KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF RENEWABLE NATURAL RESOURCES

DEPARTMENT OF WILDLIFE AND RANGE MANAGEMENT



# IMPACT OF LAND USE / LAND COVER CHANGES ON AFRICAN SAVANNAH ELEPHANT'S (*LOXODONTA AFRICANA*) USE OF THE RED VOLTA VALLEY CORRIDOR

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# Impact of land use / land cover changes on African savannah elephant (*Loxodonta africana*) use of the Red Volta Valley Corridor.

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**A Thesis submitted to the Department of Wildlife and Range Management, College of Agriculture and Natural Resources Kumasi in partial fulfilment of the requirements for the degree of**

**MASTER OF SCIENCE IN GEO-INFORMATION SCIENCE FOR NATURAL RESOURCE MANAGEMENT**

**NOVEMBER, 2019**

# DECLARATION

I hereby declare that this submission is my own work towards the MSc and that, to my best of knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text

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**DEDICATION**

I dedicate this work to my little son, Banya Al- Islam and my late father Mr. Banya Nagre Sumaila May Allah almighty have mercy upon your soul.

**ABSTRACT**

The Savannah elephant (*Loxodonta africana*) is one of the threatened mammal species in the world and listed as vulnerable by the IUCN Red lists criteria as its population has drastically declined. Its population decline is largely as a result of habitat loss due to agriculture extension and other human related land use changes. The Red Volta Valley is one of the important migratory corridors established to connect the elephant ranges in Ghana, Burkina Faso, Niger, Benin, and Togo. This study therefore aims to assess the changes in land use/ land cover systems and its effects on the savannah elephants use of the Red Volta Valley Corridor. Field survey and community participatory GIS methods were used to mark locations of elephant's presence. Using MaxEnt algorithm and 8 explanatory variables (), elephants habitat use within the corridor were modelled for 1988 and 2018. The study revealed a significant land use/land cover changes within the thirtyyear period as bare soil increased by 174.9 $km^2$ representing 233.8% followed by a reduction of 169.1 $km^2$ representing 26.6% in open savannah /Agricultural Land. Riverine vegetation also reduced by 55.1$km^2$ depicting 38%, with water indicating a reduction of 2.3 $km^2$ that is 9%. Contrary, to expectations, Close Savana however increased by 51.3 $km^2$ representing 32%. Suitable habitat predicted by MaxEnt in 1988 reduced by 155.54$km^2$. The study revealed a reduction in the suitable habitat of the elephant by 15% as a result of the changes in land use / land cover types. Also, most suitable path used by elephant across the frontiers of Togo, Ghana and Burkina Faso showed significant changes in the vegetation cover types on it and increase in length by 1km from 1988 to 2018.

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*Equation 1: top of reflectance (TOA) value*

*Equation 2: Normalised Difference Vegetation Index (NDVI)*

## LIST OF ABBREVIATION

| | |
|---|---|
| AfESG | African Elephant Specialist Group |
| | Aeronautical Renaissance coverage Geographic information |
| ArcGIS<br>system | |
| AUC | Area under the Curve |
| DEM | Digital Elevation Model |
| ERDAS | Earth Resource Data Analysis System |
| FAO | Food and Agriculture Organization |
| GARP | Genetic Rule Set for Prediction |
| GIS | Geographic Information Systems |
| GIS | Geographic Information System |
| GMT | Greenwich Mean Time |
| GPS | Global Positioning System |
| GRASS | Geographic Resources Analysis Support System |
| GWD | Ghana Wildlife Division |
| HEC | Human elephant conflict |
| IUCN | International Union for Conservation of Nature |
| KNUST | Kwame Nkrumah University of Science and Technology |
| *L. africana* | (*Loxodonta africana*) |
| L5TM | Land sat five thematic mapper |
| LCP | Least Cost Path |
| LULC | Land use Land Cover |
| MaxEnt | Maximum Entropy Algorithm |
| NDVI | Normalised Difference Vegetation Index |
| ROC | Receiver Operating Characteristic |

| | |
|---|---|
| RVV | Red Volta Valley |
| STRM | Shuttle Radar Topography Mission |
| TOA | Top of Reflectance |
| TSS | True Skill Statistics |
| IGBP | International Geosphere-Biosphere Programme |
| USGS | United States Geological Survey |

