Fall 2016

Assessing the Impact of Industrial Oil Development, Human Population Growth, and Post-Conflict Regrowth in an African Biodiversity Hotspot

Nicholas Sean Dowhaniuk
University of New Hampshire, Durham

Recommended Citation

Dowhaniuk, Nicholas Sean, "Assessing the Impact of Industrial Oil Development, Human Population Growth, and Post-Conflict Regrowth in an African Biodiversity Hotspot" (2016). *Master's Theses and Capstones*. 858.
https://scholars.unh.edu/thesis/858

ASSESSING THE IMPACT OF INDUSTRIAL OIL DEVELOPMENT, HUMAN POPULATION GROWTH, AND POST-CONFLICT REGROWTH IN AN AFRICAN BIODIVERSITY HOTSPOT

BY

NICHOLAS DOWHANIUK

B.A. Geography, University of New Hampshire, 2012

THESIS

Submitted to the University of New Hampshire

In Partial Fulfillment of

the Requirements for the Degree of

Master of Science

in

Natural Resources

September, 2016

This thesis/dissertation has been examined and approved in partial fulfillment of the requirements for the degree of Master of Science in Natural Resources by:

Co-Thesis Advisor, Dr. Joel Hartter, Associate Professor of Environmental Studies, University of Colorado

Co-Thesis Advisor, Dr. Russell G. Congalton, Professor of Remote Sensing and Geographic Information Systems

Dr. Sadie J. Ryan, Assistant Professor of Geography, University of Florida

Dr. Michael W. Palace, Associate Professor of Earth Sciences

On June 15, 2016

Original approval signatures are on file with the University of New Hampshire Graduate School

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AKNOWLEDGEMENTS

I would like to thank all of my committee members for their help, guidance and input that led to the successful completion of this thesis. First, I would like to thank Dr. Joel Hartter for introducing me to the disciplines of Geography and Conservation. Had it not been for Joel, I might never have found the passion for research in Africa that I now possess. Thank you for pushing me to always be my best, and helping me to develop a skill set that has become invaluable along the way. Additionally, I want to extend my extreme gratitude to Dr. Russell G. Congalton for introducing me to GIS and Remote Sensing. Both your academic and mentoring support throughout this entire process is a huge reason for the completion of this MS degree. Thank you to Sadie J. Ryan for agreeing to be on my committee and helping me to navigate the wide world of modeling and statistics. I'm looking forward to working with you at the University of Florida for my PhD (Go Gators!). Finally, thank you to Michael Palace for all of the technical advice on Remote Sensing and sensor systems.

This research would not have been possible without my excellent support system within Uganda. To all of the individuals in the Uganda Wildlife Authority at Murchison Falls Conservation Area, I extend my sincere appreciation for all of your help. Thank you to Dr. Eric Enyel for allowing me to work within the park boundaries and for providing me with an excellent field staff. Mawa Tom and Bagonza Allan, thank you for trekking in the hot bush with me while collection training samples. Thank you to Ogwang Jimmy for being an excellent field assistant and translator. Your knowledge of the area was invaluable, and this research truly could not have been completed without you. Finally, a big thank you to Rebecca Fuda for being an amazing friend and field partner throughout the many months in Uganda.

This research would not have been possible without the support of my many funding bodies. Thank you to the New Hampshire NASA Space Grant Consortium for providing me with one year of Fellowship to fund my studies, and UNH for providing me with one-year of funding through a teaching assistantship. Additionally, I am grateful to the National Geographic Society for funding my field research with a National Geographic Society for Research and Exploration Young Explorer’s Grant (#9551-14).

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ABSTRACT

ASSESSING THE IMPACT OF INDUSTRIAL OIL DEVELOPMENT, HUMAN POPULATION GROWTH, AND POST-CONFLICT REGROWTH IN AN AFRICAN BIODVIERSITY HOTSPOT

By

Nicholas Dowhaniuk

University of New Hampshire, September 2016

Understanding the drivers of human population growth and landscape fragmentation surrounding protected areas is vital to the success of conservation initiatives worldwide. However, the drivers of land cover change and population growth can be complex. While natural population growth is a primary cause of population growth in Africa, migration due to major anthropogenic events is increasingly common in Sub-Saharan Africa. Unprecedented mineral and oil extraction is currently occurring in Africa, often in areas of high conservation importance. Additionally, conflict often plays a large role in human migration through refugee resettlement, and many people in the region are now moving in hopes of economic improvements. I used a mixed-methods approach to understand the landscape level impacts of industrial oil development, armed conflict, and human migration has had on the Murchison Falls Conservation Area (MFCA), in northwestern Uganda. Using land cover mapping, historical gridded population data, and stakeholder interviews, I assessed changes in land cover fragmentation and conversion in 2002-2014, and quantified changes in human population density in the districts surrounding MFCA in 1969-2014. I found that that the three oil-impacted districts have a unique and increasing population growth trend compared to the non-oil impacted districts and the national average of Uganda. Population density in oil-impacted districts increased by 73%, while non-oil impacted districts increased by 29%.

These districts were also marked with higher proportional increases in total developed land and land cover fragmentation in the natural land cover class compared to non-oil impacted districts. The communities in oil-impacted districts are facing distinct challenges related to land tenure security, human health, compensation, and inter-ethnic relations. Post-conflict repopulation and industrial agriculture growth also had a major impact on both agricultural expansion, as well as inter-community conflicts due to landholder rights and land grabbing. In the district of the study area most impacted by post-conflict regrowth, agriculture increased by 95% between 2002 and 2016. This study provides an increased understanding of how oil and other major anthropogenic events can shape and alter human-environment interactions outside of a globally important protected area.

CHAPTER 1

INTRODUCTION

Protected areas (hereafter PAs) in Sub-Saharan Africa (SSA) are arguably some of the most important reserves of biodiversity worldwide. They are also some of the most threatened (Newmark & Hough 2000; Brooks et al 2002; Newmark 2008; Brearley et al. 2013). High human population growth in poor, rural communities of SSA are one of the primary causes of habitat loss and fragmentation (Barbier 2004). Rural communities often have a high reliance on natural resources for their livelihoods (Adams & Hulme 2001; Otsuka 2001; Mayaux 2013), and convert grasslands, wetlands, woodlands and forests to agriculture and grazing land at a rapid pace.

Increasing human populations put added pressure on biodiversity and access to resources within and outside of PAs. However, the reasons for population growth surrounding PAs, along with the pace and scale of this growth, is a highly contentious topic (Wittemyer et al. 2008; Joppa et al. 2009). Some analyses of population density and change have found higher population densities and growth surrounding PA boundaries (Hartter et al. 2015). Others have found there to be no elevated population growth at PA borders, when compared to other areas of rural population growth within a region (Salerno et al. 2013). Some further suggest that population growth is likely a factor of family and social ties, rather than influence from the PA (Zommer & MacDonald 2012).

There are three general models that are used when studying population growth surrounding PAs: the attraction model, the incidental model, and the frontier engulfment model (Sholte and de

Groot 2009). The attraction model views the economic and social benefits provided by PAs to be drivers of increased population growth at their boundaries (Wittemyer et al. 2008). Benefits offered by PAs include employment, health related infrastructure from revenue sharing programs, and access to resource pools. Other studies have rejected claims of increased population growth at PA boundaries, and attribute these studies to inadequate and incorrect analyses and statistical techniques (Joppa et al. 2009). Rather, population growth surrounding PAs is the result of the existing human population centers expanding up to the PA boundaries (Joppa et al. 2009). Under the incidental model, populations surrounding PAs can grow by chance. Incidental reasons for migration to PA boundaries include being forcibly evicted from within the PA and relocating to the edges. In times of conflict, PAs become incidental areas of refuge (Hanes 2006; Debroux et al. 2007; Oglethorpe et al. 2007). Lastly, the frontier engulfment model occurs when an isolated protected area is developed by an extractive frontier and subsequent agricultural frontier (Sholte and de Groot 2009). An extractive frontier can include logging and/or mineral extraction, while an agricultural frontier includes cattle and cropping. In this model, increased population is first due to an increase in-migrant worker populations, which is subsequently followed by farmers who settle on the newly cleared land. Real world examples often involve multiple components of each of the three models.

PAs are becoming increasingly threatened by industrial oil and mineral development (Rabanal et al 2010; Prinsloo et al 2012; Coghlan 2014). According to a 2011 estimate, mining concessions now overlap 27% of world heritage sites (Osti et al. 2011). Increased overlap of mining concessions and world heritage sites marks an increased interaction between two competing land-uses. Mining infrastructure fragments and degrades natural habitat through the creation of roads and railways (Edwards et al. 2013), and in the most extreme cases, can result in

PA downgrading, downsizing and degazettement (PADDD) (Duran et al. 2013; Edwards et al. 2013). Downgrading occurs when governments reduce legal restrictions on the types of human activities occurring in Pas; downsizing occurs through a restructuring of PA boundaries to reduce the size and location of a PA; and degezettement is when all legal protections of a PA are removed (Mascia & Pailler 2011). Industrial extraction and development was responsible for the majority (37.5%) of all PADDD events in Africa, Asia, Latin America and the Caribbean between 1900-2010 (Mascia et al. 2014). Increased road and rail networks due to mining can also threaten PAs due to increased access to biodiverse regions (Laurance et al. 2009). Increased access near PAs can cause drastic change to land cover due to large migration of human populations into areas with little human population and footprint (Wilkie & Carpenter 1999; Wilkie et al. 2000; Laurance et al 2014).

Uganda is a prime example of the impacts mineral extraction and extreme population growth can have on important protected area landscapes. Within the country, oil development is coinciding with the IUCN category II Murchison Falls Conservation Area (MFCA). Commercially viable oil reserves in Uganda and the Lake Albert Nile were officially discovered in 2006. Initial estimates placed the reserves at 2.5 billion barrels of oil within the Ugandan Albertine Rift, with a projected daily yield of 200-350 thousand barrels per day. This estimate would make Uganda the fifth largest oil producer in Africa (Vokes 2012), and would garner approximately $2 billion USD per year over more than 20 years (Shepherd 2013). Recently, these estimates have been revised upward by 85% to 6.5 billion barrels (Biryabarema 2014). While an initial projected production date was slated for 2016 or 2017 (Barkan 2011), this has been pushed back until at least 2018 due to weakened global oil prices (Graeber 2015). The oil development within Uganda is of serious concern to conservationists and ecologists due to large reserves set to be recovered from within the IUCN category II Murchison Falls Conservation Area (MFCA).

In this thesis, I investigate the impacts of human population growth, industrial oil development, post-conflict regrowth, and changes to human livelihoods on landscape level change in the MFCA landscape. I define the MFCA landscape to include both the PA and a 5-km buffer surrounding the PA This thesis is arranged in 4 chapters. This first chapter provides a brief introduction to threats to protected areas. Chapters 2 and 3 are meant to be stand-alone manuscripts. Each of them contain literature review, a description of the study area, methods, analysis, and discussion. Chapter 4 provides concluding remarks, limitations of the study, and recommendations for further research.

More specifically, in chapter 2 I investigate the impact industrial oil development is having on the MFCA landscape to address three primary questions: 1) How has human population grown and where are localized hotspots of population growth around MFNP since oil development has started?; 2) Which districts surrounding MFNP have had the biggest changes in development, including fragmentation and land cover conversion?; and 3) How has oil development impacted the surrounding communities? To answer these questions, I first created gridded human population density datasets to track changes in population density by district between 1969 to 2014. I also created a binary natural and developed land cover classification for the years of 2002 and 2014. I used the binary classifications to track changes in developed and natural lands between pre-oil development (2002) and current (2014) conditions. The binary classifications were derived from the seven class land cover classifications created in chapter 3 of this thesis. Finally, I conducted group and key informant interviews to understand and highlight impacts of oil development on human livelihoods and population growth.

In chapter 3, I investigated the drivers of land cover change surrounding MFCA to answer two questions: 1) How has the landscape in and around MFCA changed in terms of land cover and landscape fragmentation between 2002 and 2014?; and 2) What are possible anthropogenic and cultural drivers of land cover change and natural land conversion outside of MFCA? To achieve this goal, I used Object Based Image Analysis (OBIA) to classify two Landsat satellite scenes. I used these two land cover maps to understand changes in land cover and fragmentation between 2002 and 2014 in two key areas of interest of the MFCA landscape: MFCA and a 5-km buffered area surrounding the PA. Additionally, I conducted group and individual key informant interviews in communities near MFCA to provide historical, social and cultural context to land cover change occurring outside of the PA. The interviews allowed me to attach a narrative to the change illustrated by the land cover maps.

CHAPTER 2

THE IMPACT OF INDUSTRIAL OIL DEVELOPMENT ON A PROTECTED AREA LANDSCAPE: A CASE STUDY OF MURCHISON FALLS CONSERVATION AREA, UGANDA

Abstract:

Understanding the drivers of human population growth and landscape fragmentation surrounding protected areas is vital to the success of conservation initiatives worldwide. Unprecedented mineral and oil extraction is currently occurring in Africa, often in areas of high conservation importance. I used a mixed-methods approach to understand the landscape level impacts of industrial oil development on the Murchison Falls Conservation Area (MFCA), in northwestern Uganda. Using land cover mapping, historical gridded population data, and stakeholder interviews, I assessed changes in both developed and natural land fragmentation and conversion in 2002-2014, and quantified changes in human population density in the districts surrounding MFCA in 1969-2014. I found that that the three oil-impacted districts have a unique and increasing population growth trend compared to the non-oil impacted districts and the national average of Uganda. Population density in oil-impacted districts increased by 73%, while non-oil impacted districts increased by 29%. These districts were also marked with higher proportional increases in total developed land and land cover fragmentation in the natural land cover class compared to non-oil impacted districts.

The communities in oil-impacted districts are facing distinct challenges related to land tenure security, human health, compensation, and inter-ethnic relations. This study provides an increased understanding of how oil can shape and alter human-environment interactions outside of a globally important protected area.

Introduction

Africa is currently undergoing record international investment and economic growth. Six of the thirteen fastest growing economies worldwide are found in Sub-Saharan Africa (Holodny 2015). Despite the global perception of increased investment risk due to political, social, technical, and environmental issues (Frynas & Paulo 2006), the continent's importance in the global oil and mineral market has been increasing faster than any other region of the world. This interest has sparked increased attention and competition between foreign investors and global petroleum companies, often leading to mineral extraction in and around ecologically important protected areas (PAs) (Osei & Mubiru 2010; Janneh & Ping 2011; Annan 2012).

Large industrial and extractive activities within PAs usually cause immense changes in the subsistence livelihoods of surrounding indigenous communities (Suárez et al. 2009). The surge in human population and the expansion of the human footprint in these rural landscapes can lead to an increase in illegal bush meat hunting and timber extraction. New roads and increased access near PAs open up new markets of economic activity, added land conversion for farms, and loss of biodiversity (Prinsloo et al. 2012). Large influxes of migrant worker populations could have dramatic impacts on land-use, human livelihoods, and ecosystems, both within and outside of PAs. Increased population pressure and land-use intensification surrounding PAs threatens PA sustainability (Cincotta et al. 2000), strains PA-neighbor relations because of crop raiding by PA-protected wildlife on adjacent farms (Mackenzie & Ahabyona 2012), and alters ecological function and biodiversity within PAs (Hansen & DeFries 2007).

Increasing human populations has put added pressure on biodiversity and access to resources within and outside of PAs. However, the reasons for population growth surrounding PAs, along with the pace and scale of this growth, is a highly contentious topic (Wittemyer et al.

2008; Joppa et al. 2009). Some analyses of population density and change have found higher population densities and growth surrounding PA boundaries (Hartter et al. 2015). Others have found there to be no elevated population growth at PA borders, when compared to other areas of rural population growth within a region (Salerno et al. 2013). Some further suggest that population growth is likely a factor of family and social ties, rather than influence from the PA (Zommer & MacDonald 2012).

There are three general models that are used when studying population growth surrounding PAs: the attraction model, the incidental model, and the frontier engulfment model (Sholte and de Groot 2009). The attraction model views the economic and social benefits provided by PAs to be drivers of increased population growth at their boundaries (Wittemyer et al. 2008). Benefits offered by PAs include employment, health related infrastructure from revenue sharing programs, and access to resource pools. Other studies have rejected claims of increased population growth at PA boundaries, and attribute these studies to inadequate and incorrect analyses and statistical techniques (Joppa et al. 2009). Rather, population growth surrounding PAs is the result of the existing human population centers expanding up to the PA boundaries (Joppa et al. 2009). Under the incidental model, populations surrounding PAs can grow by chance. Incidental reasons for migration to PA boundaries include being forcibly evicted from within the PA and relocating to the edges. In times of conflict, PAs become incidental areas of refuge (Hanes 2006; Debroux et al. 2007; Oglethorpe et al. 2007). Lastly, the frontier engulfment model occurs when an isolated protected area is developed by an extractive frontier and subsequent agricultural frontier (Sholte and de Groot 2009). An extractive frontier can include logging and/or mineral extraction, while an agricultural frontier includes cattle and cropping. In this model, increased population is first due to an increase in-migrant worker populations, which is subsequently followed by farmers who settle on the newly cleared land. Real world examples often involve multiple components of each of the three models.

Uganda is an important exemplar of mineral extraction in Sub-Saharan Africa, whereby it stands to have impacts on livelihoods, biodiversity, and the conservation landscape. The increased value of land, potential economic growth, and prospect of employment has driven human migration to the hotspots of oil in western Uganda (Uganda Lands Alliance, 2011). While oil exploration is relatively recent, it is located primarily in and near PAs. The proximity to PAs marks an increased interaction between two competing land-uses. Mining infrastructure fragments and degrades natural habitat through the creation of roads and railways (Edwards et al. 2013), and in the most extreme cases, can result in PA Downgrading, Downsizing and Degazettement (PADDD) (Duran et al. 2013; Edwards et al. 2013). Industrial extraction and development were responsible for the majority (37.5%) of all PADDD events in Africa, Asia, Latin America and the Caribbean between 1900-2010 (Mascia et al. 2014). Increased road and rail networks due to mining can also threaten PAs due to increased access to biodiverse regions (Laurance et al. 2009). Increased access near PAs can cause drastic change to land cover due to large migration of human populations into areas with little human population and footprint (Wilkie & Carpenter 1999; Wilkie et al. 2000; Laurance et al. 2014).

Commercially viable oil reserves in Uganda and the Lake Albert Nile were officially discovered in 2006. Initial estimates placed the reserves at 2.5 billion barrels of oil within the Ugandan Albertine Rift, with a projected daily yield of 2-3.5 thousand barrels per day. This would make Uganda the fifth largest oil producer in Africa (Vokes 2012), and would garner approximately $2 billion USD per year over more than twenty years (Shepherd 2013). Recently, these estimates have been revised upward by 85% to 6.5 billion barrels, and Tullow Oil has estimated that Uganda could earn up to $50 billion from the reserves (Biryabarema 2014). While an initial projected production date was slated for 2016 or 2017 (Barkan 2011), this has been pushed back until at least 2018 due to weakened global oil prices (Graeber 2015).

Local communities surrounding PAs in Uganda face complex challenges, which could be exacerbated by wildlife displacement caused by seismic and industrial oil development activities. Crop-raiding in Uganda near PA boundaries is a widespread problem (Kagoro-Rugunda, 2004; Hartter 2009; Mackenzie & Ahabyona 2012). This is a conservation concern, due to the importance of support from the local human population to make successful elephant conservation possible. Frustrations due to human-wildlife conflict can induce local people to kill the raiding species (Sitati 2007). This is particularly germane at MFCA, as the elephant population is reportedly increasing (Rwetsiba & Nuwamanya 2010). There have been considerable reports of crop raiding from communities surrounding Murchison Falls National Park (MFNP) (Marais et al. 2013), which has been identified as one of the factors contributing most strongly to illegal hunting (MTWA 2012; Olupot et al. 2009). This situation is important to note, since oil development has the potential to shift elephant ranges to peripheral areas of PAs due to loud noise and seismic activities (Borasin et al. 2002; Rabanal et al. 2010; Prinsloo et al. 2012). This may help to explain recent reported increases in crop-raiding and migration of elephants to peripheral areas of MFNP, especially true in areas with increased human population since oil development began (Emorut 2014a).

To date, there have been limited independent (i.e., not contracted or conducted by stakeholders) assessments on oil development near and in Uganda’s PAs. Therefore, it is important to provide a baseline perspective and assessment of short-term landscape change in order to understand the potential long-term impacts to this highly sensitive region. This study addresses three main questions: 1) How has human population grown and where are localized hotspots of population growth around MFNP since oil development has started?; 2) Which districts surrounding MFNP have had the biggest changes in development, including fragmentation and land cover conversion?; and 3) How has oil development impacted the surrounding communities?

Study Area

Established in 1952, Murchison Falls Conservation Area (MFCA) is located within the Albertine Rift, a biodiversity hotspot that is highly threatened because of enormous human population growth and land conversion to agriculture (Fisher & Christopher 2007). The conservation area includes four different PAs (Figure 2.1), with varying levels of protection status: 1) Murchison Falls National Park (MFNP, IUCN Category II, 3,840 km^2); 2) Bugungu Wildlife Reserve (BWR, IUCN Category III, 748 km^2); 3) Karuma Wildlife Reserve (KWR, IUCN Category III; 720 km ^{2}); 4) Budongo Forest Reserve (BFR, IUCN Category III, 825 km^2). MFNP is one of seven Ugandan national parks located within the Albertine Rift, and is predominantly a savannah-woodland landscape, but also includes wetland and tropical forest habitats. Its habitats are considered highly irreplaceable (Hartley et al 2007). It is also home to 780 species of birds, mammals, reptiles, amphibians, and plant species (Plumptre et al. 2003), and it is of great ecological importance due to the presence of numerous globally and regionally threatened species (NEMA 2009). The only remaining, naturally occurring population of the Rothschild's Giraffe (*Giraffa camelopardalis* rothschildi), an endangered subspecies with fewer than 470 wild individuals left, is present within MFCA (Fennessy & Brenneman 2010).

