EFFECTS OF OIL AND GAS EXPLORATION ON VEGETATION AND BIRD ABUNDANCE: A CASE STUDY OF KINGFISHER DEVELOPMENT AREA, KIKUUBE DISTRICT, UGANDA

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DECLARATION

I **Ashaba Hellen** declare that this dissertation is my original work and has never been presented in any institution of higher learning for any award.

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APPROVAL

This dissertation was prepared under our supervision and is now ready for examination.

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May God bless you abundantly.

DEDICATION

I dedicate this dissertation to my mum Komwaka Grace, my Sisters Tushabire Justine, Ayebazibwe Anitah and Nomuhwezi Adellah, my husband Bakamuto Simon Peter and our son Ahabwomugisha Shawn.

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ABSTRACT

Uganda discovered commercially viable deposits of petroleum in 2006. However, most of these areas where petroleum was discovered are considered to be centers for "biodiversity hotspot" and Kingfisher Development Area is among. Oil development has a potential of destroying these ecosystems and the species inhabiting those areas if not well planned and controlled. The research aimed at assessing the effects of Oil and Gas Exploration on vegetation and bird abundance in Kingfisher. The study objectives were; To determine the spatial and temporal trends in Land Use and Land Cover changes from 1990 to 2019, To determine the effects of oil and gas exploration on vegetation relative abundance; To determine the effects of oil and gas exploration on bird abundance. Remotely sensed methods were used to determine the spatial and temporal changes in Land Use and Land Cover using Satellite images of 1990, 2010, 2014 and 2019. The study used observation and survey methods for data collection on vegetation and bird abundance. Vegetation relative abundance and diversity was determined by observing, counting and recording plants using a (1x1)M, (3x3)M and (5x5)M quadrats along a 50M line transect for both oil pads and control areas. The study determined bird abundance by walking, observing and listening to sounds along a 1 km line transect within a distance of 200m on either side of each transect. A binocular and an experienced local ornithologist were used. Seasonal variations were also put into consideration. Results showed a slight change in the spatial and temporal variations in the classified images in land use and land cover changes from the year 1990 to 2019 highlighting some land uses that have experienced a minimal change over the years. These equate to the total land cover loss to (6.29%) in forest area, (7.66%) in bushland, (4.13%) in farmland, (4.46%) wetlands, open water (0.32%) 17.4% in grassland and 5.46% built-up areas. The study identified thirty-five plant species and among these; three were recorded in oil pads, six in control areas and twenty-six were recorded in both oil pads and control areas. The study recorded the mean vegetation diversity of (1.92±0.06) in oil pads and (1.82±0.08) in control areas. Results showed no significant difference in mean vegetation relative abundance for both oil pads and control areas at $P<0.05$. The study encountered twenty-five different bird species and the results revealed that there is no significant difference between the mean number of bird species recorded in oil pads and the ones recorded in control areas at $P<0.05$. Findings also showed that mean number of bird species observed in both oil pads and control areas for wet season significantly differed from that of dry season at $P < 0.05$. The mean number of bird species recorded in the oil pads and control areas during wet season was not significantly different at $P<0.05$. It is therefore important to note that oil and gas exploration is not a significant contributor to land use and land cover change in the area. However, there are other factors like overgrazing, fuel wood collection, agriculture, fishing to mention but a few that were observed as indicated in Appendices that could be contributing to this change. The study therefore recommends that Ministry of Energy and Mineral Development, National Environmental Management Authority to continue ensuring that oil companies and other stakeholders follow the guidelines put in their Environmental and Social Impact Assessment reports and project briefs for biodiversity protection and conservation. The study also recommends that local authorities should work together to ensure that the activities taking place in the protected areas are regulated or prohibited.

LIST OF ACRONMYS

AR	Albertine Rift
FR	Forest Reserve
WR	Wildlife Reserve
CBD	Convention on Biological Diversity
CFR	Central Forest Reserve
CNOOC	Chinese Offshore Oil Company
CPF	Central Processing Facility
EA	Exploration Area
EACOP	East African Crude Oil Pipeline
EIA	Environmental Impact Assessment
ES	Ecosystem Services
ESIA	Environmental and Social Impact Assessment
ESIAS	Environmental and Social Impact Studies
GIS	Geographical Information Systems
GPS	Global Positioning System
GSPC	Global Strategy on Plant Conservation
IUCN	International Union for Conservation of Nature
KF	Kingfisher
KFDA	Kingfisher Development Area
LPG	Liquefied Petroleum Gas
LULC	Land Use and Land Cover
MEA	Millennium Ecosystem Services

MEMD	Ministry of Energy and Mineral Development
MLA	Maximum Likelihood Arigorithm
NARO	National Agricultural Research Organization
NEMA	National Environmental Management Authority
NP	National Park
PCA	Principle Component Analysis
PCs	Principle Components
PEPD	Petroleum Exploration and Production Department
UBOS	Uganda Bureau of Statistics
UNOC	Uganda National Oil Company
UWA	Uganda Wildlife Authority
USGS	United States Geological Survey

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Petroleum, also known as oil and gas or hydrocarbons, is the key energy source of modern civilization because it is widely used as ingredients in many industrial uses, from pharmaceuticals and plastics, to computer chips (Matutinovic, 2009). According to the Energy Information Administration (EIA, 2007) fossil fuels will remain the major source for energy generation and are still expected to meet about 84% of energy demand in 2030. Therefore, a continuing search for new reservoirs of oil and gas to meet the growing global energy demand, oil companies are expanding their exploration and production activities into some of the planet's most sensitive and remote ecosystems (Rosenfeld *et al.*, 2001). However, the history of petroleum development in sensitive tropical ecosystems has been marked by conflicts with environmentalists and isolated indigenous communities. In many cases, this development has resulted in irreversible environmental damage and severe social disruption (Matt, 2008). This is because there is a tendency for both companies and governments to downplay environmental concerns because of the highly lucrative oil development business (Queiroz *et al.*, 2008). The rate at which biodiversity is lost is estimated at 0.5-1.5% of natural habitats and species populations per year (Balmford *et al.*, 2003; Jenkins *et al.*, 2003; Bird Life International, 2004). Most indicators of biodiversity are still in decline with no significant reductions in rate while pressures on biodiversity still continue to increase (Butchart *et al.*, 2010).

Africa as a whole is currently undergoing unequalled international investment and economic growth (African Development Bank, 2014). Out of the 13 fastest growing economies worldwide, 6 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 and Paulo, 2007), the continent's importance in the global oil and mineral market has been increasing faster than any other region of the world. This has therefore raised much attention amongst the foreign investors and global petroleum companies, thereby leading to increased extraction of minerals even in biodiversity hotspots (Annan, 2012; Janneh and Ping, 2012; Osei and Mubiru, 2010).

In Uganda, oil was first discovered in western region in the 1870s and since then there has been exploration in the Albertine Graben, however, commercially viable oil deposit was confirmed in 2006 (Rwakakamba and Lukwago, 2013) and in Western Uganda (NEMA, 2010). Approximately 2.5 billion barrels of commercially-viable oil was discovered under the Ugandan portion of the Albertine Rift in 2006 (Shepherd, 2013). In the revenue sector, this puts Uganda to the fifth position in the largest oil producing countries in Africa (Vokes, 2012).

However, the changes in the landscape and vegetation of the Albertine region of Uganda have continually occurred for the past 50 years (Ssekandi *et al.,* 2017). Anthropogenic changes were commonly linked to agricultural and forest uses which were most significant, representing 86% of changes to the landscape before oil and gas explorations begun (Ssekandi *et al.*, 2017). Oil exploration and related infrastructure occupy a small piece of land but it receives much attention compared to other activities.

Uganda's Auditor-General report, (2014) noted that the manner in which oil waste is currently disposed-off may lead to an ecological disaster in the region. He further noted that degradation of land, contamination of water and change in the ecosystem will lead to vegetation destruction linked to biodiversity richness. The audit further found that drilling waste generated in the Albertine Graben were not being treated but instead stored in designated waste consolidated areas. Ecosystem or vegetation cover loss and environmental degradation from the oil sector can happen at different points such as from exploration, extraction, processing and transportation. Impacts of this will be associated with; habitat destruction and land take for drill, pads workers camps and equipment storage camps (Golombok and Jones, 2015).

The oil sites in the Albertine Rift are also faced with threats like, forest loss, hunting, timber exploitation, mining and oil (Luke, 2015). Few ecosystems are entirely devoid of human activity, and as the global human population continues to grow, the extent and frequency of human disturbances are increasing (Geldmann, *et al.*, 2014). Oil and gas development involves several stages that may take decades to complete and most exploration depends on advanced technology to detect and determine the extent of these deposits (Havard, 2013). Once potential production areas are identified, seismic surveys are used to obtain details of subsurface geological structures (Borasin *et al.*, 2002). Following seismic testing, exploration wells are drilled to determine commercial viability of the reserve. Four to ten years following a discovery, the production phase begins, which may involve construction of additional wells, pipelines and refineries (Borasin *et al.*, 2002).

Species populations especially birds continue to be impacted through the conversion and destruction of habitat to infrastructural developments directly and indirect losses associated with the avoidance of these industrialized and converted areas (Harju *et al.*, 2010) and it is difficult to evaluate the potential integration of high value habitat and oil and gas accumulations to ensure a balance between conservation and development (Copeland *et al.*, 2009). This is even seen in even developed countries where environmental governance rules are very strict (Peterson *et al*., 2003). This therefore created the need for the study to establish the effects of oil and gas exploration on vegetation and bird abundance in the Kingfisher area where these activities have taken place and restoration has been made.

1.2 Problem statement

Uganda confirmed the presence of commercially viable quantities of oil and gas in the Albertine Graben which is the northern part of the Albertine Rift Region within the country's boundary and Kingfisher Development Area was among the exploration areas where reasonable amounts of oil were found. The region is of great importance for conservation. It was identified as an 'Endemic Bird Area' by Bird Life International (International Council for Bird Preservation, 1992) and as an 'Ecoregion' by the World Wide Fund for Nature (Olson and Dinerstein, 1998) and was listed as a 'Biodiversity Hotspot' by Conservation International (2011). The importance of the area for conservation comes from not only the high number of species but also the high level of endemism (Plumptre *et al.*, 2003). However, petroleum exploration and development is associated with a wide number of activities. The selected sites go through seismic surveys and other geological surveys to obtain details of subsurface geological structures, drilling to determine commercial viability of the reserve (Epstein and Selber, 2002), and vegetation clearing to set up equipment, camp sites for workers and opening up new access routes for transportation (Finer *et al.*, 2008) to enable oil and gas operations to take place. All these activities are associated with human traffic, running of heavy machines, hooting, lighting, vibrations and these can affect vegetation cover, influence land cover change, climate change, pollution and land fragmentation which in turn affect biodiversity and to be specific, the avifauna (Trail, 2006; Alemagi, 2007; Ramirez, 2009). According to Carter (2008), IUCN Red List reveals that of the

243 threatened amphibians and 232 birds in Africa and Madagascar, 9% of amphibians and 8% of birds are threatened wholly or in part by mining activities. In addition, Thomsen *et al.,* (2001); Ko and Day, (2004) also stated that impacts of oil and gas development on flora through vegetation removal and chemical pollution are beginning to emerge. Numerous studies have made it clear that oil exploration and production phases have a huge impact on bird species diversity and abundance (Patricelli and Blickley, (2006); Bee and Swanson, (2007); Brumm, (2004); Habib, *et al.,* (2007); Blickley and Patricelli, (2010); Gavin and Komers, (2006); Ramirez, (2009); and Trail, (2006) through habitat destruction and disruption of feeding and breeding patterns. This study therefore sought to find out whether the oil and gas exploration activities in Kingfisher Development Area have had an impact on vegetation and bird abundance.

1.3 Objectives of the study

1.3.1 General objective

To assess the effects of Oil and Gas Exploration on vegetation and bird abundance in Kingfisher development area in Kikuube District, Western Uganda

1.3.2 Specific objectives

i. To classify and map land-use and land-cover (LULC) from 1990 to 2019 using remote sensing and Geographical Information Systems (GIS) techniques

ii. To determine the effects of oil and gas exploration on vegetation relative abundance and diversity in Kingfisher development area

iii. To determine the effects of oil and gas exploration on bird abundance in Kingfisher development area

1.4 Research questions

i. What are the changes in land use and land cover in the study area from 1990 to 2019?

ii. What are the effects of oil and gas exploration on vegetation relative abundance and diversity in the selected regions of Kingfisher development area?

iii. What are the effects of oil and gas exploration on bird abundance in the selected regions of Kingfisher development area?

1.5 Scope of the study

The study was conducted in Kingfisher development area in Buhuka parish, a flat plain bounded by the Albertine rift escarpment to the East and Lake Albert to the West, Kikuube District, Uganda. It is approximately 15.2km long, 3km wide and covers an area of 32.3 km^2 (Petroleum Authority Uganda, 2019) comprising of pad 1 and pad 2 at GPS coordinates 1.24639^{O}N 30.74120^{O}E, 1.25478^{O}N 30.74998^{o}E respectively in Kyabasambu village, pad 3 at 1.23038^o N 30.73165^{O}E in Nsunzu village. The study was carried out during both dry and wet seasons which occurred between 17th February, 2019 to 3rd March, 2019 and 20th May, 2019 to 4th June, 2019 respectively.

The study looked at the sites of KF 1, KF 2 and KF 3, with Control Area 1, 2 and 3 for both dry and wet seasons. The study focused on the effects of oil and gas exploration on vegetation and bird abundance by looking at vegetation relative abundance and diversity as well as counting birds in and outside the former exploration oil pads. The study used scientific methods and remotely sensed methods to achieve the results. However, the study only focused on three oil pads KF 1, KF 2 and KF 3 and did not cover the fourth pad KF 4A since it is not yet developed.

1.6 Significance of the study

The study has a great contribution to the body of knowledge. It will help the future researchers who may use the data for either study purposes or analyzing the gaps. It will also support the different stakeholders engaged in policy making to come up with polices that can promote effective oil and gas exploration and reduce vegetation cover loss and loss of bird species. The study also helped to improve on my research skills, analytical skills and conceptual skills and to other researchers carrying out similar study, it may be a source of literature.

1.7 Definition of key terms

Abundance: This refers to how common or rare a species is relative to other species in a given community.

Species abundance: This refers to the number of individuals per species.

Relative abundance: This refers to the evenness of distribution of individuals among species in a community.

Species diversity: This refers to a measure of the diversity within an ecological community that incorporates both species richness and the evenness of species' abundances.

Biodiversity: This refers to the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part.

Endemism: This refers to the ecological state of a species being unique to a defined geographic location.

Endemic species: These are plants and animals that exist only in one geographic region.

Exploratory oil well drilling: This refers to a test hole drilled on land or in sea to ascertain the extent of recoverable gas and/or oil in a probable but yet-unproved location.

Extinction: This refers to an evolutive process that leads to the disappearance of a species or a population.

Land cover: This refers to the observed physical material at the surface of the earth.

Land use: This refers to the arrangements, activities and inputs people undertake in a given land cover type to produce, change or maintain it.

Oil: This refers to any neutral, non-polar chemical substance that is a viscous liquid at ambient temperatures and is both hydrophobic and lipophilic.

Seismic survey: This refers to a method of investigating subterranean structure, particularly as related to exploration for petroleum, natural gas, and mineral deposits.

Species of conservation concern: This refers to species with rare or declining populations or habitats, often number in the hundreds or even thousands within a given ecosystem

Threatened species: This refers to any species that is likely to become extinct within the foreseeable future throughout all or part of its range and whose survival is unlikely if the factors causing numerical decline or habitat degradation continue to operate.

Vegetation: This refers to an assemblage of plant species and the ground cover in which they provide

Impact: This refers to any change, potential or actual, to the physical, natural, or cultural/social environment, and affects the surroundings as a result of the activity being proposed or undertaken.

Oil and Gas Exploration: This refers to the search for hydrocarbons beneath the ground which entails geophysical prospecting of an area that hold deposits of oil and natural gas. **Development:** This refers to a stage of opening up an ore deposit for production. **Production:** This is a stage in oil and gas chain where liquid hydrocarbons extracted from wells are separated from the non-saleable components such as water and solid residuals.

Habitat: It is an ecological or environmental area that is inhabited by a particular species of animal, plant or other type of organism

Environmental and Social Impact Assessment Process: This refers to the analytical process that systematically examines the likely environmental and social impacts of a proposed project, evaluates alternatives and designs appropriate mitigation, management and monitoring measures, considering interrelated social-economic, cultural and human health impacts, both beneficial and adverse.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of oil and gas exploration

Well drilling for exploration is a multistage process during which the upper parts of a borehole, once drilled, are sealed with steel casing and cemented into place (Arjen van der Wal, 2008).

In 2013, Uganda drilled its 104th wellbore in its exploration program for petroleum resources in the Albertine Region following the three decades of intensive oil and gas exploration activity in the country (World Bank, 2013). The first deep oil well drilled in Uganda was Waki B-1 and this was drilled in 1938, by African and European Investment Company to a total depth of 1,221 metres (World Bank, 2013). These efforts were evident when Heritage Oil and Gas company signed a Production Sharing Agreement with Government in 1997 and undertook seismic data acquisition in 1998 (World Bank, 2013). The company drilled its first well Turaco-1 to a total depth of 2487.7 m in September, 2002 after a period of 64 years since the drilling of Waki B-1 well. The exploration program in Uganda has had a huge success with 92 of 104 explorations and appraisal wellbores drilled having found oil and/or gas signifying a success rate of close to 90%. The discovered resources in the Albertine Graben are currently estimated at over 3.5 billion barrels of oil equivalent in place with at least 1.2 billion barrels recoverable (PEPD, 2014). Over US $2 billion has been invested in the sector since 1998 and this is expected to increase as the country progresses from "Exploration and Appraisal" to "Development and Production" (MEMD, 2018). Investments have been mainly in seismic data acquisition and drilling of exploration and appraisal wells. The government is now putting in place necessary infrastructure to support development and production of discovered oil and gas that are expected to contribute to transforming Uganda into a middle-income country (MEMD, 2008). A number of wells were drilled and among these were the Kingfisher well pads namely; Kingfisher-3A, Kingfisher-1A, Kingfisher-2 wells (Kityo, 2011).

Dingle and Drake, 2007 noted that oil and gas activities are known to disturb the migrations which present a history strategy that represents an essential component of the ecological niche of a variety of taxa most common bird species. This has resulted into destruction of migratory paths leading to a decrease in species populations (Johnson, 2007).

2.1.1 Seismic survey activities

Seismic method is a petroleum exploration method in which sound energy is put into the earth using a source at specified points along a relatively straight survey line. The sound energy reflects off subsurface sedimentary rock layers and is detected by many sensors arranged along several kilometres of the survey line in 2-Dimensional, or over several square kilometres in the case of a 3-Dimensional, and recorded (Hyne, 2001). Line preparation may involve cutting vegetation prior to surveying the data point and sensor locations. As recording progresses along the survey line, the sensors are moved to new positions along the survey line by crews using vehicles or helicopters. The data are processed by computer to map the underlying strata and help define the size and shape of any geological structure worthy of further investigations (Yilmaz, 2001).

According to Joint E&P forum (1997) exploration survey is the first stage of the search of hydrocarbon-bearing rock formations, geological maps are reviewed in desk duties to identify major sedimentary basins and data acquisition is carried out. The extent of these changes is especially important to local groups, particularly indigenous people who may have their traditional lifestyle affected. The key impacts may include changes in land-use patterns, local population levels as a result of immigration, land use conflicts, conflict between development and protection and displacement (Festus, 2016).

Clayton (2011) commented that seismic surveys are used to locate and estimate the size of offshore oil and gas reserves. To carry out such surveys, ships tow multiple air gun arrays that emit thousands of high-decibel explosive impulses to map the seafloor. These disturbances can disrupt and displace important migratory patterns.

2.1.2 Exploratory well drilling

Once a promising geological structure has been identified, the only way to confirm the presence of hydrocarbons, and the thickness and internal pressure of a reservoir is to drill exploratory wells. The location of a drill site is dependent upon the characteristics of the underlying geological formations. Modern drilling techniques allow some flexibility in choice of location, allowing consideration of both environmental protection and logistical needs, while still reaching the reservoir development objectives (Joint E&P forum, 1997). All wells that are drilled to discover hydrocarbons are called 'exploration' wells commonly known by drillers as 'wildcats'. The location of a drill site depends on the characteristics of underlying geological formations (Festus, 2016). It's generally possible to balance environmental protection criteria with logistical needs and the need for efficient drilling.

For land-based operations; vegetation is cleared, drilling area is levelled and a pad is constructed at the chosen site to accommodate drilling equipment and support services. A pad for single exploration well occupies between 4000-15000 square metres. The type of pad construction depends on terrain, soil conditions and seasonal constraints. Land-based drilling rigs and support equipment are normally split into modules to make them easier to move. Drilling rigs may be moved by land, air or water depending on access, site location and module size and weight. Once on-site, the rig and a self-contained support camp are then assembled (Joint E&P forum, 1997).

Joint E&P forum (1997) points out that building of roads and site preparation, comments are centered on vegetation clearance, possible erosion and changes in surface hydrology; vibration and noise from earth moving equipment; disturbance of population and wildlife; bird species destruction; plant species destruction; impacts related to influx and settlement through new access routes; drainage and soil contamination; loss of habitat and many more disruptions.

The drilling process results in waste generation namely; drill cuttings and excess cement, drilling mud, produced water, and other chemicals that may cause detrimental ecological effects (Sharif *et al.,* 2017). The chemical composition of drilling muds is regarded to be diverse, and has changed from the more toxic oil-based muds to more modern synthetic and water-based fluids. The types of fluids that are commonly used currently are generally regarded to be less toxic other than oil-based fluids however, they are not without adverse biological effects (Breuer *et al.*, 2004; Bakhtyar and Gagnon, 2012; Gagnon and Bakhtyar, 2013). Research conducted show that the detected ecological changes attributed to current practices have typically been found within 200-300 metres of the well-head (Currie and Isaacs, 2005; Gates and Jones, 2012), though can occasionally extend to 1-2 km for sensitive species (Paine *et al.,* 2014) in water ecosystems.

Exploratory well drilling activities last from 1 to 2 years. Commonly, 2 or 3 wells are drilled during this exploratory stage (Festus, 2016, Nwankwo, 2015).

According to Fahrig, (2003), the most important causes of habitat fragmentation and destruction is as a result of the expansion and intensification of human land use. Therefore, these contribute to a decline in biological diversity in the natural habitats.