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Background

Land use practices throughout the world vary greatly, however, their resultant outcome is mostly the same. Many decades of studies have now shown the environmental impacts of human land use throughout the world, ranging from changes in atmospheric composition to the extensive modification of Earth's ecosystems (Vitouseck *et al.*, 1997; Foley *et al.*, 2005). This phenomenon is altering many physical and biological systems and causing a great deal of concern for the survival of many wildlife species (Thomas *et al.*, 2004; Hoffman and Willi 2008). The most precarious challenge arising from many land use systems is the fragmentation and loss of wildlife habitat (Wilcox and Murphy 1985). Currently, the world is experiencing biodiversity and species decline and many literature (Sisk *et al.*, 1994; Ogutu *et al.*, 2016) work are linking the phenomenon to loss of habitat resulting from present land use change. In Ghana, the magnitude and extent of these declines including their suggested underlying courses are similar to those described in Sisk et al., 1994 and Ogutu et al., 2016. Several wildlife species including the big cats, such as the African lion (*Panthera leo*) (Burton *et al*, 2011), the African elephant *(Loxodonta africana*) (Bouche, 2007), primates, such as the chimpanzee *(Pan troglodytes verus)* (Danquah *et al.*, 2012), Reptiles such as the dwarf crocodiles (*Osteolaemus tetraspis)* (Amoah, 2018) and terrestrial birds, such as the White-necked Rockfowl (*Picathartes hydrocephalus*) (Freeman, Sunnarborg, and Peterson, 2019) all being affected.

Elephants are particularly considered vulnerable due to their large habitat requirements (Green *et al.*, 2018) and should be given special conservation interest (Bandara and Tisdell, 2005). Although the species has enjoyed some considerable attention in research (Blanc *et al.*, 2007), there are, gaps in knowledge on the species habitat requirement (Perera, 2009) and will require studies to understand and document imperative evidence of the impact of land use/land cover changes on the use of the Red Volta Corridor species, principally because it is considered as a flagship, an umbrella and charismatic species that is species, whose conservation will definitely go a long way to cover other lesser-known species (Simberloff, 1998). Globally, there are two species of the elephant: The Asian elephant (*Elephas maximus)* and the African elephant (*Loxodonta africana)*, of these species the African elephants are threatened and listed as Vulnerable by the International Union for Conservation of Nature (IUCN). The history of the elephant in Ghana runs from medieval to pre-colonial times, through to colonial era where it was significant for its ivory (Kwarteng, 2006).

Ghana still possesses some elephant populations. In 2002, the Wildlife Division (GWD) of the Forestry Commission estimated the population between 1000 to 2000 individuals in eleven different ranges (Blanc *et al.*, 2003). Ghana's elephant population is made up of two subspecies: the forest elephant *(Loxodonta cyclotis)* which occupies the forest zone of Ghana and the savannah elephant (*Loxodonta africana Africana)* occupying the Savanah ecosystem of Ghana. Currently, however, the only remaining viable range of the savannah elephant is the Mole National park and its extended enclaves (Bouche, 2007). Before 1970, the corridor was uninhabited, uncultivated and had little or low livestock population, due to the endism of glossina and simulium damnosum, human and livestock disease vector but when the vector was eradicated in the area towards the late 1980s and 1990 by Onchocerciasis eradication project, there was an exponential increase in economic Activities (agricultural cultivation as well as permanent settlement in close proximity to the corridor as nearby settlers had moved in to take advantage the fertile land along the valley) (World , 1995) leading to unprecedented declining population of the elephant.

Ghana and her neighbours (Burkina Faso, Niger, Benin and Togo) recreated a transboundary wildlife corridor (the eastern and the western wildlife corridor) to link elephant ranges of the

Nazinga game ranch, Kabore-Tambi National Park of southern Burkina Faso, the 'W' National Park Complex in the eastern part of Burkina Faso, (the W national park complex extends across the three countries: Burkina Faso, Niger, Benin) and northern Togo to provide access for migrating population between these habitats. The Red Volta Corridor has severally been assessed for the presence of elephant (Sam, 1994; Okoumassou *et al.*, 1998; Adjewodah 2004, 2010), since the corridors were created, it has not been adequately assessed to determine whether they are serving their intended purpose as migratory routes of elephants. Coupled with the ever increasingly rapid nature of habitat degradation resulting from many human activities (Bouche, 2007), understanding the environmental factors, land use / land cover change pattern and the spatial dynamics that influence spatial distributions of elephants is relevant in providing insight knowledge into the species requirement hence, assisting in conservation strategies for both elephant and habitat.

