural woodland succession through their foraging activities (Hoft and Hoft 1995, Schmidt 1992). Impacts can occur because of, 1) elephant tracks which compact the soil, 2) mud wallowing depressions, 3) debarking of trees which leads to eventual death, 4) stripping of leaves and breaking of branches, and 5) uprooting of trees (Jachmann and Croes 1991). In fact, sustained elephant foraging pressure has been shown to reduce the resilience of savanna systems (Hoft and Hoft 1995, Laws 1970).

Jachmann and Croes (1991) determined that in savannas with moderately high (879 mm per year) rainfall, elephant densities of 2.5 animals per km^2 resulted in a direct reduction of total woody plants by 22% per year.

Reed (1983) found the density of acacia trees in a northern Kajiado (Athi River Plains) savanna area to be between 0.2/ha and 593.9/ha (mean 210.2/ha). In AB, in a similar savanna habitat, I found the density to be between 50 and 137 (mean 80/ha, s.e. = 5.26) trees per hectare. Reed's (1983) estimate was obtained using the Point Centered Quarter method while I used strip transects; hence the differences in results could be due to method or differences in soils and rains in the two areas. But it is more instructive to note that the area sampled by Reed (1983) does not have elephants and is not therefore affected by the destructive foraging and modifying grazing behavior of elephants. This may help to explain the higher number of acacias there. More importantly, this does seem to explain the results in my sampling that density of acacia trees seems to increase away from ANP. Thus, elephants may be depressing acacia densities near the park.

The elephant population in Amboseli was estimated at 600 individuals in 1980 (Moss 1988). The current (1997) estimates are slightly over 1200 individuals (Mr. Edin Kalla, Warden, ANP, pers. Comm.,). Thus there has been a doubling in elephant population in the last 18 years, most of it due to natural increase (Table 3.6). These changes in elephant population most likely have affected habitats. This is especially so inside the park where most acacia trees have been knocked down by elephants. Most of the park is now without trees; destructive feeding behavior can also be observed in the woodlands outside the park. It is perhaps safe to speculate that the low density of acacia trees near the park is due to heavy elephant browsing pressure due to the increased density.

Other data show that the low density of acacia trees could indirectly be a function of the density of elephants in a given area. Jachmann and Croes (1991) noted that in areas receiving < 600 mm of rainfall, elephant densities above 0.4 animals per km^2 lead to significant foraging-related tree mortality. Amboseli receives about 400 mm of rainfall annually and the current analysis shows that elephant density is 0.4 animals per km^2 for the whole basin and 3.1 animals per km^2 for Amboseli National Park (Table 3.6). It appears that these densities are high enough to cause tree destruction by elephants in this arid and semi-arid area. Elephant density within ANP is 7.8 times the threshold for tree damage. Thus, elephants are likely a major contributor to the near complete destruction of acacia woodlands inside the park.

As the abundance of acacia browse in AB has declined, the grassland ecosystems have increased. Whereas the wet season foraging dynamics of elephants may not be significantly affected, this will present limitations to elephants during the dry season. However, even though elephant foraging activities and the ecology of acacia are supposed to be symbiotic (Coe and Coe 1987, Gwynne 1969, Mwalyosi 1990), heavy pressure on acacias has ensured that little or no regeneration of acacia takes place inside ANP, which has changed the landscape dynamics in AB. Between the mid-1970s and now, there has been a tremendous change of habitat within ANP from acacia woodlands to bare and/or grassy areas. This has been attributed to destructive elephant foraging. The result has been increasingly poor dry season habitat within the park while relatively well wooded areas still remain outside the park, especially around swamps to the east of the park. Elephants move there on a daily basis for foraging; such movements may, and do, result in direct conflicts with humans.

3.3.3. Potential effects of human disturbance on habitat quality

Elephants in Amboseli area have been known to move 80 km or more in response to localized rain (Leuthold and Sale 1973) which brings flushes of green vegetation. This mobility enables elephants to exploit patchy resources in different areas in order to sustain their high numbers in this limited environment. But such mobility can only be sustained if barriers to movement are absent or insignificant. The ongoing agricultural development to the east of the park presents a challenge to elephant foraging movements in this area. Irrigation schemes have been shown to have negative effects on elephant (and other wildlife) ranging patterns in Kenya’s arid and semi-arid lands (Ledec 1987).

Habitat quality is affected by the degree of human disturbance to dry season fallback areas, in terms of areas converted to farming. The basin is now split into 5 dominant and increasingly independent subsystems of land and natural resource use and ownership. These are, 1) small holder farms, 2) individual ranches, 3) irrigation in swamps and around springs, 4) group ranches (pastoralists), and 5) Amboseli National Park. With the exception of ANP, the other four land use types present varying degrees of limitations to elephant foraging outside park boundaries. In particular the growth of irrigation farming in areas formerly used for dry season grazing by elephants and pastoralists is a major concern. Hence there is a real need to consider land use change as a component in any model that depicts elephant use of habitat.

Cropped area represents the most direct way humans compete with elephants for space and other resources. Also, cropped areas represent zones of habitat loss for elephants and other species of wildlife. Incidentally, farmed areas occur in areas that have traditionally been used by wildlife and pastoralists as dry season fallback foraging areas (see Chapter 2). Even though such areas comprise only a small fraction of the total area covered by AB, the critical role they play in the overall functioning of the system cannot be overemphasized. Hence the ability of the ecosystem to provide critical dry season forage for elephants and other species is affected by the rate and amount of withdrawal of such areas for sedentary agricultural purposes.

Between 1975 and 1993, low quality habitats, i.e., bare ground and agriculture, increased by 27,206 ha and 21,539 ha respectively (Table 2.3). During the same period, moderate to high quality habitats, i.e., shrubland, bushland, forested woodland and riverine vegetation, decreased by 48,313 ha, 50,053 ha, 4,379 ha and 7,401 ha respectively (Table 2.3). As a result, weighted HSI in the basin declined by 0.13 and habitat potential was reduced by 40,567 habitat units (Tables 3.4, 3.5). Based on my analysis, it appears that > 92% (288,848 ha) of the basin is of low (HSI < 0.2) to medium (HSI, 0.2 – 0.59) habitat quality (Table 3.4). This could be due in part to the distribution of water sources in the basin. Most of the water sources are located in the middle eastern part of the study area. This distribution means that most of the western and northern parts of the study area are > 40 km away from the nearest natural dry season water source.

I surveyed and counted 15 springs. Seven of them (Namelok, Isinet, Kimana, Tikondo, Oloorika, Impiron, Inkisanchani) have been taken over partially or completely by irrigation farming. This leads to a 40% drop in density of springs in the basin due to agricultural development. Loss of water sources and access to those that are available is a problem in the basin, due to irrigation.

Withdrawal of critical areas for agricultural development is permanent. The 21,539 hectares represent a decline in dry season fallback areas of about 41%. I assumed that, 1) these areas were previously available for unhindered elephant foraging during critical periods, 2) crops grown are not foraged upon by elephants, and 3) the drop in habitat quality is largely due to land use activities such as farming and not natural variations. In the absence of other contradictory data, assumption 1 is strong. However, assumption 2 is weak since elephants raided farms every day during the period I was doing my fieldwork. Assumption 3 is also weak since not all the decline in habitat quality in the basin can be attributed to farming. However, these assumptions are useful for analytical purposes. Also, human-produced crops should not really be used as components in a habitat model.

3.4. Summary

This analysis has shown that dry season elephant food supplies in Amboseli, specifically acacia browse, can be interfered with by, 1) appropriation of habitat for agricultural activities, and 2) excessive use by high concentrations of elephants. Other factors that may affect the dry season habitat quality in Amboseli are natural droughts and fire. These factors are interrelated and when they obtain simultaneously, probably act in concert to exert a stronger effect. However, withdrawal of dry season habitat for agricultural purposes seems to be the more permanent and potent factor.

The wildlife sector in Amboseli, indeed in the whole of Kenya, is financially sustained by a tourist industry based on game viewing. In Amboseli, elephant viewing is the main activity. Thus there has been a deliberate passive policy to let the density of elephants increase as much as possible so that the probability of the individual tourist actually seeing these animals at any time is maximized. Such a dense population, geared towards the viewing tourist, has been termed 'camera carrying capacity' (Behnke and Scoones 1992). An unavoidable by-product of such high density may be the thinning of woody vegetative cover in the basin by elephants. This thinning has the effect of negatively interfering with habitat quality for elephants and other wildlife, and increasing the ease of tourists sighting elephants and other game in the park. Both effects are clearly noticeable in the park.

The present elephant density in AB/ANP is leading to arrested tree growth and destruction and therefore lowering of habitat quality. The most practical way to minimize this effect would be to reduce density of elephants or allow for migration corridors into the Chyulu/Tsavo areas to the east of the park (see Figure 1.1). If no migration corridor is established, then the current AB density may need to be reduced to 0.3 animals/km^2 (i.e., 800 individuals). This would just barely keep the population below the threshold density. This would leave the ANP density at 2.0 animals per km^2 which should be sufficient to meet the camera carrying capacity desired by the tourism oriented Kenya Wildlife Service. Nevertheless, this park density would still be too high to expect habitats to recover.

If agricultural conversions of native habitats continue unchecked, then the elephant density in AB may need to be actively reduced to 1980 levels. This density will probably still sustain the tourism activities in the park. More importantly though, the habitat, at least in the park itself, may be allowed time to regenerate. However, there are major national and international ramifications on how such a reduction in numbers can be attained.

Elephants do not necessarily have to destroy their savanna habitats. In fact unstable equilibra have been observed between elephants and woodland habitat in moister savanna conditions (e.g., Miombo woodlands of southern East Africa) favoring high plant production accompanied with relatively low elephant density (Jachmann and Bell 1985).

Also, even in areas of low rainfall, random and unhindered elephant movements have ensured heterogeneous vegetation utilization with no significant damage remaining on the landscape (Ben-Shahar 1993). However, this mobility cannot be sustained with increased conversion of nonpark areas into farmland. However, the dry season conditions in Amboseli are different. The elephant density (3.1 for the park and 0.4 for the basin) is above what has been suggested as a maximum for other similar dry areas of Africa. Development of agriculture around water sources, swamps, and other wetter areas to the east of Amboseli has significantly affected the dry season foraging movements of elephants. This implies that the high densities of elephants are overusing the limited resources available in the basin. The observable destruction of acacia trees within and outside ANP by elephants is in part a result of these factors.

Dry season water supplies for elephants in AB may fail due to 1) human interference through introduction of irrigation farming, 2) severe droughts, and 3) expansion of non-irrigated farming on the slopes of Mt. Kilimanjaro. Irrigation competes directly with elephants for available water. However, rainfed agricultural expansion on the slopes of Mt. Kilimanjaro affects water availability in Amboseli indirectly. The lakes and springs of Amboseli are believed to originate form the nearby snow-capped Mt. Kilimanjaro (Sombroek et al. 1982, Western 1983). Hence the slopes of Mt. Kilimanjaro form the most important water catchment area for Amboseli. Agricultural related vegetation clearing in this area will continue to have an indirect but significant impact on rainfall water flow from the slopes of the mountain. This will in turn affect the natural re-charge of the springs and other water sources in Amboseli.

The decline in HSI and therefore habitat quality for elephants seems to have been accompanied by an increase in elephant population density during the evaluation period. This could be due to the fact that elephants are generally long-lived animals and may take a long time (lag time) to respond to the decline in habitat quality. Also, it is possible that the pre-1980 elephant population in the basin was higher than the current number. This would imply that even though the elephant population has increased, it is still below the pre-1980 levels.

This analysis seems to suggest that human actions, mainly the withdrawal of habitat for agriculture, may be having the most serious effect on dry season habitat quality for elephants in Amboseli. The area withdrawn for agriculture may appear small when the whole basin is considered, but the areas withdrawn are the most critical for elephant survival during the most limiting season. This underscores the importance of the need for elephant managers to recognize the landscape ecology of this area and look beyond ANP so that strategies that seek to sustain critical habitats are effected in conjunction with the local landowners.

Table 3.1. Dry season composition of some Acacia species and grasses found in Amboseli Basin.

Species	% Dry Matter (DM)		% Crude Protein (CP)		% Lignin (LIG)	
	Leaves	Pods	Leaves	Pods	Leaves	Pods
Acacia seyal	44.5	--	12.8	--	4.6	--
A. xanthophloea	41.9	91.4	16.9	8.5	12.3	16.4
A. mellifera	71.3	--	18.2	--	9.6	--
A. drepanolobium	47.3	93.5	15.6	10.1	14.7	16.4
Themeda triandra	-		4.1		7.6	
Pennisetum mezianum	-		5.8		12.6	
Pennisetum stramineum	-		6.8		13.4	
All grass species	-		6.1		10.0	

Source: Adapted from Reed (1983).

Table 3.2. Composition of acacia seeds and pods from three locations in the East African savanna rangelands.

Species	Location	Plant Part	% Dry Matter (DM)	% Crude Protein (CP)	% Nitrogen Free Extract (NFE)
Acacia albida	Baringo, Kenya	Seed	91.06	20.84	33.09
		Pods	90.63	6.84	63.23
		Seed & Pods	92.65	12.44	46.65
Acacia nilotica	L. Manyara, Tanzania	Seed	88.75	26.65	58.94
		Pods	89.37	7.81	52.46
		Seed & Pods	89.74	13.48	43.26
Acacia hockii	Muko area, Uganda	Seed	92.31	25.92	31.68
		Pods	92.27	8.96	40.33
		Seed & Pods	92.50	16.53	48.04

Source: Adapted from Gwynne (1969).

Table 3.3. Acacia tree density (#/ha) and associated food suitability index by cover type in Amboseli Basin.

Cover type	Density of acacia trees	SI
Bare ground	0	0.0
Swamps	0	0.0
Wooded grassland	61	0.4
Shrubland	75	0.4
Bushland	78	0.4
Forested woodland	137	0.8
Riverine vegetation	104	0.6
Agriculture	0	0.0
Open water	0	0.0

Table 3.4. Combined dry season Habitat Suitability Index (HSI) values and areas for variables of distance to water and acacia tree density in Amboseli Basin. The HSI values are for the evaluation years, 1975, 1988, and 1993.

HSI	Area (ha) covered by HSI value		
	1975	1988	1993
> 0.8	7,255	5,369	2,006
0.6 – 0.79	67,411	49,521	21,202
0.4 – 0.59	166,590	152,977	132,548
0.2 – 0.39	30,430	28,379	46,372
< 0.2	40,370	75,810	109,928

Table 3.5. Weighted elephant HSI and the corresponding habitat units (ha basis) for 1975, 1988, and 1993 in Amboseli Basin. The habitat units were determined by multiplying the weighted HSI with the total area (312,056 ha) covered in this study.

Year	Weighted HSI	Total Habitat Units
1975	0.47	146,666
1988	0.42	131,064
1993	0.34	106,099

Table 3.6. Changes in elephant density in Amboseli between 1980 and 1997.