In addition, the exploration and extraction of oil and gas processes produce the waste materials such as used drilling fluids and drilling cuttings like complex mixtures of clays and chemicals. Usually these wastes are discharged directly from the platforms into the marine water and other surrounding environment which in turn affect biodiversity (Lodungi *et al*., 2016)

2.1.3 Oil Pad and Workers Camp construction

During oil exploration in the Albertine area, there was land clearing of 200 x 200 m. This amount of area would be required for construction of the workers' camp and a storage yard. The drill pad area had a shorter life time (2-3 months) than the workers camp and storage yards which would then be one drill site. Some of the direct impacts would therefore be shorter on drill sites than on a camp and storage yard site. Drill pad areas have subsequently been reduced to an area of direct impact of only 100 x 100m (UNEP, 1997).

Pad construction at a certain site is meant to accommodate drilling equipment and support services. UNEP, 1997 stated that a pad for a single exploration well occupies between 4000-15,000 m^2 and the type of pad construction depends on terrain, soil conditions and seasonal constraints. Infrastructure development include construction of access roads, support camp which tends to be self-contained and generally provides workforce accommodations, canteen facilities, communications, waste treatment and disposal, vehicle maintenance, parking areas, a fence and sometimes a helipad if need be to access remote areas. CNOOC tried to minimize the drilling operations to minimize the surface footprint by reducing the number of drill pads to a 100 m x 100 m and roads constructed (Kagolo, 2014).

However, the concern on conservation is that the access roads and traffic may be reduce or even eliminate plant species of conservation importance and most common bird species since the habitats are altered (Trombulak and Frissell, 2000). In ecology, infrastructural developments namely hub and linear infrastructure, leads to alteration in ecosystems disrupting the food chains and thereby causing death of species (McDonald *et al.*, 2009).

UWA, 2012 stated that the construction of drill pads, access roads, camp sites, storage facilities, airstrip, fences and other operations may lead to loss of biodiversity more especially wildlife. This can be seen through habitat fragmentation and vegetation clearance. In relation, the oil spills from drilling operations may have a negative impact on the environment (Rwakakamba *et al*., 2014). Northrup and Wittemyer, 2013 stated that development impacts on biodiversity may be harmful as a result of pollution, removal of vegetation for roads and oil pads, and shelter habits. Oil and gas linear and hub development poses huge threats towards environmental conservation of the Earth's biodiversity (Ericson, 2014). Increased linear construction causes a huge change to land cover due to population influx into such areas with low human population density (Laurance *et al*., 2014; Wilkie *et al*., 2000).

2.2 Biodiversity in the Albertine region

Biodiversity refers to the variability of life on Earth. It shows the numbers of different species, genetic variation between and within species, and the extent and variety of natural habitats and ecosystems (Roe *et al*., 2019). It ranges from genes to biome distribution on the planet (Mooney, 2002). Biodiversity is much important in ensuring clean environment for example providing clean air, water, and many more for a variety of species. The loud and excessive noise, indiscriminate disposal of waste has also been reported to adversely affect biodiversity (Bankole and Owoseni, 2010). The increasing instability conditions of soil, landscape destruction, irradiation hazards and the extensive destruction of vegetation for access is a serious threat to avifauna and flora (Nwilo and Badejo, 2005a).

Albertine region has a high degree of both plant and bird species diversity of great conservation importance and is globally recognized as a biodiversity hot spot containing 50% of birds, 39% of mammals, 19% of amphibians and 14% of reptiles and plants found in mainland Africa (Kityo, 2011; NO and EIITO, 2006). Bird species have habitats ranging from forest and grassland to wetlands and deltas and many other ecosystems. The swamps are well known for wide variety of water birds, including the Shoebill (Nature Uganda, 2010). The Albertine Rift Region is of great importance for conservation. It has been identified as an 'Endemic Bird Area' by BirdLife International (International Council for Bird Preservation, 1992, Birdlife International, 2010) and as an 'Ecoregion' by the World Wide Fund for Nature (Olson and Dinerstein, 1998) and was listed as a 'Biodiversity Hotspot' by Conservation International (2011). The importance of the area for conservation stems from not only the high number of species but also the high level of endemism (Table 2.1). It has more endemic species than any other region in Africa and also contains 78 threatened terrestrial vertebrates according to IUCN Red Data Book listings (Plumptre *et al.*, 2003). It has several sites described as Important Bird Areas (IBA) (Byaruhanga *et al.*, 2001).

Table 2.1: Species number of endemics and threatened species for the Albertine Rift

Taxon	Species number	Endemic species	Threatened species
Mammals	402	34	35
Birds	1,061	41	25
Reptiles	175	16	2
Amphibians	118	34	16
Butterflies	-	117	-
Fish	-	366+	-
Plants	5,793	567	40

Source: Plumptre *et al.*, 2003

The region is also associated with a wide number of important protected areas (BirdLife International, 2010). This is shown in table 2.2 below.

Table 2. 2: Important Protected areas in the Albertine Region

Reserve	Size (ha)	% Forest cover	% Savannah	% Grassland	% Wetland	% Shrubland
Budongo FR	82,530	74	2			
Bugomaza central FR	40,100	82		18		
Bugungu WR	74,830					
Bwindi Impenetrable NP	33,100	97				
Echuya FR	4,000	61				
Kasyhoha-Kitomi FR	39,464	100				
Kibale NP	76,600	83	7			
Kyambura WR	15,510	68	8		12	7
Mgahinga Gorilla NP	4,750	75	4	1		
Murchison Falls NP	39,000	37	16		10	4
Queen Elizabeth NP	223,000	51	4	2	20	5
Rwenzori Mountains NP	99, 600	78	11	2		
Semliki NP	21,900	89				
Semliki WR	115,000	28	15	2		4

***Source:* Bird Life International, 2010**

In the Albertine region most importantly the studied area Kingfisher development area has a number of catchment areas namely; the Masika and Kamasing riverine wetlands which are responsible for maintaining thriving biological resources however these lie within the areas of oil and gas exploration and development sites as indicated in the figure 2.1

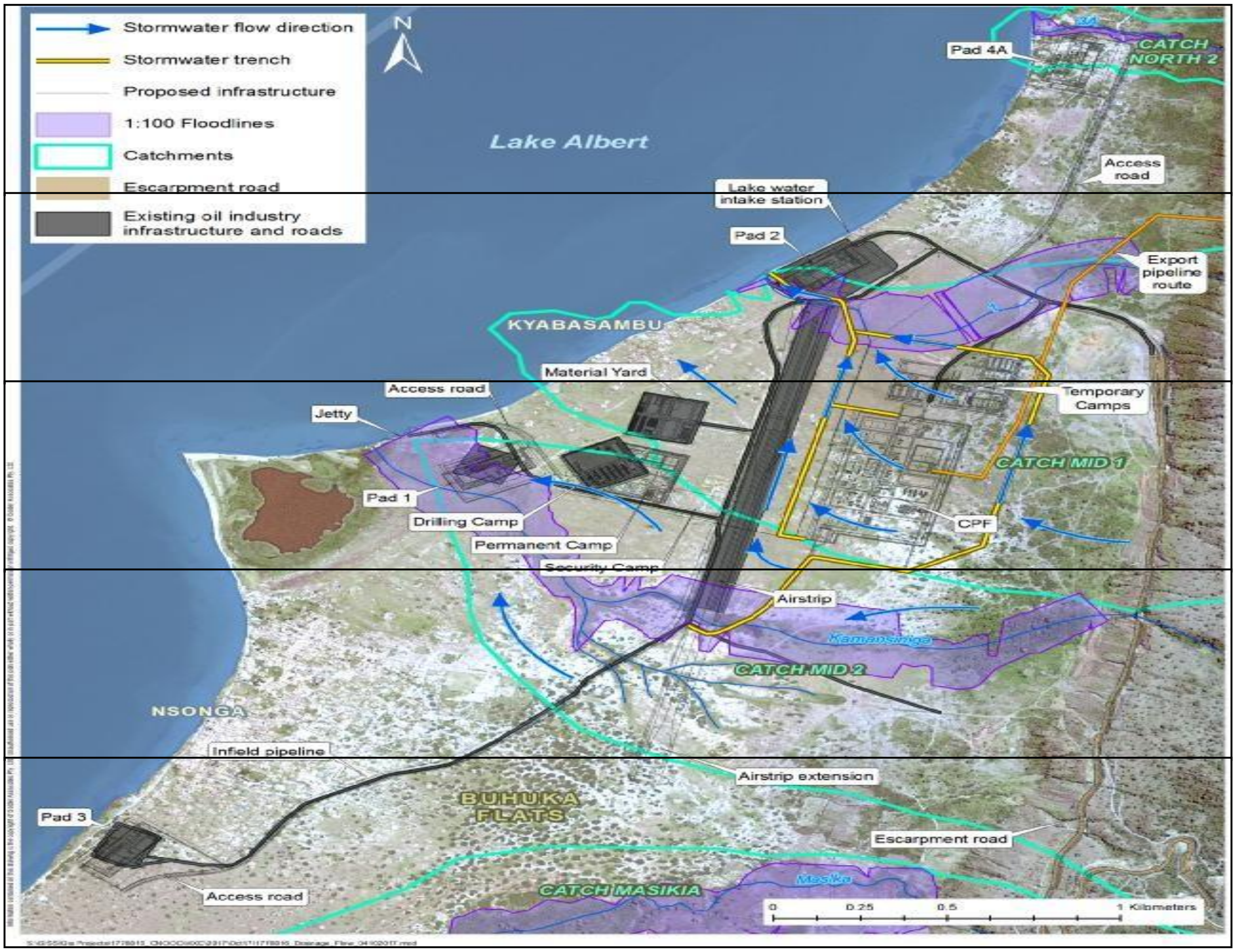

Figure 2.1: Exploration activities in catchment areas of Kingfisher (Adopted: Biodiversity Assessment Review Report, 2018)

2.3 Land use and land cover changes (LULC)

Land cover is the observed physical cover that exist on the Earth’s surface namely vegetation and built up areas. And land use is characterized by the arrangements, activities and inputs people undertake in a given land cover type to produce, change or maintain it (FAO, 2005). Land use affects land cover and changes in land cover affect land use (Ayele, 2017). Therefore, accurate, efficient and effective mapping and assessment of the changes on a given land use is critical and important for monitoring various activities and both human and natural effects on these important systems (Baker *et al.,* 2007, FAO, 2005).

Land use and land cover information is always required for policy making. With their spatial details, the data are likewise crucial for environmental protection and spatial planning (Rwanga and Ndambuki, 2017). Remote sensing has always been applied in monitoring many aspects. For instance, remotely sensed data have been applied widely in monitoring land cover change, mostly in terms of deforestation and forest degradation (Margono *et al.,* 2012). It has been used to map out areas of different land cover types that have been converted into other land uses (Melack and Hess, 2011). Landsat imagery to be specific is largely used in capturing floristic variations associated with various vegetation types (Margono *et al.*, 2014) and the Landsat data inputs mainly used are Landsat 7, 8, Enhanced Thematic Mapper Plus (ETM+) and Landsat Thematic Mapper (TM) imagery.

Landsat satellite images are also frequently used to evaluate land cover distribution and to update existing geospatial features (Rwanga and Ndambuki, 2017). A wide variety of land cover types are well known to exist in the Albertine region and mainly on the mountain and escarpment slopes and in the valleys and flats (NO and EIITO, 2006).

There have been changes in land use to meet the growing needs of the world's population and these have shifted in the ecological functions of various ecosystems (Villa, 2014). Emissions from these land uses have increased drastically over the past years due to the expansion of cropland, infrastructure development and as well population influx (Geist and Lambin, 2001).

The main driver of land use change and vegetation cover loss is the conversion to agriculture, linear and hub infrastructure development, urbanization (Zedler and Kercher, 2005). For instance, clearing for agriculture has been the main cause of wetland loss up to date with an estimation of 26% of the global land area (Davidson, 2014) and the loss of these biological resources reduce the watershed capacity to maintain biodiversity (Margono *et al.,* 2014). However, this has not been well documented in developing countries (Abebe and Kim, 2003).

Jacob and Winner, 2009 stated that oil and gas exploration in ecosystems of biodiversity value poses great environmental and socio-economic risks most especially deterioration of air quality. The operations can have negative primary and secondary impacts on ecosystems and the quality of air, water and soil. The development of oil and gas resources in any area leads to an influx of people hoping to find employment. As the local population increases in oil and gas development areas and new access roads open previously inaccessible areas, the need for housing, food and other goods and services will also grow, often through totally unplanned and uncontrolled new settlements. This will put additional pressure on natural resources resulting in vegetation destruction and land use change (Douglas *et al.,* 2008) and this in turn lead to increased carbon emissions in the atmosphere which lead to climate change (IPCC, 2007).

Noise from drilling operations and extension of road networks stresses wildlife, gives poachers easy access to previously remote areas, and can have a negative impact on the tourism potential of a region (Dara and Sarah, 2003) and as well cause land cover and land use change.

The clearance of vegetation may result into the introduction of invasive species which also cause significant and long term disturbance to an ecosystem. Over time, a high proportion of the vegetation of Uganda has been modified by cutting, cultivation, burning, grazing and other anthropogenic actions, and many of these vegetation types have been significantly reduced in quality and range over time (Douglas *et al.*, 2008).

NO and EIITO, 2006 stated that 25 million tons of wood are consumed annually in Uganda, which translates to about 1.1 ton per capita per year thereby reducing the forest cover. Several companies have drilled exploratory wells inside Uganda's national parks and other protected areas which scare away wildlife and bring about land use change (Lacher and Byakagaba, 2016). These drivers of change are posing much pressure on the natural vegetation communities in these areas. However, the quantification of these changes in Ugandan context are still limited (Twongyirwe *et al.*, 2015).

Ecosystems for instance wetlands, forests play an important role in the provision and supply of ecosystem services ranging from provisioning, regulating, cultural and supporting (MA, 2005). Therefore, the modification of Land use and Land cover affects the ecosystems which indirectly affect climate and weather patterns (Balogun *et al.*, 2009).

Natural processes and both direct and indirect effects of human activities are major drivers of land use and land cover change (Turner and Meyer, 1991). Land-use change is a primary factor causing water-quality and habitat degradation (USGS, 2005). Change in land-cover influence soil quality, water runoff, sedimentation rates, earth atmosphere interactions, biodiversity, the hydrological cycle, and biogeochemical cycling of carbon, nitrogen and other elements at regional to global scales (Binford *et al.,* 2000). In addition, changes in land use and land cover can be indicative of regional environmental problems from impairment in both abiotic and biotic processes. UNU-IIASA, 2003 suggested that an understanding of changes in land use over the next years is key to sustainability

There is now a growing attention placed on the potential of GIS as a spatial decision support tool in local and regional environmental impact assessment, planning, and implementation of governmental policies at a local level and national level (Munier *et al.*, 2002). Agarwal *et al.*, (2000) discuss land use change as an important and complex environmental issue that needs "many eyeballs" to work together.

Patterns of land use, land-cover change, and land management are formed by the interaction of economic, environmental, social, political, and technological forces. These drivers may have considerable effects on future land use and cover (Abbott *et al.*, 2003). In temporal scales, human activities are basic drivers in shaping land use change. Some of them become these drivers as a result of particular management practices while others because of social, political and economic forces that affect land uses (Medley *et al.*, 1995). Jane, 2003 performed a characterized canopy disturbance in a reduced-impact logging operation in central Amazonia using remotely sensed data. Result show that spatial methods were effective at characterizing the different logging feature treatments at different plot sizes. To study the socio-economic effects on landscape change in metropolitan region, Wang and Zhang (2001) developed a dynamic landscape simulation. The model consists of two sub-models: urban growth simulation and a land cover simulation. Allen *et al.*, (1999) applied GIS-based methodologies for analysis, modeling and prediction of coastal land-use change. Hansen *et al.*, 2009 employed remote sensing to quantify the changes in the rates of forest ecosystem that was cleared in Indonesia.

Anderson, 1976 stated that one of the prime prerequisites for better use and management of land resources is information on existing land use/cover patterns and changes in LULC through time. Spatial and temporal status of the LULC of a given area is an important parameter in understanding the interactions of the human activities with the environment (Anil *et al.,* 2011; Etefa *et al.*, 2018). Land use and land cover patterns change in keeping with demands for natural resources (Anderson 1976). Studies have shown that although the evidences of land use/cover changes dates back many 1000 years, the recent rates, extents and intensities of human pressure on land and its scarce resources is more rapid and extensive than in any comparable period of time (Petit and Lambin, 2002; Petit and Lambin, 2001; MEA 2005; Ellis and Pontius, 2006). This unprecedented human and environment interactions have been verified by LULC changes. LULC is well known to have a change on social and economic benefits however; this dynamic and complex process usually has an unintentional interlocked multidimensional consequence upon essential Earth's ecosystem functions and services at both the small and large scales (Lambin *et al.*, 2003; Turner *et al.*, 2007; Lambin and Meyfroidt, 2011). For instance, changes in LULC has been shown to have negative impacts on biodiversity (Klenner *et al.*, 2009), biogeochemical cycling and environmental degradation mainly due to exposure of soil to erosion forces (MEA 2005; Meshesha *et al.,* 2014; Mwehia 2015; Sewnet 2015), stream water quality (Uriarte *et al.*, 2011); contribution to local and global climate change (Bringezu *et al.*, 2014) and forest fragmentations (Rands *et al.*, 2010). All these have implications on the provisioning capacities of the watersheds. Moreover, information on LULC dynamics assists in monitoring environmental changes and developing effective land management and planning strategies at both national and local levels (Ellis and Pontius, 2006; Etefa *et al.*, 2018).

Another impact is the provision of new access routes to an undeveloped area for people who are interested in using previously inaccessible land or resources for other purposes. This access is usually facilitated by the building or upgrading of linear infrastructure, such as roads and pipelines, into such environments leading to unplanned settlements or exploitation of natural resources (Exploration and Production Forum 1993; Thomsen *et al.*, 2001; Energy and Biodiversity Initiative, 2003; Suárez *et al.*, 2009).

2.4 Vegetation relative abundance

Vegetation refers to an assemblage of plant species and the ground cover that they do provide. It is a general term, without specific reference to particular taxa, life forms, structure, spatial extent, or any other specific botanical or geographic characteristics. Vegetation extent is defined as all plant life in a given area (Thackway and Lesslie, 2006). Vegetation condition is a key aspect of determining degradation in grasslands, woodlands, forest lands and croplands (FAO, 2011). Vegetative indicators are usually used while assessing the level of disturbance of ecosystems (FAO, 2011). Keith and Gorrod (2006) define condition as a state of being or health. The assessment of vegetation condition is a context-dependent concept and involves factors like sustainable production capability, ecological function and biodiversity conservation (Oliver *et al.*, 2002).

Plant species play a great role in ensuring the ecosystem diversity (Villa, 2014). These plant communities can be used for a range of uses namely; medicinal purposes, source of food and as well climate modification. In wetland and forest ecosystems, these plant communities most especially tree species help in the uptake of carbon emissions in a given area through the process of photosynthesis (Villa, 2014). In addition, increased rates of carbon in the atmosphere due to vegetation destruction most especially for oil and gas exploration may result in large amounts of carbon which may lead to other undesirable conditions like disruption of hydrology, loss of biodiversity and many more (Jones and Humphries, 2002).

The type of vegetation cover is influenced by the hydrological conditions of a given place (Bernal and Mitsch, 2012). This indicates that the management of maintenance of vegetation cover types influences a lot in the existence of plant communities. It is therefore important to measure biodiversity since it helps in determining species level and species diversity at different scales (Ardakani, 2004). Numerous studies have been carried out all over the world on the various components of biodiversity (Isango, 2001). Sandifer *et al*., 2015 states that plant diversity is very helpful in determining the health of both ecosystems and human well-being. It is however globally threatened by anthropogenic ecosystem degradation and land use.

Clearing of vegetation along seismic lines and pipelines can fragment habitat and alter predator–prey interactions (Borasin *et al.,* 2002; Dyer *et al.,* 2002). Construction of drill pads and new roads and fences results in habitat loss and exacerbates fragmentation (UWA, 2012). Vegetation cover loss occurs in different ways such as clearing for the preparation of establishments, poor waste disposal and among others. The natural habitats have been destroyed, and environments have been polluted, causing diseases in both humans and animals and many other species. The need to assess the rate of human influence in relation to oil and gas exploration on these communities is very important (Lal, 2008).

The land use directly changes ecosystems through modifications, fragmentation and intensification (Sala *et al.,* 2000). Therefore, sustainable land use is needed to sustain ecosystem health in the long term, balancing human needs and ecosystem functioning. In addition, quantitative knowledge about the effects of land use on ecosystem responses more especially on plant species diversity is highly important (DeFries, *et al.*, 2004). In plant species diversity, there are alien species whose introduction and spread threaten biological diversity and these may come as a result of human influence on the ecosystems. The destruction of vegetation by the alien species has been continuing at an alarming pace due to a variety of causes the majority being the human factors (Rai, 2015). Kumpula *et al*. (2011) also stated that oil and gas exploration has negative impacts on vegetation which is a source of plant species diversity. This is seen through vegetation clearing for seismic surveys and other activities.

The study conducted by Trombulak and Frissell, 2000 also commented that the access roads and traffic may be reduce or even eliminate plant species of conservation importance in a given habitat. Kolb *et al.*, 2002 reported that there are many factors that bring about invasion such as disturbance, resource availability, habitat fragmentation, predation, mutualism and many more. These factors interact with each other and bring about changes in individual characteristics. Plant species help in providing a wide range of functions and uses and among these may include medicinal benefit (Shrinivas *et. al.*, 2007). Traditional medicine is important in maintaining the health of individuals in Africa (Maundu *et al*., 2006). Statistics have it that the 40,000 and more flowering plants found on planet, an estimate of 15-25% are used in traditional medicine (Maundu *et al*., 2006).

Kingfisher development site is well known to be a centre of biodiversity most especially in the Buhuka Flats. They harbor a lot of plant species existing in various ecosystems (Environmental Project Brief, 2018). They range from grasses, herbs to trees. However, the most common grass species are the *Combretum spp* and the *Hyparrhenia spp* and the most seen tree species are *Albizia spp* (Environmental Project Brief, 2018).

Few ecosystems are entirely devoid of human activity, and as the global human population continues to grow, the extent and frequency of human disturbances are increasing (Rebecca *et al.*, 2018). Land clearance and conversion is one of activities attributed to oil exploration operations. It involves large expanses of land cleared to open up for well pad establishment, large seismic surveys, creation of accesses etc. These combined have led to continued habitat fragmentation and disappearance of organisms from several of their original distribution ranges and habitats (Blumstein *et al.*, 2003).

