LANDSCAPE CHANGE AROUND KIBALE NATIONAL PARK, UGANDA: IMPACTS ON LAND COVER, LAND USE, AND LIVELIHOODS

By

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Für Rachel. Nur mit deinen unendlichen Liebe und Unterstützung war diese Arbeit möglich.

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By

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Major: Geography

Rapid population growth, high population density, and intensive agriculture characterize the landscape surrounding Kibale National Park (KNP) in western Uganda. Although the park itself is completely surrounded by agricultural land and large multi-national tea estates, forest fragments and wetland areas are scattered throughout the landscape. As small rural communities in western Uganda are heavily reliant on land and resources, their livelihoods are directly linked to ecological systems. In contrast to most other studies that are concerned with parks, this dissertation research focused on the impacts of parks on its neighbors, by examining the changes in wetlands and forest fragments outside the park and the impacts of those changes on households as cascading effects of park establishment on communities.

This research uses KNP as a case study in a two-step analysis, linking landscape- and household-level data. The first step was quantifying the change in extent, pattern, and quality of wetlands and forest fragments outside KNP over time using satellite image analysis. Land cover analysis shows Kibale National Park as a nearly islandized park of forested land cover, surrounded by intensive small-scale agriculture and some large-scale tea plantations, and many unprotected wetlands and forest fragments. I found that the park boundaries remain relatively intact since 1984, while the landscape surrounding the park has become increasingly fragmented.

As fragmentation outside the park continues, the forests and wetlands in the surrounding landscape not only are becoming increasingly smaller, but more isolated and with lower productivity

In the second step of this analysis, the implications of that change on household livelihoods in communities surrounding KNP were examined using household interviews. Wetlands and forest fragments outside Kibale National Park serve as important resource bases for local people, but they are also problematic for local farmers, since wild animals come from these natural areas and raid crops. Households also recognize the decreased presence and extent of forests and wetlands outside the park. They have adopting coping strategies not only to address resource shortages, but also the problems of crop raiding. Finally, my results suggest that not only do most households feel they benefit from the park (although in ways not widely discussed in the literature on parks), but the majority also feel they are not harmed by it, and many feel no effect from the park.

CHAPTER 1
INTRODUCTION

Introduction

Parks and protected areas are designated as areas of biological, geological, or cultural significance and have served as key mechanisms for conservation (Howard et al. 2000). McNeely (1990) sees parks as making fundamental contributions to sustaining human societies. However, park establishment is not necessarily benign, especially to those living in or near a park, and parks should not be viewed in isolation from the landscape in which they sit. Many parks in Africa have adopted the traditional model, with the establishment of hard boundaries and the near to complete exclusion of residents from access, extractive, and settlement privileges (Hayes, 2006).

As a result, the landscapes around parks are important. The landscapes around protected areas have become mosaics of natural and human-influenced patches, and becoming increasingly fragmented. This landscape outside the protected area can be influenced by edge effects, population growth, and changing patterns of land use, among other factors. Unprotected lands outside the park represent reservoirs of land, resources, and potential income. Increased tourism-based activities or other secondary industries are likely to attract migrants. Since the park boundaries for the most part, prohibit settlement and resource extraction, increasing population and land and resource pressure stimulates intensified land use surrounding the park, leading to a reduction in forests and wetlands that serve as important resource bases.

Patterns of land cover change in many tropical developing countries are closely linked to land use changes and anthropogenic impacts. Land use intensification and extensification are common responses not only to the limitation and constriction of resources, but also to the opportunities that “unused” lands, such as forests and wetlands, represent (Lambin and Geist, 2001). All methods of intensifying agriculture concentrate resources in time and space. The varying responses of different economic and ethnic groups to economic opportunities, crop loss, and resource needs can have quite different effects on the spatial organization of land use (Stone, 1996; Kagoro-Rugunda, 2004).

Under the traditional conservation model (a.k.a. fines and fences, fortress conservation) the presence of a protected area is a hard barrier to settlement, extensification, and resource extraction, which affects farmers' land use and livelihood options. Since resource extraction and other forms of land use are forbidden within the park boundaries, people turn to the only available land to meet their needs. Those wetlands and forest fragments that remain continue to be relied upon to produce resources for subsistence and commercial use. As their use continues, there is potential for overuse, degradation, reduced size and connectivity with other areas, and elimination of these areas. The landscape around the park changes and inevitably becomes more fragmented as new land covers and land uses are replaced with new ones or eliminated. The unprotected forests and wetlands, important to household livelihoods, present both opportunities and challenges to households and the community at large. This change in presence, spatial extent, and quality of resources will influence the livelihoods of neighboring communities.

Estimates of the numbers of people generating much of their livelihoods (i.e., income, energy, food) from forests range from one million to more than one billion (Byron and Arnold, 1999) and the number of people indirectly or directly dependent on wetlands worldwide at least one billion (Fischer et al. 1997). Especially on the African continent, rural livelihoods continue to be heavily reliant on the land and its resources (Scoones, 1998; Abalu and Hassan, 1998). The amount of forest global loss is no less striking. Forest loss worldwide is estimated at 7.3 million hectares (between 2000-2005) (FAO, 2006), where forest loss in Africa has been as high as 10.5% (between 1980 and 1995) (Chapman and Peres, 2001) and now 9.7% (between 2000-2005) (FAO, 2006).

As Africa's population continues to grow, the number of people dependent on forest and wetland land and resources has the potential to increase substantially. In Eastern and Southern Africa, 63% of the population is rural with an average 1.8% population increase annually (US Census Bureau, 2006). Uganda is a slightly different story. Nearly 80% of the 27 million people have rural-based livelihoods and more than 80% of land is used for small-scale farming (Uganda Bureau of Statistics, 2005). The population has increased 240% between 1960 and 2000, with a continued national population increase estimated to be 3% annually (US Census Bureau, 2006). Uganda's forest and wetland resources are essential for the survival of the majority rural population, providing energy, income, and food (Banana and Gombya-Ssembajjwe, 1998). As such, unprotected wetlands and forest fragments are converted to agriculture, grazing land, or woodlots at faster rates.

Forests and Fragments

Forests and woodlands cover approximately 4.9 million ha in Uganda and nearly 60% remain unprotected and are vulnerable to overexploitation and agricultural encroachment (NEMA, 2001). At the estimated current rate of forest conversion, although estimates vary, Uganda continues to lose between 0.8% (NEMA, 2001) and 3% (Kayanja and Byarugaba, 2001) annually (about 50,000 ha). Nationwide, unsustainable domestic tree harvesting for firewood and non-timber forest products continues (Kayanja and Byarugaba, 2001). Closed-canopy tropical forest once covered 20% of the country's land area, but deforestation has reduced this to just 3% (Howard et al. 2000). Furthermore, Uganda lost 18% of its remaining forest between 1990 and 2000 (Howard et al. 2000).

Kabarole District in western Uganda is a good example of the pressure on forest resources and subsequent landscape fragmentation. In the densely populated Kabarole (8109 km^2, 91 individuals/km^2), only 2501 km^2 of forest remain (NEMA, 2001) The once dominant moist, evergreen, closed-canopy forest that dominated the region has for the most part succumbed to agricultural expansion at least since 1959 (Gillespie and Chapman, 2006). Nearly all of the forests found on potentially arable lands have been converted to small-scale agriculture, tea, or pasture and soil degradation is a major concern (NEMA, 2001). The remaining forests typically occur in valley bottoms or on the steep rims of crater lakes (Gillespie and Chapman, 2006; Hartter, pers. obs.). These unprotected forests provide a number of ecological services such as stabilization of the local climate, erosion control, nutrient uptake, and carbon sequestration (Laurance and Bierregaard, 1997). Forest fragments also serve as species corridors, habitat, and breeding and feeding grounds (Onderdonk and Chapman, 2000; Marsh, 2003).

Forests fragments are extremely important to sustain livelihoods in Uganda. Ninety-five percent of all Uganda's energy needs are met with fuelwood and charcoal, and two-thirds of this amount is used at the household level (Kayanja and Byarugaba, 2001). They provide wood products: fuelwood, timber, building poles, but also non-timber products such as indigenous medicines and food (Banana and Gombya-Ssembajjwe, 1998). Hardwoods within the fragments are especially sought to burn charcoal (Naughton-Treves et al. 2005). Many are also being converted into farmland, pasture, or woodlots (Kayanja and Byarugaba 2001).

Despite their socio-economic importance, only recently has research addressed tropical forest fragments (Chatelain et al. 1996; Laurance and Bierregaard, 1997), but most research has focused on South America (Laurance and Bierregaard, 1997). Previous African studies have addressed the effects of fragmentation on animal and tree species (Hill and Curran, 2003;

Chapman et al. 2003; Marsh et al. 2003; Stouffer and Bierregaard, 1995). However, little work has studied the role forest fragments play in providing resources such as fuelwood, timber, poles, thatching, handcraft materials, indigenous medicines, and edible plants to communities (Turner and Corlett, 1996; Gillespie and Chapman, 2005).

Wetlands

Wetlands include all areas where plants grow and animals live in association with permanent or temporary flooding (Kisamba-Mugerwa and Nuwagaba, 1993). Uganda's wetlands, dominated by papyrus (*Cyperus papyrus* L.) comprise about 13% of the country's total land surface (Mukiibi, 2001a) and fill a critical ecological role in flood abatement, groundwater recharge, and as nature's biological filter. Wetlands have vital importance in maintaining the quality and volume of surface and ground water (Muthuri et al. 1989; Mukiibi, 2001b). They are key spawning grounds for fish (Crisman et al. 2003), and provide other services such as biodiversity, aesthetic beauty, and cultural heritage.

Wetlands are important to livelihoods of surrounding communities in several ways. In most cases, they have been intensively used or drained. Many households are growing fuelwood and timber trees in drained wetlands. They provide a subsistence resource base for water, thatching, handcraft materials, and indigenous medicines. Wetlands are also commercially important, providing a source of revenue from tourists, and medicinal plant and handcraft sales. Overexploitation occurs in the context of harvesting resources, such as clay for brick building, and pottery and papyrus for thatching houses and making mats (Chapman et al. 2001, MacLean et al. 2003). Similar to forests, Uganda's wetlands represent unclaimed or underutilized land and are often encroached to cultivate crops (Crisman et al. 2003; MacLean et al. 2003). Wetlands are often drained and converted to other land uses such as growing crops and fuelwood, particularly *Eucalyptus spp*., and expanding grazing land. Some wetlands are diverted to irrigate crops. They are also an important source of water for livestock, leading to high nutrient loading and increased turbidity. In addition, as the dry season lingers and temporary wetlands dry up, livestock are brought to more permanently inundated wetlands (Haack, 1996).

Despite maintaining one of the highest net primary productivity rates in the world (Muthuri et al. 1989), people in the past treated wetlands more like wastelands (Mukiibi, 2001b) or as a repository of land for potential agricultural expansion. Several studies have attempted to quantify wetland ecosystem services in terms of economic potential (Costanza et al. 1997; Batagoda et al. 2000; Turner et al. 2001; Balmford et al. 2002).

The Fragmented Landscape

Landscapes around parks are also affected by wild animals that raid their crops and livestock. Households are affected by crop raids by primates, elephants, and birds; livestock loss; and even human fatalities occurring in lands near parks (Naughton-Treves, 1997; de Boer and Baquete, 1998; Gillingham and Lee, 1999). Land scarcity has forced many farmers to live and farm at the forest edge (Naughton-Treves, 1998) and as a result, human-wildlife conflict is a considerable risk for those farms directly adjacent to these natural areas. Although the amount of damage varies, farmers must constantly make decisions and create coping strategies to deal with crop-raiding (Goldman, 1996; Naughton-Treves, 1998). Little research has addressed either anthropogenic influences on land-cover change outside protected areas, or the resulting effects of altered ecosystems back onto the communities (Pickett et al. 1995; Turner et al. 2001).

Studies on fragmented landscapes outside protected areas have focused on biodiversity conservation but there has been little research into human-environment linkages (Turner and Corlett, 1996). Moreover, fragmentation literature discusses landscape fragments and biodiversity in terrestrial ecosystems, but there is very little discussion of aquatic systems

(Pickett et al. 1997). While the use of forest fragments as a means to sustain livelihoods is well documented elsewhere in the world, East Africa is strikingly absent from the literature (Marsh et al. 2003), as are studies on the smaller, interstitial wetlands and forest patches characteristic of western Uganda. Little research has addressed anthropogenic influences of land-cover change, or the resulting effects of altered ecosystems back onto the communities. Studies of fragmented systems must include consideration of ongoing human influences (Laurence and Bierregaard, 1997). In order to understand land cover change in the landscape surrounding a park, it is necessary to examine resource consumption patterns of park neighbors. Since most of the resources collected in the wetlands and forest fragments are only obtained locally, households must respond in some way to shortages, in turn shaping the landscape. Many livelihoods, and thus responses to shortages and problems, are determined through cultures and traditions, and economic, ecological environment, and demographic variables (Chambers and Conway, 1991). Therefore variables such as ethnicity, wealth, and gender as well as distance from the park may all be related to these responses (Rocheleau and Edmunds, 1997; Hill 1997; Byron and Arnold, 1999; Goebel et al. 2000; Kagoro-Rugunda, 2004). Resource use may vary by ethnicity, wealth, location, and gender (Rocheleau and Edmunds, 1997; Byron and Arnold, 1999; Goebel et al. 2000).

Around Kibale National Park (KNP) in western Uganda, what changes have occurred in the natural resource base, how these changes have affected decisions about land and resource use, and how land and resource use varies by ethnicity and wealth has not been addressed in the literature. This research addresses these questions among others.

This research examined the changes in forest fragments and wetlands outside KNP and the adaptation in livelihood strategies and natural resources use by different ethnic and economic groups living within the densely populated agricultural landscape surrounding KNP in western Uganda. Two main ethnic groups, the Bakiga and Batoro, dominate the population living in the area, and generally practice distinctive patterns of land and resource use. As in many similar cases around parks, there has been substantial population growth from both in-migration and a high rate of population increase. The area has become a mosaic of diverse agricultural land intermixed with patches of remaining natural areas. These forest fragments and wetlands serve as important resource bases, but are also problematic for farmers. This research links landscape and household levels in a cross-scale analysis that looks at change in both spatial extent and quality of wetlands and forest fragments, as well as the livelihood consequences of that change.

Landscape level changes in wetlands and forest fragments are the product of many decisions made at the household level. Household head gender, wealth, ethnicity, and distance to the park boundary may all be important factors in contributing to livelihoods. Sustaining livelihoods have spatial implications, and it is important to understand how they physically manifest themselves in land-use (e.g., loss of wetlands and forests). In the surrounding landscape, land cover will change as a result of households' coping mechanisms to resource shortages and human-wildlife conflict. These changes in land cover and the result coping mechanisms are the focus of the research questions for this dissertation. Four fundamental questions outline this research.

- How have the extent and quality of wetlands and forest fragments in the landscape around KNP changed over time?
- What resources and problems are associated with wetlands and forest fragments around KNP; and how have these changed over time?
- How have households adapted to the declines in the wetlands and forest fragments in the areas around KNP?
- How are neighboring communities helped or harmed due to the presence of KNP?

The research presented in this dissertation is divided into several chapters, which in aggregate address how landscapes and households within that landscape are impacted by park establishment. Each of the chapters deals with separate research questions. The last chapter of the dissertation provides broad conclusions and implications of this research.

Study Area

KNP in western Uganda is illustrative of the agricultural expansion and intensification surrounding protected areas. Kibale Forest was demarcated in 1932 as a Forest Reserve and elevated to national park status in 1993 (Struhsaker, 1997). Known for its diverse primate population, KNP ranks fifth in terms of species richness and sixth in overall biodiversity importance among all Ugandan forests (Howard et al. 2000). It is perhaps most well-known because it is home to the largest known community of chimpanzees.

The park is an ecological island – a dense, closed-canopy forest surrounded by a large agricultural population, large tea estates, and a vast network of wetlands and bottomland forest fragments. KNP is a medium-altitude tropical moist forest covering about 795 km^2 in western Uganda (Figure 1-1)[1]. This transitional forest (between lowland rainforest and montane forest) is at an average elevation of 1110-1590m and is a remnant of a previously larger mid-altitude forest region (Struhsaker, 1997). The climate is warm throughout the year, with an average range of 15-23°C (Struhsaker, 1997). Although the amount of rainfall and length of season change, the average annual rainfall for the region is 1543mm (average 1903-1999) and 1719mm (1990-2005) (Chapman et al. 2005).

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[1] While officially KNP now includes a "game corridor" that connects the southern portion of KNP to Queen Elizabeth National Park, this corridor was formally gazetted as part of KNP in 1993 but has not been cleared of human settlement and treated as part of the park until the last year and currently replanting etc. is still in progress. Before that time, it was mixed agricultural land. Therefore, it was not classified as park in this analysis. By doing so, our analysis is conservative since the addition of the corridor would tend to lessen the difference between park and non-park. Excluding the game corridor, the Kibale Forest in this analysis contains 561km^2.

Rapid population growth, high population density, and heavy reliance on agriculture for income characterize the landscape surrounding KNP (Archabald and Naughton-Treves, 2001). Land pressure continues to increase (Naughton-Treves, 1996). Nearly 43% of the land within a 5 km periphery of the park is under cultivation or pasture (Hartter, unpublished data). Tea dominates much of the landscape bordering the northwest portion of KNP, covering nearly 21% within 1 km of the park boundary (Hartter, unpublished data). Farm sizes on average are less than five hectares (Hartter, unpublished data) and both ethnic groups interplant more than 30 species of subsistence and cash crops (Naughton-Treves, 1996). Most of the crops produced are consumed at the household level, with few being sold outside of immediate household or local community markets.

Agriculturalists in the area belong to two dominant ethnic groups: the Batoro (west side of KNP) and the immigrant Bakiga (east side of KNP), who came to the Kibale region from southwestern Uganda beginning the 1950s and 1960s (Turyahikayo-Rugyema, 1974; Naughton-Treves, 1998). A 1988 census estimated the population within the park and the surrounding communities to be 61,000 (Aluma et al. 1989). Naughton-Treves (1998) estimated the population density has nearly trebled around the park between 1959 and 1990.

Methods

This research combined extensive household interviews with an analysis of Landsat satellite imagery over 20 years. As with landscape change, it is important to maintain a connection with people across both space and time (Walsh et al. 2003). Remote sensing provides a robust and efficient technique to observe and monitor the changes that occur within different land-covers over a large area and multiple dates (Lu, 2004). However, while satellite data provide a firm empirical base for measuring the spatial configuration of land-cover, they do not themselves explain the causes for these land-use strategies. Integrating landscape level change detection with household level processes requires a sampling scheme that links household surveys to remotely sensed data. Surveys provide valuable fine-scale, ground-data (Turner, 2003). Household-level decision making is critical to understanding the changes in land-use and land-cover and their effects on livelihoods (Rindfuss et al. 2003). Combining household and landscape level data in a cohesive analysis can help explain both proximate and distal effects of environmental change (Geoghegan et al. 1998; Rindfuss et al. 2003).

Diminishing Resources

Protected areas have long served as centerpieces of the conservation movement (Howard et al. 2000). They are areas designated as areas of biological, geological, or cultural significance. In Sub-Saharan Africa, early park-based conservation was derived largely from Western roots, from the Yellowstone Model (Runte, 1997). Applying the wilderness model after Yellowstone National Park, the Africa continent has seen a dramatic growth in parks, both in number and area protected. This type of 'conservation' was built on strict exclusion of humans, the prevention of consumptive use, and minimization of other forms of human impact within park boundaries (Hulme and Murphree, 2001). To do this effectively, park managers believed that humans must be taken out of the equation. Boundaries were erected and even though the park itself may have been part of a continuous landscape, park managers sought to separate it from the landscape surrounding it. People were meant to use resources outside of the park and plants and animals were meant to stay in the park.

Outside parks in Sub-Saharan Africa, the majority of the population is dependent on the land for their livelihoods. They depend on the land for growing food, economic opportunity, building materials for their homes, and to meet energy needs. As population outside the park swells and people are prohibited from resource extraction inside its boundary, the demand for resources and agriculture land not only increases, but competes. Since land is a premium with increasing population, the remaining unprotected wetlands and forest fragments are sought after. Those wetlands and forest fragments that remain continue to be relied upon to produce resources for subsistence and commercial use. Not only is the presence of forests and wetlands diminishing, but they are also being degraded, reducing the quality of resources. As a result, the landscape around a park has become a mosaic of natural and human-influenced patches. In this chapter, I examine the spatial extent and quality of these diminishing resource bases at the landscape level using discrete and continuous data analyses of satellite imagery and place the results within the social context of western Uganda and fortress.

Specific research questions addressed in Chapter 2 are

- How has the productivity and spatial extent of forests and wetlands in the landscape surrounding KNP changed over time?
- How does this change vary in communities on the east side of the park versus the west side of the park?
- How does this change relate to change in land under cultivation and tea?

Resource Use and Household Livelihoods

The livelihoods of rural communities in western Uganda are directly linked to ecological systems since they are heavily reliant on land and resources, their livelihoods are directly linked to ecological systems. Unprotected wetlands and forest fragments (i.e., those not gazetted as parks, wildlife reserves, or other forms of protected areas) serve as important resource bases for local people as well as biodiversity habitats that harbor many wild plant and animal species. However, they are also problematic for local farmers, since crop raids by primates, elephants, and birds emanate from these fragments. In addition, there has been extensive conversion of wetlands to grazing or cropland, as well as increasing extraction of fuelwood, timber, and other resources from forest fragments, all of which are diminishing their area and ecological integrity. This chapter examines the dual character of these natural areas within the agricultural landscape around KNP in terms of the social and environmental benefits and problems they represent to local households that vary in ethnicity, wealth and distance from the park.

Specific research questions addressed in Chapter 3 are:

- What resources and problems are associated with wetlands and forest fragments around KNP?
- How do these benefits and problems vary by distance, wealth, gender, and ethnicity from the park boundary?

Responses to Resource Availability

Although protected areas have become the primary mechanism for biodiversity conservation, their establishment can have long-term impacts on land use, land cover, and livelihoods of people living near them. Since land use and most resource access within KNP's boundaries are prohibited, park neighbors turn to the forest fragments and wetlands to meet their resource needs. In the past with adequate supply and access, households could accommodate their resource needs. However, the decline of wetlands and forest fragments has an impact on households and their ability to secure resources and sustain their livelihoods. Since most of the resources collected in the wetlands and forest fragments are gathered locally and not purchased, households must respond in some way to shortages. Some will purchase fuelwood, others will have to find new sources or travel longer distances to collect fuelwood and water. Land use and land cover are inextricably linked. Strategies to increase land under cultivation and resources from the natural areas not only influence land cover within the landscape (i.e., more wetlands drained and converted to make way for agricultural lands or pasture), but can also lead to human-wildlife conflict (Naughton-Treves and Salafsky, 2004). This chapter examines the ways households have adapted to a degraded resource bases of the unprotected wetlands and forests and problems with wildlife in the landscape surrounding a park.

Specific research questions addressed in Chapter 4 are:

- How have the presence and extent of wetlands and forest fragments in the landscape surrounding KNP changed over time?
- How have households adapted to the declines in the wetlands and forest fragments in the landscape surrounding KNP?

The Impacts of a Forest Park

The fortress conservation model has sparked many debates given its treatment of park-people relationships. In many cases, parks have excluded residents from resource access and settlement. Certainly, park establishment can be considered an instigator of conflict in rural East Africa, with few benefits accruing at the local level and most at the national and international scales. Those who bear the majority of the costs are the local, rural poor, while most beneficiaries of parks tend to be the wealthier and foreign visitors. Discontentment and disenchantment of conservation policies in Uganda amongst neighboring communities is a common effect of park establishment under the fortress conservation model. However, is fortress conservation always a negative model to local people? This chapter examines the case of KNP, a forest park, examining how the park has helped and hurt park neighbors.

Specific research questions addressed in Chapter 5 are:

- Do households perceive that KNP has helped, hurt, or had no positive or negative impact on their family?
- What are the perceived benefits and problems associated with KNP?

Conclusions

From this dissertation, a number of important conclusions can be drawn. The land cover analysis revealed that since 1984 KNP's boundaries remain relatively intact while the surrounding landscape has become increasingly fragmented as land and resource pressure builds outside the park over time. Since the population outside the park is dependent on the land to sustain their livelihoods and because extraction within park boundaries is prohibited, park neighbors turn to the forest fragments and wetlands outside the park to meet their resource needs. The remaining natural areas of forest and wetlands outside the park serve as resource bases and are also believed to be associated with ecosystem services such as fresh air and adequate rainfall.

Despite their many benefits, these natural areas are sources of problems. Wild animals were identified as the most prolific problem in the surrounding landscape as a result of the presence of wetlands and forests. Increasing extraction of fuelwood, timber, and other resources all lead to diminishing area and ecological integrity of forest fragments. Households continually create coping strategies to address resource shortages as well as crop raiding, cited as a major problem due to wetland and forest presence both closer and further from the park boundary. Lastly, despite the exclusion from access and resources within park boundaries and the forceful eviction of settlers from the park in 1993, I found that that most people are not overtly hostile towards the park. Results suggest that not only do most households benefit from the park, but the majority is also not hurt and many feel no effect from the park. In fact, most respondents say that given the choice and weighing both the benefits and the costs, the park should stay.

Most work on protected areas has examined at the impact of humans on parks and the impacts of extraction and resource exploitation. This study instead examined how parks are not benign within the landscape and have various spatial and temporal impacts on park neighbors. Linking household- and landscape-level data is vital to address the complex nature of human-environment interactions. This research introduced an innovative methodology for measuring cross-scale linkages. This sampling framework linked both landscape and household level scales used to examine changes in the landscape surrounding the park and how those changes have impacted park neighbors.

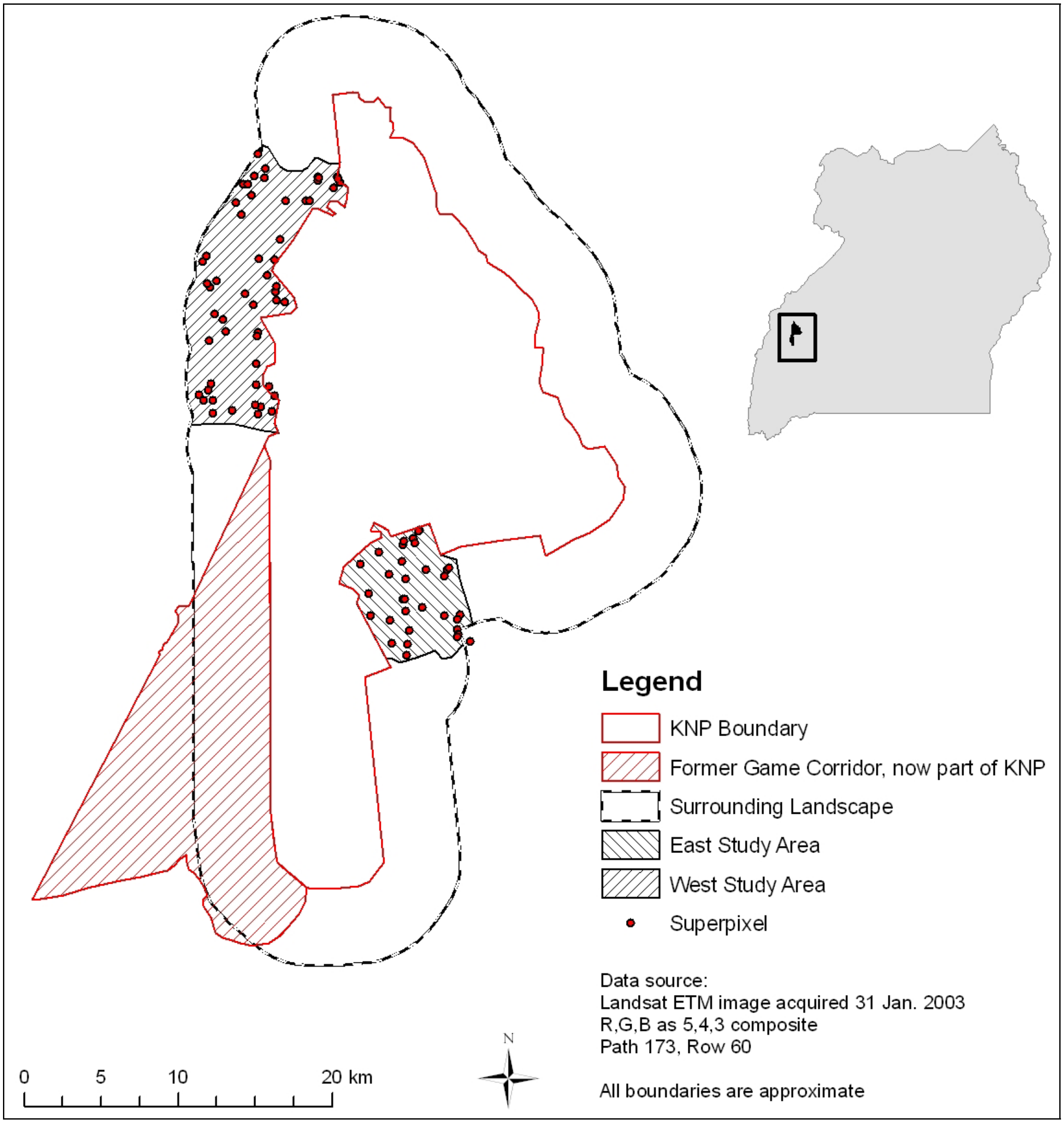

Figure 1-1. Kibale National Park and surrounding landscape in western Uganda

CHAPTER 2
DIMINISHING RESOURCES: WETLANDS AND FOREST FRAGMENTS AROUND KIBALE NAITONAL PARK, UGANDA

Introduction

Protected areas have long served as centerpieces of the conservation movement (Howard et al. 2000). They are areas designated as areas of biological, geological, or cultural significance. In Sub-Saharan Africa, early park-based conservation was derived largely from Western roots, from the Yellowstone Model (Runte, 1997). Applying the wilderness model after Yellowstone National Park, the African continent has seen a dramatic growth in parks in the twentieth century, both in number and area protected. This type of conservation was built on strict exclusion of humans, the prevention of consumptive use, and minimization of other forms of human impact within park boundaries (Hulme and Murphree, 2001). Park managers believed that humans must be taken out of the equation. Boundaries were erected and even though the park itself may have been part of a continuous landscape, park managers sought to separate it from the landscape surrounding it. People were meant to use resources outside of the park, and not to disturb the plants and animals were meant to stay inside the park

Outside parks in Sub-Saharan Africa, the majority of the population is dependent on the land for their livelihoods. They depend on the land for growing food, economic opportunity, building materials for their homes, and to meet energy needs. For example, in Uganda, over 80% of the land used for small-scale farming and nearly 80% of the population are farmers (Mukiibi, 2001a). As a result of exclusion from hunting, foraging, and grazing lands or areas of cultural or spiritual significance, park neighbors must go elsewhere to sustain their livelihoods or face punitive measures if caught poaching within park boundaries. Furthermore, the presence of a park represents a barrier to settlement and further extensification, affecting farmers' land use and livelihood options. The soaring population characteristic of most Sub-Saharan countries further intensifies the issue. Thus, land use strategies are altered, often increasing the pressure on land and resources.