Location	Area (km^2)	Year	Density ($\#/km^2$)
Amboseli Basin	3000	1980	0.2[a]
Amboseli N. Park	392	1980	1.5[a]
Amboseli Basin	3000	1997	0.4
Amboseli N. Park	392	1997	3.1

Notes: [a] were sourced from Moss (1988). The rest are estimates made in this study.

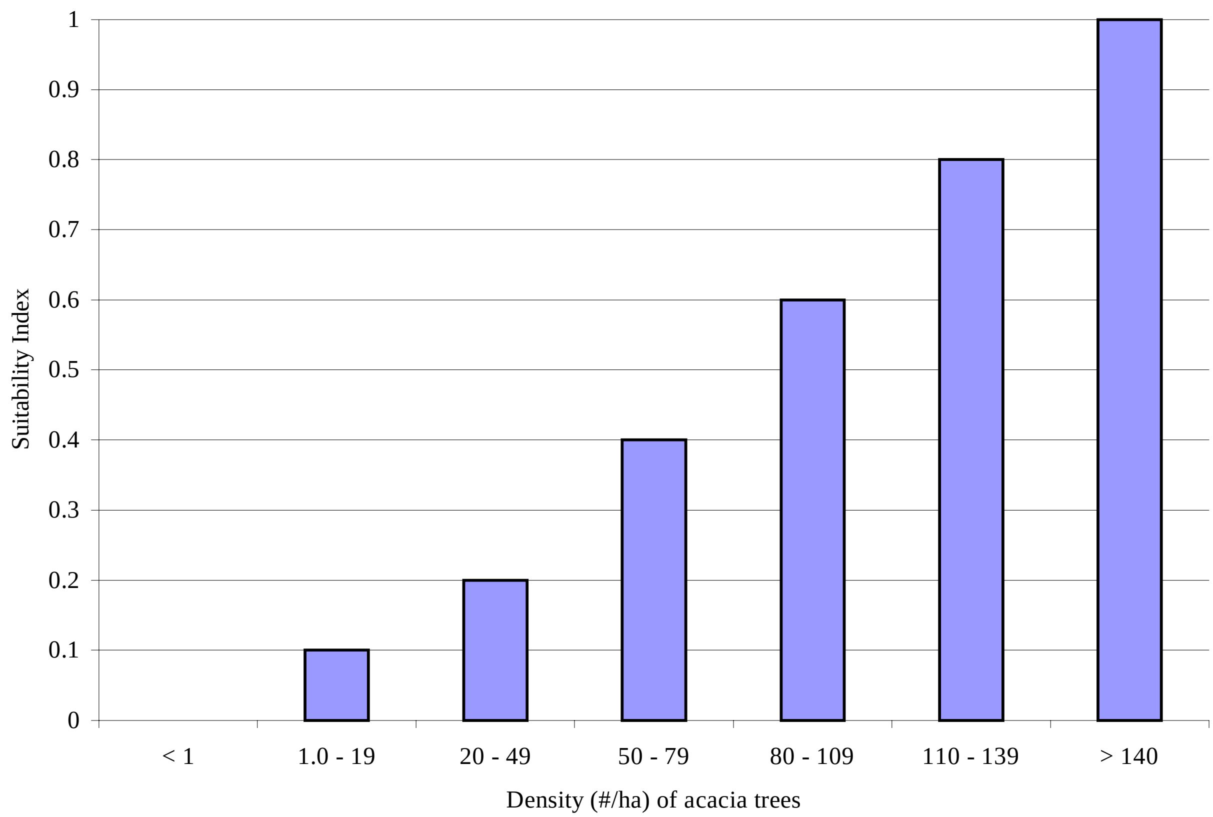

FIGURE 3.1. DRY SEASON FOOD SUITABILITY INDEX (SI) HISTOGRAM FOR THE AFRICAN ELEPHANT IN THE SAVANNA RANGELANDS OF AMBOSELI BASIN. THE SUITABILITY IS DERIVED FROM THE DENSITY (NUMBER PER HECTARE) OF ACACIA TREES.

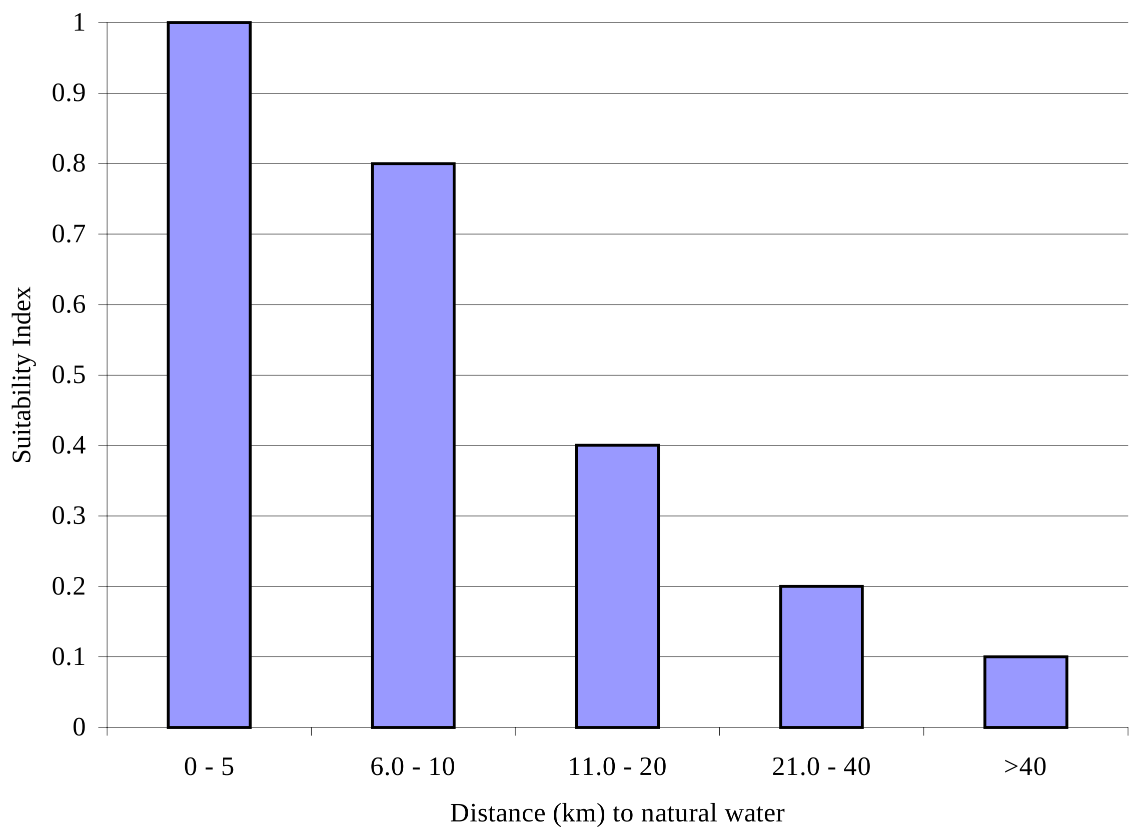

FIGURE 3.2. DRY SEASON WATER SUITABILITY INDEX (SI) HISTOGRAM FOR THE AFRICAN ELEPHANT IN THE SAVANNA RANGELANDS OF AMBOSELI BASIN. THE SUITABILITY IS DERIVED FROM THE DISTANCE (KM) TO NATURAL WATER SOURCES IN THE BASIN.

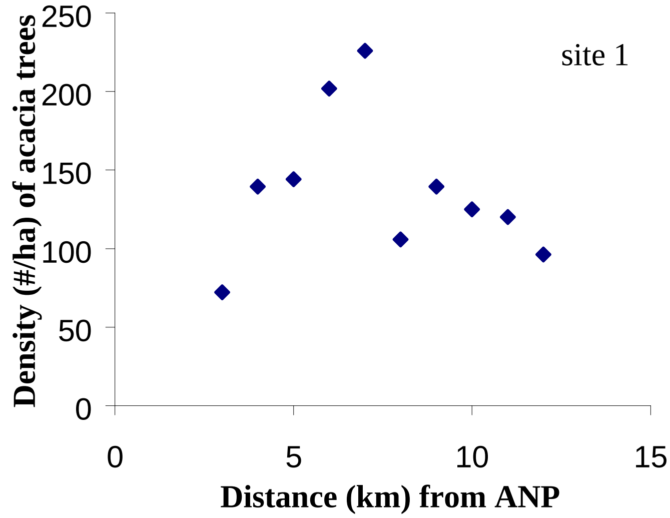

FIGURE 3.3. DENSITY OF ACACIA TREES AT SITE 1 ON KIMANA GROUP RANCH, SOUTHEAST (SE) OF AMBOSELI NATIONAL PARK.

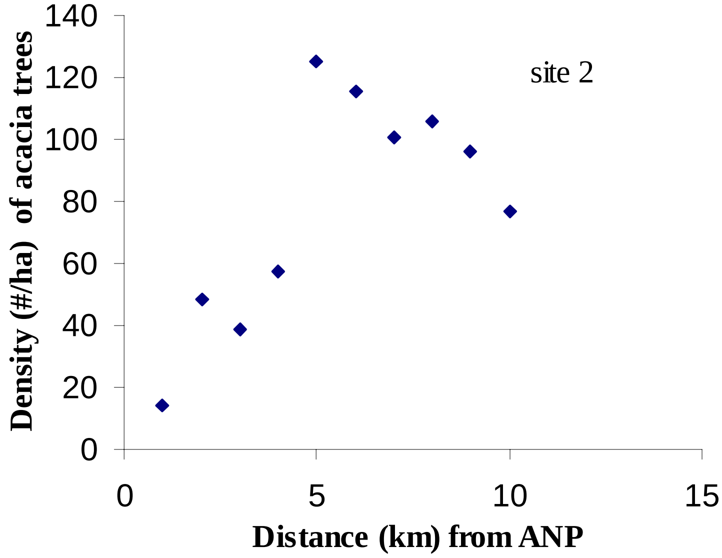

FIGURE 3.4. DENSITY OF ACACIA TREES AT SITE 2 ON KIMANA GROUP RANCH, EAST (E) OF AMBOSELI NATIONAL PARK.

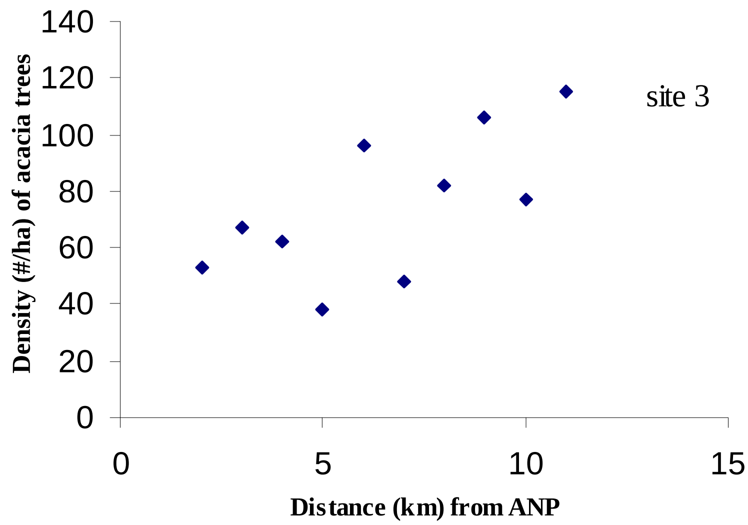

FIGURE 3.5. DENSITY OF ACACIA TREES AT SITE 3 ON OLGULULUI GROUP RANCH, NORTHWEST (NW) OF AMBOSELI NATIONAL PARK.

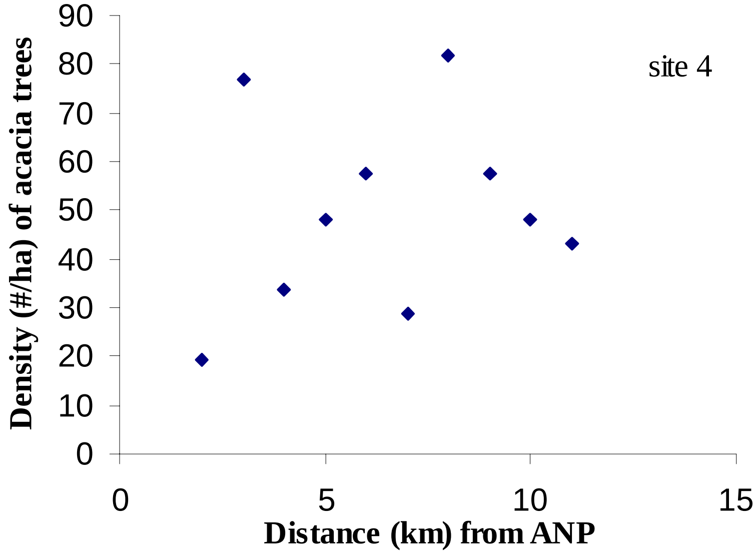

FIGURE 3.6. DENSITY OF ACACIA TREES AT SITE 4 ON OLGULULUI GROUP RANCH, SOUTHWEST OF AMBOSELI NATIONAL PARK.

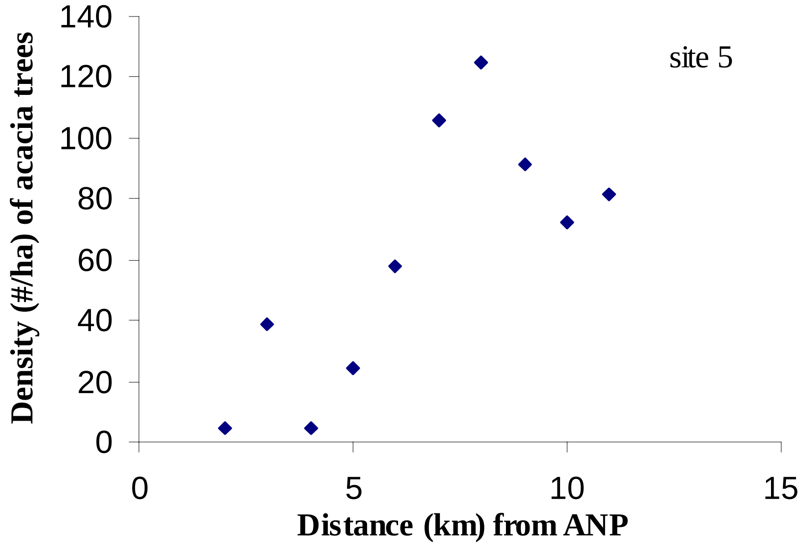

FIGURE 3.7. DENSITY OF ACACIA TREES AT SITE 5 ON OLGULULUI GROUP RANCH, WEST (W) OF AMBOSELI NATIONAL PARK.