Habitat changes within the vicinity of the road surface may attract certain species thereby creating a population sink. Construction may also result in the loss of certain habitat features, such as exposed rocky areas, that previously supported snakes and their prey base (Dodd and Smith, 2003). Increased road density inevitably results in an increased number of road-killed individuals and a reduction in the amount of available habitat, which could ultimately lead to reduced population sizes (Riiters and Wickham, 2003). Crude oil contamination affects plants by creating conditions which make essential nutrients like nitrogen and oxygen needed for plant growth unavailable (Pezeshki *et al.*, 2000; Ogbo *et al.*, 2009). Plant sensitivity to oil pollution varies with species, age of plant, and season of spill and also depends on the volume of the spill (Pezeshki *et al.*, 2000). The ability to predict the impacts of oil on vegetation is still limited because no single study has addressed the many factors controlling vegetation responses to oil pollution (Pezeshki *et al.*, 2000). Research also shows that the process of plant species to recover from anthropogenic disruptions is always slow and might take a very long time to rejuvenate (Ebersole *et al*., 2001). The construction of roads, camp sites and other associated infrastructure diminishes the functioning capacity of the habitats more especially the natural ones thereby leading to biodiversity decline (Edwards *et al*., 2014).

2.5 Bird abundance

Birds are good indictors of ecosystem functionality and play a major role in maintaining the natural balance in the food chain in nature (Desai and Shanbhag, 2007). There are several importance of birds as they act as browsers, pollinators and seed dispersers (Satish *et al.*, 2013). Birds also play an important role in wetland ecosystem. Wetlands are important especially for bird habitats. Birds use wetlands for breeding, nesting and teaching young, as a source of drinking water, for feeding, resting, shelter and for social interaction (Satish *et al.*, 2013). Wetlands and other ecosystems provide food for birds in the form of plants, vertebrates and invertebrates. Some feeders forage for food in wetland soils. Some feed on water column, some feed on the vertebrates and invertebrates that live on submerged and emergent plants. Birds have daily and seasonal dependence on wetlands for food and other life supporting systems (Stewart, 2001). Uganda is rich in bird species diversity with about 1040 species recorded, of which about 800 are resident species (Carswell *et al.*, 2005). Albertine region is well known to have most pastoral areas that are known to be species-rich. Unlike some bird species that require native trees for breeding, most species found in this region are typically not of conservation importance (Douglas *et al.*, 2008). The bird species of conservation importance in the region were highlighted in the EACOP Project, 2018 and these are listed in table 2.3 below.

Table 2.3: Birds of Conservation Importance

Common Name	Scientific Name
White-backed duck	*Thalassornis leuconotus*
Grey-crowned crane	*Balearica regulorum*
African woollyneck	*Ciconia microscelis*
Saddlebill	*Ephippiorhynchus senegalensis*
Striated heron	*Butorides striata*
Rufous-bellied heron	*Ardeola rufiventris*
Hooded vulture	*Necrosyrtes monachus*
Ovambo sparrowhawk	*Accipiter ovampensis*
Grey parrot	*Psittacus erithacus*

Source: **EACOP Project, 2018**

However, the distribution and abundance of birds is affected by several factors. Little change in physical, chemical or biological properties put forth intense effects on bird's habitats (Murphy *et al.*, 1984). Therefore, any change in the physical, chemical and biological factors in the catchment and other ecosystems exert severe impact on these species habitats for instance wetlands exert a big pressure on bird species numbers and distribution. The bird assemblages are affected by various factors like the food availability, the size of the wetland (Paracuellos, 2006) and the abiotic changes in the wetlands (Lagos *et al.,* 2008).

These in turn affect the dependent communities as well as the ecosystem attributes such as species richness, its distribution and density (Burkert *et al.*, 2004) and ultimately, these changes disrupt the food web and food chain structures at the primary and secondary production levels (Wrona *et al.*, 2006).

Short-term impacts associated with oil development include increased human presence and traffic, as well as increased generation of anthropogenic noise. During seismic surveys, large crews of workers operate vibrating and recording vehicles and explosives. During the exploration and production phases, noise is generated by construction of roads, pads and fences as well as operation of drilling equipment (Patricelli and Blickley, 2006). This noise disrupts the communication among the species (Bee and Swanson, (2007); Brumm, (2004); Habib, *et al.*, 2007) and lead to an increase in perceived predation risk (Blickley and Patricelli, (2010); Gavin and Komers, (2006); Baptiste and Nordenstam, (2009). However, many nations throughout the world would still cherish to discover oil and gas within their territories. This is because the availability of such natural resources is seen as a point of economic transformation and as a blessing. The world's population is estimated to increase from the current 6 billion to about 9 billion in 2050 (UN, 2003), it is therefore logical that the world's energy level increases to meet the demands of this increasing population. There is therefore increased demand for energy and economic development world-wide which has boosted the oil and gas industry. However, most of these resources lie within areas of conservation importance (Harfoot *et al*., 2018).

Though, this comes with the removal of habitat features, including foraging, watering, and security areas, directly affects the ability of ungulates to persist. Whether caused by exurban development or mineral extraction, the resulting footprint of homes, well pads, roads, or mining infrastructure equates to a measurable loss of habitat (Watkins *et al.,* 2007).

Research conducted by Harju *et al.,* 2010 also showed that some places with at least one well of oil or gas within a 0.25 miles radius presents 35%-91% fewer attending males than leks with no well within this radius.

Birds might also tend to avoid suitable habitat as the density of roads, power lines, or energy development increases (Holloran, 2005). Oil and gas companies may cut or hay shrubs near energy roads and trails as a means to reduce fire risk, increase visibility, or limit snow accumulation. This landscaping, however, negatively affects some bird species most especially the songbirds. Haying during the breeding and brood-rearing seasons destroys nests, eggs, and young of ground-nesting grassland birds and leads to increased abandonment and predation (Bollinger *et al.,* 1990). In all habitats, the removal of existing natural habitat by oil and gas activities may result into habitat loss for species that used it and a habitat gain for those species that might prefer the altered conditions (Bayne *et al.,* 2008).

Oil and gas exploration and production typically results in the creation of communication towers, power lines, well pads, flare stacks, and compressor stations. The height of these structures increases the risk of collision by birds (Mabey and Paul, 2007).

The invasion of exotic plants also negatively impacts the grassland birds. This is due to the fact that development exposes bare soil or mixes soils with machinery used in the drilling of oil pads and the access roads and other supporting infrastructure thereby facilitating the introduction and subsequent spread of nonnative plants (Larson *et al.,* 2001, Gelbard and Belnap, 2003, Gelbard and Harrison, 2003). Grassland birds tend to exhibit avoidance. Research shows that there is always a non-significant pattern of reduced abundance in the vicinity of minimal-disturbance gas wells and their access trails compared with more-distant areas (Linnen, 2006).

The vehicles also act as a vector for seed dispersal and subsequent establishment along roadways (Von der Lippe and Kowarik, 2007), and non-native cover is higher at well pads, pipelines, and access routes than the native vegetation (Bergquist *et al.,* 2007). This may also have an impact on the biodiversity in that area.

Oil and gas exploration is also associated with repeated human visitation. This also creates acoustic, physical, and visual disruptions that birds may avoid indefinitely. Because some bird species more especially the songbirds use acoustic signaling to communicate, anthropogenic noise is of particular concern (Bayne *et al.,* 2008). Sound that interferes with bird communication has the potential to reduce habitat quality.

The increased traffic, construction equipment to create and maintain infrastructure, and engines to compress and transport oil and gas through pipelines are all sources of energy-related anthropogenic noise. Suitable habitat also might be avoided by birds if communication is continually interrupted by noise (Bayne *et al.,* 2008). Noise from human activities such as traffic or industrial noise is more disastrous than the natural one because of occurring more often and this is said to have a huge impact on bird species diversity (Blickley and Patricelli, 2010).

Research conducted by Bayne *et al.,* 2008 on songbirds indicated that bird density was 1.5 times higher in boreal aspen forests with no anthropogenic noise than the same habitat beside a noise-generating compressor station. One-third of the bird species detected were less abundant within 328 yards of the source of the noise. Another study conducted by Habib *et al.,* 2007 found out that male ovenbirds in quiet areas were significantly more likely to attract a mate than those near active compressor stations.

It is therefore noted that the abundance and nest densities of some bird species may be lower near narrow walking paths that are created while carrying out oil and gas operations (Miller *et al.,* 1998). Species with restricted distributions, a need for shrubs, an aversion to non-native plants, are most likely to respond negatively to disturbances created by oil and gas exploration and development (Bayne and Dale, 2011).

Copeland *et al.,* (2009) modelled the potential impacts of oil and gas development on Sage grouse in 12 states of Intermountain West USA and predicted that petroleum development in that part of USA could lead to 7-19% decline in their population numbers.

Some bird species namely Grey Crowned-cranes (*Balearica regulorum*) are found throughout the mixed wetland-grassland habitats of Eastern and Southern Africa (Meine and Archibald, 1996). These are non-migratory though they make local and seasonal movements (Pomeroy, 1987) and are most abundant in Uganda, Kenya and Tanzania (Meine and Archibald, 1996) and their conservation status is currently listed as vulnerable with an estimated population of approximately 47,000-59,000 animals (Bird Life International, 2009). However, due to increased human activity, this has primarily led to the loss of habitat (Meine and Archibald, 1996), populations are in declining steadily (Beilfuss *et al.,* 2007). In Uganda, to be specific, this species is recognized as the national bird, though the current populations may be as low as 13,000 birds' country wide, a potential decline of more than 60% since 1985 (Beilfuss *et al.*, 2007). Of even greater concern is the low breeding success. Muheebwa-Muhoozi (2001) reported a decline in breeding success of 0.42 birds that is; Grey Crowned-cranes (*Balearica regulorum*) fledged per clutch over a 25-year period. If this trend continues, there will be no successful breeding pairs within Uganda in the next few years. Uganda contains an extensive network of wetlands and swamps in Africa, which has important implications for conservation and management since cranes most often use wetland edges for nesting (Olupot and Plumptre, 2006). The country is also predominantly 38% covered by cropland (Bartholomé and Belward, 2005), which often results in conflict with humans since many of these agricultural lands border wetlands and are often used as nesting and foraging sites (Olupot and Plumptre, 2006).

Petroleum development is accompanied by production of waste fluids during exploration and production phases. In general, these fluids are a mixture of water with a variety of contaminants, commonly including drilling muds, concentrated salts, hydrocarbons not removed in the separation process, and trace amounts of potentially toxic metals (Ekpubeni and Ekundayo, 2002). Therefore, the contents of a particular reserve pit used to store these waste fluids depends on the type of drilling mud used (Trail, 2006), the formation drilled, and other chemicals added to the mud circulation system during the drilling process (Ramirez, 2009). Trail (2006) reviewed impacts of waste fluids on birds in the oil producing regions of the United States and reported that from 1992-2005, a minimum of 2,060 individual birds representing 172 species and 44 families were identified from body remains recovered from oil pits. The study concluded that oil pits pose a threat to virtually all species of birds that encounter them. Birds were the predominant vertebrate group recovered from oil pits in the United States (Grover, 1983).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

The study was done in Kikuube district, a new district in Western Uganda curved out of Hoima district following the approval of Parliament in 2015 Western Uganda. It comprises of Buhimba town council, Bugambe, Kyangwali, Kikuube town council.

Kingfisher oil development project is located on the Buhuka Flats in Kyangwali Sub-county, Kikuube District bordering Lake Albert to the West and a flat plain bounded by the Albertine rift escarpment to the East. It is being developed by CNOOC Uganda, a Chinese company and it has one discovery, the Kingfisher Discovery. The project's main components are four onshore well pads comprising 20 producer wells and 11 water injection wells, a central processing facility located on the Buhuka plain, a water abstraction station, production and injection flowlines, supporting facilities (including camps, a helipad, supply base, and safety check station), local service roads, an access road (generally called the Escarpment Road) from Ikamiro to the project site, and a 46 km feeder pipeline running from the Central Production Facility to the Kabaale refinery. The Kingfisher oil field was discovered by Kingfisher-1 wildcat well in 2006 by Heritage Oil and Gas Limited that conducted the exploratory drilling and is approximately 15.2km long, 3km wide and covers an area of 32.3 km^2 (Petroleum Authority Uganda, 2019) comprising of pad 1 (KF 1) and pad 2 (KF 2) at GPS coordinates 1.24639^{O}N 30.74120^{O}E, 1.25478^{O}N 30.74998^{o}E respectively in Kyabasambu village, pad 3 (KF 3) at 1.23038^o N 30.73165^{O}E in Nsunzu village. The oil pads had similar environmental conditions with the Control Areas (CA) CA 1, CA 2 and CA 3. The temperature of the region ranges between 20-

30°C with annual rainfall between 1,000 mm and 1,800 mm and follows a typical East African bimodal seasonal pattern. Below is figure 3.1 which shows the location of the study area.

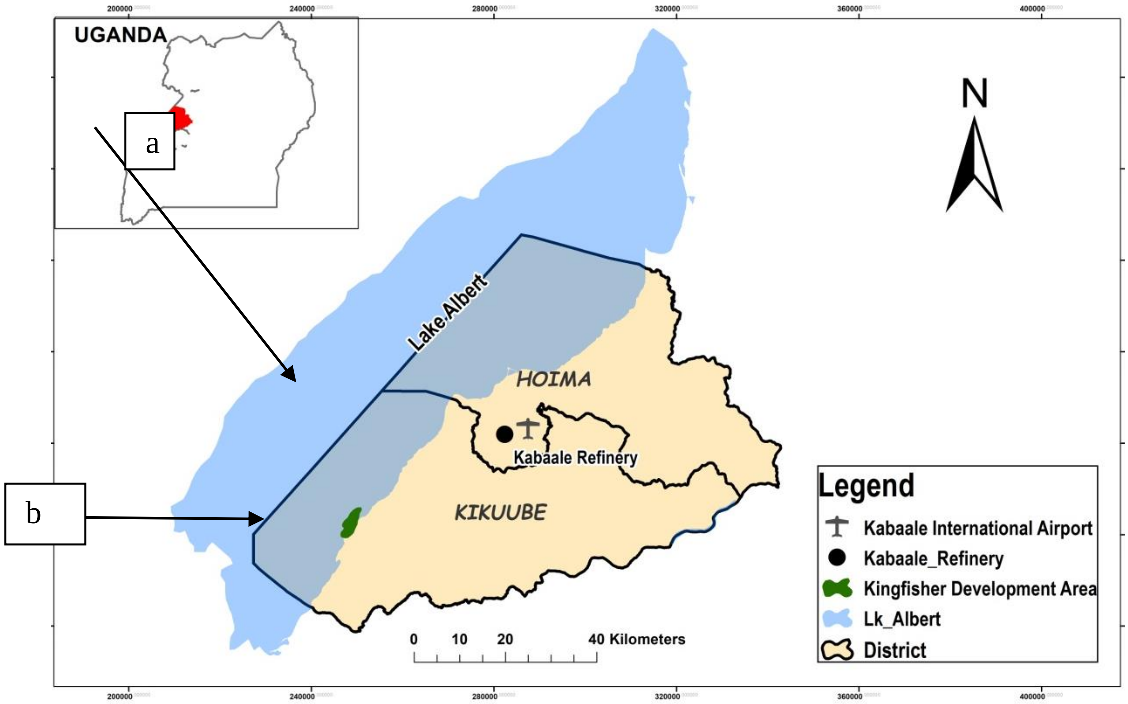

Figure 3. 1: A map of Kikuube district showing the location of Kingfisher development area

**a: shows the map of Uganda*

**b: Kingfisher development area*

3.2 Research design

The research used both qualitative and quantitative research designs. Purposive sampling was used to select the oil exploration sites and the control areas. The oil sites under the study were selected due to the fact that they were already drilled and that they comprised of a variety of biological resources. The control areas were chosen due to the fact they had similar environmental conditions like the selected KF 1, KF 2 and KF 3 oil sites and these had not faced oil and gas operation disturbances. The study was carried out during both dry and wet seasons for both plants and bird species in both oil sites and control areas. Bird counts were done in the morning between 7:00 am to 11:00 am and evening between 5:00 pm to 7:00pm to avoid noise disturbances and were with help of a binocular and a field guide book along a transect of 1 km.

Plant species were determined with the help of a dichotomous key along the transects laid and the quadrats drawn in each oil pad and the control area and these were replicated to get a full representation and reducing bias in results obtained. The distance between exploration areas and the control areas was approximately 4km.

Trends in Land use and land cover change were obtained with the help of remotely sensed methods whereby satellite images were obtained from a free website of USGS Earth Explorer and were integrated with the ground truthed results which were obtained with the help of a GPS version of Etrex 30x Garmin that took the coordinates for accuracy purposes.

3.3 Data collection tools

3.3.1 Mapping spatial and temporal trends in Land use and land cover changes

To conduct this study, quantitative data was used. Primary data was collected through ground truthing (obtaining the coordinates) and secondary data was got from both published and unpublished documents. Based on the results got, a number of data sets were obtained and used for the implementation of the study. Table 3.1 shows all the collected spatial data sets, their description and source.

Table 3.1: Summary of spatial data sets

No	Data	Description
1.	Landsat imagery (Landsat 5 TM and Landsat 8 OLI)	These were acquired from the USGS for years of 1990, 2010 2014 and 2019
2.	Districts	This was obtained from the districts map by the UBOS of 2016
3.	Roads	This was obtained from the UBOS of 2012
4.	Rivers	This was obtained from the UBOS of 2008

3.3.2 Framework for Land cover mapping and accuracy assessment

Below is a summarized framework on how land cover mapping and accuracy assessment was done. This is seen in figure 3.2 below

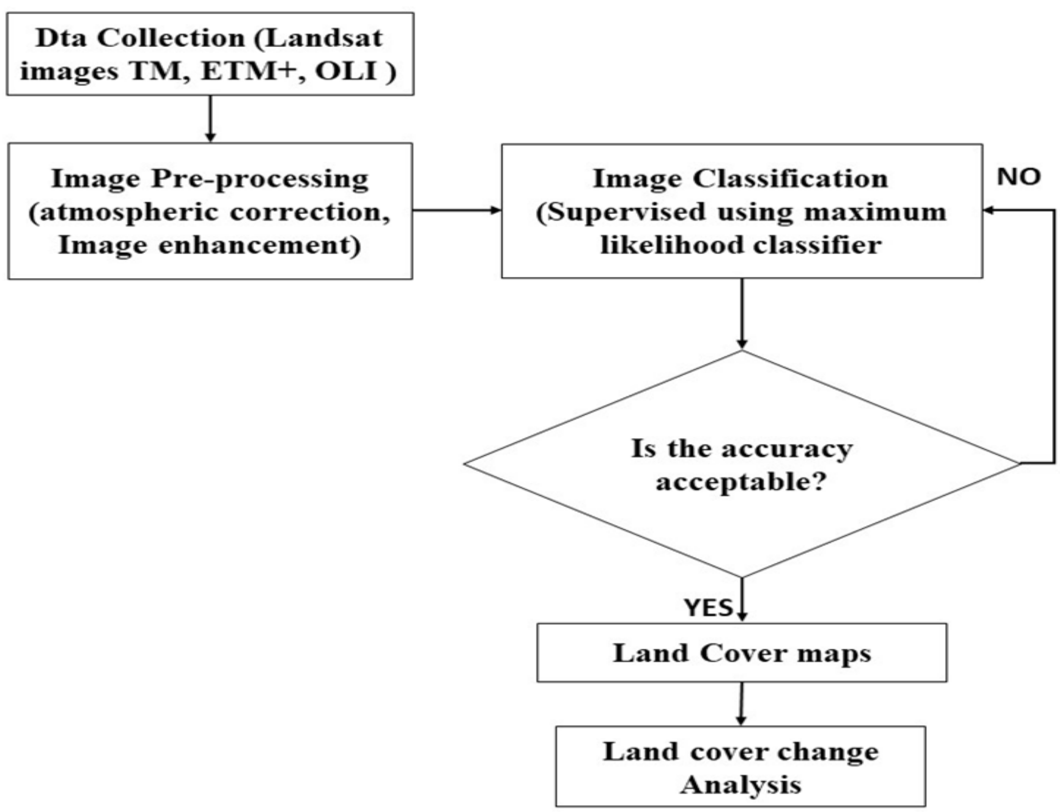

Figure 3. 2: Summarized framework for land cover mapping and assessment (**Ayele, 2017)**

3.3.2.1 Land cover mapping

A series of four cloud free Landsat Imagery (1990, 2010 2014 and 2019) path/Row of 172/060 and 172/059 were accessed through the open source of United States Geological Survey (USGS) with a spatial resolution of 30m. For 1990 and 2010, Landsat 5 was used and for images of 2014 and 2019; Landsat 8 was used using ARCMAP 10.5 software as shown in table 3.2

Table 3.2: Images selected and corresponding sensors used

No.	Type of Data/sensor	Scale/Resolution	Path/Row	Date
1	Landsat 5 (TM)	30m	172/060	22/12/1990
2	Landsat 5(TM)	30m	172/060	27/01/2010
3	Landsat 8 OLI	30m	172/060	14/01/2014
4	Landsat 8 OLI	30m	172/059	14/01/2019

3.3.2.2 Data Pre-Processing

This involved operations prior to processing and analysis. The images were corrected for atmospheric correction using dark object subtraction like path radiance, scattering and sky irradiance using ENVY 5.3 software. The satellite imageries were stacked into different bands to produce different colour composite. Image sub setting was carried out to extract the area of interest. Different image enhancement techniques namely; PCA, NDVI and band composites were used to improve their visual interpretation for identification of different land cover classes.

3.3.2.3 Image classification

The Landsat images were visually interpreted and seven land cover classes were identified in the study area and classified using ENVY 5.3 software. These include; Forested area, bushlands, Grasslands, open water, farmland, wetlands and bare land/built-up. To map the extents of these classes, supervised classification based on MLA was used. The supervised method permits selection of pixels (training areas) that represent land use features. Perception of the training areas was based on visual interpretation which takes care of all kinds of information like size of object, shape of object, tone, colour, texture, pattern and association of various spectral covers. The training sites were digitized and each class was assigned to a different colour for easy differentiation. It also helped in calculating the distance from each feature vector to the class means. The class variability was taken care of by adding a vector, which is a function of the variance- covariance matrix of that class as in equation put by Marther, (1987) as shown in equation (i)

$$\boldsymbol{D_i(X) = ln|V_i| + (X - M_i)^T V_i^{-1}(X - M_i)}\ldots\ldots\ldots(\mathbf{4.1})$$ **..(Equation i)**

Where

$D_i(X)$ = distance between pixel vector X and class mean based on probabilities; X = pixel vector X; M_i = mean vector of the class considered; V_i = the variance-covariance matrix of the class considered; V^{-1} = the inverse of V_i; |Vi| = determinant of the variance-covariance matrix; $(X-M_i)$ = the distance towards a class mean; and $(X-M_i)^T$ =the transposition of $(X-M_i)$.