## 1.2 Problem statement

The Red Volta Valley system (corridor) had served as a corridor and a refuge for the savannah elephant for decades. However, the increase in ongoing agricultural activities, surface mining and human settlement in the area is threatening the survival of the corridor and the remnant elephant population (Bouche, 2007). Studies on the elephant in the corridor have primarily focused on estimating their population (Sam, 1994; Sam *et al.*, 1996; Bouche, 2007) and assessing human-elephant conflicts (Adjewodah *et al.*, 2003; 2010). Although the results of these studies have been relevant in providing conservation managers with population data which currently is on the downward trend (Sam *et al.*, 1996; Bouche, 2007) and management strategies. There is no empirical and quantitative information on the changes in land use/land cover of the Red Volta Valley landscape due to the persistent encroachment by human activities. Also, information on the spatial distribution and habitat use of (*L. Africana)* in the corridor is unavailable both in literature and in management reports.

## 1.3 Justification

West Africa has some of the fastest-growing human population of the continent in recent years (Barnes, 1999). Population growth goes with its attendant increase in demand for space and resources for its sustenance (Garg, 2017). And since land is fixed, space for human settlement, agricultural and amenities expansion, must have come from previously unhuman inhabited areas (wildlife habitat). Consequently, decreasing wildlife habitats Green *et al.*, 2005). Increasingly, there is growing evidence in literature that, population growth and human activity has largely and often negatively affected the natural world. A phenomenon usually described as environmental degradation and pollution (Bouche *et al.*, 2011). Ghana's land use land cover has equally changed drastically over the few decades particularly in northern savannah regions (Cotillion *et al*., 2016). For example, from 1975 – 2013 increase in agricultural land alone is estimated at 32% of Ghana's total land space resulting in about (40-50)% loss of the savannah ecosystem whiles settlement expanded to about 161% within the same period ( Cotillion *et al.*, 2016) Consequently, many of wildlife original habitat has been transformed into agro-pastoral areas ( Bouche *et al.*, 2011).

The Savanah elephant, (*Loxodonta africana)* is considered a keystone species and contributes significantly to biodiversity conservation (Riddle *et al.*, 2010). The economic, Socio-cultural and ecological importance of the savannah elephant is well documented in literature (Western, 1989; Sukumar 2003; Banc *et al.*, 2007; Blake *et al.*, 2007).

The Red Volta corridor is an important IUCN sanctioned elephant and wildlife corridor in Ghana, that is linking forest and wildlife reserves in Ghana and Burkina Faso including Kabore _Tambi National and Nazinga Game Ranch to the North and the Triparty Complex also known as the 'W' Complex in the east and northern Togo including Fossie Lions Aux Park and the Keran National park (Bouche, 2007). Wildlife corridors play an integral role in any species conservation agenda particularly in West Africa, given the fragmented nature of populations and habitats in the sub-continent, by ensuring gene flow between the remaining population since most of the protected areas are often small and surrounded by agricultural and pastoral fields (Sam, 2010). Studies of (Adjewodah, 2004, 2010; Bouche, 2006) have shown that there are a serious encroachment and a change in the land use/land cover of the Corridor. Their results largely attributed the conversion of the elephant range to other land uses such agricultural fields, cattle ranch, settlement and mining camps (Parker and Graham 1989; Hoare and du Toit, 1999; Adjewodah 2004; Bouche, 2006; Adjewodah 2010). Given the socioeconomic importance of the elephant, and the corridor in maintaining the remaining elephant population in and around the country, it is appropriate that a study to look at the impact of land use / land cover change on the use of the corridor by elephants be done to identify factors that govern elephant use of the area and provide Spatio-temporal distribution of the elephant in the Red Volta Valley. This will serve as baseline data for rehabilitating and maintaining the Red Volta Corridor.