Patterns of land cover change in most tropical developing countries are closely linked to these land use changes and anthropogenic impacts. Land use intensification and extensification are common responses not only to the limitation and constriction of resources, but also to the opportunities that the unused natural areas (wetlands and forests in this case) represent (Geist and Lambin, 2001). All methods of intensifying agriculture concentrate resources in time and space. However, the varying responses of different economic and ethnic groups to crop loss and resource needs can have quite different effects on the spatial organization of land use (Stone, 1996; Kagoro-Rugunda, 2004).

Landscapes around parks have become mosaics of natural and human-influenced patches and have been modified for thousands of years by humans. The once continuous natural habitats are becoming increasingly fragmented. This landscape outside protected areas encompasses edge effects, population growth, and changing patterns of land use, among other factors. Pressure on residual or unused lands (e.g. forest fragments) continues to mount as local populations increase. In addition, most protected areas are already too small to conserve most species of biodiversity (McNeely, 1994), and the severity and occurrence of human-wildlife interactions are increasing. These aspects will influence the livelihoods of the neighboring communities.

Studying the effects of human activities on land use and land cover typically involves the analysis of remotely sensed and other spatial data (Rindfuss et al. 2003). Remote sensing using satellite imagery provides robust techniques to efficiently observe and monitor the changes that occur within different land cover types over multiple dates at multiple locales over a large area using land-cover classification maps (Lu, 2004). Continuous data analysis can supplement discrete analyses to examine more subtle, within-class variability (Southworth et al. 2004). In the heterogeneous landscapes around many parks, land parcels can be relatively small and land-use is highly diverse, continuous data analyses can provide more revealing spatial analyses and focuses more on biophysical indicators. NDVI captures photosynthetic activity, and thus is used in this study as a proxy of vegetation productivity and quality (Serneels et al. 2001; Rey-Baenayas and Pope, 1995), with higher values of NDVI indicating increased vegetation productivity and health. In addition remote sensing techniques can be used to analyze spatial patterns that are difficult to capture solely at the household level. Fragmentation analyses are useful in understanding the spatial pattern and arrangement of patches within the landscape, providing critical insights for biodiversity and processes impacting land use change (Forman, 1995; Marsh et al. 2003; Nagendra et al. 2006; Southworth et al. in review).

This study examines the impact of park establishment on the landscape. Kibale National Park (KNP) in western Uganda is an important case study not only because of its biological diversity, but also because over 37 years of continuous research has been conducted within KNP and still little is known about landscape change in this area. As population outside the park swells and people are prohibited from resource extraction inside its boundary, the demand for resources and agriculture land not only increases, but competes. As a result, the remaining unprotected natural areas – wetlands and forest fragments – become targets for degradation and conversion. We address whether conservation of land inside the park and exclusion of access is related to fragmentation and resource degradation. We further examine the spatial extent and quality of these diminishing resource bases at the landscape level using discrete and continuous data analyses of satellite imagery and place the results within the social context of western Uganda and fortress conservation.

Despite their ecological importance, much of the research addressing forest fragments has focused on Amazonia and South America (Chatelain et al. 1996; Laurance and Bierregaard, 1997). Studies on fragmented landscapes outside protected areas have focused on biodiversity conservation to the detriment of research into human-environment linkages (Turner and Corlett, 1996). Previous studies have focused on the effects of fragmentation on animal and tree species (Stouffer and Bierregaard, 1995; Chapman and Chapman, 1999; Chapman and Lambert, 2000; Gillespie and Chapman, 2006). While the use of wetlands and forests as a means to sustain livelihoods is well documented elsewhere in the world, East Africa is less prominent in the literature (Turner and Corlett, 1996; Marsh et al. 2003), as are studies on the smaller, interstitial wetlands and forest fragments characteristic of western Uganda. Little research has addressed anthropogenic influences of land-cover change, or the resulting effects of altered ecosystems back onto the communities.

Study Area

Kibale National Park in western Uganda is illustrative of the agricultural expansion and intensification surrounding protected areas. Kibale Forest was demarcated in 1932 as a Forest Reserve and elevated to national park status in 1993 (Struhsaker, 1997). Known for its diverse primate population, KNP ranks fifth in terms of species richness and sixth in overall biodiversity importance among all Ugandan forests (Howard et al. 2000). It is perhaps most well-known because it is home to the largest known community of chimpanzees.

The park is an ecological island – a dense, closed-canopy forest surrounded by a large agricultural population, large tea estates, and a vast network of wetlands and bottomland forest fragments. KNP is a medium-altitude tropical moist forest covering about 795 km^2 in western

Uganda (Figure 2-1)[2]. This transitional forest (between lowland rainforest and montane forest) is at an average elevation of 1110-1590m and is a remnant of a previously larger mid-altitude forest region (Struhsaker, 1997). The climate is warm throughout the year, with an average range of 15-23°C (Struhsaker, 1997).

Forests and woodlands cover approximately 4.9 million hectares in Uganda and nearly 60% remain unprotected (NEMA, 2001). Nearly three million hectares of unprotected forests are vulnerable to overexploitation and agricultural encroachment. Forest clearing throughout Uganda became extensive in the last 200 years, but NEMA (2001) reports that the deforestation has been particularly acute in the last 50 years. At the estimated current rate of forest conversion, Uganda continues to lose 50,000 ha of its forest annually (NEMA, 2001). The Kabarole District in western Uganda, where KNP lies, is a prime example of this forest loss and subsequent landscape fragmentation. The once dominant moist, evergreen, closed-canopy forest that dominated the region has for the most part succumbed to agricultural expansion, especially since 1959 (Gillespie and Chapman, 2006). Nearly all of the forests found on potentially arable lands were converted to small-scale agriculture, tea, or pasture. The remaining forests typically occur in valley bottoms or on the steep rims of crater lakes (Gillespie and Chapman, 2006; Hartter, pers. obs.). Despite their loss, such unprotected forest fragments have been shown to be important for carbon sequestration, species habitats and corridors (Onderdonk and Chapman, 2000; Laurance and Bierregaard, 1997), as well as for commercial- and subsistence-base activities.

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[2] While officially KNP now includes a "game corridor" that connects the southern portion of KNP to Queen Elizabeth National Park, this corridor was formally gazetted as part of KNP in 1993 but has not been cleared of human settlement and treated as part of the park until the last year and currently replanting etc. is still in progress. Before that time, it was mixed agricultural land. Therefore, it was not classified as park in this analysis. By doing so, our analysis is conservative since the addition of the corridor would tend to lessen the difference between park and non-park. Excluding the game corridor, the Kibale Forest in this analysis contains 561km^2.

Uganda's wetlands comprise about 12% of the country's total land surface (Mukiibi, 2001a) and fill a vital ecological role in flood abatement, groundwater recharge, and as nature's biological filter. In the past, people treated wetlands more like wastelands (Mukiibi, 2001b) or as a repository of land for potential agricultural expansion. Wetlands have vital importance in maintaining the quality and volume of surface and ground water (Mukiibi, 2001b). Several studies have attempted to quantify wetland ecosystem services in terms of human welfare (Costanza et al. 1997; Batagoda et al. 2000; Turner et al. 2001; Balmford et al. 2002). They are important to livelihoods of surrounding communities in several ways. They provide a subsistence resource base for water, thatching, handcraft materials, and local medicines. Wetlands are also commercially important through sales of these materials to community members and also from visiting tourists. They are key spawning grounds for fish (Crisman et al. 2003), and provide other services such as biodiversity, aesthetic beauty, and cultural heritage.

Rapid population growth, high population density, and heavy reliance on small-scale agriculture and natural resources to sustain livelihoods characterize the social landscape surrounding KNP (Archabald and Naughton-Treves, 2001). The elevation of Kibale to national park status in 1993 meant that nearly all forms of commercial and subsistence based resource extraction and all settlements were prohibited. Resource unavailability inside the park coupled with increasing population has caused land pressure outside the park to increase. Wetlands are under serious threat of conversion due to population growth, in-migration, and intensification of agriculture in the surrounding landscape.

Agriculturalists in the area belong to two dominant ethnic groups: the Batoro (west side of KNP) and the immigrant Bakiga (east side of KNP) (Figure 2-1), who came to the Kibale region from southwestern Uganda beginning the 1950s and 1960s (Turyahikayo-Rugyema, 1974;

Naughton-Treves, 1998). A 1988 census estimated the population within the park and the surrounding communities to be 61,000 (Aluma et al. 1989). In the Kabarole District, where KNP lies, 95% of the population sustains their livelihoods through agricultural-based activities. This region is one of the most densely populated areas on the African continent (Lepp and Holland, 2006), with a district population density of 92 individuals/km^2 (NEMA, 2001). Naughton-Treves (1998) reported that population around KNP more than tripled between 1959 and 1990, with the current population estimated to be between 270 and 315 individuals/km^2 (Hartter, unpublished data).

Since land is a premium with increasing population, the remaining unprotected wetlands and forest fragments are sought after. Those wetlands and forest fragments that remain continue to be relied upon to produce resources for subsistence and commercial use. Not only is the presence of forests and wetlands diminishing, but they are also being degraded, reducing the amount of large trees (Kayanja and Byarugaba, 2001). Therefore, the landscape surrounding the park must change and the unprotected forests and wetlands outside the park must change as their produce is vital to community livelihoods. land scarcity has forced many farmers to farm at the forest edge (Naughton-Treves, 1998). Typical farm sizes are less than 5 ha (Hartter, unpublished data) and farmers plant more than 30 species of subsistence and cash crops). Most of the crops produced are consumed at the household level, with few being sold outside of immediate household or local community markets.

Methods

Landsat TM imagery was chosen because it offers the best combination of spatial, spectral, temporal and radiometric resolutions. Three dry-season images have been acquired: May 26, 1984, January 17, 1995, and January 31, 2003 (path 132, row 060). The first image provides baseline data prior to official park establishment (it had been a protected area as Kibale Forest

Reserve prior to this point), the second captures conditions at park establishment, and the third represents current conditions. All images underwent standard preprocessing of image calibration to correct for differences in time, sensor and atmospheric conditions, and were co-registered to within an RMS of <0.5 (below 15 m accuracy) (Southworth et al. in review).

Variation in Interannual Rainfall

While all images have been geo-rectified and radiometrically corrected to account for sensor drift and differences in solar angle and other atmospheric conditions, precipitation trends must also be considered. Satellite image analysis is especially susceptible to differences in precipitation. The normalized difference vegetation index (NDVI) has been proven to be a robust measure of vegetation attributes (net primary productivity, green biomass, and green leaf area index) (Serneels et al. 2001). NDVI has also been found to be well correlated with climate variables, such as evapotranspiration and precipitation (Anyamba et al. 2001). Healthy vegetation will have higher evapotranspiration rates. In addition more precipitation can increase vegetation productivity. Richard and Poccard (1998), Eklundh (1998) and Davenport and Nicholson (1993) have examined the relationship and subsequent sensitivity of NDVI to inter-annual rainfall. Their work has concluded that there is a high correlation between vegetation performance measured by NDVI and rainfall in areas where rainfall is limiting (<900mm) and those that have a distinct dry and wet season. Serneels et al. (2001) also found that NDVI was a good indicator of the impact of inter-annual climate variability on vegetation conditions in their study site (weakly bi-modal rainfall pattern, with a gradient of 500-1200mm/yr). However, in his meta-analysis of net primary productivity (NPP) and global climate in the wet tropical forests, Schuur (2003) found that net primary productivity becomes less sensitive to mean annual precipitation at high precipitation levels. Schuur (2003) found that as precipitation approaches

2445 mm annually, NPP levels off and then declines. Wang et al. (2001) also report the lowest correlations of NDVI to differences in precipitation with forest.

Precipitation in the Kibale region is extremely local. Although the amount of rainfall and length of season change, the average annual rainfall for the region is 1543mm (average 1903-1999) and 1719mm (1990-2006) (Chapman et al. 2005). The bi-modal rainfall pattern produces two major rainy seasons. The long rains are between late February and early May and the short rains occur between late August to early December.

This analysis focuses on two land covers: forest and wetlands, both of which are not limited in available soil moisture in this region. NDVI is more variable in more seasonal vegetation such as field crops and pasture grass, but the remaining unprotected forests outside the park tend to be in bottomlands with enough available soil moisture. Most of the wetlands are permanent wetlands as the seasonal ones tend to be converted first by the local population for smallholder agriculture. The papyrus wetlands are not seasonally quiescent and are permanent wetlands, interannual rainfall variation would have little impact. In addition, interannual phenological responses in forests in the Kibale region result in differences in fruit production and food availability (Chapman et al. 2005). In this region, the forest canopy remains intact.

Three Landsat images are used in this analysis. However, an annual time scale may not be the best scale to examine precipitation because of the bi-model rainfall pattern. While annual trends may be identified, a more appropriate time scale is defined by the local social and biophysical conditions. Trees' and plants' processes are determined not by calendar years, but by precipitation cycles in this area. Planting and harvesting by the local smallholder agriculture populace are based on rainfall patterns. Therefore, it is appropriate to examine monthly precipitation trends as well as precipitation totals for both the long and short rainy seasons.

Figures 2-2 and 2-3 shows the annual and monthly precipitation respectively and bi-modal distribution for the park and the years preceding image acquisition. It is important to note that for the image capture dates, the total monthly precipitation for that month is <50mm.

The January 1995 and 2003 images were captured after the long rains (Figure 2-4). The 1995 and 2003 are not anomalous and their monthly precipitation falls within 1 standard deviation above/below the mean. The 1984 image was captured following the short rains. It is appropriate instead to examine the trends in the short rains. The monthly precipitation for the 1984 image was also within 1 standard deviation of the mean for the short rains.

Each of the images were captured following abundant rainfall during the rainy seasons and all three images are not anomalous (not in peak or trough precipitation months). If the area was precipitation limited, we would expect that there would be a distinct seasonal difference. However, the Kibale region, receiving more than 1500mm of rainfall annually, is not precipitation limited. Serneels et al. (2001), Richard and Poccard (1998) report the sensitivity of NDVI to inter-annual rainfall in rainfall limited regions (<1200mm/yr and <900mm/yr respectively). There is a distinct dry and wet season in the Kibale region, but local farmers report that these seasons are becoming less and less distinct and increasingly blend into one another. In addition, seasonality has little, if any, impact on wetland and forest vegetation. Thus, we can conclude that vegetation conditions represented in the 1984, 1995, and 2003 Landsat images are comparable, and the use of NDVI will be an appropriate measure of long term vegetation changes, not interannual variation in precipitation.

Land Cover Analysis

During the 2004 and 2005 field seasons 180 training samples were collected and used to construct a supervised classification. The classified image was constructed using a layer stack including all bands 1-5, 7, texture bands of layers 1-5, 7, plus an NVDI layer. The final classification obtained an overall accuracy of 89.1% and an overall kappa statistic of 0.867 (Southworth et al. in review). Three classes were used in the classification: 1) forest, 3) wetland (papyrus [*Cyperus papyrus* L.] and elephant grass [*Pennisetum purpureum*]); 3) other.

The land-cover analysis was also used to determine the amount and spatial distribution of loss or increase of wetland and forest classes over time. This allows us to address issues of the size and location in the landscape of patches of different land covers across the different dates, as well as to determine conversion from and to classes, e.g., conversion from forest to agriculture. In addition, NDVI composites from each date were used in a separate analysis of mean NDVI values over time to quantify the amount and type of change in forest and wetland productivity from 1984 to 2003. NDVI was examined by land cover class of interest, so changes in land cover class do not compromise the change in NDVI values.

Fragmentation Analysis

Landscape metrics were used to identify trends in landscape heterogeneity over time. Fragstats 3.3 (McGarigal and Marks, 1995) was used to calculate these metrics. We wanted to focus the analysis on natural forests and not small kitchen gardens, spectral confusion perhaps with banana plantations, or small household stands of *Eucalyptus spp*., *Maesopsis eminii*, *Grevillea robusta*, and other species grown predominantly for fuel and/or sustenance. Therefore, only forests greater than 0.5ha in size were considered.

Results

Land Cover Analysis

Land cover classifications from the three image dates (Figure 2-5) show the difference between in-park and in the surrounding landscape. Over time, there remains little difference in forest cover inside the park.

Figure 2-5 also shows the difference in land cover allocations between the east study area, dominated by the Bakiga ethnic group, and the west study area, dominated by the Batoro ethnic group. The main difference between these two areas is the presence of tea and lower percentage of wetland in the west study area. The east side has about 55% of its land under natural areas (forest + wetland) and the west side has 45% natural areas. Overall, there is a loss in forest cover and papyrus and elephant grass and a corresponding increase of land under cultivation.

Productivity Assessment

Table 2-3 shows the NDVI values for forest and wetland across time. Mean NDVI values are decreasing over time in both forests and wetlands. The decreasing trend of NDVI values indicates the decrease in forest and wetland productivity over time both in the park and surrounding landscape.

Fragmentation Analysis

Tables 2-2 and 2-4 compare the pattern of the different land covers in the surrounding landscape to the park. Within the park, the dominant land cover is forest. Outside the park however, there are three dominant land covers – forest, wetland, and crops with the highest proportion of land under cultivation. Compared to the park, the natural areas – wetlands and forest – are smaller, more plentiful, and have much more edge in the surrounding landscape. Inside the park, there is a trend of consolidation; higher clumpiness and connectivity values compared to the surrounding landscape that is more fragmented.

The trends in the east and west study areas are similar to the entire surrounding landscape (Tables 2-4, 2-5, and 2-6). From Tables 2-5 and 2-6 and Figure 2-6, both study areas are becoming increasingly fragmented. Clumpiness and connectivity values decrease over time while distance to the nearest patch edge increases. Comparing the two study areas, mean patch size is less on the east side, and there are fewer patches of forest and papyrus and they have less edge. In addition, the percentage of the landscape comprised by the largest patch in the east side is more because of the large continuous Magombe Swamp that is protected through a community conservation program Kibale Association for Rural and Economic Development (Lepp and Holland, 2006). The clumpiness, connectivity, and cohesion values for both the east and west study areas are similar. In general, the forests and wetlands in these areas are becoming increasingly isolated and clumped together in the east and west study areas.

Discussion

Park boundaries are relatively intact and the forest cover within Kibale National Park has not decreased over time and has in fact become more consolidated over time (less fragmented) in contrast to what has happened in the landscape surrounding the park. Our results indicate little change of forest extent inside the park since 1984. Mulley and Unruh (2004) report in their analysis of KNP and the surrounding landscape from 1955-2001 that most of the park remained forest, while nearly all of the deforestation took place outside the park boundaries. Outside the park, there is evidence of continued active conversion. The clearing of wetlands and forests is highly variable in each fragment because of local land tenure, resource needs of households, and the number of households dependent on the particular forest fragment, human-wildlife interaction, local geography and ecology, and other factors. Outside the park, a higher number of fragments will have increased access by more households. In turn, more fragments are used. These new fragments become more isolated and edge density increases as they are used. Larger fragments become smaller and smaller as the continuous landscape is broken up. This process of increased fragmentation and opening up the interior of remaining fragments leads to degradation, more open/disturbed forest and towards secondary vegetation (Schelhas and Greenberg, 1996).

Chapman et al. (2006) report a decrease both in basal area and stem density (stems>10cm diameter at breast height (dbh) between 2000 and 2003 in forest fragments located on the western flank of KNP. At the broad landscape level, Mugisha (2002) found that the landscape surrounding Kibale National Park showed a dramatic land cover change from 1955-2000. This landscape showed the largest expansion of smallholder agriculture by approximately 137%, while at the same time there was a decrease of wetlands by 19% and forest by nearly 20%. While this change is notable, Mugisha (2002) does not define the extent of the study area boundary outside the park. Although less dramatic, our analysis shows the overall decrease in forest and wetland and the corresponding rise of cultivated land and tea (Figure 2-6).

The loss of extent and decrease in productivity of wetlands in the landscape surrounding the park has important implications, both environmental and social. Laurance and Bierregard (1997) describe forest loss and fragmentation as the most pressing threat to global biodiversity. While more natural areas are converted to cultivated lands to support the growing population and their resource and economic needs, the landscape surrounding KNP has become increasingly fragmented. As a result, the amount and density of edge has likewise increased. Edge effects are widespread, complex, and unique to the landscape matrix, but the effects of edge cannot be ignored. Hill and Curran (2005) found that area of a fragment was the most important influence on tree species and composition in Ghanaian forest fragments. Furthermore, Gascon et al. (2000) report that those fragments less than 5000 ha, are especially vulnerable to edge effects. Surrounding KNP the mean patch size is substantially smaller (10 ha). The matrix surrounding the remaining natural areas – land and resource pressures and the intensified land use can result in edge effects penetrating further into the forest (Gascon et al. 2000). As the wetland and forest fragments steadily decrease and edge effects penetrate further, the result is an impoverished interior. This impoverishment has further implications.

As the population outside KNP continues to cut forests or drain wetlands seeking land and resources and to prevent crop raiding, long term detriment is caused to the lands. There is anecdotal evidence to suggest that the increased isolation of the forest fragments within the intensely cultivated landscape is related to trees dying out in the fragments. Even though some of the fragments remain, many farmers have noticed that bigger trees are dying and they say that it is taking longer for the endemic species to grow to even pole size. Fragmentation not only lowers species number, but also alters community composition and their ecosystem processes because of the reduction in size and the change in shape (Hill and Curran, 2003). Laurance et al. (2000) found that forest fragment size and tree species diversity were directly related. As the amount of edge is increased and interior decreased, forest regeneration is slowed. The forest edge becomes degraded and dispersed with weedy species that are useless for home consumption. Fragment size is important. Higher mortality rates in forest fragments are found in smaller fragments in the Amazon (Laurance et al. 2000) and Laurance and Bierregard (1997) found that the number of rare species increased with fragment size.

The loss of extent and decrease in productivity of wetlands in the landscape surrounding the park has important implications. Not only does species richness and diversity increase with loss of wetlands and forest, but the ability of these forests and wetlands to fulfill important ecological processes is severely handicapped by increased fragmentation, loss, and degradation (Tinker, 1997; Laurance, 2004). Bolwig et al. (2006) suggest that fragmentation can lead to a loss of biodiversity to as high as 2.5% in some agroecosystems. The presence and quality of forest fragments has been found to affect rainfall, microclimate, plant and tree species abundance and diversity (Kapos et al. 1997). There is a loss of net primary productivity, carbon sequestration ability, nutrient level maintenance and ecosystem maintenance and pollutant mitigation (Coops et al. 2004).

The degradation, decrease productivity, and increased fragmentation of the remaining wetlands outside the park have similar environmental impacts. As wetlands continue to degrade in size and quality, their ability to control erosion and floods and to maintain water and volume of water likewise decreases (Chapman et al. 2001). Less papyrus productivity has social and bio-environmental impacts. A degraded wetland will produce less above- and below-ground biomass, thus limiting the ability to filter and recharge water. Jones and Humphries (2002) showed that papyrus swamps have the potential to sequester large amounts of carbon (1.6 kg $C/m^2/yr$) when detritus accumulates under water in anaerobic conditions. These swamps also may be a net source of carbon release to the atmosphere (1.0 kg $C/m^2/yr$) when water levels fall to expose detritus and rhizomes to aerobic conditions. The relatively homogenous stands of papyrus often extend over large areas up to tens of kilometers in western Uganda (Chapman et al. 2001). Therefore, wetlands in the KNP region represent potentially large carbon sinks. In addition, the continued conversion producing fewer and less productive wetlands is reducing the overall ability of the landscape to sequester carbon and may instead become carbon sources (De la Cruz, 1986).

The impacts of size, shape, and isolation of forest fragments are not limited to vegetation and ecological processes. The ecological relationships are complex. As the micro-climate is altered, changes in solar radiation, humidity and wind pattern that are important for many organisms can impact viability and survival (Ranta et al. 1998). Biological attributes such as predator and prey relationships, habitat, migration corridors, and species survival probabilities are also impacted (Laurance et al. 2002). Gillespie and Chapman (2006) report that fragments with higher stump densities (those with higher anthropogenic influence) strongly influenced the prevalence of parasitic nematodes in primates. Habitat fragmentation can also cause local extinctions, but also can have long term effects on populations through changes in pollination, predation, and food availability. In forest fragments outside KNP, red colobus abundance (*Procolobus rufomitratus)* declined with the loss of food trees (Chapman et al. 2006).

Landscape fragmentation and loss and degradation of wetlands and forests outside KNP also have important social implications. The degradation of habitat, breeding grounds, and nutrition can cause wildlife to seek supplemental sources. Farms neighboring the park become easy targets because of the abundant food supply and the high probability of a successful raid. The increased fragmentation of the landscape causes further detriment because the limited natural areas that act as corridors through which species such as the vervet monkey (*Cercopithecus aethiops*), the redtail monkey (*Cercopithecus ascanius*), and olive baboon (*Papio anubis*) travel. Those fragments that remain act to channel the primates especially through agricultural lands because of the narrow passages connecting remaining wetlands and forest. Furthermore, the wetlands and fragments are opened up for human intrusion, thus escalating the number and severity of human-wildlife encounters (Hill, 1997; Naughton-Treves, 1998). Landscape metrics measuring landscape connectivity are important tools in understanding the impacts of wildlife. Connectivity is determined based on threshold values. A threshold of 60m was set initially, which is quite small. In reality, we found that the vervet, redtail, and L'hoesti monkeys (*Cercopithecus lhoesti*) and baboons raided fields over 500 m from the forests and wetlands. Elephants (*Loxodonta africana*) were found to raid fields at distances less than 400 m from these natural areas (Hartter, unpublished data). As threshold values were increased, forest, wetland, and total natural area (that is, forest + wetland) connectivity increases (Figure 2-7).

A less productive and smaller wetland and forest area also means a reduced ability to filter toxins from the drinking supply or to control erosion. Regeneration in forests may be slowed or arrested because of lower nutrient levels, larger more common gaps, human intrusion that lead to topsoil erosion or younger trees may be out-competed by lower quality and/or weedy pioneer species such as elephant grass and the sub-woody shrub *Acanthus pubescens* (Chapman et al. 1999; Chapman and Chapman, 1999). As the ability to conduct ecosystem functions is reduced, so will the availability of resources to meet subsistence needs. Wetlands dry up and produce less papyrus. Forests are high-graded for their hardwoods, medicinal purposes, building materials, musical instruments, or for other reasons. In the process, the large, straight, and vigorous tree species that are important seed trees are removed.

Unprotected wetlands in Uganda have intensively been used to extract resources or have been drained to cultivate crops. As the outer edges are cultivated each growing season, the wetland continues to decline in size and water levels recede. When converted, the detritus-based ecosystems of the papyrus swamps initially have fertile soils. However, as the soil is exposed, it begins to oxidize, leading depletion of soil nutrients and increased soil acidity (Cooper 1975, Crisman et al. 1996). Not only does soil moisture and fertility dramatically decrease after the first few growing seasons, but also it is difficult to reclaim abandoned drained papyrus wetlands. Forests have been cut for resources and to make way for crops, pasture, or to reduce crop-raider habitat. Overexploitation occurs in the context of harvesting resources. In wetlands, clay for brick building, and pottery and papyrus for thatching houses and making mats are commonly extracted (Chapman et al. 2001; MacLean et al. 2003). In forests, indigenous medicines, building poles, timber are taken. Firewood is also procured for fuelwood or for firing bricks.

The shortage of fuelwood has also intensified the situation. Ninety-five percent of all Uganda's energy needs are met with fuelwood and charcoal (MacLean et al. 2003). The hardwoods are gone and households must turn to softer exotics to meet their needs. As a result, many households are growing fuelwood and timber trees in drained wetlands or converted bottomland forests. In the 1950s, *Eucalyptus spp.* were introduced in many parts of Uganda as a solution to wood shortages, because it is fast-growing, coppices, and can provide poles and timber as early as three and eight years respectively after planting. While it has been successful at providing resources, *Eucalyptus* has also become problematic. *Eucalyptus'* water uptake demands are substantial (Shiva and Bandyopadhyay, 1983). Many households in the Kabarole District in western Uganda for instance, complain of decreased water levels corresponding to the increase of *Eucalyptus* trees planted at the edge of wetlands or within drained areas (Hartter, unpublished data, Richardson 1993).

The current situation of population increase and land and resource pressures has created a negative feedback loop in the landscape surrounding KNP. The more the areas become exploited and overused to get resources and to cultivate crops and reduce the threat of crop raiding wildlife, the more degraded the forest and wetland remnants become, and in turn their ability to provide abundant and high quality resources in the future is compromised.

Despite their social and ecological uses and the broader implications of degradation on livelihoods, forest and wetland conversion continues. Chapman et al. (2006) concur, concluding that many of the forest fragments surrounding KNP will disappear in the coming years. Conservation value is low for the small unprotected natural areas because they cannot support viable populations of primates and other species in the long-term. This has implications on monitoring because it requires the location, extent, and pattern of land cover change to be known. Identifying 'hot-spots' is an important phase in allocating limited resources in wetlands and forest management. A mixed-methodological approach is necessary to examine landscape change from a broad spatial scale, but also to understand the fine-scale implications on biodiversity and households.

Future research is needed to further examine the changes in land cover extent, pattern, and productivity. It is evident that productivity is decreasing both inside and outside the park and new vegetation indices should be developed describe within-class variation. In addition, Southworth et al. (in review) described the difficulty in differentiating elephant grass and papyrus because of similar spectral signatures. This gives a conservative land cover assessment by including elephant grass with papyrus together in one land cover class. Southworth (2004) and Boyd et al. (1996) note the usefulness of using the Landsat thermal band for assessing forest regeneration in tropical dry forests. The thermal band can be incorporated in a new analysis to examine within-class variation of forest to investigate loss of productivity within park vs. surrounding landscape. In addition, papyrus appears exclusively in valley bottoms and elephant grass many times, but not always, is found in the uplands. New vegetation indices, surface temperatures, and a digital elevation model can be incorporated to create a new rule-based classification to improve overall classification accuracy. KNP is an important park not only because of its biological diversity, but also because of the islandized nature of the park. KNP represents an important litmus test for the impacts of park establishment on the surrounding landscape in mid-elevation moist tropical rainforests, typical more of central Africa (e.g. Gabon, Democratic Republic of Congo). These results should also be compared to park landscapes that are more precipitation limited such as in southern Africa savannah landscapes.