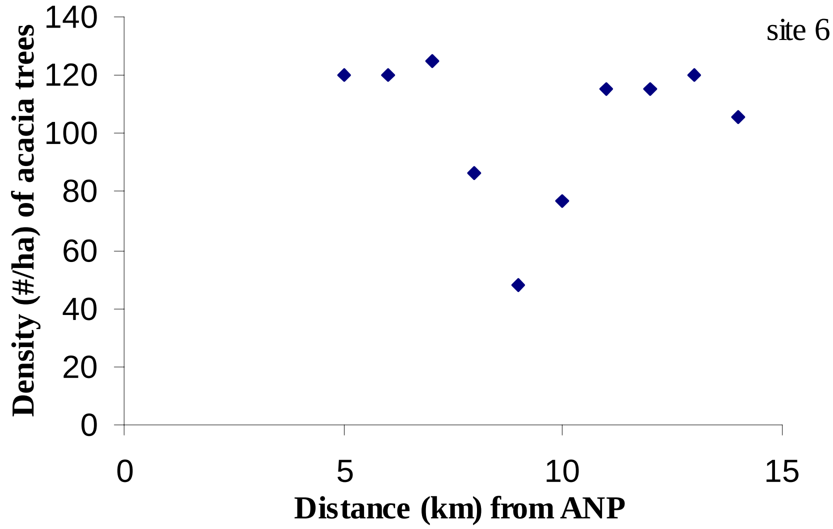

FIGURE 3.8. DENSITY OF ACACIA TREES AT SITE 6 ON OLGULULUI GROUP RANCH, SOUTHEAST (SE) OF AMBOSELI NATIONAL PARK.

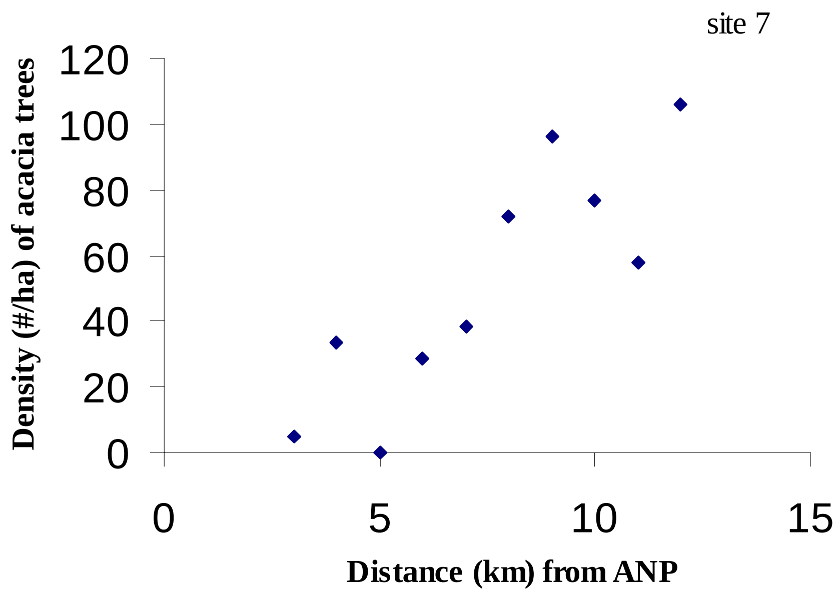

FIGURE 3.9. DENSITY OF ACACIA TREES AT SITE 7 ON OLGULULUI GROUP RANCH, NORTH (N) OF AMBOSELI NATIONAL PARK.

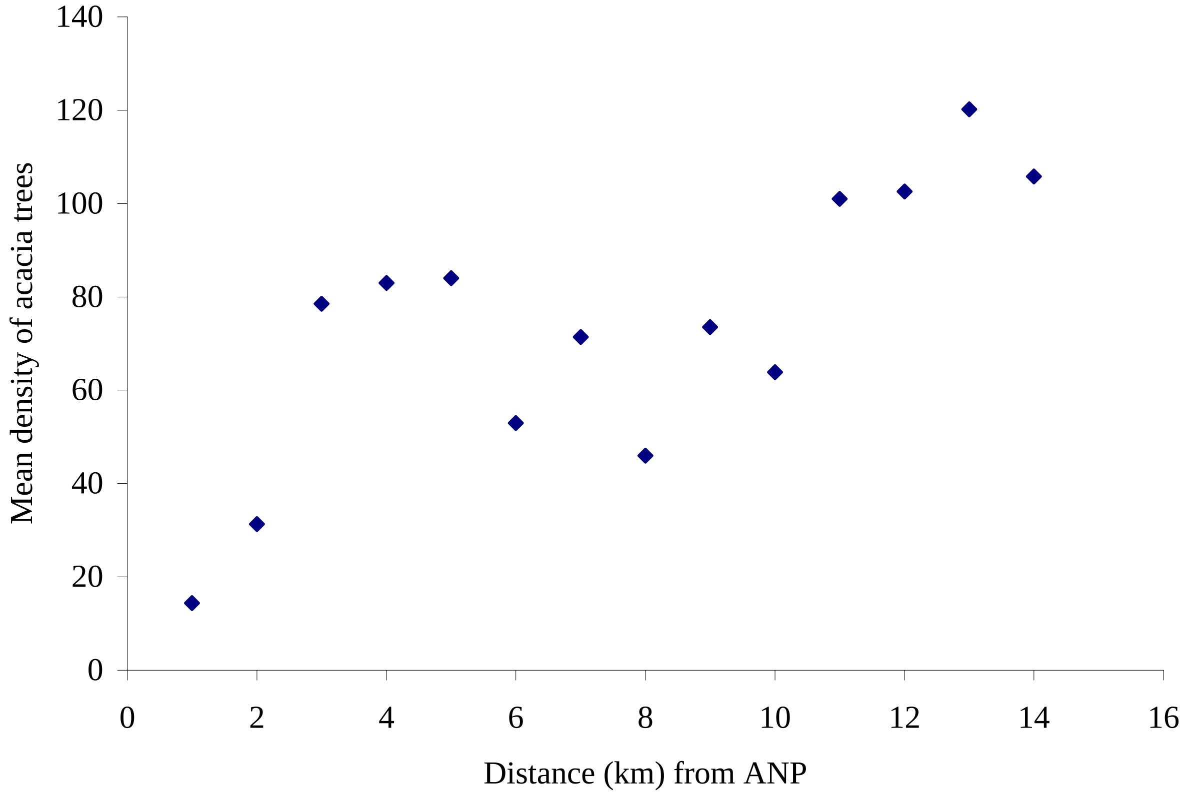

FIGURE 3.11. MEAN DENSITY OF ACACIA TREES (#/HA) WITH INCREASING DISTANCE (KM) FROM AMBOSELI NATIONAL PARK BOUNDARY. DATA ARE BASED ON 70 SAMPLING POINTS TAKEN IN 1996-1997.

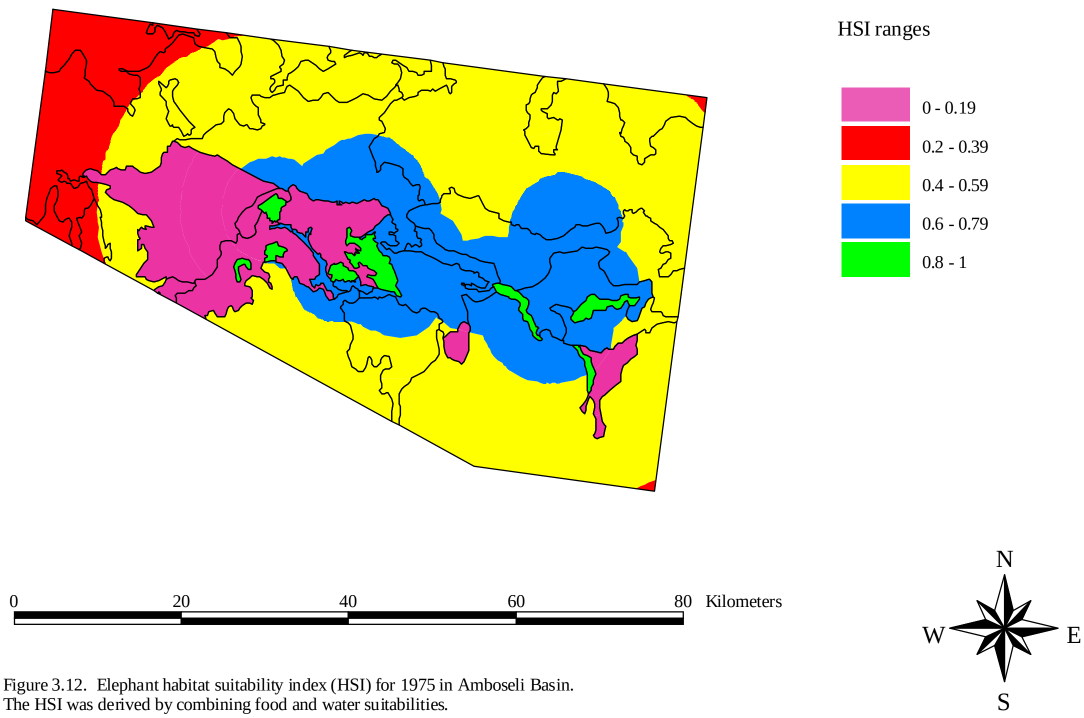

Figure 3.12. Elephant habitat suitability index (HSI) for 1975 in Amboseli Basin.
The HSI was derived by combining food and water suitabilities.

FIGURE 3.12. ELEPHANT HABITAT SUITABILITY INDEX (HSI) FOR 1975 IN AMBOSELI BASIN. THE HSI WAS DERIVED BY COMBINING FOOD AND WATER SUITABILITIES.

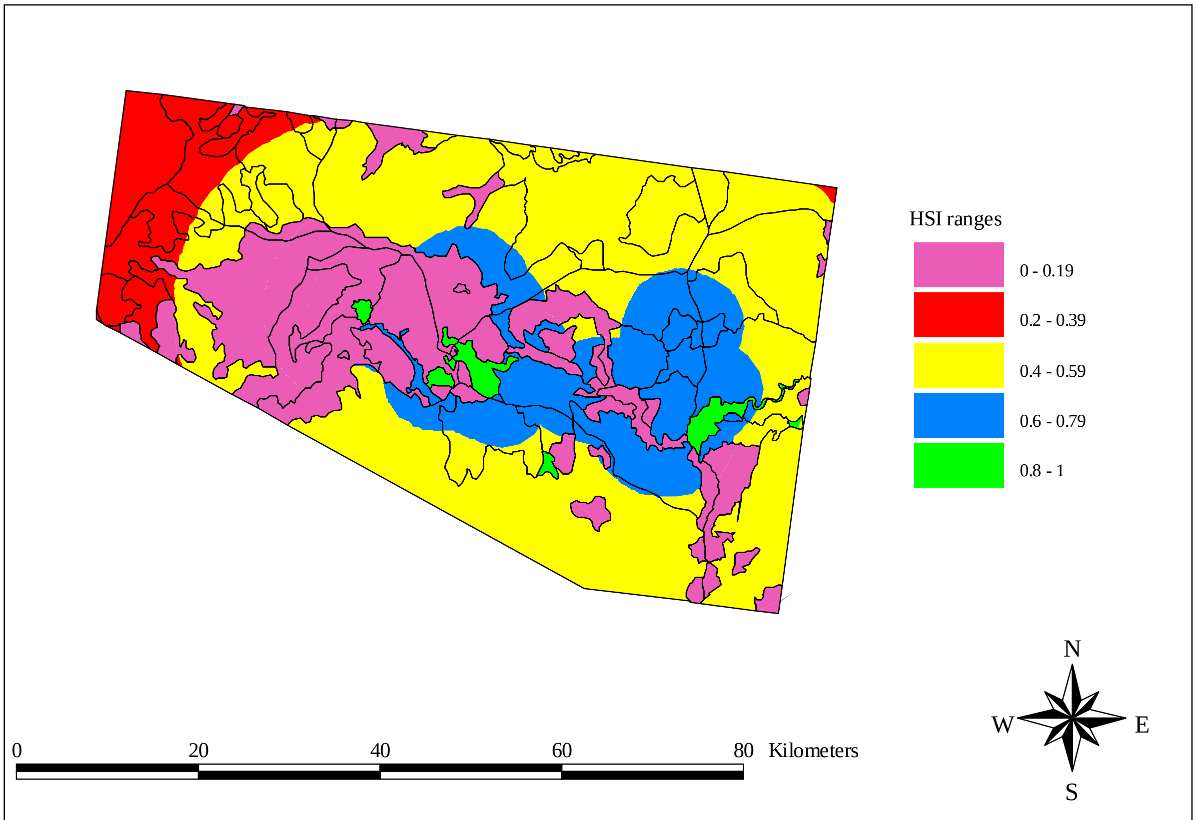

Figure 3.13. Elephant habitat suitability index (HSI) for 1988 in Amboseli Basin. The HSI was derived by combining food and water suitabilities.

FIGURE 3.13. ELEPHANT HABITAT SUITABILITY INDEX (HSI) FOR 1988 IN AMBOSELI BASIN. THE HSI WAS DERIVED BY COMBINING FOOD AND WATER SUITABILITIES.

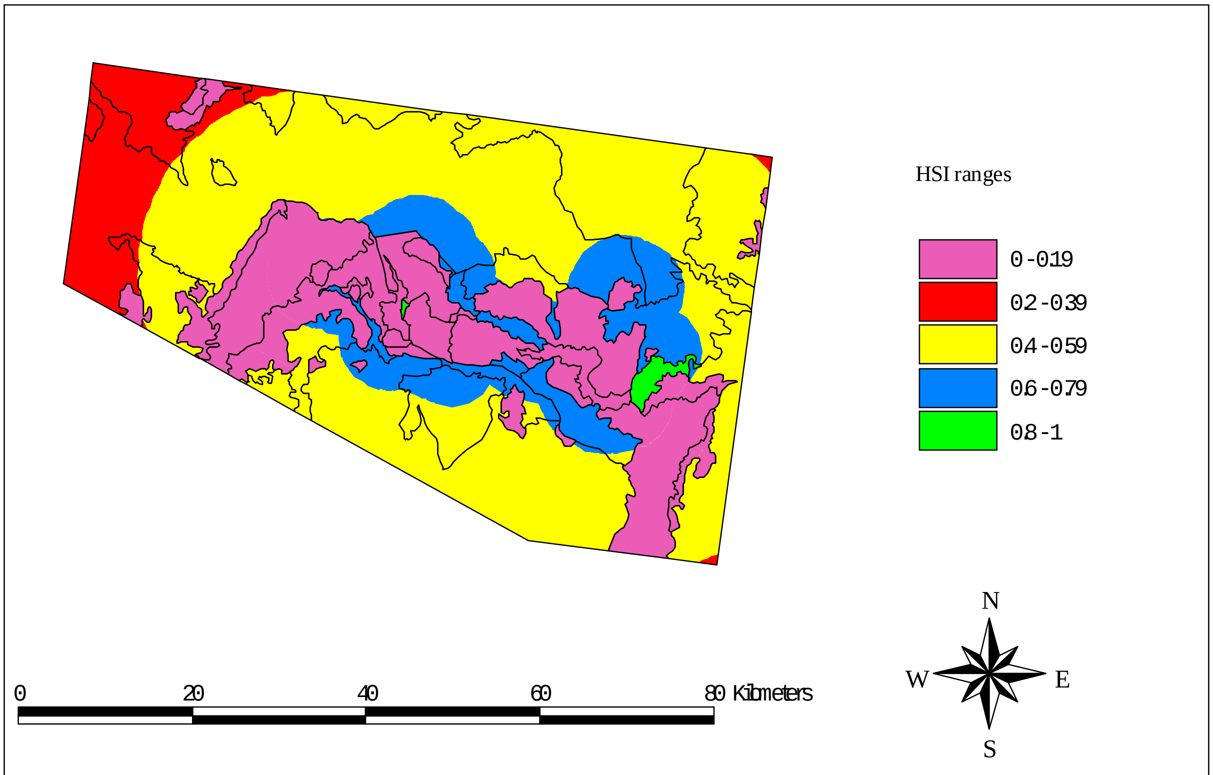

Figure 3.14. Elephant habitat suitability index (HSI) for 1993 in Amboseli Basin. The HSI was derived by combining food and water suitabilities.