During classification, the measurement vector was assigned to the class in which it had the highest probability of membership. It considered the mean and covariance of training set as basic marks for classification.

3.3.2.4 Accuracy assessment

Accuracy assessment was performed on the classified images using ground truth data that was acquired using Google earth images and data from National Forestry Authority. The user's accuracy or reliability is the probability that a pixel classified on the map actually represent that category on the ground (Jensen, 2005). The ground truth data was obtained by generating reference points that were randomly selected from reference images of the corresponding years. Accuracy assessment was done through generating confusion matrices based on test samples for each land cover map. The Kappa index of agreement was used as the evaluation criteria for the classification. It is a measure of how the classification results compare to values assigned by chance. The statistic k (kappa) estimates the difference between the observed agreement of two images and the agreement that might be attained solely by chance matching of the two images.

Kappa analysis is a discrete multivariate technique used in accuracy assessment and it can be computed as;

$$\boxed{k = \frac{\textit{Observed - expected}}{\textit{1 - expected}}}$$

Where

"Observed" represents the value for "percentage correct"

"Expected" estimates the effect of chance agreement upon the observed percentage correct.

The Kappa value ranges between 0 and 1. If kappa coefficient equals to 0, there is no agreement between the classified image and the reference image. If kappa coefficient equals to 1, then the classified image and the ground truth image are totally identical (in perfect agreement). So, the higher the kappa coefficient, the more accurate the classification is. If the test samples are in perfect agreement, then values for the Kappa index (Kap) are equivalent to 1.

3.3.2.5 Land cover change analysis

Different statistical analyses were conducted using EDRIS SELVA software to give area computations. This included the percentage change (trend) and annual rate of change (%) in land use between 1990, 2010, 2014 and 2019 (a period of 20 years).

Annual rate of change = (% change/100) x number of years…………………………….ii

% change (trend) = (observed change/ sum of change) x 100……………………………..iii

3.3.2.6 Change detection

Change detection is defined as the process of identifying differences in the state of an object or phenomenon by observing it at different times (Mausel *et.al*., 2003). This process is applied to Earth surface changes at two or more times. The temporal image differencing procedure was used to subtract the first date image from the second date image, pixel by pixel to produce a different map that indicates areas of change.

3.3.2.7 Map preparation

The classified maps were again drawn using ARCMAP 10.5 software.

3.3.3 Effects of oil and gas exploration on vegetation abundance

The study used observation, counting and recording method. Plant species were counted and recorded in and outside the three oil pads. It used a systematic random sampling as put by Smith, 1983. The researcher used a (1x1) M quadrat for grass species, (3x3) M quadrat for tree species and a (5x5) M quadrat for shrub species along a 50m line transect and noted all the observed plant species. The study followed sampling technique by Cox, 1990 of using quadrats to study plant communities. The study followed a procedure of placing each quadrat every after 10m along a straight line in and outside the oil pad for four line transects. Each transect begun from the center of the oil pad going in all directions. This was intended to get the true representation of each studied site and avoid bias in results obtained and the same was done for the control area. Plant species were determined with the help of a dichotomous key along the transects laid and the quadrats drawn in each oil pad and the control area and these were replicated to get a full representation and reducing bias in results obtained. Species that could not be easily identified were collected, placed in a collection bag and taken to the Makerere University Herbarium for further identification and naming. The coordinates and elevation were taken using a GPS version of Etrex 30x Garmin and a camera PENTAX Digital 1-10 was used in capturing images.

Materials that were used in the identification of plant species also included field book guides of the Trees of Uganda by Hamilton, 1981 and 115 grasses of Uganda by Phillip *et al*., 2003. Data was recorded in a format as indicated in Appendix 3.

3.3.4 Effects of oil and gas exploration on bird abundance

The study used Point Count method along a line transect as described by Bibby *et al.* (2000). Bird species were studied along a 1 km line transect from the center of the oil pad or the control area. Four transects were drawn per site moving in all the directions. The researcher made four points at each transect for a distance of 250m. On reaching the site, the researcher stood quietly while observing, counting and noting the number of birds in the surrounding using naked eyes and with the help of a Nikon's Black 8x42 Prostaff 3S Binocular to enhance the sighting of birds located at longer distances. This was with the assistance of an experienced local guide and a field guide book titled "The Birds of East Africa" by Stevenson and Fanshawe (2002) and about 5-10 minutes were spent per point of count. All birds sighted within a distance of 200m on either side of each transect were counted and recorded. All counts were made during average weather conditions as NO counts were made during extreme weather conditions for instance during heavy rainfall or too much sunshine. The study was conducted in the morning starting at 7:00 am to 11:00 am and in the evening between 5:00 pm to 7:00pm. This is because at these times, the birds tend to be settled in their habitat places due to less disturbances in the outside environment. This was done for both dry (February) and wet (May) seasons for both oil pads and control areas. Precautions were taken not to double count. Data were recorded in a format, as indicated in Appendix 4.

PCA was also carried out to reduce the dimensionality of the data sets that consisted of large number of interrelated attributes. This process was done by linear transformation of the original set of attributes into a smaller set of attributes called principal components (PCs). Principal components are uncorrelated and ordered so that the first few retain most of the variation present in all of the original attributes.

3.4 Data analysis for land use and land cover change

Arc GIS was used to analyze the data. This was done using a point-based approach. Data analysis for accuracy assessment involved creation of contingency tables which summarize misclassification rates for each land cover type.

3.5 Data analysis for vegetation and bird abundance

Shannon Weiner diversity index (H) was determined and corresponding H Max values and evenness values for each transect were calculated using Microsoft Word Excel 2016. IBM SPSS Statistics 21 Developer was used as a statistical tool for Descriptive statistics in order to determine the frequencies for the relative abundance of both vegetation and birds. Principle Component Analysis was also performed as a dimension reduction tool using R- version 3.0 software. Seasonal variations determination for bird species was done in Microsoft Excel 2007.

CHAPTER FOUR

RESULTS

4.1 Spatial and temporal trends in land use and land cover changes (LULC)

To determine the spatial and temporal trends in land use and land cover changes, the collected data sets were manipulated with GIS tools to obtain the results. And these results are represented in form of maps and tables.

4.1.1 Land cover maps

The land cover maps obtained were from the supervised maximum classification of 1990, 2010, 2014 and 2019. Landsat imagery had seven classes which were identified namely; Forested area, bushlands, Grasslands, open water, farmland, wetlands and bare land/built-up. This is shown in figure 4.1 below.

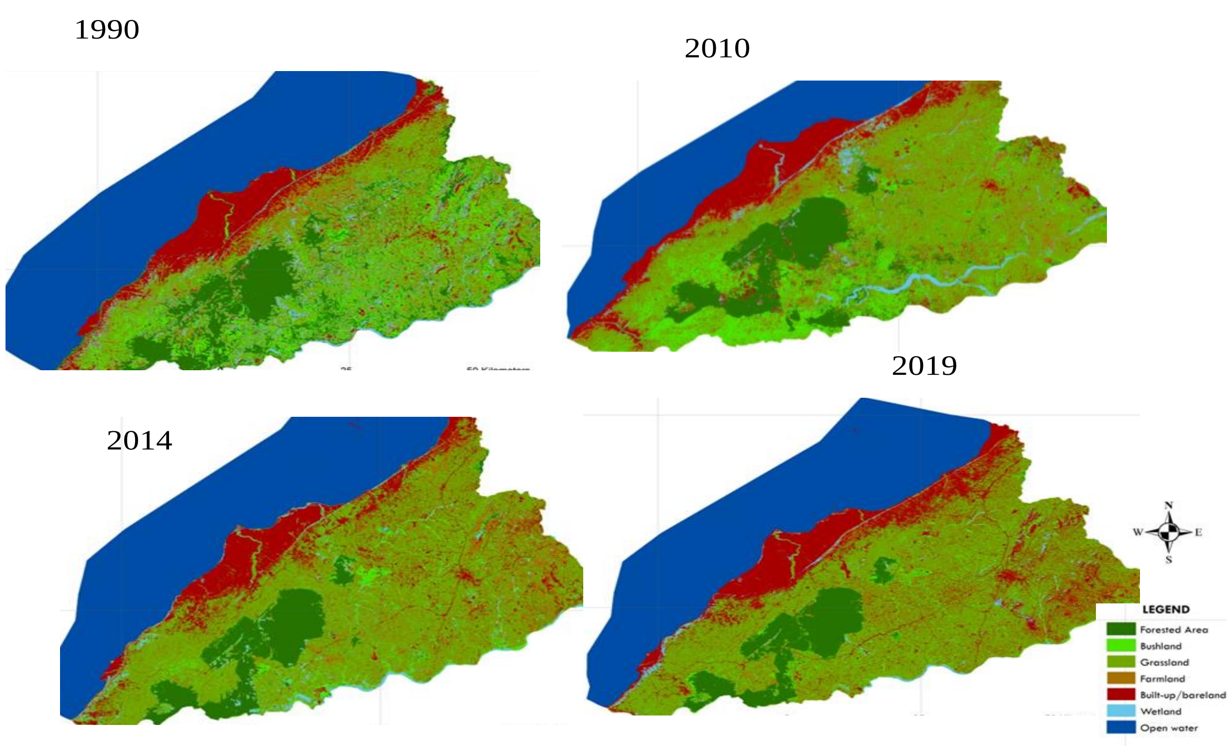

Figure 4.1: Classified land cover maps of 1990, 2010, 2014 and 2019

4.1.2 Accuracy Assessment

To use GIS tools to estimate the lost areas occupied by different activities, accuracy assessment was conducted using a point-based approach as described in section 3.2.4.4. This was aimed at assessing the level of accuracy of the map classes (Forested area, bushlands, Grasslands, open water, farmland, wetlands and bare land/built-up) with one or more evaluation points representing each map class. The map represents vegetation types using one or more polygons per type as described in section 3.2.4.4. Table 4.1 below presents the accuracy results of the classified images for different time periods.

Table 4. 1: Results for accuracy assessment of classified images

Type of Data/sensor	Scale/Resolution	Path/Row	Acquisition Date	Overall accuracy (%)	Kappa statistics (%)
Landsat 5 (TM)	30m	172/060	22/12/1990	83.4955	82.35
Landsat 5(TM)	30m	172/060	27/01/2010	85.33	81.67
Landsat 8 OLI	30m	172/060	14/01/2014	95.122	94.07
Landsat 8 OLI	30m	172/059	14/01/2019	79.012	74.4

The overall accuracies of all the images were within allowable limits, thereby giving good results for remote sensing image based analysis as given in Herold *et al.,* (2005).

4.1.3 Land cover distribution

Based on the results presented in section 4.1.1 and 4.1.2, the areas in hectares occupied by the different land cover classes over a given period of time were computed as shown in table 4.2 below.

Table 4. 2: Land Cover distribution between 1990 and 2019

Class	1990 Area(Ha)	2010 Area (Ha)	2014 Area (Ha)	2019 Area (Ha)
Forested Area	71789	58866.3	40490.1	37701.63
Bushlands	51656.4	56480.5	15226.1	10161.45
Grasslands	114039	178323	207959	208291.50
Farmlands	39650.5	47881.5	31343.3	17300.79
Built-up/Bare land	57936.5	58853.3	60368.9	87535.71
Wetlands	31574.6	15744.4	11844	7398.00
Open water	175041	125538	174456	173298.06
Total	**541687**	**541687**	**541687**	**541687**

Table 4.2 above showed that there was a consistent reduction in forested area and wetlands from 1990 to 2019. However, an increase in coverage for built-up and grasslands from 1990 to 2019 was observed.

Basing on the results presented in section 4.1.3, the percentage land cover distribution was also computed as shown in table 4.3 below.

Table 4. 3: Percentage land cover distribution in the studied area

Class	1990 (%)	2010 (%)	2014 (%)	2019 (%)
Forested Area	13.25	10.87	7.47	6.96
Bushlands	9.54	10.43	2.81	1.88
Grasslands	21.05	32.92	38.39	38.45
Farmlands	7.32	8.84	5.79	3.19
Built-up/Bare land	10.70	10.86	11.14	16.16
Wetlands	5.83	2.91	2.19	1.37
Open water	32.31	23.18	32.21	31.99

Results in table 4.3 above indicated that there was a consistent decline in percentage land cover distribution in forested area and wetlands to the expense of other land use classes.

Throughout the years, forested area and wetlands progressively lost area to other land use types namely; Built-up/bare land and grasslands whereas these have gained their coverage over time.

4.2 Vegetation relative abundance per transect in Kingfisher Development Area

The findings were used to determine the vegetation relative abundance of the various plant species observed during the study. This is seen in table 4.4 below. Results showed that the vegetation relative abundance in the oil pads was not significantly different from the one in the control areas at $P<0.05$.

Results revealed that most plant species exist in both former oil pads and the control areas that were purposively chosen. However, findings also showed that some plant species were more abundant in former oil pads than the control areas and as well some were more in control areas than the oil pads. The results are shown in tables 4.4 and 4.5 below.

Findings also showed that the commonest plant species in the study area were; Common thatching grass (*Hyparrhenia hirta),* Rat's tail grass (*Sporobolus robustatus),* Giant rat's tail grass (*Sporobolus pyramidalis),* Thorn apple (*Solanum incanum),* Feather finger grass (*Chloris virgate),* Love grass (*Eragrostis congesta) and Eragrostis namaquensis,* and Nut grass (*Cyperus rotundus.)* with the high number of species observed.

Table 4.4: Mean Number (± Standard Error Mean) vegetation relative abundance of the observed plant species per transect in both oil pads and control areas

Common name	*Scientific name*	Family	Vegetation/ Growth form	Oil pad	Control area
Couch grass	*Cynodon dactylon*	Poaceae	Grass	22.8±4.8	20.3±8.0
Giant rat's tail grass	*Sporobolus pyramidalis*	Poaceae	Grass	143.2±33.2	159.6±39.6
Birch leaved cat tail	*Acalypha fruticose*	Euphorbiaceae	Shrub	0.3±0.2	0.8±0.4
Sparrow grass	*Asparagus africanus*	Asparagaceae	Grass	4.9±4.1	5.3±3.8
Common reed	*Phragmites kirkii*	Poaceae	Grass	0±0	3.3±1.3
Bulrush	*Typha capensis*	Typhaceae	Grass	0.4±0.2	0.5±0.4
Guinea Rush	*Cyperus articulates*	Cyperaceae	Grass	9.9±3.7	10.3±4.3
Candle bush	*Senna alata*	Fabaceae	Tree	1.8±1.0	0±0
African teak	*Milicia excels*	Moraceae	Tree	0.1±0.1	0.2±0.1
Tamarind	*Tamarindus indica*	Fabaceae	Tree	0±0	0.9±0.5
Candelabra tree	*Euphorbia candelabra*	Euphorbiaceae	Tree	0.5±0.3	0.9±0.6
Neem	*Azadirachta indica*	Meliaceae	Tree	0±0	1.6±1.3
Barbados nut	*Jatropha curcas*	Euphorbiaceae	Shrub	6.2±3.7	7.7±3.1
Castor oil plant	*Ricinus communis*	Euphorbiaceae	Shrub	0.6±0.2	0.8±0.3
Tick berry	*Lantana camara*	Verbenaceae	Grass	1.9±1.9	0±0
Giant sensitive tree	*Mimosa pigra*	Fabaceae	Tree	0±0	0.3±0.3
Jelly bean tree	*Parkinsonia aculeate*	Fabaceae	Tree	0.5±0.3	0.7±0.3
Shellflower	*Pistia stratiotes*	Araceae	Shrub	0±0	1.3±0.7
African bermuda grass	*Cynodon nlemfuensis*	Poaceae	Grass	16.4±6.7	12.5±5.3
Cup grass	*Eriochloa procera*	Poaceae	Grass	9.3±3.3	9.8±3.4
Rat's tail grass	*Sporobolus robustatus*	Poaceae	Grass	103.7±24.7	109.0±32.3
Coffee *senna*	*Cassia*	Fabaceae	Shrub	0.6±0.4	0±0

	occidentalis				
Whistling acacia	*Acacia hoki*	Fabaceae	Tree	0±0	0.4±0.3
Aloe lateritia	*Aloe lateritia*	Asphodelaceae	Shrub	0.7±0.7	1.2±0.5
Thorn apple	*Solanum incanum*	Solanaceae	Shrub	47.7 ±16.3	51.8±30.0
Feathery Rhodes-grass	*Chloris pycnothrix*	Poaceae	Grass	10.7±3.5	17.7±7.6
Feather finger grass	*Chloris virgate*	Poaceae	Grass	30.2±7.9	40.0±10.0
African *asparagus*	*Asparagus flagellaris*	Asparagaceae	Shrub	18.8±4.5	16.4±3.5
Love grass	*Eragrostis congesta*	Poaceae	Grass	45.7±9.9	54.2±7.7
Love grass	*Eragrostis namaquensis*	Poaceae	Grass	60.1±7.1	57.8±7.0
Silk tree	*Albizia*	Fabaceae	Tree	0.1±0.1	0.3±0.1
Nut grass	*Cyperus rotundus*	Cyperaceae	Grass	33.3±5.6	34.8±5.7
Garden pink-sorrel	*Oxalis latifolia*	Oxalidaceae	Grass	10.2±5.2	8.8±7.5
Creeping woodsorrel	*Oxalis corniculate*	Oxalidaceae	Grass	16.3±7.8	10.5±7.5
Common thatching grass	*Hyparrhenia hirta*	Poaceae	Grass	117.6±39.8	134.3±28.0

4.2.1 The plant species observed in both oil pads and control areas

Thirty five plant species were encountered and recorded throughout the study. They included 18 grass species, 8 shrub species and 9 tree species in both oil pads and control areas. In oil pads, they were 16 grass species, 4 tree species, and 5 shrub species. In control areas, they were 17 grass species, 7 shrub species, and 8 tree species. Most of the plant species observed were recorded in both oil pads and control areas, while others were in either of the two sites as seen in table 4.5 below.

Table 4. 5: Plant species observed in both oil pads and control areas of Kingfisher area

Common name	*Scientific name*	Family	Vegetation/Growth form	Oil pad	Control area
Couch grass	*Cynodon dactylon*	Poaceae	Grass	Present	Present
Giant rat's tail grass	*Sporobolus pyramidalis*	Poaceae	Grass	Present	Present
Birch leaved cat tail	*Acalypha fruticose*	Euphorbiaceae	Shrub	Present	Present
Sparrow grass	*Asparagus africanus*	Asparagaceae	Grass	Present	Present
Common reed	*Phragmites kirkii*	Poaceae	Grass	Absent	Present
Bulrush	*Typha capensis*	Typhaceae	Grass	Present	Present
Guinea rush	*Cyperus articulates*	Cyperaceae	Grass	Present	Present
Candle bush	*Senna alata*	Fabaceae	Tree	Present	Absent
African teak	*Milicia excels*	Moraceae	Tree	Present	Present
Tamarind	*Tamarindus indica*	Fabaceae	Tree	Absent	Present
Candelabra tree	*Euphorbia candelabra*	Euphorbiaceae	Tree	Present	Present
Neem	*Azadirachta indica*	Meliaceae	Tree	Absent	Present
Barbados nut	*Jatropha curcas*	Euphorbiaceae	Shrub	Present	Present
Castor oil plant	*Ricinus communis*	Euphorbiaceae	Shrub	Present	Present
Tick berry	*Lantana camara*	Verbenaceae	Grass	Present	Absent
Giant sensitive tree	*Mimosa pigra*	Fabaceae	Tree	Absent	Present
Jelly bean tree	*Parkinsonia aculeate*	Fabaceae	Tree	Present	Present
Shellflower	*Pistia stratiotes*	Araceae	Shrub	Absent	Present
Africanbermuda grass	*Cynodon nlemfuensis*	Poaceae	Grass	Present	Present
Cupgrass	*Eriochloa procera*	Poaceae	Grass	Present	Present
Rat's tail grass	*Sporobolus robustatus*	Poaceae	Grass	Present	Present
Coffee *senna*	*Cassia*	Fabaceae	Shrub	Present	Absent

	occidentalis				
Whistling acacia	*Acacia hokii*	Fabaceae	Tree	Absent	Present
Aloe lateritia	*Aloe lateritia*	Asphodelaceae	Shrub	Present	Present
Thorn apple	*Solanum incanum*	Solanaceae	Shrub	Present	Present
Feathery rhodes-grass	*Chloris pycnothrix*	Poaceae	Grass	Present	Present
Feather finger grass	*Chloris virgate*	Poaceae	Grass	Present	Present
African *asparagus*	*Asparagus flagellaris*	Asparagaceae,	Shrub	Present	Present
Love grass	*Eragrostis congesta*	Poaceae	Grass	Present	Present
Love grass	*Eragrostis namaquensis*	Poaceae	Grass	Present	Present
Silk tree	*Albizia*	Fabaceae	Tree	Present	Present
Nut grass	*Cyperus rotundus*	Cyperaceae	Grass	Present	Present
Garden pink-sorrel	*Oxalis latifolia*	Oxalidaceae	Grass	Present	Present
Creeping wood-sorrel	*Oxalis corniculate*	Oxalidaceae	Grass	Present	Present
Common thatching grass	*Hyparrhenia hirta*	Poaceae	Grass	Present	Present

Principle component Analysis was also done to show the distribution of plant species in various study sites. The species were normally distributed across the study sites. However, species like *Senna alata, Lantana camara,* and *Cassia accidentalis* were only found in oil pads and species like *Phragmites kirkii, Tamarindus indica, Azadirachta indica, Pistia stratiotes, Mimosa pigra and Acacia hokii* were noted only in control areas. A principle component analysis Biplot was constructed to show this distribution. This is illustrated in figure 4.2 below.