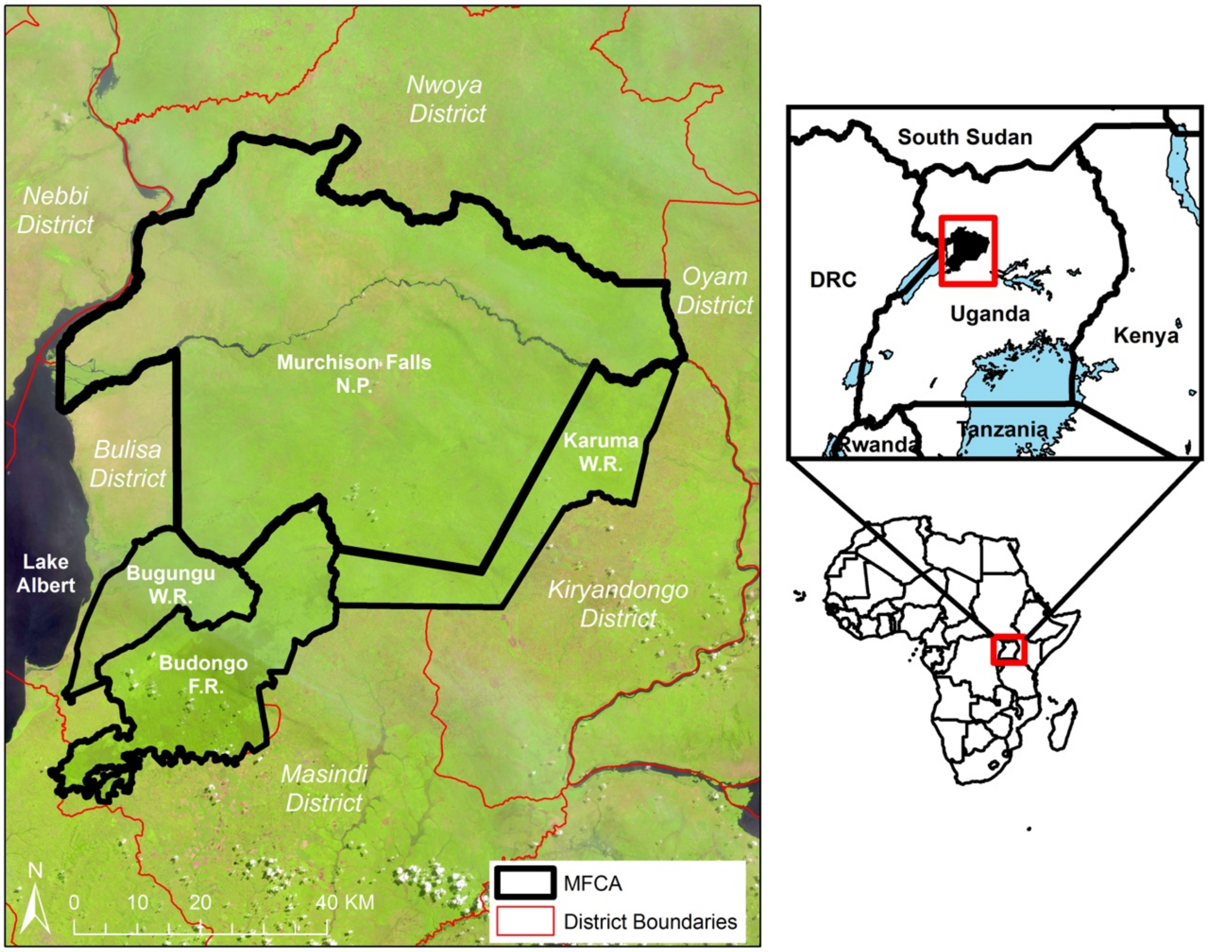

Figure 2.1: Landsat 8 Natural Composite image (Bands 4,3,2) Murchison Falls Conservation Area (MFCA) landscape, consisting of four separate parks: 1) Murchison Falls National Park, 2) Bugungu Wildlife Reserve, 3) Budongo Forest Reserve, 4) Karuma Falls Wildlife Reserve. The districts bordering the park are also shown: Bulisa, Kiryandongo, Masindi, Nebbi, Nwoya, Oyam.

Multiple ethnic groups live within the greater MFCA landscape. The ethnic groups with the highest proportion of residents in each district are the Alur and Jonam in Nebbi (Figure 2.1), the Acholi in Nwoya, the Langi in Oyam and Kiryandongo districts, the Bunyoro and Bagungu in both Bulisa and Masindi Districts. Between 1986 and 2006, Nwoya district was caught in a long running civil war with the Lord’s Resistance Army (LRA). During this time, many people moved into Internal Displaced Person (IDP) camps, sought refuge in major towns like Gulu, or relocated to other districts within the country. The conflict greatly changed the human landscape, resulting in an estimated 66,000 children who were abducted (US Department of State 2012), along with an additional 1,700,000 people displaced between 1986 and 2007 (UNOCHA 2005). Since the LRA left the area in 2006, the area has experienced a regrowth of the human population, as people formerly in IDP camps have returned to this area, and people from outside districts have migrated to the area seeking available land and economic opportunity.

Methodology

I used a mixed methods approach to understand changes in human livelihoods, human migration, and the increase in developed land surrounding the MFCA. I achieved this through the use of group and key informant interviews, the creation of census-based historical gridded population data, and two binary land cover maps for the years of 2002 and 2014.

Historical Gridded Population Change Analysis

It is difficult to track changes in historical populations in Africa, largely due to the lack of high quality spatial data. Changes and adjustments to administrative boundaries, as well as the creation of new administrative zones, inhibit the ability to use raw census data to compare changes in population density within an administrative unit through time (Gould 1995). Therefore, I created gridded population datasets to track spatio-temporal changes in human population density for each district surrounding MFCA on census years between 1969 and 2014. I used official Ugandan census data to create ~1 kilometer gridded rural population density data for the years 1969, 1980, 1991, 2002, and 2014. Administrative boundaries were georeferenced (WGS 84) to the smallest possible administrative unit below the district level for each year using historical maps. The maps were obtained from the National Archives, the Surveys and Mapping Department Headquarters, and Uganda Bureau of Statistics (UBOS). I input census population data into the GIS attribute table for each of the administrative regions for each year. I then adjusted population density data to achieve rural population density in three ways: 1) waterbodies were removed, due to lack of human habitation; 2) PAs were removed, since by law no one can live within a PA (although there are some exceptions); so it was assumed that no humans live within their boundaries; 3) both population counts and area in urban areas were removed, since my area of interest is exclusively rural areas.

In order to calculate the area of each of the resulting administrative polygons (km^2), the data were projected into Africa Alber's Equal Area Conic Projected Coordinate System. Population density was subsequently calculated by dividing the total human population of each polygon by total polygon area to achieve people per km^2 within ArcGIS 10.3. The resulting polygons were then projected back to the WGS 84 Geographic Coordinate System. A vector-to-raster conversion was used to create the gridded data, using the maximum area function (population density values that covered the majority of an individual pixel was assigned). Each raster was resampled to 1-km pixels. The mean population density value was then calculated for each 2014 district boundary for each census year to analyze change in population through time.

Land Cover Mapping and Fragmentation Analysis

In order to simplify the illustration of the impacts of oil development on the natural landscape, I recoded the original 7 class land cover map created in chapter 3 of this thesis into a binary classification of developed and natural landscapes. By reducing the number of classes in the map, it is easier to understand and interpret the total increase in developed land and reduction of natural lands within the study area. The 2 classes included in the binary land cover classification are as follows:

1. **Developed**: Developed, Agriculture/Village-Agriculture Mosaic.
2. **Natural**: Water, Savanna Woodland, Closed Shrub Thicket, Forest, Wetland, Grassland, Savanna Grassland, Open Shrubland.

Spatial pattern and changes can be assessed through time to monitor changes. The monitoring and measurement of landscape level patterns is in increasing demand due to the idea that ecological pattern can predict and is linked to ecological processes (Gustafson 1998). After recoding the classifications, I used the software Fragstats (McGarigal 2012) to understand changes in total land cover and fragmentation in the developed and natural land cover classes within each district surrounding MFCA. Fragstats uses spatial statistics to describe the spatial pattern of thematic land cover maps at the landscape, class and patch level. I calculated the following three metrics (1 class level and 2 patch level metrics) for each individual district for each individual date of imagery:

1. **Class Area and Percentage of Landscape:** How much of the landscape is comprised of a class type;
2. **Number of Patches:** Number of individual patches within a class type;
3. **Mean Patch Size:** The average of the size of each patch within a class type.

Group and Key Informant Interviews

I used semi-structured group and key informant interviews to understand the context and drivers of human population growth and natural land conversion in this area of Uganda, and what anthropogenic events have had the most significant impact on land cover change. The key informant interviews were conducted with local government officials: Local Council 1 (LC1, village) chairperson, Local Council 2 (LC2, parish) chairperson, Local Council 3 (LC3, sub-county) chairperson, Local Council 5 (LC5, district) chairperson, Resident District Commissioner (RDC), and District Security Officer (DiSO). A local enumerator and interpreter was hired to translate the questions and subsequent responses between English and various local languages (e.g., Runyoro, Luo, Swahili, Luganda) spoken among the community members. The interview questions covered topics of marriage, migration, and the importance of human population growth on local communities and the landscape. Locations of the interviews were selected opportunistically, based on village and town proximity to MFCA boundary (≤5km) and availability of the government officials.

I received all appropriate permissions from Uganda Council for Science and Technology, the Office of the President, and also district, sub-county, and village, prior to initiating each interview. I also received approval from the Institutional Review Board for the Protection of Human Subjects in Research (IRB# 5405). After I completed a key informant interview with the

LC1 chairman, the LC1 chairman recruited a group of 10 village residents, half men and half women, to participate in the group interview, which generally occurred the following day. However, due to the community-oriented nature within this region, I often had higher participation within communities, and a higher proportion of men than women participating in the interview. Transcripts of each interview were coded into a two-level coding structure. For instance, the first level oil development theme was further separated into subsets of employment, pollution, and compensation. After the transcripts were coded, thematic interpretations of the interviews were created to provide a narrative of influences on land cover change and population growth within and outside of MFCA.

Results

Population Change Analysis

Human population growth showed spatial variation (Figure 2.2). Each district surrounding MFCA exhibited unique changes in population density between each census years (Figure 2.3). Raw population density values for each district are given in Table 2.1, and percent change in population density between census years in Table 2.2. There was a large difference in population density growth between the oil-impacted districts of Bulisa, Nebbi, and Nwoya, and the non-oil-impacted districts of Kiryandongo, Oyam, and Masindi between 2002 and 2014.

All three oil-impacted districts had different trajectories in population between the 1969 and 2002 census dates. However, all three oil-impacted districts had large increases in population density between 2002 and 2014 when compared to historical trends. In Bulisa, there was slower growth in population density in each census year between 1969 and 2002. For instance, between 1969 and

1980, the population density in Bulisa increased by 56.54%. Then, between the next two census dates, population density decreased by 38.87%. Between the 1991 and 2002 census years, population density increased by 31.63%. By the 2014 census year, population density increased by 65.24%. In Nebbi District, change in population density increased steadily in all census years. Between 1969 and 1980, the population density of the district increased by 9.10%. By 1991, it had increased by 25.09%, and then by 2002 it increased another 30.07%. Between 2002 and 2014, population density increased by 61.10%. Between 1969 and 1980, Nwoya District had a 14.44% growth in population density. At the 1991 census, the population density decreased by 32.03%. In 2002, the population density started to rise again, with an increase in population density of 8.06%. Finally, by 2014, the population density started to grow at a very fast rate, increasing by 169.9% from 2002.

In general, non-oil impacted districts have exhibited slower growth in the most recent census. Between 1969 and 2002, the population density in Kiryandongo increased by 15.35%. By 1991, there was a 62.56% increase in population density. Between 1991 and 2002, the population density of Kiryandongo increased substantially by 124.39%, before the district experienced a highly reduced rate of growth in population density between 2002 and 2014 of 5.73%. Between 1969 and 1980, Masindi's population density increased by 67.09%. This followed a muted growth between 1980 and 1991 of 11.12%, before there was a more defined growth of 52.39% between 1991 and 2002. Between 2002 and 2014, there was a 38.52% increase in population density within the district. Finally, Oyam experienced a 60.86% increase in population density between 1969 and 1980. Between 1980 and 1991, the district's growth rate reduced to 46.15%, before increasing slight in the 2002 census to 51.62%. Between 2002 and 2014, Oyam's population density increased by 41.46%.

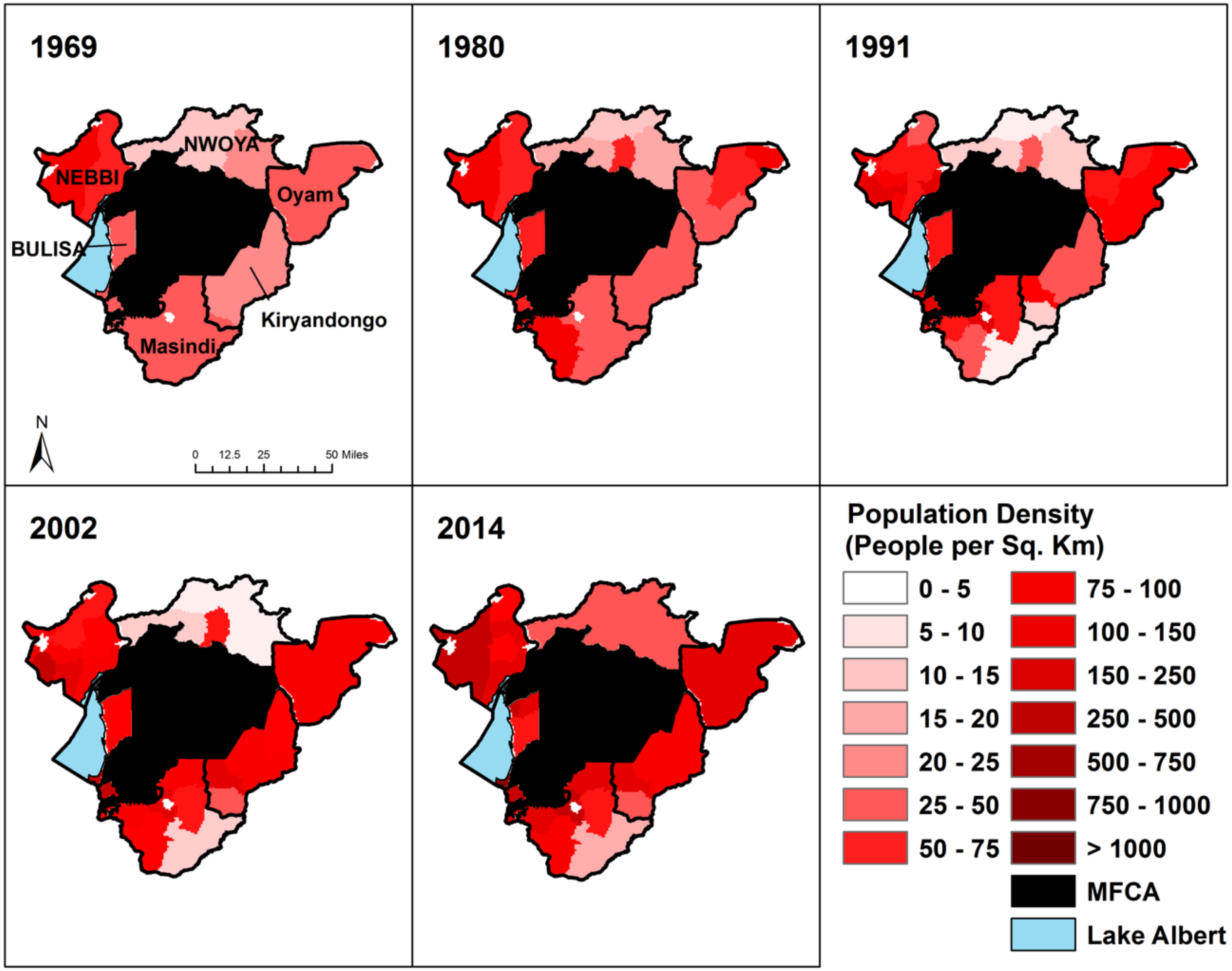

Figure 2.2: Population density in the six districts surrounding Murchison Falls Conservation Area, between 1969-2014. Oil-impacted districts denoted by all capital letter, while non-oil-impacted districts are denoted by lowercase names.

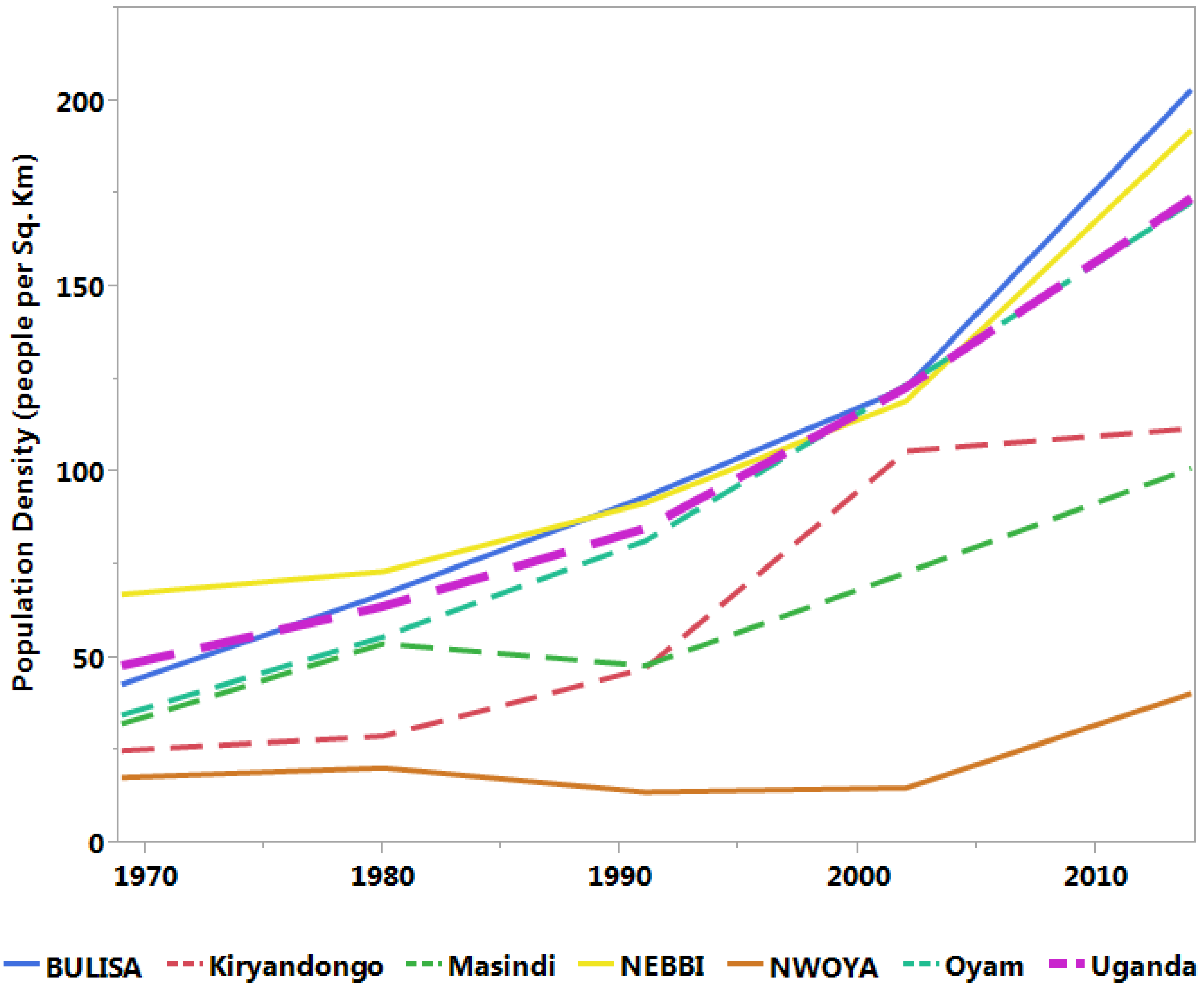

Figure 2.3: Population density in the six districts surrounding Murchison Falls Conservation Area, between 1969-2014. Oil-impacted districts denoted by all capital letter names and non-dashed line, while non-oil-impacted districts are denoted by lowercase names and dashed (---) line.

Table 2.1: Population density values for each district surrounding Murchison Falls Conservation Area, as well as Population Density for the entire country of Uganda for comparison, for each census year between 1969 - 2014. Oil-Impacted districts denoted by all capitalized and bolded names.

Year	**BULISA**	Kiryandongo	Masindi	**NEBBI**	**NWOYA**	Oyam	Uganda
1969	42.98	25.15	32.3	67.25	17.87	34.7	48
1980	67.28	29.01	53.97	73.37	20.45	55.82	64
1991	93.43	47.16	47.97	91.78	13.9	81.58	85
2002	122.98	105.82	73.1	119.375	15.02	123.69	123
2014	203.21	111.88	101.26	192.31	40.54	172.88	174

Table 2.2: Percent change in population density for each district surrounding Murchison Falls Conservation Area, and all of Uganda for comparison, for each census year between 1969 - 2014. Oil-Impacted districts denoted by all capitalized and bolded names.