FIGURE 3.14. ELEPHANT HABITAT SUITABILITY INDEX (HSI) FOR 1993 IN AMBOSELI BASIN. THE HSI WAS DERIVED BY COMBINING FOOD AND WATER SUITABILITIES.

Chapter 4. Assessment and Evaluation of Elephant Damage in Amboseli Basin

4.0. Introduction

Conservation is not a cost-free undertaking. In several African countries, human-elephant conflicts are no longer perceived as just nuisances, but have become major concerns for conservation and local peoples (Dublin et al. 1995, Tchamba 1996). On the other hand, few thorough studies have been done to address this issue. Planning and legislation on wildlife damage issues cannot be thorough and proactive if realistic information is lacking or inadequate. Without area and time-specific assessments and evaluations, efforts to address elephant damage may consistently fall far short of official intentions. Rural land use changes will continue to occur and, Kenya having an agrarian economy, agriculture will continue to expand into areas that were assumed available for elephant foraging outside parks.

The ecological nature of our parks and mobility of elephants will ensure that issues of elephant damage are not going away soon and in fact may intensify as the human population increases. It is important to point out that the *fact* of elephant damage has been a fixture of rural areas where elephant conservation is practiced. Historical records show that elephants have been a problem to farmers in various parts of Kenya for a long time. For example, elephants were regarded as a problem to farmers in Laikipia District by the 1920's (Kenya Colony 1935). In 1934, 80 elephants were shot specifically for control by the Game Department in Laikipia. Therefore, the fact of elephant damage should not be in dispute; the *effect* and pattern of such incidences is what elephant managers and planners need to understand in order to minimize the damage.

If elephant damage is recognized as a significant issue, then there is a need to use a planning approach that reduces the problem to 'manageable' pieces and seeks solutions to each one. However, this piece-by-piece (e.g., a fence here and there in response to outcries, or shooting rogue elephants) approach of dealing with this problem (as KWS has been doing) will not correct the larger issues of the situation. Just 'getting rid of what is not wanted' will not necessarily bring what is desired. In recognition of this fact, with this project I sought to study and understand the elephant damage problem situation as a system of interconnected and interacting biological (elephant populations, habitats) and socio-economic-political metrics. Such analyses and evaluations are necessary for going beyond incremental and disjointed plans of dealing with the damage and designing strategies that incorporate ecological as well as socio-economic interdependencies. Hence, any sound strategy aimed at addressing this issue must be internally consistent with the areas' socio-economic and biological realities.

Elephant-human conflict occurs in 26 districts of Kenya, and is especially acute where farmland borders conservation areas (Table 1.3). Between 1989 and 1995, 272 elephants were killed for control while 148 people were killed and 48 others were injured by elephants (KWS 1996). It is vital to note here that these are the reported cases (there are cases that go unreported). Elephants present a special case as problem animals because local people increasingly regard them as dangerous pests that need to be controlled; but on the other hand, elephants are endangered animals under strict conservation rules including an international ban on ivory trade. Compensation for elephant damage has not been a realistic option for most victims of elephant damage to date.

There have been few studies that have directly addressed the elephant damage problem in Kenya (Hoare 1990, Thouless 1994, Thouless and Sakwa 1995). These studies covered a tiny area of the elephant conservation range. Even though Amboseli elephants have had numerous studies conducted on them, there has been no study that has directly addressed the human-elephant conflicts in Amboseli Basin. Thus, there is a major information gap in this area. Given the importance that the Kenya Wildlife Service (KWS) places on Amboseli National Park, it seems that purposeful collection of data on the human-elephant conflict dynamic in this area would be useful. Without reliable information on the patterns and magnitudes of elephant damage across the landscape, it is possible that the inaction in dealing with this issue will continue. A clear understanding of the extent, severity, and distribution (spatial and temporal) of elephant damage to human subsistence and other activities in the Amboseli Basin would provide useful data for designing mitigation, compensation, and other intervention programs. Hence, in this chapter I seek to evaluate elephant damage and provide information that rural communities and wildlife authorities can use in dealing with this issue.

4.1. Stakeholders in the elephant problem in Amboseli

Elephant damage is a multi-dimensional issue affecting different layers of stakeholders to varying degrees. It is therefore important to clearly define who the stakeholders are and how they are affected. For the purposes of this study, I identified 8 stakeholder groups that are in some way directly affected by the elephant damage issue in Amboseli. These are local farmers, local Maasai pastoralists, the Kenya Government, the Kenya Wildlife Service (KWS), non-governmental organizations (NGOs), tourists and tour operators, conservationists and researchers, and the elephants themselves. A brief description of the different stakeholders follows.

Local farmers: Local farmers have either lease- or freehold rights to use their land to the exclusion of elephants and other wildlife. Most farmers are subsistence oriented with minimal involvement in commercial agriculture. Most grow crops such as onions and tomatoes for sale so that they can get money to purchase foodstuffs and meet other livelihood needs. Generally, farmers are affected negatively by the crop raiding behavior of elephants. Also, some people in this group are injured/killed by elephants.

Local Maasai pastoralists: This group extensively grazes their livestock in the basin. Their interaction with elephants has generally been viewed as that of co-existence (Kangwana 1995, Western 1982). However, recent events indicate that negative interactions between elephants on one hand and Maasai and their livestock on the other, are on the rise. Elephants occasionally injure/kill livestock or Maasai pastoralists and Maasai generally retaliate by spearing the elephants.

Kenya Government: Elephants and the rest of wildlife are a state monopoly (i.e., the government has sole rights of ownership and use). The State also has monopoly over revenues generated by the wildlife-based tourism. Most tourists come to Amboseli to see elephants. Therefore the government has a strong interest in the Amboseli elephant population. The elephant population in Amboseli affects the government positively through the generation of tourist revenues that go straight into the state consolidated fund.

Kenya Wildlife Service (KWS): KWS is charged with the preservation of elephants and other wildlife throughout the country. KWS is also the landowner of conservation areas (parks and reserves), including ANP. KWS places special emphasis on ANP since it generates the highest revenues in the country. ANP (together with Aberdares and Lake Nakuru National Parks) has been classified as a category "A" park. These 3 parks have been assessed the highest entry fees ($ 27.00 per adult person). Even though parks have been viewed as the main conservation tool, elephants extensively use nonpark areas around ANP. So far, the policies of KWS have tended to ignore the important role nonpark areas play in conservation of elephants. The actions and policies of KWS seem to imply that 'Parks = Elephants'.

Non-governmental Organizations (NGOs): Examples include the African Wildlife Foundation (AWF) and Wildlife Conservation International/New York Zoological Society (WCI/NYZS). These 2 organizations have vigorously advocated maximum protection of the Amboseli elephants at all costs. The dynamics of the whole basin are generally not considered in their programs, which tend to be very species oriented. The AWF specifically exists because of elephants and therefore is expected to act in the interest of its members. These NGOs receive their funding by, in part, championing the plight of the elephant. These organizations are not local, but North American institutions with most of their members based in North America. In fact, none of the Kenyan locals in Amboseli can afford to pay membership fees to these organizations.

Tourists and Tour operators: Most tourists who visit Amboseli come to view wildlife. Hence a non-consumptive attitude towards wildlife is strong. They prefer high population density of elephants since this means that they can easily see elephants within the shortest time possible. Thus anything that may affect individual elephants is viewed with alarm by this group.

Conservationists/Researchers: This group is diverse and has varying interests and nationalities. Most of them have concentrated their research efforts within the confines of ANP and on the biology of elephants and other species. One of the oldest research teams here is the Amboseli Elephant Project which has been in existence for more than 15 years. This group has gathered much data on the natural history of elephants here. However, the most striking omission is that no study has attempted to look at the elephant damage and human dimensions issues in the basin.

Elephants: The current population is slightly over 1,200 individuals. Park boundaries are meaningless to them and they move wherever food resources can be accessed within the basin, including farms.

From the foregoing, it appears that local farmers and pastoralists are the ones affected negatively and directly by elephant damage. These 2 groups are also the ones that make daily land use decisions that affect elephant habitat quality and quantity outside ANP. Therefore, my assessment of elephant damage focuses on these 2 groups.

4.2. Methods

4.2.1. Definitional issues

What constitutes elephant damage is central to this study. I define elephant damage as that activity by an individual or group of elephants that during their foraging activities outside Amboseli National Park boundaries causes crop depredation, livestock death/injury, human death/injury, or destruction of other property such as houses. Incidents that occur within recognized park boundaries are not considered to be damage in this study. Damage was classified into 3 categories: 1) crop damage, 2) livestock injuries and deaths, and 3) human deaths and human injuries. For purposes of this study, crops refer to tomatoes, cabbages, onions, corn, beans, kale, mangoes, bananas, chilies, and citrus. I did not analyze damage by crop type since most farms had mixed crops.

The elephant population was treated as stable or increasing. In any case, the population of elephants per se may not be the issue. In areas where wildlife damage is the issue, Cultural Carrying Capacity (CCC) has been shown to be more critical than Biological Carrying Capacity (BCC) (Ellingwood and Caturano 1988). CCC has been defined as the maximum number of animals that can coexist compatibly with local human populations (Ellingwood and Spignesi 1986). BCC has been defined as the number of animals that a given parcel of land can support in good physical condition over an extended period of time (Ellingwood and Caturano 1988). In this case then, CCC is a function of the sensitivity of the local human populations to elephant foraging patterns outside of parks and this sensitivity will be dependent on local land use practices, local elephant density and the attitudes and priorities of local communities. Thus, one elephant terrorizing a village may cause the CCC to be exceeded even though the actual elephant population density in the area may be quite low. However, CCC does not a particular level or number for a given area. Different stakeholders will have different levels of wildlife acceptance capacity (WAC) (Minnis and Peyton 1995). Thus, CCC for any given species in any given area and time will have a range of values that are acceptable to different stakeholders.

4.2.2. Locals' perceptions of elephant damage

Two tools were used to assess the views and perceptions of the local farmers. These tools are 1) short questionnaire, and 2) direct observation and qualitative interviews (Patton 1980, Salmen 1995). Twenty households from each of the 5 irrigation schemes studied (Namelok, Isinet, Kimana, Tikondo, and Impiron) were randomly selected from a list provided by the Kimana area agricultural officer. The 100 farmers were interviewed using a series of 7 short answer questions (Table 4.5). In addition a group of 40 pastoralists were interviewed using the same questionnaire to see whether their perceptions varied from those of farmers.

The second step involved conducting qualitative interviews with a smaller group of farmers (20) and pastoralists (9) in their working environments. The interviews were limited to 35 minutes per session and were conducted around 5 major themes (Table 4.6) using the format advanced by Salmen (1995). Qualitative interviews allow the respondent to address a topic freely and with candor. Sometimes direct questions, especially on sensitive topics such as elephant damage, put people on the defensive and may lead to responses which are considered in the respondent's best interests or what will please the interviewer. Qualitative interviews tend to be more indirect and are meant to elicit more valid expressions of opinion, or fact (Salmen 1995). The use of apparatus (such as pens and notebooks) that could inhibit respondents was avoided; I used a micro-cassette to record all the conversations and I transcribed the information to paper when I returned to base. The respondents were informed that their opinions were important and would be transmitted to agencies that may be able to assist in minimizing the problem. The interviews were conducted in the Kiswahili language.

4.2.3. Types, pattern and frequency of damage

Between 6/1/96 and 7/30/97, elephant damage information from the 3 daily national newspapers (The Daily Nation, The Standard, and Kenya Times) was gathered. Every issue was scanned for any reports of elephant damage in the study area and the rest of the country. In the event that an incident was reported in any of the papers, the date, type of damage, geographic location, and the nearest National Park were recorded. Care was taken to ensure that incidents that were cross-reported by different papers and issues were not recorded as separate. Also, the KWS Occurrence Books (OB) at Amboseli National Park Headquarters and Kimana Ranger Outpost were checked every 2 weeks and reports of elephant damage extracted for the same evaluation period. The OB is KWS's official log of all the wildlife-related incidents that occur within and outside protected areas. The incidents are supposed to be entered every day by an officer on duty.

In order to be able to estimate the frequency of elephant damage, the selected 100 farmers were visited every 7 days and asked if any elephant raid had occurred on their farms or their neighbors' farms. Since elephants do not select and raid each farm in isolation, I assumed that incidents within 500 meters around the selected farm should be recorded if identified. The number of raids in the preceding 7 days, and the approximate distance away from ANP were recorded. These were independent of the reports in the OB. Only those incidents that could be verified by my field team were recorded. I had 4 field assistants and 2 KWS rangers assisting in the verification of damage reports. I assumed that 7 days was a short enough period for farmers to be able to recall incidences of elephant damage on their farms and neighborhood.

4.2.4. Valuation of damage to locals

Valuation of elephant damage was done using direct monetary costs to locals. Using the documented reports and interviews with the selected group of 100 farmers, elephant damage was evaluated to estimate the financial costs incurred by the locals in Amboseli due to elephant damage. Evaluation was done using the prevailing market prices of the destroyed property. The prevailing (1997) market prices of crop produce and livestock were provided by the area agricultural officer (Mr. Kimani, Ministry of Agriculture) and verified by me at the local Kimana market center. In the cases of human death/injury, other considerations were taken into account since I could not use the market to capture such costs. To estimate the total cost in the study sites, the number of incidents per category was multiplied by the prevailing dollar (or local shilling) value.