Conclusion

Parks have long served as centerpieces of the conservation movement. However, their establishment is not benign and can have lasting impacts on the landscape and livelihoods of people living near them. As population outside the park swells, the demand for resources and agriculture land not only increases, but competes. Remaining wetlands and forest become targets for degradation and conversion. Remote sensing techniques and fragmentation analysis were useful tools to address the amount and location of change and also provided the ability to compare within and outside park boundary change. We have shown the landscape surrounding the park has become increasingly fragmented since 1984. As fragmentation outside the park continues, the forests and wetlands in the surrounding landscape not only are becoming increasingly smaller, but increasingly isolated and decreasing in productivity, producing both environmental and social implications.

Characteristic of fortress conservation is its measures of success. To this movement, the status of plants, animals, and the ecological community as a whole is the ultimate measure of successful conservation (Struhsaker, 2002). KNP's boundaries remain relatively intact, while the surrounding landscape has become increasingly fragmented as land and resource pressure builds outside the park over time. While it could be argued that KNP is a muted success story for fortress conservation, the reduction in forest and wetland productivity should not be ignored and further research should address the phenomenon. Parks are associated with landscape change. Whether the exclusive nature of such parks for the promotion of biological diversity conservation can hold out in the face of mounting pressure to sustain human livelihoods is an important question that must be addressed.

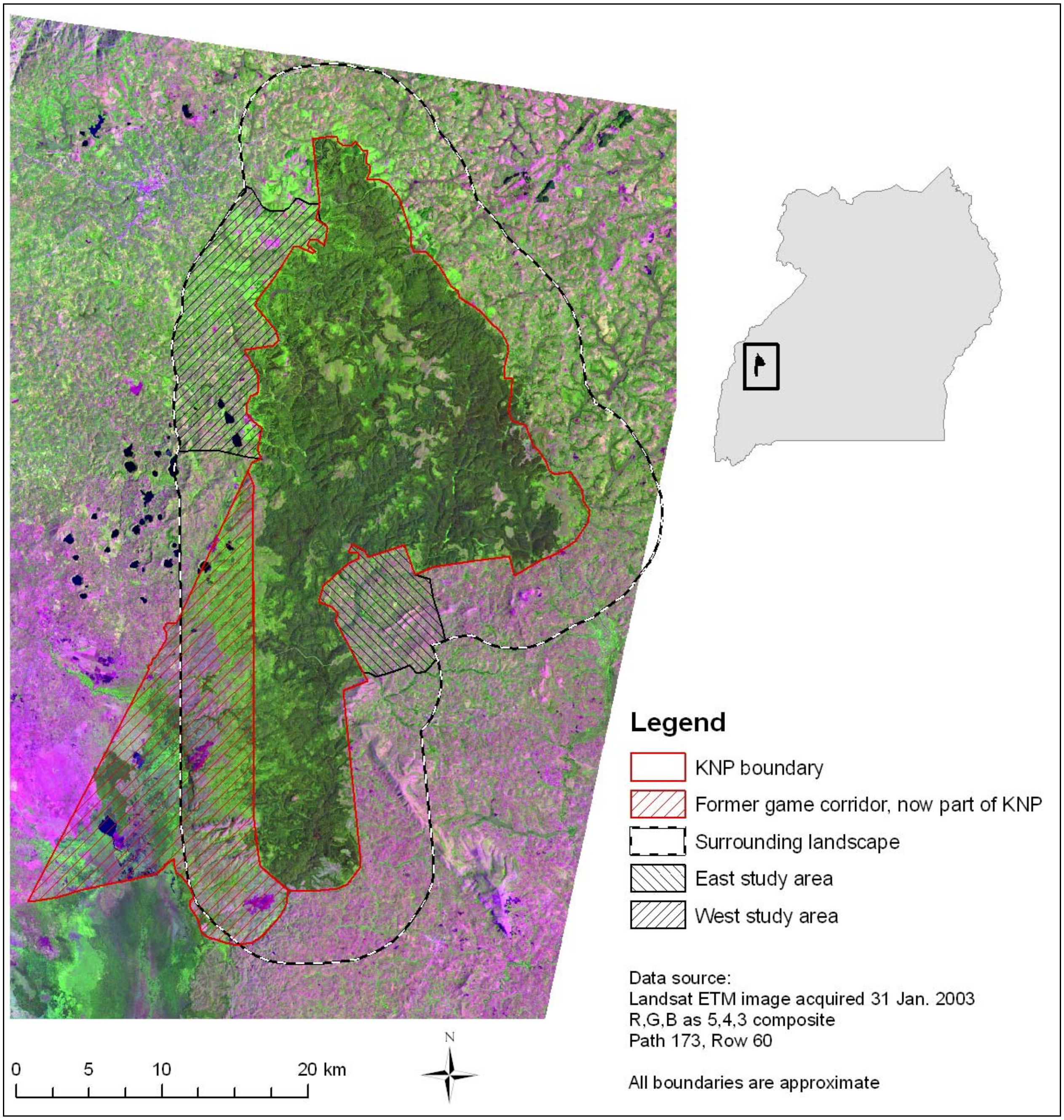

Figure 2-1. Kibale National Park and surrounding landscape in western Uganda

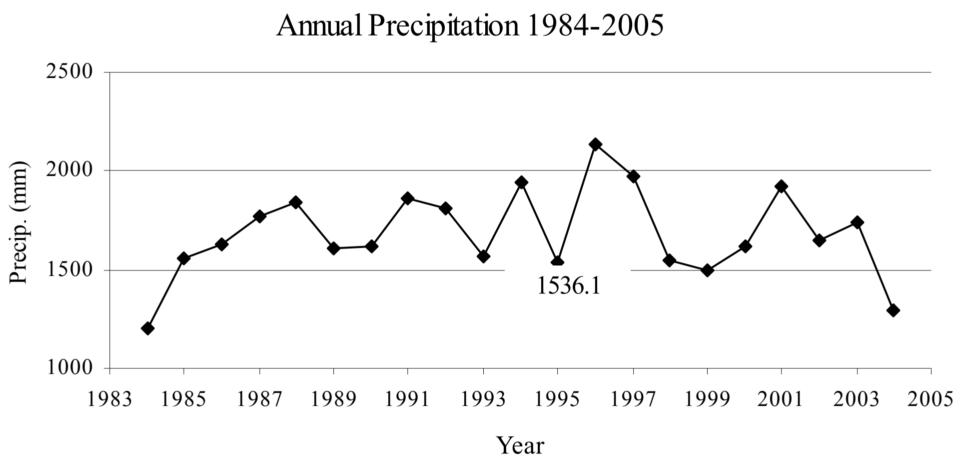

Figure 2-2. Annual precipitation collected at the Kibale research station (Kanyawara). Annual precipitation totals for image capture years are noted. No data was acquired during September 13-21, 2004 while the broken rain gauge was repaired.

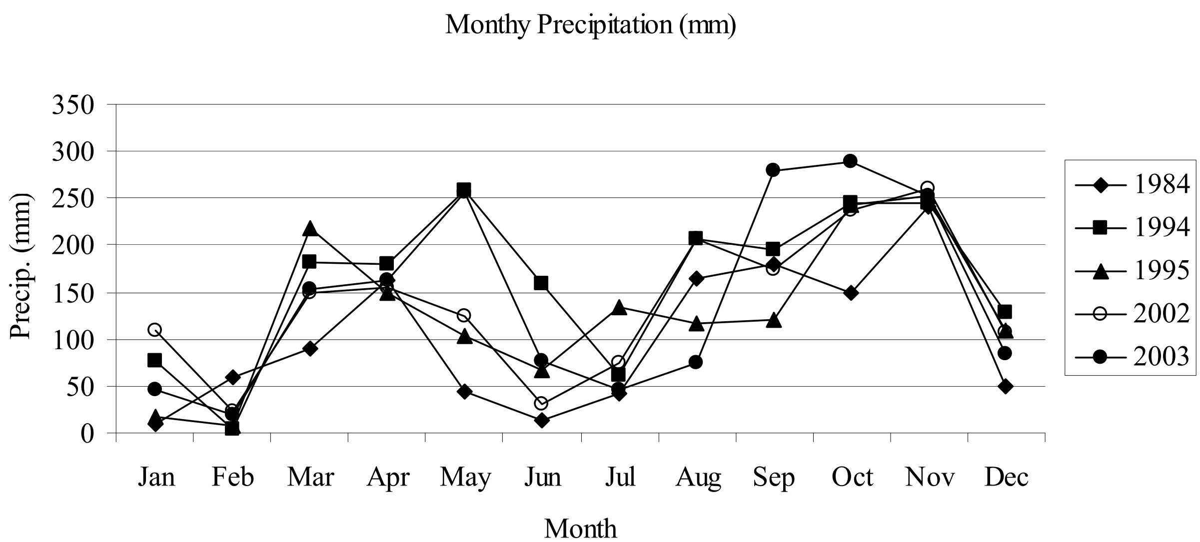

Figure 2-3. Monthly precipitation data for the three image years (May 1984, January 1995, and January 2003) and the years preceding image capture (1983 data was unavailable) at the Kibale research station (Kanyawara).

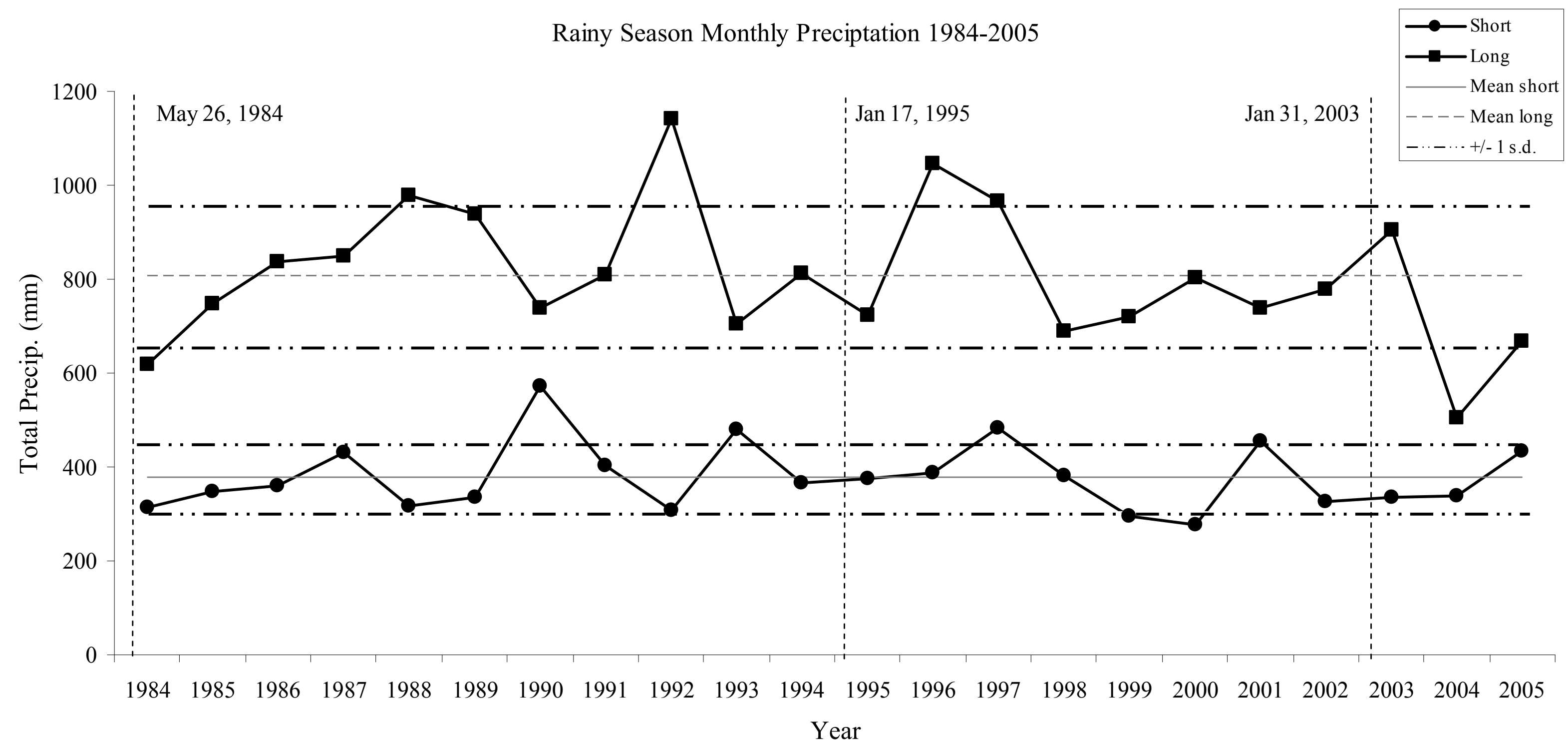

Figure 2-4. Precipitation totals for the short and long rainy seasons between 1984 and 2005. Mean values and +/- 1 standard deviations are given for each rainy season.

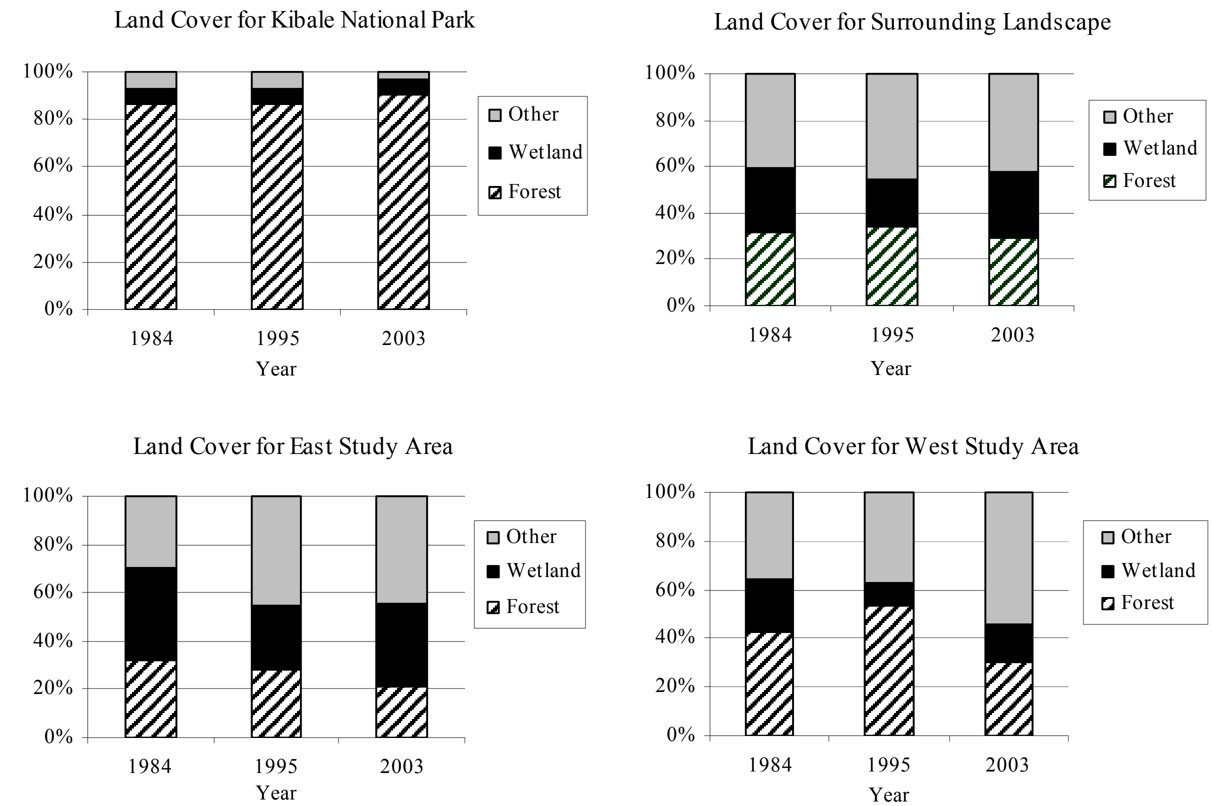

Figure 2-5. Land cover change in-park and in the surrounding landscape, including the east and west study areas

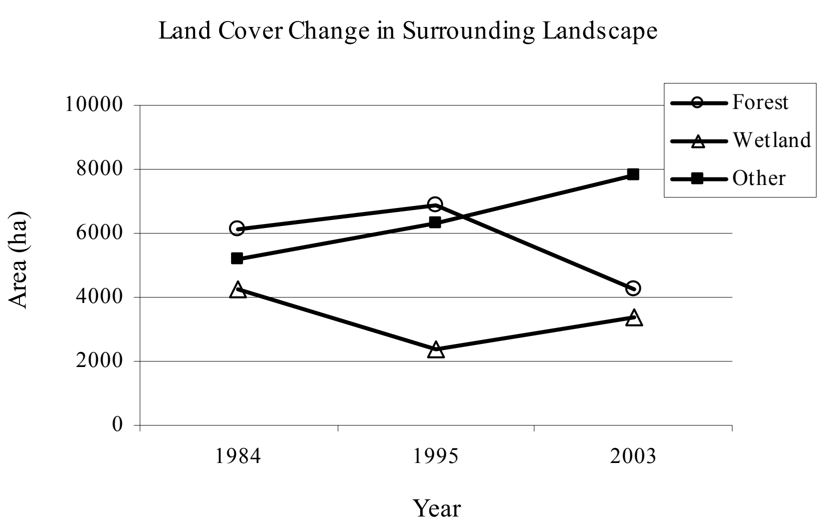

Figure 2-6. Land cover extent in the surrounding landscape 1984-2003

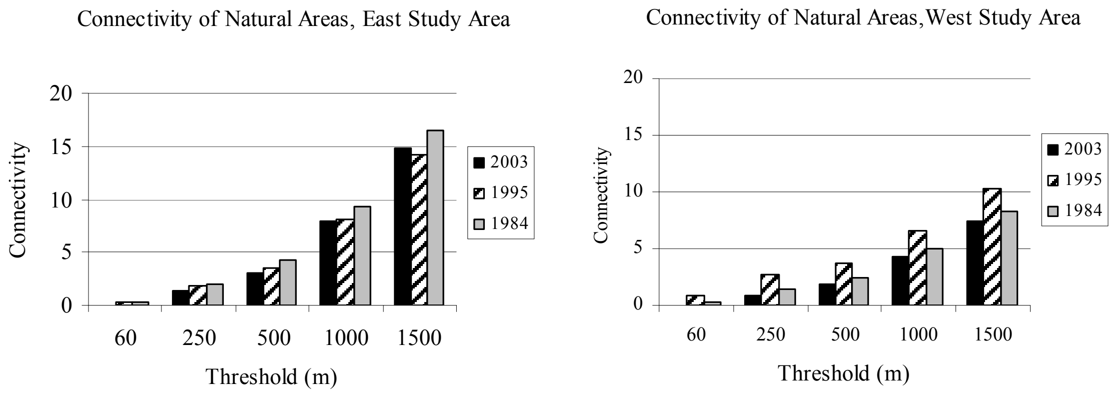

Figure 2-7. Connectivity of natural areas in east and west study areas

Table 2-1. Definitions of landscape metrics incorporated within this analysis of fragmentation of forest and wetland patches, from 1985, 1995 to 2003

Landscape Metric	Description
PLAND	Proportion of the landscape covered by each land cover
LPI	Percent of landscape comprised by largest patch
NP	Number of patches
MPS	Mean patch size (ha)
ED	Edge density is the sum of all edge segments, divided by total area for each class (m/ha)
ENN	Euclidean distance to nearest patch edge (m)
Connectivity	(range 0 to 100, expressed as a percent). Measurement of connections between patches of the corresponding patch type divided by the number of possible connections. A value of 0 is when either the class consists of a single patch or none of the patches of the focal class are connected; and a value of 100 indicates that every patch of the class is connected.
Cohesion	(range 0 to 100). Measurement of physical connectedness of the corresponding patch type. Values tend towards 0 as the proportion of the landscape comprised of the class decreases and becomes increasingly subdivided and less physically connected. Values increase as patch type becomes more clumped or aggregated in its distribution.
Clumpiness	(range -1 to 1) Measurement of the aggregation of patches within a class. A value of -1 is when the patch type is maximally disaggregated; 0 when the focal patch type is distributed randomly; and when the value approaches 1 when the patch type is completely aggregated.

Note: A complete description of these and other metrics are provided at http://www.umass.edu/landeco/research/fragstats/fragstats.html.

Table 2-2. Inside-park fragmentation analysis

Land Cover	Year	Proportion of Total Land Area (%)	Largest Patch Size (ha)	No. Patches	Mean Patch Size (ha)	Edge Density	Clumpiness Є (-1 - +1)	Connectivity* Є (0-100)
	1984	86.3	39.54	672	73.3	18.7	0.94	0.152
Forest	1995	85.5	25.64	668	73.1	12.85	0.95	0.122
	2003	90.1	41.49	412	124.9	13.39	0.96	0.000
	1984	6.0	0.36	4267	0.8	13.16	0.63	0.010
Wetland	1995	6.3	0.23	6995	0.5	10.48	0.58	0.005
	2003	6.6	0.38	3262	1.2	11.12	0.71	0.000

*threshold at 60m

Table 2-3. Forest and wetland productivity as assessed by NDVI (NDVI values between -1 and +1). Values close to +1 indicate higher productivity.

Year	Land Cover	Location	Mean NDVI	NDVI Std. Dev.	NDVI min.	NDVI max.
1984	Forest	KNP	0.591	0.078	0.315	0.805
1995	Forest	KNP	0.548	0.055	0.143	0.770
2003	Forest	KNP	0.360	0.052	0.133	0.559
1984	Forest	SL	0.644	0.063	0.338	0.799
1995	Forest	SL	0.580	0.044	0.333	0.778
2003	Forest	SL	0.398	0.049	0.043	0.586
1984	Forest	East SA	0.597	0.055	0.370	0.759
1995	Forest	East SA	0.553	0.034	0.400	0.664
2003	Forest	East SA	0.378	0.044	0.119	0.508
1984	Forest	West SA	0.682	0.038	0.462	0.799
1995	Forest	West SA	0.611	0.038	0.378	0.730
2003	Forest	West SA	0.410	0.052	0.085	0.586
1984	Wetland	KNP	0.561	0.059	0.097	0.759
1995	Wetland	KNP	0.506	0.054	0.071	0.706
2003	Wetland	KNP	0.303	0.061	-0.133	0.518
1984	Wetland	SL	0.556	0.065	0.013	0.767
1995	Wetland	SL	0.482	0.049	0.111	0.647
2003	Wetland	SL	0.263	0.075	-0.260	0.511
1984	Wetland	East SA	0.533	0.064	0.140	0.708
1995	Wetland	East SA	0.472	0.036	0.246	0.595
2003	Wetland	East SA	0.274	0.057	-0.200	0.492
1984	Wetland	West SA	0.598	0.054	0.101	0.757
1995	Wetland	West SA	0.519	0.039	0.137	0.647
2003	Wetland	West SA	0.305	0.059	-0.260	0.496

Table 2-4. Fragmentation analysis for surrounding landscape

Year	Land Cover Type	No. Patches	Edge Density (m/ha)	Mean Patch Size (ha)	Clumpiness Є (-1 - +1)	Connectivity Є (0-100)	Distance to Nearest Patch Edge (m)
1984	Natural Areas	2733	35.48	14.98	0.8307	0.028	78.3
1995	Natural Areas	2912	34.63	12.70	0.8188	0.028	76.5
2003	Natural Areas	3879	44.68	9.82	0.7939	0.000	72.9
1984	Forest	1514	27.88	14.07	0.7725	0.039	106.2
1995	Forest	1426	29.35	16.08	0.7721	0.041	102.1
2003	Forest	1780	21.39	10.53	0.8235	0.000	118.5
1984	Wetland	9587	38.78	2.05	0.6637	0.008	77.3
1995	Wetland	10200	30.91	1.38	0.6297	0.006	84.5
2003	Wetland	8581	39.16	2.25	0.6868	0.000	80.0
1984	Other	9013	35.48	3.10	0.7714	0.008	76.4
1995	Other	6314	34.63	5.09	0.7981	0.012	75.8
2003	Other	10311	44.68	3.02	0.7582	0.000	74.2

Table 2-5. Fragmentation analysis for east study area

Year	Land Cover Type	No. Patches	Edge Density (m/ha)	Mean Patch Size (ha)	Clumpiness Є (-1 - +1)	Connectivity Є (0-100)	Distance to Nearest Patch Edge (m)
1984	Natural Areas	204	83.67	17.68	0.7422	0.425	72.8
1995	Natural Areas	327	99.14	7.81	0.6455	0.257	72.6
2003	Natural Areas	397	99.44	6.48	0.6475	0.000	69.0
1984	Forest	165	52.41	9.44	0.7359	0.244	97.5
1995	Forest	211	57.51	6.31	0.673	0.230	91.1
2003	Forest	207	35.51	4.34	0.7202	0.000	108.7
1984	Wetland	731	108.00	2.80	0.5612	0.136	69.9
1995	Wetland	884	66.44	1.38	0.5992	0.058	77.5
2003	Wetland	761	86.87	2.20	0.5917	0.000	72.5
1984	Other	949	83.67	1.82	0.6103	0.095	71.1
1995	Other	729	99.14	3.82	0.6605	0.149	66.2
2003	Other	575	99.44	4.81	0.6567	0.000	65.8

Table 2-6. Fragmentation analysis for west study area

Year	Land Cover Type	No. Patches	Edge Density (m/ha)	Mean Patch Size (ha)	Clumpiness Є (-1 - +1)	Connectivity Є (0-100)	Distance to Nearest Patch Edge (m)
1984	Natural Areas	299	62.92	21.58	0.7818	0.359	71.8
1995	Natural Areas	159	61.57	39.05	0.7824	0.661	72.5
2003	Natural Areas	816	63.06	5.13	0.7139	0.000	74.9
1984	Forest	284	61.10	14.97	0.7240	0.284	79.8
1995	Forest	118	71.29	44.46	0.7218	0.826	74.4
2003	Forest	395	41.20	7.25	0.7488	0.000	95.3
1984	Wetland	1890	56.32	1.17	0.5686	0.037	75.8
1995	Wetland	1646	29.62	0.59	0.5161	0.027	92.2
2003	Wetland	1871	39.59	0.71	0.5207	0.000	85.9
1984	Other	1499	62.92	2.56	0.6923	0.057	73.8
1995	Other	1433	61.57	2.85	0.7119	0.054	72.9
2003	Other	861	63.06	7.09	0.7728	0.000	68.7

CHAPTER 3
RESOURCE USE ANDHOUSEHOLD LIVELIHOODS: LIVING NEAR WETLANDS AND FOREST FRAGMENTS NEIGHBORING KIBALE NATIONAL PARK

Introduction

Landscapes around parks are important areas. The matrix outside a park, consisting of edge effects, population growth, changing patterns of land use, and others, will influence livelihoods of adjacent communities and shape the surrounding landscape. They are potential reservoirs of land, resources, and economic opportunity. Park landscapes are likely to attract migrants because of tourism-based activities, increased infrastructure for tourists and researchers, or because of other industries directly or indirectly related to park establishment. Increasing population will likewise extend the need for land and resources. In addition, these landscapes are critical for biodiversity (McNeely, 1994). Patches of forests and wetlands outside parks serve as important wildlife corridors and critical habitat and feeding grounds and resource bases for local communities (Barbier, 1993; Byron and Arnold, 1999).

To secure their livelihoods, most of the rural population in Sub-Saharan Africa turns to the land. Land use intensification and extensification are common responses to limitation and constriction of resources. However, protected areas are commonly barriers to settlement, extensification, and resource extraction, which in turn affects farmers' land use and livelihood options (Brockington et al. 2006; Wilkie et al. 2006). Since resource extraction and most forms of consumptive land use are often forbidden within the park boundaries, people intensify land use on their own land and turn to the only available land to meet their needs. Unprotected wetlands and forest fragments become targets for conversion to agriculture, grazing land, or woodlots or are harvested at unsustainable levels. In order to understand land cover change in the landscape surrounding a park, it is necessary to examine resource consumption patterns of park neighbors. Resource use may vary by ethnicity, wealth, location, and gender (Rocheleau and Edmunds, 1997; Byron and Arnold, 1999; Goebel et al. 2000).

Patterns of land cover change and landscape fragmentation in most tropical developing countries relate significantly to anthropogenic impacts (Nagendra et al. 2003). To date, fragmentation literature has focused heavily on impacts to ecology and survival/degradation of species and habitat (Chatelain et al. 1996; Onderdonk and Chapman, 2000; Hill and Curran, 2003; Chapman et al. 2003), with a heavy geographical preference to Amazonia and South America (Stouffer and Bierregaard, 1995; Laurance and Bierregaard, 1997; Marsh et al. 2003, 1997). Only limited work has acknowledged (and commonly, only briefly mentions) the role forest fragments play in providing resources such as fuelwood, timber, poles, thatching, handcraft materials, indigenous medicines, and edible plants to communities (Turner and Corlett, 1996; Gillespie and Chapman, 2005). Studies on fragmented landscapes instead have focused on biodiversity conservation and larger fragments, thus to the detriment of research into human-environment linkages (Turner and Corlett, 1996). The human use of small (less than 100ha), interstitial fragments characteristic of agricultural mosaic has not been highlighted. Studies of fragmented systems must include consideration of ongoing human influences (Laurence and Bierregaard, 1997). Despite these acknowledgements, the impacts of resource base diminishment at the household level remains largely unaddressed in the literature.

In Uganda, resources obtained from unprotected forest fragments and wetlands are essential for survival of the majority rural population (Banana and Gombya-Ssembajjwe, 1998; Kayanja and Byarugaba, 2001). At the same time, the unprotected wetlands and forests outside parks and protected areas are problematic. Intensified use of forests and wetlands and landscape fragmentation has caused a substantial decline in habitat and foraging lands for wildlife

(Onderdonk and Chapman, 2000; Chapman et al. 2001). Households are commonly affected by crop raids by primates, elephants, and birds; livestock loss; and even human fatalities occurring in lands near these natural areas (Tchamba, 1996; Naughton-Treves, 1997; de Boer and Baquete, 1998; Gillingham and Lee, 1999). Little research has addressed either anthropogenic influences on land-cover change outside protected areas, or the resulting effects of altered ecosystems back onto the communities (Pickett et al. 1995; Turner et al. 2001).