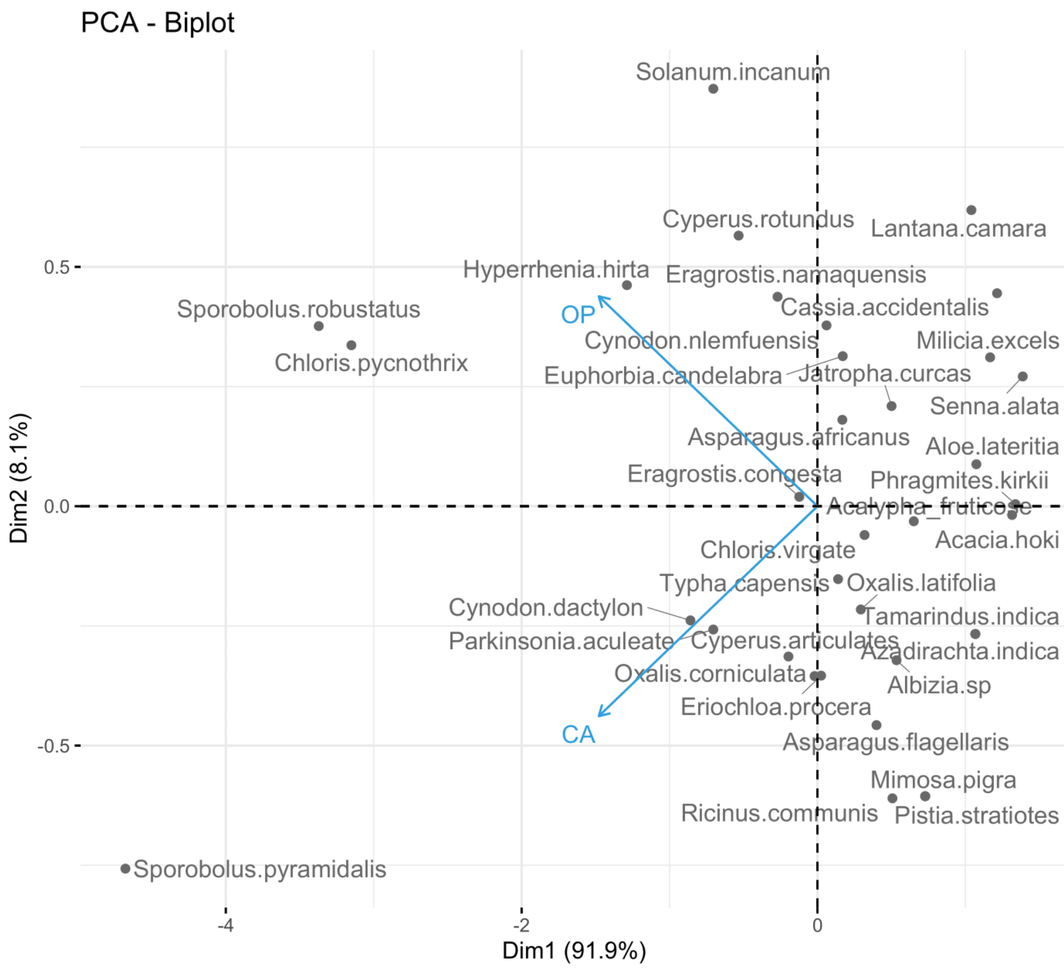

Figure 4. 2: A principle component analysis (PCA) diagram showing the distribution of plant species in the studied areas

* OP-Oil Pad CA-Control Area

4.2.2 Vegetation diversity per transect in oil pads and control areas

The results of Shannon Weiner vegetation index per transect at both oil pads and control areas are presented in Table 4.6. The results show (1.92±0.06) as the mean vegetation diversity per transect at oil pads and (1.82±0.08) at control areas. The study results show a non-significant difference in the vegetation diversity between the former oil pads and control areas (t= 1.198, d.f

=11, P =0.256). The mean evenness of vegetation per transect in oil pads and control areas is (0.82±0.02) and (0.83±0.03) respectively.

Table 4. 6: Vegetation Diversity at oil pads and control areas

Oil pads transects	***H value***	***H max***	***E value***	**Control areas transects**	***H value***	***H max***	***E value***
KF 1 E	1.96	2.48	0.79	CA1 E	1.84	2.20	0.84
KF 1 S	2.16	2.56	0.84	CA1 S	2.46	2.71	0.91
KF 1 W	1.87	2.32	0.81	CA1 W	2.06	2.26	0.91
KF 1 N	1.61	2.20	0.73	CA1 N	1.42	2.08	0.68
KF 2 E	1.63	2.20	0.74	CA2 E	1.61	2.30	0.70
KF 2 S	1.93	2.40	0.80	CA2 S	1.78	2.20	0.81
KF 2 W	1.91	2.48	0.77	CA2 W	1.61	2.40	0.67
KF 2 N	1.86	2.20	0.85	CA2 N	1.72	2.20	0.78
KF 3 E	2.20	2.82	0.78	CA 3 E	1.78	1.86	0.96
KF 3 S	2.14	2.53	0.85	CA 3 S	1.69	1.97	0.86
KF 3 W	1.76	1.98	0.89	CA 3 W	2.22	2.36	0.94
KF 3 N	1.98	2.05	0.97	CA 3 N	1.63	1.89	0.86

KF-*Kingfisher,* H *value- Shannon Weiner vegetation index,* H *max- Maximum species', E value-Species' evenness*. E-East, S- South, W- West, N- North, CA- Control area

4.3 Bird abundance

The study observed and noted a variety of bird species throughout the study sites in Kingfisher Development Area. These species are presented in table 4.7 below.

The study observed and noted that Plovers *spp* namely; the Sand Plovers (*Charadrius mongolus),* Common ringed plovers (*Charadrius hiaticula),* Kittlitz plovers (*Charadrius pecuarius),* Brown cheeked hornbill (*Bycanistes cylindricus),* and the Piapiac (*Ptilostomus afer),* White headed saw wing (*Psalidoprocne albiceps),* Common sandpiper (*Tringa hypoleucos),* Black-billed barbet

(*Lybius guifsobalito)* were the most abundant bird species throughout the entire Kingfisher development area in both oil pads and control areas as these were observed in big numbers.

The study also noted that there were a few species of Grey crowned cranes (*Balearica regulorum)* and these were seen near Masika wetland. Other species observed in few numbers were; the grey heron (*Ardea cinerea)* which were seen near the shores of Lake Albert and these were absent in the oil pads, Cattle egret (*Bubulcus ibis)* which were also absent in the control areas. These were observed mixed with cattle that were grazing in the grassland of Buhuka flats East of oil pad 1.

Research findings revealed that majority of the bird species noted were present in both oil pads and control areas.

However, the study also noted that some bird species were observed during specific weather seasons. For example, species namely; Sedge warbler (*Acrocephalus schoenobaenus),* African reed warbler (*Acrocephalus baeticatus),* Eurasian reed warbler (*Acrocephalus scirpaceus)* were observed in big numbers during wet season and these are considered to be migratory birds.

Results therefore showed that there is no significant difference between the mean number of bird species recorded in oil pads and the ones recorded in control areas at ($t = -1.180$, d. f = 24, $P = 0.250$)

Table 4. 7: (Mean Number ±S.E) recorded bird species in both oil pads and control areas

Common name	Scientific name	Oil pad	Control area
Sedge warbler	*Acrocephalus schoenobaenus*	11.9±4.1	43.8±7.5
Eurasian reed warbler	*Acrocephalus scirpaceus*	8.1±2.6	20.0±6.5
African reed warbler	*Acrocephalus baeticatus*	9.4±2.6	18.9±4.4
Brown cheeked hornbill	*Bycanistes cylindricus*	59.8±29.4	48.3±7.2
Sand plover	*Charadrius mongolus*	55.0±5.5	55.6±28.7
Common ringed plover	*Charadrius hiaticula*	65.3±28.9	69.8±28.3
Kittlitz plover	*Charadrius pecuarius*	33.6±8.0	60.9±29.6
White headed saw wing	*Psalidoprocne albiceps*	38.5±8.1	41.7±9.9
Piapiac	*Ptilostomus afer*	77.3±13.9	60.5±15.0
Spot flanked barbet	*Tricholaema lacrymosa*	27.4±8.1	31.8±16.2
Common sandpiper	*Tringa hypoleucos*	51.7±16.3	55.3±9.9
Black loved babbler	*Turdoides sharpie*	23.8±7.0	26.4±7.1
White backed vulture	*Gyps africanus*	18.7±11.2	18.6±6.2
Cattle egret	*Bubulcus ibis*	0.8±0.8	0.0±0.0
Saddle billed stork	*Ephippiorhynchus senegalensis*	15.8±8.6	9.5±2.6
Grey crowned crane	*Balearica regulorum*	0.3±0.2	0.0±0.0
White winged tern	*Chlidonias leucopterus*	19.8±12.2	12.8±5.5
Grey heron	*Ardea cinerea*	0.0±0.0	0.7±0.7
Black-billed barbet	*Lybius guifsobalito*	43.6±10.9	30.4±7.6
Didric cuckoo	*Chrysococcyx caprius*	34.2±7.2	39.8±7.0
Copper sunbird	*Cinnyris cuprea*	8.8±3.2	9.5±3.3
Brown babbler	*Turdoides plebejus*	35.8±12.1	22.8±8.2
African grey hornbill	*Tockus nasutus*	29.2±11.7	39.1±11.4
Barn swallow	*Hirundo rustica*	16.4±7.2	30.9±12.4
Beautiful sunbird	*Cinnyris pulchella*	10.6±3.0	16.3±3.3

4.3.1 Seasonal variations in bird species populations

The research findings noted that the mean number of the recorded bird species in both oil pads and the control areas under the study for the wet and dry seasons significantly differed. The mean number of bird species recorded in the oil pads during wet season significantly differed from the bird species recorded in the oil pads during dry season during the study ($t = 2.711$, $d.f = 24$, $P < 0.05$). The mean number of bird of species recorded in the control areas during the wet season of the study significantly differed from the ones recorded during the dry season of the study ($t = 3.209$, $d.f = 24$, $P < 0.05$).

The mean number of bird species recorded in the oil pads and control areas during wet season was not significantly different ($t = 1.254$, $d.f = 24$, $P = 0.222$). There was no significant difference between the mean number of bird species recorded in oil pads and control areas during dry season ($t = 1.052$, $d.f = 24$, $P = 0.303$).

4.3.1.1 Warblers (*Acrocephalus*)

These bird species were observed in big numbers during the rainy season compared to the dry season. They preferred shrub type of vegetation. This is seen in figure 4.3 below

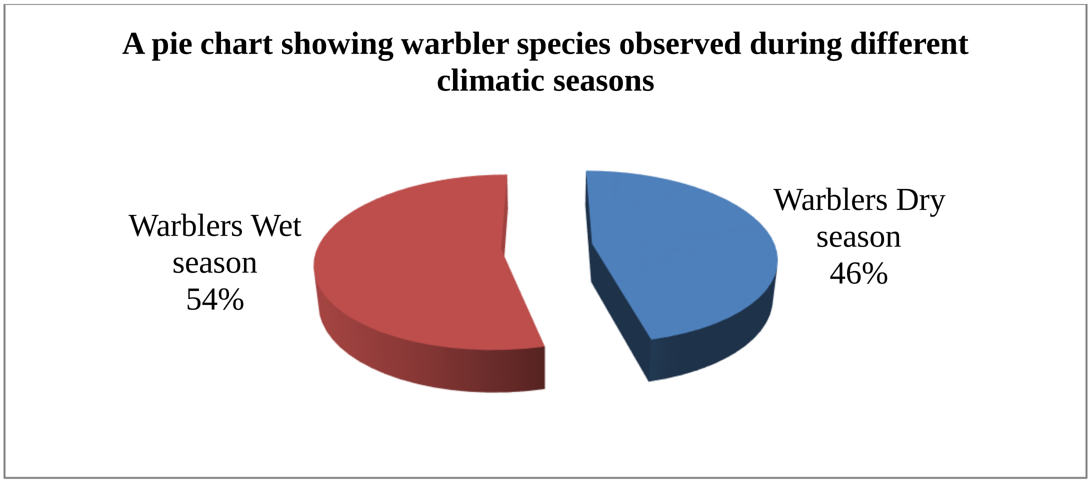

Figure 4. 3: Shows warbler species encountered in the study

4.3.1.2 Brown cheeked hornbill *(Bycanistes cylindricus).*

The Brown cheeked hornbill species were found to be more in the wet season compared to the dry season. This is illustrated in figure 4.4 below

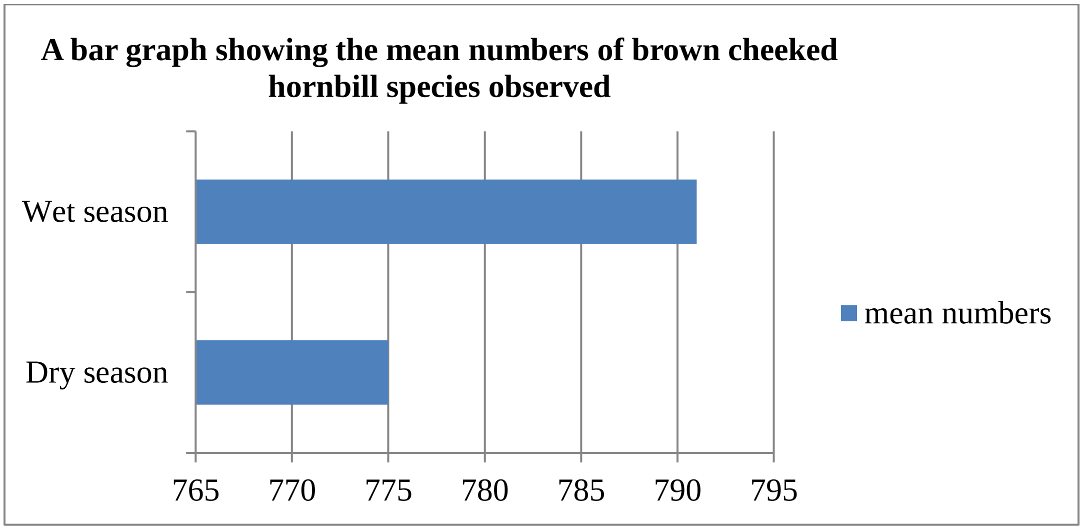

Figure 4. 4: Shows the Brown cheeked hornbill species observed

4.3.1.3 Plovers *(Charadrius).*

The number of species observed in dry season showed no significant difference from the ones observed in the wet season. They also preferred short savannah type of vegetation

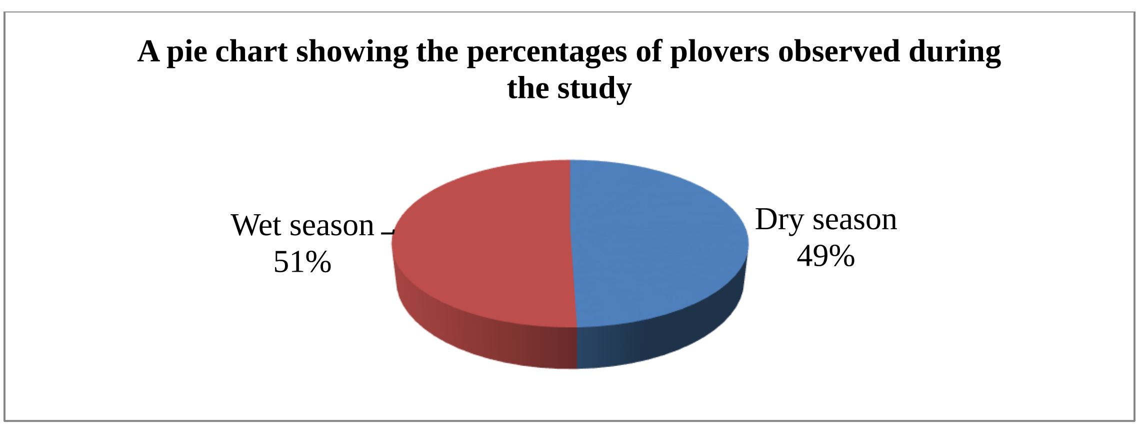

Figure 4. 5: Shows the percentage of plovers observed during the study

4.3.1.4 Piapiac *(Ptilostomus afer)*

The mean number of piapiac species observed in dry season showed no significant difference from the ones noted during wet season.

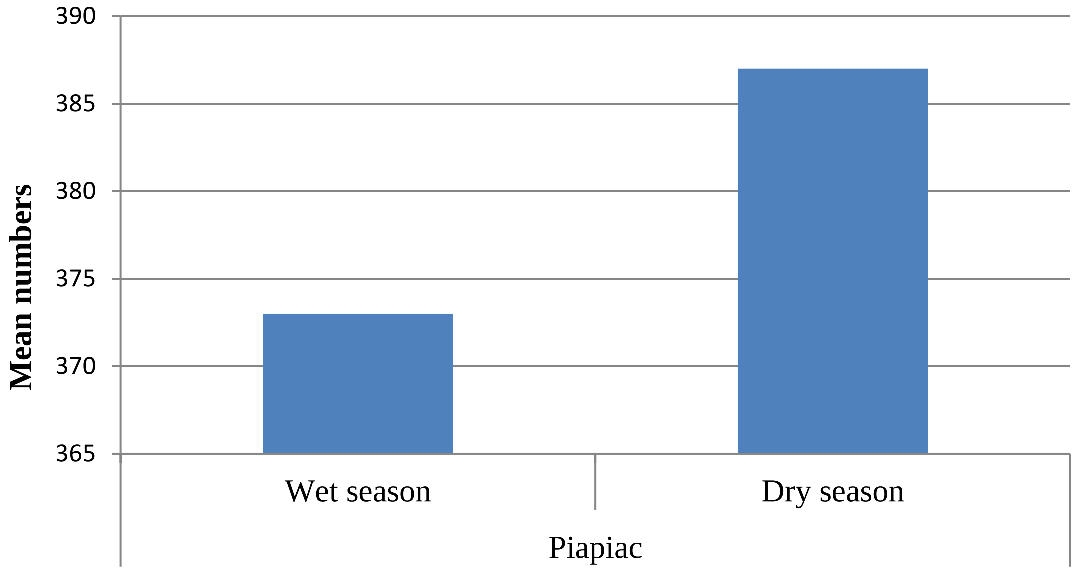

Figure 4. 6: Shows the Piapiac species seen during the study

4.3.1.5 Common sandpiper *(Tringa hypoleucos)*

These species were observed in big numbers during the wet season compared to dry season and the majority was seen in and near Masika wetland ecosystem in Kyabasambu village.

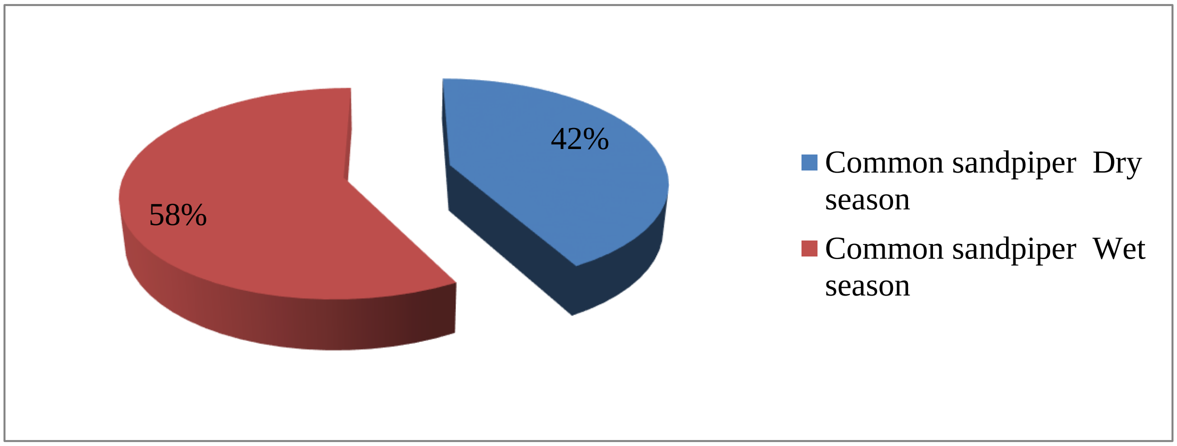

Figure 4. 7: Shows the percentages of Common sandpiper observed

4.4 Human activities taking place in Kingfisher Development Area

During the study, several methods of data collection were used and among these were the observation method. With this method, a number of anthropogenic activities were observed taking place or have taken place in the project area at Kingfisher. These are discussed below;

4.4.1 Cattle rearing

It was evident that cattle grazing is common and is taking place in the designated area for oil and gas operations at Kingfisher. This was seen at Kyabasambu near oil pad 1. This kind of practice is capable of leading to vegetation destruction. This can be seen in figure 4.8 below

Figure 4. 8: Showing cattle grazing at Kyabasambu village

4.4.2 Road construction

It was observed that linear infrastructural developments have taken place in the area as a result of oil and gas operations at Kingfisher. There was a 2.5km extension of infield access roads connecting the main escarpment road to the drilling camps and well pads 1, 2 and 3. The construction started in 2015 and was completed in 2016. In addition, the escarpment road that stretches for about 6.9km to Kingfisher site was constructed. The construction started in 2014 and was completed in 2016. This can be seen in figure 4.9 below

Figure 4. 9: Shows the access road connecting to oil pad 1

4.4.3 Firewood collection

The study also found out that firewood collection in the area was the order of the day. This is due to the fact that many residents were seen in the project area carrying and looking for firewood. This kind of activity fosters vegetation clearing and if not controlled or regulated, it might lead to a reduction in species populations. This is seen in figure 4.10 below

Figure 4.10: Shows firewood collection in Kingfisher development area

4.4.4 Construction of a jetty

The study also observed that the jetty was constructed on the shores of Lake Albert. This was constructed in 2006 as a key access point to Kingfisher development site during exploration drilling. The facility was upgraded in 2014 to accommodate the boats that were the sole means of delivery of heavy construction and drilling supplies at the time. This can be seen in figure 4.11 below

Figure 4. 11: Shows the set-up of a jetty on the shores of Lake Albert

4.4.5 Construction of well pads

Three well pads were constructed namely; pad 1 (KF 1), pad 2 (KF 2) at GPS coordinates 1.24639^{O}N 30.74120^{O}E, 1.25478^{O}N 30.74998^{o}E respectively in Kyabasambu village, and pad 3 (KF 3) at 1.23038^{o} N 30.73165^{O}E in Nsunzu village. These were designed and developed to a standard fit for exploration drilling, with each pad measuring 100 m x 100 m and consisted of one exploration well. Upon completion of the project, the wells were suspended and the well pads partially restored. However, in 2014, well pad 2 was reconstructed to allow for drilling of the Kingfisher 4 appraisal well.

Figure 4. 12: Shows the outward look of well pad 2

CHAPTER FIVE

DISCUSSION OF RESULTS

5.1 Spatial and temporal trends in land use and land cover changes (LULC)

The area and percentage coverage of each land cover class over the years was computed as seen in Tables 4.2 and 4.3. Findings indicate that there has been a decline in the percentage cover of forested area, bushland, farmland, wetlands, and open water. This could have been as a result of rapid construction of linear and hub infrastructure in the region namely; newly constructed roads for instance the escarpment road, material yard, camp sites and the jetty which was built on the shores of Lake Albert as seen in section 4.4. Fishing on Lake Albert has on the other hand attracted increased built-up settlements in the area which has also put more pressure on the available resources leading to encroachment on the sensitive ecosystems.