### 1.4 Aim

The aim of this research is to assess the changes in land use/ land cover types and its effects on the savannah elephants use of the Red Volta Valley Corridor.

### 1.5 Objectives

1. To determine the changes in land use/land cover types from 1988 to 2018 for the Red Volta Valley.
2. To model changes in habitat use of the savannah elephants in the Red Volta Valley using Maximum Entropy algorithms.
3. To determine network of paths used by elephants in the corridor from the Ghana-Togo boarder closest to the Fassie Lions national forest and Ghana - Burkina Faso frontier from 1988 to 2018.

## 1.6 Research questions

1. What are the significant land use/ land cover changes in the Red Volta Valley since 1988?

2. What has been the trend in elephant habitat use of the Red Volta Valley over the years?

3. What are the current areas utilised by an elephant in the Red Volta Valley?

4. What are the most suitable paths elephant are likely to use in the Red Volta Valley?

## 1.7 Hypothesis

1. The Land use / land cover of the Red Volta Valley corridor remains unchanged since 1988.

2. The suitable habitat of the savannah elephant of 1988 in the Red Volta Corridor remains unchanged.

3. Land use / land cover types on elephant's suitable path of 1988 and land use land cover types of elephant suitable path of 2018 in the Red Volta Valley has not changed.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Land Use / Land Cover Changes

### 2.1.1 Land use land cover definitions

The terms "land use" and "land cover" are multi-disciplinary and esoteric just as the word 'land'. And are closely linked such that they are treated together in land cover classification to avoid ambiguity (Osei, 2009). Although these two words are used together and sometimes interchangeable to describe the same feature, they are different and have specific meanings (Coffey, 2013).

'Land-use' refers to the function that humans have put land into, usually with emphasis on the importance of land in an economic activity including all activities, undertaken on certain land cover type in other to drive social, cultural and economic benefits (Asubonteng, 2007) whiles

Land cover refers to the physical natural and man-made features that covers the earth surface (Thompson, 1996) which provide visible prove of land use (Campbell, 2002). According to Lambin, Rounsevell and Geist (2000) Land cover refers to the attributes of parts of the Earth's surface and its immediate subsurface, including fauna and flora, soil, topography, water bodies, and human-constructed feature.

In terms of change process Land use and land cover change is a complex and dynamic process that shares a common source in the form of anthropogenic activities including an increase in the human population and its subsequent response to economic opportunities (Meyer and Turner II, 1992). land cover change is defined as the loss of natural features, mostly forests cover and replaced by human-constructed features (exurban development), or the loss of agricultural lands to urban or exurban development whereas Land use change is the conversion of vegetated natural areas to the built environment (Sealey, Binder, and Burch, 2018). Dye (2003) denotes land cover change is the removal or alteration of the vegetation on the Landscape whereas Braissoulis (2000) also define land use land cover changes as the areal extent of a given type of land use or land cover, respectively. Land use has been changing since man first began to manipulate their environment (Metzger *et al.*, 2006) and has now become an important environmental issue. The problems of haphazard, uncontrolled environmental degradations, loss of land and wildlife habitat is resulting from changes in land use and land cover (Grzybowski, 2012).

Globally as well as locally, Land use change is widespread and spatially diverse. Change in land use land cover ranges from subtle modification to a total conversion in forest density and from forest to agriculture land (Geist and Lambin, 2001). According to Skole (1994) Land cover conversion involves a change from one cover type to another whereas Land cover modification involves alterations of feature or function without a complete change from one type to another, it may be changed in biomass, productivity, or phenology.

Asubonteng, (2007) noted that landscape conversion is easy to assess and document due to the ease in measuring its parameters as compared to modifications. This is particularly convincing given the fact that significant progress has been made in increased availability spatial data sets from remotely sensed data (e.g. satellite imagery of land cover) which is used as a means of obtaining land cover information. Remotely sensed data (satellite imagery) is able to separate explicitly land cover information than land use which requires further synthesis of land cover information.

### 2.1.2 Global trends in land use land cover change

Studies on land use land cover change has been long in history, generating numerous publications and receiving global research attention (Wang and Feng, 2011).