Protected area establishment presents a challenge for households to sustain livelihoods because of exclusion of land and restriction of resources. Social systems and livelihoods of small rural communities are tightly linked to the environment that surrounds them. This paper examines the dual character of these natural areas within the agricultural landscape around Kibale National Park in western Uganda as both benefits and hazards. Two questions are addressed, 1) What resources and problems are associated with wetlands and forest fragments around KNP? and 2) How do these benefits and problems vary by distance from the park boundary, gender, wealth, and ethnicity?

Study Region

Ecological System

Kibale National Park (KNP) (Figure 3-1) in western Uganda is illustrative of the agricultural expansion and intensification surrounding many protected areas. Kibale Forest was demarcated in 1932 as a Forest Reserve and elevated to national park status in 1993, leading to the eviction of a few thousand settlers within the park (Struhsaker, 1997; Chapman and Lambert, 2000). Kibale National Park is a medium-altitude tropical moist forest covering 795 km^2 in western Uganda[3] (Naughton-Treves, 1998). This transitional forest (between lowland rainforest

[3] While officially KNP now includes a “game corridor” that connects the southern portion of KNP to Queen Elizabeth National Park, this corridor was formally gazetted as part of KNP in 1993. Before that time, it was mixed

and montane forest) is ranges in elevation of 1110-1590m and is a remnant of a previously larger mid-altitude forest region (Struhsaker, 1997). Although the amount of rainfall and length of season change, the average annual rainfall for the region is 1543mm (average 1903-1999) and 1719mm (1990-2005) (Chapman et al. 2005).

The landscape outside the park has become a patchwork of small farms (most <5ha in size), tea estates in some areas, and a collection of forest fragments and wetlands, effectively isolating the park. In addition, 43% of the land within a 5 km periphery of the park is under cultivation or pasture (Hartter, unpublished data). Tea dominates much of the landscape bordering the northwest portion of KNP, covering nearly 21% within 1km of the park boundary (Hartter, unpublished data). Tea producers range from large multinational companies with hundreds of hectares, to smaller individual holdings of less than one hectare (Mulley and Unruh, 2004).

Forest fragments and wetlands that extend out from the park's boundaries and isolated within the agricultural matrix surrounding the park vary in size, shape, and resource types and amount. Forest fragments range in size in Bakiga communities (east side of KNP) from 0.5ha to approximately 150ha and 0.5ha to approximately 210ha in Batoro communities (west side of KNP). Wetlands vary in size on both sides of the park with Dura Swamp (~220ha) and Magombe Swamp (~420ha) being the largest on the west and east side respectively being the largest. Since nearly all of these natural areas occur in bottomland areas, many of the forests and wetlands are combined, effectively extending the resource bases and wildlife corridors.

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agricultural land. Therefore, it was not classified as park in this analysis. Since 1993, the total park area is 795km^2, but only 561km^2 of parkland (excluding the game corridor) is covered in this analysis.

Forest fragments

Forests and woodlands cover approximately 4.9 million hectares in Uganda and nearly 60% of these remain unprotected (NEMA, 2001). These unprotected forests provide a number of ecological services such as stabilization of local climate, erosion control, nutrient uptake, and carbon sequestration (Laurance and Bierregaard, 1997). Forest fragments also serve as species corridors, habitat, and breeding and feeding grounds (Onderdonk and Chapman, 2000; Marsh, 2003). These areas are used for commercial and subsistence purposes. They provide fuelwood, indigenous medicines, timber, charcoal, poles, and non-timber products (Banana and Gombya-Ssembajjwe, 1998).

Nearly three million hectares of unprotected forests remain vulnerable to overexploitation and agricultural encroachment. Uganda continues to lose 50,000 ha of its forest annually (NEMA, 2001). Kabarole District in western Uganda, where KNP lies, is a good example of forest degradation and loss associated with rapid population growth and unsustainable harvesting levels, leaving only patches behind. NEMA (1997) estimated 21% of the forests in the district have been degraded. As agriculture continues to encroach upon unprotected forests mainly to meet subsistence needs, these forests become progressively degraded and/or isolated.

Wetlands

Wetlands include all areas where plants grow and animals live in association with permanent or temporary flooding (Kisamba-Mugerwa and Nuwagaba, 1993). Uganda's wetlands, dominated by papyrus (*Cyperus papyrus* L.) comprise about 13% of the country's total land surface (Mukiibi, 2001a) and fill a critical ecological role in flood abatement, groundwater recharge, and as nature's biological filter. Wetlands have many environmental values including maintenance of water quality and volume, pollutant filtration, flood abatement, and serve as habitat for a diverse range of aquatic and terrestrial species (Mukiibi, 2001b; Bakema and Iyango, 2001; Crisman et al. 2003). Despite being one of the most productive ecosystems in the world (Muthuri et al. 1989), people in the past treated wetlands more like wastelands (Mukiibi, 2001b) or as a repository of land for potential agricultural expansion.

Wetlands are also important to the livelihoods of surrounding communities. They also serve as resource bases for household- and commercial-based resources and activities such as water, thatching, handcrafts, medicinal plants, and tourism. Despite their social and ecological benefits however, Uganda's wetlands are under serious threat of conversion due to population growth, in-migration, and intensification of agriculture in the surrounding landscape (Chapman et al. 2001; MacLean et al. 2003). Wetlands are often drained and converted to other land uses such as growing crops and fuelwood, particularly *Eucalyptus spp*., and expanding grazing land (Crisman et al. 2003). As with forest fragments, wetlands represent unclaimed or underutilized land in many cases. As a result, both areas continue to be degraded and converted, while rural communities are challenged to sustain their livelihoods on a day-to-day basis.

Social System

Rapid population growth, high population density, and heavy reliance on agriculture for income characterize the landscape surrounding KNP (Archabald and Naughton-Treves, 2001) and land pressure has steadily increased (Naughton-Treves, 1996). Economic inequality, ethnic disparity, increasing land use intensity, and a decreasing resource base in these communities serve to illustrate a common trend around protected areas in developing countries. In Kabarole District, 95% of the population sustains their livelihoods through agricultural-based activities. With limited land availability, farm sizes are characteristically.

Agriculturalists in the area belong to two dominant ethnic groups: the Batoro (west side of KNP) and the Bakiga (east side of KNP) (Figure 3-1). The Batoro are the largest ethnic group in the area (~52% of population), but immigration of Bakiga who came to the Kibale region from southwestern Uganda beginning the 1950s and 1960s (Turyahikayo-Rugyema, 1974; Naughton-Treves, 1998) and others have greatly increased population growth and demand for agricultural land and resources (MFEP, 1992; NEMA, 1999). This region is one of the most densely populated areas on the African continent (Lepp and Holland, 2006), and population around KNP more than tripled between 1959 and 1990 (Naughton-Treves, 1998). The current population (2006) is estimated at 262 individuals/km^2 on the west side of the park and 335 individuals/km^2 on the east side within 5km of the park boundary (Hartter, unpublished data).

Methods

I designated a study unit an area both large enough and small enough to include the scales of land cover, biodiversity, and human activities and enable us to measure them so that satellite remote sensing images and the on-the-ground measurements are tied operationally to the same area of land (Southworth et al. in review). To provide this link, sampling units (named "superpixels") comprising 9ha areas were used. These superpixels are centered on spatially randomly selected coordinates within 5km of the KNP boundary and within two areas (Figure 3-1). In all, 95 superpixels were selected. These 95 superpixels are found within 60 villages (a cluster of houses typically within 250m and part of the same administrative unit) and include sample pool of 417 households (that is, households controlling land in one form or another contained within at least 1 of the superpixels). Between May and August 2006, 130 semi-structured household interviews were conducted. At each superpixel, respondents were chosen opportunistically, based on population weighting. The number of respondents for each study was proportional to the number of landholders containing land within the study area. Therefore, study areas with smaller landholders, and thus more landholders, had a higher sampling intensity. During the course of fieldwork, additional interviews with village chairmen (LC1), key informants, KNP wardens, tea estate mangers, and representatives from local conservation groups were conducted. All interviews were conducted in English or in Rutoro or Rukiga using an interpreter.

At each respondent's house, GPS locations were obtained. GPS points were also taken at access points for the nearest forest fragment and wetland for each house. These GPS points were used to calculate the straight-line distance from the house to the nearest wetland and/or forest fragment. Distance from each house to the park boundary was calculated using the KNP boundary polygon. Thus, I mapped the social and ecological units of interest together.

Wealth and distance categories were determined using hierarchical cluster analysis. Wealth indicators used were number of animals (goats and cows) per household, head of household gender, total amount of land held, house category (based on a 5-category classification of house construction materials). The sample population was broken into three wealth classes – "more poor", "less poor", and "not poor". Three distance categories were defined also using hierarchical cluster analysis to relate the straight-line distance of the respondent's house to the KNP boundary – "closer" (<1000m), "moderate" (1001-3000m), and "further" (3001-5000m). I used χ^2 test for independence to examine the relationship between the response and distance to the park, wealth, gender, and ethnicity. A significance value of 0.1 was used to reduce type I errors and given the use of recalled information.

Results

Forest Fragment and Wetland Benefits to Households

Nearly all of the respondents derived some sort of benefit from wetlands outside KNP (Table 3-1). While the majority derived benefit in some way from forests outside KNP (78%), the proportion of respondents perceiving benefits was less than for wetlands (92%). Only a small percentage reported they had never derived any benefit from forests and wetlands. In addition to reporting benefits, the vast majority also reported that the forests and wetlands were sources of problems to their household (Table 3-1).

I found that perceived benefits and problems from wetlands and forests and distance to the park were not independent ($\chi 2$ test for independence, $p>0.1$ in all cases). This result suggests households find wetlands and forests beneficial and problematic throughout the surrounding landscape. However, the specific benefit and problems and their relationship to distance to the park had different results.

Firewood, water, handcraft materials, indigenous medicines, and ties (vines used to tie building poles together for house and fence construction) were most often cited as benefits from the wetlands (Table 3-2). Wetland resources: firewood ($p=0.070$), poles ($p=0.042$), and medicines ($p=0.011$) showed trends of increasing use at distances further from the park boundary were found not to be independent of distance from the park. More men reported firewood as a benefit from the wetlands than female respondents ($p=0.078$). Ethnicity and wealth class appeared to play less of a role in responses to wetland benefits ($p>0.1$).

Firewood, medicines, building poles, handcraft materials, and water were the most reported benefits of forests (Table 3-3). Ethnicity and wealth were not significantly related to these resources and gender was only related to building poles. Distance was found to be negatively related to firewood, poles, medicines, and handcraft materials ($p<0.1$). These data suggest that more households derive benefits from these resources at further distances from the park. Results from Tables 3-2 and 3-3 suggest that crafts, water, and ties can be obtained throughout the surrounding landscape. However, medicines and firewood from wetlands were more often gathered at distances further from the park.

In addition, ecosystem services were mentioned as important benefits of wetlands and forests. There is evidence to suggest that responses and ethnicity (p=0.012), gender (p=0.001), and wealth (p=0.029) class were not independent for wetland ecosystem services. Bakiga, male respondents, and "not poor" respondents perceive more often perceived these benefits (Table 3-2). Surprisingly, only 9% of respondents reported ecosystem services as benefits from forests, substantially less than the 32% reported from wetlands (Tables 3-2 and 3-3). For forests, only ethnicity was found to be related to perceived ecosystem services from forests (p=0.003).

Most respondents fill most of their household water needs from an improved source (bore hole, improved well; 51%), while only 24% collect most of their water from the natural areas (Table 3-4). In addition, most households meet their energy needs from the natural areas (38%), while planted firewood supplies energy needs for 30% or respondents. Only 10% of respondents fulfilled most of their energy needs by buying firewood and charcoal. Local charcoal burners report the shortage of hardwoods in the forest fragments, the fear of punitive measures by the KNP rangers, and the relative abundance of *Eucalyptus spp*. From anecdotal evidence, most of the firewood, charcoal, and trees purchased are not endemic hardwood species, but instead planted species.

Problems to Households

Wetlands and forests are also sources of hazards (Table 3-5). Most respondents (90%, n=130) said they had problems because of the nearby forests and wetlands. Most of the respondents identified wild animals that raid their crops and chickens and goats as problems directly related to forest presence (including KNP) and wetlands (74%, n=130). However, these responses were not significantly related to ethnicity, gender, wealth, or distance to park, suggesting wild animals do not discriminate between demographics or distance from the park boundary. Similarly, the problem of less available resources was unrelated to distance, suggesting that resource scarcity is a problem throughout the surrounding landscape. Maize was the crop that was reported to be raided most, followed by bananas, and then hens. Respondents also identified other problems. Respondents also noted the problem with less available resources (e.g. firewood, handcraft materials, medicines) in the forest fragments and wetlands that they could gather.

They also reported the problem of owner and/or government stopping them from gathering resources. The χ^2 test for independence suggests that owner and/or government intervention is identified as a problem closer to KNP than further away. Responses also varied by demographic category. Ethnicity was found to be significantly related to 'nuisances', with Bakiga reporting this problem nearly two times more than Batoro. Nuisances were also significantly related to gender, and wealth class ($p<0.1$). Males and those closer to KNP tended to report the reduction and/or unavailability of resources more than women ($p<0.1$). Interestingly, mosquitoes, tsetse flies, ticks, and biting ants were also mentioned as key problems because of the presence of wetlands and forests. Although respondents identified this as a problem due to the presence of a forest and/or wetland, it is prevalent in the landscape – both in areas closer to and further from natural areas. Nearly 10% of respondents said that they had no problems from the natural areas.

Wild animals were reported most often as problems for landholders. Of those that reported animals as a problem, the redtail (*Cercopithecus ascanius*) (65%, n=96) and vervet monkeys (*Cercopithecus aethiops*) (51%, n=96) were cited most as perpetrators on farms around the park (Table 3-6). Although only a small percentage identifies birds as a crop raiding animal, this group is probably under-reported because there is no distinction in Rutoro and Rukiga with 'animal' and 'bird'.

More Batoro farmers reported problems with elephants (*Loxodonta africana*) (p=0.096), than Bakiga farmers. However, a higher proportion of Bakiga farmers reported problems with redtail monkeys (p=0.068), vervet monkeys (p=0.106), with L'hoesti monkeys (*Cercopithecus lhoesti*) (p=0.001), mongoose (p=0.003), serval cats (*Felis serval*) (p=0.003), and foxes (p=0.003) than Batoro farmers. Male respondents reported problems with baboons (p=0.049), black and white colobus (*Colobus guereza*) (p=0.033), vervet monkeys (p=0.085), red colobus (*Procolobus rufomitratus*) (p=0.096), and birds (p=0.068) than female respondents. Wealth was not related to problem animals (p>0.1).

Distance and ethnicity were significantly related to certain crop raiders. At closer distances to the park boundary, baboons (*Papio anubis*) (p=0.000), elephants (p=0.000), L'hoesti monkey (p=0.016), red colobus (p=0.062), bush pig (*Potomochoerus porcus*) (p=0.011) were reported. At further distances, a great number of households reported vervet monkeys (p=0.011), mongooses (p=0.024), and serval cats (p=0.068).

Of those that reported problems with wildlife (n=96), 51% of respondents say that small monkeys (vervet, redtail, black and white colobus, red colobus, and L'hoesti monkeys) were the greatest problem overall (Table 3-7). Small were greater problems in households located further from the park (p=0.000). Conversely, households closer to the park boundary reported elephants and baboons as main problems more than those located further from the park boundary (p=0.000 and p=0.007 respectively).

Although small monkeys were reported as the main crop raiding problem at further distances from the park boundary, farmers at all distances reported problems with them. However baboons and elephants were only reported at households less than 3km and less than 2km from the park boundary respectively (data from GPS coordinates of actual incidences;

Figure 3-2). Small monkeys and baboons traveled well beyond the boundaries of the natural areas to raid farmers fields, while elephants tended to stay closer (<300m) to the natural areas (Figure 3-3).

In addition to the problems of wild animals, many households report a reduction in the available resources for them to collect from the forests and wetlands (33%, n=130) (Table 3-7). Although not everyone has noticed a reduction, the majority of respondents believe that there will not be enough wetland (56%, n=130) and forest (71%, n=130) to meet their needs in the future (Table 3-8).

Despite the problems, I found that most people would rather live closer than further from forests and wetlands (Table 3-9). Female respondents overwhelmingly would prefer to live closer to the natural areas, while there was little difference within wealth and ethnicity and distance to the park. Those living further from the park also had the largest proportion of respondent's that preferred to live closer to the natural areas.

Discussion

Benefits from Wetlands and Forests

Social and ecological systems are tightly linked in the landscape surrounding KNP. Most people derive benefit in some way from the forests and wetlands – both consumptive and non-consumptive uses. Most report the consumptive uses such as firewood, water, handcraft materials, or building poles. However, it is also evident that perceived non-consumptive benefits from forests and wetlands (i.e., ecosystem services) are important to landholders. It is also important to examine benefits and their relationships to each category: wealth, gender, ethnicity, and distance from park. For example, water use was not significantly related to distance from the park. The majority of the respondents have access to bore holes or local or improved wells for their main water sources (71%, n=130; Hartter, unpublished data). Although the sample population was dependent on wood products to meet most, if not all, energy needs, wetlands are depended on more than forests.

These results suggest that firewood is more important from the wetlands further from the park. One possible explanation is that the forests and wetlands near the park are so degraded that firewood is less available and must turn to either forest fragments and wetlands further away or go illegally to the park. In addition, people closer to the park have a more limited selection of firewood sources because collection in most cases is prohibited inside park boundaries. Migrants also seeking land found that land nearest the park was available, further diminishing wetlands and forests as they were cleared for fields and pasture. Many people in the area have also begun growing fuelwood, perhaps relieving some of the pressure on the forest fragments. I found that while only 37% (n=130) report the use of forest fragments and wetlands as their main source for firewood, 71% and 48% report they use the forest fragments and wetlands respectively for at least some of their firewood.

People also recognized the environmental benefits of forests and wetlands. Benefits such as rain and "fresh air" were cited most often and believed a direct result of the presence of wetlands and forests in the area (and has been verified by other independent researchers in the area). Other services such as "good and/or maintained soil fertility", "soil moisture", and wind breaks were noted. In their minds, these areas not only brought rain, but were responsible to provide enough rain and in a timely fashion for planting, growing, and harvesting crops. Respondents also mentioned that forests and wetlands "keep the environment", meaning these areas were important not only for the ecosystem services such as rain and soil moisture, but also climate and temperature regulation. Many respondents also reported these areas "keep animals". From their point of view, because the park and other natural areas are around, wild animals do not come to their fields at all or come less. They believe that because these remaining natural areas provide a haven for wildlife – food and habitat. If these areas were gone, they would surely come to their lands to raid their fields. By the same token, the benefits of rain, fresh air, soil moisture, etc. would not be available.

Despite being most often cited, these “non-material” benefits are based on perception, rather than entirely on fact. Their perceptions, while they may be true ,partly true, or untrue in some cases, are based on conjecture of their own beliefs and schooling, second-hand information, misinformed environmental educators or park outreach representatives, and their own experience.

Though both provide many benefits, wetlands and forests are perceived differently. More people derive benefit from the wetlands than the forests. Three times more respondents cited ecosystem services as an important benefit from wetlands than forests. Ethnicity, gender, and wealth class were significantly related to reported wetland environmental benefits, but oddly only ethnicity was significantly related to reported forest ecosystem services. Males and those that were not poor reported more environmental benefits from the wetlands. Males typically stay in school longer, have more opportunities for socialization and work off the farm and therefore are more exposed to extension services or talk to other farmers. The people who are “not poor” are also those who tend to be more educated and have more access to printed information or extension agents. In addition, the Bakiga, who are generally poorer and further from population center, and generally have less infrastructure, could be less aware of environmental benefits. However, many respondents cited education programs by the community conservation program, KAFRED (Kibale Association for Rural and Economic Development) as major contributors to their understanding of the environment (Lepp and Holland, 2006).

Environmental Impacts from Social Benefits

Despite the benefit of environmental services from wetlands and forests, population increase and land shortage has led to intense pressure on the remaining resource bases. Perceived, intangible benefits are difficult to assess and are valued differently by different households. Households tend to forego what will not directly and immediately benefit their short-term gains, even if it does decrease the long-term standard of living or sustainability of resources and livelihoods (Hyden, 1998).

The environmental implications of conversion and resource extractions are similar in the remaining forest fragments surrounding KNP. Turner (1996) reported fragmentation causes a local loss of species; and isolated forests have fewer tree species. Fragmentation and loss of trees that serve as key habitats or foods contributes to a loss of other taxa, a change in microclimate, and may have long term effects on pollination, predation, and other ecological processes (Ranta et al. 1998).

Studies from within KNP show forest recovery on degraded lands is a slow process. This recovery requires soil nutrients (which are removed with resources), the absence of human disturbances and fertile soil and viable seed bank (Duncan and Chapman, 2002). In addition, large canopy gaps that are created from harvesting larger trees are related to limited survival of seedlings and higher mortality (Chapman et al. 1999, Kasenene and Murphy, 1991). In most cases, harvesting in forest fragments is done selectively, one tree at a time and processed one tree at a time (e.g. pit-sawing) reducing gap sizes and neighboring tree and seedling mortality (Chapman and Chapman, 1996). However, Chapman and Chapman (1999) and Paul et al. (2004) suggest even though conditions may be favorable to support high levels of regeneration, low-seedling recruitment and survival are threatened by high disturbance and the *Acanthus pubescens* may dominate because of canopy collapse that can suppress seedling establishment.

Forest fragments, through a long period of high-grading, now are left with few remaining timber-sized trees and lower quality understory species. The proliferation of *Acanthus pubescens* and fast-growing pioneer species in canopy openings and forest edge can be used for firewood, but it suppresses the important longer-growing, hardwood species that are used for building poles. Landholders seek hardwoods because they burn hotter and can withstand termites and rot longer. High quality hardwood species used for saw-logs are now more difficult to find in forest fragments, and those that remain are often protected by either the National Forest Authority or adjacent landholders. However, poles-sized trees (typically <20cm diameter at breast height) are deemed acceptable for harvest by many landholders. Many respondents reported a decrease in timber-sized trees, but continue to extract poles at a constant or increased rate. This becomes problematic because these trees are typically hardwoods that not only have fought off suppression and established themselves, but also grow slower and are the most productive. Continued extraction of these smaller trees decreases the periodicity of disturbance and nutrient removal, but reduces the juvenile class that would eventually grow to larger trees. As a result of continued resource extraction and no effort to replant trees in species or in number, there are fewer seed trees and reduced habitat important for seed-dispersing frugivores and aviaries. The long-term survival of the forest resource base is in jeopardy. There is also anecdotal evidence to suggest that forest fragments are being degraded to a point that the big trees in the fragments are dying (Hartter, pers. obs.), consistent with what is reported in the Amazon (Laurance et al. 2000).

Problems

Several problems related to wetland and forest fragment (non)presence were identified Nearly one third of the people said there was a noticeable change in available resources that were gathered in the forests and wetlands, and that their responses were independent of distance from the park. As the landscape around the park becomes increasingly fragmented and the forests and wetlands become smaller and more isolated, the availability of high quality resources decreases. As resources become scarcer, landholders begin to intervene and closely monitor and control the use of "their" forest in order to preserve their ability to access resources into the future. Others regard this control of access and stipulations of the amount and type of resources that can be gathered within the forests and wetlands as a problem. With the creation of the National Environment Management Authority in 1995 as the "principal agency for the management of the environment" (NEMA, 2001), the national government and local councils have been more proactive in wetlands protection. Landholders reported that within the last two years the National Environment Management Authority, the District Environmental Officer, local council leaders, and other landholders have limited extraction. As a result, local landholders cited government intervention and restriction of access as one of the main problems they have had with obtaining enough firewood and other resources.

Most of the respondents reported that animals were a problem and these problems were due to the presence of wetlands and forests. I found that distance to the park boundary, ethnicity, wealth, and respondent gender were related to problems and problem animals. However, distance appears to be the most important indicator for resource consumption and problems. Despite being generally regarded as more intensive land users, the Bakiga respondents cited a mean usage of forest and wetlands nearly the same as the Batoro in number of uses (4.5, 5.0 respectively). However, a higher percentage of Bakiga respondents reported problems with animals. Only with respect to elephants did Batoro respondents report more problems the Bakiga. Despite the differences, I believe that these results are more indicative of location effects than the influence of ethnicity on land use. For example, L'hoesti monkeys and serval cats generally occur on the east side of the park, which is made up predominantly of Bakiga landholders. Anecdotal evidence from scientists having work there for nearly two decades and local farmers, report only rare sightings, if any of L'hoesti monkeys on the west side of the park (C. Chapman, pers. comm.). Ethnicity is important because ethnic group and the associated culture and land tenure patterns can determine where households will be located (Hill, 1997).

Naughton-Treves (1997; 1998) focused on park neighbors and found that proximity to the KNP boundary was the strongest predictor of crop raiding. In farms studied close to the park boundary (≤0.5km), baboons were identified as the worst crop raider (Naughton-Treves, 1996; 1997) and small monkeys (cercopithecine) were most prevalent (Naughton-Treves, 1998). Her work showed that the frequency of damage events to crops decreased further from the park boundary (maximum 500m).

A decade later, the presence of animals as a problem was not significantly related to distance from the park boundary, also indicating that crop raiding is indiscriminant and happens all over in the surrounding landscape. Instead of targeting specific farms adjacent to the park boundary, I included a larger, geographic random sampling of households at multiple locales. I found that distance was related to which animals raided farms (i.e., baboons, elephants, small monkeys). Small monkeys were found to be the most prevalent raiders and overall were reported as worse problems than the baboon or elephant in the surrounding landscape (i.e., ≤ 5km from the park boundary). Farmers report these small monkeys are in the fields almost daily, especially during the two harvests in January and mid- to late-July through August, while elephants are infrequent raiders that may come once, twice, or not at all in a season. They typically arrive at night and they can appear unpredictably throughout the year, but typically from January to May along the western and northern borders and then shifting to the eastern and southern borders from June to December (Chiyo et al. 2005). When they do visit fields, the result is often catastrophic losses to an entire season's field or crop. They indiscriminately pass through fields to feed on bananas, maize, and sweet potatoes, and other crops (Naughton-Treves, 1998; Chiyo et al. 2005; Hartter, pers. obs.).

As other studies have shown distance from the park boundary and distance from the natural areas is also strongly related to farm vulnerability to crop raiding (Hill, 1997, Naughton-Treves, 1998; Chiyo 2000). Landowners report that baboons and elephants only use the fragments as corridors, but reside inside the park, while vervets, redtails, and other small primates reside within these same fragments. These results concur with these reports.

Vervets are more problematic in farms further from the park than closer. Further from the park, the remaining forests and wetlands tend to be islandized (i.e., not connected to other fragments and the park) within the surrounding agricultural matrix. These fragments are far away from the continuous habitat of the Kibale forest. Vervets can live within disturbed habitat (Onderdonk and Chapman, 2000), while other primates reside in the forest, but have larger home ranges. I found that baboons raided farms up to 3km from the park boundary, but forays were greater than 0.5km from the natural area corridors. Elephants and baboons tend to raid farms closer to the park boundary, while small monkeys are present all over in the surrounding landscape (χ^2 $p<0.1$). The forest fragments and wetlands are then used as corridors to move within the surrounding landscape. Chiyo (2000) and Naughton-Treves and Treves (2005) reported that elephant damage is "tightly confined" to distances less than 200m from the park boundary during their studies in the 1990's. However, I found that elephants affect farms much further from the park boundary, traveling up to 2km from the nearest edge.

Within that landscape, elephants tend to stay closer to the forest fragments, while baboons and small monkeys are much bolder and venture through the agricultural matrix to the particular fields. The redtail monkey, which was the second greatest problem animal, was not significantly related to distance from the park boundary. Distance was also found to relate significantly to reported problems with red colobus monkey. Both of these results confirm Onderdonk and Chapman's (2000) research with fragments outside KNP. Red colobus' dietary preferences may prevent them from living far from the continuous forest, while redtail monkeys can reside in disturbed forests and supplement their diets by raiding neighboring farms.

These results are also important because they reveal farmers' perceptions of threats and origins of those threats. There may be some inherent bias to for respondents to say that most of the crop raiders come from the park because of ambivalence toward the park or because the respondent thought the research team had some affiliation with the park. However, these perceptions, especially on farms away from the park, have implications on land use and land cover.

As the population and other pressures increase, wetlands and forests become increasingly utilized, more intrusion into their interior, increasingly isolating them within the surrounding matrix of farms, and producing greater edge density (Byron and Arnold, 1999; Gascon et al. 2000). Many respondents believed that crop raiding incidence was directly related to the presence of natural areas. As a result, in some cases forests are cut for timber and building poles; to make way for crops or pasture; or even to reduce crop-raider habitat. Many say that they cut forests as a "pre-emptive" strike to clear their habitat and feeding areas. They believe that if they reduce the forests and wetlands, there will be no where to go and will be forced to retreat within the boundaries of KNP or other fragments. Others say the best defense against crop raiding is to have their farm buffered by at least another farmer closer to the forest or wetland. This fragmentation of the landscape not only has impacts on households and farmers seeking resources and land, but it also has detrimental impacts on the ability to provide ecosystem services (i.e., water volume maintenance and filtration, and carbon sequestration) and the biodiversity (Tinker, 1997). Not only has more edge been created, but also the interior of the forests have become more accessible to hunting and other forms of resource extraction. Habitats and food supplies are shrinking. Primates and other animals must travel further distances and ultimately across farm, pasture, and fallow lands to the next natural area (wetland and forest).

Nearly one third of the respondents perceived noticeable shortages of resources from some time in the past, but most believe that there will not be enough resources from either forest or the wetlands in the future. Those who said there will be enough resources in the future, live further from the national park. It is because of these perceptions about the problems, benefits, but also about the future availability of resources that the overwhelming majority would rather live closer than further from natural areas. Respondents say these problems are predictable and they can do something about that (e.g. guarding their fields), but they cannot do anything about resource unavailability. Simply put, their priority is to survive (i.e., maximize short-term gains). Forests and wetlands provide resources to do that. Since resource use within KNP is restricted, the fulfillment of the neighboring population's needs place the remaining forest fragments and wetlands in jeopardy and almost certain extinction not only of land and resources, but also of biodiversity. While the boundaries of KNP have remained intact over time (Southworth et al. in review), evidence from this study showed that resource shortages are escalating. In the end, can Kibale withstand the social pressures outside its boundaries? Once remnant forest and wetlands are destroyed or degraded beyond use, then pressure on protected areas may increase (Chhetri et al. 2003). Many farmers report the positive impacts of the park such as keeping animals and ecosystem services. Future research should address a deeper understanding of attitudes toward the park and the people's relationship with the environment and their land use practices and their impact on different taxa (Twyman, 2001; Brockington et al. 2006). Only then can amenable solutions to crop raiding and resource shortages between the park and its neighbors be conceived.