However, there was an increase in the percentage cover of grassland and built-up areas throughout the years. The increased settlements in the area have led to destruction of forests and other ecosystems like wetlands encouraging the regeneration of grassland land cover type. These increased built-up areas could have been as a result of improved access to social amenities in the region. This is in line with Villa, (2014) who stated that there have been changes in land use to meet the growing needs of the world’s population and these have shifted in the ecological functions of various ecosystems.

The reduction in forested area cover, and bushland is in line with Zedler and Kercher, (2005) who put that the main driver of land use change and vegetation cover loss is the conversion to agriculture, linear and hub infrastructure development, and urbanization.

The decline in the percentage cover of wetland is in line with Davidson, (2014) who stated that clearing for agriculture has been the main cause of wetland loss up to date with an estimation of 26% of the global land area.

The decline in open waters is in line with Margono *et al.,* (2014) who stated that the loss of biological resources reduce the watershed capacity.

The rise in the percentage cover of Built-up areas is an indication that vegetation was cleared to establish both linear and hub infrastructure. This is in line with Watkins *et al.,* (2007) who stated that exurban development or mineral extraction results into footprint of homes, well pads, roads, or mining infrastructure equates to a measurable loss of habitat.

It is as well in line with Laurance *et al*., (2014); Wilkie *et al*., (2000) who put that increased linear construction causes a huge change to land cover due to population influx into such areas with low human population density.

Results are also in line with Douglas *et al.,* (2013) who stated that population influx in an area also results in unplanned and uncontrolled new settlements.

Results are in line with Thomsen *et al.,* (2001); Energy and Biodiversity Initiative, (2003); Suárez *et al.,* (2009) who stated that oil and gas operations are associated with the provision of new access routes to an undeveloped area. This is usually facilitated by the building or upgrading of linear and hub infrastructure, such as roads leading to unplanned settlements. This is evident with field findings as seen in section 4.4.2 showing the escarpment road leading to Kingfisher oil site.

Results are also in line with Petit and Lambin, (2002); MEA, (2005); Ellis and Pontius, (2006) who put that the recent rates, extents and intensities of human pressure on land and its scarce resources is more rapid and extensive than in any comparable period of time.

There is a continued increase in the percentage of grasslands and a reduction in wetland cover, this could probably be as a result of people clearing land for agriculture. This is because in the studied area, there is a group of pastoralists called the Bagungu who largely depend on cattle keeping.

Similar trend of results was obtained from the research carried out by Baker *et al.,* (2007) while studying vegetation cover change specifically wetland change detection using Landsat images.

Results obtained indicate a reduction in forest cover throughout the years. This is in line with NO and EIITO, 2006 who stated that 25 million tons of wood are consumed annually in Uganda, which translates to about 1.1 ton per capita per year thereby reducing the forest cover. This is evident with field findings as seen in section 4.4.3.

More importantly, Powter *et al.*, 2012 puts that decommissioning stage commonly known as the reclamation stage is associated with a wide range of activities for instance replanting of vegetation can at times bring about succession. This has been evident with the introduction of new species which commonly known as invasive species thereby reducing the rate of recovery and as well bringing about extinction of some species. This therefore affects the vegetation structure of the area.

5.2 Vegetation relative abundance

Regarding vegetation abundance, the study conducted showed that there is no significant difference in the relative abundance of various vegetation types in both oil pads and the control areas that were chosen for study. This could have been as a result of plant communities that had regenerated where anthropogenic disruptions took place. For instance in areas where the oil pads were drilled, restoration had been carried out. These results contradict with those of Ebersole *et al.*, 2001 who stated that the process of plant species recovery from anthropogenic disruptions for instance the development of linear and hub infrastructure is always slow and that it might take a very long time to rejuvenate. Research study pointed out that the different vegetation types at the former pads are fully recovering.

However, findings also showed that some plant species were either only in oil pads or the control sites. For instance, oil pads had plant species like Candle bush (*Senna alata*), Coffee *senna (Cassia occidentalis),* and Tick berry (*Lantana camara).* This could be as result of the destruction of the native vegetation and now the invasive species are dominating. Through the process of oil pad construction, the original vegetation is completely removed and soil is highly degraded through removal of the topsoil organic layer, soil horizon mixing and soil compaction. This is in line with Villa *et al.,* (2014) who stated that vegetation cover loss poses a great risk of changing soil quality.

In control areas, there were species of Whistling acacia *(Acacia hokii)* Shellflower *(Pistia stratiotes),* giant sensitive tree *(mimosa pigra), neem (Azadirachta indica), Tamarind (Tamarindus indica),* and Common reed (*Phragmites kirkii*). Most of these species are tree species and this is an indication that there was no disturbance in the area.

In addition, some of the observed and recorded plant species were more significantly abundant in oil pads than control areas and they include; Candle bush (*Senna alata*), giant rat's tail grass S*porobolus pyramidalis),* and Common thatching grass *(Hyparrhenia hirta).* These are species commonly found in disturbed environments. It is therefore an indicator that initially the vegetation was tampered with.

Results also showed that some species were more abundant in control areas than the oil pads and these are; Guinea Rush *(Cyperus articulates),* bulrush *(Typha Capensis),* Candelabra tree *(Euphorbia candelabra),* and African bermuda grass (*Cynodon nlemfuensis)*. Therefore there was higher species diversity in the unaffected areas than the disturbed ones. This could have been as a result of clearing vegetation to pave way for the oil and gas operations that led to destruction of some plant species and these were unable to regenerate. These results are therefore in line with Simmers and Galatowitsch (2010) who put that in some environments most especially the semi-arid environments, habitats that get affected by human influence always show a lower species diversity than the undisturbed ones.

It is noted that most plant species exist in both oil pads and the control areas and these include; couch grass (*Cynodon dactylon)*, giant rat's tail grass (*Sporobolus pyramidalis),* feather finger grass *(Chrolis virgata),* African *asparagus* (*Asparagus flagellaris), Aloe lateritia*, Guinea rush *(Cyperus articulates),* Barbados nut *(Jatropha curcas),* jelly bean tree *(Parkinsonia aculeate)*, star grass *(Cynodon nlemfuensis), rat's tail grass (Sporobolus robustatus), Aloe lateritia,* thorn apple *(Solanum incanum),feathery rhodes grass (Chloris pycnothrix),* love grass *(Eragrostis congesta),* love grass *(Eragrostis namaquensis),* silk tree *(Albizia),* Common thatching grass *(Hyparrhenia hirta),* Creeping woodsorrel *(Oxalis corniculata),* Garden pink-sorrel (*Oxalis latifolia),* Nut grass *(Cyperus rotundus)* and many more. It therefore means that the presence of these plant species in oil pads is evident enough that the effect on plant diversity did not take a long period of time since much of the vegetation has gone back to its original state. This shows that vegetation has not been fully altered which contradicts with Lee *et al*. (2013); Northrup and Wittemyer, 2013; Ericson, 2014 that pointed out that species diversity may reduce due to hub and linear infrastructure development. It also contradicts with Kumpula *et al*. (2011) who mentioned that oil and gas exploration has negative impacts on vegetation which is a source of plant species diversity. In addition, it is not in line with Mulondo *et al.*, 2011 who pointed out that oil and gas exploration and development leads to a reduction in vegetation cover. The results got from the study contradict with those of UNEP, 1997; Joint E&P forum (1997) who stated that oil and gas exploration has well known impacts on vegetation.

The fact that the vegetation diversity in oil pads is similar to that in control areas is a good indicator that the habitats for bird species were/are not affected by oil and gas exploration which is different from Ochieng *et al.,* 2019 who stated that oil exploration leads to loss of habitats in the oil pads.

However, the presence of some species in the control areas and not in the oil pads regardless of the similar environmental conditions is an indicator of habitat change. This is in line with Sandifer *et al*., 2015 who stated that plant diversity is globally threatened by anthropogenic ecosystem degradation and land use. It is also in line with Sala *et al.,* 2000 who stated that land use directly changes ecosystems through modifications, fragmentation and intensification.

The presence of plant species namely; *Mimosa pigra* (Giant Sensitive Tree), *Lantana camara* (Lantana), Castor oil (*Ricinus communis*), Neem (*Azadirachta indiza1ca*), Jatropha (*Jatropha curcas*), and Parkinsonia (*Parkinsonia* sp.) which are known to be invasive species in the area is an indicator of vegetation destruction. This is in line with Rai, (2015) who stated that alien species introduction has been continuing at an alarming pace due to anthropogenic influence. It is as well in line with Kolb *et al.,* 2002 who reported that there are many factors that bring about invasion such as disturbance, and habitat fragmentation.

The presence of some plant species namely; ***Milica excelsa*** indicates that Kingfisher development area is a biodiversity hotspot and still harbours species of conservation importance as stated by (Kityo, 2011; NO and EIITO, 2006; Plumptre e*t al.,* 2003). This specie is as well indicated on the Red List of trees of conservation concern worldwide as stated by (IUCN, 1994). However, this is contrary to Trombulak and Frissell, 2000 who stated that the access roads and traffic may be reduce or even eliminate plant species of conservation importance in a given place.

The presence of plant species such as Common thatching grass (*Hyparrhenia hirta) a well-known grass specie and, Albizia spp* well known tree species is an indicator that Kingfisher development site is still well known to be a center of biodiversity. This is in agreement with the results in the Environmental Project Brief Report, 2018 which also pointed out the presence of the above mentioned species in that area.

The presence of some plant species in oil sites than control areas are an indicator that these areas/habitats have not been affected by oil and gas exploration. This brings about controversial issues with Edwards *et al*. (2014) who noted that infrastructural establishments both hub and linear infrastructure diminishes the functioning capacity of the habitats more especially the natural ones. The study showed no significant difference of plant diversity in oil pads and control areas. This is contrary to Thomsen *et al.,* 2001; Ko and Day, 2004 who stated that oil and gas activities may have a negative impact on vegetation. It should be noted that the study measured vegetation relative abundance and did not look at the relative frequency of the observed plant species.

5.3 Bird abundance

The study revealed that there is no significant difference between the bird species observed in both oil pads and the control areas. This therefore shows that vegetation was not fully altered by the oil and gas exploration activities and can still act as a habitat to most bird species. In addition, the presence of bird species in the oil pads could be an indicator that these species have been able to return to their original habitats and are enjoying similar environmental conditions as they were before since restoration was carried out and vegetation is regenerating. This is in line with Lal, (2008) who stated that the restoration of degraded ecosystems for instance wetlands and maintenance of the existing ones may help in overcoming the challenges of species loss and extinction. It is however, not in line with Pelletier *et al.*, 2007 who stated that habitats are always hard to replace after oil and gas developments. This is as well not in line with Bankole and Owoseni, 2010 who stated that loud and excessive noise resulting from drilling activities has also been reported to adversely affect biodiversity. It is in addition contrary to Nwilo, 2005 who pointed out that increasing instability condition of soil, landscape destruction, irradiation hazards and the extensive destruction of vegetation for access is a serious threat to avifauna and flora.

The presence of bird species in the study area is an indicator of habitat restoration. This is not in line with Burkert *et al.*, (2004) who stated that any change in the physical, chemical and biological factors in the catchment and other ecosystems exert severe impact on bird species numbers and distribution.

The presence of bird species namely; Grey heron (*Ardea cinerea),* Grey-crowned crane (*Balearica regulorum)* is a good indicator that Masika and Kamasing wetlands found in the study area still perform the role of supporting. This is in line with Satish *et al.,* (2013) who stated that birds use wetlands for breeding, nesting and teaching young, as a source of drinking water, for feeding, resting, shelter and for social interaction.

It is as well in line with Stewart, (2001) who stated that birds have daily and seasonal dependence on wetlands for food and other life supporting systems. It is as well in line with Olupot and Plumptre, (2006) who put that cranes most often use wetland edges for nesting.

The presence of a few number of bird species to be specific, the grey crowned crane (*Balearica regulorum)* is an indicator that noise levels resulting from drilling and other exploration activities could have altered their behavior and altered their breeding patterns. This is in line with Blickley and Patricelli, (2010) who stated that noise from human activities such as traffic or industrial noise is more disastrous than the natural one because of occurring more often and this is said to have a huge impact on bird species diversity.

It is also in with EACOP Project Report, (2018) which noted the extension of well pad 1 through Masika wetland may lead to habitat loss for most species.

The presence of vegetation diversity in both oil pads and control areas is a good indicator that the habitats for birds were/are not affected by oil and gas exploration activities or have fully recovered from disturbance which is contrary to Ochieng *et al.,* (2019) who stated that oil exploration leads to loss of habitats in the oil pads. In addition, this also does not agree with Northrup and Wittemyer, (2013) who stated that development impacts on biodiversity may be harmful as a result of pollution, removal of vegetation for roads and oil pads, and shelter habits.

The presence of grey crowned crane (*Balearica regulorum)* is an indicator that Kingfisher development area is a center for biodiversity of conservation importance. This is in line EACOP Project Report, (2018); Carswell *et al.,* (2005); Kityo, (2011); Plumptre *et al.,* (2003); Byaruhanga *et al.*, (2001); International Council for Bird Preservation, (1992); Conservation International, (2011); BirdLife International, (2010); and NO and EIITO, (2006) who stated that Albertine region is a centre for biodiversity of conservation importance. In addition, it is in line with Beilfuss *et al.,* (2007) who stated that this species is recognized as Uganda's national bird and Bird Life International, (2009) who put that its conservation status is currently listed as vulnerable globally.

The observation of a few bird species within the radius of 500m from the oil pad is an indicator of disturbance from the oil operations. This is therefore in line with Burkert *et al.,* (2004); Watkins *et al.,* (2007); Harju *et al.,* (2010); Lyon and Anderson, (2003), Holloran (2005) who stated that birds tend to avoid some habitats as the density of roads, power lines, or energy development increases.

Most bird species encountered in the study namely; Sand plover (*Charadrius mongolus),* Common ringed plover (*Charadrius hiaticula),* Kittlitz plover (*Charadrius pecuarius),* Piapiac (*Ptilostomus afer) to mention but a few* were typically of less conservation importance. This is line with Douglas *et al.*, 2013 who stated that most species found in the Albertine region are typically not of conservation importance.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Results got from Remote Sensing and Geographical Information Systems showed a slight change in the spatial and temporal variations in land use and land cover changes throughout the years.

It was found out that a lot of activities take place in the area namely; cattle rearing among the Bagungu people, massive firewood collection and population influx due to fishing activity on the shores of Lake Albert, West of Kingfisher Development Area and then the oil and gas operations as seen in section 4.4.

Results showed that oil and gas exploration in Kingfisher has a non-significant difference on vegetation relative abundance in both oil pads and the control areas.

The study pointed out species of conservation concern for instance African teak (*Milica excelsa*) a tree species, also referred to as a "sacred" tree in the community and serves a number of functions. This specie is listed on the Red List of trees. It therefore deserves conservation priority.

The study noted the presence of invasive species namely; *Mimosa pigra* (Giant Sensitive Tree), *Lantana camara* (Lantana), Castor oil (*Ricinus communis*), Neem (*Azadirachta indiza1ca*), Jatropha (*Jatropha curcas*), and Parkinsonia (*Parkinsonia* sp.) an indicator of vegetation destruction.

Results also revealed that there is no significant difference in bird abundance between the oil pads and control areas.

The study also found out that some bird species encountered are on the National and IUCN List of species of conservation concern. They included; White backed vulture (*Gyps africanus),* Saddle billed stork (*Ephippiorhynchus senegalensis) and* the Grey crowned crane (*Balearica regulorum).*

The study also noted a few numbers of Grey Crowned Crane (*Balearica regulorum)* also known as a "national bird" for Uganda near Masika wetland. This specie prefers this type of vegetation for their habituary.

6.2 Recommendations

Restoration should be carried out with immediate effect when activities are done to allow fast growth of vegetation in the area.

The extension of well pad 1 through Masika wetland should not implemented to protect and conserve the avifauna that use it as habitat and as well a breeding place more especially the Grey Crowned Crane (*Balearica regulorum).*

Cattle rearing should not be allowed near the drilled oil pads to enable fast growth of the plant communities in that area.

Ex-situ conservation strategies should be adopted. This will help in the protection of species like White backed vulture (*Gyps africanus),* Saddle billed stork (*Ephippiorhynchus senegalensis) and* the Grey crowned crane (*Balearica regulorum)* that are categorized as endangered species

Heavy traffic associated with oil and gas exploration should be regulated in order to protect biodiversity from extinction.

The government of Uganda through the Ministry of Water and Environment should take keen interest in ensuring that vulnerable and endangered species are protected in case they are found in areas where oil and gas exploration and development is to take place. This is because more discoveries are still ongoing and there is a likelihood that such species can be affected. This can be through in-situ or ex-situ conservation strategies.

NEMA should put in place measures for guarding the protection of the vegetation cover with much consideration given to threatened plant species existing in the vicinity of oil and gas exploration operations that are on the verge of getting extinct.

MEMD and NEMA should ensure that oil companies and other stakeholders follow the guidelines put in their ESIA reports and project briefs.

Landscape analysis should always be considered first as it helps in identifying fragmentation and other agents of change in a given area and this should be an integral part of any biodiversity action plan in the oil and gas industry.

The polluter-pays-principle should also be part of any biodiversity action plan. Oil and gas companies operating in the Albertine region MUST clean-up areas polluted as a result of their operations.

NEMA should impose pollution and damage standards as a MUST to oil production and in a manner that reflects the Albertine region to assimilative and self-restoration capacities.

The biodiversity action plan should demonstrate corporate social and environmental responsibility by providing for a biodiversity fund. Together with a pre-determined portion of the government revenues from oil, oil companies should be encouraged to contribute part of their profits to a biodiversity or environment fund.

NEMA and UWA should be expected to conduct interim and long-term monitoring of biodiversity impacts of oil and gas exploration and production as part of their mandate.

The researcher also recommends use of other methods of data collection to establish if there are differences or similarities in the results obtained and embed other oil and gas operations other that drilling of pads.

The oil and gas companies should adopt other options of drilling rather than making the big placards which may destroy big chunks of vegetation. This may eventually affect bird population abundance and distribution.

REFERENCES

Abbott M. R. (2003). Strategic Plan for the Climate Change Science Program Final Report. A Report by the Climate Change Science Program and the Subcommittee on Global Change Research.

Abebe Y.D. and Kim, G. (2003). Wetlands of Ethiopia. Proceedings of a seminar on the resources and status of Ethiopia's wetlands

Ardakani, M. R. (2004). Ecology. Tehran University Press, 340

African Development Bank. (2014). African Development Bank group strategy for addressing fragility and building resilience in Africa. Abidjan, Cˆote d’Ivoire: African Development Bank Group. Available athttp://www.afdb.org/fileadmin/uploads/afdb/Documents/Policy-Documents/Addressing_Fragility_and_Building_Resilience_in_Africa_The_AfDB_Group_Strategy_2014%E2%80%932019.pdf. Accessed November 12, 2015.

Agarwal, C., Glen, M., Green, J., Morgan, G., Tom, P., Evans, Charles, M., Schweik (2000). A Review and Assessment of Land Use Change Models dynamics of space, time, and human choice. CIPEC Collaborative Report Series No. 1

Alemagi, D., (2007). The Oil Industry along the Atlantic Coast of Cameroon: Assessing Impacts and Possible Solutions. *Resources Policy,* 32**,** 135-145.

Allen, J., Kang, S., Thomas, D. (1999). A GIS- based analysis and prediction of parcel land use change in a coastal tourism destination area. Presented at the 1999 World Congress on Coastal and Marine Tourism Vancouver, British Columbia, Canada.

Anderson, J.R. (1976). A land use and land cover classification system for use with remote sensor data, vol 964. US Government Printing Office, Washington, DC

Andren, H. (1994). Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. *Oikos*, 355-366.

Anil, N., Sankar, G., Rao, M., and Sailaja, U. (2011). Studies on land use/cover and change detection from parts of South West Godavari District, AP—using remote sensing and GIS techniques. J Ind Geophys Union 15(4):187–194

Annan, K. (2012). Momentum rises to lift Africa's resource curse. *New York Times*, 14.

Auditor-General report, (2014): Waste Management for oil and gas in the Albertine Graben *www.oag.go.ug › uploads › 2016/07 › NEMA-waste-Management-final*

Ayele A. T. (2017). Land use and land cover change detection analysis using Remote sensing techniques: the case of Hawassa Town, Southern Ethiopia. Msc. Thesis

Baker, C., Rick, L., Clifford, M., Duncan, P. (2007). Change detection of wetland ecosystems using Landsat imagery and change vector analysis

Bakhtyar, S., and Gagnon, M. (2012). Toxicity assessment of individual ingredients of synthetic-based drilling muds (SBMs). *Environ. Monit. Assess.* 184, 5311–5325. doi: 10.1007/s10661-011-2342

Balogun, A.A., Balogun, I.A., Adefisan, A., Abatan, A. (2009). Observed characteristics of the urban heat island during the harmattan and monsoon in Akure, Nigeria. http://ams.confex.com/ams/pdfpapers/152809.pdf

Balmford, A., Green, E., and Jenkins, M. (2003). Measuring the Change State of Nature. *Trends in Ecology and Evolution,* 18**,** 326 - 30.

Bankole and Owoseni, (2010). The environmental effects of indiscriminate disposal of waste in Akuremetropolis of Ondo State, Nigeria, Proceeding of the forth African Regional Conference on Sustainable Development

Baptiste, A., and Nordenstam, B. (2009). Impact of oil and gas drilling in Trinidad: factors influencing environmental attitudes and behaviours within three rural wetland communities. Environmental Conservation. Pp 1-8.

Bartholomé, E., Belward, A. (2005). A new approach to global land cover mapping from Earth observation data. Int. J. Remote Sensing, 26(9): 1959-1977.

Bayne, E., Habib, L., and Boutin, S. (2008). Impacts of chronic anthropogenic noise from energy-sector activity on abundance of songbirds in the boreal forest. Conservation Biology 22:1186-1193.

Bayne, E., and Dale, B. (2011). Effects of energy development on songbirds. Energy development and wildlife conservation in western North America. Island Press, Washington, D.C., USA Pages 95-114.

Bee, M., and Swanson, E. (2007). Auditory masking of anuran advertisement calls by road traffic noise. *Animal Behavior*, 74, 1765–1776. https://doi.org/10.1016/j.anbehav.