4.3. Results and Discussion

4.3.1. Locals' views and perceptions of the elephant problem

4.3.2. Farmers

50% of those interviewed (n = 100) said that they personally considered the elephant as the most dangerous animal in the basin. The African buffalo (*Syncerus caffer)* was ranked second with 34% of the respondents saying it was the most dangerous. However, when asked which animal was the most destructive, the overwhelming majority (83%) identified the elephant. Seventy six percent of the respondents said they were not satisfied with the yields of agricultural produce from their farms, specifically tomatoes and onions. All of these 76 farmers identified wildlife as the main cause of reduced yields. When asked to rank which wildlife species were the main cause of the declining yields, respondents from Kimana, Tikondo, Isinet, and Namelok identified the following ranking: elephant > zebra > gazelles > buffalo. However, respondents from Impiron had a different ranking of the problem wildlife species: eland > zebra > giraffe > elephant.

Amongst these 5 study sites, Impiron is the farthest (48 km) from ANP. This may explain the reduced significance of elephants as a problem species in terms of crop damage. Eighty three percent (n=100) of the respondents said they did not report incidents of elephant damage because: a) there would be no action from KWS staff, b) there was no compensation, and c) ANP offices were too far for them to walk there to report. Whereas the majority (94%) of the respondents felt that elephants should not be killed randomly, 57% (n=94) of this group said that rogue elephants found destroying crops should be shot on sight, 15% said they should be translocated to other areas since KWS valued them very much, and 28% said fences should be constructed to keep marauding elephants from their farms. Eighty nine percent of the farmers said they were willing to accommodate some elephant damage as long as KWS shared the cost in some form (e.g., compensation). They took strong exception to non-compensation and noted that they do not grow crops to aid elephant foraging. However, farmers did not retaliate by harming elephants found on their farms. Six of the total sample said they would prefer that elephants are eliminated from this area altogether.

4.3.3. Pastoralists

Pastoralists (66%) ranked the African buffalo as most dangerous followed by elephant. However, they ranked hyena as the most destructive (47%) followed by leopard (34%) and lion (19%). Pastoralists were generally less bothered by elephants except when their livestock were killed or one of their own people was injured or killed by elephants. In fact the reaction of pastoralists to such acts by elephants was almost always retaliatory; they would either spear the elephant involved themselves or they would appear at the ANP offices and demand that KWS staff come and shoot the elephant involved. In the event that KWS staff showed hesitation, the Maasai Morans (warriors) would simply threaten to spear more than one elephant in retaliation. These threats were taken very seriously by KWS and were acted upon almost immediately. Hence, even though elephant damage to pastoralists is not being compensated, the local Maasai have found a way to deal with the problem in a manner that seems to 'satisfy' their immediate anger.

The rationale behind such retaliatory reactions appears to be the reasoning that elephants do not eat meat and hence when they kill domestic animals they are simply being destructive. It appears that elephants killing livestock is not a behavior that the local pastoralists are willing to tolerate. It is interesting to note that even though pastoralists ranked hyenas as the most destructive animal, they did not retaliate on cases of hyenas killing their livestock, neither did they hold KWS accountable for the livestock predation by hyenas. In other words, livestock depredation by carnivores is a cost which the pastoral production system has to a large extent internalized.

4.3.4. Types, pattern and frequency of elephant damage

Between June 1996 and July 1997, there were 223 cases of wildlife damage reported in the 3 daily newspapers covering different parts of the country. Of the 223 cases, 114 (51%) were reported as elephant damage. The majority of the elephant cases (80 cases) involved crop damage. The other cases involved human injury (9), human death (15), and destruction of other property such as houses (10). However, none of the reported incidents were from Amboseli. This is significant considering the importance of Amboseli to the national economy. One can make the argument that the newspapers cannot possibly cover every part of Kenya, but Amboseli is a prime tourism zone in Kenya that should be well covered by the national papers. Indeed, during the evaluation period, 2 papers (The Daily Nation and The Standard) ran special features on tourism facilities in Amboseli National Park. However the local land realities, challenges, and the (uncompensated) costs that local people incur from elephants did not appear in any of the papers.

This underscores the fact that elephant damage is a local issue that should be dealt with at the local level. Any national level planner scanning the national press for elephant damage hot-spots would easily have overlooked Amboseli since it was not mentioned during the evaluation period. Also, my analysis shows that newspapers may be grossly under-reporting incidences of elephant damage across the country. Hence, any strategy aimed at dealing with the elephant problem should not use newspaper reports as the main source of information. At best, newspaper reports should only be used in combination with other data sources.

During the evaluation period, a total of 143 elephant damage incidents (mean = 10.2/month, s.d. = 5.6) was reported and recorded in the OB at Amboseli and Kimana (Table 4.1). The number of incidents reported in the OB ranged from 2 for the month of December 1996 to 27 for the month of February 1997. Of these 143 incidents, 20 involved livestock deaths (10 cows, 3 bulls, 3 calves, and 4 goats). Twelve other incidents involved human deaths (3 male adults) and 9 human injuries (7 male adults and 2 boys). All the cases of human deaths/injuries and livestock deaths were also independently reported in my study. All the livestock and human deaths/injuries were verified by the park authorities and my team. The remaining 111 cases (mean = 8/month, standard deviation = 3.8) were reported as crop raids by elephants. The crop raids reported in the OB were not independently verified. Hence, the majority (78%) of the elephant damage incidents reported in the OB related to crop damage and affected the local farmers.

My study recorded a total of 489 incidents. I recorded 457 cases (mean = 33/month, s.d. = 14.4) of crop damage by elephants (Tables 4.1, 4.2). The range in my study was 16 incidents for the month of June 1996 to 72 incidents for the month of February 1997. Incidences relating to human deaths/injuries and livestock deaths were similar for both the OB and my study reports (Table 4.2). There is also apparent agreement between the OB reports and my study that the month with the highest incidents is February. This coincides with the peak dry season in this area.

4.3.5. Frequency of damage

For the 14 months covered in my study, the total number of days is 426. In terms of frequency, the OB reports suggest that there are 0.34 incidents per day. In other words, the OB suggests that there is an elephant damage incident about every 3 days (i.e., 426/143 incidents). However, my study suggests that there are 1.15 elephant damage incidents per day. Alternatively, my study suggests that there is an elephant damage incident every 0.87 days in the basin (i.e., 426 days/489 incidents).

The OB yielded 10.2 reported incidents/month (se = 1.67) and my study 34.9 reported incidents/month (se = 4.85). A paired t-test on the differences in reported incidents (between OB and my study) for each month showed that the OB significantly under-reported the number of elephant damage incidents in Amboseli basin ($n = 14$, mean of the difference = 24.7 incidents/month, $t = 5.8$, $p < 0.0001$). However the general trend in reporting was similar. The reports from the OB and my study were weakly correlated ($r = 0.51$, $P = 0.063$) and both seemed to reflect the general trend in reported incidents in time (Figure 4.1).

4.3.6. Crops

The reports in the OB suggest that there are 0.26 crop raids every day, which translates into an elephant crop raid every 3.84 days. From my study, I estimated that there are about 1.1 elephant crop raids every day. This translates into 1 elephant crop raid every 0.932 days. The differences in the number of incidents reported in my study and the OB are substantial. In fact my study suggests that for each incident of crop damage reported in the OB, there are 3 other cases that are not reported. Thus the reports in the OB may not be a true representation of the actual elephant damage situation in the basin. The implication is that the OB is under-reporting the cases of elephant damage in the basin (Figure 4.1). This is significant given the fact that this is the official KWS log of the incidents that affect elephant management in this area. More importantly, the OB reports may suggest that the elephant crop raids are not a problem in the basin. My study results present a different picture.

The frequency of reporting elephant damage incidents in the OB may be a function of the distance to the nearest KWS offices (Table 4.3). The majority of the incidents in the OB originated from Namelok and Kimana (Table 4.3). Namelok is closest to ANP Headquarters offices (6 km) while there is a KWS ranger outpost at Kimana. From the interviews conducted, farmers had indicated that the long distances to the nearest KWS offices was one of the reasons they did not report damage incidents. This implies that the cases reported in the OB would be much higher if there was an effort to reduce the distance farmers have to walk to report damage incidents to the relevant authorities. The distance barrier could be reduced by regularly surveying the basin for damage incidents. My study suggests that reducing the distance barrier can result in higher reporting of verified damage incidents.

4.3.7. Human deaths/injuries

There was a total of 12 human deaths and injuries (Table 4.2). This translates into an elephant related human death/injury almost every month. Three of these cases involved deaths of adult men. The other cases involved serious injuries. This implies that there is an elephant related human death every 4.7 months, and an injury every 1.6 months. Since all the human injury/deaths cases were reported in the OB, it would be safe to say that this frequency is not under-reported by the KWS.

4.3.8. Livestock

The OB and my study reported that there was a total of 20 livestock deaths during the 14 month study period (Table 4.3). This suggests that there is an elephant related livestock casualty every 21 days. The 20 livestock cases involved 10 cows, 3 bulls, 3 calves, and 4 goats. Again the KWS OB did not under-report cases involving livestock deaths. The main reason for the seemingly up-to-date reportage of human and livestock casualties is the emotive nature of these damage categories. It appears that livestock and human elephant related casualties elicit emotive and immediate responses from the locals and in some cases KWS officials are forced to act immediately to at least pacify the affected individuals. Some of the actions taken by KWS officials involved shooting the rogue elephants and assisting in transporting the injured to hospital.

4.4. Valuation of elephant damage

4.4.1. Crops

For the purposes of this analysis, I assumed that 'crops' referred to onions and tomatoes. All the farmers interviewed had grown one or either of these as the main crop. Based on observed cropping patterns and records from Kimana Area Agricultural Office, I assumed a 50:50 ratio in the allocation of farm areas to either onions or tomatoes. Since these 2 were the predominant crops, I used them for general analysis. The average farm size per farmer was 0.2 ha. The area agricultural officer (Mr. Kimani) estimated that the 1997 cost of growing onions or tomatoes on 0.2 ha of land was 15,000 shillings ($250) per farmer (1997 exchange rates: 1 US dollar = 60 Kenya Shillings). He also estimated that farms here achieved a productivity level of 25 tons/ha (i.e., 5 tons/0.2 ha) for tomatoes and 10.5 tons/ha (i.e., 2.1 tons/0.2 ha) for onions. Based upon field observations of elephant damage sites, I assumed that a successful elephant raid will clear 0.2 ha of onions or tomatoes. I also assumed that farmers are not able to work in any other location or occupation.

The 1996-97 farm price of onions was Kenya Shillings 360/= per 14 kgs while tomatoes were selling for Kenya Shillings 450/= per 40 kgs (Area Agricultural Officer, Mr. Kimani, pers. Comm.). Thus going by the collected data on crop raids, the total crop area destroyed by elephants during the evaluation period was 22.2 ha (OB estimates) or 91.4 ha (my study's estimates). This translates into a total cost of $ 20,392 by OB estimates and $ 83,987 by my estimates (Table 4.4). Estimates from my reports show that elephant damage is in the order of $ 919 per ha ($ 184/0.2 ha). The total costs as estimated by the two methods (OB and my study) vary by a factor of 4, but the costs for each hectare damaged are the same. Therefore the importance of accuracy in reporting the frequency of damage incidents and area damaged cannot be overemphasized.

It is important to point out that the per capita income in Kenya is $ 260 (The daily Nation, 4/26/98). Therefore, an elephant destroying 0.2 ha of a crop in Amboseli Basin causes a loss on average of $184 to the individual farmer. This would represent 71% of the farmer's per capita income. Since crop damage is not compensated, it can be argued that elephant damage in Amboseli is a contributing factor to the poverty afflicting farmers in this arid and semi-arid area. This analysis suggests that ways need to be found to compensate the farmers for the loss of their crops due to elephant damage.

4.4.2. Human deaths/injury

During the study period 3 people were killed and 9 others were injured by elephants. The Kenya Government compensates victims at a rate of $ 500 per life lost and $ 400 for injuries. The compensation process is very laborious and none of the victims affected had been considered for compensation at the end of my fieldwork. However, when local farmers and pastoralists were asked what would be fair compensation, they suggested $ 12,250 for death and $ 7,500 for injury. The rationale for these figures was based on local Maasai customs and traditions governing compensation. If a man kills another, by Maasai tradition the assailant is required to pay 49 head of cattle to the family of the victim. Hence, if an elephant kills someone, the minimum compensation should be 49 bulls or equivalent cash. If someone injures another, the compensation would be 30 bulls. The price of 1 bull at the local Kimana market was verified to be $ 250 in 1997. This implies that the compensation figure by local customs should be 24.5 X more than what the government currently offers. Using government rates, the cost of human life would be $ 1500 and $ 3600 for injuries for the study period. This gives a total of $ 5,100. However, when the figures suggested by the locals are considered, the total cost is $ 104,250. To date, none of the 49 compensation claims lodged since 1992 with the Kajiado District Compensation Committee had been paid. Given this performance, it is doubtful that the cases of human deaths and injury recorded in this study will be compensated in the near future.

4.4.3. Livestock

During the period of analysis, 16 head of cattle and 4 goats were killed by elephants. I assumed that 3 calves are equivalent to 1 cow. Going by the prevailing market prices (1997 prices: 1 cow cost $ 167; 1 bull cost $ 250; 1 goat cost $ 60) the area lost $2,827 due to elephant damage to livestock. If other livestock-related benefits (e.g., milk, 'banking', exchangeability/transactions) are considered, the cost would be much higher.

I have considered only the direct financial costs. This is a conservative approach to evaluating the cost since it only looks at the monetary value of recorded cases. In situations where reporting and recording of elephant damage incidents is not exhaustive or non-existent, this approach is bound to under-estimate the cost. Given the fact that reporting of elephant damage in Amboseli appears to be of minimum priority to the authorities concerned, it is possible that the costs presented here are the minimum. However, this approach is easy and quick to operationalize and for a manager with a limited compensation budget (in cases where compensation is an implemented policy) may be desirable, although suboptimal. This may not present the true picture.

Therefore the purely monetary values in this study combined to give a cost of $ 191,064. This divided by the estimated 1989 population (54,000) of the area yields a cost of $ 3.5/person due to elephant damage. Alternatively, elephant conservation in Amboseli costs the locals $ 63.70/km^2. The efficiency with which resources are used to a large degree determines the average standard of living of the society (Lipsey et al. 1987). It has been shown that poverty is one of the forces driving poor and inefficient use of resources (The World Bank 1994). It certainly is not a positive thing for wildlife and specifically the endangered elephant to further contribute directly and indirectly to the poverty afflicting the rural communities with which they share resources.

An elephant clearing a subsistence farmer’s onion farm may not be the most efficient way of using the onions and may make the household’s ability to meet basic food requirements harder, thereby lowering the already low standards of living. In the long run, the wider society bears these costs. For a start, this cost has to be removed/compensated before any other step is taken; one cannot start community projects on one hand while not effectively containing the wildlife damage cost to the community.

4.5. Mitigative measures the locals employ to minimize elephant damage

From my interviews and observations in the field, I found that the local farmers employed a variety of techniques in order to minimize elephant damage.