Conclusion

Forests and wetlands outside KNP are both beneficial and problematic to households in the surrounding landscape. I found that while respondent gender, wealth class, and ethnicity do not relate strongly to extracted resources from wetlands and forest fragments since the vast majority of rural households depend on the natural areas in one way or another, regardless of demographic. However, the spatial allocation of those resources (i.e., distance from the park) was related. The reduction in the size and number of forest fragments has reduced the available resources from these areas for households, and also decreased habitat and food for wildlife. Most households perceive resource shortages and most report problems of crop raiding. Wild animals were identified as the main problem in the surrounding landscape as a result of the presence of wetlands and forests. The vervet and redtail monkeys are the worst crop raiders, but baboons and elephants are also extremely problematic. Elephants and baboons tend to raid farms closer to the park boundary, while small monkeys are present throughout the surrounding landscape. The superpixel methodology was useful to identify the sample population, and will provide a linkage from these household-level results to the landscape-level analysis as part of the larger research effort. The superpixel is an appropriate sampling framework to collect data from multiple locales and was appropriate for densely settled agricultural landscapes that receive abundant rainfall. Ethnicity is important because it relates to settlement patterns of farms.

Though the forests and wetlands are perceived to be sources of both problems and benefits, most landholders say they are worried about the availability of resources in the future and would rather live closer to these areas. So while KNP remains intact, heavy reliance on the land and its resources outside the park place remaining forests and wetlands in jeopardy of severe degradation or extinction.

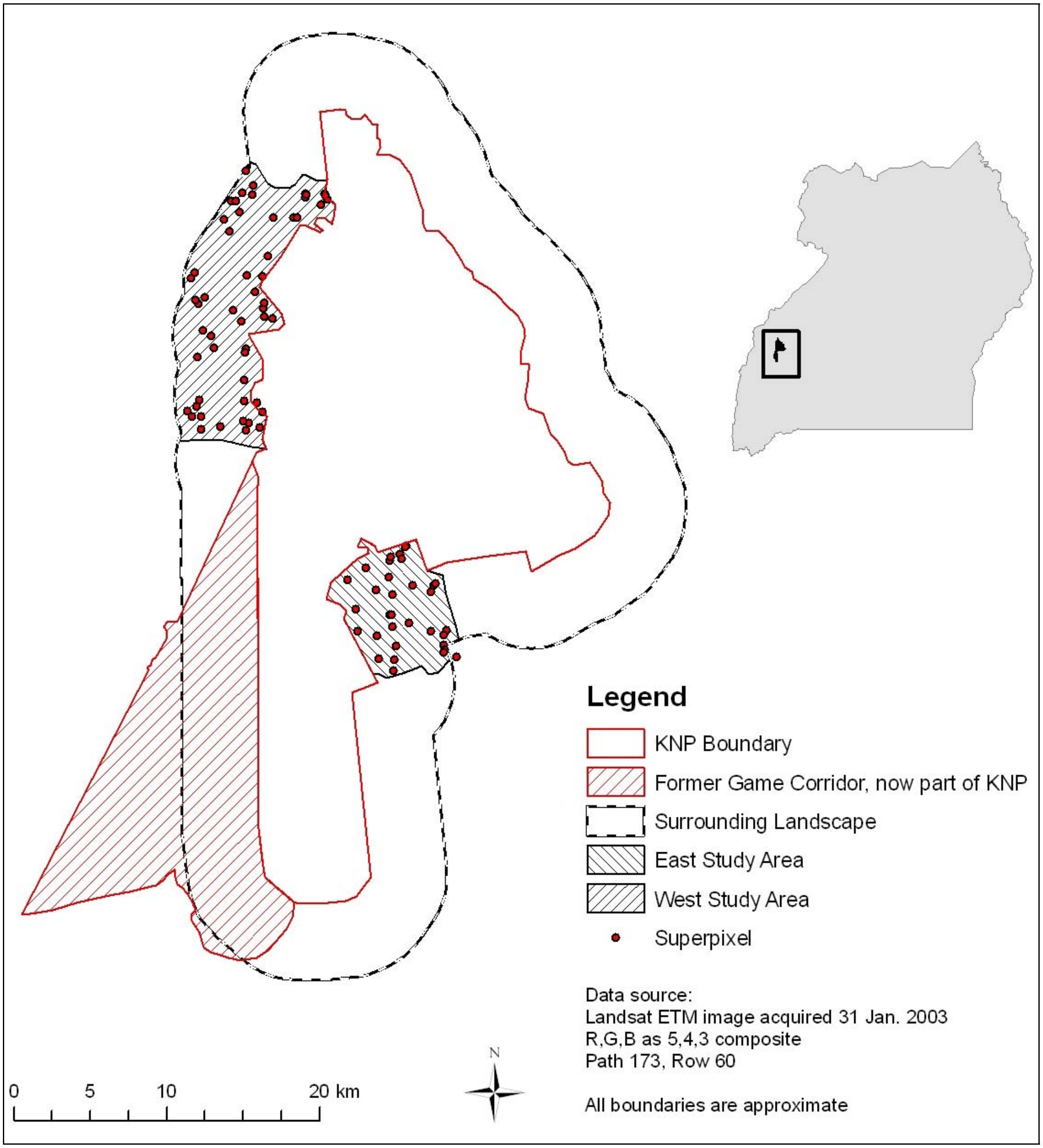

Figure 3-1. Kibale National Park and surrounding landscape in western Uganda

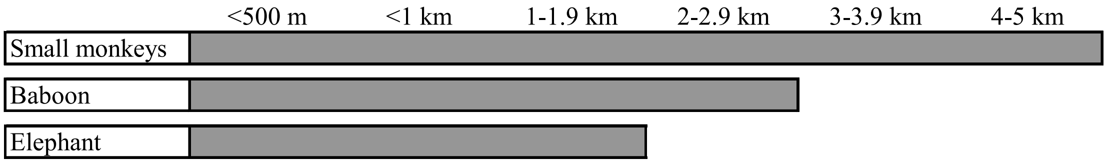

Figure 3-2. Distance of households to KNP boundary reporting problems with wild animals for leading crop raiders

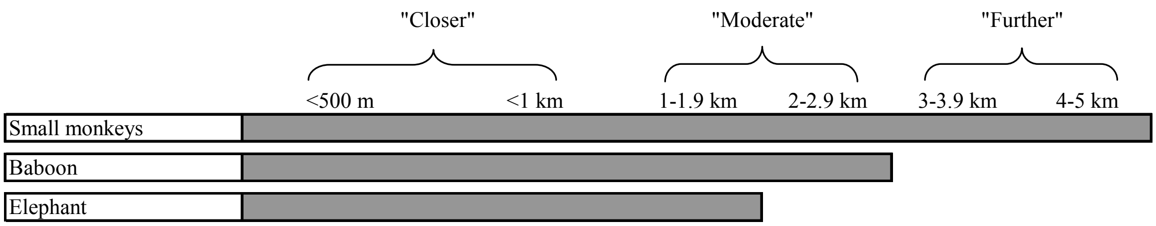

Figure 3-3. Distance of households to natural areas reporting problems with wild animals for leading crop raiders

Table 3-1. Benefits and problems from natural areas

Category		Wetlands useful Yes	Wetlands useful No	Forest useful Yes	Forest useful No	Perceived problems from forests/wetlands Yes	Perceived problems from forests/wetlands No	n
All Respondents		92%	8%	78%	22%	90%	10%	130
Ethnicity	Mtoro	94%	6%	78%	22%	90%	10%	72
	Mkiga	87%	13%	78%	22%	93%	7%	46
	Other	100%	0%	58%	42%	75%	25%	12
Respondent Gender	Male	92%	8%	78%	22%	95%	5%	63
	Female	93%	7%	75%	25%	85%	15%	67
Wealth Class	More Poor	90%	10%	76%	24%	93%	7%	58
	Less Poor	93%	7%	78%	22%	88%	12%	59
	Not Poor	100%	0%	69%	31%	85%	15%	13
Distance to KNP	Closer	90%	10%	70%	30%	92%	8%	61
	Moderate	91%	9%	76%	24%	91%	9%	33
	Further	97%	3%	86%	14%	86%	14%	36

Table 3-2. Top five benefits derived from wetlands (n=130).

Wetland Benefit	Proportion of Respondents (n=130)	Ethnicity	Respondent Gender	Wealth Class	Distance to KNP
Crafts	76%	0.791	0.687	0.646	0.144
Water	65%	0.917	0.943	0.112	0.167
Firewood	51%	0.830	0.078*	0.458	0.070*
Medicines	49%	0.641	0.722	0.256	0.011*
Ties	38%	0.366	0.927	0.117	0.333
Ecosystem services	32%	0.012*	0.001*	0.029*	0.729

*response and wetland benefit not independent ($p<0.1$)

Table 3-3. Top five benefits derived from forests (n=130).

Forest Benefit	Proportion of Respondents (n=130)	Ethnicity	Respondent Gender	Wealth Class	Distance to KNP
Firewood	69%	0.593	0.884	0.998	0.098*
Medicines	49%	0.145	0.722	0.936	0.034*
Poles	46%	0.796	0.037*	0.838	0.082*
Crafts	45%	0.122	0.753	0.535	0.018*
Water	38%	0.929	0.781	0.589	0.348
Ecosystem services	9%	0.003*	0.673	0.782	0.821

*response and forest benefit not independent ($p<0.1$)

Table 3-4. Respondents reported their primary sources for household water and energy use

Most water from:	(n = 130)	Most energy from:	(n = 130)
Bore Hole	33.1%	Natural forest*	30.0%
Wetland	20.8%	Planted firewood	30.0%
Improved well	17.7%	Resting/bush	20.8%
Local well	17.7%	Buying firewood	7.7%
Stream/spring (well)	5.4%	Swamp/forest combined**	5.4%
Forest	3.1%	Swamp/wetland	2.3%
Rain tank	0.8%	Buying charcoal	2.3%
Lake	0.8%	Tea cuttings	1.5%
Piped from town	0.8%		

*Natural forest refers to a forest fragment that is not purposefully planted
**Some swamps and forests are combined and difficult to distinguish between the two land cover types
***This value may be under-reported

Table 3-5. Perceived problems due to presence of forest (including KNP) and wetlands

Problem	Proportion of Respondents (n=130)	Ethnicity	Respondent Gender	Wealth Class	Distance to KNP
Animals	74%	0.429	0.323	0.588	0.702
Less available resources	33%	0.683	0.068*	0.774	0.164
Owner/government intervention	25%	0.022*	0.543	0.717	0.008*
Nuisances[◊]	63%	0.000*	0.023*	0.052*	0.944
Mosquitoes	58%	0.000*	0.138	0.047*	0.848
Flies	34%	0.000*	0.766	0.178	0.834
Ticks	18%	0.168	0.394	0.724	0.507
Ants	16%	0.003*	0.178	0.476	0.062*
None	10%	n/a	n/a	n/a	n/a

[◊]Although respondents identified this as a problem due to the presence of a forest and/or wetland; it is prevalent in the landscape - both in areas closer to and further from natural areas.

*response and distance to KNP boundary not independent (p<0.1)

Table 3-6. Most commonly reported problem animals identified by local landholders

Problem animals	Proportion of Respondents (n=130)	Ethnicity	Respondent Gender	Wealth Class	Distance to KNP
Olive Baboon (*Papio anubis*)	35.4%	0.611	0.049*	0.468	0.000*
Black and White Colobus (*Colobus guereza*)	25.0%	0.171	0.033*	0.494	0.388
African Elephant (*Loxodonta africana*)	32.3%	0.096*	0.155	0.956	0.000*
L'Hoesti Monkey (*Cercopithecus lhoesti*)	10.4%	0.001*	0.156	0.548	0.016*
Redtail Monkey (*Cercopithecus ascanius)*	64.6%	0.068*	0.852	0.917	0.169
Vervet Monkey (*Cercopithecus aethiops*)	51.0%	0.106*	0.085*	0.275	0.011*
Red Colobus (*Piliocolobus tephrosceles*)	18.8%	0.828	0.096*	0.570	0.062*
Birds	9.4%	0.976	0.068*	0.423	0.135
Bush Pig (*Potomochoerus porcus*)	8.3%	0.404	0.320	0.958	0.011*
Mongoose (*unknown sp.)*	38.5%	0.003*	0.542	0.391	0.024*
Serval Cat (*Felis serval*)	24.0%	0.003*	0.692	0.170	0.068*
Fox (unknown sp.)	5.2%	0.003*	0.361	0.705	0.006*

Note: When asked about crop raiding animals, most landholders only knew one word for the general term ‘monkey’ (*enkende* in Rutoro and Rukiga). Respondents identified the specific species after being shown pictures of primates endemic to the Kibale region.
*response and distance to KNP boundary not independent (p<0.1)

Table 3-7. Greatest problem animals reported by respondents and responses relative to distance from the park boundary

Problem	Proportion of Respondents (n=96)	n	χ^2 sig. (2-sided)	Distance to KNP Closer	Moderate	Further
Small monkeys	51.0%	49	0.000*	29.8%	50.0%	92.0%
Vervet	28.1%	27	0.000*	8.5%	29.2%	64.0%
Redtail	21.9%	21	0.709	21.3%	16.7%	28.0%
Black and white colobus	0.0%	0	n/a	0.0%	0.0%	0.0%
Red colobus	1.0%	1	n/a	0.0%	4.2%	0.0%
L'hoesti	0.0%	0	n/a	0.0%	0.0%	0.0%
Elephant	17.7%	17	0.000*	34.0%	4.2%	0.0%
Baboon	16.7%	16	0.007*	27.7%	12.5%	0.0%
Others	12.5%	12	n/a	6.4%	33.3%	4.0%

*response and distance to KNP boundary not independent ($p<0.1$)

Table 3-8. Perceptions of respondents whether or not there will be enough wetlands and forest nearby to meet their needs in the future

Response	Proportion of Respondents (n = 130) Enough wetland	Enough forest
Yes	27.7%	18.5%
No	56.2%	70.8%
Don't know	13.1%	4.6%
N/A	3.1%	6.2%

Table 3-9. Preferences for living closer or further from natural areas.

Category	Sub-Category	Closer	Further	n
All Respondents	All	66.9%	33.1%	130
Ethnicity	Mtoro	66.7%	33.3%	72
	Mkiga	65.2%	34.8%	46
	Other	75.0%	25.0%	12
Respondent Gender	Male	57.1%	42.9%	63
	Female	76.1%	23.9%	67
Wealth Class	More Poor	67.2%	32.8%	58
	Less Poor	66.1%	33.9%	59
	Not Poor	69.2%	30.8%	13
Distance to KNP	Closer	65.6%	34.4%	61
	Moderate	63.6%	36.4%	33
	Further	72.2%	27.8%	36

Note: the results are based on the respondent's own definition of "closer" and "further"

CHAPTER 4
THE LANDSCAPE SURROUNDING A PARK: RESPONSES BY HOUSEHOLDS TO RESOURCE AVAILABILITY IN RURAL COMMUNITIES

Introduction

Parks, protected areas, and reserves have become the cornerstones of most national strategies to conserve biological diversity in developed and developing countries (Howard et al. 2000; Wilkie et al. 2006). Arguably, exclusionary approaches to park management have become the most effective way to conserve habitats and protect biodiversity (Terborgh, 1999). However, parks cannot be viewed in isolation separate from the landscape where they are located (Robinson and Ginsberg, 2004) and often the effects of parks and reserves on local communities are not considered (Newmark et al. 1994). Since neighboring communities have restricted access to land and resources within many parks, they face two choices: use land and resources illegally or use unprotected lands outside the park. Deterred by fear of punitive measures against illegal activity (Struhsaker et al. 2004), many households turn to the unprotected resources. In addition, intensive land use and high population growth rates around many parks compound the issue. As population increases, pressure mounts on remaining unprotected wetlands and forest fragments to provide resources, but are also converted to other land uses to make way for agriculture or pasture (Banana and Gombya-Ssembajjwe, 1998). The dynamism of household resource needs impacts the landscape; changing the spatial extent of farmland, forest, wetland, and other land cover types.

Landscapes around parks in East and Southern Africa have become mosaics of natural and human-influenced patches. Fragmentation of tropical forests has been called the single greatest threat to global biological diversity (Turner and Corlett, 1996). Hill and Curran (2003) assert that fragmentation negatively impacts species composition due to a reduction in forest area and an isolation of the remaining forest fragments. In general, species richness and the number of rare species decline as fragment area decreases (Collinge, 1996; Laurance and Bierregard, 1997; Laurance et al. 1998), and mortality rates of trees in the Amazon are higher in smaller fragments (Laurance et al. 2002). As the wetland and forest fragments steadily decrease and edge effects penetrate further, the result is an impoverished interior (Gascon et al. 2000). As more forest is converted and not replanted, fragments become increasingly isolated. Therefore, the presence, absence, and quality of resources along with the presence of wild animals can impact livelihoods of the adjacent communities. As a result of forest resource exploitation, the conversion of lands to agriculture, such resource bases have become diminished and those that remain continue to be degraded. Edge habit increases and the ability of large animals to range widely without crossing agriculture diminishes (Newmark et al. 1994; Naughton-Treves et al. 1998), thereby further increasing human-wildlife encounters (Naughton-Treves et al. 1998). Although the amount of damage varies, farmers must constantly make decisions and create coping strategies to manage losses due to animal raids (Goldman, 1996; Naughton-Treves, 1998).

Land cover and land use and are inextricably linked. The adaptation to resource shortages and crop raiding is manifested through land cover change (i.e., more wetlands drained and converted to make way for agricultural lands or pasture). At a broader scale, analysis of satellite imagery has been used to examine these changes. Remote sensing is increasingly incorporated into land-use land-cover research that studies relationships between human societies and the biophysical environment to monitor changes over multiple dates and locales (Roughgarden et al. 1991; Turner, 2003; Kerr and Ostrovsky, 2003). While coarse, landscape level effects can be detected using satellite imagery, lower level analyses applied at the village, or household level may be best be suited to capture the decision making process behind land cover change (Evans and Moran, 2002). Despite improvements in land cover characterization through advancing satellite technology, land uses are poorly enumerated (Lambin et al. 2001). What is needed is an enhanced understanding of the causes of change. To do this, we must move beyond separate methodologies examining landscape change through remote sensing methods or social methods (e.g. census data, rapid appraisals, or household surveys). Research must span temporal and spatial scales. Combining household and landscape level data in a cohesive analysis can help explain both proximate and distal effects of environmental change (Geoghegan et al. 1998; Rindfuss et al. 2003).

Recent studies on conservation and local peoples, have called for a better understanding of local knowledge and perceptions of land and natural resources (Fairhead and Leach, 1996; Hulme and Murphree, 2001). However, previous research has focused on the effects of fragmentation on animal and tree species (Stouffer and Bierregaard 1995; Chapman and Chapman, 1999; Chapman and Lambert, 2000), and very few have related the resources that forest fragments provide to surrounding communities (Turner and Corlett, 1996) and the social implications of exclusionary approaches to park management (Southworth et al. in review).

Since most of the resources collected in the wetlands and forest fragments are only obtained locally, households must respond in some way to shortages, in turn shaping the landscape. Many livelihoods, and thus responses to shortages and problems, are determined through cultures and traditions, and economic, ecological environment, and demographic variables (Chambers and Conway, 1991). Therefore variables such as ethnicity, wealth, and gender as well as distance from the park may all be related to these responses (Stone, 1996; Hill, 1997; Byron and Arnold, 1999; Goebel et al. 2000; Kagoro-Rugunda, 2004). This paper examines the ways households have adapted to a degraded resource bases of the unprotected wetlands and forests and problems with wildlife in the landscape surrounding a park by addressing two critical questions: 1) How have the presence and extent of wetlands and forest fragments in the landscape surrounding Kibale National Park changed over time? And 2) How have households adapted to the declines in the wetlands and forest fragments in the landscape surrounding Kibale National Park? Understanding coping mechanisms of households about resource use and wildlife conflict for communities living near protected areas can greatly add to knowledge about and ability to address issues of conservation of forested areas.

Study Region

Physical Environment

Rural livelihoods in Sub-Saharan Africa are heavily reliant on the land and its resources (Scoones, 1998; Abalu and Hassan, 1998). In Uganda nearly 80% of the 27 million people have rural-based livelihoods and more than 80% of land is used for small-scale farming (Mukiibi, 2001). The population has increased 240% between 1960 and 2000, with a continued national population increase estimated to be 3% annually (US Census Bureau, 2002).

Kibale National Park (KNP) (Figure 4-1) in western Uganda, one of Uganda's 10 national parks, is illustrative of the agricultural expansion and intensification surrounding forested parks in Africa. Kibale is a medium-altitude tropical moist forest covering about 795 km^2 in western Uganda (Naughton-Treves, 1998). This transitional forest (between lowland rainforest and montane forest) is at an average elevation of 1110-1590m and is a remnant of a previously larger mid-altitude forest region (Struhsaker, 1997). Average annual rainfall for the region has ranged from 1543mm (average 1903-1999) to 1719mm (1990-2005) (Chapman et al. 2005).

The landscape outside the park has become a patchwork of small farms (most <5ha in size), tea estates in some areas, and a vast network of bottomland forest fragments and wetlands that serve as important resource bases for water and fuelwood, effectively isolating the park. These dendritic networks are typically found in valley bottoms and vary in size, shape, and resource availability. Forest fragments range in size in the communities on the east side of KNP from 0.5ha to approximately 150ha and from 0.5 ha to approximately 210ha in communities on the west side of KNP (Hartter, unpublished data). Wetlands vary in size on both sides of the park with Dura Swamp (~220 ha) and Magombe Swamp (~410 ha) being the largest on the west and east side respectively being the largest (Hartter unpublished data). Since nearly all of these natural areas occur in bottomland areas, many of the forests and wetlands are combined, effectively extending the resource bases and wildlife corridors. These areas generally represent wildlife habitats and corridors on the one hand as well as areas of resource extraction on the other.

Land scarcity has forced many farmers to farm to the edges of forests (Naughton-Treves, 1998). In addition, 43% of the land within a 5km periphery of the park is under cultivation or pasture (Hartter, unpublished data). Tea covers much of the landscape bordering the northwest portion of KNP. Tea producers range from large multinational companies with hundreds of hectares, to smaller individual holdings of less than one hectare (Mulley and Unruh 2004).

Social Environment

Rapid population growth, high population density, and heavy reliance on agriculture for income characterize the landscape surrounding KNP (Archabald and Naughton-Treves, 2001) and land pressure has steadily increased (NEMA, 2001). Agriculturalists in the area belong to two dominant ethnic groups: the Batoro (west side of KNP) and the Bakiga (east side of KNP). The Batoro, the largest ethnic group in the area (~52% of population) (Naughton-Treves, 1998), the Bakiga, and other ethnic groups have greatly increased population growth and demand for agricultural land and resources (NEMA, 1999). This region is one of the most densely populated areas on the African continent (Lepp and Holland 2006). Naughton-Treves (1998) reported that population around KNP more than tripled between 1959 and 1990. We estimate the current population estimated to be 262 individuals/km2 on the west side of the park and 335 individuals/km2 on the east side within 5km of the park boundary. Population growth rates in surrounding parishes range between 3 and 4% per year (NEMA, 1999). In the Kabarole District, where KNP lies, 95% of the population sustains their livelihoods through agricultural-based activities.

Methods

To examine and then link landscape- and household-level data we designated a study unit area both large enough and small enough to include measure land cover, biodiversity, and human activities. Through this linkage satellite remote sensing images and the on-the-ground measurements are tied operationally to the same area of land (Southworth et al. in review). These sampling units (named superpixels) comprising 9ha areas were centered on spatially randomly selected coordinates within 5km of the KNP boundary and within two areas (Figure 4-1) representing the two ethnic groups on the east and west sides of the park. In all, 95 superpixels were selected randomly. These 95 superpixels are found within 60 villages and include sample pool of 417 households (that is, households that have land contained within at least one of the superpixels). Research was conducted through a multiple-scale approach, combining remote sensing techniques and household surveys.

Remote Sensing

The first step was quantifying the change in extent, pattern, and quality of wetlands and forest fragments outside KNP over time using satellite image analysis. Landsat TM imagery was chosen because it offers the best combination of spatial, spectral, temporal and radiometric resolutions. Three dry-season images have been acquired: May 26, 1984, January 17, 1995, and

January 31, 2003 (path 132, row 060). The first image provides baseline data prior to park establishment, the second captures conditions at park establishment, and the third represents current conditions. During the 2004 and 2005 field seasons 180 training samples were collected and used to construct a supervised classification. The classified image was constructed using the original bands (minus thermal), texture of the original bands, and a Normalized Difference Vegetation Index (NDVI) layer. The final classification obtained an overall accuracy of 89.1% and an overall kappa statistic of 0.867 (Southworth et al. in review). Five classes were used in the classification: water; bare soil, field crops, pasture grass; forest, wetland – comprised of papyrus (*Cyperus papyrus* L.) and elephant grass (*Pennisetum purpureum*); and tea.

Landscape Fragmentation

Landscape metrics were used to identify trends in landscape heterogeneity over time. Size, shape, edge, and relative connectivity are important characteristics of forest fragments and wetlands to characterize the extent of landscape fragmentation. Fragstats 3.3 was used to calculate these metrics. Only forests greater than 0.5ha were considered in the land cover classification to conform to IFRI forest size standards (Hayes, 2006), to focus the analysis on natural forests and not small kitchen gardens and household woodlots.

Household Interviews

We examined the implications of that change on household livelihoods in communities surrounding KNP using household interviews. Between May and August 2006, 130 semi-structured household interviews were conducted. At each superpixel, respondents were chosen opportunistically, based on population weighting. The number of respondents for each study was proportional to the number of landholders containing land within the study area. Therefore, study areas with smaller landholders, and thus more landholders, had a higher sampling intensity. All interviews were conducted in English, or Rutoro or Rukiga using a local interpreter. At each respondent's house, GPS locations were obtained. GPS points were also taken at access points for the nearest forest fragment and wetland for each house. These GPS points were used to calculate the straight-line distance from the house to the nearest wetland and/or forest fragment. Distance from each house to the park boundary was calculated using the KNP boundary polygon.

Within the household-level analysis, data was broken into several groups to address key socioeconomic characteristics, respondent ethnicity, wealth class, and head of household gender and distance from park boundary. In the Bakiga and Batoro culture, the man is traditionally the head of the household. However, if a female respondent is widowed, divorced, or unmarried, then the head of household is a woman. Wealth and distance categories were determined using hierarchical cluster analysis. Wealth indicators used were number of animals (goats and cows), head of household gender, total amount of land held, and house category (based on a 5-category classification of house construction). The sample population was broken into three wealth classes – "more poor", "less poor", and "not poor". Three distance categories were used to relate the straight-line distance of the respondent's house to the KNP boundary – "closer" (<1000m), "moderate" (1001-3000m), and "further" (3001-5000m). We used $\chi 2$ test for independence to examine the relationship between response and distance to the park, ethnicity, wealth, and gender. We chose a significance value of 0.1 for household data analysis instead of 0.05 used in the land cover analysis to reduce type I errors given the use of recalled information.

Results

Remote Sensing

Since 1984, there was a net loss in forest and wetland while there was an increase in land under cultivation and tea ("other land cover") in the landscape surrounding KNP in both the east and west study areas (Tables 4-1 and 4-2). However, the east and west study areas differ in their land cover proportions. The east study area has a higher proportion of wetland and lower proportion of forested land than the west study area. On the east side of the park, there is no tea, and all “other” land consisted of cultivated land. Contrasting the two sides of the park, the west side has a lower total percentage (46%) of natural areas but also a higher proportion of “other” land cover (54%), which includes cultivated land and tea, in 2003 than the east side (56%, 44% respectively).

In the east side, nearly 26% of the land is converted from natural areas to cultivated land from 1984 to 1995 and 15% converted from 1995-2003 (Table 4-3). From 1984 to 1995 and 1995 to 2003, only 29% and 27% of the land remained as natural areas respectively. The west study area is less intensively farmed and is interspersed with large tea plantations. Comparatively less of the land remains under continuous cultivation and more of the land remains under natural areas. From 1984 to 1995, 18% of the natural areas are converted to crops or tea. From 1995 to 2003, more land remains under cultivation and tea, while a further 25% of the natural areas were converted to crops and tea. Each year both the west and the east side continue to lose more forest and less forest remains as forest at each time step, while land under crops not only increases each time step, but also the amount that stays under cultivation increases. Wetland areas in both the east and the west continue to be converted, but interestingly only in the east side is there more land that remains wetland from 1995 to 2003 than from 1984-1995.

Landscape Fragmentation

Forest and wetlands loss is evident (Tables 4-1 and 4-2), and as such the landscape surrounding the park has become increasingly fragmented. In the east and west study areas, the number of patches, edge density, and distance to the nearest same-class patch increased, while the mean patch size has decreased for natural areas from 1984 to 2003 (Tables 4-1 and 4-2). We found that connectivity decreased over time for the forest and wetland areas. Conversely, the land under tea and crops (shown as “other land cover”) continues to consolidate over time (i.e., connectivity increases). The number of patches decreases while the mean patch size increases.

Forest and wetland loss varied over time. Two measures of the change and fragment isolation within the agricultural matrix are mean patch size and the distance to the nearest patch (Table 4-4). Mean patch size in both the east and west study areas was not significantly different for forests ($p>0.05$) for the 1984-1995 time step. However, the mean patch size was significantly different for the 1995-2003 time step for the forest class for both study areas ($p<0.05$). Distance to the nearest patch was not significantly different in the first time step, but was for the second time step.

In the east, the mean patch size and distance to the nearest patch in wetland areas were significantly different in the east ($p<0.05$) for both time steps. In the east study area, distance to the nearest patch and mean patch area were not significantly different between 1984 and 1995, but was between 1995 and 2003. Conversely, only distance to the nearest patch was significantly different ($p<0.05$) in the west study area.