Begon,1990. Ecological Approaches to Biodiversity consrvation *https://www.google.com/search?q=cormas.cirad.fr+%E2%80%BA+demarch+%E2%80*

%BA+ecologi&oq=cormas.cirad.fr+%E2%80%BA+demarch+%E2%80%BA+ecologi&aqs=chrome..69i57j33l4.793j0j9&sourceid=chrome&ie=UTF-8

Beilfuss, R., Dodman, T., and Urban, E., (2007). The status of cranes in Africa in 2005. Ostrich, 78(2): 175-184

Benítez-López, A., Alkemade, R., and Verweij, P. (2010): The impacts of roads and other infrastructure on mammal and bird populations: a meta-analysis. *Biological conservation*, *143*(6), 1307-1316. *journal homepage: www.elsevier.com/locate/biocon*

Bergquist, E., Evangelista, P., Stohlgren, T., and Alley, N. (2007). Invasive species and coal bed methane development in the Powder River Basin, Wyoming. Environmental Monitoring and Assessment 128:381-394.

Bernal, B., and Mitsch, W. (2012). Comparing carbon sequestration in temperate fresh water wetland communities. Global Change Biology: doi: 10.1111/j.1365-2486.2011.02619

Bibby, C. J., Burgess, N. D., Hill, D. A. and Mustoe, S. H. (2000). *Bird Census Techniques*, Second Edition, London: Academic Press

Binford, M., Barnes, G., Dewitt, B., Gholz, H., and Smith, S. (2000). Land-Use and Land Cover Change: Decadal-Scale Dynamics of Carbon Storage Patterns as a Function of Land Ownership in the Southeastern Lower Coastal Plain Region of the U.S. Proposal submitted to NASA.

BirdLife International (2004). *State of the World's Birds,* Cambridge, BirdLife International.

BirdLife International (2009). Species factsheet: Balearica regulorum. Downloaded from http://www.birdlife.org

Blickley, J. L., and Patricelli, G. L. (2010). Impacts of anthropogenic noise on wildlife. Research priorities for the development of standards and mitigation. *Journal of International Wildlife Law and Policy*, 13(4), 274-292.1

Blumstein, D. T., Laura, A.L., Harcourt, R., and Ross, G. (2003). Testing a key assumption of wildlife buffer zones: is flight initiation distance a species-specific trait. Biological Conservation, 110(1), 97-100.

Bollinger, E. K., Bollinger, P. B., and Gavin, T. A. (1990). Effects of hay-cropping on eastern populations of the bobolink. Wildlife Society Bulletin 18:142-150.

Borasin, S., Foster, S., Jobarteh, K., Link, N., Miranda, J., Pomeranse, E., and Somaia, P. (2002). *Oil: A life cycle analysis of its health and environmental impacts*. Retrieved from https://www.fraw.org.uk/library/toxics/epstein_2006.pdf

Breuer, E., Stevenson, A. G., Howe, J. A., Carroll, J., and Shimmield, G. B. (2004). Drill cutting accumulations in the Northern and Central North Sea: a review of environmental interactions and chemical fate. *Mar. Pollut. Bull.* 48, 12–25. doi: 10.1016/j.marpolbul.2003.08.009

Bringezu, S., Schütz, H., Pengue, W., O'Brien, M., Garcia, F., Sims, R., Howarth, L., Swilling, M., Herrick, J. (2014) Assessing global land use: balancing consumption with sustainable supply. United Nations Environment Programme

Brooks, T. M., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., Rylands, A. B., Konstant, W. R., and Hilton-Taylor, C. (2002). Habitat loss and extinction in the hotspots of biodiversity. *Conservation biology*, 16(4), 909-923.

Brown, S., and Lugo, E. (1982). The storage and production of organic matter in tropical forests and their role in the global carbon cycle. BIOTROPICA (14) 3:161-187

Brumm, H. (2004). The impact of environmental noise on song amplitude in a territorial bird. *Journal of Animal Ecology*, 73, 434–440. https://doi.org/10.1111/j.0021-8790.2004.00814.

Burgess, R.L. and Sharpe, D.M. (1981). Forest island dynamics in man dominated landscapes. Springer-Verlag, New York.

Burkert, U, G. Ginzel, H. D. Babenzien and R. Koschel. (2004).The hydrogeology of a catchment area and an artificially divided dystrophic lake - consequences for the limnology of Lake Fuchskuhle. Biogeochemistry 71: 225-246.

Butchart, S.H.M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M.,

Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Morcillo, M.H., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., 1Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vié, J.-C. and Watson, R. (2010). Global Biodiversity: Indicators of Recent Declines. *Science*, 328**,** 1164-1168.

Byaruhanga, A., Kasoma, P.M.B. and Pomeroy, D. (2001). *Important Bird Areas in Uganda*, Kampala, the East African Natural History Society.

Carswell, M., Pomeroy, D., Reynolds, J. and Tushabe, H. (2005). *The Bird Atlas of Uganda*, London: British Ornithologists' Club and British Ornithologists' Union.

Carter, S.A. (2008). Mining and Conservation. *Africa Analyst,* 3**,** 1-17.

Clayton (2011). Gas hydrate occurrences. Andaman offshore

Copeland, H. E., Doherty, K. E., Naugle, D. E., Pocewicz, A., and Kiesecker, J. M. (2009). Mapping oil and gas development potential in the US Intermountain West and estimating impacts to species. http://www.plosone.org/article/comments/info%3adoi%2f10.1371%2fjournal.pone.0007400;jsessionid=2a056db3d4118265156223ac6930af8c

Conservation International (2011). *Biodiversity Hotspots: Eastern Afromontane.* Available at:

http://www.biodiversityhotspots.org/xp/hotspots/afromontane/pages/default.aspx#indept

Costanza *et al.*, (2014b) Twenty years of ecosystem services: How far have we come and how far do we still need to go? *https://www.robertcostanza.com › wp-content › uploads › 2017/02 › 2017.*

Cox, G. (1990). Laboratory manual of general ecology 6th Ed. *Dubuque, Iowa*: William C. Brown.

Cui, B., Zhao, S., Zhang, K., Li, S., Dong, S., and Bai, J. (2009). Disturbance of Dabao highway construction on plant species and soil nutrients in Longitudinal Range Gorge Region (LRGR) of Southwestern China. *Environmental monitoring and assessment*, 158(1-4), 545.

Currie, D. R., and Isaacs, L. R. (2005). Impact of exploratory offshore drilling on benthic communities in the Minerva gas field, Port Campbell, Australia. *Mar. Environ. Res.* 59, 217–233 doi: 10.1016/j.marenvres.2004.05.001

Dara *et al.,* (2003). Potential risks and impacts of oil and gas development in. and around protected areas. *www.uws.or.ug › wp-content › uploads › Oil_Document3*

Davidson, N. C. (2014). How much wetland has the world lost? Long-term and recent trends in global wetland area. Marine and Freshwater Research, 65(10), 934-941. http://dx.doi.org/10.1071/MF14173

DeFries, Foley and Asner. (2004). Land-Use Choices: Balancing Human Needs and Ecosystem Function. Frontiers in Ecology and the Environment, 2, 249-257. https://www.scirp.org/(S(lz5mqp453edsnp55rrgjct55))/reference/ReferencesPapers.aspx?ReferenceID=1892816

Desai, M. and Shanbhag, A. (2007). Birds breeding in unmanaged Monoculture plantations in Goa, India. Indian Forester 133:1367- 1372

Dingle, H., and Drake, V. A. (2007). What is migration? *Bioscience*, 57(2), 113-121.

Dodd Jr, C., Smith, L. (2003). Habitat Destruction and Alteration. Historical Trends and Future Prospects for Amphibians

Douglas, I., Alam, K., Maghenda, M., Mcdonnell, Y., Mclean, L. and Campbell, J. (2008), “Unjust waters: climate change, flooding and the urban poor in Africa”, *Environmental Urbanization* Vol 20, No 1, pages 187–205.

Dyer, J.S., O'Neill, J.P., Shawn, M.W. and Boutin, S. (2001). Avoidance of Industrial Development by Woodland Caribou. *Journal of Wildlife Management,* 65**,** 531-542.

Dyer, S. J., O'Neill, J. P., Wasel, S. M., & Boutin, S. (2002). Quantifying barrier effects of roads and seismic lines on movements of female woodland caribou in northeastern Alberta. *Canadian Journal of Zoology*, 80, 839–845. https://doi.org/10.1139/z02-060

EACOP Project (2018). Section 6: Environmental and Social Baseline Conditions Uganda *https://nema.go.ug/sites/all/themes/nema/docs/ESIA_NTS_Tilenga_ESIA_13-09-18.pdf*

Ebersole, J. J., Forbes, B. C., and Strandberg, B. (2001). Anthropogenic disturbance and patch dynamics in circumpolar arctic ecosystems. *Conservation Biology*, 15(4), 954-969.

Edwards, D. P., Sloan, S., Weng, L., Dirks, P., Sayer, J., and Laurance, W. F. (2014). Mining and the African Environment. *Conservation Letters*, 7, 302-311.

EIA (2007). *Annual Energy Outlook with Projections to 2030,* Washington, Energy Information Administration.

Ekpubeni, F.A. and Ekundayo, O.E. (2002). Effects of Exposure of Crocodiles to Sub-Lethal Concentration of Petroleum Waste Drilling Fluid in the Niger Delta Basin of Midwestern

Nigeria *Environmental Monitoring and Assessment* 76**,** 291-298.

Ellis, E. and Pontius, R.G. Jr. (2006) Land-use and land-cover change encyclopedia of earth. Environ Protect 2:142–153

Energy and Biodiversity Initiative (2003). *Integrating Biodiversity Conservation into Oil and Gas Development*, Washington, Energy and Biodiversity Initiative, Conservation International.

Environmental Project Brief, (2018): Environmental project brief of feeder line supplementary geotechnical and geophysical survey and geohazard assessment. *report no. AWE/CNOOC/GGPB/2018*

Epstein, P. R., and Selber, J. (2002). Oil: A life cycle analysis of its health and environmental impacts. The Center for Health and the Global Environment. Harvard Medical School, Boston.

Ericson, K, (2014). "A Crude Awakening: The Relationship between Petroleum Exploration and Environmental Conservation in Western Uganda". *Independent Study Project (ISP) Collection.*1924.

Etefa, G., Frankl, A., Lanckriet, S., Biadgilgn, D., Gebreyohannes, Z., Amanuel, Z., and Nyssen, J. (2018) Changes in land use/cover mapped over 80 years in the highlands of northern Ethiopia. J GeogrSci 28(10):1538–1563. https ://doi.org/10.1007/s1144 2-018-1560-3

Exploration and Production Forum (1997). *Environmental Management in Oil and Gas Exploration and Production: An Overview of Issues and Management Appproaches,* London, Joint E&P Forum/UNEP Technical Publication.

FAO (2005). Land Cover Classification System. Classification concepts and user manual. Environmental management assessment and monitoring global environmental change.

FAO (2011). Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture. Rome. http://www.fao.org/docrep/015/i2624e/i2624e00.pdf

Festus, W. (2016). Relationship between oil exploration activities and land conflicts in Hoima district, Uganda: a case study of Buseruka subcounty Masters' thesis https://utamu.ac.ug/docs/research/studentresearch/masters/proposals

Finer, M., Jenkins, C. N., Pimm, S. L., Keane, B., and Ross, C. (2008). Oil and gas projects in the western Amazon: threats to wilderness, biodiversity, and indigenous peoples. PloS one, 3(8).

Frynas, J. G., and Paulo, M. (2007). A new scramble for African oil? Historical, political, and business perspectives. *African affairs*, 106(423), 229-251.

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., and Gibbs, H. K. (2005): Global consequences of land use. science, 309(5734), 570-574. *www.scirp.org › reference › ReferencesPapers*

Gagnon, M. M., and Bakhtyar, S. (2013). Induction of fish biomarkers by synthetic-based drilling muds. *PLoS ONE* 8:e69489. doi: 10.1371/journal.pone.0069489

Gates, A. R., and Jones, D. O. B. (2012). Recovery of benthic megafauna from anthropogenic disturbance at a hydrocarbon drilling well (380 m Depth in the Norwegian Sea). *PLoS ONE* 7:e44114. doi: 10.1371/journal.pone.0044114

Gavin, S. D., and Komers, P. E. (2006). Do pronghorn (*Antilocapra americana*) perceive roads as a predation risk? *Canadian Journal of Zoology*, 84, 1775–1780. https://doi.org/10.1139/z06-175

Geist, H.J. and Lambin, E.F. (2001) what drives tropical deforestation? A meta-analysis of proximate and underlying causes of deforestation based on subnational case study evidence. LUCC Report Series No. 4. University of Louvain, Louvain-la-Nueve

Gelbard, J. L., and J. Belnap. (2003). Roads as conduits for exotic plant invasions in a semiarid landscape. Conservation Biology 17:420-432.

Gelbard, J. L., and S. Harrison. (2003). Roadless habitats as refuges for native grasslands: interactions with soil, aspect, and grazing. Ecological Applications 13:404-415.

Geldmann, J., Joppa, L. N., and Burgess, N. D. (2014). Mapping change in human pressure globally on land and within protected areas. *Conservation Biology*, **28**, 1604–1616. https://doi.org/10.1111/cobi.12332

Gill, J. A., Norris, K., and Sutherland, W. J. (2001). Why behavioral responses may not reflect the population consequences of human disturbance. *Biological Conservation*, 97(2), 265-268.

Golombok, R., Jones, M. I. (2015). Oil Governance in Uganda and Kenya: A review of efforts to establish baseline indicators on the impact of the oil sector in Uganda and Kenya. UNEP, Nairobi, Kenya

Government of Uganda (2013). *Strategic Environmental Assessment (SEA) of Oil and Gas Activities in the Albertine Graben,* Kampala, Ministry of Energy and Mineral Development.

Gray, J. S., Clarke, A. J., Warwick, R. M., and Hobbs, G. (1990). Detection of initial effects of pollution on marine benthos: an example from the Ekofisk and Eldfisk oilfields, North Sea. *Mar. Ecol. Prog. Ser.* 66, 285–299. doi: 10.3354/meps066285

Greig-Smith, P. (1983). *Quantitative plant ecology* (Vol. 9). Univ of California Press.

Greenway, P. J. (1973): A classification of the vegetation of East Africa. *Kirkia*, *9*(1), 1-68. *https://books.google.co.ug › books*

Grover, V.L. (1983). *The Reduction of Wildlife Mortality in the Sump Pits of Southeast New Mexico* Carlsbad, New Mexico, USA, Bureau of Land Management.

Habib, L., Bayne, E.M., and Boutin, S. (2007). Chronic industrial noise affects pairing success and age structure of ovenbirds *Seiurus aurocapilla*. Journal of Applied Ecology, 44, 176-184. https://doi.org/10.111/j.1365-2664.2006.01234.

Haines, M., Young, R., Fish, R. and Turner, R.K. (2011): Handbook of Ecosystem Services. *https://cices.eu › 2017/12 › 3_Potschin_RHY_2016_Defining-ES_CICES*

Hamilton, A. (1981). A Field Guide to Ugandan Forest Trees

Hansen, M., Stehman, S., Potapov, P., Arunarwati, B., Stolle, F., and Pittman, K. (2009). Quantifying changes in the rates of forest clearing in Indonesia from 1990 to 2005 using remotely sensed data sets. Environmental Research Letters, 4, 034001, doi:10.1088/1748-9326/4/3/034001.

Harju, S. M., Dzialak, M. R., Taylor, R. C., Hayden-Wing, L. D., and Winstead, J. B. (2010). Thresholds and time lags in effects of energy development on greater sage grouse populations. Journal of Wildlife Management 74:437-448.

Harfoot, M. B., Tittensor, D. P., Knight, S., Arnell, A. P., Blyth, S., Brooks, S., and Scharlemann, J. P. (2018). Present and future biodiversity risks from fossil fuel exploitation. *Conservation Letters*, 11(4), e12448.

Havard Devold, (2013). Oil and gas production handbook. An introduction to oil and gas production, transport, refining and petro-chemical industry. *https://library.e.abb.com/public/34d5b70e18f7d6c8c1257be500438ac3/Oil%20and%20gas%20production%20handbook%20ed3x0_web.pdf.* Accessed on 22/2/2019

Herold M., Keith C., Joseph S., (2005) The Use of Remote Sensing and Landscape Metrics to Describe Structures and Changes in Urban Land Uses

Holloran, M. J. (2005). Greater sage-grouse (Centrocercusurophasianus) population response to gas field development in western Wyoming. Dissertation, University of Wyoming, Laramie, USA.

Holodny, E. (2015). The 13 fastest-growing economies in the world. *Business Insider* UK.

Hyne, J.N. (2001). *Non Technical Guide to Petroleum Geology, Exploration, Drilling, and Production*, Tulsa, Oklahoma, PennWell Corporation.

International Council for Bird Preservation (1992). *Putting Biodiversity on the Map: Global Priorities for Conservation*, Cambridge, International Council for Bird Preservation.

IPCC, (2007). The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the intergovermental panel on climate change. Solomon S, Qin D, Manning M, Chen Z, Marquis M et al. Eds. Cambrige, UK.

Isango, J. (2001). A Partially Annotated Bibliography of Biodiversity Studies in the Eastern Arc Mountains

IUCN (1994). IUCN Red List Categories. Gland, Switzerland: International Union for the Conservation of Nature, Species Survival Commission.

Jacob, D. J. and Winner, D.A (2009). “Effect of Climate Change on Air Quality,” Atmospheric Environment 43, no. 1 (January 2009): 51–63, doi:10.1016/j.atmosenv.2008.09.051

Jane, M. (2003). Spatial Analyses of Logging Impacts in Amazonia Using Remotely Sensed Data. Photogrammetric Engineering and Remote Sensing, 69(3), pp. 275-282

Janneh, A., and Ping, J. (2012). Africa as a pole of global growth. *Economic Commission for Africa and African Union Commission*: Addis Ababa.

Jenkins, M., Green, E.R. and Madden, J. (2003). The Challenge of Measuring Global Change in Wild Nature: Are Things Getting Better or Worse? *Conservation Biology*, 17**,** 1-4.

Jensen, J.R. (1996). Introductory Digital Image Processing (Second Edition)

Jensen, J. R., (2005). Introductory Digital Image Processing: A Remote Sensing Perspective. Upper Saddle River: Prentice-Hall

Johnson, L. (2007). Assessing the impacts of energy developments and developing appropriate mitigation in the Uganda portion of the Albertine Rift. *Wildlife Conservation Society and Uganda Wildlife Authority*, Kampala, Uganda.

Joint E&P forum, (1997). Relationship between oil exploration activities and land conflicts in Hoima district, Uganda: a case study of buseruka sub-county. *https://utamu.ac.ug › research › studentresearch › masters › dissertations page 12*

Jones, M.B., and Humphries, S.W. (2002). Impacts of the C4 sedge *Cyperus papyrus L*. on carbon and water fluxes in an African wetland. Hydrobiologia 488:107-113

Kagolo, F. (2014). Government adopts friendlier oil drilling method. Kampala, Uganda: New Vision.

Kamara, E. D., Nina, P. M., and Ochieng, L. A. (2019). Effects of Oil and Gas Exploration in Murchison Falls National Park on Wildlife Resources. *African Journal of Environment and Natural Science Research*, 2(2), 48-57.

Kaweesi, E. (2014): Environmental Law Compliance and its Implications for Oil and Gas Exploration and Production in Uganda.

https://www.academia.edu/12503318/Environmental_Law_Compliance_and_its_implications_for_Oil_and_Gas_exploration_and_production_in_Uganda

Keith, D. and Gorrod, E. (2006). The meanings of vegetation condition. Ecological Management and Restoration 7(S1): S7-S9.

Kityo. M. R (2011). The effects of oil and gas exploration in the Albertine Rift region on biodiversity. A case of protected areas (Murchison Falls National Park) *www.natureuganda.org › downloads › Oil and Gas in the AR*

Klenner, W., Arsenault, A., Brockerhoff, E.G., and Vyse, A. (2009) Biodiversity in forest ecosystems and landscapes: a conference to discuss future directions in biodiversity management for sustainable forestry. For Ecol Manag 258: S1–S4

Kolowski, J.M. and Alonso, A. (2010). Density and Activity Patterns of Ocelots (*Leopardus Pardalis*) in Northern Peru and the Impact of Oil Exploration Activities. *Biological Conservation,* 143**,** 917-925.

Ko, J.Y. and Day, J.W. (2004). A Review of Ecological Impacts of Oil and Gas Development on Coastal Ecosystems in the Mississippi Delta. *Ocean and Coastal Management,* 47**,** 597623.

Kolb, A., Alpert, P., Enters, D., and Holzapfel, C. (2002). Patterns of invasion within a grassland community. *Journal of Ecology*, *90*(5), 871-881.

Kumpula, T., Pajunen, A., Kaarlejärvi, E., Forbes, B. C., and Stammler, F. (2011). Land use and land cover change in Arctic Russia: Ecological and social implications of industrial development. *Global Environmental Change*, 21(2), 550-562.

Lacher Jr, T., and Byakagaba, P. (2016): Oil, gas, wildlife, and communities: Capacity building to mitigate conflict in Uganda. *https://oaktrust.library.tamu.edu › handle*

Lagos, N. A, Paolini, P., Jaramillo, E., Lovengreen, C., Duarte, C. and Contreras, H. (2008). Environmental processes, water quality degradation, and decline of waterbird populations in the Rio cruces wetland, Chile. Wetlands 28: 938–950

Lal, R. (2008). Carbon sequestration. Phil. Trans. *R. Soc. B* 363,815-830 doi:10.1098/rstb.2007.2185

Lambin, E., Geist, H., and Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. Annu Rev Environ Resour 28:205–241

Lambin, E, and Meyfroidt, P. (2011). Global land use change, economic globalization, and the looming land scarcity. Proc Natl Acad Sci 108:3465–3472. https ://doi.org/10.1073/pnas.11004 80108

Lara, J. A. (2016): Phylogeography of the natal puddle frog Phrynobatrachus natalensis (Anura: Phrynobatrachidae) in Sub-Saharan Africa: The University of Texas at El Paso.

Larson, D. L., P. J. Anderson, and Newton, W. (2001). Alien plant invasion in mixed-grass prairie: effects of vegetation type and anthropogenic disturbance. Ecological Applications 11:128-141.

Laurance, W. F., Clements, G. R., Sloan, S., O'connell, C. S., Mueller, N. D., Goosem, M., and Van Der Ree, R. (2014). A global strategy for road building. *Nature*, 513(7517), 229-232.

Laurance, W. F., Goosem, M., and Laurance, S. G. (2009). Impacts of roads and linear clearings on tropical forests. *Trends in ecology and evolution*, 24(12), 659-669.

Lee, C. B., Chun, J. H., Song, H. K., and Cho, H. J. (2013). Altitudinal patterns of plant species richness on the Baekdudaegan Mountains, South Korea: mid-domain effect, area, climate, and Rapoport's rule. *Ecological research*, *28*(1), 67-79.