Making noises by beating empty containers was done as a cooperative effort among neighboring farmers. The farmers noted that this method was not effective since the elephants quickly got used to the noise.

Some farmers lit fires around the farm and guarded their crops. Farmers said that the fires were more effective but had to be kept burning the whole night. They also said that the habitual raiding elephant still attacked even when the fires were burning.

Some threw stones at the elephants. Farmers said that this method worked minimally but in some cases got the elephants agitated and they charged and attacked farmers. Four cases of farmers being attacked while trying to 'stone' elephants were reported.

Some farmers reported to KWS officials after-the-act. If possible, KWS rangers showed up one night to scare the elephants by shooting flares or blanks. However, this is not effective since rangers cannot cover a large area and some elephants were used to the noise. Also, rangers showed up long after the elephants had raided farms and left.

Hence all these cases seem to suggest that techniques used by the locals, and to some degree KWS, to minimize elephant damage are largely haphazard and ineffective. It appears that there is a need for a more pragmatic approach to this issue, such as removal of the known rogue elephants every year. This may lessen the problem but will in no way reduce the elephant damage problem to zero.

4.6. Options for minimizing elephant damage in AB

Some of the potential options for dealing with the elephant damage issue in AB are briefly presented below.

Translocation: Moving problem elephants away from Amboseli could be a very costly exercise. Besides, “there is no there” to shift the problem to. And finally, there is no guarantee that the remaining animals will not cause further damage or that the translocated animals will not walk back after several weeks.

Culling the population: This is a visible exercise that can be a major negative experience for tourists wishing to visit Amboseli. Under current conditions, Kenya is guaranteed to receive negative international publicity if any elephant herd within its borders is culled. This could affect tourism badly. However, this is easy to implement and may actually lower/minimize elephant-human conflicts. The meat could be shared by locals and the ivory could be stockpiled for legal sale.

Shooting for control: This is not very visible since it would target the rogue/problem individuals outside the park. This is inexpensive and easy to implement and may be able to lower the conflicts. However, there will be opposition from some stakeholders (e.g., African Wildlife Foundation) opposed to the killing of elephants under any circumstances.

Financial compensation: This can be expensive and provides no guarantee that the problem will be resolved. In fact when poorly managed, financial compensation can have the effect of perpetuating the problem. Also, assessment and valuation of damage can be very difficult. Compensation can be effective if it is closely monitored and well funded by tourism revenues from the park. One option is to do a survey of the tourists visiting ANP and see if they would be willing to pay an additional 1 or 2 US dollars on their park entry fee. This money would then be set aside specifically to compensate the victims of wildlife damage in Amboseli Basin. Given the high volume of visitors to ANP, the potential to raise substantial revenues for compensation is high.

Fencing and other barriers: Fences have been shown to be ineffective as barriers. All the pilot electric fencing around Namelok irrigation scheme is in a state of disrepair. Also, it is very expensive to construct and maintain fences. The cost of fencing in Kenya is high, about $ 3,561 per km (East African Standard, 5/17/1997).

Thouless and Sakwa (1995) evaluated the different types of barrier (stone wall, 2-strand fence, 3-strand fence, 6-strand fence; all the wire fences were electric) used against elephant in Laikipia District Kenya. The barriers were judged to be ineffective since elephants broke through all of them. Some of the fences had 7 kV of power running through but the elephants ran through them and cut the wires anyway. Elephants used their legs to break fence posts, or pushed them over with their tusks, or just ran through the fence regardless of the electric current (Thouless and Sakwa 1995). On one ranch, Lewa Downs, some elephants were de-tusked in 12/1992 to see if this would reduce pulling at wires (tusks are good insulators) and pushing over posts. However, this action had no noticeable effect on the fence breaking behavior by the de-tusked animals.

In 1990, KWS estimated the capital costs of fencing to be $ 2,000/km for stone walls, $ 9,333/km for high tensile fencing, and $ 5,000/km for electric fencing (KWS 1990). These estimates do not include other initial work such as bulldozing and clearing. Also, recurrent costs and maintenance need to be considered. In 1990, KWS estimated that about 25 km needed to be fenced around Kimana in order to reduce elephant damage. Since the fence was never constructed, the current cost of putting up such a fence would be $125,000. It is questionable whether this would limit the elephant problem since currently other irrigation schemes also would need to be fenced.

Sukumar (1989, 1991) noted that fences were more effective against Asian elephants than African elephants. This could be due to the fact that African elephants make use of their tusks in destroying fences while in Asian elephants, all females are tuskless and most males have only residual or no tusks. Also, the high soil moisture in the wetter ranges of the Asian elephant increases soil conductivity which makes electric shocks more effective than in drier African savannas (Thouless and Sakwa 1995). Given this evidence, there is a need to proceed cautiously with fencing. It is possible this money could be used to pay unavoidable damages and run efficient control operations.

In Malaysia, it was observed that the ability of the habitat to provide adequate food for elephants may be a factor determining effectiveness of electric fences against elephants (Rice 1990). Hence, in highly seasonal and variable habitat areas such as AB, even the best designed fence may not be effective since elephants will break through in search of food; this is especially true given the fact that most of the park dries up in the dry season and the rest of the areas around the park are increasingly heavily grazed by livestock. The costs of maintaining the fence may be too high and there is no one who will commit to doing this for decades to come. Hence, fences should only be used as part of an overall strategy.

Land use planning and zoning: This is political and hard to achieve since people may not agree to have the use of their land legislated without any compensation. The government on its part has shown no demonstrated interest and commitment in leading in the debate and drafting of land use policy that affects wildlife areas. If pursued well, this option has the potential of creating migration corridors that would ensure that elephants have access to critical resources in areas within and beyond the basin. Also, KWS could set up 'zones of compensation' around ANP. For example, certain areas could be designated whereby if they fall within a certain distance of ANP, then farmers cultivating in these zones are not eligible for compensation. On the other hand, wildlife damage beyond such designated areas could be assessed for compensation. This may have the effect of limiting intense human activities near the park boundary.

From the foregoing, it appears that shooting for control and culling are the most feasible ways of minimizing elephant damage, at least from a cost, logistics, and operational point of view. Financial compensation and land use zoning seem to be realistic options that should be pursued. However, no single method is adequate in dealing with the elephant problem.

4.7. Summary

National policy makers and managers of national parks and reserves require accurate information on recent wildlife damage in order to assess future trends and to attempt to deal with the current situation. KWS recognizes that prevention of damage to property by wildlife is one of the issues to be tackled (KWS 1990). In July 1994, KWS appointed a five-person review group to solicit views on human-wildlife conflicts from local communities. Of the 10 districts visited by the group, elephant damage was listed as a major problem in eight districts (KWS 1996). However, the review group only lasted for seven weeks and made 27 field visits outside Nairobi city (the other 9 'visits' on their field program were conducted in offices in Nairobi). It is not possible to fully comprehend the nature of this problem within 7 weeks, let alone make practical suggestions for dealing with it.

This section has provided first-cut empirical guideposts to the often neglected but emerging area of elephant damage in Amboseli. The absence of location-specific data on different types of damage and when they occur may indeed create the impression that elephant damage is insignificant. There needs to be purposeful collection and recording of this information followed by thorough analyses in order to facilitate informed decision making regarding this issue. Currently, there is not a coordinated effort to collect this information. The lack of such substantive data at the local and regional levels may be serving as a disabling factor in KWS formulating adequate response strategies that are both technical and non-technical.

Table 4.1. The total number of reported elephant damage incidents by month in Amboseli Basin during the period June 1996 to July 1997. Recorded incidents from the Occurrence Book (OB) at ANP and my study are both shown.

Month	Rainfall (mm) amount	Number of days it rained	Number of reported incidents		Mean distance (km) from ANP
			OB	My Study	
06/96	0.5	1	11	16	6.9
07/96	0.5	1	5	27	5.7
08/96	2	1	9	20	7
09/96	0	0	6	26	12
10/96	43	2	5	29	8
11/96	61.9	8	10	20	27
12/96	65	11	2	45	40
01/97	0	0	19	53	31
02/97	2.4	4	27	72	34
03/97	63	6	8	70	19
04/97	76.1	8	10	29	21
05/97	52.2	6	9	24	22
06/97	0	0	10	24	19
07/97	6	2	12	34	26
Total	372.6	50	143	489	

Table 4.2. Elephant damage reports by type as reported in the Occurrence Book (OB)at ANP and my study. The period covered is June 1996 to July 1997.

Damage type	OB reports	My Study reports
Crops	111	457
Livestock	20	20
Human injury/death	12	12
Total	143	489

Table 4.3. The number of reported elephant crop raids by irrigation scheme. Records from the Occurrence Book (OB) at ANP and my study are shown.

Location of irrigation scheme	Approximate distance (km) from ANP	Number of reported crop raids		OB/My Study
		OB	My Study	
Namelok	5	59	124	48%
Isinet	30	17	105	16%
Kimana	35	47	136	35%
Tikondo	40	20	89	22%
Impiron	48	0	35	0

Table 4.4. The estimated area (ha) of farms and tonnage of crops destroyed by elephants and the accompanying financial losses (in US dollars) to the farmers in Amboseli Basin. The evaluation period covered is June 1996 to July 1997.

Crop type	Area (ha) destroyed		Tonnage destroyed		Total costs (US $)	
	OB	My study	OB	My study	OB	My study
Tomatoes	11.1	45.7	55.5	228.5	10,406	42,844
Onions	11.1	45.7	23.3	96.0	9,986	41,143
Total	22.2	91.4	78.8	324.5	20,392	83,987

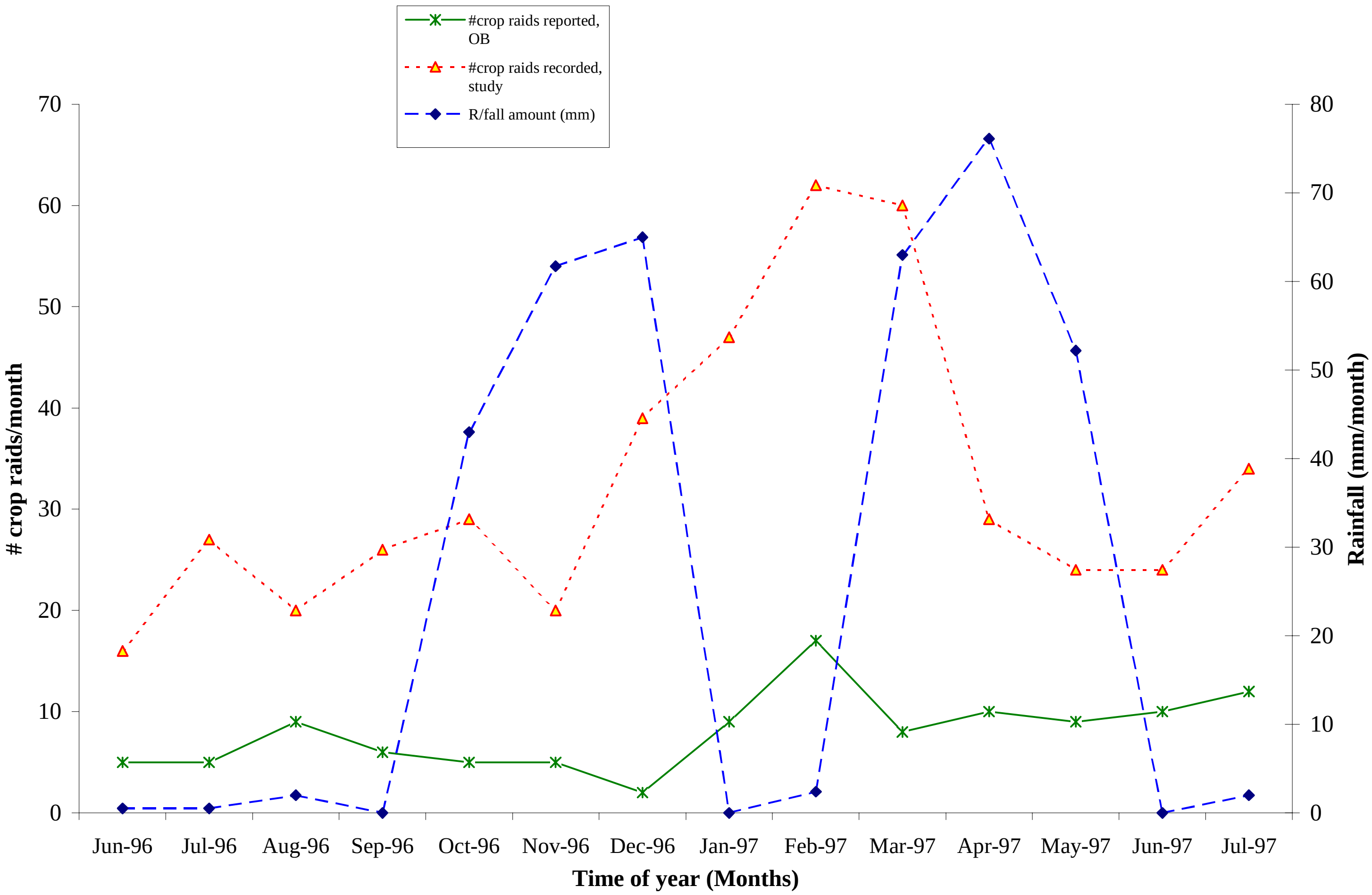

FIGURE 4.1. THE RELATIONSHIP BETWEEN THE NUMBER OF ELEPHANT CROP RAIDS RECORDED IN THE OCCURRENCE BOOK (OB) AT ANP AND BY MYSELF, AND MONTHLY RAINFALL IN AMBOSELI BASIN BETWEEN JUNE 1996 AND JULY 1997.

Table 4.5. Short questionnaire presented to farmers (100) and pastoralists (40) in Amboseli Basin, June 1996 to July 1997.

Questions presented to farmers and pastoralists, June 1996 to July 1997
1. As a resident of this area, which animal do you personally consider to be the most dangerous? Why?
2. Which animal do you consider to be the most destructive in this area? Why?
3. As a farmer, are you satisfied with your crop yields? Why?
4. Is crop damage by elephants a problem to you?
5. Do you report crop damage to the Kenya Wildlife (KWS) service every time it happens?
6. In the last 12 months, how often have you met with KWS officials to discuss wildlife issues?
7. Do you feel KWS has the capability to deal with the elephant damage problem?

Table 4.6. Qualitative interview themes presented to farmers in Amboseli Basin, June 1996 to July 1997.

Conversational Themes
1. Conservation and development in locals' contexts and perspectives
2. Amboseli National Park and the Kenya Wildlife Service
3. Elephant population density in the basin
4. Elephant damage
5. Elephant damage mitigation and compensation issues

LITERATURE CITED

Allen, A. W. 1987. Habitat suitability index models: gray squirrel, revised. US Fish and Wildlife Service. Biological Report 82 (10.135). 16 pp.