Household Interviews

At the household level, most respondents also report changes in the wetlands (88%) and forest (66%) within the last 10 years (n=130) (Table 4-5). Some of the changes that are reported are lower water level in the wetlands, a decrease in overall size, fewer trees in the forests, and increased use from more people (Table 4-6). Not only is tree density lower in the forest fragments, but also nearly 72% (n=130) farmers report there are tree species sought specifically for building poles, saw logs, firewood, drums, medicines, or other uses that are presently unavailable in these areas.

Forty-five percent and forty-two percent of respondents said it has become more difficult to obtain resources in the wetlands and forest fragments respectively (n=130). Most people cited fewer resources as the reason for difficulty (over 80%), while others reported restricted access because of the government or other landholders, and more people competing for resources (Table 4-7).

Farmers have recognized the change in forest and wetland extent and the wetland and report that resources have become more difficult to obtain. These changes in resource availability worry local farmers (Table 4-8). The availability of firewood is an important concern for all classes (85%, n=130). However, most believe that there will not be enough forest (71%) and wetland (56%) to meet their future needs. Despite the changes in resource availability, 43% of landholders said there are fewer problems with crop raiding compared to the past.

Though, the availability of firewood is a concern for most respondents, there is no significant relationship between response and ethnicity, wealth, head of household gender, or distance to the park ($p>0.1$) (Table 4-9). These results suggest that firewood is a concern throughout the landscape, independent of demographic. Overall, we found that ethnicity and head of household gender were not related to response, but wealth and distance were related ($p<0.1$) to some responses. Wealth class was significantly related to perception of forest resources for the future ($p<0.1$). Those who were more poor (69%, n=58) tended to perceive future shortages than those who were not poor (46%, n=13). We also found that distance was related to perceptions of future forest resources ($p<0.1$). More respondents closer to the park boundary (77%, n=61) felt there would not be enough forest resources in the future than those further from the park (58%, n=36). Those closer to the park boundary (36%, n=61) felt crop raiding has become worse than those further (17%, n=36).

The land cover analysis and results from the household survey indicate resources are becoming scarcer and that they are unsure about resources in the future. Since households depend on these resources, they adapt to shortages in various ways (Table 4-10). The five main responses were: planting trees for fuelwood, building poles, timber, and/or sustenance (70%, n=130); increasing the travel time to the forest or wetland (n=36%, n=130) and also increasing the amount of time it takes to gather all the firewood, medicines, etc. needed once at the site (n=68%, n=130); going to a different forest or wetland for at least some of the households' needs (n=34%); and to supplement the energy needs by purchasing some firewood or charcoal (n=42%).

A higher proportion of Bakiga respondents plant trees (78%, n=46) than Batoro respondents (65%, n=72) ($p<0.1$) (Table 4-11). Results suggest that a higher proportion of Batoro will go to a different resource base to obtain firewood (42%, n=72) and buy at least some firewood and/or charcoal and/or trees for energy (56%) than Bakiga respondents (20% each) ($p<0.1$). We also found that of these responses, distance was only significantly related to going to a different place to obtain firewood. More landholders living closer to the park boundary (41%, n=61) looked for a new resource source than those further (22%, n=36). Overall, wealth and head of household gender were not significantly related to responses to resource shortages.

Landholders are particularly susceptible to wild animals, since wild animals emanate from wetlands and forests to raid farmers' fields and attack their livestock. Nearly 74% (n=130) of respondents said that they have problems with wild animals (Table 4-12). Of those that perceive problems from these areas, 78% (n=96) reported that they take action in some way to mitigate the problems of crop and livestock raiding.

In response to crop raiding, landholders reported five methods to mitigate problems with wildlife (Table 4-13). Of those that work to control or mitigate the problems of crop and animal raiding, the most common response is guarding fields with family members, day laborers, or dogs (91%, n=75). A smaller number of households choose not to plant crops that seem to be especially palatable to wildlife (e.g. maize, bananas) in fields closest to the forest fragments and wetlands (49%). The particular crop varies based on site-specific conditions (i.e., what species visit the farm, presence/absence of a forest or swamp, and other factors). Some people stop growing crops in a field, stop renting land, or move away from an area because the crop raiding has been such a hardship for them (29%, n=75). The least common response is to continue farming, but stopping certain crops (5%, n=75).

Household responses to crop raiding varied by ethnicity (Table 4-14). A higher proportion of Bakiga guard (100%, n=33) than the Batoro respondents (75%, n=40) ($p<0.1$). However, a higher proportion of Batoro stop growing and/or living in an area (40%) or do not plant certain field crops in areas closest to wetlands and forests (63%) because of crop raiding than the Bakiga respondents (18% and 33% respectively) ($p<0.1$).

Responses to crop and animal raiding differed by wealth class (Table 4-14). Results suggest that a higher proportion of those that are in the ‘more poor’ class guarded their fields (94%, n=35) than those that are ‘not poor’ (38%, n=8) ($p<0.1$). Overall, distance from the park boundary and head of household gender were not related to response ($p>0.1$), suggested that landholders throughout the surrounding landscape had to develop measures to mitigate crop raiding. Similarly, both male and female-headed households had to derive a single or mixture of methods.

Discussion

Our results show the landscape surrounding KNP has become increasingly fragmented since 1984. Onderdonk and Chapman (2000) reported that the process of forest isolation has been ongoing since at least 1959. We found the number and size of forest and wetland patches continues to decline while land under cultivation has increased. In addition, as larger forests are broken into smaller fragments, access to these smaller and more numerous fragments increases. In turn, more fragments are used. These new fragments have become more isolated and edge density increases as they are used. In this process, larger fragments become smaller and smaller as the continuous landscape is broken up. This process of increased fragmentation and opening up the interior of remaining fragments leads to degradation, more open/disturbed forest and towards secondary vegetation (Schelhas and Greenberg, 1996). Increased landscape fragmentation has cascading effects. A decrease in size of forest can be detrimental to tree species diversity and the presence of rare species (Laurance et al. 2000; Hill and Curran, 2003), which could be key timber trees or medicinal plants. The increase in amount and density of edge makes smaller fragments more vulnerable to edge effects (Forman, 1995; Gascon et al. 2000). Gascon et al. (2000) report that fragments less than 5000 ha in size are extremely vulnerable, which is especially worrisome in the Kibale landscape since we found the largest forest fragment to be no more than 210 ha.

The impacts of landscape fragmentation are not limited to vegetation. The micro-climate can be altered, changing wind patterns, humidity, and solar radiation that are important for organisms (Ranta et al. 1998). The loss of habitat can also cause local declines or extinctions of species (Chapman et al. 2006). These conditions lead to a negative feedback for households that depend on forest and wetland resources. The increasing population, intensive land use practices lead to further encroachment into these areas as large converted tracts or as small annual increments of expansion as new ribbons of cultivated land continues. Scherr (2000) asserts that often no concern is shown regarding resource degradation because they do not consider it a serious threat. However, our results show that people in the area do recognize changes, report increased hardship in obtaining resources, and are worried about shortages in the future. By converting the forests and wetlands to other land uses, households forego long term resource security for short term survival (Hyden, 1998). Our results show though that the majority of the people are responding especially to fuelwood shortages by planting trees.

Though the Bakiga were found to respond more than Batoro respondents to shortages by planting trees, this analysis does not account for the amount or type of trees planted per household and the geographic characteristics.   Generally, the Bakiga were poorer, held less land, and tended to farm intensively. Conversely, Batoro respondents were wealthier and therefore had more land and the financial means to grow more trees. In addition, there is also a higher proportion of land as forest and wetland on the east than on the west, but nearly 16% of the land on the east side of the park is protected as the Bigodi wetlands (KAFRED). Since many forms of harvesting are prohibited within this wetland sanctuary, the Bakiga may be inclined to grow trees.

Both the Batoro and Bakiga recognize the shortages and changes in the wetland and forest resources. However, the Bakiga are also thought to use forests more intensively than the Batoro (Chapman et al. 2003), but this may not be the most accurate portrayal. Our analysis showed that more Batoro have had to go to a different place to get firewood and buy at least some firewood, charcoal, and/or trees. This would suggest that firewood resources seem somewhat scarcer than on the east side. Future research should address the differences in forest and wetland consumptive practices from the Batoro and Bakiga.

We also found that distance to the park did not strongly correlate to response to resource shortage, which suggests that shortages are not limited one area or the other or closer or further from the park. In addition, these problems impact all wealth classes and households with male and female heads. Households must adapt their livelihood strategies to provide these resources, regardless of where they live or financial status.

In addition to the common responses discussed in this paper, households also respond to resource shortages in other ways. First, many households substitute one species for another. Since many of the endemic hardwoods have been harvested from the forest fragments, households use other planted species such as *Eucalyptus* spp. The once-common *ebigoya* (vines that are used to tie building poles together) are substituted for dried skin from a banana plant. Second, some households are buying or renting more land, if they have the financial means that is closer or further from wetlands and forests depending on household needs and concerns. The new land is planted differently or used to grow trees. Third, households also convert more land, especially to grow trees. Fourth, some supplement their resource needs by going illegally to KNP or other community forests. Illegal use patterns are difficult to track because respondents are fearful of punitive measures. More research is needed to address and quantify the harvesting practices. Many people perceive hardships in obtaining enough resources and are worried about the future, but still many households cannot do anything. They do not have enough land to grow trees, live far from wetlands and forests to gather resources there, or do not have the financial means to secure their resources for the future. More research is needed understanding the factors leading to and adoption of the complex mix of coping mechanisms.

We have shown that connectivity of forest fragments and wetlands has decreased since 1984, while the mean distance to the nearest forest or wetland has increased. Predator-prey relationships, habitat, and migration corridors have been undoubtedly impacted (Laurance et al. 2002). Increased edge habitat and the degradation of habitat, breeding grounds, and nutrition is detrimental to primates in KNP (Onderdonk and Chapman, 2000). The reduction in connectivity between natural areas forces primates to adapt to reduced home ranges (Baranga, 2004) or they must travel within the agricultural matrix. Those farms neighboring forests and wetlands are vulnerable to attacks on their small-stock and crop raiding. The increased fragmentation of the landscape causes further detriment because the limited natural areas that act as corridors through which common crop and animal raiding species such as the vervet monkey (*Cercopithecus aethiops*), the redtail monkey (*Cercopithecus ascanius*), olive baboon (*Papio anubis*), and elephants (*Loxodonta africana)* travel. Those fragments that remain channel the primates and especially elephants through agricultural lands because of the narrow passages connecting remaining wetlands and forest.

Our results show a departure to research done a decade earlier. Hill (1997) and Naughton-Treves et al. (1998) assert that as the amount of forest edge continues to grow, human-wildlife encounters will increase. Such studies tended to focus on a single locale or geographic area (i.e., those villages closest to the park boundary) where crop raiding has historically been worst and tensions with the neighboring park are highest (Mkanda and Munthali, 1994; de Boer and Baquete, 1998). We found that less than one-third respondents reported that crop raiding was worse than 10 years ago. More landholders reported that problems with crop raiding had actually become better (43%) or at least stayed the same (10%). Similarly Kagoro-Rugunda (2004) showed that crop damage increases with decreasing population density outside Lake Mburo National Park in Uganda. Landscape fragmentation, intensive land use, and a growing population could have been a “good” thing in some ways. Many say that they cut forests because they believe that if they reduce the forests and wetlands, the wild animals will be forced to retreat within the boundaries of KNP or other fragments. The increase in population in the area has also led to increased settlement. As Naughton-Treves (1997) and Hill (1997) found, many farmers still say the best defense against crop raiding is to have their farm buffered by at least another farmer closer to the forest or wetland.

Ethnicity is important because it is a key factor because it determines household location. In addition, ethnicity is important in determining the neighbors that surround the farm. A higher proportion of Bakiga respondents were found to guard their fields than Batoro. Wealth is also important in a household's ability to cope with animal raiding and the poorest households are the most vulnerable (Naughton et al. 1999). Bakiga respondents were generally poorer and have smaller plots of land and were more intensive land users. Large landholdings, grazing lands adjacent to the natural areas, and crops planted far from these areas and near the house are characteristic of the "not poor" wealth class, who also happen to be Batoro. Households that are wealthier tend to have more land. Not only do they cultivate less land per total amount of land owned, leaving the lands closest to forest and wetland as pasture, they can also plant their subsistence crops near the house where they can be closely monitored.

Naughton-Treves et al. (1998) recommended that highly palatable crops should not be planted close to the forest edge in order to ameliorate crop losses. Wealthy landholders have enough land so they can buffer these crops with those that are less palatable such as tea or they can grow trees. This recommendation is unrealistic for two reasons. First, most farm sizes are less than 5 ha in size (mean=3.8 ha) in the Kibale landscape. Poorer landholders have less flexibility and ability to choose which land they would like and which land to farm. More land is allocated to crops and less to pasture or a woodlot. We also found that given the choice most respondents (67%, n=130) would prefer to live closer rather than further from the forests and wetlands (Hartter unpublished data). Second, some have planted unpalatable species such as tea, coffee, tobacco which serendipitously have only provided limited relief from crop raiding. Other field crops such as soybeans and sunflowers have been attempted, but with limited success (Naughton-Treves and Salafsky 2004). While Chiyo et al. (2005) report elephants do not consume Irish potatoes and groundnuts, these crops have been raided by other species (Hartter unpublished data). Though tobacco is not raided, but it proves ineffective in deterring animals because cultivated tobacco is not densely planted, only planted in small amounts, and is easy for monkeys and baboons to travel through (Hartter, pers. obs.). Many people neighboring tea plantations and even those living within the tea plantation compounds also complain of elephants. It is uncommon for the elephants to travel through the tea, but they do frequently use the tea companies' foot paths and roads for travel to nearby fields (E. Ijaku, Estate Manager. James Finlays (Uganda) LTD. Interview conducted July 14, 2006).

Though it may be the most effective measure, guarding also has arguably the most dramatic social impacts because of the indirect costs of crop raiding: labor investment, lost opportunities, and increased exposure to malaria vectors (Tchamba, 1996; Hill, 2004; Naughton-Treves et al. 2005; Linkie et al. 2007). Increased time guarding means women must have to spend more time in the fields and away from household duties. Children may be pulled out of school to care for younger brothers and sisters or to cook at home or to collect resources while the mother is away. Other children are pulled out of school to guard their family's fields. Although fields are guarded year round, crop raids by primates is especially bad during the harvest times, and children can spend three days or more per week in the fields instead of in school. The more well-off households can hire workers to work and guard their fields or may use dogs, while their children stay in school. Households also cope with crop and animal raiding in other ways. Many households sell their livestock to buy food lost from crop raiding. Others will sell or buy land because of its susceptibility to crop raiding. An unknown number of kill wildlife.

Farming at the edge or near forests and wetlands is difficult for local farmers (Figure 4-2). Edge management is important in order to reduce the attractiveness and food availability for would-be raiders. Many practitioners have preferred a hard boundary, especially in the case of separating the park and its neighbors (Hayes, 2006). KNP has tested a number of different strategies, such as digging a trench along with planting Mauritius thorn (*Caesalpinia decapetala*) along a portion of the boundary on the east side of the park in 2001 (Chhetri et al. 2003). Other methods such as electric fencing has been used in protecting small farming areas in Kenya and Zimbabwe (Kassilly, 2002; Osborn and Parker, 2002), but materials, installation, and maintenance for large-scale applications is impractical and unaffordable for most rural communities near KNP. Another typical tactic has been for scare-shooting by wildlife rangers, but this has little deterrence upon crop raiders (Osborn and Parker 2002). In most cases, the animals are gone from the field by the time the farmers submit a complaint via the LC1 (village chairperson) or in person to park guards.

Collective management has been recommended as one of the most important mechanisms to address crop raiding and resource shortages (Scherr, 2000; Chiyo et al. 2005). Such actions would include crop selection, planting, weeding, or defensive strategies such as guarding. In the densely populated landscape outside the park, effectively combating crop raiding must be done cooperatively. Prevention measures will be foiled if one or more farmers plants maize at the edge of the wetland, while others plant buffer crops or trees. However, such strategies have cultural issues.

In this area, it is uncommon for the Batoro to manage or farm collectively, but Bakiga typically engage in collective farming arrangements (Hartter, pers. obs.). Group organization for guarding is done rarely in this area. When done so, only the Bakiga will participate (Hartter unpublished data). Others have called for building local management institutions to balance conservation objectives (i.e., KNP) and the needs of local farmers (Infield and Namara, 2001; Hill, 2004). However, most respondents believed the responsibility of responding to crop raiding fell on KNP (52%) and on the local government (30%) (Hartter, unpublished data). Around KNP, no one perfect solution will exist. Instead a combination of measures is appropriate; one that incorporates the dynamic interactions of social and natural systems (Berkes, 2004), but also ones that do not rely on fads or solely on anecdotal evidence (Salafsky et al. 2002). For the estimated up to one billion people who generate much of their livelihoods from forests (Byron and Arnold, 1999), more research is therefore needed to address the efficacy of a series of direct and indirect mechanisms to help cope with wildlife and resource shortage problems outside KNP and other protected areas.

Overall, the superpixel was effective in identifying a geographic random sampling of households and integrating multiple scales effectively for study of KNP and its surrounding landscape. While landscape level approaches may show more coarse scale trends, household land uses and adaptations over time are useful to verify that this change is happening. Results from the land cover analysis show a net decrease in forests and wetland area outside KNP while land under cultivation has increased. These results coincide with reported trends at the household interviews. Superpixels can reduce costs because they can provide an accurate representation of landscape change and temporal trends, but more importantly can be used to understand household-level trends. Using such techniques in a linked methodology can lead to an improved examination and understanding of land change processes and to better informed management decisions (Vogt et al. 2006) and could be a useful monitoring tool for protected area managers.

However, while the superpixel methodology has been shown to be useful in dense agriculturally-dependent settlements outside a forested park, these results should be compared to communities outside savannah parks, where raiding by large, migratory animals is more common. The superpixel methodology was appropriate within a landscape where landholdings are relatively small. This methodology could be tested in Latin America where landholdings are much larger or in pastoral landscapes where communal land tenure is common.

Conclusion

Although protected areas have become the primary mechanism for biodiversity conservation, their establishment can have long-term impacts on land use, land cover, and livelihoods of people living near them. Since land use and resource access within Kibale National Park's boundaries are prohibited, park neighbors turn to the forest fragments and wetlands to sustain their livelihoods. These areas serve as important resource bases for local people as well as biodiversity habitats that harbor many wild plant and animal species. They are also problematic for local farmers, since crop raids by primates and elephants emanate from these natural fragments. While the boundaries of Kibale National Park have remained intact over time (Southworth et al. in review), there has been extensive conversion of wetlands and forest fragments which diminishes the supply of resources. Households have coped with resource shortages and crop raiding in many ways. Most people plant trees or spend longer to gather enough resources. Guarding was cited most as a response to crop raiding, but avoiding planting crops nearest the forest and wetlands was also a common strategy. Our results suggest that wealth, ethnicity, and distance from park are important factors in determining response to these issues, but head of household gender was not. While there is no perfect solution to effectively mitigate crop raiding animals and to supply resources, we found that engaging in a mixture of activities is the needed. Finally, the superpixel methodology was useful in linking landscape- and household-level scales to examine the impacts of park establishment. More research is needed however to test this methodology in areas with dispersed settlements and larger landholdings or savannah landscapes.

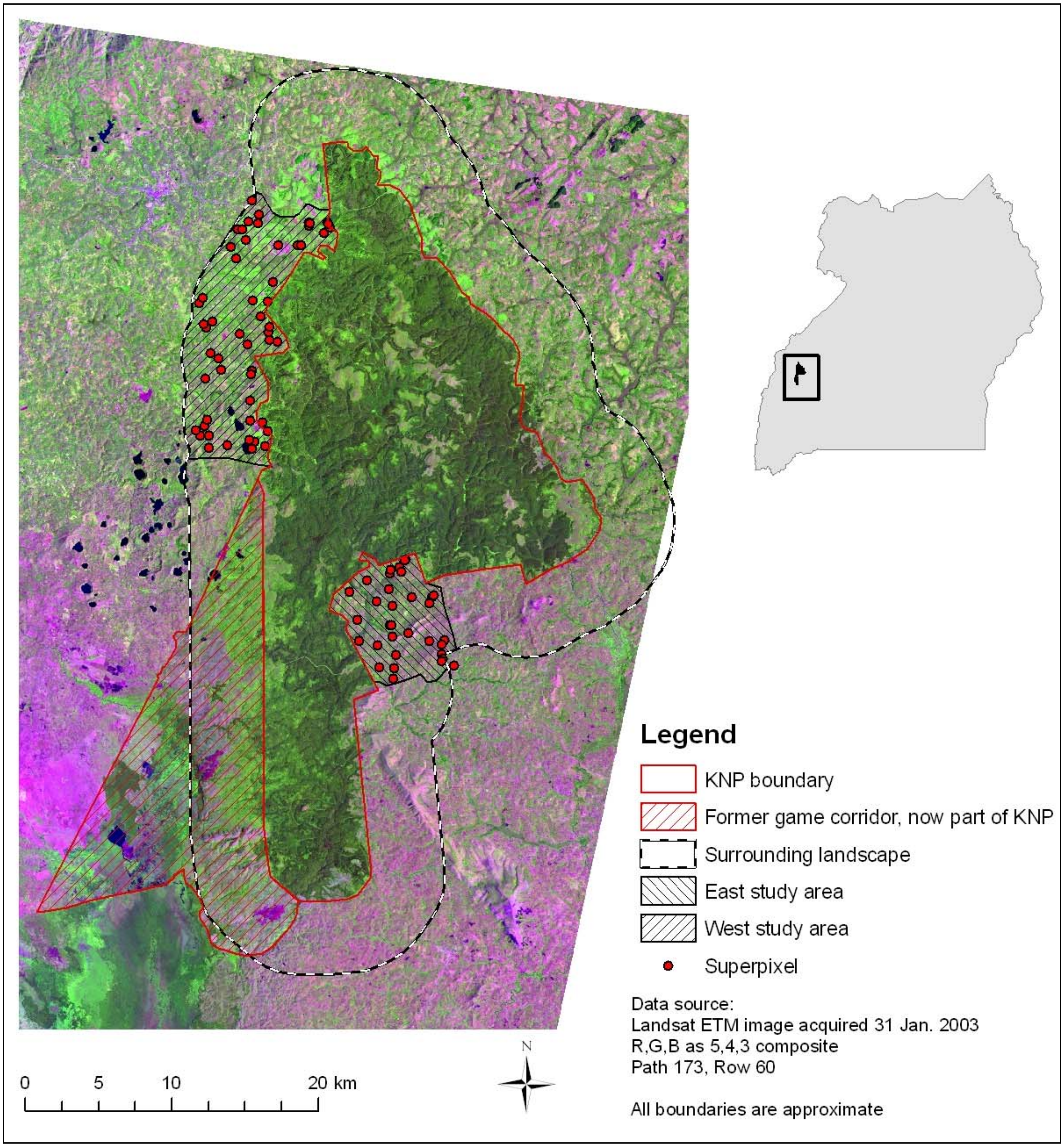

Figure 4-1. Kibale National Park and surrounding landscape in western Uganda. (Note: while officially KNP now includes a “game corridor” that connects the southern portion of KNP to Queen Elizabeth National Park, this corridor was formally gazetted as part of KNP in 1993. Before that time, it was mixed agricultural land. Therefore, it was not classified as park in this analysis. Since 1993, the total park area is 795km^2, but only 561km^2 of parkland (excluding the game corridor) is covered in this analysis.

Figure 4-2. Farming along the forest edge. The KNP boundary is clearly demarcated by *Eucalyptus* trees, separating forest (left) and fields of maize (right) (Photo by J. Hartter)

Table 4-1. Land cover proportions and class-level metrics outside KNP in the East Study Area (based on 5-class land cover classification from 2003 Landsat image)

Year	Land Cover	Proportion of Total Land Area	No. Patches	Edge Density (m/ha)	Mean Patch Size (ha)	Connectivity Є (0-100)	Dist. to Nearest Patch Edge (m)
1984	forest	32.0%	165	52.4	9.4	0.244	97.5
1995	forest	28.3%	211	57.5	6.3	0.230	91.1
2003	forest	21.4%	207	35.5	4.3	0.000	108.7
1984	wetland	38.4%	731	108.0	2.8	0.136	69.9
1995	wetland	26.1%	884	66.4	1.4	0.058	77.5
2003	wetland	34.0%	761	86.9	2.2	0.000	72.5
1984	other land cover	29.6%	949	83.7	1.8	0.095	71.1
1995	other land cover	45.6%	729	99.1	3.8	0.149	66.2
2003	other land cover	44.5%	575	99.4	4.8	0.000	65.8

Note: Connectivity: range 0 to 100, expressed as a percent) Measurement of connections between patches of the corresponding patch type divided by the number of possible connections. A value of 0 is when either the class consists of a single patch or none of the patches of the focal class are connected; and a value of 100 indicates that every patch of the class is connected. Here, we used threshold=60m.

Table 4-2. Land cover proportions and class-level metrics outside KNP in the West Study Area (based on 5-class land cover classification from 2003 Landsat image)

Year	Land Cover	Proportion of Total Land Area	No. Patches	Edge Density (m/ha)	Mean Patch Size (ha)	Connectivity Є (0-100)	Dist. to Nearest Patch Edge (m)
1984	forest	42.8%	284	61.1	15.0	0.284	79.8
1995	forest	52.0%	118	71.3	44.5	0.826	74.4
2003	forest	30.5%	395	41.2	7.2	0.000	95.3
1984	wetland	21.4%	1890	56.3	1.2	0.037	75.8
1995	wetland	9.4%	1646	29.6	0.6	0.027	92.2
2003	wetland	15.4%	1871	39.6	0.7	0.000	85.9
1984	other land cover	35.8%	1499	62.9	2.6	0.057	73.8
1995	other land cover	38.6%	1433	61.6	2.8	0.054	72.9
2003	other land cover	54.1%	861	63.1	7.1	0.000	68.8

Table 4-3. Land cover change detection for the east and west study areas

	East SA				West SA			
	1984-1995		1995-2003		1984-1995		1995-2003	
Loss of Natural Area	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest → Crops	432	8.3	430	8.3	713	6.9	1503	14.6
Forest → Tea	n/a	n/a	n/a	n/a	455	4.4	743	7.2
Wetland → Crops	961	18.6	338	6.5	702	6.8	277	2.7
Wetland → Tea	n/a	n/a	n/a	n/a	59	0.6	40	0.4
Addition of Natural Area								
Crops → Forest	190	3.7	240.48	4.6	1067	10.36	422	4.1
Tea → Forest	n/a	n/a	n/a	n/a	276	2.7	143	1.4
Crops → Wetland	345	6.7	632.34	12.2	261	2.5	374	3.6
No Change								
Forest → Forest	843	16.3	625	12.1	3020	29.3	2310	22.5
Wetland → Wetland	649	12.6	774	15.0	454	4.4	398	3.9
Crops → Crops	971	18.8	1474	28.5	1425	13.8	1821	17.7
Tea → Tea	n/a	n/a	n/a	n/a	132	1.3	449	4.4

Table 4-4. Patch-level statistics for east and west study areas

		East Study Area Mann-Whitney U Test Asymp. Sig. (2-tailed)		West Study Area Mann-Whitney U Test Asymp. Sig. (2-tailed)	
Date	Land Cover	Mean Patch Area	Dist. to Nearest Patch	Mean Patch Area	Dist. to Nearest Patch
1984-1995	Forest	0.359	0.175	0.242	0.092
1984-1995	Wetland	0.000*	0.000*	0.545	0.000*
1984-1995	Other land cover	0.000*	0.025*	0.677	0.259
1995-2003	Forest	0.036*	0.000*	0.008*	0.000*
1995-2003	Wetland	0.000*	0.000*	0.000*	0.000*
1995-2003	Other land cover	0.000*	0.000*	0.060	0.000*
1984-2003	Forest	0.001*	0.005*	0.059	0.000*
1984-2003	Wetland	0.000*	0.375	0.000*	0.000*
1984-2003	Other land cover	0.000*	0.000*	0.021*	0.000*

*significant at 0.05 level

Table 4-5. Respondents' perception of change in resource bases in the last 10 years

Perceived changes in resource bases (n = 130)	Wetland	Forest
Yes	87.7%	66.2%
No	7.7%	23.8%
n/a	4.6%	10.0%

Table 4-6. Reported changes in forest fragments and wetlands

Reported changes in forest (n = 86)	Proportion	Reported changes in wetland (n = 114)	Proportion
More people	73.3%	Lower water level	57.7%
Smaller size	80.2%	More people	53.1%
Fewer trees	84.9%	Smaller size	52.3%
Fewer tree spp.	71.5%		

Table 4-7. Reported reasons for difficulty in obtaining resources in wetlands and forest fragments

	Wetland	Forest
Reason for the difficulty	n = 59	n = 55
Less resources	89.8%	83.6%
Stopped by owner	13.6%	16.4%
Stopped by government	1.7%	3.6%
More people	1.7%	3.6%
Must travel further	3.4%	0%

Table 4-8. Resource and wild animal concerns among to all respondents

	Response (n = 130)			
Question	Yes	No	Don't know	N/A
Firewood a concern?	85.4%	14.6%	0%	0%
Enough forest to meet future needs?	18.5%	70.8%	4.6%	6.2%
Enough wetland to meet future needs?	27.7%	56.2%	13.1%	3.1%
Crop/livestock raiding compared to past?	30.8%	43.1%	10.0%	16.2%

Table 4-9. Relationship of response and ethnicity, wealth, head of household gender, and distance to the park boundary

	Relationship of Response and Variable			
Question	Ethnicity	Wealth	Head of HH Gender	Distance to KNP
Firewood a concern?	0.362	0.587	0.206	0.345
Enough forest to meet future needs?	0.957	0.030*	0.113	0.009*
Enough wetland to meet future needs?	0.312	0.730	0.364	0.600
Crop/livestock raiding compared to past?	0.480	0.402	0.455	0.098*

*significant at 0.1 level

Table 4-10. Household responses to resource shortages among all respondents. (Note: households can partake in a variety of combinations of responses, choosing one, several, or none of these responses to shortages)

Reported Responses to resource shortages	Proportion (n=130)
Plant trees?*	70.0%
Increase time to gather resources	67.7%
Buy some fuelwood/charcoal/trees*	41.5%
Increase travel time to resources	35.4%
Go to different place to get fuelwood*	33.8%

Table 4-11. Relationship of response to resource shortage and ethnicity, wealth, head of household gender, and distance to the park boundary

	Relationship of Response and Variable			
Question	Ethnicity	Wealth	Head of HH Gender	Distance to KNP
Plant trees	0.014*	0.537	0.852	0.409
Increase time to gather resources	0.305	0.478	0.983	0.744
Buy some fuelwood/charcoal/trees	0.013*	0.429	0.255	0.442
Increase travel time to resources	0.115	0.225	0.195	0.262
Go to different place to get fuelwood	0.039*	0.677	0.814	0.168

*significant at 0.1 level

Table 4-12. Questions posed to households regarding problems of and response to crop and/or livestock raiding

Question	Yes	Proportion
Do you and/or your household have problems with wild animals?	73.8%	96 of 130 respondents
do you and/or your household do anything about the wild animals?	78.1%	75 of 96 respondents

Table 4-13. Household responses to crop raiding. (Note: an unknown number of offending animals are killed by landholders)

Reported response to crop raiding	Proportion (n=75)
Guard	90.7%
Certain crops not planted close to natural areas	49.3%
Stopped growing/living in certain area	29.3%
Stopped growing certain crops	5.3%

Table 4-14. Household responses to resource shortages among male and female heads of household

	Relationship of Response and Variable			
Question	Ethnicity	Wealth	Head of HH Gender	Distance to KNP
Guard	0.004*	0.000*	0.964	0.693
Certain crops not planted close to natural areas	0.066*	0.193	0.308	0.250
Stopped growing/living in certain area	0.064*	0.542	0.471	0.249
Stopped growing certain crops	0.640	0.058*	0.325	0.342

*significant at 0.1 level

CHAPTER 5
IMPOSING WILDERNESS? THE IMPACTS OF A FOREST PARK

Introduction

In the century and a quarter since the formation of Yellowstone NP, the world's first national park, the number of national parks, reserves, and other protected areas around the world has grown substantially. There are now over 100,000 parks and protected areas around the world, covering well over 10% earth's land area[4] (Hayes, 2006). Although protected areas have become the most recognizable mechanism for terrestrial conservation, their establishment and management certainly are not without criticism. As the park system worldwide not only has grown, but also (arguably) matured, the "park concept" has evolved to encompass multiple meanings and interpretations. The World Conservation Union defines a protected area as "an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (as cited in Murphree, 2002)." Among other features, this and similar statements illustrate that preservation of biological diversity has supplanted wilderness preservation as the ultimate objective and justification of conservation oriented parks.