Several of these studies (Turner *et al.,* 1990; DeFeries *et al., 2004*) have documented the impacts of humankind on changing the landscape in attempts to improve his standard of life. Man has appropriated natural land to build landscape, slowly at first, and at an increasingly faster rate later on, with increased capacity to extract natural resources (Ramankutty *et al.,* 2006).

Many researchers have identified three different stages at which man manipulated the natural landscape. Thus, the control of fire, domestication of species, and use of fossil-fuel as key to enabling increased use of natural resources (De Vries and Goudsblom 2004; Turner II and McCandless, 2004).

During the Stone Age, (Paleolithic period), man manipulation of the landscape was characterized by the use of stone tools and fire. The use of stone tools by hunters changed habitats and was partly responsible for the extinction of megafauna at the beginning of the Holocene (Barnosky *et al*., 2004)

This capability allowed humans to expand his territory by migrating from their homes in Eastern Africa to new areas in Australia, the Americas and Eurasia (Ramankutty, *et al.*, 2006)

The second phase of human development history began with the domestication of plants and animals, which started roughly ten centuries ago in several places around the world. The introduction of sedentary agriculture has produced changes in the landscape that far exceed those resulting from the fire. Agricultural lands presently occupy approximately a third of the earth land surface (Goldewijk, 2001)

The third stage of human development was marked by the human extraction of energy stored in fossil-fuels characterized by the rising industrial Revolution and capitalism followed by globalization. A period that saw the world's human population increased in several folds. The rate at which human activities on the global landscape has increased tremendously during the last few centuries. Large tracts of natural lands are being converted for agricultural and settlement use than ever whiles there is a continuing decline in forest cover throughout the tropics (Koop and Tole, 2001; Williams, 2003)

A recent publication by the World Conservation Service indicates that "human footprint" covers 83% of the global land surface (Sanderson *et al*. 2002). And (Ramankutty *et al*., 2006) suggesting that agricultural expansion was the greatest force of land cover transformation on the global environment with approximately a third of the Earth's surface currently under crops or grazing cattle.

Before the turn of the 19th century, land in sub-Saharan Africa was used largely for hunting, gathering, herding, and shifting cultivation and by the turn of the 19$^{th}$ century, there was settled agriculture (Kimble, 1962). However by the turn of the 19th century, and with European invasions of the continent coupled with their high demand for tropical forest resource, Africa's landscape had begun to resemble those of the Europeans (Barton, 2001).

Agricultural land since that period has increased drastically matching population growth resulting from improved public health provision, as well as the absence of the wars, epidemics, and famines that had characterized the late 19th century (Kimble, 1962)

Researchers have continued to reaffirm that population pressure is one of the universal underlying causes of pantropical land cover changes. Global land cover land use change is a replica of the situation in Ghana. Increases in agricultural land in all parts of the country forms a significant portion of land use and land cover changes in Ghana. Synonymous to those described globally, as a result, the government has established several institutions with the task of protecting the remaining few landscape resources.

### 2.1.3 Driving factors in land use land cover changes

According to International Geosphere-Biosphere Programme IGBP (1993 b), most likely driving forces of land cover and land use changes can be grouped into six categories namely, population, level of affluence, technology; political economy or political structure, attitudes, and values of the people

However, Briassoulis (2001), analysis of land use / land cover change drivers limit it two key topics thus: biophysical and socio-economic drivers of change. The *bio-physical drivers* of change include processes of the natural environment such as weather and climate variations, landform, topography, and geomorphic processes, volcanic eruptions, plant succession, soil types and processes, drainage patterns, availability of natural resources Whereas the *socioeconomic drivers* comprises demographic, social, economic, political and institutional factors and processes such as change in population, industrial development, technology and technological change, the family, the market, various public sector bodies and related policies and rules.

Biophysical drivers of change do not directly cause land-use change however, they do cause land cover change (or changes) which, in turn, may influence the land use decisions (e.g. no farming on barren lands (Briassoulis, 2001). On other occupations, land use changes on a landscape may lead to land cover changes which, in turn, feedback on land use decisions resulting in perhaps new levels of land-use change (Briassoulis, 2001).