Andere, D. K. 1992a.. MAASAI-MARA: Game Reserve. In: Kenya from Space: An Aerial Atlas. DRSRS (Kenya) & CREDU (France). pg. 84-87. Nairobi, Kenya.

Andere, D. K. 1992b. AMBOSELI. In: Kenya from Space: An Aerial Atlas. DRSRS (Kenya) & CREDU (France). pg. 136-139. Nairobi, Kenya.

Anderson, J., E.E. Hardy, J.T. Roach, & R. Witmer. 1976. A Land Use and Land Cover Classification for Use with Remote Sensor Data. U.S. Geological Survey Professional Paper 964.

Andere, D.K., J.G. Stelfox, & S.W. Mbugua. 1981. Distribution and Densities of Livestock and Wildlife in the Rangelands of Kenya: 1977-1978. KREMU Technical Report No. 21. Kenya Rangeland Monitoring Unit, Nairobi.

Anderson, S. H., and K. J. Gutzwiller. 1994. Habitat evaluation methods. Pages 592-606 in T. A. Bookhout, ed. Research and management techniques for wildlife and habitats, Fifth ed. The Wildlife Society, Bethesda, Md.

Armbruster, P. & R. Lande. 1993. A Population Viability Analysis for African Elephant (*Loxodonta africana*): How Big Should Reserves Be?. Conservation Biology. Vol. 7, No. 3.

Barnes, R. F. W. 1983. The elephant problem in Ruaha National Park, Tanzania. Biol. Cons. 26, 127- 148.

Beekman, J. H. & Prins, H. H. 1989. Feeding strategies of sedentary large herbivores in East Africa, with emphasis on the African buffalo, *Syncerus caffer*. African Jnl. of Ecology, Vol. 27, pg.129-147.

Bekure, S.; P. N. de Leeuw; B. E. Grandin; P. J. H. Neate (eds). 1991. Maasai Herding: An analysis of the livestock production system of Maasai pastoralists in eastern Kajiado District, Kenya. ILCA Systems study 4. ILCA (International Livestock Center for Africa), Addis Ababa, Ethiopia. 172 pp.

Ben-Shahar, R. 1993. Patterns of elephant damage to vegetation in Northern Botswana. Biological Conservation, 65:249-256.

Berger, Dhyani J. 1993. Wildlife Extension. Participatory Conservation by the Maasai of Kenya. ACTS Press. Nairobi, Kenya. 193 pp.

Bell, R. H. V. 1990. Trial and Error in Wildlife Management. In: Wildlife Research for Sustainable Development. Conference paper summaries. pg. 4-5. Conference held at National Museums of Kenya. 22-26/04/90. KARI, KWS, NMK. Nairobi, Kenya.

Behnke, R. H. & I. Scoones. 1992. Rethinking Range Ecology: Implications for rangeland management in Africa. Dryland Network Programme Paper No. 33, ODI, London.

Bie, Stein W. 1989. Dryland Degradation Measurement Techniques. Policy and Research Division, Environment Department, The World Bank. Washington, D.C.

Birch, J. W. 1968. Rural land use: a central theme in geography. Pg. 13-28 in E. Embleton and C. Coppock, eds. Land use and Resources: studies in applied geography. Alden and Mowbry, London, UK.

Bogdan, A.V. and D. J. Pratt. 1974. Common Acacias of Kenya. Government Printers, Nairobi.

Bromley, D & Cernea, M. 1989. The management of common property natural resources. Some conceptual and operational fallacies. World Bank Discussion paper; 57. The World Bank, Washington DC.

Campbell, J. B. 1987. Introduction to remote sensing. The Guilford Press. NY. London. 551 pp.

Caughley, G. 1976. Elephant problem - an alternative hypothesis. E. Afri. Wildl. J. 14, 265-283.

Child, Brian. 1990. Assessment of Wildlife Utilization as a Land Use option in the Semi-arid Rangeland of Southern Africa. pg. 155-175. In: Living with Wildlife: Wildlife Resource Management with Local Participation in Africa. (ed.) Kiss, Agnes. World Bank Technical Paper No. 130. Africa Technical Department series. The World Bank. Washington, D.C. 217 pp.

Coe, Malcom. 1985. A natural history of the Kora national reserve, Kenya. pp. 240. George Phillip.

Coe, M. J., D. M. Cumming, and J. Phillipson. 1976. Biomass and production of large African herbivores in relation to rainfall and primary production. Oecologia, 22: 341-354.

Coe, M. and C. Coe. 1987. Large herbivores, acacia trees and bruchid beetles. South Afr. J. Sciences, 83:624-635.

Cooperrider, A.Y. 1986. Habitat evaluation systems. pp. 757-776 in Cooperrider, A.Y., R. J. Boyd, and H.R. Stuart; eds. Inventory and monitoring of wildlife habitat. US Dept. Interior, Bur. Land Manage. Service Center, Denver, Colorado.

Croze, H.; A. K. K. Hillman; E. M. Lang. 1981. Elephants and their habitats: how do they tolerate each other. In: Dynamics of large mammal populations . (Eds) Fowler, C. W. & T. D. Smith. John Wiley, NY.

Department of Resource Surveys and Remote Sensing (DRSRS). 1994. Summary of Aerial Surveys for Kajiado District, 1994. Ministry of Planning and National Development, Nairobi, Kenya.

Deering, D.W.; J.W. Rouse; R.H. Haas, and J.A. Schall. 1975. Measuring Forage Production of Grazing Units from Landsat MSS data. Proceedings of the 10th International Symposium on Remote Sensing of the Environment, Ann Arbor, Michigan, p. 1169.

Dobson, A. P., A. D. Bradshaw, and A. J. Baker. 1997. Hopes for the future: Restoration Ecology and Conservation Biology. Science, Vol. 277: 515-522.

Dublin, H.T.; T. Milken and R.F.W. Barnes. 1995. Elephants - four years after the ivory trade ban. Oryx, 29 (2): 74-76.

Dublin, H. T. and I. Hamilton. 1987. Status and trends of elephants in the Serengeti-Mara ecosystem. African Jnl. of Ecology, 25: 19-33.

Dublin, H. T., A. R. E. Sinclair, and J. McGlade. 1990. Elephants and fire as causes of multiple stable states in the Serengeti-Mara woodlands. Journal of Animal Ecology, 59: 1147-64.

Ellingwood, M.R. and J.V. Spignesi. 1986. Management of an urban deer herd and the concept of cultural carrying capacity. Trans. Northeast Deer Technical Committee, 22:42-45.

Ellingwood, M.R. and S.L. Caturano. 1988. An Evaluation of Deer Management options. A joint publication of the New England Chapter of The Wildlife Society, the Northeast Deer Technical Committee, and the Northeast Wildlife Administrators Association.

Esikuri, E. E. 1991. Group Ranches, National Parks, and Agriculture: resource use conflicts and opportunities for pastoral and wildlife development in Kenya. M.Sc. Thesis, NORAGRIC, Agricultural University of Norway, Aas. 187 pp.

Estes, E. J.; Stow, D.; Jensen, R. J.. 1982. Monitoring land use and land cover changes. In: Remote sensing for resource management. Eds. Johannsen, J. C. & Sanders, L. J.. pp. 665.

Field, C. R. 1971. Elephant ecology in Queen Elizabeth National Park, Uganda. E. Afr. Wildl. J. 9, 99-123.

Fowler, C. W. & T. D. Smith. 1973. Characterizing stable populations: an application to the African elephant population. J. Wildl. Manage. 37, 513-523.

Fish and Wildlife Service (US). 1980a. Habitat as a Basis for Environmental Assessment. Ecological Services Manual 101. U.S. Department of Interior, Fish and Wildlife Service, Division of Ecological Services. Government Printing Office, Washington, D.C. 28 pp.

Fish and Wildlife Service (US) 1981a. Standards for the Development of Suitability Index Models. Ecological Services Manual 103. U.S. Department of Interior, Fish and Wildlife Service, Division of Ecological Services. Government Printing Office, Washington, D.C. 68 pp. + appendices.

Guy, P. 1989. The influence of elephants and fire on the Brachystegia-Julbernardia woodland in Zimbabwe. Journal of Tropical Ecology, 5: 215-26.

Gwynne, M.D. 1969. The nutritive values of acacia pods in relation to acacia seed distribution by ungulates. E. Afr. wildl. J., 7:176-178.

Grunblatt, J.; W. K. Ottichilo; R. K. Sinange. 1989. A Hierarchical approach to vegetation classification in Kenya. Department of Resource Surveys and Remote Sensing. In: Afr. J. Ecol. Vol. 27, pg. 45-51.

Hall, L. S., P. R. Krausman, and M. L. Morrison. 1997. The habitat concept and a plea for standard terminology. Wildlife Society Bulletin, 25 (1):173-182.

Hanks, J. & J. E. A. McIntosh. 1973. Population dynamics of the African elephant (Loxodonta africana). J. Zool., Lond. 169, 29-38.

Hays, R.L., C. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. USDI. Fish and Wildlife Service. FWS/OBS-81/47. 111pp.

Hepinstall, J. A., L. P. Queen, and P. A. Jordan. 1996. Application of a modified habitat suitability index model for moose. Photogrammetric Engineering and Remote Sensing, Vol. 62, No. 11: 1281-1286.

Hepinstall, J. A. and S. A. Sader. 1997. Using Bayesian statistics, Thematic Mapper satellite imagery, and breeding bird survey data to model bird species probability of occurrence in Maine. Photogrammetric Enginnering and Remote Sensing, Vol. 63, No. 10: 1231-1237.

Hoare, R.E. 1990. Observations of elephant crop raiding behavior and evaluation of electric fence designs in Laikipia District. Report to Kenya Wildlife Service, Laikipia Elephant Project. KWS, Nairobi.

Hoft, R. and M. Hoft. 1995. The differential effects of elephants on rain forest communities in the Shimba Hills, Kenya. Biological Conservation, 73: 67-79.

Houghton, R. A. 1994. The worldwide extent of land-use change. BioScience. Vol. 44, No. 5: 305-313.

Houghton, R. A., D. S. Lefkowitz, and D. L. Skole. 1991. Changes in the landscape of Latin America between 1850 and 1980. A progressive loss of forest. Forest Ecology and Management, 38: 143-172.

Houghton, R. A., J. D. Unruh, and P. A. Lefebvre. 1993. Current land cover in the tropics and its potential for sequestering carbon. Global Biogeochemical Cycles, 7: 305-320.

Jachmann, H. 1989. Food selection by elephants in the Miombo biome in relation to leaf chemistry. Biochem. Syst. & Ecol., 17:15-24.

Jachmann, H., and R. H. V. Bell. 1985. Utilization by elephants of the Brachystegia woodlands of the Kasungu National Park, Malawi. African Journal of Ecology, 23:245-58.

Jachmann, H. 1987. Elephants and woodlands, II. Pachyderm, 8:11-12.

Jachmann, H. and T. Croes. 1991. Effects of browsing by elephants on the Combretum/Terminalia woodland at the Nazinga Game Ranch, Burkina Faso, West Africa. Biological Conservation, 57:13-24.

Kabigula, J. 1993. Feeding habits of elephants in Ngorongoro crater, Tanzania. African Journal of Ecology, 31:156-64.

Kajiado District Development Plan (KDDP). 1988. Kajiado District Development Plan, 1984-1988. Ministry of Finance and Planning, Nairobi, Kenya.

Kajiado District Atlas. 1990. Kajiado District Atlas. Ministry of Reclamation and Development of Arid, Semi-Arid Areas and Wastelands. ASAL Programme, Kajiado District. 123 pp.

Karime, Obed N. I. 1990. The Changing Land Use Patterns in the Ngorengore/Loita Plains. Technical Report No. 135. Dept. of Resource Surveys & Remote Sensing (DRSRS), Ministry of Planning & National Development. Nairobi, Kenya. PP 32.

Kangwana, K. 1995. Elephant-Maasai interaction in Amboseli, Kenya. In Integrating People and Wildlife for a Sustainable Future. Proceedings of the Fisrt International Wildlife Management Congress. J. A. Bisonnette and P. R. Krauseman, eds. The Wildlife Society. Bethesda, Md. 697 pp.

Kelso, B. J. 1995. The Ivory Controversy. In: Africa Report. March-April, 1995. pg. 50-55.

Kenya Wildlife Service (KWS). 1991. Amboseli National Park Management Plan (1991-1996). Planning Department, KWS. Nairobi, Kenya. 80 pp.

Kenya Wildlife Service (KWS). 1990. A Policy Framework and Development Programme, 1991-96. Kenya Wildlife Service. Nairobi, Kenya. 220 pp.

Kenya Wildlife Service (KWS). 1996. Wildlife-Human conflicts in Kenya. Report of the five-person review group, 19th December 1994. 33 pp.

Kenya Wildlife Service (KWS). 1996. Kenya: National Parks and Reserves Tour Planner. Kenya Wildlife Service. Nairobi, Kenya.

Kenya Wildlife Service (KWS). 1995. Annual Report 1995. Kenya Wildlife Service. Nairobi, Kenya.

Kenya Wildlife Service (KWS). 1996. Annual Report 1996. Kenya Wildlife Service. Nairobi, Kenya.

Kenya Colony. 1935. Game Department Annual Report, 1935. Government Stationers, Nairobi.

Kenya Wildlife Service. 1990. Policy Framework and Development Programme, 1991-96. Annex 6: Community Conservation and Wildlife Management outside parks and reserves. KWS, Nairobi. 181 pp.

Kenya Wildlife Service. 1995. Annual Report, 1995. KWS, Nairobi, Kenya. 29 pp.

Kenya Wildlife Service. 1996. Wildlife-Human Conflicts in Kenya. Report of the Five-Person Review Group, 12/19/1994. KWS, Nairobi, Kenya. 33 pp.

Kituyi, M. 1989. Becoming Kenyans. History and Adaptation in the Transformation of the Pastoral Maasai. University of Bergen, Norway.

Kufwafwa, J.W. 1985. Numbers and Distributions of Livestock and Wildlife in Kenya: An Overview. In: Wildlife/Livestock Interfaces on Rangelands. pg. 83-92. Proceedings of a conference held at Taita Hills Lodge, Kenya. 4/22-25/1985. Ed. MacMillan, S. p. 212.

Laws, R. M. & I. S. C. Parker. 1968. Recent studies on elephant populations in East Africa. Symp. Zool. Soc. Lond. 21, 319-359.

Laws, R.M. 1970. Elephants as agents of landscape change in East Africa. Oikos, 21: 1-15.

Laws, R. M., I. S. C. Parker, and R. C. B. Johnson. 1975. Elephants and their habitats: the ecology of elephants in North Bunyoro, Uganda. Clarendon Press, Oxford.

Lefkovitch, L.P. & L. Fahrig. 1985. Spatial characteristics of habitat patches and population survival. Ecol. Modelling 30:297-308.

Leuthold, W. 1972. Home range, movements, and food of a buffalo herd in Tsavo national park. East African Wildlife Jnl. 10:237-243.