Fortress conservation, or more colloquially 'fines and fences', is characterized by strict exclusion of humans, the prevention of consumptive use, and minimization of other forms of human impact (Hulme and Murphree, 2001) and originally having no linkage with livelihoods or development goals (Salafsky and Wollenberg, 2000). People are meant to use resources outside of the park, and plants and animals are meant to stay in the park. As such, wildlife enthusiasts and policy-makers in East Africa believed that national parks would create a sand harmonious

[4] We use the term "park" to refer to all types of protected areas. The World Conservation Union (IUCN) prescribes 6 categories.

balance between man and wildlife without disturbing the region's social and economic development (Ofcansky, 2002). However, with the erection of boundaries, relations of neighboring communities often soured and entailed conflict (Western, 1994; Brockington, 2002). Compliance by the local population was based on a fear of punitive measures (Wells and Brandon, 1992).

The idea of fortress conservation has sparked many debates over the past few decades, especially since the rise of other conservation narratives (Hulme and Murphree, 2002; Ferraro and Kiss, 2002). Early parks in Sub-Saharan Africa (SSA) in general were not established for the purpose of biodiversity conservation. Although protected areas' primary objectives were protection of "wild places" and big game for hunting and timber supplies, it was not until the 1970's, with the growth of the environmental movement that parks incorporated biologists' attempts to maintain the integrity of wild ecosystems (Child, 2002).

Key conservation proponents in SSA including such biologists as J. Terborgh, T. Struhsaker, and J. Oates among others have remained steadfast in their support for exclusionary boundaries (Oates, 1999; Terborgh, 1999; Terborgh, 2002; Struhsaker et al. 2005). Struhsaker argued that biodiversity conservation and humans cannot coexist in a park and that "human presence in the park may lead to the introduction of exotic plants, animals, and diseases that may adversely affect indigenous wildlife." (Struhsaker, 2002, p. 100). Moreover, he called other approaches such as extractive reserves, sustainable harvest extremely problematic for conserving the full array of biodiversity (Struhsaker et al. 2005). Both Oates (2002) and Struhsaker (2002) continue to call for increased priority of wildlife protection and to assert that rigorous policing by armed guards in the park is necessary. Terborgh (1999) claims the fate of the rain forest is threatened by constant economic demands and human influence. Under this narrative, the survival of biodiversity supersedes the immediate material needs of humans. The benefits of a park to society as a whole are considered to outweigh the cost to the relatively small number of individuals whose lives may be directly impact (Terborgh and Van Schaik, 2002).

Though the fortress conservation approach persists in SSA, its support has waned in the last two decades with the introduction of other narratives within the conservation community (i.e., community conservation and integrated conservation and development projects) (Salafsky and Wollenberg, 2000; Hulme and Murphree, 2002). In recent years, it is has been recognized that whole landscapes cannot be isolated from the influence of humans. In order for conservation to succeed, their livelihood needs must be considered (Adams and Hulme, 2001; Brown, 2002), especially those of communities neighboring the park (Salafsky and Wollenberg, 2000). Differentiating human livelihoods from what is deemed as pristine nature was not only considered unsustainable, but also impossible (McNeely, 1994; Western, 2001; Brown, 2002) and often led to hostility towards the park (Brockington, 2004).

Kibale National Park (KNP) in western Uganda was formally established as a national park in 1993 (it was elevated from a forest reserve) in the midst of this ongoing conservation debate. Like the other forest parks in SSA, it is surrounded by smallholder agriculture that depended on the resources outside of the park (Howard et al. 2000). As with other parks in Uganda, the creation of KNP was guided by the Uganda Wildlife Statue, 1996, which states, "a national park… shall be an area of international and national importance because of its biological diversity, landscape or national heritage" (Uganda Wildlife Authority, 2003). It sought to preserve biodiversity within park boundaries first and foremost. In 1993 the park excluded nearly all resource collection and timber concessions and forcibly removed settlers from within its borders (Chapman and Lambert, 2000). By 1992, there were approximately 13,000 people living inside the corridor. These people were evicted and relocated to land north of KNP (Chege et al. 2002). In addition, while a national revenue sharing program was installed, few benefits have accrued at the local level (Archabald and Naughton-Treves, 2001).

Characteristic of fortress conservation is its measures of success. Within this view, it is held that the status of plants, animals, and the ecological community as a whole is the ultimate measure of successful conservation (Struhsaker, 2002; Salafsky et al. 2002). On the other hand, community conservation proponents argue that without the support of neighboring communities, the protected area cannot be deemed a success or even sustainable (Wells and Brandon, 1992; Hulme and Murphree, 1999). Protected areas around the world are centerpieces for the conservation movement and protection of biodiversity, and they have been established often against the wishes of the local population, excluding them from access, resources, and settlement Brockington, 2004). Often, those most impacted by the park most are the local, rural poor, and most of the beneficiaries seem to be the wealthier and foreign visitors. However, is there a case that a park, which by many, can be considered an ecological and biological success, also can be accepted by the neighboring communities? This paper examines two questions regarding the perceptions of households in communities surrounding KNP; 1) Do households perceive that Kibale National Park has helped, hurt, or had no positive or negative impact on their family? and 2) What are the perceived benefits and problems associated with KNP?

Study Region

Physical Environment

Kibale National Park is a medium-altitude tropical moist forest covering about 795 km^2 in western Uganda and its boundaries correspond to those of the 1932 forest reserve boundary combined with the former Kibale Forest Corridor Game Reserve (Chege et al. 2002). This transitional forest (between lowland rainforest and montane forest) is at an average elevation of

1110-1590m and is believed to be a remnant of a previously larger mid-altitude forest region (Struhsaker, 1997). Although the amount of rainfall and length of season change, the average annual rainfall for the region is 1543mm (average 1903-1999) and 1719mm (1990-2005) (Chapman et al. 2005).

The landscape outside the park has become a patchwork of small farms (most <2ha in size), tea estates in some areas, and a network of bottomland forest fragments and wetlands that serve as a resource base for water and fuelwood, effectively isolating the park. Land scarcity has forced land scarcity has forced many farmers to farm to the edges of forests (Naughton-Treves, 1998). In addition, 58% of the land within a 1.5 km periphery of the park is used for small holder agriculture (Naughton-Treves, 1998). Uganda continues to lose 50,000 ha (9.8%) of its forest annually (National Environment Management Authority, 2001, mostly to conversion to agriculture. As agriculture continues to encroach on unprotected forest lands mainly for substance purposes, these forests become more isolated, ranging in size from 1.2 to 8.7 hectares in size (Gillespie and Chapman, 2006). In addition, wetlands continue to be drained and converted into other land uses such as growing crops and fuelwood and expanding grazing land continues to take place (Crisman et al. 2003).

Tea dominates much of the landscape bordering the northwest portion of KNP. Tea producers range from large multinational companies with hundreds of hectares, to smaller individual holdings of less than one hectare (Mulley and Unruh, 2004). Established in the 1950's and re-established in the late 1980's following stagnation during the Amin (1971-1979) and Obote years (1980-1985), the land under tea has been limited mainly by soil pH (optimal is 5.2) and limited to the west side because of land availability[5].

[5] A.T. Joseph, General Manager. Rwenzori Commodities LTD. Interview conducted July 21, 2006.

Social Environment

Rapid population growth, high population density, and heavy reliance on agriculture for income characterize the landscape surrounding KNP (Archabald and Naughton-Treves, 2001) and land pressure has steadily increased (Chege, 2002; Lepp and Holland, 2006). Economic inequality, ethnic disparity, intensive subsistence agriculture, and a decreasing resource base in these communities serves to illustrate a common trend around protected areas in developing countries. Country-wide, 90% of Uganda's population are directly dependent on natural resources for subsistence needs (Uganda Ministry of Water, Lands, and Environment, 2002), but around KNP, nearly everyone depends on the nearby resources to sustain their livelihoods (Hartter, pers. obs.)With limited land availability, farm sizes are characteristically small (< 5 acres on average, Hartter, unpublished data).

This region is one of the most densely populated areas on the African continent (Lepp and Holland, 2006). Population outside the park has nearly trebled between 1959 and 1990 (Naughton-Treves, 1998) and has grown by 76% between 1980 and 2002 (Uganda Bureau of Statistics, 2005). Density is estimated to be 262 individuals/km^2 on the west side of the park and 335 individuals/km^2 on the east side within 5km of the park boundary (Hartter, unpublished data). Agriculturalists in the area belong to two main ethnic groups: the Batoro (west side of KNP) and the immigrant Bakiga (east side of KNP), who came to the Kibale region from southwestern Uganda beginning the 1950s and 1960s (Turyahikayo-Rugyema, 1974; Naughton-Treves, 1998).

Employment opportunities are limited on both the east and west side of the park and most can be considered unskilled labor. On the east side, some are employed outside the home to work in cultivated fields or as taxi drivers. Others earn income from small shops in town, or from selling charcoal, trees, or crops. Another small percentage is employed by KNP or through tourist-based activities. The opportunities are similar on the west side of KNP except for employment with scientists and the presence of the tea companies. Here, some landholders grow small patches of tea on their own land and sell it to the tea companies. The largest percentage is employed by the area's tea-growers (Mulley and Unruh, 2004). On both the east and west side, access to external markets is difficult, as the nearest population center is located nearly 20km from the western edge of KNP.

Methods

The analysis presented in this paper represents a portion of a larger study that investigated the impacts of protected areas on surrounding landscapes. A practical way to integrate different objectives of our larger study is to designate a study unit an area both large enough and small enough to include the scales of land cover, biodiversity, and human activities and enable us to measure them so that satellite remote sensing images and the on-the-ground measurements are tied operationally to the same area of land (Southworth et al. in review; Hartter, in review). This sampling strategy differs from previous social science studies outside KNP that were limited to one or a small number of locales (Naughton-Treves, 1997; Edmunds, 1997; Lepp, 2004). To provide this link, sampling units (named "superpixels") comprising 9 ha areas were used. These superpixels are centered on spatially randomly selected coordinates within 5 km of the KNP boundary and within two areas (Figure 5-1). The "West Study Area" is dominated by the Batoro ethnic group, while the "East Study Area" is dominated by the Bakiga. In all, 95 superpixels were selected randomly within these areas. These 95 superpixels include 60 villages and a sample pool of 417 households (i.e., households that hold land contained within at least one of the superpixels). Between May and August 2006, 130 semi-structured household interviews were conducted. At each study area, respondents were chosen opportunistically, based on population weighting (i.e., the number of respondents for each study was proportional to the number of landholders holding land within the study area). Superpixels containing more landholders had a higher sampling intensity. In addition, 16 interviews were conducted with village chairmen[6] (LC1's) within these communities. All interviews were conducted in English, or in Rutoro or Rukiga using an interpreter.

Results

Respondents were asked whether KNP had helped them and/or harmed them. If it had neither helped nor harmed, there was no perceived impact from the park (Figure 5-2). Most respondents believed that the park helped them in some way (61%). The benefit reported most was that the park "keeps the environment", meaning timely and adequate rainfall, climate regulation, temperature regulation, moisture levels, "fresh air", and also the intrinsic value (Figure 5-3). Another important benefit was that KNP was perceived to "keep animals". This expresses the common perception that the park and other natural areas "contain" most wild animals, which as a result do not come to their fields at all or come less often. There seems to be a belief that in the absence of the park and other natural areas, animals would surely come to their lands to raid their fields. Only 14% of the respondents mentioned employment as a direct benefit, either as contractual unskilled labor or tourism or the research station maintained by Makerere University. A smaller percentage, 6%, felt their household benefited in some way from tourism.

[6] The local council system (LC) was implemented to serve as institutions for local self-governance. It would enable Ugandans to participate in decision making at a more equal level regardless of gender, age, ethnicity or political affiliations, while giving local governments autonomy, meaning they have the legislative and executive authority within their listed areas of jurisdiction. The LC system has five levels of local government: village, parish, sub-county, county, and district. For more on the LC system, see Saito (2003).

Thirty four percent of respondents (44 of 130) felt they were harmed in some way by the national park (Figure 5-2 By far, wild animals that trampled, otherwise damaged, or ate their crops, or attacked their livestock were perceived as an important problem due to the park's existence (Figure 5-5). Only 11% felt that being denied access to resources within the park was a significant problem to them. Smaller percentages still felt that no help from the park, displacement, and land prices were significant problems. In addition to the 66% of respondents who felt that their household was not harmed by the park, 21% of respondents perceived both positive and negative impacts from the park's presence (Figure 5-2).

Another question posed to gauge assessments of the park was whether given the choice, they would rather live closer or further from the park boundaries. Sixty-nine percent (n=130) said that they would prefer to live closer to KNP than further from its boundaries (Figure 5-5).

Most respondents felt that, if given the choice, KNP should remain (73%, n=130) rather than be abolished (9%) (Figure 5-6). It is clear that people find environmental benefits and keeping animals away as the two major benefits of the park, and these perceived benefits are major reasons respondents said the park should remain intact (Table 5-1). Smaller proportions of people reported other reasons such as education, employment, and generating revenue for the government (11%, 13%, and 12% respectively). One important benefit that was noted was the belief by some respondents that the park may lessen its strict regulation on resource harvesting in the future. Residents say that park management will see the plight of the poor households surrounding the park and they will help them in the future. Although the vast majority reported that they would like the park to stay, some said that the park caused too many problems and it was best that it be dissolved. Nearly all of respondents who reported the park should be dissolved cited human-wildlife conflict as the reason (Table 5-2).

We also asked local chairmen (LC1) about the park (Table 5-2). Most said that their zone had benefited in some way from the park's existence. School infrastructure, including classroom renovation and construction as well as teachers' house construction were cited most often as benefits from the park. "Keeping the environment" and chasing animals from respondents' lands were also important benefits of the park.

Discussion

The results of the household surveys reveal that the majority of households feel that they benefit in some way from of the national park. Whether these benefits (e.g. fresh air, providing rainfall, fertile soil, and keeping animals from their fields) are real or only perceived, they are important. When asked, we found that education programs, a well-intentioned, but perhaps misinformed volunteer, even park officials, and local lore were all responsible for perpetuating these perceptions of park benefits. Landholders also believe that the park will keep animals away from their fields. In some instances, landholders rely on the tactic of scare-shooting by wildlife rangers. However, this action has little deterrence on crop raiders (Osborn and Parker, 2002). In most cases, the animals are gone from the field by the time the farmers submit a complaint via the LC1 or in person to park guards. According to them, the park has abundant forage and habitat and by maintaining the park, the wild animals have little reason to stray far from its boundaries to raid their fields. Only those closer to the park are vulnerable.

In fact, several landholders also mentioned that land prices had increased as a result of the park's presence, a major contrast to results of a decade earlier in which land near the park was said to be worth less than that more distant from the park (Naughton-Treves 1997). Many landholders farm near the KNP boundary and nearly all complain about crop raiding (Naughton-Treves, 1997; Chege, 2002). Historically, since the land next to the park was considered more vulnerable to wild animals and limited extractive privileges were allowed within KNP, this land was given or sold to Bakiga immigrants (Naughton-Treves, 1998), or poorer landholders who only could afford a small parcel. The only available or cheaper parcels of land were adjacent to the park. However, recently this land seems to have become more valuable. Although the land continues to be vulnerable to the largest variety of animals, (Hartter, unpublished data) landholders have come to realize that only the wealthier households will be seeking to buy land here and using them to grow trees or tea, which will not be raided[7]. Landholders realize that the only people looking to buy this land have the financial capital to absorb the risk and enough capital to invest in income-generating activities and consequently, land prices in some instances have increased.

Surprisingly the environmental services of parks were mentioned more often as benefits than employment, infrastructure, or other material impacts. Very few reported that jobs were benefits. Some in the area are employed through timber concessions in cutting and sawing the *pinus* and *cupressus* exotics within the park. Another small percentage of the local population finds employment as research assistants, selling crafts to tourists, game guards, park management and staff, and contractual and short-term labor. The vast majority of the population remains engaged in activities not directly linked to the park.

KNP allows only very limited extraction of downed fuelwood, but only through organized groups and special agreements. Park authorities have often denied requests by individuals to enter and collect medicines and other resources, even those of traditional and cultural importance. Park officials stress that communities must organize themselves. They not only expect communities to organize to petition for permission to harvest within its boundaries, but also to manage crop raiding. Declining size and increasing isolation of forests and wetlands

[7]Respondent 37. Interview conducted June 29, 2006.

outside the park, increased fragmentation of the landscape, and increased population and land under cultivation all have had dramatic impacts. Edge habit has increased and the ability of large animals to range widely without crossing agriculture is extremely limited (Newmark et al. 1994; Naughton-Treves et al, 1998), thereby increasing human-wildlife encounters along the forest boundary. In aggregate though, we learned that only one third of respondents feel crop raiding has become worse in the last ten years (Hartter, unpublished data).

As mentioned above, 31% of the respondents felt that the park harmed their household in some way. Nearly all of these said that they had problems with wild animals. The park acknowledges these problems and many of the landholders want compensation for their losses. However, under the Uganda Wildlife Statue 1996, compensation to individual farmers for lost crops due to crop raiding is not permitted in any form (e.g. monetary, loans, food replacement, food vouchers). Even though respondents feel that the park (52%, n=130) and the government (31%, n=130) must manage the crop raiding, most communities and individuals, especially those not directly neighboring the park, must develop their own deterrence strategies, or develop their own means to cope with losses.

Protected areas are celebrated for their preservation of local biodiversity and endemic species; mitigation of illegal poaching and timber exploitation; and protecting potential water sources. Ecotourism derived from park establishment is often touted as the selling point to communities because of its ability to contribute to both conservation and development goals (Dixon and Sherman, 1991; Ashley et al. 2000). As tourism builds, if the communities have a direct economic benefit from tourism, such as revenue sharing program, their attitudes are likely have a positive influence on local perception of protected area (Naughton-Treves, 1998; Walpole and Goodwin, 2001; Archabald and Naughton-Treves, 2001; Infield and Namara, 2001).

Recognizing the needs and plight of communities, through the Uganda Wildlife Statue 1996, the Ugandan government mandated that 20% of the gate receipts from national parks were to be shared with local communities (Chhetri et al. 2003). However, the amount of money that returns to communities is small, and its allocation is complicated. Kibale National Park is a relatively small park, and unlike most of the large parks in East Africa and Sub-Saharan Africa in general, it is a forest park. Large game species generally either do not exist or are difficult to see in forest parks. Kibale's main attraction is the opportunity to see and track chimpanzees (*Pan troglodytes*). Other tourists come for bird-watching in the nearby wetlands or sometimes for the other primate species in the forest. On the whole, though, forested parks such as Kibale do not have the visible charismatic megafauna, vast open expanses of land, and easily accessed wildlife as in the many famous East African savannah parks such as Serengeti and Ngorongoro National Parks. 5-3 shows park visitor statistics compared to the Uganda national park system and compared to two parks in Uganda. The first is Murchison Falls (3,860km^2), the largest park in Uganda and the second is Bwindi Impenetrable National Park (331km^2), a popular forest park in southwest Uganda on the border with the Democratic Republic of Congo known for its contingent of endangered mountain gorillas (*Gorilla gorilla beringei*).

KNP appears to function more as a stop over point for tourists traveling onward to Queen Elizabeth National Park than a primary destination of its own. Each year, a relatively small number of tourists visit the park. Encouraging though is the rapid growth in visitor numbers and the high fees visitors pay to track chimpanzees, but few tourists spend more than one night, if any at all. On average, KNP represents less than 5% of the total number of visitors to the Uganda national park system and only park entry fees are disbursed among neighboring communities. Each visitor pays US$25 (tariff as of July 1, 2006-June 2008 for non-residents for

1 day) for park entry. Forested parks do not attract large numbers of tourists (Table 5-3; Struhsaker et al. 2005) and therefore, the pool of possible revenue to be disbursed to communities is quite small. Expenses exceeded their revenue generated (Archabald and Naughton-Treves, 2001), which is common for many parks in the world (James et al. 2001). In addition, an estimated 80-85% of the tourists go to the popular Kanyanchu tourist site for chimpanzee tracking[8]. So while the entry fee of US$25 is considered "gate fees" and eligible for distribution to the local communities, the US $70 (tariff as of July 1, 2006-June 2008 for non-residents) fee paid by tourists to track chimpanzees is not.

Archabald and Naughton-Treves (2001) reported that of the 27 parishes that border KNP and are eligible for disbursement of the funds, only five successfully received benefits from the park in 1999. Of the total US$3000, if divided evenly, only (US$600) actually came back to each of the five parishes. Within each parish, the LC1 zones (typically 5-10) must submit their case to the LC3 (sub-county level) for review. Spread over the entire community's population, the actual benefits at the LC level, the household, or at the individual level are miniscule, as demonstrated in villages outside Lake Mburo National Park (Infield and Namara, 2001) and Mgahinga Gorilla National Park in Uganda (Adams and Infield, 2003). The meager amount of money that does come back to the communities is most commonly used in two ways: to build and maintain roads and bridges; and building schoolrooms or staff houses. While the limited funds can be useful, projects are small and securing funds is problematic. Each LC1 zone must reapply the following year if projects have not been completed. Only six of ten LC1s we interviewed said they had applied for funding or planned on applying within the current and future five-year elected term.

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[8]Tumwesigye, C. KNP Chief Warden. Interview conducted June 12, 2007.

Some respondents also indicated one of the benefits of being near the park was that they were situated to take advantage of potential tourist-based activities. If they had the capital or could organize a group of community members with common interests, then perhaps they could reserve some forest or wetland outside the park for tourists to see birds and primates. Others thought they could establish businesses dependent on the tourism-based revenue such as restaurants, guest houses, or selling firewood to lodges. Table 5-3 illustrates some of the tourism potential in the area. Approximately 5,000 visitors come to the park annually, but few stay more than a single day (Obua and Harding, 1996). With such limited economic opportunity derived indirectly or directly from the park, it is unclear how substantial either the individual or community benefits can be.

Some residents also felt that the park could be a potential future source of resources. They believe that park management might eventually acknowledge the poverty and struggles of neighboring communities and permit greater extraction of wood and other resources. Even though there was no indication from KNP officials that such harvesting would be permitted, some were still optimistic and wanted to be situated close to the park in order to take advantage of the opportunity when (and if ever) it materializes.

Protected areas are celebrated for their preservation of local biodiversity and endemic species; mitigation of illegal poaching and timber exploitation; and protecting potential water sources. Ecotourism derived from park establishment is often touted as the selling point to communities because of its ability to contribute to both conservation and development goals (Dixon and Sherman, 1991; Ashley et al. 2000). As tourism builds, if the communities have a direct economic benefit from tourism, such as revenue sharing program, their attitudes are likely have a positive influence on local perception of protected area (Naughton-Treves, 1998; Walpole and Goodwin, 2001; Archabald and Naughton-Treves, 2001; Infield and Namara, 2001). But in actuality, the amount of revenue shared with communities is small and only small and only a small proportion of households directly benefit from employment or tourism revenue outside of Kibale (Table 5-3). The same is true outside Mgahinga Gorilla National Park in Uganda (Adams and Infield, 2003).

While some communities may be in favor of protected areas, there is still the prevailing feeling of wanting that protected area “not in my backyard” (Marcus, 2001). De Boer and Baquete (1998) found crop raiding to be the most significant variable influence attitudes about the protected area. Outside Budongo Forest Reserve in Uganda, 65% of respondents said that they were in favor of elephant conservation, but respondents are apprehensive of having that conservation area near their lands (Hill, 1998). Similarly 88% of households held a positive attitude towards the Maputo Elephant Reserve in Mozambique, but in areas where crop raiding was highest, the attitudes were lowest (de Boer and Baquete, 1998). Research in communities neighboring other parks indicate that damage to crops and livestock caused by wildlife leads to negative perceptions of the park (Infield and Namara, 2001; Mugisha, 2002). Furthermore, hostility towards the nearby national parks further arises when the people feel that have not been adequately compensated for livestock or crop damages (Naughton-Treves and Salafsky, 2004; Gadd, 2005).

There are other key influences that shape negative attitudes towards parks and other conservation initiatives. Lepp and Holland (2006), Mugisha (2002), and Twyman, (2001) suggest that the restriction of resources contributes to ambivalence toward the protected area. In Machalilla National Park in Ecuador, Fiallo and Jacobson (1995) found similar reactions; most people living within and near the park did not find the park to be beneficial in any way. One of the biggest contributors was the fact that the park prohibited the collection of most forest resources, including the fuelwood they depended on. Intensive community extension and work can also improve community attitudes towards the park (Infield and Namara, 2001).

KNP is a different case. The landscape surrounding KNP has all the ingredients for hostility between the park and neighboring communities. There is little direct benefit to communities from revenue sharing programs. There is continuous crop raiding and no provision for compensation under Ugandan law. KNP maintains only a relatively small community outreach and environmental education program. We found that most people in the surrounding landscape are not pervasively hostile towards the park despite the losses from crop raiding and other problems they perceive. In places there are negative attitudes about the park as Lepp and Holland (2006) found around Bigodi town, but such negative attitudes are not at all as widespread as Edmunds (1997) suggested. Naughton-Treves and Salafsky (2004) found that some people are apprehensive of park intervention on their land. However, we found that only two of 130 respondents think that the park will expand in the future. Given the high density population and agricultural saturation of the surrounding landscape, park expansion seems unlikely. Not only did most respondents say they are not hurt by the park or feel no effect, the vast majority said that given the choice and weighing both the benefits and the costs, the park should stay and not be abolished. Even for local political elites, 14 of 16 LC1s said that KNP overall has been a good thing for their LC zone.

Our results may be different than traditional studies for a number of reasons. The superpixel sampling framework includes a random selection of the landscape and a much larger spatial extent and did not target specific villages along the park boundary (Naughton-Treves, 1996; Edmunds, 1997) or those that have had problems with crop raiding (Mkanda and Munthali, 1994; de Boer and Baquete, 1998). We would expect that farmers in villages directly adjacent to the park boundary were harmed especially by animals. However, we found that the park impacts quickly diminished and by 5 km; park impacts were hardly noticeable. Those far from the park, within the agricultural matrix, are far from the continuous "tree habitat" used especially by primates and thus reduced risk (Hill, 1997). Even though intensive land use has decreased has decreased forest and wetlands resources, it has also decreased primate habitat and buffered many farms by other farms and tea plantations, thus decreasing the extent and number of crop raids by wildlife in the last 10 years (Hartter, unpublished data)

Often, the value of parks to local people is generally thought of in terms of foreign exchange through tourism (Newmark et al. 1993) and many are opposed to abolishment of the park (Newmark and Leonard, 1991), but this line of thinking tends to originate from big savannah parks. Conversely, the main benefit and reason the park should remain cited was because of the environmental benefits KNP provides. One respondent explains his rationale, "What are we do to if the park is gone? How will we get those [resources and benefits]? We can do something about the animals… we can guard, but we can't do anything about not having rain."[9]

Can Kibale National Park be considered a successful example of fortress conservation? From the landscape-level, park boundaries remain intact and stable over time, and dense forest continues to dominate the park (Southworth et al. in review). Healthy and viable populations of many primate species prevail within the park. The largest and only viable population of the once threatened red colobus monkey (*Procolobus rufomitratus*) resides within KNP (Struhsaker,

[9] Respondent 97. Interview conducted July 14, 2006.

2005). In addition, one of Struhsaker's (2002) indicators of park success is a decrease in illegal activities. Anecdotal evidence suggests large-scale encroachment into the park has virtually halted and boundaries are well understood and maintained. In landscapes with adequate rainfall, dense population, and where forest abuts the agricultural landscape, a harder edge may be appropriate (Naughton-Treves et al. 1998). Wherever wildlife habitat neighbors agriculture, there will be some risk of crop loss and human-wildlife conflict. It seems people understood this and continue to take measures to mitigate problems associated with the forest such as guarding their crop fields.

There are many approaches to conservation, but there is no single solution for all cases. Is fortress conservation necessarily bad? Is a community-conservation-based approach invariably preferable? It is not appropriate to assume that all of the elements of a narrative or received wisdom (e.g. fortress conservation) are 'wrong' and should disappear from policy and practice, while all the elements of a counter-narrative (e.g. community conservation) are 'right' and should be adopted. In the case of KNP, while the local people may bear the disproportionate brunt of crop raiding and forego many types of activities in and out of the park, the park appears to be socially acceptable. However, human activities are key drivers in landscape change and their impacts must be considered with any park management plan. Therefore, the more pressing contemporary issue is how to relate and a mix of strategies that incorporate elements of fortress conservation and community conservation, not to prove that one is always better than the other.