Socio-economic drivers of change are those fundamental societal factors that link humans to nature and which bring about global environmental changes. Examples of those factors include: population growth, technological advancement, sociocultural/socioeconomic organization

According to USGS (2013) Ghana's land use/land cover has been classified into five major categories: Forest, agricultural land, savannah, buided-up (settlement) and water bodies. Although high interdependencies in social-ecological systems make it difficult to identify the main drivers of land use land cover change.

In Ghana, political policies, change in technology, attitudes and values of the people (IGBP, 1993) couples with extensive economic development, and population growth estimated to increase significantly from 5 million in 1950 to an estimated 50 million by the end of 2050 (Coulter *et al.*, 2016) constitute key drivers of land use land cover change. According to Kleemann *et al*., (2017) Land use and land cover change in Ghana is the result of complex human-environmental interactions, in which the savannah landscape experiences the greatest loss, from about 40 to 51 percent of the total land area from 1975 to 2013 (USGS, 2013 ). Population growth, with an already high population density of 94 people/km$^2$ in rural areas (GSS, 2012), are considered as an important driver of land use land cover changes in the savannah landscape and exacerbates land cover change environmental problem (Kleemann *et al.*, 2017)

Besides the population growth, government policies also play a key role in land use land cover changes. For instance the State Lands Act, 1962 empowered the Central Government to compulsorily acquire any parcel of land for the public interest including conservation and any other development and compensate landowners (Alhassan, 2003). However there are often allegations against the Government not compensating landowners properly on these acquired land, this results in the encroachment of such public lands by the people for farming, illegal lumbering, and mining (Atampugre, 2010). Also, the past political economic climate has also impacted on land cover change in Ghana. As noted by Leonard (1989) cited in Atampugre (2010) as a result of the decline in economic growth rate in the 1980s, many developing countries including Ghana, sought to address the problems of 'balance of payments' and debt servicing by expanding agricultural production, intensification of timber export, minerals and other natural resources exploitation as a result changing significant portions of Ghana's land use land cover systems.

### 2.1.4 Implications of land use land cover change for wildlife species

Land use land cover changes dates back to prehistoric times. However, the current rate of land cover modification is never wetness. Driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales (Pontius and Schneider, 2001). These changes pose a lot of environmental concerns to climate change DeFeries *et al* (2004), biodiversity loss and the pollution of water, soils and air (Graetz, Fisher and Wilson, 1992). Usually, when primary forests are cleared for farming purposes, the loss of forest species within the cleared areas is immediate (Oteng-Yeboah, 1994). Wuver and Attuquayefio, (2006) also established that, species habitat suitability of forests and other ecosystems around intensive use area usually affected by habitat fragmentation, which exposes and decreases their core habitat area. USGS (2013) also noted that, previous uninterrupted continuous savanna landscapes and Central Transitional Zone are now highly fragmented, with large tracts of natural habitat broken into myriad patches of farmland, reducing the suitability of habitat for many wildlife species.

The combined effects of land use land cover change and extreme climatic condition including draught can also have serious consequences on the health and survival of wildlife. (e.g., heat mortality, injury, fatalities). For instance, road construction through wildlife areas is reported to be associated with increased bushmeat hunting, which may threaten many wildlife species (Wolfe *et al.*, 2005).

Habitat modification, such as road and dam construction and irrigation facilities increases people and livestock proximity to wildlife habitats and could lead to modification of transmission some of infectious and zoonotic disease leading to outbreaks or emergence of new both wildlife and human disease, because 75% of human diseases have links to wildlife or domestic animals (Patz *et al*., 2004). For instance, land-use change has been linked to the emergence of bat-borne Nipah virus in Malaysia (Chua *et al.*, 1990) and in India (Plowright et al., 2019)

In Ghana, major land use /land cover changes that affect wildlife habitat and their species include Deforestation through logging, Agricultural expansion Fragmentation and mineral mining activities. For instance, studies conducted by Antwi *et al*, (2014) reported an increment in arable lands by 6168.98 $km^2$, decreased in forest and plantation in many areas whiles afforestation barely occurred except in a few rainforests.