Year	**BULISA**	Kiryandongo	Masindi	**NEBBI**	**NWOYA**	Oyam	Uganda
1980	56.54%	15.35%	67.09%	9.10%	14.44%	60.86%	33.33%
1991	38.87%	62.56%	11.12%	25.09%	-32.03%	46.15%	32.81%
2002	31.63%	124.39%	52.39%	30.07%	8.06%	51.62%	44.71%
2014	65.24%	5.73%	38.52%	61.10%	169.91%	39.77%	41.46%

L*and Cover Change and Fragmentation*

Land cover conversion and fragmentation varied considerably across the districts (Figure 2.4; Table 2.3) surrounding MFCA, with oil-impacted districts having the highest loss of natural land cover, along with largest increases in developed land cover. Additionally, all oil-impacted districts had higher proportional increase in natural area patches compared to the non-oil-impacted districts, representing increased fragmentation. All land cover change metrics are measured in proportional change, whereby the 2014 metric value for each land cover was subtracted from the 2002 metric value, then subsequently divided by the 2014 metric value.

Oil-Impacted Districts

Nwoya District had the highest proportional increase in development out of all districts at +116.34, with a proportional decrease in natural area of -0.3. Nwoya also had the highest proportional change in both developed and natural patches at +2.11 and +2.19, respectively. Additionally, Nwoya had the largest proportional decrease in mean patch size in both the natural and developed classes at -0.77 and -4.44, respectively. In Bulisa, the proportional increase in developed land was +0.27, while there was a proportional decrease in natural land of -0.13. Proportional patch area increased by +0.68 in the natural class and +1.43 in the developed class in Bulisa. The proportional change in mean patch size in Bulisa decreased by -0.48 in the natural class and -0.48 in the developed class. In Nebbi, there was a proportional decrease in total area of the natural class by -0.17, and a proportional increase in developed area by 0.21. Proportional change in patch number increase by 0.41 in the natural class, and 1.09 in the developed class. Finally, the proportional change in mean patch size in Nebbi decreased in both the natural and developed classes by -0.41 and -0.42, respectively.

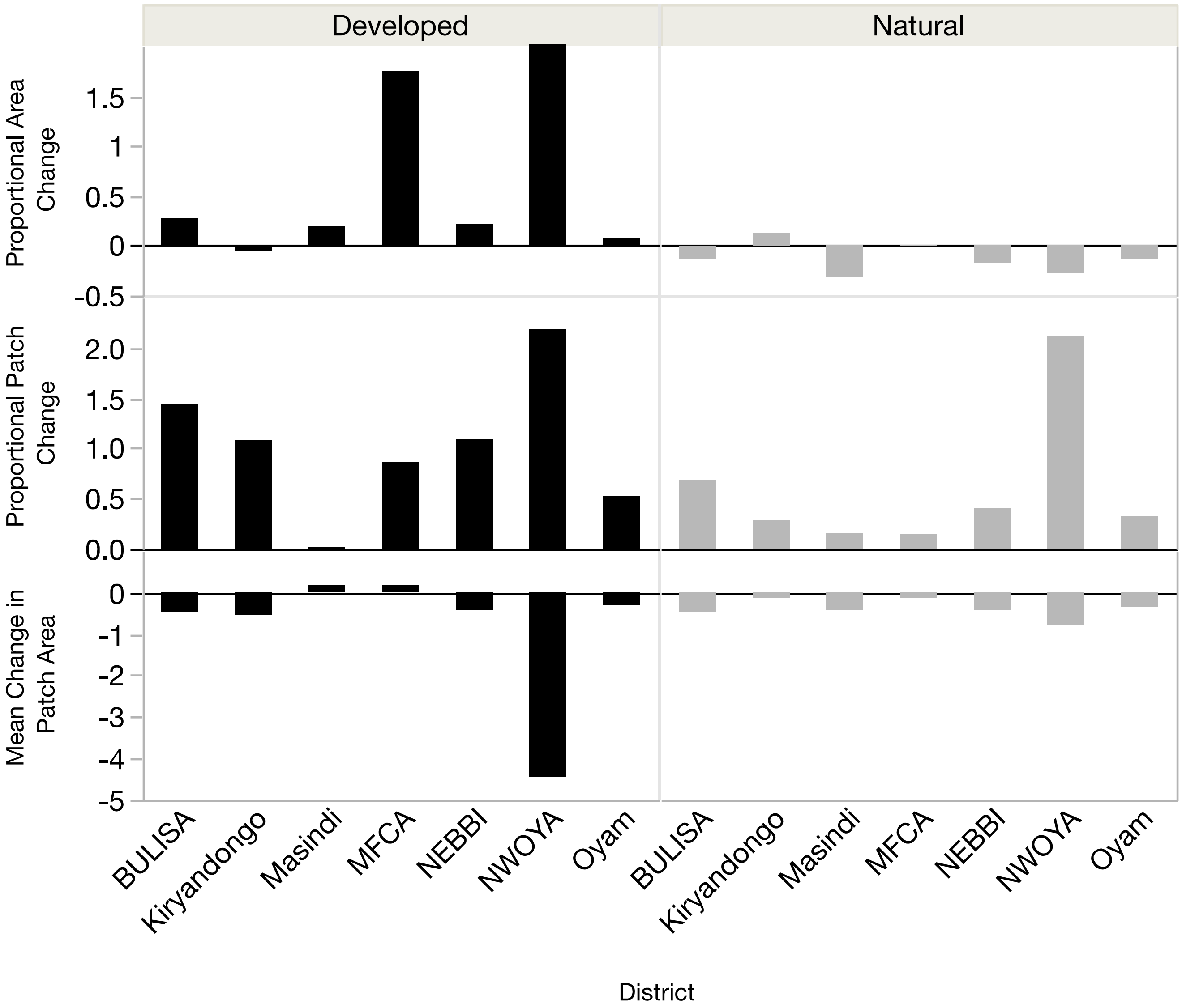

Figure 2.4: Proportional change in landcover type (D/N), proportional change in total patches, and proportional change in mean patch area for the developed and natural classes between 2002-2014 for all six districts surrounding Murchison Falls Conservation Area. Oil-impacted districts denoted by all capital letter name, while non-oil impacted districts are denoted by lower-case names.

Table 2.3: Proportional change in total area (TA), total patches (TP), and mean patch size (MPS) for natural (N) and developed (D) landcover classes (LC) for each district surrounding Murchison Falls Conservation Area between 2002-2014. Oil-Impacted districts denoted by all capitalized and bolded names.

	BULISA		Kiryandongo		Masindi		**NEBBI**		**NWOYA**		Oyam		MFCA	
LC	N	D	N	D	N	D	N	D	N	D	N	D	N	D
TA	-0.13	0.27	0.12	-0.05	-0.32	0.19	-0.17	0.21	-0.28	116.34	-0.14	0.08	-0.01	1.75
TP	0.68	1.43	0.28	1.08	0.16	0.02	0.41	1.09	2.11	2.19	0.33	0.52	0.15	0.87
MPS	-0.48	-0.48	-0.12	-0.54	-0.41	0.17	-0.41	-0.42	-0.77	-4.44	-0.35	-0.29	-0.13	0.17

Non-Oil-Impacted Districts

In Masindi, there was a proportional increase in developed land of +0.19, and a proportional decrease in natural land of -0.32. Proportional change in total patches in the natural and developed class were +0.16 and +0.02, respectively. Additionally, there was a proportional decrease in mean patch size in the natural class of -0.41, and a proportional increase in the developed class of 0.17. Kiryandongo had a proportional increase in natural class of 0.12, and a proportional decrease in the developed class of -0.05. Kiryandongo also became increasingly fragmented, with a proportional increase in total patches in the natural and developed classes of 0.28 and 1.08, respectively. Mean patch size decreased for both the natural and developed classes at -0.12 and -0.54, respectively. Finally, Oyam had a proportional decrease in natural area of -0.14, and a proportional increase in developed area of 0.08. Total patches in Oyam increased proportionally in both the natural and developed classes by 0.33 and 0.52, respectively. Proportional mean patch size decreased by -0.35 in the natural class and -0.29 in the developed class.

Group and Key Informant Interviews

I conducted a total of 37 interviews, including 13 group interviews, along with key informant interviews with 15 LC1, 1 LC1 Secretary, 4 LC3, 1 LC5, 1 District Security Officer, 1 NGO, and 1 UWA official. The total group interview participants included 171 Men and 112 Woman, averaging 13 men and 9 women per interview. The percentage of women in the group interviews ranged from 21-66%. The majority of respondents were either farmers or fishermen. The amount of discussion among group participants and government officials regarding oil development varied by district. It became apparent from the interviews that the oil activities were having large effects on Bulisa, Nebbi, and Nwoya Districts, with minimal impacts on the districts of Kiryandongo, Masindi, and Oyam.

Migration and land conflict due to oil development

In the interviews, we found that migration was a common theme related to oil development, where people from outside of the oil-impacted districts have immigrated to the area in hopes of purchasing land to gain royalties and other benefits. In fact, all group interviews in the oil impacted districts cited oil development as a cause for migration. On the other hand, non-oil impacted districts were more likely to discuss natural population increase and refugee migration as reasons for population growth. Residents within the three oil impacted districts have also been selling their land cheaply to investors, and are often left regretting their decision when the money is inevitably spent and they are left with no land. As one LC5 stated:

> *Oil has also affected us and the land. People think that oil is in the community, but for now, oil is in the park. People were anticipating oil in the land, and had big dreams of becoming rich. They would purchase land in hopes of royalties from the oil companies finding oil on their land. This attracted people from other parts of the country to buy land, and speculators have purchased small plots up to the Nile...People are heading towards danger. They are selling their land very cheaply because they want to get money. This will cause problems for the next generation, because they will have nothing, nowhere to settle.*
>
> -LC5, June 27, 2014

Additionally, land grabbing has become a concern to many in the oil-impacted regions. Land grabbing is when domestic or international companies, governments, or individuals lease or purchase large plots of productive land from locals, often in a manner that skirts the customary system of the local community.

> *There has been grabbing of oil wells and land by rich men and these oil companies. I have an oil well on my land, and a rich man comes to buy my land, and I tell him I am not selling. He finds someone else who says he owns the land, and he returns to my place with all of the papers saying he owns the land.*
>
> -LC1, July 10, 2014

In addition to land grabbing and selling land, some communities claim that when they do not cooperate with the district's desire for the community owned land to be sold to oil companies, they are often shunned ignored by the district. This was especially prevalent in the group interviews that occurred in Bulisa District.

> *In this area even the government doesn't [care about] us, even district doesn't [care]. The district takes [us] as strangers because they refused to sell to the oil. District leaders want them to sell to the wells. The people are not in good condition because of the district.*
>
> -Focus Group, July 26, 2014

Inadequate Compensation Schemes

One of the most frequently discussed topics by group participants was compensation. Many participants said the compensation scheme for reimbursement of property damage is inadequate, in both monetary reimbursement and logistics. A common theme in many of the areas impacted by oil development is the lengthy time it takes for the oil companies to evaluate, and finally reimburse, those who had damaged land and crops due to surveying and seismic activities. Many villages gave estimates of having to wait up to a year for reimbursement for property and crop damage to come through, which they considered to be an additional hardship on their subsistence-based livelihoods. While many of the groups considered the compensation amount to be inadequate, one LC3 pointed out that the compensation prices are negotiated through the district, and he felt that the districts and central government need to be held more accountable for the low compensation rates.

> *A major problem was compensation. The district is in charge of the rates, however. We are taking our district to revise the rate. I don't blame the oil workers; I have no problem with them. They are working on behalf of the government of Uganda.*
>
> -LC3, June 25, 2014

Lack of Employment

An additional theme common within active oil districts was lack of local employment by the oil companies. Oil companies are mainly hiring locals as casual laborers, of which the contracts last only a matter of weeks. Casual jobs include those that are physically oriented, not requiring expertise within the oil sector. Respondents felt that in addition to lack of employment, the companies are unwilling to purchase goods and food from local farmers, and rather ship the food in from Kampala. Government officials were quick to cite the lack of adequate training and certification of their local communities for technical jobs, leading to the importation of workers from Kampala and abroad. One LC3 stated that there should be more programs that work to train local residents, and to sensitize them on how to pursue the oil related careers.

> *Few are recruited as casual laborers. We don't have the skills here. No Ugandans were going to school about oil, so unskilled labor is all there is.*
>
> -LC3, June 25, 2014

However, there have been programs put into place by NGOs working to bridge the education and awareness gap in the communities, with hopes of fostering employment among the local communities, and building an understanding among local residents on what skills are needed and how to find the job postings.

> *There are 2 NGOs seriously trying. One is RICE…* [Rural Initiative for Community Empowerment, http://riceuganda.org]. *They move around and advocate and link people with the oil companies.*
>
> -LC3, June 25, 2014

A few areas, mainly in Nebbi District, had high expectations of oil benefits, only to be disappointed by dry wells. This created strain between local communities and oil companies. In particular, one LC3 in Nebbi District discussed how all the wells surrounding his region have turned up dry, leading to high levels of disappointment among residents.

> *We at times say oil is a curse. Here, there is no oil found so far. They have only hit dry wells. Crops have been destroyed, and someone's land was used, and that person has not benefited. There has been no benefit apart from business people.*
>
> -LC3, June 25, 2014

Prostitution and Disease Transmission

Social issues, such as prostitution, were also cited as a result of the oil industry. In the oil producing regions (particularly Nebbi and Bulisa Districts), many people spoke of increases in prostitution. This is largely due to female sex workers moving to the area and pushing up prostitution rates higher than in other areas of the country, largely driven by the increased spending power that the oil workers bring to the area. Additionally, respondents in oil producing regions feel that oil workers are bringing sexually transmitted diseases to the area.

> *When money saturation is high — the girls who have studied but are without jobs, rush to the areas of money saturation and sell themselves for prostitution. If you go to Pakwach, it is there. There are some lodges there. The culture is changing. It used to be that men would only sleep with their wives. I don't know if you can call it development.*
>
> -UWA Official, May 24, 2014

> *There is a high rate of prostitution. We have intervention concerning AIDS from AMICAALL [Alliance of Mayors and Municipal Leaders for Community Action on AIDS at the Local Level]. When the oil people came, the cost of commercial sex*

> *workers increased, in many ways doubling. This made many people from Congo, Arua, Gulu want to come and target the oil people for their commercial sex work, since they could charge much more than other areas.*
>
> -LC3, June 25, 2014

> *There is also high spread of diseases. Men who work for the oil companies use our sisters. Infection, they have been brought this way.*
>
> -Focus Group, July 26, 2014

Women's Education and Teen Pregnancy

Multiple group interviews in oil-impacted districts also raised the impact the influx of oil workers have had on women's education. Oil workers who move to these areas meet local women and impregnate them. One LC1 said that the workers then go back to their homes, never to be heard from again, while the female then has to drop out of school to take care of the child, and often faces backlash and shame from family and friends.

> *They come from Kampala without wives, and they are not marrying them, just do business with them and leave them like that. Ladies are dropping out of school because of this, impregnated, and those men run away.*
>
> -LC1, July 10, 2014

Discussion

The MFCA landscape represents a complex and rapidly changing region. Two major events have had a large impact on human migration and population growth within this area. The first is due to the large refugee populations that entered the area from leaving the LRA occupation of northern Uganda. Additionally, refugees from conflicts in the eastern Democratic Republic of the Congo (DRC) have settled in the area. A large number of refugee camps are located within the district of Kiryandongo (UNHCR 2015). Increased refugee population has led Kiryandongo to have a unique growth in population density between the 1992 and 2002 census, differing from the Uganda-wide average. The large spike in population density within the non-oil impacted district leveled off between the 2002 and 2014 census. The low growth in Kiryandongo between the 2002-2014 period is likely due people returning to northern districts of Uganda (such as previously unstable Nwoya District). Additionally, as the security situation in the Eastern DRC has improved, Congolese refugees have started to return to their home country (UNHCR 2015). The rebel activity also explains the low population growth rates in Nwoya District between 1982 and 2002, when the LRA had its largest and most threatening presence in the area. The population in Nwoya has rebounded since security returned to the area in 2006.

The second event that has had a major demographic impact on this region is the discovery of oil in 2006. While human population growth in the non-oil impacted districts followed the national average of Uganda since 2002 (Fig. 3), average growth rates in the oil-impacted districts (73%) were much higher than non-oil districts (29%). Greater land cover change and fragmentation was also found in oil-impacted districts, manifesting as higher proportional increase in total patches, decrease in patch size and patch area, and increased isolation of natural areas compared to non-oil impacted districts. Since the developed landscape class included both agriculture and infrastructure (including roads), the oil districts are increasingly fragmented due to increases in roads and growth in small-holder agriculture. A likely driver of this fragmentation is an influx of migrants to the area. Conversely, the non-oil-impacted district of Masindi had a higher proportional decrease in natural area compared to any other district. Masindi also had a much smaller increase in total patches in both classes, and an increase in patch size of the developed class. The type of fragmentation exhibited in Masindi is much different from all other districts in this study. Fragmentation seen in Masindi may illustrate the impacts of commercial sugarcane agriculture within Masindi, or outgrowth from Masindi Town Center (currently the fourth fastest growing municipality in Uganda between 2002 and 2014, at 8.9% growth). Outgrowth of the large sugarcane plantations would likely show up as much less fragmented on fragmentation metrics than subsistence agricultural growth (large areas of converted swaths, rather than of smaller, fragmented fields).

Industrial and development activities often bring agricultural expansion through increased road networks and access to locations that were previous difficult to reach (Wilkie et al. 2000). In areas where population growth, agricultural potential, and biodiversity are high, increased access to isolated areas can create regions where development can be detrimental to important ecological areas (Laurance et al 2014). Agricultural expansion due to increased road networks fits within the results of my study, as the oil-producing districts had the highest proportional increase in both road network and conversion of natural land. Much of the areas with higher proportional conversion of natural lands straddled new roads often in areas that were likely difficult to access prior to road expansion (highlighted in Figure 2.5 inset A). This figures illustrates a new road with development straddling it in 2014 that was absent in 2002. While literature that specifically connects oil development to the growth of agricultural corridors is sparse, this study highlights agricultural expansion as an additional potential indirect impact of new roads. Isolation (also known as islandization) of PAs in the areas surrounding PA boundaries reduces the ability of PAs to maintain ecological processes and maintain species richness (DeFries et al. 2005). Since much of this land conversion is occurring at PA boundaries, the roads from oil development could further lead to the isolation of MFCA. PA Isolation is an issue of road development, population growth, and agricultural land cover conversion continent-wide (Newmark 2008). The high rates of natural land conversion and human population growth within a 5km radius outside of MFCA in the oil-impacted districts shows the impact human activates are having in further isolating MFCA.

Oil and mineral extraction and development in remote areas of developing countries (such as PAs) can lead to new makeshift mining communities. These new population centers can influence increases in the sex worker industry due to demand created by the large increases in migrant worker populations (US Department of State, 2015). Increased incidence of HIV cases has been on the rise in many mining areas in West Africa (Amponsah-Tawaiah & Dartey-Baah 2011), Southern Africa (Muchadenyika 2015), Central Africa (Jobin 2003), and South America (McAnarey, 2013). While the Ghana AIDS Commission (2012) suggests that there is a lack of empirical evidence to support the idea of increased HIV risk among mining towns in Ghana, the migration of people from areas of high risk areas of HIV/AIDS and other sexually transmitted infections, such as urban city centers, to rural mining communities, could increase transmission risks (Obeng-Odoom, 2014). The Uganda Land Alliance (2011) reported that Bulisa District had a large increase in prostitution due to oil development. Increased prostitution and disease incidence and risk were frequently mentioned themes by both government officials and focus group respondents in the oil-impacted districts surrounding MFCA. A report completed by the Uganda Land Alliance (2011) directly connected the flood of sex work in Bulisa District to oil. This substantiates the idea that migrant workers and increased wealth in the area are driving the demand for prostitution in these new mining boom areas. These results provide additional evidence that increased prostitution is not limited to urban centers, but is also becoming prevalent in rural communities.

Oil has had a history of influencing and shaping relationships between ethnic groups in Sub-Saharan Africa (Ejobowah 2000; Casertano 2012). Influence from oil often leads to claims of ethnic groups grabbing land, attempting to gain unfair political advantages, and feeling entitled to payments for oil and mineral extraction based on historical rights to land. Oil in Uganda is projected to have impacts on ethnic identity and inter-ethnic relationships across Uganda, as well as historical ethnic claims to land and revenue (Olanya 2014). Squatters have moved to areas that are considered oil rich in hopes of receiving payment from the government for being located on the valuable lands (Kathman & Shannon 2011). The Bunyoro tribe, in particular, have become concerned with squatters coming to their land. They fear that the migration of squatters to the area will eventually lead to job loss and weakened political influence for the tribe. Revenue sharing mitigation plans are often plagued with paradox (Kathman & Shannon 2011). On one hand, if revenue sharing is increased with the Bunyoro people, more migrants could be influenced to move to their area through the pull factor. Under this circumstance, land and inter-ethnic conflicts could increase. On the other hand, equal revenue sharing among all Ugandans could lead to further disapproval by government of the local tribes in the oil developed areas.

Squatters are not the only land issue currently gripping Bulisa District. Investors have preyed on the communal land tenure system in Bulisa District in order to gain land for cheap (Ssebuyira 2013). While a 50x100 plot in Bulisa Town Council has skyrocketed from 500,000 Ugandan Shillings (UGX) to 3-5,000,000 UGX (exchange rate June 2016: 1 USD = 3,400 UGX) since the discovery of oil (Ssekika 2011), investors skirt communal land ownership customs. At the request of regional government and investors, police evict the protesting residents off of their land, resulting in a substantial loss in income for the communal owner.

There are still a few hurdles ahead for oil production in Uganda. Low global oil prices in 2015 could have a significant impact on Uganda and its path towards utilizing the resource which sits underneath. Uganda's "break-even" point for oil production is considered to be at $50-60 per barrel (New Vision 2015), while Standard Chartered Bank believes that price should be $70 (Muhumuza 2016a). With commodity prices as low as $30 a barrel, oil production will be a major challenge in places like Uganda, where expensive infrastructure and pipelines still need to be built. In fact, Uganda has decided to delay construction of a major oil production facility (in Hoima) until 2020, mainly due to the low price of oil. In 2015, low oil prices caused the Ministry of Energy and Mineral Development to extend the deadline for companies to submit bids for Albertine Graben oil block licensing, as the ministry was disappointed with low bids in the initial round that were largely influenced by an unstable market (New Vision 2015). Adding to the complexity of oil bidding are the risks involved with drilling within the boundaries of MFCA. New infrastructure within the PA will bring with it increased road networks, and visible oil pads within the main tourist tracks of the PA. Additionally, a pipeline will likely be built that will transect the park to bring oil to a southern refinery in Hoima (personal communication; Uganda Wildlife Authority Staff). The pipeline marks a venture that historically comes with increased risk of oil spill, and the subsequent financial and public relations risk for the company undertaking the venture.