Leuthold, W. 1977. Changes in tree populations of Tsavo East National Park, Kenya. East African Wildlife Journal, 15:61-9.

Lock, J. M. 1977. Preliminary results from fire and elephant exclusion plots in Kabalega National Park, Uganda. East African Wildlife Journal, 15: 229-32.

Lock, J. M. 1993. Vegetation change in Queen Elizabeth National Park, Uganda: 1970-1988. African Journal of Ecology, 31: 106-17.

de Leeuw, P. N., B. E. Grandin & S. Bekure. 1991. Introduction to the Kenyan rangelands and Kajiado District. In: Maasai Herding: An analysis of the livestock production system of Maasai pastoralists in eastern Kajiado District, Kenya. (Eds.) Bekure, S.; P. N. de Leeuw; B. E. Grandin; P. J. H. Neate. ILCA Systems study 4. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 172 pp.

Ledec, G. 1987. Effects of Kenya's Bura Irrigation settlement project on biological diversity and other conservation concerns. Conserv. Biol., 1:247-258.

Leuthold, W. & J. B. Sale. 1973. Movements and patterns of habitat utilization of elephants in Tsavo National Park, Kenya. E. Afri. Wildl. J. 11, 369-384.

Leuthold, W. and J.B. Sale. 1973. Movements and patterns of habitat utilization of elephants in Tsavo National Park, Kenya. E. Afr. Wildl. J., 11: 369-384.

Lewis, D. M. 1986. Disturbance effects on elephant feeding: evidence for compression in Luangwa Valley, Zambia. African Journal of Ecology, 24: 227-41.

Lipsey, R. G., P. O., Steiner, and D. D. Purvis. 1987. Economics. Eigth Edition. Harper & Row. New York. 942 pp.

Lindsay, W. K. 1987. Integrating Parks and Pastoralists: Some Lessons from Amboseli. In: Conservation in Africa: People, policies and practice. Ed. Anderson, D. & Grove, R.

Matson, P.A., W.J. Parton, A. G. Power, M. J. Swift. 1997. Agricultural intensification and ecosystem properties. Science. Vol. 277: 504-509.

McNaughton, S.J. and G.A. Sabuni. 1988. Large African mammals as regulators of vegetation structure. In: Plant form and vegetation structure. Eds., Werger, M.J.A.; P.J.M. Van der Aart; H.J. During and J.T.A. Verhoeven. Academic Publishing, The Hague. pp. 339-354.

Mushove, P. 1994. Multitemporal Satellite Image Analysis for Monitoring Human Encroachment on Forest Reserves. In: Desertification Bulletin, No. 25. pg. 34-39.

Murindagomo, F. 1990. CAMPFIRE Program (Dande Communal Lands) - Zimbabwe. pg. 123-140. In: Living with Wildlife: Wildlife Resource Management with Local Participation in Africa. (ed.) Kiss, Agnes. World Bank Technical Paper No. 130. Africa Technical Department series. The World Bank. Washington, D.C. 217 pp.

Mead, A. R.; L. T. Sharik; P. S. Prisley; T. J. Heinen. 1981. A computerized spatial analysis system for assessing wildlife habitat from vegetation maps. Canadian Jnl. of remote sensing. vol. 7, # 1, pg.34-40. July 1981.

Meyer, W. B., and B. L. Turner II. 1992. Human population growth and global land-use/cover change. Annual Review of Ecological Systems, 23: 39-61.

Moss, Cynthia. 1988. Elephant Memories: Thirteen years in the life of an elephant family. William Morrow and Company, Inc. New York. 336 pp.

Miller , M.F. and M. Coe. 1993. Is it advantageous for acacia seeds to be eaten by ungulates? Oikos, 66 (2):364-368.

Minnis, L. D. and R. B. Peyton. 1995. Cultural Carrying Capacity: Modeling a notion. Pages 19-34 in J. B. McAninch, ed., Urban deer: A manageable resource? Proceedings of the 1993 Symposium of the North Central Section, The Wildlife Society. 175 pp.

Mwalyosi, R.B.B. 1990. The dynamic ecology of Acacia tortilis woodland in Lake Manyara National Park, Tanzania. Afr. J. Ecol., 28:189-199.

Nummelin, M. 1990. Relative habitat use of duikers, bushpigs, and elephants in virgin and selectively logged areas of the Kibale Forest, Uganda. Tropical Zoology, 3:111-20.

Ottichilo, W. K. 1992. NAROK: Large-scale wheat farming and Maasai settlements. In: Kenya from Space: An Aerial Atlas. DRSRS (Kenya) & CREDU (France). pg. 80-83. Nairobi, Kenya.

Odenyo, Victor. 1979. Application of LANDSAT Data to the study of land and range resources in the Narok area, Kenya. Research report 79-4. Canada Center for Remote Sensing, Ottawa. 69pp.

Ojima, D. S., K. A. Galvin, and B. L. Turner. 1994. The Global Impact of Land-use Change. BioSience, Vol. 44, No. 5: 300-304.

Ottichilo, W. K. 1987. The causes of the recent heavy elephant mortality in the Tsavo Ecosystem, Kenya. Biological Conservation, 41:279-289.

Owen-Smith, R. N. 1988. Megaherbivores. The influence of very large body size on ecology. Cambridge University Press. Cambridge. 369 pp.

Parker, I. S. C. and A. D. Graham. 1989. Men, elephants and competition. Symposium of the Zoological Society of London. 61:241-152.

Patton, M. Q. 1980. Qualitative Evaluation Methods. Beverly Hills, California: Sage.

Pellew, R.A. 1983. The impact of elephant, giraffe and fire upon the Acacia tortilis woodlands of the Serengeti. African Journal of Ecology, 21:241-267.

Pestana, K.E. 1986. Remote sensing technique for identifying potential red-cockaded woodpecker habitat. In: Wildlife management and habitats. Proceedings of the conference on science in the national parks. Singer, F.J. (ed.). Colorado State University. 13- 18/07/1986.

Pratt, D.J. & M.D. Gwynne. 1977. Rangeland Management and Ecology in East Africa. Hodder & Stoughton. London. P. 310.

Reed, J. D. 1983. The Nutritional Ecology of Game and Cattle on a Kenyan Ranch. Ph.D. Thesis, Cornell University. 167 pp.

Rice, C. 1990. Don't forget to pack the trunk. Wildlife Conservation, 93:58-67.

Richards, J. F. 1990. Land transformation. pg. 163-178 in B. L. Turner II, W. C. Clark, R.W. Kates, J. F. Reynolds, J. T. Mathews, and W. B. Meyer, eds. The Earth as transformed by human action. Cambridge University Press, New York.

Ruess, R.W. and F.L. Halter. 1990. The impact of large herbivores on the Seronera woodlands, Serengeti National Park, Tanzania. Afr. J. Ecol. 28: 259-275.

Rutten, M. M. E. M. 1992. Selling wealth to buy poverty. The process of the individualization of landownership among the Maasai pastoralists of Kajiado District, Kenya, 1890-1990. Verlag breintenbach publishers, Saarbrucken. 510 pp.

Salmen, L. F. 1995. Beneficiary Assessment. An Approach described. Environment Department Papers, Social Assessment Series. Paper No. 023. The World Bank. Washington, DC. 24 pp.

Schmidt, R. 1992. Degradation of a forest in the Shimba Hills National Reserve, Kenya, as initiated by man and maintained by wildlife. In Tropical forests in transition, ed. J. G. Goldmmer. Birkhauser, Verlag, pp. 85-104.

Sherry, B. R. 1975. Reproduction of elephant in Gonarezhou, southeastern Rhodesia. Arnoldia (Rhodesia) 7, 1-13.

Skole, D. and C. Tucker. 1993. Tropical deforestation and habitat fragmentation in the Amazon: satellite data from 1978 to 1988. Science. Vol. 260: 1905-1909.

Sikes, S. K. 1971. The natural history of the African elephant. New York. 397 pp.

Smith, David L. 1986. Amboseli: Nothing Short of A Miracle. Nairobi, Kenya. 96 pp.

Sombroek, W. C.; H. M. H. Braun; B. J. A. van der Pouw. 1982. Explanatory soil map and agro-climatic zone map of Kenya. Report E1. National Agricultural Laboratories, Soil Survey Unit, Nairobi, Kenya. 56 pp.

Sperduto, M. B. and R. G. Congalton. 1996. Predicting rare Orchid (small whorled Pogonia) habitat using GIS. Photogrammetric Enginnering and Remote Sensing, Vol. 62, No. 11: 1269-1279.

SPOT Image Corporation. 1989. The Great Dismal Swamp: SPOT provides the total picture. SPOT Image Corporation, Reston, VA, USA.

Sellers, P.J. 1985. Canopy reflectance, photosynthesis and transpiration. Int. J. Remote Sensing, 6: 1335-1338.

Sukumar, R. 1991. The management of large mammals in relation to male strategies and conflict with people. Biological Conservation, 55: 93-102.

Sukumar, R. 1989. The Asian elephant: Ecology and Management. Cambridge University Press.

Tchamba, M.N. 1996. History and present status of the human/elephant conflict in the Waza-Logone Region, Cameroon, West Africa. Biol. Conser. 75:35-41.

The Daily Nation; September 14th and 17th, 1994. Nairobi.

The Daily Nation; June 29th 1996. Nairobi.

The East African Standard; May 17th 1997.

Thouless, C.R. and J. Sakwa. 1995. Shocking elephants: fences and crop raiders in Laikipia District, Kenya. Biol. Conser. 72: 99-107.

Thouless, C.R. 1994. Conflict between humans and elephants on private land in northern Kenya. Oryx, 28: 119-127.

Townshend, J.R.G. and C.O. Justice. 1986. Analysis of the dynamics of African vegetation using normalized difference vegetation index. Int. J. Remote Sensing, 7 (11): 1435-1445.

Tieszen, L. L.; T. W. Burton; W. K. Ottichilo; D. E. Nelson; D. H. Brandt. 1989. An assessment of long-term food habits of Tsavo elephants based on stable carbon and nitrogen isotope ratios of bone collagen. Afr. J. Ecol. Vol. 27, 219-226.

Touber, L. 1983. Soils and vegetation of the Amboseli-Kibwezi area. Kenya soil survey R6, Ministry of Agriculture, Nairobi, Kenya. 125 pp.

Turner, B. L. II, W. C. Clark, R.W. Kates, J. F. Renolds, J. T. Mathews, and W. B. Meyer, eds. The Earth as transformed by human action. Cambridge University Press, New York.

Tucker, C. J., C. O. Justice and S. D. Prince. 1986. Monitoring the grasslands of the Sahel 1984-1985. International Journal of Remote Sensing, 7: 1571-1581.

Tucker, C.J. 1986. Maximum normalized difference vegetation index images for sub-Saharan Africa for 1983-1985. Int. J. Remote Sensing, 7 (11): 1383-1384.

Tucker, C. J., H. E. Dregne, and W. W. Newcomb. 1991. Expansion and contraction of the Sahara Desert from 1980 to 1990. Science. Vol. 253: 299-301.

Van Soest, P.J. 1982. Nutritional ecology of the ruminant. O and B Books, Inc., Corvallis, Oregon.

Vitousek, P.M., H.A. Mooney, J. Lubchenco and J.M. Melillo. 1997. Human domination of Earth's ecosystems. Science. Vol. 277: 494-499.

van Wijngaarden W. 1985. Elephants-trees-grass-grazers: Relationships between climate, soil, vegetation and large herbivores in a semi-arid savanna ecosystem. ITC publication 4. Enschede, The Netherlands. 165 pp.

Western, D. & W. K. Lindsay. 1984. Seasonal herd dynamics of a savanna elephant population. Afr. J. Ecol. 22, 229-244.

Western, D. 1982. Amboseli National Park: Enlisting land owners to conserve migratory wildlife. Ambio. Vol. 11, # 5.

Western, David. 1989. Conservation without parks: wildlife in the rural landscape. In: Conservation for the twenty-first century. Edited by Western, D. & Pearl, M. C. pp 365. NYZS. Oxford university Press.

Western, D. & J. J. R. Grimsdell. 1979. Measuring the Distribution of Animals in Relation to the Environment. Handbook No. 2. 2nd edition. African Wildlife Leadership Foundation. Nairobi, Kenya. pp. 64.

Western, D. 1994. Ecosystem Conservation and Rural Development: The Case of Amboseli. In: Natural Connections. Perspectives in Community-based Conservation. (eds.) Western, D.; R. M. Wright & S. C. Strum. Island Press. Washington, D.C. 581 pp.

Western, D. 1983. A Wildlife Guide and A Natural History of Amboseli. Nairobi, Kenya. 75 pp.

Western, D. & J. Ssemakula. 1981. The Future of the Savannah Ecosystems: Ecological Islands or Faunal Enclaves? In: African jnl. of Ecology. Vol. 19 Nos. 1 & 2. pages 7-19.

Western, D. and V. Finch. 1986. Cattle and pastoralism: survival and production in arid lands. Human Ecology, 14 (1): 77-94.

World Resources Institute (WRI). 1994. World Resources, 1994-95. A Report by The World Resources Institute. In collaboration with The United Nations Environment Programme and The United Nations Development Programme. NY. Oxford. 400 pp.

World Commission on Environment and Development (WCED). 1987. Our Common Future. Oxford University Press, New York.

Wyatt, J. R. and S. K. Eltringham. 1974. The daily activity of the elephant in the Rwenzori National Park, Uganda. East African Wildlife Journal, 12:273.

World Bank. 1993. Ecologically Sensitive Sites in Africa. Vol. II: East Africa. (Compiled by the World Conservation Monitoring Centre). The World Bank, Washington, DC, USA. 152 pp.

World Bank, The. 1994. Reversing the Spiral. The population, agriculture, and environment nexus in Sub-Saharan Africa. The World Bank. Washington, DC. 22 pp.

Wilson, A. D. and N. D. Macleod. 1991. Overgrazing: present or absent? Journal of Range Management, 44 (5): 475-482.

Wilson, A. D. and G. J. Tupper. 1982. Concepts and factors applicable to the measurement of range condition. Journal of Range Management, 35 (6): 684-689.

VITA

Enos E. Esikuri graduated in 1988 with a B.Sc. in Wildlife Management from Moi University, Eldoret, Kenya. In 1989 he proceeded to NORAGRIC, the Agricultural University of Norway, Aas, where in 1991 he obtained a Diploma in Natural Resource Management and Sustainable Agriculture. In 1991 he obtained an M.Sc. degree in Natural Resources Management from the same university. In 1992, he was selected as a Bullard Fellow in Environmental Policy at Harvard University, Cambridge, MA, USA. He joined the Department of Fisheries and Wildlife Sciences, Virginia Tech, in Fall 1993 to pursue his doctorate in Wildlife Sciences. Upon completion of the requirements for his doctoral program, he plans to return to Kenya to continue his career in conservation.