Lendrum, P. E., Anderson Jr, C. R., Long, R. A., Kie, J. G., and Bowyer, R. T. (2012). Habitat selection by mule deer during migration: effects of landscape structure and natural-gas development. *Ecosphere*, 3(9), 1-19.

Linke, J., Franklin, E.S., Huettmann, F. and Stenhouse (2005). Seismic Cutlines, Changing Landscape Metrics and Grizzly Bear Landscape Use in Alberta. *Landscape Ecology,* 20**,** 811-826.

Linnen, C. (2006). The effects of minimal disturbance shallow gas activity on grassland birds. Northern Enviro-Search Limited, Saskatoon, Saskatchewan, Canada. <http://www.ceaa.gc.ca/050/documents/29492/29492E.

Lodungi J.F., Alfred D.B., Khirulthzam A.F., Adnan F.F., and Tellichandran, S. (2016). A Review in Oil Exploration and Production Waste Discharges According to Legislative and Waste Management Practices Perspective in Malaysia. Int J Waste Resour 7: 260. doi: 10.4172/2252-5211.1000260

Luke, Patey. (2015). Oil in Uganda. Hard bargaining and complex politics in East Africa *https://www.oxfordenergy.org › Publications*

MA (2005). Ecosystems and Human Well-being: Current State and Trends. *https://www.researchgate.net › publication › 266373793*

Mabey, S., and Paul, E. (2007). Impact of wind energy and related human activities on grassland and shrub-steppe birds. Literature review for National Wind Coordinating Collaborative and The Ornithological Council. <http://www.mtaudubon.org/issues/energy/documents/impactofwindenergyandrelatedhumanactivitiesongrasslandandshrub-steppebirds.pdf>.

Maldonado, O., Aveling, C., Cox, D., Nixon, S., Merlo, D., Pintea, L., and Williamson, E. A. (2012). Grauer's gorillas and chimpanzees in eastern Democratic Republic of Congo (Kahuzi-Biega, Maiko, Tayna and Itombwe landscape): conservation action plan 2012–2022: IUCN. *https://dspace.stir.ac.uk*

Margono, B.A., S.; Zhuravleva, I.; Potapov, P.V.; Tyukavina, A.; Baccini, A.; Goetz, S.; and Hansen, M.C. (2012). Mapping and monitoring deforestation and forest degradation in Indonesia using Landsat Time series Data sets from 1990 to 2010. Environ. Res. Lett. 7 (3), 034010

Margono., Jean Robert, B., Belinda, A., Bwangoy., Potapov., Peter, V., Matthew, C., and Hansen. (2014). Mapping wetlands in Indonesia using Landsat and PALSAR data sets and derived topographical indices

Mariano J.B and La Rovere E. L. (1999) Environmental impacts of the oil industry. *Petroleum Engineering Downstream.*

Mather, P.M. (1987). Computer processing of remotely-sensed images *https://journals.sagepub.com › doi › abs*

Matutinovic, I. (2009). Oil and Political Economy of Energy. *Energy Policy*, 37**,** 4251-4258.

Maundu, P., Kariuki, P., and Eyog-Matig, O. (2006). Threats to medicinal plant species-an African perspective. Conserving Medicinal Species: Securing a Healthy Future.

Mausel, P., Brondizio, E., and Lu, D. (2003). Change detection techniques. Center for the Study of Institutions, Population and Environmental change (CIPEC), Indiana University.

McDonald-Madden, E., Gordon, A., Wintle, B. A., Walker, S., Grantham, H., Carvalho, S., and Possingham, H. P. (2009). "True" conservation progress. *Science*, 323(5910), 43-44.

MEA (2005) Ecosystems and human well-being: biodiversity synthesis. World Resources Institute, Washington, DC

Medley, K., Okey, B., Barrett, G., Lucas, M. and Renwick, W. (1995). Landscape change with agricultural intensification in a rural watershed, southwestern Ohio, USA. Landscape Ecology, Volume 10

Meine C.D, and Archibald G.W (1996). The cranes - status survey and conservation action plan. Gland, Switzerland, and Cambridge, U.K. International Union for Conservation of Nature and Natural Resources

Melack, J.M and Hess, L.L. (2011). Remote sensing of the distribution and extent of wetlands in the Amazon basin pp 43-59

MEMD (2008). National oil and gas policy for Uganda http://pau.go.ug/uploads/NATIONALOILANDGASPOLICYFORUGANDA.pdf

MEMD (2018). Ministry of Energy and Mineral Development Energy and Mineral Development Sector, Sector Development Plan 2015/16 – 2019/20 http://npa.go.ug/wp-content/uploads/2018/01/Energy-Sector-Development-plan-Final.pdf

Meshesha, D.T., Tsunekawa, A., Tsubo, M., Ali, S.A., and Haregeweyn, N. (2014) Land-use change and its socio-environmental impact in eastern Ethiopia's highland. Reg Environ Change 14:757–768

Miller, S. G., Knight, R. L., and Miller, C. K. (1998). Influence of recreational trails on breeding bird communities. Ecological Applications 8:162-169.

Mittermeier, R. A. (2004). Hotspots revisited: Cemex https*://wedocs.unep.org › handle*

Mooney, (2002). Effects of Biodiversity on Ecosystem Functioning: A Consensus of Current Knowledge *https://www.jstor.org › stable*

Muheebwa-Muhoozi, J. (2001). The status of the Grey Crowned Crane, Balearica regulorum in Uganda, with special reference to breeding. Ostrich Suppl., 15: 122-125.

Muhereza, F. E. (2015). MISR WORKING PAPER. Edition, Kampala. *https://www.researchgate.net › publication › 321001090*

Mulondo, P., Prinsloo, S., Mugiru, G., and Plumptre, A. J. (2011). Measuring responses of wildlife to oil operations in Murchison Falls National Park. *Wildlife Conservation Society and Uganda Wildlife Authority*.

Munier, B., J. S. Schou, and K. Birr-Pedersen (2002). Ecological and economic modeling in agricultural land use scenarios. Ecological Modelling, Volume 174, Issue 1-2, 1 May 2004, Pages 5-18.

Murphy, S. M., Kessel, B., Vining Source, L.J. (1984). Waterfowl Populations and Limnologic Characteristics of Taiga Ponds. J. Wild. Manag. 48: 1156-1163.

Mwehia, M.D. (2015). Effects of land-use and land-cover change on land degradation in Kijabe Longonot catchment, Kenya. Int J Sci Res Innov Technol 2(10):2313–3759

Nature Uganda (2010). Important Bird Areas in Uganda, training manual for Important Bird Areas Site Monitors. The East Africa Natural History Society, Kampala. *natureuganda.org › downloads › IBA Training Manual*

NEMA (2010). Environmental Sensitivity Atlas for the Albertine Graben. 2nd Edition. *https://www.google.com/search?q=wedocs.unep.org+%E2%80%BA+handle&oq=wedocs.unep.org+%E2%80%BA+handle&aqs=chrome..69i57j33l2.1406j0j9&sourceid=chrome&ie=UTF-8*

NO and E.I..I.T.O (2006). Uganda Biodiversity and Tropical Forest Assessment. *https://www.vub.be/klimostoolkit/sites/default/files/documents/uganda_biodiversity_assessment_usaid.pdf*

Northrup, J. M., and Wittemyer, G. (2013). Characterising the impacts of emerging energy development on wildlife, with an eye towards mitigation. *Ecology letters, 16*(1), 112-125.

Nwankwo, B. (2015). Global oil industry conflict. Oil and gas journal U.S.A Oil and gas; Journal, June 7, 1982

Nwilo, C.P. and Badejo, T.O., (2005a). Impacts and Management of Oil Spill Pollution along the Nigerian Coastal Areas. Department of Survey and Geoinformatics, University of Lagos, Lagos, Nigeria. www.fig.net/pub.figpub36/chapters/chapter_8.pdf

Ochieng, L. A., Kamara, E. D., Nina, P. M., (2019). Effects of Oil and Gas Exploration in Murchison Falls National Park on Wildlife Resources. *African Journal of Environment and Natural Science Research*, 2(2), 48-57.

Ogbo, M.E., Zibigha, M. and Odogu, G. (2009). The Effects of Crude Oil on Growth of the Weed (*Paspalum Scrobiculatum* L.) - Phytoremediation Potential of the Plant. *African Journal of Environmental Science and Technology,* 3**,** 229 - 233.

Olawoyin, R., Oyewole, S. A., and Grayson, R. L. (2012): Potential risk effect from elevated levels of soil heavy metals on human health in the Niger delta. Ecotoxicology and environmental safety, 85, 120-130 *https://www.ncbi.nlm.nih.gov › pubmed*

Oliver, I., Smith, P. L., Lunt, I. and Parkes, D. (2002). Pre-1750 vegetation, naturalness and vegetation condition: What are the implications for biodiversity conservation? Ecological Management and Restoration 176-178.

Olson, D.M. and Dinerstein, E. (1998). The Global 200: A Representation Approach to Conserving the Earth's Most Biologically Valuable Ecoregions. *Conservation Biology*, 12**,** 502-515.

Olupot, W. and Plumptre, A.J. (2006). The status of Crowned-Cranes in Uganda: A national assessment of breeding, population distribution, and threats. Unpublished Wildlife Conservation Society report.

Osei, B., and Mubiru, A. M. (2010). Chinese trade and investment activities in Africa. *African Development Bank's Policy Brief*, 1(4), 1-12.

Paine, M. D., DeBlois, E. M., Kilgour, B. W., Tracy, E., Pocklington, P., and Crowley, R. D., (2014). Effects of the Terra Nova offshore oil development on benthic macro-invertebrates over 10 years of development drilling on the Grand Banks of Newfoundland, Canada. *Deep Sea Res. II* 110, 38–64. doi: 10.1016/j.dsr2.2014.10.015

Paracuellos, M. (2006). How can habitat selection affect the use of a wetland complex by waterbirds? Biodiversity and Conservation 15: 4569-4582.

Pelletier, R., Hrtley, D., J. Koivula, M., R. Spence, J., and E. Ball, G. (2007). Effects of urbanization on ground beetle assemblages (Coleoptera, Carabidae) of grassland habitats in western Canada. *Ecography*, *30*(5), 673-684.

PEPD (2014), Petroleum discoveries in the Albertine Graben. Ugandan Petroleum Exploration and Production Department

Peterson, C. H., Rice, S. D., Short, J. W., Esler, D., Bodkin, J. L., Ballachey, B. E., and Irons, D. B. (2003). Long-term ecosystem response to the Exxon Valdez oil spill. *Science*, *302*(5653), 2082-2086.

Petit, C. and Lambin, E. (2002) Long-term land-cover changes in the Belgian Ardennes (1775–1929): model-based reconstruction versus historical maps. Glob Change Biol 8:416–630

Petit, C. and Lambin, E. (2001) Integration of multi-source remote sensing data for land cover change detection. International Journal of Geographical Information Science, 15, 785–803.

Petroleum Authority of Uganda, (2019). Environmental and Social Impact Assessment, KingfisherDevelopmentProject.https://pau.go.ug/site/assets/files/1116/pau_booklet_english_compressed.pdf

Pezeshki, S.R., Hester, M.W., Lin, Q. and Nyman, J.A. (2000). The Effects of Oil Spill and Cleanup on Dominant Us Gulf Coast Marsh Macrophytes: A Review. *Environmental Pollution,* 108**,** 129-139.

Phillips, S., Namaganda, M., Lye, K.A. (2003). 115 Ugandan grasses. In:Makerere Herbarium Handbook No. 1. Makerere University Herbarium,Department of Botany, Makerere University, Kampala.

Plumptre, A.J., Behangana, M., Davenport, T., Kahinda, C., Kityo, R., Ssegawa, P., Eilu, G., Nkuutu, D. and Owiunji, I. (2003). *The Biodiversity of the Albertine Rift. Biological conservation*, *134*(2), 178-194. *https://africanbirds.fieldmuseum.org ›africanbirds.fieldmuseum.org › files*

Pomeroy, D. (1987). The ecology and status of Crowned Cranes in East Africa. Proceedings of the 1983 International Crane Workshop. International Crane Foundation, Wisconsin, USA. pp. 323-330.

Purcell, P. (2014). Oil and gas exploration in East Africa: a brief history. Search and Discovery Article, 30388. *www.searchanddiscovery.com › 2014 › 30388purcell › ndx_purcell*

Queiroz, S.d.J., App, B., Morin, R. and Rice, W. (2008). *Partnering with Extractive Industries for the Conservation of Biodiversity in Africa: A Guide for USAID Engagement*, Washington, United Statest Agency for International Development.

Rai P., 2015. What makes the plant invasion possible? Paradigm of invasion mechanisms, theories and attributes

Ramirez, P.J. (2009). *Reserve Pit Management: Risks to Migratory Birds.*, Cheyenne, Wyoming, United States Fish and Wildlife Services Region 6.

Rands M, Adams W, Bennun L, Butchart S, Clements A, Coomes D, Entwistle A, Hodge I, Kapos V, and Scharlemann J (2010) Biodiversity conservation: challenges beyond 2010. Science 329:1298–1303

Rebecca K., Sadie J., Jonathan B., Joel H, and Jacqueline L., 2018. Assessing the impacts of oil exploration and restoration on mammals in Murchison Falls Conservation Area, Uganda https://doi.org/10.1111/aje.12568

Riitters K and Wickham J (2003) How far to the nearest road? Frontiers in Ecology and the Environment 1:125–129

Roe, D, Seddon, N and Elliott, J (2019): Biodiversity loss is a development issue: a rapid review of evidence. IIED Issue Paper. IIED, London. *https://pubs.iied.org/17636IIED/*

Rosenfeld, B.A., Gordon, L.D. and Guerin-McManus, M. (1997). *Reinventing the Well:*

Approaches to Minimizing the Environment and Social Impacts of Oil Development in the Tropics, Washington, Conservation International.

Rwakakamba, M., and Lukwago, D. (2013). Farmers in Uganda's oil economy: deal or no deal. *Kampala: Agency for Transformation*.

Rwakakamba, M., Mpiira, A. S., and Turyatemba, J. (2014). Tourism in Uganda's oil economy: Deal or no Deal! *Agency for Transformation*.

Rwanga, S. and Ndambuki, J. (2017). Accuracy Assessment of Land Use/Land Cover Classification Using Remote Sensing and GIS. 10.4236/ijg.2017.84033, International Journal of Geosciences

Sala O, Chapin III F, Armesto J (2000) Global Biodiversity Scenarios for the Year 2100. Science, 287, 1770–1774.

Sandifer P, Sutton-Grier A, Ward B (2015) Exploring connections among nature, biodiversity, ecosystem services and human health and well-being: opportunities to enhance health and biodiversity conservation. Ecosyst Serv 12:1–15

Satish, A.P., Ranav, S. P., David, A. B., Sharif, S. A. (2013). Modeling highly pathogenic avian influenza transmission in wild birds and poultry in West Bengal, India

Sawyer H., Kauffman, J.M. and Nielson, M.R. (2009). Influence of Well Pad Activity on Winter

Habitat Selection Patterns of Mule Deer. *Journal of Wildlife Management,* 73**,** 10521061.

Schwarte, C. (2008): Public participation and oil exploitation in Uganda: International Institute for Environment and Development. *https://pubs.iied.org/pdfs/14574IIED.pdf*

Sewnet A (2015) Land use/cover change at Infraz watershed, Northwestern Ethiopia. J Landsc Ecol 8:69–83

Shepherd, B. (2013). *Oil in Uganda: international lessons for success*. London, UK: Royal Institute of International Affairs.

Shrinivas K., Grierson D., Afolayan A., 2007. Ethnobotanical information of medicinal plants used for treatment of cancer in the Eastern Cape Province, South Africa https://www.researchgate.net/publication/228343304_

Simmers, S. M., and Galatowitsch, S. M. (2010). Factors affecting revegetation of oil field access roads in semiarid grassland. *Restoration Ecology, 18*, 27-39.

Ssekandi, J., Mburu, J., Wasonga, O., Macopiyo, L., Charles, F. (2017). Effects of Post Eviction Resettlement on Land-Use and Cover Change in Uganda's Oil Exploration Areas 10.4236/jep.2017.810072, Journal of Environmental Protection

Stevenson T and Fanshawe J (2002): *Birds of East Africa*. Helm Field Guides, Christopher Helm, London.*https://www.abebooks.com/first-edition/Helm-Field-Guides-BIRDS-EAST AFRICA/16592036342/bd*

Stuart C, Stuart T, and Hoffmann M (2008): *Dologale dybowskii*. The IUCN Red List of Threatened Species. Version 2017-3. <*www.iucnredlist.org*>.

Suárez, E., Morales, M., Cueva, R., Bucheli, V.U., Zapata-Ríos, G., Toral, E., Torres, J., Prado,

W. and Olalla, J.V. (2009). Oil Industry, Wild Meat Trade and Roads: Indirect Effects of Oil Extraction Activities in a Protected Area in North-Eastern Ecuador. *Animal Conservation,* 12**,** 364-373.

Sutherland WJ, Newton I and Green RE (eds) (2004): *Bird Ecology and Conservation: a handbook of techniques*. Oxford University Press, Oxford. *https://moodle.ufsc.br/pluginfile.php/822762/mod_resource/content/1/Bird%20Ecology%20and%20Conservation%20-%20A%20Handbook%20of%20Techniques.pdf*

Thackway, R. and Lesslie, R. (2006). Reporting vegetation condition using the Vegetation Assets, States and Transitions (VAST) framework. Ecological Management and Restoration 7(S1): S53-S62.

Thomsen, B.J., Mitchell, C., Piland, R. and Donnaway, R.J. (eds.) 2001. *Monitoring Impacts of Hydrocarbon Exploration in Sensitive Terrestrial Ecosystems Perspectives from Block 78, Peru,* London, Oxford University Press.

Trail, W.P. (2006). Avian Mortality at Oil Pits in the United States: A Review of the Problem and Efforts for Its Solution. *Environmental Management*, 38**,** 532-544.

Trombulak, S. C., and Frissell, C. A. (2000). Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation biology*, *14*(1), 18-30.

Turner, B.L. II and W.B. Meyer (1991), Land use and land cover in global environmental change. Climatic Change 28: 45-64.

Turner B, Lambin E, Reenberg A (2007) The emergence of land change science for global environmental change and sustainability. Proc NatlAcad Sci 104:20666–20671. https://doi.org/10.1073/pnas.07041 19104

Twongyirwe, R., Bithell, M., Richards, K. S., and Rees, W. (2015): Three decades of forest cover change in Uganda's northern Albertine Rift landscape. *Land Use Policy*, *49*, 236-251. *https://www.spri.cam.ac.uk › people › rees*

Ugochukwu, C. N., and Ertel, J. (2008). Negative impacts of oil exploration on biodiversity management in the Niger De area of Nigeria. *Impact assessment and project appraisal*, *26*(2), 139-147.

UN (2003). World Population Prospects; The 2002 Revision. Population Division, Department of Economic and Social Affairs, United Nations, New York.

UNEP (1997). World Atlas of Desertification. United Nations Environment Programme, London.

UNU-IIASA (2003), Report International Institute for Applied Systems Analysis (IIASA)

Uriarte M, Yackulic CB, Lim Y, Arce-Nazario JA (2011) Influence of land use on water quality in a tropical landscape: a multi-scale analysis. Landsc Ecol 26:1151–1164

USGS (2005), Final Agenda for the USGS Chesapeake Bay Science Workshop, May 12-13.

UWA (2012). *General management plan for Murchison Falls National Park, Karuma Wildlife Reserve, and Bugungu Wildlife Reserve 2012–2022*. Retrieved fromUgandaWildlifeAuthoritywebsite https://www.ugandawildlife.org/images/pdfs/general_management_plans/Murchison_Falls_Protection_Area_GMP.pdf

Villa. A., 2014. Carbon Dynamics of Sub-tropical wetland communities in South Florida. Phd /dissertation. The Ohio State University. pp. 160

Villa, F., Bagstad, K.J., Voigt, B., Johnson, G.W., Portela, R., Honzak, M., and Batker, D., (2014). A methodology for adaptable and robust ecosystem services assessment. Plos one, 9(3), e91001.

Vokes, R. (2012). The politics of oil in Uganda. *African Affairs*, *111*(443), 303-314.

Von der Lippe, M., and I. Kowarik. 2007. Long-distance dispersal of plants by vehicles as a driver of plant invasions. Conservation Biology 21:986-996.

Wang, Y., and Zhang, X. (2001), A dynamic modeling approach to simulating socioeconomic effects on landscape changes. Ecological Modelling, Volume 140, Number 1, 30 May 2001 , pp. 141-162(22).

Watkins, B. E., C. J. Bishop, E. J. Bergman, A. Bronson, B. Hale, B. F. Wakeling, L. H. Carpenter, and D. W. Lutz. 2007. Habitat guidelines for mule deer: Colorado Plateau shrubland and forest ecoregion. Mule Deer Working Group, Western Association of Fish and Wildlife Agencies, USA.

Wilcox, B. A., and Murphy, D. D. (1985). Conservation strategy: the effects of fragmentation on extinction. *The American Naturalist*, *125*(6), 879-887.

Wilkie, D., Shaw, E., Rotberg, F., Morelli, G., and Auzel, P. (2000). Roads, development, and conservation in the Congo Basin. *Conservation Biology*, 14(6), 1614-1622.

World Bank, 2013. Environmental and Social Management Framework, Albertine Region

Wrona, F.J., Prowse T.D., Reist J.D., Hobbie J.E., Levesque, L.M.J. and Vincent W.F. (2006) Climate change effects on aquatic biota, ecosystem structure and function. *Ambio* 35, 359– 369.

Zedler, J.B. and Kercher, S. (2005) Wetland resources: status, trends, ecosystem services, and restorability. Annu Rev Environ Resour 30:39–74 https://doi.org/10.1146/annurev.energy.30.050504.144248

APPENDICES

APPENDIX 1

Figure showing some plant communities in Kingfisher development area

APPENDIX 2

Figure showing bird nests a breeding place for birds in Masika wetland near oil pad 3

APPENDIX 3

Data sheet for bird species counts

Name of Count Site: ____

1.Count Protocol

a) Is it flying?

b) Is it stationary?

c) In what type of vegetation is it found?

2. Observation Date: ______________________________ Start time: _____________

3. Duration (minutes) ______Distance traveled _____

Record all species observed and heard

Species name	**Total number of Individuals**

APPENDIX 4

Data sheet for plant species counts

Name of study site:…………………………………………………………………………..

Number of transect:…………………………………………………………………………..

Type of vegetation ……………………………………………………………………………

Species present

Species name	**Total number of Individuals**