Threats to parks can rise from inequitable costs and benefits, and limited distribution of benefits to communities (McNeely, 1990). Scale is important in considering where benefits of conservation and management projects will accrue (Salafsky and Wollenberg, 2000; Jones and Murphree, 2004) and especially when determining the claim of tourist revenue (Adams and

Infield, 2003). As such, the scale of benefits will be addressed in future research. Should financial benefits of a national park accrue at the village, parish, regional, or national level? The question remains as to what scale revenues can be allocated to be the most effective to the rural poor majority who are the most vulnerable and have the least capacity to cope.

Conclusion

Contrary to popular belief of exclusionary approaches to conservation, our results suggest that not only do most households feel they benefit from KNP (although in ways not widely discussed in the literature on parks), but the majority also feel they are not harmed by it, and many feel no effect from the park. The two main benefits of the park cited were environmental services such as rain and fresh air and keeping animals within the park boundary. The most cited harm predictably was crop and livestock raiding by wild animals. Over 70% of respondents say that given the choice and weighing both the benefits and the costs, the park should stay. Even the large majority of local political leaders also said that KNP overall has been good for their local area. Since the study included a geographic random sample of multiple locales and did not target specific villages, households, or set(s) of demographics, our results are representative of household perceptions about the park in the landscape surrounding KNP. Future research however should test the superpixel in other environments such as pastoral landscapes, dry savannah landscapes, or around parks outside of the African continent.

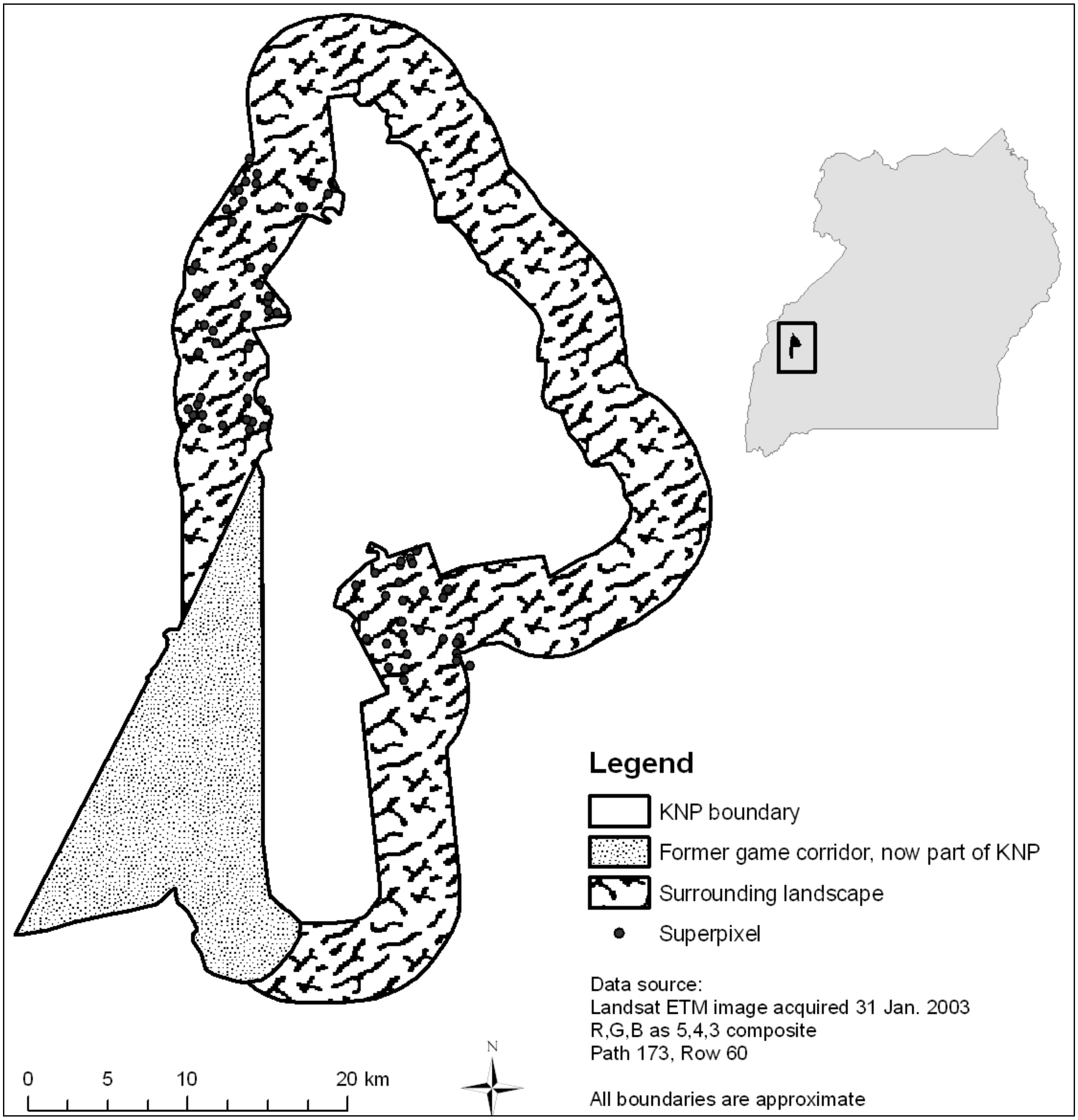

Figure 5-1. Kibale National Park and surrounding landscape in western Uganda

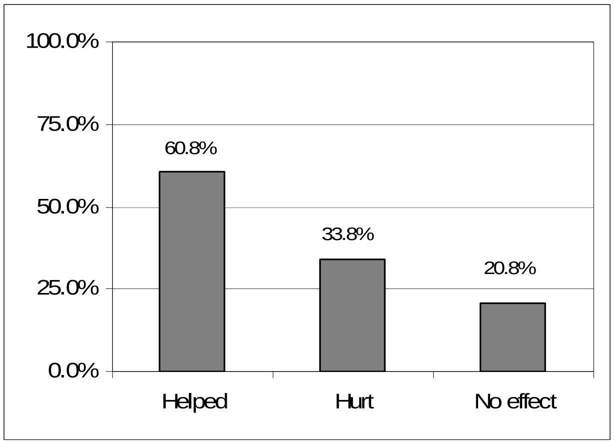

Figure 5-2. Perceived impact of KNP, n=130

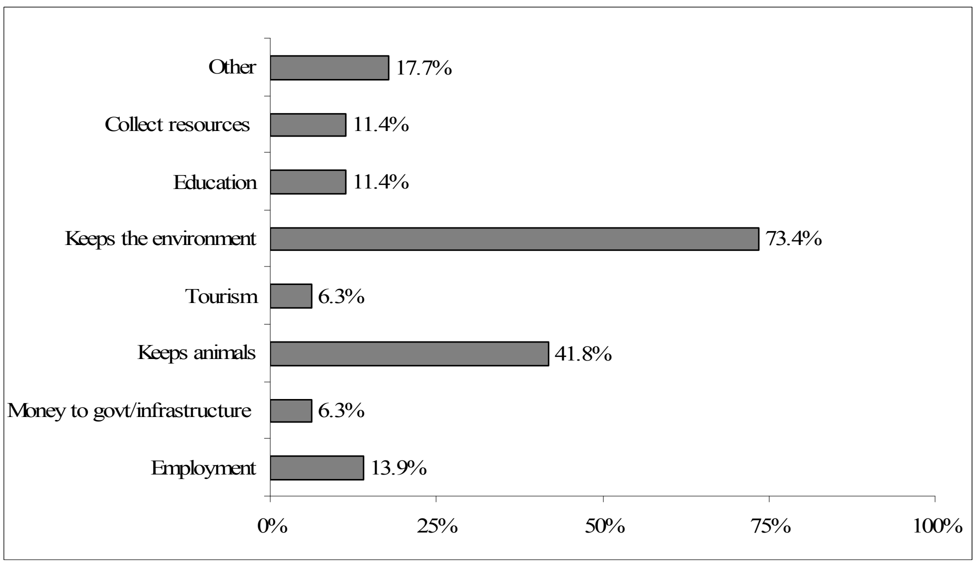

Figure 5-3. Perceived benefits from KNP, n=79

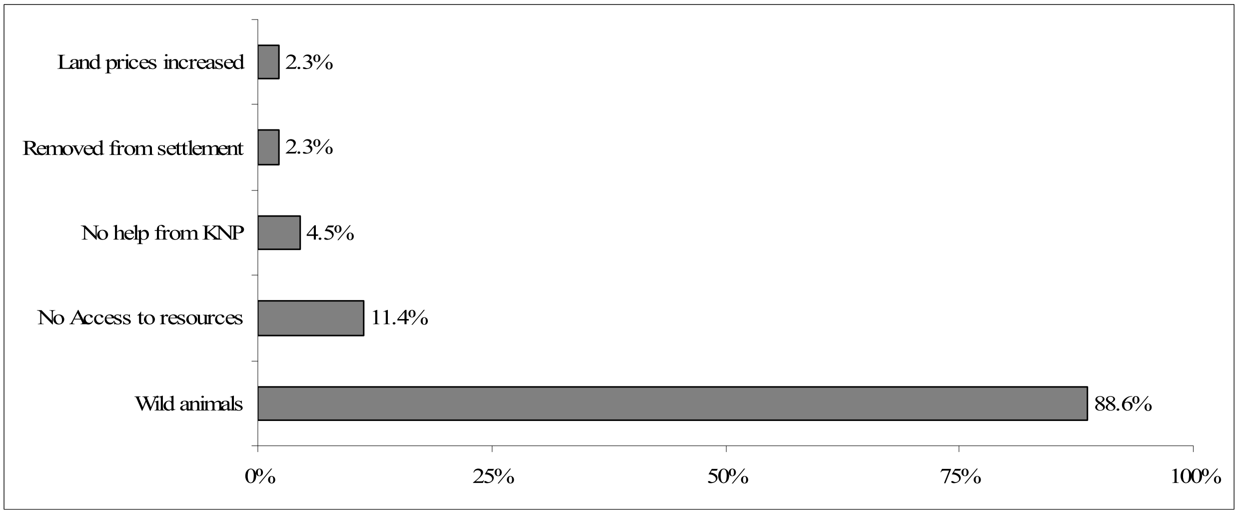

Figure 5-4. Perceived problems from KNP, n=44

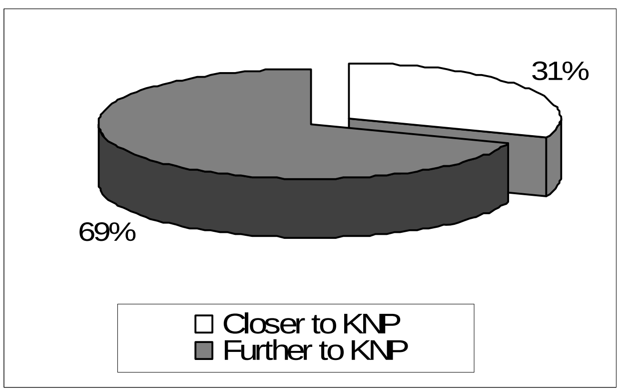

Figure 5-5. Where would you rather live?, n=130. The definition of “closer” and “further” was left to the respondent to interpret

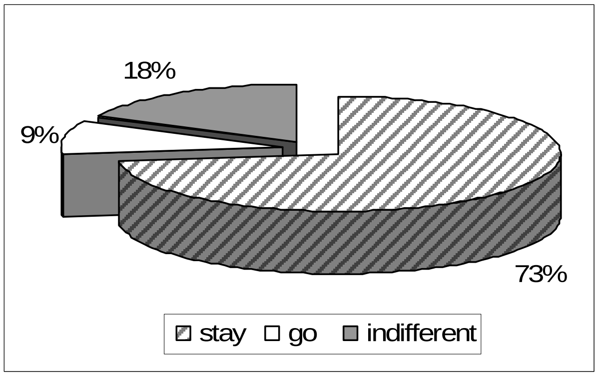

Figure 5-6. Should KNP stay or go?

Table 5-1. Reasons reported why KNP should stay or be dissolved

Why KNP should stay?	n	Proportion
Money to government	11	12%
Possibility to collect resources in future	9	10%
Protects the environment (air, rain)	50	53%
Soil fertility	4	4%
B/c the government wants/uses it	2	2%
Tourism	7	7%
Keeps animals away	31	33%
Education about environment	10	11%
Employment	12	13%
Infrastructure (e.g. building schools, roads)	4	4%
Obtain resources	5	5%
Spiritual/cultural significance	2	2%
No reason	1	1%
Why KNP should be dissolved?		
Crop raiding	11	92%
Park will expand in future	2	9%

Table 5-2. Has the LC zone benefited from KNP and the perceived benefits by the LC1

Has your LC zone benefited from KNP?	n	Proportion
Yes	11	73%
No	5	33%
How have they benefited?		
built/maintained roads	2	18%
built bridges	2	18%
school classrooms/staff houses	7	64%
chase animals/scare shoot	5	45%
keep the environment	5	45%
jobs for constituents	4	36%
increased business	4	36%

Table 5-3. Visitor statistics for Uganda national parks, Murchison Falls, Bwindi and Kibale National Parks. Kibale National Park Gross Revenue generated and revenue shared with communities is also given.

UWA Parks[6,7]	Annual Visitors MFNP[6,7]	BINP[6,7]	KNP[5,7]	Total KNP Revenue (USD)	KNP revenue shared (20% of gate fees)[8]	Total KNP revenue shared w/ communities
28,098	6,817	1,106	465		N/A	N/A
32,027	7,041	2,461	1,890		N/A	N/A
42,783	11,039	3,214	3,640		N/A	N/A
			2479			
39,839	12,099	3,437	1850	$70,238 [1]		$3,000 [1]
36,943	12,713	2,100	845	$79,988 [2]	$269	$3,269
52,161	23,169	3,983	1156	$34,930 [2]	$865	$3,865
58,004	20,284	4,517	1852	$52,499 [2]	$1,617	$4,617
90,061	34,241	5,075	4872	$116,300-$130,900 [2,3]	$7,800-$11,050 [3]	$12,417-$15,667
			6133	$191,600[4]	$24,532[9]	
			5391	212,200[4]	$21,564[9]	
			5639	267,411[4]	$22,556[9]	

[1]Archabald and Naughton-Treves (2001)
[2]Chhetri et al. (2003)
[3]discrepancy in values reported in Chhetri et al. (2003)
[4]based on totals from UWA given as shillings and converted at 1 USD=1600 Ug. shillings
[5]visitor information from Archabald and Naughton-Treves(2001), Chege et al. (2002), Chhetri et al. (2003), UWA (2005)
[6]UWA (2005)
[7]National Environment Management Authority (1997)
[8]The Wildlife Statute 1996 makes provision for sharing 20% of gate receipts with local communities
[9]approximated from US$20 park entry fee

CHAPTER 6
CONCLUSION

Though protected areas have become the most recognizable mechanism of the world's interest in conservation, their establishment and their management certainly have a significant impact – both positive and negative – on the neighboring communities. This research examined these impacts of park establishment by focusing on forest fragments and wetlands outside Kibale National Park (KNP). As in many similar cases, in the landscape around the park, there has been substantial population growth from both in-migration and a high rate of natural increase. The park is surrounded by agricultural land and large multi-national tea estates and a network of forest fragments and wetland areas is scattered throughout the landscape.

Since small rural communities in western Uganda are heavily reliant on land and resources, their livelihoods are directly linked to ecological systems. As population in the area continues to climb, land and resource pressure likewise increase. Thus, the landscape surrounding KNP has become a mosaic of diverse agricultural land intermixed with patches of remaining natural areas as households construct strategies to sustain their livelihoods. Remaining ungazetted forest fragments and wetlands serve as important resource bases, but are also problematic for farmers. Gender, wealth, ethnicity, and distance to the park boundary can be important factors in contributing to resource use, adaptation to shortages, problems, and means of mitigating crop raiding. This dissertation research quantified the change in spatial extent and productivity of wetlands and forest fragments. I then examined how that decline in extent and quality and increased fragmentation of these natural areas has impacted households and their corresponding coping mechanisms to resource shortages and human-wildlife conflict. In this chapter, I will also discuss the broader significance and implications for this research as well as future directions.

Diminishing Resources

As population outside the park swells and people are prohibited from resource extraction inside its boundary, the demand for resources and agriculture land not only increases, but competes. As a result, the remaining unprotected natural areas – wetlands and forest fragments – become targets for degradation and conversion. The objective of this chapter was to establish what change is occurring in the landscape outside the park and to quantify that change. Specific research questions addressed were:

- How has the productivity and spatial extent of forests and wetlands in the landscape surrounding Kibale National Park changed over time?
- How does this change vary in communities on the east side of the park versus the west side of the park?
- How does this change relate to change in land under cultivation and tea?

The primary conclusions from this section were:

- Since the formation of the park, the landscape outside the park has become increasingly fragmented and the forests and wetlands outside the park have become increasingly isolated – there are more patches within each class, mean patch size for forests and wetlands has decreased, the distance between wetland and forest patches has increased.
- Land under cultivation and tea has increased, especially in the two key study areas (East and West Study Areas), while forest and wetland areas have declined.
- KNP’s boundaries remain relatively intact with only minimal encroachment since 1984.
- There has been a substantial decrease in NDVI in forests and wetlands both inside and outside the park since 1984, but there is no clear explanation for this decrease.

Resource Use and Household Livelihoods

Wetlands and forest fragments outside KNP serve as important resource bases for local people. However, they are also problematic for local farmers, since crop and livestock raids by primates, elephants, and other animals seem to emanate from these natural fragments. This chapter examined the dual character of these natural areas within the agricultural landscape around KNP in terms of the social and environmental benefits and problems they represent to local households that vary in ethnicity, wealth, and distance from the park. Specific research questions addressed were:

- What resources and problems are associated with wetlands and forest fragments around KNP?
- How do these benefits and problems vary by distance from the park boundary, gender, wealth, and ethnicity?

The primary conclusions from this section were:

- For the majority of respondents, forests and wetlands serve as important resource bases. Most benefit in some way from wetlands and forest, but more claim benefits from wetlands than from forests. Benefits include firewood, building poles, handcraft materials, water, medicines and other resources. Other also claim fresh air, timely rain, and soil moisture as direct benefits of wetland and forest presence.
- Respondent gender was significantly related to some benefits such as poles, firewood, and fish because of defined cultural gender roles, but gender is not found to be significant with most other resources.
- Wealth class and ethnic group did not significantly relate to extracted resources from wetlands and forest fragments.
- Distance related significantly to most of the benefits from the wetland and forest.
- Wild animals were identified as the most prolific problem in the surrounding landscape as a result of the presence of wetlands and forests. The vervet and redtail monkeys are worst crop raiders, but baboons and elephants are also problematic.
- Whether or not households had problems with crop raiding was not significantly related to distance. However, distance was significantly related to all of the worst crop raiders – small monkeys, baboons, and elephants. Elephants and baboons are identified as the

worst problems by farmers closer to the KNP boundary, while, small monkeys are identified as the most problematic animals by farmers further from the park boundary.

- Wealth and gender were found less significant in relation to these problem animals. Ethnicity is important because it determines where farmers will settle.
- Though the forests and wetlands are perceived to be sources of both problems and benefits, most landholders say they are worried about the availability of resources in the future and would rather live closer to these areas.

Responses to Resource Availability

Forests and wetlands provide resources, but are also sources of problems. For households that are heavily dependent on the land for its resources to sustain their livelihoods, the decline of these natural areas has an impact on households and their ability to secure resources and sustain their livelihoods. Since most of the resources collected in the wetlands and forest fragments are obtained locally, households must respond in some way to shortages. Some purchase fuelwood, others must find new sources or travel longer distances to collect fuelwood and water. Landscape fragmentation and decline in forests and wetlands has increased edge and decreased not only resources, but also natural habitat. As a result, human-wildlife conflict for local landholders is imminent. Landholders' response to human-wildlife conflict and resource shortage in relation to four different factors was measured: ethnicity, head of household gender, wealth, and distance to the park. This chapter quantified the loss of wetlands and forest fragments outside KNP, landscape fragmentation, and the ways households have adapted to a degraded resource bases of the unprotected wetlands and forests and problems with wildlife in the landscape surrounding a park.

Specific research questions addressed were:

- How have the presence and extent of wetlands and forest fragments in the landscape surrounding Kibale National Park changed over time?
- How have households adapted to the declines in the wetlands and forest fragments in the landscape surrounding Kibale National Park?

The primary conclusions from this section were:

- Forests and wetlands are decreasing in patch size and those that remain are increasingly isolated within the landscape since 1984.
- Most people recognized changes within the landscape and perceived difficulty in obtaining resources and current and future resource shortages.
- Distance from park was an important factor in determining perceptions of resource availability.
- Distance from the park was not significantly related to response to resource shortages.
- While there was no perfect solution to effectively mitigate crop raiding animals and to supply resources, we recommend engaging in a mixture of activities is necessary.

The Impacts of a Forest Park

Protected areas around the world are centerpieces for the conservation movement and protection of biodiversity. The fortress conservation model has sparked many debates given its treatment of park-people relationships. Often, those most impacted by the park most are the local, rural poor, and most of the beneficiaries seem to be the wealthier and foreign visitors. This chapter examined whether a forest park established under the fortress conservation model can be accepted by neighboring rural communities in western Uganda.

Specific research questions addressed were:

- Most people say the park has helped or at least had no effect on them. However, most say that they would rather live further than closer from the park boundary.
- The most prolific benefits are perceived environmental benefits and containment of wild animals. Relatively few people mention tangible benefits such as employment, infrastructure, or tourism.
- Of those that perceive problems from the park, most report problems with wild animals.
- Despite the many problems mentioned, the overall sentiment towards the park is not overtly hostile to park’s existence
- Results suggest that KNP could be a muted success under the fortress conservation model. Although it is perceived to be the source for raiding wild animals, many households benefit

from KNP. Though many costs are associated with park presence, most respondents agree the park should stay.

Research Significance and Implications

This research is significant in a number of ways. First, my research adds another perspective to the often divisive and conflicting conservation dialogues in Uganda, East Africa and beyond. This research will fill a gap in the conservation literature about the effects of changing resource bases on household livelihoods. Within conservation and development, there is no clear understanding of how ethnicity and cultural differences influence land-use strategies and shape the landscape (Stone, 1996). This study responds to the call in the conservation literature for linking landscape and household level data as they pertain to land-use patterns, natural resource use, and livelihoods. This will contribute to the growing body of land-use and land-cover change studies being conducted at multiple spatial and temporal scales (Geoghegan et al. 1998).

Second, Kibale National Park and the surrounding landscape represent an important case study that links protected area establishment and the impacts on social-ecological systems. The larger KNP area has already been identified as a site where conflict over resources occurs. Most work on protected areas has examined at the impact of humans on parks and the impacts of extraction and resource exploitation (e.g. Liu et al. 2001; 2003). This study instead examined how parks are not benign within the landscape and have various spatial and temporal impacts on park neighbors. In a country and discourse where "fines and fences" conservation agendas have historically dominated, the reduction of resources as a result of landscape fragmentation has yet to receive sufficient attention within the conservation arena.

Furthermore, KNP is an important park not only because of its biological diversity, but also because of the islandized nature of the park. KNP represents an important litmus test for the impacts of park establishment on the surrounding landscape in mid-elevation moist tropical rainforests, typical more of central Africa (e.g. Gabon, Democratic Republic of Congo). The population and resource pressures and the subsequent islandization and the management of the landscape are closely linked to other regions. This study shows how park-based conservation and management decisions, such as the protection of biodiversity, can have lasting effects on adjacent wetlands and forest fragments. The results of this research will establish baseline information for measuring the impact of future management practices.

Third, this research introduced an innovative methodology for measuring cross-scale linkages. This sampling framework linked both landscape and household level scales used to examine park impacts on the surrounding landscape. Land cover analyses revealed spatial and temporal change in extent and pattern within the entire landscape. Containing 9ha, each superpixel represented an area large enough to link land cover change at the broad landscape-level to a more manageable, yet an accurate representation of landscape change, size to link land cover changes to specific households. Superpixels contained a small enough area to link household-level decisions for land use (i.e., mechanisms for adapting to resource shortages and crop raiding) and study the impacts on land cover. In turn, since the locations of each superpixel were generated randomly, these results and demographic data can be scaled up to accurately assess park impacts and land use within the landscape.

Linking household- and landscape-level data is vital to address the complex nature of human-environment interactions (Geoghegan et al. 1998; Rindfuss et al. 2003), especially where access to resources can be limited, contested, and prohibited. The larger KNP area has already been identified as a site where conflict over resources occurs. This study shows how park-based conservation and management decisions, such as the protection of biodiversity, can have lasting effects on adjacent wetlands and forest fragments. The results of this study will establish baseline information for measuring the impact of future management practices. This spatial approach to understanding human-environment interactions has yet to be implemented in East Africa.

Fourth, while the ecological importance of Uganda's wetlands and forests has been recognized, the linkage between the social and ecological systems remains largely understudied (Chapman et al. 2001; MacLean et al. 2003). As a result, wetlands and ungazetted forests have been underemphasized and less defined in national level natural resource management (Bakema and Iyango, 2001). Not only are more legislation, regulatory measures, infrastructure, and monitoring at the central government level needed, but also cooperation, education, management, and monitoring at the local level. In the past, conservation planning and environmental policies have often relied on the subjective assessments of planners and development professionals, leading to the use of incomplete or biased data sets (Fuller et al. 1998). Appropriate environmental policy depends on accurate information on past and current conditions. Satellite imagery analysis can be used to pinpoint important hotspots for conservation and monitoring, extent, and rates of change over time (Haack, 1996). Satellite remote sensing not only can be used to determine the biophysical change characteristics, but it can also be used to consider human needs and anthropogenic influences. At the same time, the perceptions of ordinary men and women are critical in generating effective and appropriate environmental planning (Basset and Koli Bi, 2000). This synergy of biophysical and human change data at multiple scales is imperative for the formation of practical conservation policy in Uganda (Schweik and Thomas, 2002). Such analyses may be used to better inform decision makers and land managers and conservation-based non-governmental organizations.

Lastly, geography as a discipline engages with complex questions, which are often compounded by political and moral issues. As such, its research topics not only add to our academic understanding about people, but also provide opportunities to influence the processes that affect how people meet fundamental livelihood needs. The practical nature of this research, combined with its innovative spatial framework addressed both of these dimensions. At the local level, this research can provide land management agencies with detailed information about land-use change since the establishment of KNP. It will add to the dialogue guiding future research into the needs of communities living near protected areas. In addition, it will contribute to a more complete understanding of the complex interactions between communities and a shrinking resource base related to the presence of a protected area.

The future of conservation and the preservation of biodiversity depend on the relationship between protected areas and the communities surrounding those areas. Greater knowledge of how these communities respond to challenges posed by protected areas will allow for improved planning and implementation of conservation goals. Uganda is a region noticeably under-represented in the conservation and development research agenda. This research is more than a case study. It is a much-needed addition to East African case studies. The results of this study may be applicable to the long-term management of national parks and forest reserves and cooperation with neighboring communities throughout the world.

Future Research

This dissertation provides the basis for future directions for my research to examine park-people relationships. Future research will focus on the following areas:

- Examine the changes in land cover extent, pattern, and productivity. From my analysis, it is evident that productivity is decreasing both inside and outside the park in both forests and wetlands. However, there is no clear explanation for this decline. Is this decease relating to changes in fruit phenology, elephant density, or is this an indication of a greater shift in climate?

- Southworth et al. (in review) described the difficulty in differentiating elephant grass and papyrus because of similar spectral signatures. While Southworth et al.'s (in review) and my analyses are conservative in their land cover assessment by including elephant grass with papyrus together in one land cover class, future research should target the separation of these land covers. Although, they have similar growth and spectral characteristics, they are different in their surface temperatures (Hartter, unpublished data). In addition, papyrus is found in low lying areas and valley bottoms, while elephant grass generally, but not exclusively, is found in upland areas. By combining surface temperature analyses and elevation data, a new rule-based classification will be constructed.

- New vegetation indices will be developed to better describe within-class variation and to assess productivity change within the important natural areas. Southworth (2004) and Boyd et al. (1996) note the usefulness of using the Landsat thermal band for assessing forest regeneration in tropical dry forests. The thermal band can be incorporated in a new analysis to examine within-class variation of forest to investigate loss of productivity within park vs. surrounding landscape.

- The superpixel methodology has been shown to be useful in dense agriculturally-dependent settlements outside a forested park. It is also important to compare these results across other forested protected area landscapes surrounding by intensive smallholder agriculture. This methodology will be tested in the future in protected area landscapes with: limited rainfall (e.g. savannah region of southern Africa), larger landholdings, dispersed settlements, and pastoral communities.

- Much of the community-based conservation literature (e.g. Hulme and Murphree, 2001) purports that parks established under the fortress conservation model cannot be accepted by neighboring communities. KNP, arguably, is an example of a muted success for fortress conservation. Additional research will address the long-term stability of this perception in communities neighboring KNP. In addition, sample size will be increased and the study area will be widened to include areas outside the Bakiga and Batoro communities studied.

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BIOGRAPHICAL SKETCH

From 1995-2000, Joel Hartter spent four years at the University of Michigan in Ann Arbor pursuing a B.S.M.E. (mechanical engineering) and a B.S. in German. During the 1996-97 school year, he studied abroad in Germany through Wayne State University's Junior Year in Munich program at both the Technische Universität München and Ludwigs-Maximilians-Universität. Following two brief years working as a mechanical engineer, he returned to graduate school to pursue a master's in forest engineering at Oregon State University. While there, Joel concentrated on making the transition to a natural resources-based discipline. At OSU, his emphasis was twofold: 1) to make the transition into the natural resource field, and 2) to build up his academic knowledge of natural resource management. His thesis research was focused on integrating new technology to reduce environmental impacts resulting from forest harvesting. While at OSU, he also became interested in natural resource management issues in Sub-Saharan Africa. Following completion of his M.S. in 2004, Joel began to pursue a PhD at the University of Florida in geography funded through a United States Department of Education Foreign Languages and Area Studies Grant. At the University of Florida his academic emphasis has been on human and environment interactions – more specifically the impacts of landscape change on livelihoods. Joel continues to be interested in the interaction of social and ecological systems and developing synergistic remote sensing and field techniques to study the impacts of landscape change at multiple spatial and temporal scales. His PhD was completed in December 2007 with a minor in natural resource management and a certificate in African studies.