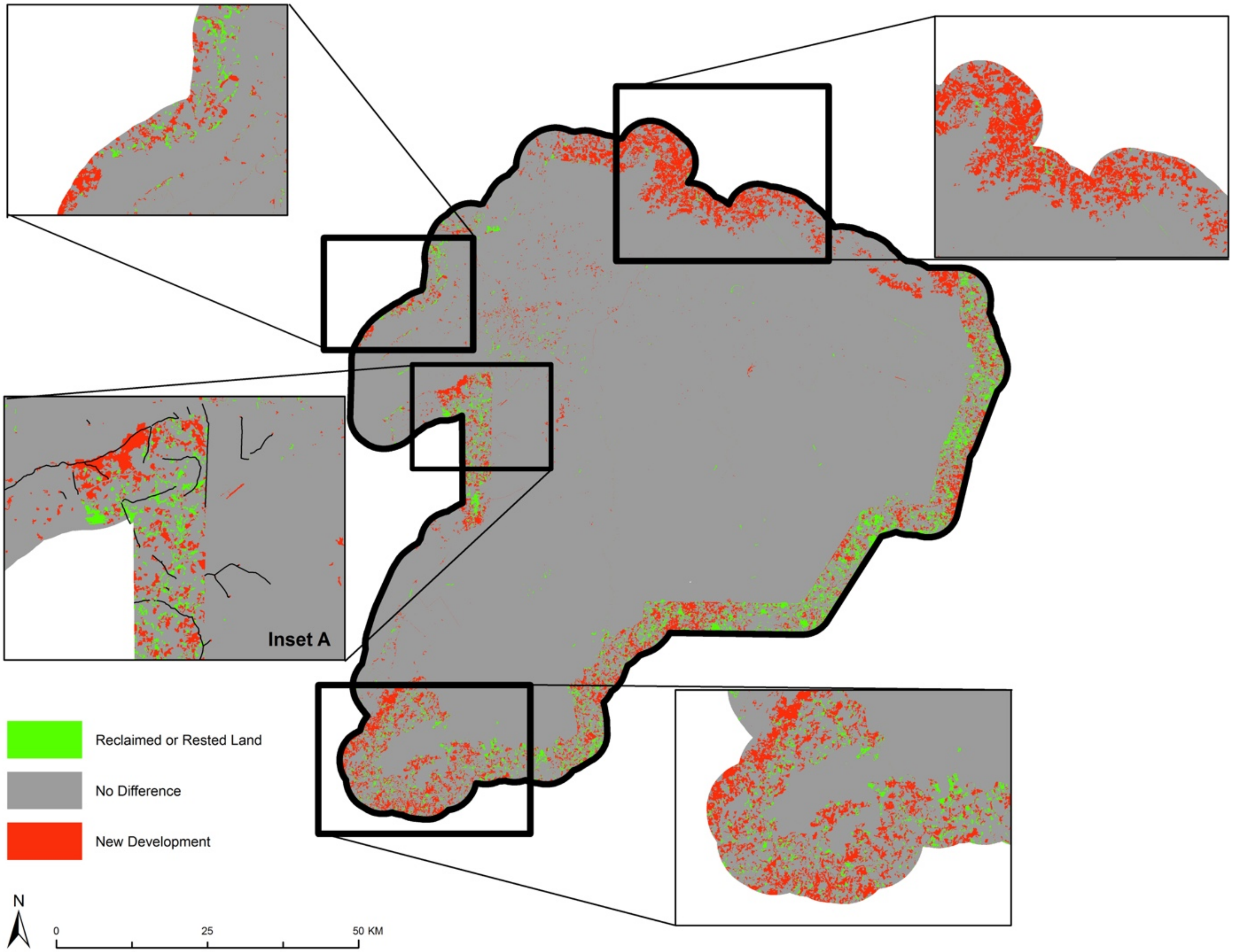

Figure 2.5: Raster difference of 2014 and 2002 developed and natural binary classification, showing reclaimed land (green), New Development (orange), and no change (gray). Inset A shows development surrounding roads built between 2002 and 2014 (black lines).

As has been seen in my results, as well as the Uganda Land Alliance (2011) report, residents are generally becoming impatient and distraught by the length of time and lack of perceived immediate benefit from oil development. Residents complained about lack of access to jobs, and lack of willingness of oil companies to purchase food from them. Oil companies simply rebut these frustrations by stating that there simply is not enough skilled labor and food for purchase available in the oil producing regions to support demand. Thus, the oil companies feel it is necessary to import both labor and supplies from Kampala and abroad. The delays introduced by low oil prices could further increase this rift. However, in a recent interview, Total E&P Uganda general manager, Adewale Feyemi, refuted claims that development in this region is expensive, and stated that Uganda can be extremely competitive in a low cost oil global market, due to what she considers low relative cost of development (Muhumuza 2016b). She insisted that the benefits will start to accrue much sooner, even in a climate of low oil prices. Some environmentalists view low oil prices as a potential savior and relief from environmentally risky oil exploration, worldwide. In much of the world, oil projects in areas in controversial areas, such as oil-based rigs and in areas of environmental sensitivity, have been dramatically halted due to low oil prices (Fahey 2014).

Conclusion

MFCA represents a rapidly changing and complex landscape of human population growth, post-conflict regrowth, industrial development, and globally important conservation. This study highlights the differences in land cover and human population growth between oil impacted districts and non-oil-impacted districts surrounding the PA, and the unique challenges and changes to local human livelihoods. First, the land cover in oil-developed districts is being converted and fragmented at a faster pace than non-oil impacted districts. Along with land cover, human population is also growing faster in oil-impacted districts than non-oil impacted districts. Increased land cover change and human population growth highlights both direct (oil infrastructure) and indirect (migration and human population growth associated with oil being a pull factor) impacts of oil development on the landscape level. New roads in oil-impacted districts have resulted in new areas of agricultural growth in previously isolated areas. Oil development is also bringing with it unique challenges to local communities. A large increase in the migrant worker population has attracted increased prostitution to the area. Large increases in the price of land and prospect owning oil rich land in oil-impacted districts has resulted increased land grabbing and conflict. The better we understand these influences of population change in the MFCA, the better we can understand and plan for the impacts of industrial development, and the impacts it has on human livelihoods, in and around important conservation areas within Sub-Saharan Africa.

It is important to tease out potentially confounding influences on changes in population within these areas, which is one of the limitations of this study. Due to the delayed release of the full 2014 Ugandan Population Census, I could not create gridded population data based on ethnicity and age. These are two important variables in understanding how much growth is likely due to migration, and how much is due to natural population growth. The census was initially due to be released at in 2015, however, at the time of submission of this thesis (June 2016), it is still not available. Other projected data sources on age and ethnicity of Uganda are not be appropriate for this project, as they were created prior to the post-conflict regrowth and discovery of oil in the MFCA landscape, thus the data would provide unreliable results. Therefore, when the 2014 census is finally released, I will create additional gridded geospatial data to help analyze inter-regional migration patterns and temporal age structures to the MFCA districts.

CHAPTER 3

LAND COVER CHANGE AND POST-CONFLICT REGROWTH SURROUNDING MURCHISON FALLS CONSERVATION AREA

Abstract:

The success of conservation initiatives worldwide often rely on understanding the drivers of human population growth and land cover fragmentation surrounding protected areas. However, the drivers of land cover change and population growth can be complex. While natural population growth is a primary cause of population growth in Africa, migration due to major anthropogenic events is increasingly common in Sub-Saharan Africa. Conflict often plays a large role in human migration through refugee resettlement, and many people in the region are now moving in hopes of economic improvements. In this study, I created two land cover maps of Murchison Falls Conservation Area (MFCA) in western Uganda for 2002 and 2014 to understand changes in land cover and fragmentation using Object Based Image Analysis and Landsat Imagery. I also conducted interviews with local communities and local government officials to understand the context of population growth and impacts on local livelihoods. My analysis shows an increasingly fragmented landscape outside of MFCA, with large increases in agricultural area. Post-conflict repopulation, oil development, and industrial agriculture growth had a major impact on both agricultural expansion, as well as inter-community conflicts due to landholder rights and land

grabbing. In the district of the study area most impacted by post-conflict regrowth, agriculture increased by 95% between 2002 and 2016.

Introduction

Protected areas (PAs) are the primary mechanism for protecting biodiversity against the negative impacts of high human population growth. High human population growth has resulted in increased complexity of conservation efforts (Pfeifer et al. 2012). Biodiversity hotspots have a disproportionate population growth rate compared to other areas of Earth. While biodiversity hotspots account for just 12.9% of inhabitable global surface area, they contain 23% of the total human population (Cincotta et al 2000; Williams 2013). Not only do biodiversity hotspots contain a disproportionate amount of people, the population within them is growing at a faster rate than the global average. The population growth rate of biodiversity hotspots was 38% higher than the global average between 1995 and 2000 (Williams 2013). Although overall fertility has fallen in these regions, the low average age structures within biodiversity hotspots will ensure population growth rates will remain high into the future.

Increasing human populations add pressure to biodiversity and access to resources within and outside of PAs. However, the reasons for population growth surrounding PAs, along with the pace and scale of this growth, is a highly contentious topic (Wittemyer et al. 2008; Joppa et al. 2009). Some analyses of population density and change have found higher population densities and growth surrounding PA boundaries (Hartter et al. 2015). Others have found there to be no elevated population growth at PA borders, when compared to other areas of rural population growth within a region (Salerno et al. 2013). Some further suggest that population growth is likely a factor of family and social ties, rather than influence from the PA (Zommer & MacDonald 2012).

There are three general models that are used when studying population growth surrounding PAs: the attraction model, the incidental model, and the frontier engulfment model (Sholte and de Groot 2009). The attraction model views PAs to be drivers of increased population growth, mainly due to the economic and social benefits they provide (Wittemyer et al. 2008). Benefits offered by PAs include employment, health related infrastructure from revenue sharing programs, and access to resource pools. Other studies have rejected claims of increased population growth at PA boundaries, and attribute these studies to inadequate and incorrect analyses and statistical techniques (Joppa et al 2009). Rather, population growth surrounding PAs is the result of the existing human population centers expanding up to the PA boundaries (Joppa et al. 2009). Under the incidental model, populations surrounding protected areas can grow by chance. Incidental reasons for migration to PA boundaries include being forcibly evicted from within the PA and relocating to the edges. In times of conflict, PAs become incidental areas of refuge (Hanes 2006; Debroux et al. 2007; Oglethorpe et al. 2007). Lastly, the frontier engulfment model occurs when an isolated protected area is developed by an extractive frontier and subsequent agricultural frontier (Sholte and de Groot 2009). An extractive frontier can include logging and/or mineral extraction, while an agricultural frontier includes cattle and cropping. In this model, increased population is first due to migrant worker influx, which is subsequently followed by farmers who settle on the newly cleared land. Real world examples often involve multiple components of each of the three models.

The monitoring and measurement of change in landscape level pattern is important since ecological pattern can predict and is linked to ecological processes (Gustafson 1998). Habitat fragmentation is a particularly important process to monitor (Fahrig 2003). Fragmentation is the study of how land cover patches are converted into smaller patches, resulting in an increasingly complex, heterogeneous landscape configuration than previous time periods (Harris & Weiner 2003). Agricultural intensification is the primary reason for habitat fragmentation and changes in the spatial pattern of landscapes (Tynsong & Tiwari 2011). Fragmentation often has a significant impact on the conservation of plant and animal communities (Villard et al. 1999; Cumming & Vernier 2002; Betts et al. 2006). As patches become smaller, they can only support a smaller number of species due to resource competition and crowding (Laurance et al. 2002; Hobbs & Yates 2003; Stevenson & Aldana 2008), leading to species loss. Additionally, as landscapes become more fragmented, the movement of plant and animal species across the landscape is severely hampered (Fischer & Lindenmayer 2007).

Security of land tenure is important during mineral discovery, as mineral resources are often directly tied to government recognized land titles, not customary claims to the land (Mennen 2013). Ambiguous land rights can increase local conflicts, often putting local residents, local governments, companies, foreign investors and national governments against each other for mineral and land rights. Similarly, insecure land rights are an issue in areas of severe civil conflicts. People who previously were forced to seek refuge away from home during a war have their previous claims to land challenged upon their return, resulting in conflict and a disruption of the peace-building process (Unruh 2004; Hetz et al. 2006; Unruh and Williams 2013).

In particular, PAs in Uganda are experiencing an increasingly diverse set of anthropogenic pressures. First, Uganda has extraordinary population growth. It is currently growing at a rate of 3.3% per year, making it the 8th fastest growing country in the world (World Bank 2014). Resource and conservation managers need to understand and quantify anthropogenic impacts of land cover conversion to better plan for future impacts on biodiversity and to locate hotspots of change. Within the previous two decades, there has been considerable changes occurring outside of Murchison Conservation Area (MFCA) in western Uganda. In 2006, the longstanding armed conflict between government forces and the rebel group Lord's Resistance army directly north of MFCA ended. At the end of the war, previously displaced people returned to the area. Within the same year, oil was discovered. Industrial oil development has the potential to have a large impact on the landscape surrounding MFCA through human migration and the development of oil infrastructure (Chapter 2).

In this chapter, I address two primary questions: 1) How has the landscape in and around MFCA changed in terms of land cover and landscape pattern between 2002 and 2014?; and 2) What are possible anthropogenic events and cultural drivers of land cover change and natural land conversion outside of MFCA? I created 2 land cover maps (2002 and 2014), which were used to quantify changes in land cover and landscape pattern of the MFCA landscape. To connect land cover change to anthropogenic impacts, I conducted group and key-informant interviews of local communities and local government officials.

Study Area

Established in 1952, Murchison Falls Conservation Area (MFCA) is located within the Albertine Rift, a biodiversity hotspot that is highly threatened because of enormous human population growth and land conversion to agriculture (Fisher & Christopher 2007). The conservation area includes four different PAs (Figure 3.1), with varying levels of protection status: 1) Murchison Falls National Park (MFNP, IUCN Category II, 3,840 km^2); 2) Bugungu Wildlife Reserve (BWR, IUCN Category III, 748 km^2); 3) Karuma Wildlife Reserve (KWR, IUCN Category III; 720 km ^{2}); 4) Budongo Forest Reserve (BFR, IUCN Category III, 825 km^2). MFNP is one of seven Ugandan national parks located within the Albertine Rift, and is predominantly a savannah-woodland landscape, but also includes wetland and tropical forest habitats. Its habitats are considered highly irreplaceable (Hartley et al 2007). It is also home to 780 species of birds, mammals, reptiles, amphibians, and plant species (Plumptre et al. 2003), and it is of great ecological importance due to the presence of numerous globally and regionally threatened species (NEMA 2009). The only remaining, naturally occurring population of the Rothschild's Giraffe (*Giraffa camelopardalis* rothschildi), an endangered subspecies with fewer than 470 wild individuals left has its only remaining, is present within MFCA (Fennessy & Brenneman 2010).

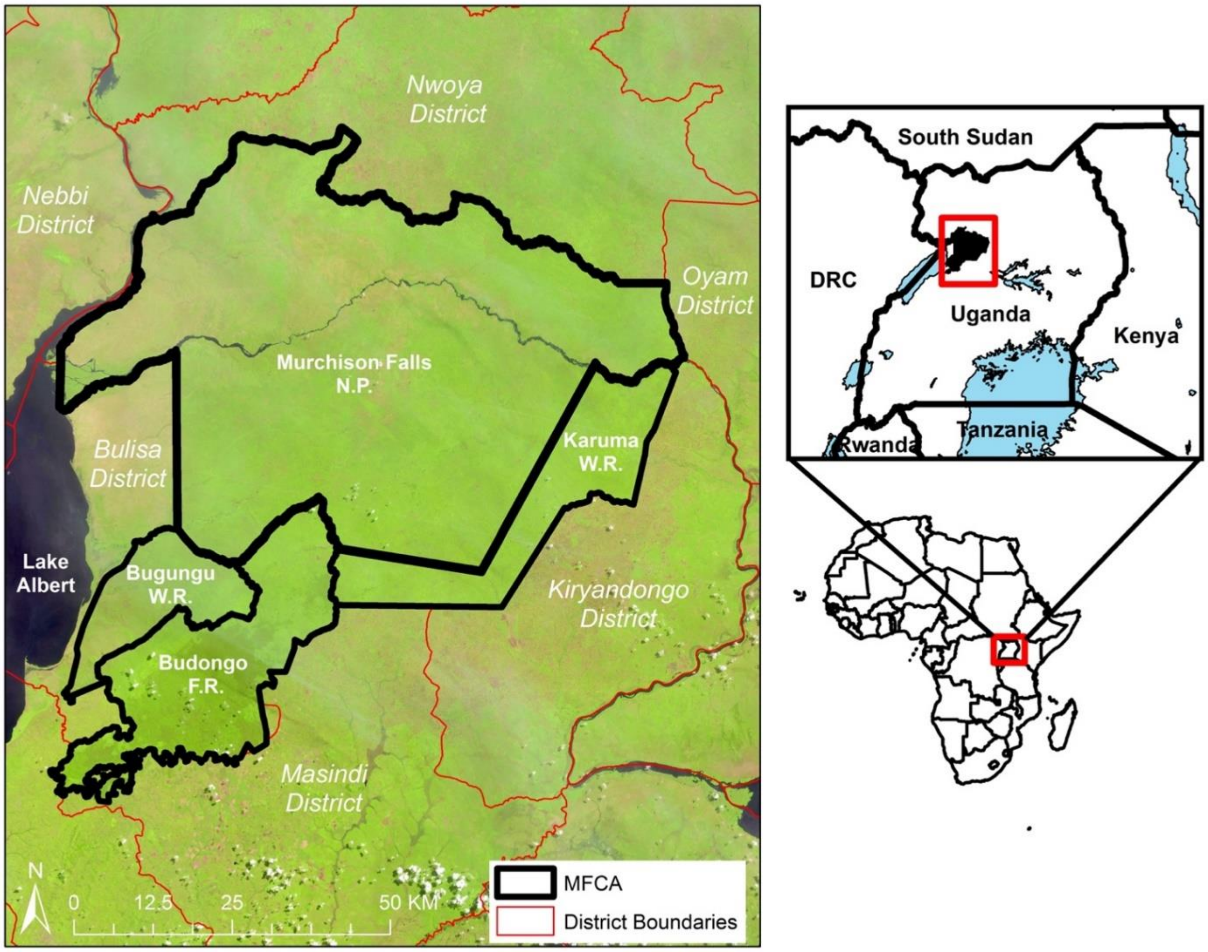

Figure 3.1: Landsat 8 Natural Composite image (bands 4,3,2) Murchison Falls Conservation Area (MFCA) landscape, consisting of four separate parks: 1) Murchison Falls National Park, 2) Bugungu Wildlife Reserve, 3) Budongo Forest Reserve, 4) Karuma Wildlife Reserve.

Multiple ethnic groups live within the MFCA landscape. The ethnic groups with the highest proportion of residents in each district are the Alur and Jonam in Nebbi, the Acholi in Nwoya, the

Langi in Oyam and Kiryandongo districts, the Bunyoro and Bagungu in both Bulisa and Masindi Districts (Figure 6). Between 1986 and 2006, Nwoya district was caught in a long-running civil war with the Lord's Resistance Army (LRA). During this time, many people moved into Internal Displaced Person (IDP) camps, sought refuge in major towns like Gulu, or relocated to other districts within the country. The conflict greatly changed the human landscape, resulting in an estimated 66,000 children who were abducted (US Department of State 2012), along with an additional 1,700,000 people displaced between 1986 and 2007 (UNOCHA 2005). Since the LRA left the area in 2006, the area has experienced a regrowth of the human population, as people formerly in IDP camps have returned to this area, and people from outside districts have migrated to the area seeking land and economic opportunity.

Methodology

I used a mixed methods approach to quantify land cover change and identify anthropogenic drivers of the change. I first classified Landsat imagery to compare change in land cover and fragmentation metrics between 2002 and 2014. Then, I conducted group and key informant interviews to understand the reasons why land cover is changing within the MFCA landscape.

Land Cover Change and Fragmentation

Image Selection and Pre-processing

Landsat scenes were downloaded for two dates, 06 February 2002 (Landsat 5 TM) and 14 January 2014 (Landsat 8), from the NASA Earth Explorer website (http://earthexplorer.usgs.gov/). Both of the images used in this study were preprocessed in ERDAS Imagine 2014 (Intergraph 2014). The images were downloaded in their raw format, with one GeoTIFF image for each spectral band. This resulted in 7 raw bands of Landsat 5 data (8-bit radiometric resolution, with 0-255 possible digital numbers; 30 meter spatial resolution) and 11 bands of Landsat 8 data (16-bit radiometric resolution, with 0-65,536 possible digital numbers; 30 meter spatial resolution). I created a layer stack for each date of imagery to stack the various bands of imagery on top of one another to create 1 .IMG file for each date of imagery. The thermal bands for each date of imagery (band 6 of the Landsat 5 data, and bands 10 and 11 of Landsat 8 data) were excluded from the layer stack due to a different spatial resolution than the other spectral bands. The study area for this analysis falls in multiple rows of Landsat Imagery, along the same path (row 58 and 59, on path 172). Therefore, the individual scenes for each respective date were mosaicked together using the maximum function in ERDAS Imagine® (Intergraph 2014) prior to atmospheric correction. It is assumed that the atmospheric and spectral conditions should be extremely similar due to the images being taken almost directly after one another. The maximum function in ERDAS Imagine® was used to help assure that image seams were not included in the final mosaicked product.

Atmospheric correction is an important part of the classification process (Lu & Weng 2007). After I mosaicked the images, I applied atmospheric correction to convert the images from the raw, digital number data to the reflectance values. I used the cosine of the sun zenith angle (COST) to correct to reflectance values (Chavez 1996; Lu et al. 2002). Landsat data must undergo atmospheric and radiometric correction to remove additive noise recorded by the sensor that can cause pixels to have inflated pixel values different from what is being reflected from the surface. This is necessary to create a usable product for feature extraction and classification. The COST method is an absolute correction method, which relies on the assumption that at least one object in an image represents a true 0 DN value in an image. The first step of the COST method is to convert the digital number (DN) values to radiance (ρ), using the formula:

$$\rho = \frac{\pi d^2 \left(L_{min} + \frac{DN_i(L_{max} - L_{min})}{DN_{max}}\right) - \left(L_{min} + \frac{DN_{min}(L_{max} - L_{min})}{DN_{max}}\right) - \left(\frac{0.01 d^2 cos^2\theta_z}{\pi E_{sun}}\right)}{E_{sun} cos^2\theta_z}$$

where L_{sat} is the spectral radiance at the sensor, L_{min} is the minimum spectral radiance for a given band, L_{max} is the maximum spectral radiance of a given band, and DN_{max} is the maximum digital number of the image range (Chavez 1988). As the only available Digital Elevation Model for this particular area being is lower spatial resolution 90 meter NASA SRTM data, I refrained from performing topographic normalization of the data.

After the 2002 and 2014 images were atmospherically corrected, I clipped the image to include only MFCA and a 5 kilometer buffer surrounding the PA. This step was performed to cut down on the processing time and computational needs of the image, and to make sure that the training samples collected for this study are all from within the area of interest.

I then generated derivative bands for each date of imagery to add additional information to the classification process. I calculated the first three Tassled Cap (TC) Components, which include a brightness, greenness, and wetness band (Kauth & Thomas 1976) in ERDAS Imagine. TC bands are calculated through linear combinations. The brightness band is associated with man-made features, bare soil, and rock outcroppings, while the greenness band is associated with green vegetation. The wetness band is associated with soil moisture and other moist features.

Additionally, I created a Normalized Difference Vegetation Index (NDVI). NDVI is a greenness derivative band, where NDVI is higher in areas that absorb highly in the red wavelengths, and reflect highly in the Near-Infrared Wavelengths. The potential values for NDVI are -1 (no vegetation) to +1 (high vegetation). In general, values that are less than 0 have little meaning, ecologically speaking. The equation for NDVI is as follows:

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

In addition to the Tasseled Cap Transformations and NDVI, I created principal component (PC) transformations of all original Landsat imagery bands, to help reduce the dimensionality of the data, and provide more information for the classification (Byrne et al. 1980). PC works by creating orthogonal (independent) bands from the original data.

Following their creation, I rescaled the derivative bands to the dynamic range of each band that was used to create the new band (i.e. the NDVI derivative band was rescaled to the dynamic range of the red and near-infrared band). The dynamic range of each band was identified through examination of each band’s histogram within ERDAS Imagine. This is important in order to not make the derivative bands more powerful than the original spectral bands. The scaled derivative bands were then stacked with the corrected spectral bands, resulting in a single stack of derivative and spectral bands for each of the years included within the study.

Training and Accuracy Sample Collection

Training data for the 2014 image were collected between the months of May and August 2014 in Uganda. For the 2002 image, land cover samples were collected from high resolution satellite imagery between 2001-2003. A minimum of 100 land cover samples for each target land cover were collected. The samples were then randomly separated so that half of the samples were used as training data to “train” the classification algorithm, and half were set aside for use in the accuracy assessment to test the validity of the final classifications.

Image Classification

I used object oriented classification to classify the images in the software package eCognition© (Trimble 2014). Object-oriented image analysis (OBIA) differs from pixel-based classification in that it first groups pixels into image-objects based on characteristics such as texture and shape (similar to how a human mind would). Then, objects are classified based on the spectral information supplied by the training samples and the geometric and shape information of the objects used in the analysis. This method of classification is advantageous in that it provides additional information not available in pixel-based analysis. It classifies in a manner that is more analogous to how the human brain thinks, and reduces the amount of “salt-and-pepper” noise that is often witnessed with per-pixel classification (Blaschke 2010).

For the classification process, I first used the multispectral segmentation platform in eCognition© to segment the image into image objects. The multispectral segmentation platform allows the analyst to adjust parameters, such as the scale (size), shape, and compactness of the image objects to achieve image segments based on both raster and thematic information that follows the shape of landscape features within the image. Trial and error was used to achieve the best image segments, and the assessment on the appropriateness of the image segments was largely a subjective, visual examination process through expert knowledge of the area.

Following the segmentation process, the Random Forest algorithm was used to classify the objects (Breiman 2001; Pai 2005; Gislason et al. 2006; Rodriguez-Galiano et al. 2012). First, all water objects were separated from the rest of the image. Due to the limited availability of imagery for the study region in the wet season, the scene occurs in the dry season. Therefore, there is significant burning associated with the image. Therefore, after separating the water from the image, the image was subsequently classified as burnt and non-burnt area, and these classified areas were further classified separately from one another. Each of the following areas were then classified using the classification system in Table 3.1.

Table 3.1: Land cover types and descriptions used in land cover classification map creation.

Land cover	**Description**
Water	Open water (stream, rivers, lakes)
Savanna Woodland	Tree cover of 50-100%, but with noticeable residence of grasses and shrubs and no closed canopy.no closed canopy.
Forest	~100% Tree Cover with predominantly closed canopy.
Wetland	Soil or substrate periodically saturated or covered with water, and predominate vegetation are hydrophilic.
Savanna Grassland	Tree cover of less than 50%, with landscape dominated by grasses. Includes open shrubland areas.
Agriculture	Greater than 50% cover by agriculture, including both industrial agriculture and village-agriculture mosaics.
Developed	Areas characterized by greater than 30% of constructed materials (including buildings, concrete, and asphalt).

Although open shrubland could be appropriately separated from Savanna Grassland in the non-burnt areas, there was significant confusion between the two classes in the burnt areas. Therefore, the two classes were combined into one class for the entire analysis. For similar reasons, large-scale agriculture and subsistence agriculture village mosaic were also combined into one class.

Following the classification process, I used error matrices to assess the accuracy of the classification maps (Congalton 1991; Congalton & Green 2009). There are three important accuracy measurements computed within the error matrices: overall accuracy, producer's accuracy and user's accuracy (Story & Congalton 1986). Overall accuracy shows the total agreement between all reference data and the map. It is calculated by dividing the sum of the major diagonal of the error matrix by the total number of reference samples in the accuracy assessment. User's and producer's accuracy are vital for interpreting the accuracy of individual land cover classes within a classification map. User's accuracy calculates errors of commission. To calculate user's accuracy, the number of correctly classified samples is divided by the total number of samples for each class. Producer's accuracy calculates errors of omission. To calculate producer's accuracy, the number of correctly classified samples within each land cover class are divided by the total number of samples for each land cover class.

I used the software Fragstats (McGarigal 2012) to quantify changes in each land cover class, and the subsequent fragmentation occurring within each class. Fragstats uses spatial statistics to analyze the pattern of thematic land cover maps at the landscape, class and patch level. I calculated the following eight metrics for each image date:

1.) **Class Area (CA):** Total area of an individual land cover class covering a landscape, measured in hectares.
2.) **Percentage of Landscape (PLAND)**: How much of the landscape is comprised of a class type;
3.) **Number of Patches (NP)**: Number of individual patches within a class type;
4.) **Patch Density (PD):** The total number of patches per unit area.
5.) **Largest Patch Index (LPI):** The percent of landscape that the largest patch in a land cover class covers in the total landscape.
6.) **Total Edge (TE):** Cumulative edge of all patches within an individual land cover class, measured in kilometers.
7.) **Mean Patch Size (MPS)**: The average of the size of each patch within a land cover class, measured in hectares.
8.) **Mean Patch Distance (MPD):** average distance between all patches within a land cover class.

Group and Key Informant Interviews

I used semi-structured group and key informant interviews to understand the context and drivers of human population growth and natural land conversion in the MFCA landscape. Additionally, I was able to observe which anthropogenic events had the most significant impact on land cover change. The key informant interviews were conducted with local government officials: Local Council 1 (LC1, village) chairperson, Local Council 2 (LC2, parish) chairperson, Local Council 3 (LC3, sub-county) chairperson, Local Council 5 (LC5, district) chairperson, Resident District Commissioner (RDC), and District Security Officer (DISO) government officials. A local enumerator and interpreter was hired to translate the questions and subsequent responses between English and various local languages (e.g., Runyoro, Luo, Swahili, Luganda) spoken among the community members. The interview questions covered topics of marriage, migration, and the impact of human population growth on local communities and the landscape. Locations of the interviews were selected opportunistically, based on village and town proximity to MFCA boundary (≤ 5km) and availability of the government officials.

I received all appropriate permissions from the national, district, sub-county, and village levels prior to initiating each interview. I also received approval from the Institutional Review Board for the Protection of Human Subjects in Research (IRB# 5405). After I completed a key informant interview with the LC1 chairman, the LC1 chairman recruited a group of 10 village residents, half men and half women, to participate in the group interview. The interview generally occurred the following day. Transcripts of each interview were created coded into a two-level coding structure. For instance, the first level oil development theme was further separated into subsets of employment, pollution, and compensation. After the transcripts were coded, thematic interpretations of the interviews were created to provide a narrative of influences on land cover change and population growth within and outside of MFCA.

Results

Land Cover Change and Fragmentation

Land cover maps were created for 2002 and 2014 (Figure 3.2). Overall accuracy of the 2002 and 2014 classifications are 82.6% and 84.6%, respectively (Table 3.2 and 3.3).

Land-cover Descriptions

Table 3.4 shows land cover results for MFCA. Land cover results for the individual PAs within MFCA (e.g., Budongo Forest Reserve, Bugungu Wildlife Reserve, Karuma Wildlife Reserve, and Murchison Falls National Park) can be located in the Appendix. The majority of the MFCA landscape is covered by savannah woodland (PLAND = 43.5%) and savannah grassland (PLAND = 39.6%) ecosystems. There are also large areas of forest (PLAND = 11.6%), and interspersed pockets of wetland (PLAND = 3.8%). Compared to other classes, there is a negligible amount of agriculture (PLAND = 0.2%) and developed (PLAND = 0.4%) land within MFCA.

Table 3.5 shows the land cover results for the 5-km area surrounding MFCA. Land cover results for the individual districts surrounding MFCA can be located in the Appendix. The 5-km area outside of MFCA is dominated by agricultural land (PLAND = 46.7%), with large, remnant pockets of grassland (PLAND = 18.0%) and woodland (PLAND = 17.2%). A large percentage of the landscape is covered by wetland (PLAND = 7.7%), along with small amounts of remaining forest (PLAND = 0.8%). There is also a small percentage of developed land (PLAND = 0.5%).

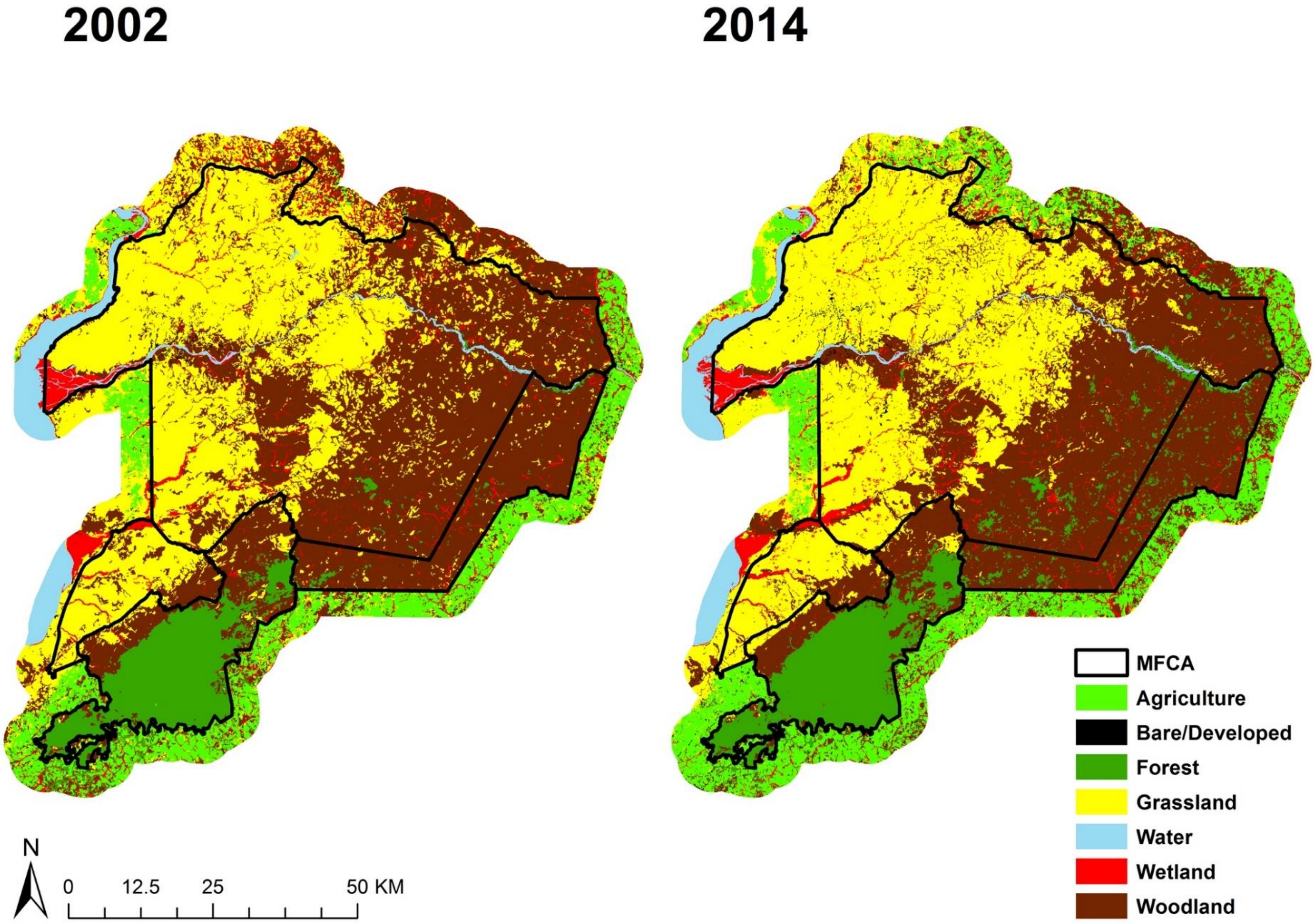

Figure 3.2: Land cover maps of the Murchison Falls Conservation Area landscape for 2002 and 2014.

Table 3.2: Error Matrix for the 2002 Classification Map (Kappa = .81).

Classification Map	Reference Data								
	Forest	**Agriculture**	**Developed**	**Grassland**	**Woodland**	**Wetland**	**Water**	**Total**	**User's Accuracy**
Forest	41	0	0	0	5	0	0	46	89.1%
Agriculture	0	43	2	0	0	0	0	45	95.6%
Developed	0	0	25	0	0	0	0	25	100.0%
Grassland	0	4	10	43	2	1	0	60	71.7%
Woodland	8	4	0	4	41	7	0	64	64.1%
Wetland	1	1	0	2	2	32	0	38	84.2%
Water	0	0	0	0	0	0	50	50	100.0%
Total	50	52	37	49	50	40	50	82.6%	
Producer's Accuracy	82.0%	82.7%	67.6%	87.8%	82.0%	80.0%	100.0%		

Table 3.3: Error Matrix for the 2014 Classification Map (Kappa = 0.82).

		Reference Data								
		Forest	**Agriculture**	**Developed**	**Grassland**	**Woodland**	**Wetland**	**Water**	**Total**	**User's Accuracy**
Classification Map	**Forest**	41	0	0	0	4	2	0	47	87.2%
	Agriculture	0	54	1	2	0	0	0	57	94.7%
	Developed	0	0	31	1	1	0	0	33	93.9%
	Grassland	0	7	3	58	9	0	0	77	75.3%
	Woodland	7	6	0	2	41	5	0	61	67.2%
	Wetland	2	0	0	4	2	48	0	56	85.7%
	Water	0	0	0	0	0	1	50	51	98.0%
	Total	50	67	35	67	57	56	50	84.6%	
	Producer's Accuracy	82.0%	80.6%	88.6%	86.6%	71.9%	85.7%	100.0%		

Fragmentation and Change in Land Cover

Figure 3.3 shows changes in land cover between 2002 and 2014. Table 3.4 shows change in spatial pattern of MFCA between 2002 and 2014. Grasslands remained stable in MFCA, increasing in area by just 3%. While the total area of grasslands increased, the total number of patches of the land cover class decreased by 42%, resulting in a decrease in patch density of 41%. Meanwhile, mean patch size of grasslands increased by 44%, with the largest patch index increasing from 15.96 to 18.52. The mean distance between patches increased slightly from 266 to 279.5 meters. Similar to grasslands, the total area of wetlands also remained stable within MFCA, increasing by just 2%. While total area was stable, the total number of wetland patches and patch density increased by 31% and 29%, respectively. The mean distance between wetland patches decreased slightly from 392 to 376 meters. Both forest and woodland land covers had the largest change in total land cover within MFCA. Total forest area increased by 21%, with total patches increasing from 195 to 848. Both the mean patch size and mean patch distance of forest decreased by 70% and 36%, respectively. Total woodland area decreased by 8%. While decreasing in total land cover area, woodlands also became increasingly fragmented, with total patches increasing from 1157 to 1510. The mean patch size of woodlands decreased by 29%, while the mean distance between patches remained stable. Developed land within MFCA nearly doubled, increasing by 45%, with the mean distance between developed patches decreasing by 15%. Total agricultural land increased by 24% within MFCA. Agricultural patches increased from 282 to 411, and the mean distance between agriculture patches decreased by 50%. Since agriculture and human settlement is illegal within MFCA, much of the agricultural land within the PA is likely due to misclassification.

Table 3.4: Land cover metrics MFCA for each land cover class for each individual year. Land cover metrics include: 1.) CA=Class Area (Hectares), PLAND=Percent of Landscape (%), 3.) NP=Number of Patches (n), 4.) PD=Patch Density (number of patches per unit area), 5.) LPI= Largest Patch Index (%), 6.) TE=Total Edge (Kilometers), 7.) MPS=Mean Patch Size (Hectares), 8.) MN Dist=Mean Distance between Patches (meters).

Landcover	Year	CA	PLAND (%)	NP	PD	LPI	TE	MPS	MN Dist
Forest	2002	51277.41	9.2	196	0.04	7.91	1086	261.6	515.1
	2014	65052.36	11.6	876	0.16	9.35	2938	74.3	376.3
Agriculture	2002	852.48	0.2	284	0.05	0.01	182	3.0	627.0
	2014	1164.51	0.2	426	0.08	0.04	249	2.7	292.1
Developed	2002	1225.62	0.2	307	0.05	0.01	403	4.0	684.5
	2014	2369.79	0.4	877	0.16	0.01	853	2.7	292.1
Grassland	2002	215913.60	38.6	1526	0.27	15.96	9688	141.5	265.1
	2014	221415.66	39.6	952	0.17	18.47	8205	232.6	273.9
Woodland	2002	264837.78	47.3	1189	0.21	33.31	11507	223	214.0
	2014	243416.70	43.5	1671	0.30	32.17	11086	145.7	207.4
Wetland	2002	20775.60	3.7	1386	0.25	0.24	3676	15.0	392.3
	2014	21282.75	3.8	2193	0.39	0.46	4385	2.7	503.3

Table 3.5: Land cover metrics for the 5 km buffer surrounding MFCA for each land cover class for each individual year. Land cover metrics include: 1.) CA=Class Area (Hectares), PLAND=Percent of Landscape (%), 3.) NP=Number of Patches (n), 4.) PD=Patch Density (number of patches per unit area), 5.) LPI= Largest Patch Index (%), 6.) TE=Total Edge (Kilometers), 7.) MPS=Mean Patch Size (Hectares), 8.) MN Dist=Mean Distance between Patches (meters).

Landcover	Year	CA	PLAND (%)	NP	PD	LPI	TE	MPS	MN Dist
Forest	2002	3804.18	1.7	202	0.09	0.18	557	18.8	415.7
	2014	2578.79	1.2	312	0.14	0.06	439	8.3	734.9
Agriculture	2002	76128.18	34.1	334	0.15	5.66	5456	227.9	213.1
	2014	103750.72	46.4	854	0.38	19.86	8494	121.5	172.6
Developed	2002	640.18	0.3	115	0.05	0.03	174	5.6	1578.3
	2014	1052.79	0.5	490	0.22	0.01	391	2.1	721.1
Grassland	2002	53497.35	23.9	1518	0.68	2.45	5454	35.2	215.7
	2014	39266.67	17.6	1691	0.76	2.83	4367	23.2	223.9
Woodland	2002	48883.52	21.9	1722	0.77	7.40	5725	28.4	198.6
	2014	39289.27	17.6	2070	0.93	4.69	6132	19.0	173.9
Wetland	2002	20369.53	9.1	1216	0.54	1.09	3733	16.8	250.3
	2014	17615.63	7.9	1951	0.87	1.03	3637	9.0	250.2

Table 3.5 shows fragmentation and land cover change results for the 5 km buffer surrounding MFCA. Total agricultural land within the 5-km buffer increased by 26%. The total number of agriculture patches increased from 330 to 752, while the mean patch size of agriculture decreased from 206 to 163 meters. The mean patch size of agriculture also decreased by 40%, while the largest patch index increased drastically from 5.8 to 20.1. The total area of the forest patches of the land cover class decreased by 42%, resulting in a decrease in patch density of 41%. Meanwhile, mean patch size of grasslands increased by 44%, with the largest patch index increasing from 15.96 to 18.52. The mean distance between patches increased slightly from 266 to 279.5 meters. Similar to grasslands, the total area of wetlands also remained stable within MFCA, increasing by just 2%. While total area was stable, the total number of wetland patches and patch density increased by 31% and 29%, respectively. The mean distance between wetland patches decreased slightly from 392 to 376 meters. Both forest and woodland land covers had the largest change in total land cover within MFCA. Total forest area increased by 21%, with total patches increasing from 195 to 848. Both the mean patch size and mean patch distance of forest decreased by 70% and 36%, respectively. Total woodland area decreased by 8%. While decreasing in total land cover area, woodlands also became increasingly fragmented, with total patches increasing from 1157 to 1510. The mean patch size of woodlands decreased by 29%, while the mean distance between patches remained stable. Developed land within MFCA nearly doubled, increasing by 45%, with the mean distance between developed patches decreasing by 15%. Total agricultural land increased by 24% within MFCA. Agricultural patches increased from 282 to 411, and the mean distance between agriculture patches decreased by50%. Since agriculture and human settlement is illegal within MFCA, much of the agricultural land within the PA is likely due to misclassification.

Table 3.5 shows fragmentation and land cover change results for the 5 km buffer surrounding MFCA. Total agricultural land within the 5-km buffer increased by 26%. The total number of agriculture patches increased from 330 to 752, while the mean patch size of agriculture decreased from 206 to 163 meters. The mean patch size of agriculture also decreased by 40%, while the largest patch index increased drastically from 5.8 to 20.1. The total area of the forest class decreased drastically by 45%. Forests outside of MFCA became increasingly fragmented, with total patches increasing by 19%. The mean distance between forest patches increased substantially from 411 to 638 meters, while the mean patch size decreased by 71%. Total area of woodland decreased by 19%, while simultaneously becoming increasingly fragmented. Total woodland patches increased from 1682 to 1902, while mean patch size decreased by 26%. The mean distance between woodland patches decreased by 14%. Although total grassland area decreased by 26%, the total number of patches remained relatively stable. Total patches increased by only 3%, and the mean distance between patches increased by only 4%. Wetland land cover area decreased by 15% outside of MFCA. Total wetland patches increased by 25%, and the mean distance between patches increased by 7%. The mean patch size of the wetland class decreased by 33%. Finally, the total area of developed land cover increased by 37% outside of MFCA. The total number of developed patches increased from 113 to 351, and the mean distance between the developed patches decreased from 1658 to 854 meters.

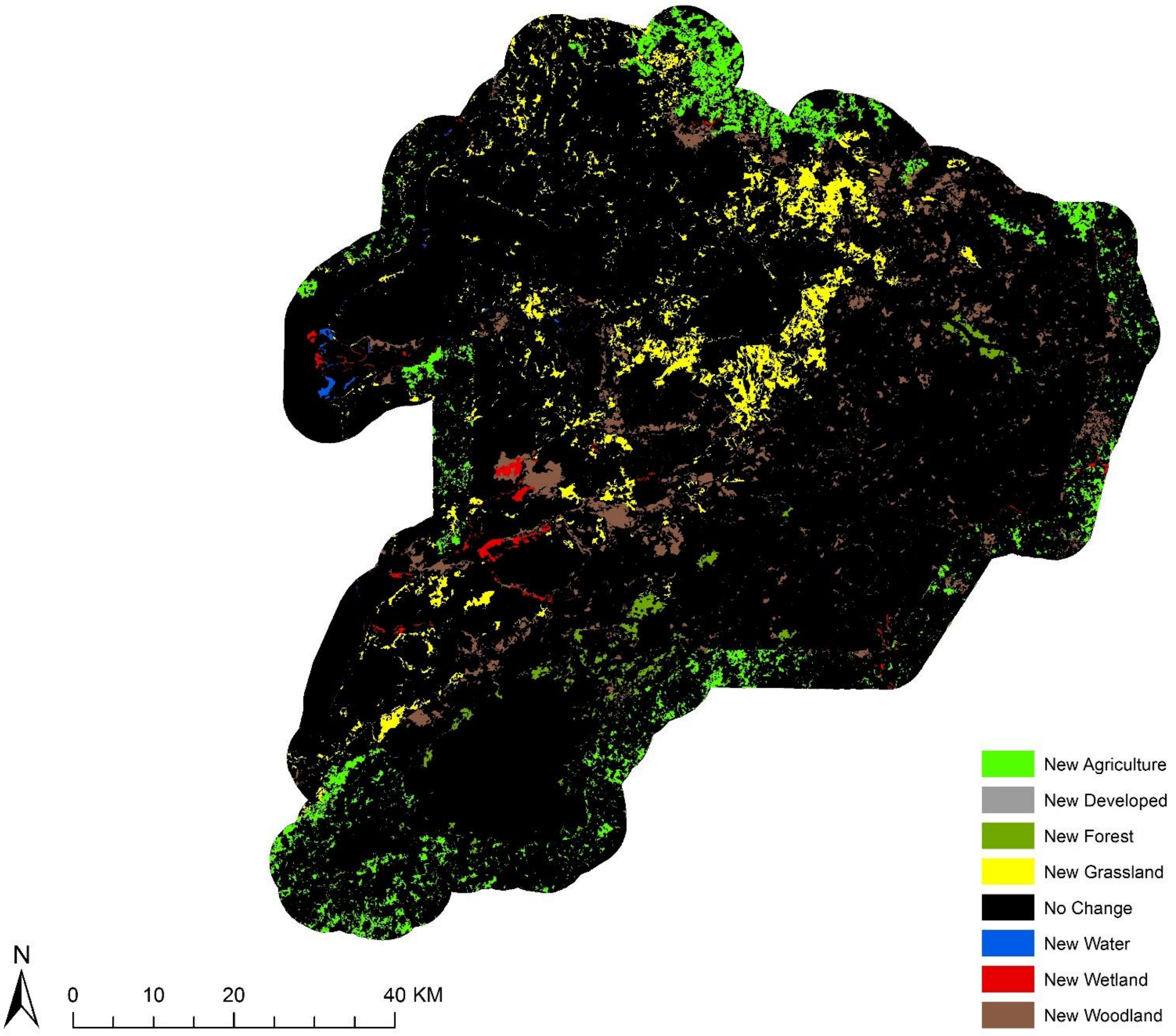

Figure 3.3: Land cover maps of the Murchison Falls Conservation Area landscape for 2002 and 2014.

Group and Key Informant Interviews

A total of 37 interviews were conducted, including 13 group interviews, along with key informant interviews with 15 LC1, 1 LC1 Secretary, 4 LC3, 1 LC5, 1 District Security Officer, 1 NGO, and 1 UWA official. Total group interview participants included 171 men and 112 woman, averaging 13 men and 9 women per interview. The percentage of women in the group interviews ranged from 21-66%. The majority of respondents were either farmers or fishermen.

Natural Increase

Natural population growth was often cited as a major reason for high human population growth. Most interview participants in both focus group interviews and individual interviews felt that in general women had a minimum of three kids. However, as one focus group respondent stated, education and literacy play a large role in determining how many children a person produces.

> *The population is increasing because people are multiplying. On average, the population of illiterate is higher than those going to school. I would say, on average, each woman is having 6 or 7 children. Women who are educated stick to family planning, and usually stop at 3.*
>
> -Focus Group, July 17, 2014

Others referred to social institutions, such as marriage and polygamy, as reasons for the drastic population growth. Although technically illegal by Ugandan law, polygamy is widely practiced in rural Uganda.

> *People also practice polygamy here. Many have 3, 4 or more wives. Myself, I have just 1, but I am not the normal. This leads to more children. More women can produce more children.*
>
> *-Local Council 1 Chairman, July 10, 2014*

Although polygamy was an oft cited reason for the high rate of natural population growth, many respondents felt that early marriage was a major cause. Early marriage occurs when children of 15 or 16 are marry. It can lead to high population numbers and decreased education among children, as many teenage girls have to drop out of school to tend to their children.

Growth Due to Conflict

> *People would leave that part and come this way. While the population in that area was retarded, the population growth here was high (referring to migration human population during conflict in Northern Uganda).*
>
> -LC3 in Nebbi District, June 25, 2014

Human conflict was often cited in focus groups and interviews as a reason for human migration and population growth within this region. One of the primary conflicts that has shaped the MFCA is the war in northern Uganda with the LRA. The war resulted in many people of northern Uganda migrating to more stable districts within the country. While all districts in this study (with the exception of Nwoya) were cited as havens for those affected by the war, Nebbi and Kiryandongo Districts, in particular, served as refuge for those displaced by the war. This is likely due to their proximity to Nwoya and stability as soon as one crossed the bridges over the Nile River which separated them. While refugees left Nwoya during war time, many participants stated that both past residents and those who did not previously live in the area are moving to back to Nwoya seeking available land.

> *Formerly, we were in the camp during the long war. Other people took refuge in other districts. Now, some have come back, and we are now expecting very many foreigners. People are coming from West Nile, Masindi, Gulu. All of the distrcits that surround this district.*
>
> -LC 3 Interview, June 26, 2014.

The regrowth since the end of conflict has resulted in a heavy increase of land conflicts and inter-neighbor violence.

> *Land conflicts are another by product of the LRA war. At least, for the LRA, you could run. But land conflicts often happen within families, and within communities. The land conflicts have claimed many lives. When people went back, they didn't know the boundaries of where one person's land started, and where theirs ended. They would then dig past their boundary, and would attack the other with a spear, ax, bow and arrow. Many times, it is the youth who are the ones who are quick to violence. They will grab a weapon, and go use it before discussing the matter. The elders are different, as they will often take the time to sit down and talk about the*

> *issues. The youth go to the field armed, and violence often breaks out. They will torch the other person's huts, slaughter the chickens, goats, cows that person owns, and everything will be destroyed because of the land conflicts.*
>
> -NGO, July 5, 2015

This is partly due to the land tenure system within this region. Since Nwoya is under a customary land tenure system, residents do not have official land ownership documents., Those who returned to the land that previously had customary claims have found other people claiming the land, sparking drastic violence, such as the burning of huts.

> *Some who grew up in camp now go back home and cause problems. The father may have died during the war, and now the kids want the land as they are returning. We have to tell people that they should not fight. We have a lot of conflict. They are even burning houses.*
>
> -District Security Officer, June 26, 2014

While the conflict is a serious concern of the population regrowth, one LC5 chairman stated that a lot of people have been slow to return to their land, and does not feel that those people's concerns are valid.

> *The population has doubled because people have come back home. We have told people, if you delay moving back, people will have taken over your land by the time they get back. If you don't come back, the assumptions is that you are not coming back. If someone has been gone for 12 years, and another person has used the land*

> *for 12 years, it is now that other persons, because no one knew if the other would return or not.*
>
> -LC 5 Interview, June 27, 2014

Conflict between residents has been just one issue occurring with population regrowth. An additional issue that many local government officials see future problems with is investors buying large areas of land in Northern Uganda for commercial scale farming. Many people who were interviewed mentioned the potential for future land conflict, as people are selling their land at cheap rates to international investors for commercial farming purposes. One NGO official stated in reference to the method at which the investors are purchasing the land:

> *Instead of talking with the local people, they went straight to the government to talk to them. The government gave them the land, and a serious conflict started. This is an ongoing case that is still in court.*
>
> -NGO Official, July 5, 2014

Migration due to oil development

Migration was a common theme related to oil development. People from outside of the oil-impacted districts have migrated to oil-impacted areas in hopes of purchasing land to gain royalties and other benefits. In fact, all group interviews in the oil-impacted districts (Bulisa, Nebbi, and Nwoya) cited oil development as a cause for migration. Non-oil impacted districts (Oyam, Kiryandongo, and Masindi) were more likely to discuss natural population increase and refugee migration as reasons for population growth. Residents within the three oil impacted districts have been selling their land cheaply to investors, and are often left regretting their decision when the money is inevitably spent. As one LC5 stated:

> *Oil has also affected us and the land. People think that oil is in the community, but for now, oil is in the park. People were anticipating oil in the land, and had big dreams of becoming rich. They would purchase land in hopes of royalties from the oil companies finding oil on their land. This attracted people from other parts of the country to buy land, and speculators have purchased small plots up to the Nile...People are heading towards danger. They are selling their land very cheaply because they want to get money. This will cause problems for the next generation, because they will have nothing, nowhere to settle.*
>
> -LC5, June 27, 2014

Additionally, land grabbing has become a concern to many in the oil-impacted regions. Land grabbing is when domestic or international companies, governments, or individuals lease or purchase large plots of productive land from locals, often in a manner that skirts the customary system of the local community.

> *There has been grabbing of oil wells and land by rich men and these oil companies. I have an oil well on my land, and a rich man comes to buy my land, and I tell him I am not selling. He finds someone else who says he owns the land, and he returns to my place with all of the papers saying he owns the land.*
>
> -LC1, July 10, 2014

Discussion

The results of this study highlight a difference between the protected and unprotected lands of the MFCA landscape. As with other areas of Africa, land cover change is often occurring much faster outside of PAs than inside (Wegmann et al. 2014). This makes sense since most PAs with national park status (such as MFCA) in Sub-Saharan Africa do not allow humans to reside, cultivate or use the natural resources of the park.

MFCA

My results suggest that MFCA has been successful in maintaining its boundaries and excluding most human activity from its border between 2002 and 2014 (with the exception of oil development and poaching). The percentage of land covered by agriculture and development within MFCA remained a relatively small percentage of the total landscape (0.2% and 0.4%, respectively). However, that does not mean there weren't large changes in land cover within MFCA. The savannah woodland ecosystem decreased the most out of all land cover classes within MFCA. Between 2002 and 2014, there was an 8% reduction in total woodland area. A portion of this decrease in woodland is likely an indirect impact of the conflict and insecurity in northern Uganda on wildlife.

Armed conflict and rebel activity in SSA often decimates wildlife populations within PAs (Dudely et al. 2002; Hanson et al. 2009). Rebel groups use wildlife products to fund their illicit activities and ammunition needs through poaching, and wildlife normally flee to peaceful regions (Beyers et al. 2011). Elephants in particular are at high risk during periods of conflict. Their ivory is in high demand on the global black market (EIA 2014; Kideghesho 2016; UNEP et al. 2013). One kilogram of ivory can net upwards of USD$2,100 (Stiles 2014). By the end of the 1980's, Uganda’s elephant population was decimated. Only 700 to 800 elephants remained within the country by the end of the 1980’s due to poaching and conflict (Plumptre et al. 2015). Elephants have a considerable impact on savanna ecosystems (Buechner & Dawkins 1961). In addition to seed dispersal, they can drastically reduce tree cover in savanna ecosystems within a very short time period by uprooting large trees (Guy 1989; Ruess & Halter 1990). The removal of elephants from savanna ecosystems has the potential to drastically alter ecosystem maintenance. The loss of elephants is particularly pertinent to the LRA conflict. The LRA severely impacted the northern sector of MFCA during their occupation. During the LRA’s stronghold in the north, elephant populations plummeted as the government could not constrain poaching. Elephants also fled to the neighboring DRC to flee the LRA conflict. With the return of stability to the country, the total number of elephants in Uganda has increased roughly 600% to over 5,000 elephants (Plumptre et al. 2015). Much of the change in land cover in the north could be explained by loss of wildlife, such as elephants (Nampindo 2005). Between 1985 and 2002, woody biomass increased significantly in the MFCA region during the conflict (WCS 2005). However, by 2014, much of this woody biomass has been reduced, transitioning back from woodland to grassland. It is likely that with the return of security and increased elephant populations within the study area, elephants started to reduce tree cover that flourished and expanded during conflict, and the landscape has slowly transitioned back into savanna grassland.

Surrounding Landscape

Post-conflict regrowth, oil-development, and the expansion of industrial agriculture have had a significant impact on the landscape surrounding MFCA. Based on the change in land cover between 2002 and 2014, it is evident that the landscape is becoming increasingly influenced by human activity. Large areas of grassland, woodland, forest and wetland have been replaced and fragmented by agriculture. Evidence for an increasingly human dominated and influenced landscape surrounding PAs has been found in many regions of Africa, including both savanna and forest PAs (Borner 1985; Clerici et al. 2007; Hartter & Southworth, 2009; Southworth et al 2010; Bailey et al. 2015). This loss of habitat in the periphery of PA boundaries reduces the effectiveness of PAs to maintain ecological processes and maintain species richness (DeFries et al. 2005; Joppa et al. 2009).

Outside of MFCA, forest and woodland habitat reduced by 32% and 20%, respectively. While both land cover types provide many direct benefits to residents (e.g., charcoal production and firewood collection), benefits are also derived indirectly. Indirect benefits mainly stem from services such as erosion control, watershed management, and carbon sequestration. Additionally, locals in western Uganda have been reported to believe living closer to PAs results in more rainfall (Hartter et al. 2014). This is due to a perception that forests could have a microclimate effect in the areas surrounding them. The main forest region of the MFCA is in the south, in and around Budongo Forest Reserve. In this area, one of the largest drivers of deforestation is sugarcane production (NEMA 2006). Between the year 1985 and 2002, land covered by the sugarcane plantation increased 10 fold. Much of this growth occurred due to outgrowers moving to the area due to financial incentives (NEMA 2006). This greatly influenced encroachment into forest patches, adding pressure to the resource pool of the area through increases in legal and illegal pit sawing of forested lands (NEMA 2006). According to an LC1 interview I conducted in a community near the sugarcane facilities, the human population has continued to grow in the past ten years due to immigration related to sugarcane opportunities (LC1 Interview, 08/01/2014). Additionally, the land occupied by sugarcane has continued to increase. Sugarcane production, along with charcoal and firewood collection, is likely a major reason for the decrease in forest and woodland cover outside of MFCA.

Armed-conflict and rebel activity often play a large role in landscape level change in biodiversity hotspots worldwide. Eighty percent of conflicts between 1950 and 2000 were located directly within biodiversity hotspots (Hanson et al. 2009). Previous studies have illustrated the introduction of armed conflict to rural areas leads to rural-urban migration (cities deemed to be safer). This out-migration results in abandoned agricultural lands in conflict regions (Suthakar & Bui 2008; Witmer 2008, Alix-Garcia et al. 2013). This abandonment can lead to conservation benefits in the form of regrowth and recovery of natural lands during the conflict period (UNEPb 2006). However, the regrowth of land cover can be temporary. Following the conflict, people who moved away may return to the land they used to farm on and/or had cultural/ancestral ties. The return of refugee populations has been tied to higher conversion in post-conflict areas than prior to the war (Kondylis 2008). In Uganda, areas where the LRA conflict was more intense often led to landscapes that were largely left untouched (USAID 2006). The LRA conflict was particularly intense in Nwoya District. After the LRA left Nwoya, people returned to cultivate the lands they previously abandoned. In fact, the population density of Nwoya District increased by 170% between 2002 and 2014 (chapter 2). New investors and migrants moved to the area to take advantage of the open lands, largely due to land shortages elsewhere. These factors have led to large areas of agricultural expansion in Nwoya District between the 2002 and 2014 land cover maps.

Land tenure plays a vital role in the peaceful repopulation of post-conflict landscapes. Residents and government officials who fled the area during the LRA conflict largely complained about their lands being taken by strangers and outsiders upon their return. There are rampant claims that customary ties to land are not being recognized. This scenario is prevalent in post-conflict regrowth literature. Customary land tenure systems in post-conflict landscapes often results in the loss of land, as government agencies and donors cannot keep up with the rush of migrants to open land (Unruh 2004; Hetz et al. 2006; Unruh and Williams 2013). Conflict results due to the contested land, often resulting in violence, and impeding the stability of the peace-building process. A report by the USAID Land Tenure Group (2006) in 2006 stressed the need for cooperation and discussion among local, customary, district and regional authorities in order to have cooperation during repopulation to better manage available lands. These discussions never took place, and as witnessed in my interviews, there has been a rapid conversion of natural lands to agriculture since the conflict ended.

As was discussed extensively in chapter 2 of this thesis, oil development is having a major impact on land cover change and human population growth in the MFCA since it’s discovery in 2006. Oil-impacted districts surrounding MFCA have been associated with higher population growth and development compared to non-oil-impacted districts (Chapter 2). Oil development often brings increased road networks and access to locations that were previously difficult to reach (Wilkie et al. 2000). This leads to natural land cover conversion and agricultural growth through easier access to isolated and available land (chapter 2). In areas with high population growth and high agricultural potential, this type of development can be detrimental to important ecological areas (Laurance et al. 2014), such as MFCA.

Finally, as was seen in this analysis through the use of qualitative interviews, human population growth and various social and cultural systems (such as polygamy and early marriage) likely play an important role in the increase of the human population of MFCA. Previous studies have highlighted high fertility and population growth rates as a driver of land cover conversion and fragmentation in South America (Evans et al. 2001; Bilsborrow et al. 2004; Carr 2005), South Africa (Biggs and Scholes 2002), the Congo Basin (Zhang et al. 2006), and Bangladesh (Islam 2014). One of the influences on high population growth rates is high adolescent pregnancy rates. The World Health Organization suggests that a reduced incidence of adolescent pregnancy could drastically reduce population growth rates, leading to a large range of economic and social benefits (WHO 2016). Uganda has the 16th highest rate of early marriages in the world (World Vision 2013), with 46% of women married prior to their 18th birthday, and 12% prior to their 15th. Therefore, in future studies of the MFCA, it will be necessary to quantify changes in age structures and ethnicity of the region to understand the regional dynamics of human population growth (migration vs. natural population growth). This will not be possible until the full 2014 census is available for Uganda, as there are currently no accurate, available estimates of age and ethnicity for this region of Uganda.

Conclusion

In Chapter 3, I used a mixed-method approach to answer two important questions: 1) How has the landscape in and around MFCA changed in terms of land cover and landscape pattern between 2002 and 2014?; and 2) What are possible anthropogenic and cultural drivers of land cover change and natural land conversion outside of MFCA? I created two land cover classifications using OBIA to track changes in land cover and fragmentation inside and outside MFCA between 2002 and 2014. Additionally, I conducted key informant and group interviews to ascertain the drivers of land cover change within the MFCA landscape.

Inside MFCA, the war with the LRA appears to have had indirect impacts on land cover through the loss and displacement of wildlife due to conflict. During the LRA occupation, grazing animals and elephants were either driven away or poached in large numbers within MFCA. This resulted in a large increase in woodlands during the conflict. Stability returned to the region in 2006. Between 2002 and 2014, large areas of woodland have been replaced by grasslands in the northern sector of MFCA. This is likely due to the reintroduction of anti-poaching measures within MFCA, and subsequent repopulation of elephants and other grazing species.

Agricultural land outside of MFCA has increased substantially within the time frame of the study. While natural population growth has likely played an important role, so have the important events that occurred in 2006. First, post-conflict regrowth since the end of the LRA conflict resulted in a dramatic amount of agricultural expansion to the north of the park. Customary land tenure arrangements have complicated the repopulation of the area, resulting in violent conflict over land rights. Additionally, oil development has driven increased human migration to the area, as migrants are drawn in hopes of economic opportunity. New roads from oil development open up new markets and agricultural frontiers, and are likely influencing land cover change to the west of the park. I covered the impact of oil development extensively in Chapter 2, and the impact it has had on the MFCA appears to be quite large. Finally, sugarcane production to the south of the PA has played a large role in deforestation and human migration due to out growers in Masindi District. As land cover outside of the PA continues to be converted within the coming decades, valuable resources that provide important ecosystems services will slowly dwindle. Residents will be forced to search for these resources further than in years prior. Therefore, understanding the drivers of land cover changes surrounding MFCA is important to PA sustainability and anticipating further pressure from communities for the resources held within.

CHAPTER 4

CONCLUSION

This thesis analyzed the impact that human activities are having on the MFCA landscape at large. While there have been many factors influencing human population growth and land cover conversion within this study area, arguably the two largest have been both post-conflict regrowth and the discovery and development of industrial oil.

In chapter 2, I used semi-structured qualitative human surveys, historical gridded population density datasets, and binary land cover classifications to assess the short-term impact that industrial oil development is having on the MFCA landscape and local livelihoods of the people who inhabit its surrounding areas. I found inflated population densities in the districts where oil development is occurring within the most recent census period, and a trajectory of population density that differs from the national average of Uganda and non-oil impacted districts. Additionally, oil-impacted districts had increased fragmentation and conversion of natural lands compared to non-oil impacted districts. People living in oil-impacted districts have faced unique changes to their livelihoods, including the perceived increased migration due to oil development, destruction of personal property and perceived lack of adequate compensation, increase in prostitution due to influx of money and market for sex industry, and lack of employment and economic benefits.

In chapter 3, I examined changes in land cover of the MFCA landscape, and the various social issues leading to this change. I observed that the area surrounding MFCA is becoming increasingly fragmented, with a high rate of natural land conversion. One of the largest influences on natural land conversion within this area is post-conflict regrowth to the north of the park. The land cover classifications highlighted this change, as the area was predominantly covered by grassland, woodland and wetlands in 2002, and experienced a boom in agricultural growth by 2014 following post-conflict regrowth. This regrowth has not only resulted in changes to the land cover of the area, but also in conflict and land-grabbing. As people who did not inhabit the area prior to the conflict are seeking land, customary claims to land have either been skirted or challenged by wealthy investors and foreigners. Within the boundary of MFCA, the landscape has remained relatively stable, with very little quantifiable human influence on the park (i.e., increases in developed or agriculture land). Human conflict from the LRA war could potentially have resulted in a large increase in woodland area during the conflict due to the reduction of elephant populations within the area. As peace returned to the area, so did elephants, and in turn grassland habitat. Finally, outgrowth of the sugarcane industry to the south of MFCA has likely been one of the main drivers of deforestation outside of MFCA.

There are potential limitations of this study that need to be addressed when interpreting the results of this thesis. First, I was unable to create gridded population data based on ethnicity and age due to the delayed release of the full 2014 Ugandan Population Census. This is important to note, since age and ethnicity are potentially confounding influences on population change within this area. These two variables are important in understanding how much growth is likely due to migration, and how much is due to natural population growth. The census was initially due to be released at in 2015, however, at the time of submission of this thesis (June 2016), it is still not available. Other projected data sources on age and ethnicity of Uganda are not be appropriate for this project, as they were created prior to the post-conflict regrowth and discovery of oil in the MFCA landscape, thus the data would provide unreliable results. Therefore, when the 2014 census is finally released, I will create additional gridded geospatial data to help analyze inter-regional migration patterns and temporal age structures to the MFCA districts.

While oil development in Uganda has the potential to bring unprecedented money and investment into the country, it adds complexity to the conservation and human landscape of the country. This is not an issue that is unique to Uganda. Throughout the world, as mining and industrial development impact new and isolated regions, having a better understanding of the drivers of landscape level change and changes to human livelihoods will be important to developing successful conservation policy. As human populations continue to grow and expand in extent and mineral extraction continues within ecologically important regions, more pressure is being placed on PAs. This research helps to increase understanding of the impact of mineral development of smallholder communities, and to increase literature on the drivers of migration and land cover change at PA boundaries. Oil development has provided large incentives for human migration to the boundaries of MFCA. This is largely due to the prospect of economic benefit from oil development. Additionally, the high availability of land following the LRA conflict provided reason for people to migrate to the boundary of MFCA.

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APPENDIX

Appendix 1: Land cover metrics for Murchison Falls National Park for each land cover class for each individual year. Land cover metrics include: 1.) CA=Class Area (Hectares), PLAND=Percent of Landscape (%), 3.) NP=Number of Patches (n), 4.) PD=Patch Density (number of patches per unit area), 5.) LPI= Largest Patch Index (%), 6.) TE=Total Edge (Kilometers), 7.) MPS=Mean Patch Size (Hectares), 8.) MN Dist=Mean Distance between Patches (meters).

Landcover	Year	CA	PLAND (%)	NP	PD	LPI	TE	MPS	MN Dist
Forest	2002	1118.16	0.3	53	0.01	0.11	136	21.1	897.0
	2014	6660.99	1.7	416	0.11	0.17	1099	16.0	530.4
Agriculture	2002	416.61	0.1	40	0.01	0.01	85	10.4	2121.8
	2014	1089.09	0.3	96	0.02	0.04	169	11.3	486.6
Developed	2002	1194.75	0.3	282	0.07	0.01	395	4.2	737.8
	2014	2370.60	0.6	843	0.22	0.01	846	2.8	433.3
Grassland	2002	186764.13	48.2	1183	0.31	23.29	8161	157.9	228.5
	2014	195671.52	50.5	773	0.20	26.87	7187	253.1	222.8
Woodland	2002	177061.14	45.7	907	0.23	27.30	8667	195.2	206.9
	2014	160478.19	41.4	1265	0.33	25.97	7826	126.9	215.7
Wetland	2002	16321.68	4.2	956	0.25	0.36	2833	17.1	412.4
	2014	16248.42	4.2	1511	0.39	0.69	3212	10.8	360.4

Appendix 2: Land cover metrics for Bagungu Wildlife Reserve for each land cover class for each individual year. Land cover metrics include: 1.) CA=Class Area (Hectares), PLAND=Percent of Landscape (%), 3.) NP=Number of Patches (n), 4.) PD=Patch Density (number of patches per unit area), 5.) LPI= Largest Patch Index (%), 6.) TE=Total Edge (Kilometers), 7.) MPS=Mean Patch Size (Hectares), 8.) MN Dist=Mean Distance between Patches (meters).

Landcover	Year	CA	PLAND (%)	NP	PD	LPI	TE	MPS	MN Dist
Forest	2002	89.82	0.3	9	0.03	0.10	13	10.0	572.0
	2014	199.44	0.6	23	0.07	0.11	33	8.7	186.0
Agriculture	2002	15.93	0.0	2	0.01	0.03	4	8.0	192.1
	2014	23.67	0.1	15	0.04	0.02	8	1.6	345.4
Developed	2002	32.13	0.1	11	0.03	0.03	12	2.9	448.3
	2014	22.59	0.1	26	0.08	0.01	9	0.9	1489.5
Grassland	2002	23468.67	69.8	69	0.21	66.97	762	340.1	121.2
	2014	23078.25	68.6	76	0.23	48.99	737	303.7	167.3
Woodland	2002	8318.34	24.7	119	0.35	14.33	695	69.9	215.5
	2014	8285.31	24.6	111	0.33	18.40	627	74.6	188.0
Wetland	2002	1708.92	5.1	70	0.21	1.96	202	24.4	364.0
	2014	2021.22	6.0	157	0.47	1.38	318	12.9	328.3

Appendix 3: Land cover metrics for Budongo Forest Reserve for each land cover class for each individual year. Land cover metrics include: 1.) CA=Class Area (Hectares), PLAND=Percent of Landscape (%), 3.) NP=Number of Patches (n), 4.) PD=Patch Density (number of patches per unit area), 5.) LPI= Largest Patch Index (%), 6.) TE=Total Edge (Kilometers), 7.) MPS=Mean Patch Size (Hectares), 8.) MN Dist=Mean Distance between Patches (meters).

Landcover	Year	CA	PLAND (%)	NP	PD	LPI	TE	MPS	MN Dist
Forest	2002	48405.96	59.3	76	0.09	54.13	744	636.9	264.4
	2014	52690.68	64.5	76	0.09	63.31	833	693.3	194.9
Agriculture	2002	374.58	0.5	179	0.22	0.04	81	2.1	339.7
	2014	404.55	0.5	246	0.30	0.02	107	1.6	250.1
Developed	2002	0	0.0	0	0.00	0.00	0	0.0	0.0
	2014	6.93	0.0	6	0.01	0.00	3	1.2	6892.7
Grassland	2002	5246.01	6.4	153	0.19	1.84	509	34.3	405.4
	2014	3767.4	4.6	120	0.15	1.32	328	31.4	425.8
Woodland	2002	26638.65	32.6	229	0.28	18.53	1290	116.3	211.5
	2014	23761.08	29.1	320	0.39	14.80	1218	74.3	210.6
Wetland	2002	1017.9	1.2	206	0.25	0.12	282	4.9	466.0
	2014	1048.41	1.3	303	0.37	0.04	374	3.5	411.4

Appendix 4: Land cover metrics for Karuma Wildlife Reserve for each land cover class for each individual year. Land cover metrics include: 1.) CA=Class Area (Hectares), PLAND=Percent of Landscape (%), 3.) NP=Number of Patches (n), 4.) PD=Patch Density (number of patches per unit area), 5.) LPI= Largest Patch Index (%), 6.) TE=Total Edge (Kilometers), 7.) MPS=Mean Patch Size (Hectares), 8.) MN Dist=Mean Distance between Patches (meters).

Landcover	Year	CA	PLAND (%)	NP	PD	LPI	TE	MPS	MN Dist
Forest	2002	1586.34	2.8	79	0.14	0.55	176	20.1	499.9
	2014	5340.87	9.3	398	0.69	0.59	945	13.4	266.6
Agriculture	2002	303.48	0.5	75	0.13	0.07	53	4.0	548.9
	2014	288.90	0.5	106	0.18	0.10	65	2.7	314.9
Developed	2002	7.47	0.0	3	0.01	0.01	3	2.5	20823.4
	2014	6.03	0.0	3	0.01	0.01	2	2.0	20043.3
Grassland	2002	1695.06	3.0	173	0.30	0.11	320	9.8	482.8
	2014	110.16	0.2	30	0.05	0.04	30	3.7	1262.8
Woodland	2002	51486.84	89.7	74	0.13	88.71	872	695.8	110.3
	2014	49372.02	86.0	106	0.18	51.26	1398	465.8	107.0
Wetland	2002	1851.93	3.2	134	0.23	0.25	395	13.8	476.5
	2014	1868.22	3.3	272	0.47	0.26	505	6.9	415.0

Appendix 5: Land cover metrics for Bulisa District for each land cover class for each individual year. Land cover metrics include: 1.) CA=Class Area (Hectares), PLAND=Percent of Landscape (%), 3.) NP=Number of Patches (n), 4.) PD=Patch Density (number of patches per unit area), 5.) LPI= Largest Patch Index (%), 6.) TE=Total Edge (Kilometers), 7.) MPS=Mean Patch Size (Hectares), 8.) MN Dist=Mean Distance between Patches (meters).

Landcover	Year	CA	PLAND (%)	NP	PD	LPI	TE	MPS	MN Dist
Forest	2002	139.68	0.3	47	0.09	0.03	287	3.0	376.8
	2014	81.00	0.2	42	0.08	0.03	177	1.9	419.0
Agriculture	2002	12721.50	23.9	49	0.09	12.48	8650	259.6	339.0
	2014	16044.12	30.2	129	0.24	1.01	11170	124.4	285.5
Developed	2002	182.70	0.3	30	0.06	0.05	473	6.1	1326.7
	2014	407.16	0.8	140	0.26	0.03	1408	2.9	584.1
Grassland	2002	18291.15	34.4	221	0.42	11.05	10831	82.8	260.1
	2014	15271.74	28.7	335	0.63	7.89	11292	45.6	234.0
Woodland	2002	4675.14	8.8	239	0.45	1.83	6455	19.6	295.8
	2014	3823.29	7.2	147	0.28	3.77	3613	26.0	281.4
Wetland	2002	20369.00	9.1	1216	0.54	1.09	3733	16.8	250.3
	2014	4482.09	8.4	181	0.34	4.65	3453	24.8	260.1

Appendix 6: Land cover metrics for Kiryandongo District for each land cover class for each individual year. Land cover metrics include: 1.) CA=Class Area (Hectares), PLAND=Percent of Landscape (%), 3.) NP=Number of Patches (n), 4.) PD=Patch Density (number of patches per unit area), 5.) LPI= Largest Patch Index (%), 6.) TE=Total Edge (Kilometers), 7.) MPS=Mean Patch Size (Hectares), 8.) MN Dist=Mean Distance between Patches (meters).

Landcover	Year	CA	PLAND (%)	NP	PD	LPI	TE	MPS	MN Dist
Forest	2002	6.57	0.0	6	0.02	0.01	13	1.1	6374.0
	2014	44.55	0.1	25	0.08	0.07	114	1.8	1521.3
Agriculture	2002	22690.44	70.9	50	0.16	39.40	13571	453.8	108.3
	2014	21584.97	67.4	92	0.29	26.96	16193	234.6	94.0
Developed	2002	47.79	0.1	11	0.03	0.03	128	4.3	2411.1
	2014	79.2	0.2	21	0.07	0.04	245	3.8	2166.2
Grassland	2002	3559.14	11.1	338	1.06	1.24	7914	10.5	224.8
	2014	932.04	2.9	105	0.33	0.38	1726	8.9	392.5
Woodland	2002	3942.45	12.3	366	1.14	0.47	7864	10.8	191.0
	2014	6774.3	21.2	544	1.70	2.98	13646	12.5	139.9
Wetland	2002	1601.91	5.0	141	0.44	0.79	3571	11.4	341.6
	2014	2448.54	7.6	263	0.82	1.09	5495	9.3	261.5

Appendix 7: Land cover metrics for Masindi District for each land cover class for each individual year. Land cover metrics include: 1.) CA=Class Area (Hectares), PLAND=Percent of Landscape (%), 3.) NP=Number of Patches (n), 4.) PD=Patch Density (number of patches per unit area), 5.) LPI= Largest Patch Index (%), 6.) TE=Total Edge (Kilometers), 7.) MPS=Mean Patch Size (Hectares), 8.) MN Dist=Mean Distance between Patches (meters).

Landcover	Year	CA	PLAND (%)	NP	PD	LPI	TE	MPS	MN Dist
Forest	2002	2048.76	5.7	209	0.58	0.95	3230	9.8	314.2
	2014	1177.29	3.3	216	0.60	0.37	2266	5.5	347.2
Agriculture	2002	22236.66	62.1	110	0.31	22.13	16432	202.2	158.3
	2014	26435.88	73.9	88	0.25	39.52	17740	300.4	76.6
Developed	2002	26.55	0.1	12	0.04	0.01	102	2.2	2480.1
	2014	147.15	0.4	54	0.15	0.04	497	2.7	1263.4
Grassland	2002	2754.36	7.7	278	0.78	0.47	5927	9.9	278.0
	2014	783.72	2.2	173	0.48	0.13	2216	4.5	416.9
Woodland	2002	5812.11	16.2	428	1.20	2.25	10172	13.6	190.4
	2014	5334.3	14.9	522	1.46	0.67	12392	10.2	186.1
Wetland	2002	2922.76	5.7	332	0.93	0.48	7995	8.8	238.3
	2014	1916.46	5.4	367	1.03	0.26	5859	5.2	273.2

Appendix 8: Land cover metrics for Nebbi District for each land cover class for each individual year. Land cover metrics include: 1.) CA=Class Area (Hectares), PLAND=Percent of Landscape (%), 3.) NP=Number of Patches (n), 4.) PD=Patch Density (number of patches per unit area), 5.) LPI= Largest Patch Index (%), 6.) TE=Total Edge (Kilometers), 7.) MPS=Mean Patch Size (Hectares), 8.) MN Dist=Mean Distance between Patches (meters).

Landcover	Year	CA	PLAND (%)	NP	PD	LPI	TE	MPS	MN Dist
Forest	2002	0.00	0.0	0	0.00	0.00	0	0.0	0.0
	2014	3.78	0.0	1	0.01	0.03	14	3.8	0.0
Agriculture	2002	4623.57	30.8	17	0.11	13.27	2614	272.0	433.6
	2014	5878.44	39.2	36	0.30	14.87	3464	163.3	148.0
Developed	2002	321.75	2.2	34	0.23	0.43	822	9.5	696.2
	2014	127.17	0.8	42	0.28	0.13	476	3.0	660.1
Grassland	2002	4834.53	32.2	57	0.38	12.45	4052	84.8	159.3
	2014	4231.71	28.2	81	0.54	14.16	3701	52.2	173.4
Woodland	2002	668.70	4.5	66	0.44	0.52	1563	10.1	359.0
	2014	0.00	0.0	0	0.00	0.00	0	0.0	0.0
Wetland	2002	787.14	5.2	34	0.23	0.40	985	23.2	291.9
	2014	963.99	6.4	73	0.49	1.32	1454	13.2	258.9

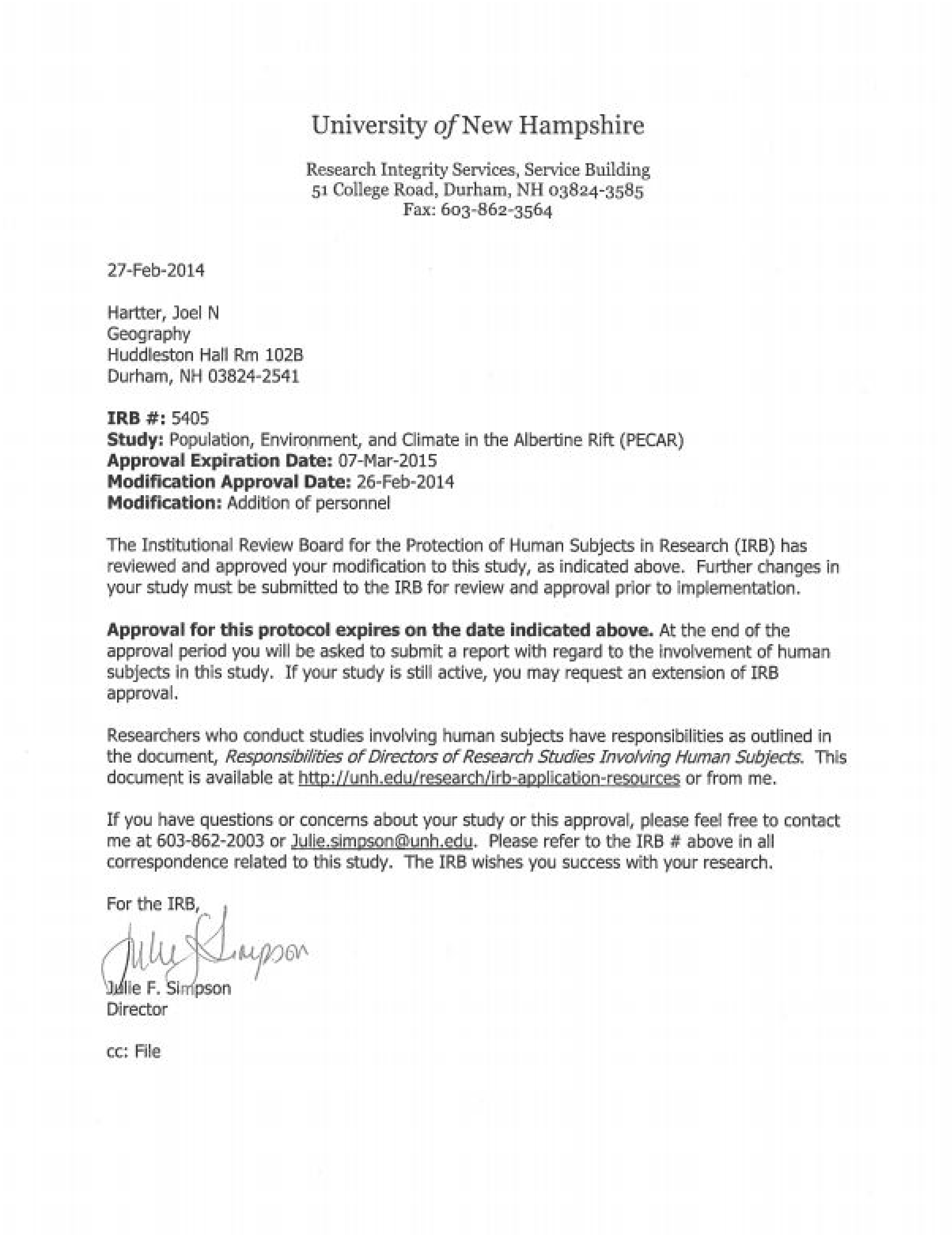
Appendix 9: Land cover metrics for Nwoya District for each land cover class for each individual year. Land cover metrics include: 1.) CA=Class Area (Hectares), PLAND=Percent of Landscape (%), 3.) NP=Number of Patches (n), 4.) PD=Patch Density (number of patches per unit area), 5.) LPI= Largest Patch Index (%), 6.) TE=Total Edge (Kilometers), 7.) MPS=Mean Patch Size (Hectares), 8.) MN Dist=Mean Distance between Patches (meters).

Landcover	Year	CA	PLAND (%)	NP	PD	LPI	TE	MPS	MN Dist
Forest	2002	0.00	0.0	0	0.00	0.00	0	0.0	0.0
	2014	156.06	0.2	33	0.01	0.03	387	4.7	1035.6
Agriculture	2002	868.23	1.3	71	0.11	0.20	1493	12.2	555.2
	2014	17320.59	26.9	380	0.59	10.57	22579	45.6	187.9
Developed	2002	46.17	0.1	20	0.03	0.01	38	2.3	3194.3
	2014	136.62	0.2	57	0.09	0.02	407	2.4	952.8
Grassland	2002	22892.94	35.5	356	0.55	9.35	21275	64.3	213.4
	2014	18257.67	28.3	635	0.98	14.45	21938	28.8	166.8
Woodland	2002	28274.94	43.9	360	0.56	26.67	22368	78.5	175.6
	2014	19011.15	29.5	431	0.67	17.73	22499	44.1	178.0
Wetland	2002	8076.33	12.5	530	0.82	0.49	15476	15.2	192.7
	2014	5299.92	8.2	701	1.09	0.54	12667	7.6	218.6

Appendix 10: Land cover metrics for Oyam District for each land cover class for each individual year. Land cover metrics include: 1.) CA=Class Area (Hectares), PLAND=Percent of Landscape (%), 3.) NP=Number of Patches (n), 4.) PD=Patch Density (number of patches per unit area), 5.) LPI= Largest Patch Index (%), 6.) TE=Total Edge (Kilometers), 7.) MPS=Mean Patch Size (Hectares), 8.) MN Dist=Mean Distance between Patches (meters).

Landcover	Year	CA	PLAND (%)	NP	PD	LPI	TE	MPS	MN Dist
Forest	2002	1.98	0.0	3	0.03	0.02	7	0.7	67.8
	2014	13.50	0.1	4	0.04	0.07	31	3.4	4020.0
Agriculture	2002	5780.16	63.8	21	0.23	57.53	47658	275.2	96.5
	2014	6264.36	69.1	28	0.31	67.47	4690	223.7	109.7
Developed	2002	13.68	0.2	5	0.06	0.08	45	2.7	2118.4
	2014	17.64	0.2	8	0.09	0.05	70	2.2	1978.1
Grassland	2002	598.59	6.6	68	0.75	0.63	1462	8.8	259.2
	2014	88.29	1.0	22	0.24	0.25	242	4.0	661.4
Woodland	2002	1268.64	14.0	126	1.39	0.62	2635	10.1	17.0
	2014	1530.81	16.9	165	1.82	2.10	3407	9.3	149.9
Wetland	2002	1385.10	15.3	66	0.73	5.57	2731	21.0	189.6
	2014	1143.90	12.6	77	0.85	3.53	2521	14.9	14.6

Appendix 11: Institutional Review Board for the Protection of Human Subjects in Research (IRB) Approval



University *of* New Hampshire

Research Integrity Services, Service Building
51 College Road, Durham, NH 03824-3585
Fax: 603-862-3564

27-Feb-2014

Hartter, Joel N
Geography
Huddleston Hall Rm 102B
Durham, NH 03824-2541

IRB #: 5405
Study: Population, Environment, and Climate in the Albertine Rift (PECAR)
Approval Expiration Date: 07-Mar-2015
Modification Approval Date: 26-Feb-2014
Modification: Addition of personnel

The Institutional Review Board for the Protection of Human Subjects in Research (IRB) has reviewed and approved your modification to this study, as indicated above. Further changes in your study must be submitted to the IRB for review and approval prior to implementation.

Approval for this protocol expires on the date indicated above. At the end of the approval period you will be asked to submit a report with regard to the involvement of human subjects in this study. If your study is still active, you may request an extension of IRB approval.

Researchers who conduct studies involving human subjects have responsibilities as outlined in the document, *Responsibilities of Directors of Research Studies Involving Human Subjects*. This document is available at http://unh.edu/research/irb-application-resources or from me.

If you have questions or concerns about your study or this approval, please feel free to contact me at 603-862-2003 or Julie.simpson@unh.edu. Please refer to the IRB # above in all correspondence related to this study. The IRB wishes you success with your research.

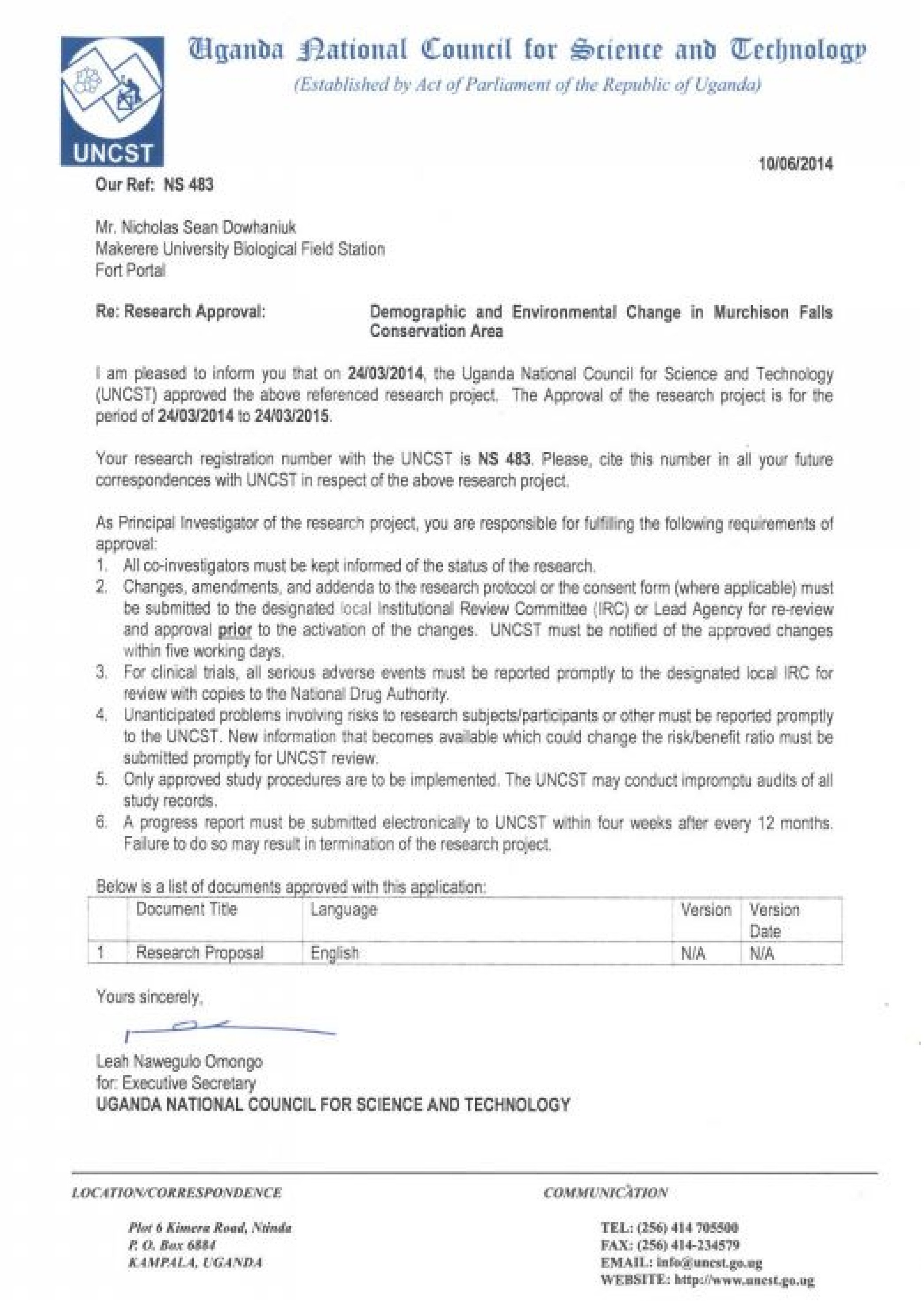
For the IRB,

Julie Simpson

Julie F. Simpson
Director

cc: File

Appendix 12: Uganda National Council for Science and Technology (UNCST) Approval



Uganda National Council for Science and Technology
(Established by Act of Parliament of the Republic of Uganda)
UNCST

10/06/2014

Our Ref: NS 483

Mr. Nicholas Sean Dowhaniuk
Makerere University Biological Field Station
Fort Portal

Re: Research Approval: **Demographic and Environmental Change in Murchison Falls Conservation Area**

I am pleased to inform you that on **24/03/2014**, the Uganda National Council for Science and Technology (UNCST) approved the above referenced research project. The Approval of the research project is for the period of **24/03/2014** to **24/03/2015**.

Your research registration number with the UNCST is **NS 483**. Please, cite this number in all your future correspondences with UNCST in respect of the above research project.

As Principal Investigator of the research project, you are responsible for fulfilling the following requirements of approval:

1. All co-investigators must be kept informed of the status of the research.
2. Changes, amendments, and addenda to the research protocol or the consent form (where applicable) must be submitted to the designated local Institutional Review Committee (IRC) or Lead Agency for re-review and approval **prior** to the activation of the changes. UNCST must be notified of the approved changes within five working days.
3. For clinical trials, all serious adverse events must be reported promptly to the designated local IRC for review with copies to the National Drug Authority.
4. Unanticipated problems involving risks to research subjects/participants or other must be reported promptly to the UNCST. New information that becomes available which could change the risk/benefit ratio must be submitted promptly for UNCST review.
5. Only approved study procedures are to be implemented. The UNCST may conduct impromptu audits of all study records.
6. A progress report must be submitted electronically to UNCST within four weeks after every 12 months. Failure to do so may result in termination of the research project.

Below is a list of documents approved with this application:

	Document Title	Language	Version	Version Date
1	Research Proposal	English	N/A	N/A

Yours sincerely,

Leah Nawegulo Omongo
for: Executive Secretary
UNCST
UGANDA NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

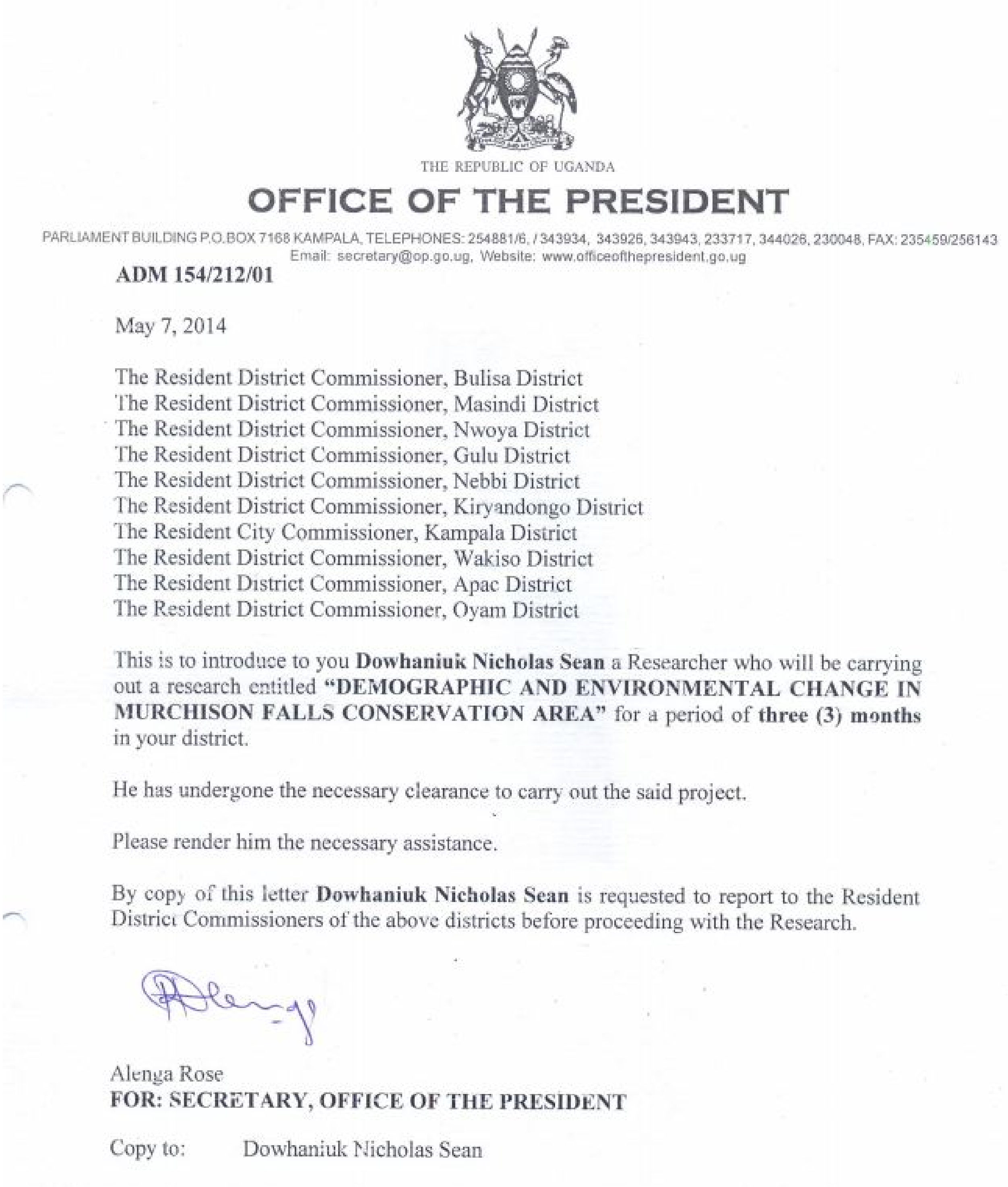
LOCATION/CORRESPONDENCE

Plot 6 Kimera Road, Ntinda
P. O. Box 6884
KAMPALA, UGANDA

COMMUNICATION

TEL: (256) 414 705500
FAX: (256) 414-234579
EMAIL: info@uncst.go.ug
WEBSITE: http://www.uncst.go.ug

Appendix 13: Office of the President Approval



THE REPUBLIC OF UGANDA

OFFICE OF THE PRESIDENT

PARLIAMENT BUILDING P.O.BOX 7168 KAMPALA, TELEPHONES: 254881/6, / 343934, 343926, 343943, 233717, 344026, 230048, FAX: 235459/256143
Email: secretary@op.go.ug, Website: www.officeofthepresident.go.ug

ADM 154/212/01

May 7, 2014

The Resident District Commissioner, Bulisa District
The Resident District Commissioner, Masindi District
The Resident District Commissioner, Nwoya District
The Resident District Commissioner, Gulu District
The Resident District Commissioner, Nebbi District
The Resident District Commissioner, Kiryandongo District
The Resident City Commissioner, Kampala District
The Resident District Commissioner, Wakiso District
The Resident District Commissioner, Apac District
The Resident District Commissioner, Oyam District

This is to introduce to you **Dowhaniuk Nicholas Sean** a Researcher who will be carrying out a research entitled **"DEMOGRAPHIC AND ENVIRONMENTAL CHANGE IN MURCHISON FALLS CONSERVATION AREA"** for a period of **three (3) months** in your district.

He has undergone the necessary clearance to carry out the said project.

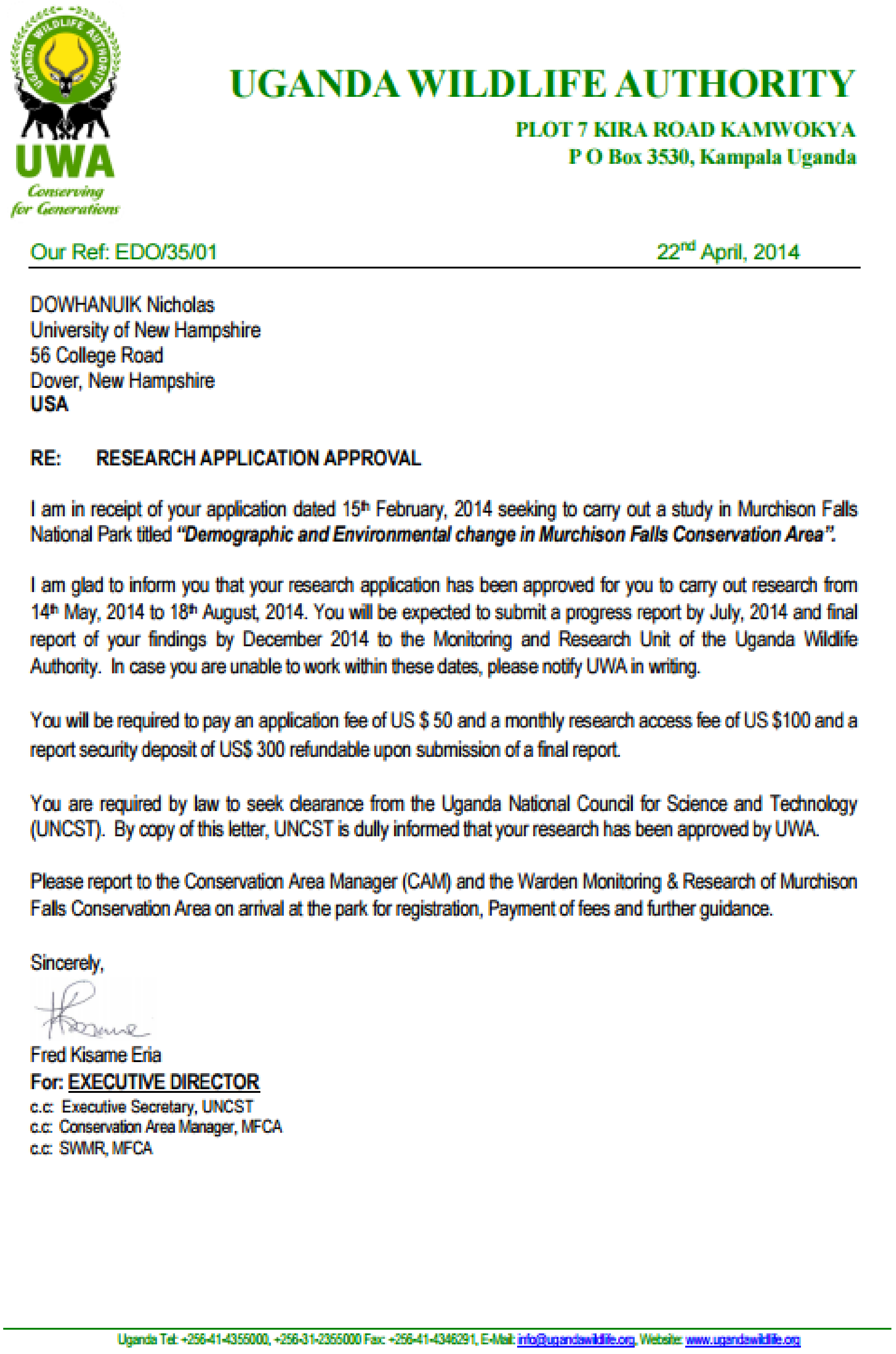
Please render him the necessary assistance.

By copy of this letter **Dowhaniuk Nicholas Sean** is requested to report to the Resident District Commissioners of the above districts before proceeding with the Research.

Alenga Rose
FOR: SECRETARY, OFFICE OF THE PRESIDENT

Copy to: Dowhaniuk Nicholas Sean

Appendix 14: Uganda Wildlife Authority (UWA) Approval



UWA
Conserving for Generations

UGANDA WILDLIFE AUTHORITY
PLOT 7 KIRA ROAD KAMWOKYA
P O Box 3530, Kampala Uganda

Our Ref: EDO/35/01 22nd April, 2014

DOWHANUIK Nicholas
University of New Hampshire
56 College Road
Dover, New Hampshire
USA

RE: RESEARCH APPLICATION APPROVAL

I am in receipt of your application dated 15th February, 2014 seeking to carry out a study in Murchison Falls National Park titled ***"Demographic and Environmental change in Murchison Falls Conservation Area".***

I am glad to inform you that your research application has been approved for you to carry out research from 14th May, 2014 to 18th August, 2014. You will be expected to submit a progress report by July, 2014 and final report of your findings by December 2014 to the Monitoring and Research Unit of the Uganda Wildlife Authority. In case you are unable to work within these dates, please notify UWA in writing.

You will be required to pay an application fee of US $ 50 and a monthly research access fee of US $100 and a report security deposit of US$ 300 refundable upon submission of a final report.

You are required by law to seek clearance from the Uganda National Council for Science and Technology (UNCST). By copy of this letter, UNCST is dully informed that your research has been approved by UWA.

Please report to the Conservation Area Manager (CAM) and the Warden Monitoring & Research of Murchison Falls Conservation Area on arrival at the park for registration, Payment of fees and further guidance.

Sincerely,

Fred Kisame Eria
For: EXECUTIVE DIRECTOR
c.c: Executive Secretary, UNCST
c.c: Conservation Area Manager, MFCA
c.c: SWMR, MFCA

Uganda Tel: +256-41-4355000, +256-31-2355000 Fax: +256-41-4346291, E-Mail: info@ugandawildlife.org, Website: www.ugandawildlife.org