According (USGS, 2013) from 1975 to 2000, agricultural lands in Ghana expanded from 13 to 28 percent of its total land surface this results in the creation of isolated patches forest hence decreasing wildlife and habitat size, value quality. Fragmentation is one of the effects of Ghana's land use land cover products with a debilitating impact on wildlife. According to FRA, (2015) between 2000 and 2010, Ghana's closed forest reduced from 2,317166 ha to 1,785,802. ha. Thus depreciating at the rate of 192,648ha per 5 years.

Another important land use issue that affects wildlife is mining activities usually large concessionary space for the tailings dam, plant site and feed stockpile, and other facilities, all these have both direct and indirect impact on wildlife habitat. Over the years, mining activities Ghana has resulted in substantial disturbance of surface soils by engaging surface mining by laterally digging the landscape for minerals resulting in, destruction of vegetation and the pollution of water and air (Ayensu *et al.*, 1996).

In the Red Volta Valley land use/ land cover debilitating land use land cover changes includes increased agricultural expansion, surface mining, charcoal burning and livestock activities from Fulani herdsmen. According to Awudi, (2002) about ten thousand prospectous have created and occupied temporary settlements in natural landscape previous reserved for wildlife.

### 2.1.5 Impact of land use/land cover change on elephants

Land-cover changes are a major driving force of habitat modifications, which has important implications on the distribution of wildlife species and ecological systems (Sintayehu, 2019). However, information on the consequences of land cover changes on wildlife habitat particularly elephant and conservation at local scales is scanty. Although habitat loss and fragmentation have been severally linked to the elephant population declines (Sukumar, 1989; Leimgruber, *et al*., 2003). Elephant's survival threat had previously come from poaching to satisfy ivory trade demand, this has been the major threat faced by elephants worldwide in the previous centuries (Douglas-Hamilton, 1987). However, with the continuous increase in world population accompanied by technological advancement, the shortage of landscape for habitat is increasingly becoming a major addition to the already devastating threats to wildlife and concerns for natural resource managers (Kideghesho, 2006). Naturally, in the end, the dominant species will occupy the limited landscape. And, as the human race continues to expand coupled with their superiority over all living species (Taylor, 1984) wildlife will be forced to negotiate on their habitat (Meyer, 2015).

The impact of land use /land cover changes to wildlife species and particularly elephants could be summarised into three major threats (Rogan and Lacher 2018): 1. Habitat loss 2. Habitat fragmentation 3. Poaching.

Habitat loss due to land-cover changes is a serious threat to biodiversity worldwide (Rouget, 2003). Among species that have greatly suffered habitat lose is the elephant due to its large home range, long-distance migratory nature requiring large corridor, competition for a resource with humans and livestock and large habitat requirements outside conservation areas (Yirmed et al., 2006). Habitat loss stems from population growth resulting in the expansion of agriculture land, logging, forest fires as well as the clearing of large forest areas for purposes of planting oil palms, rubber trees and pulpwood (Soule, 1991; Dale *et al.,* 1994; Sala, *et al* 2000). Conversion of natural vegetation to farmland is documented as a significant source of habitat loss (Sukumar, 2003). For instance, Farming have led to vast areas of natural forest being burned, chopped down, or otherwise destroyed, because the soil is not ideal for crops and sometimes farmers are successful only for a few years, after which barren and farmers have to move on and destroy another area for their crop plant consequently large areas destroyed with time (Meyer, 2015). In a related case cultivating a small piece land around sources of permanent water body prevent the use of large areas (Pringle and Diakite, 1992) because the presence humans or farm 'protection unites' on the field will prevent the elephant from accessing adjoining landscape.

Also, in developing countries, such as Africa and Asia where elephant range exists, overgrazing is a growing problem. Grazing livestock has completely destroyed the land and its nutrients, rendering it completely barren (Dettenmaier *et al.,* 2017). As this problem spreads over increased farming areas, the space available to elephants decreases exponentially (Meyer, 2015). In this regards elephants will now require to cover large vegetative areas to be able to meet their nutritional needs.

The existence of human infrastructure known as 'fragmentation geometries' such as settlements, roads and agricultural fields do not only obstruct animal movement but also fragment their habitats (Burnsilver, Worden & Boone, 2008; Western, Groom & Worden, 2009). Since fragmentation may cause subdivisions of suitable continuous habitat into smaller patches leading to a situation where a single patch may be incapable of harbouring elephant population.

Selection of foraging areas by elephants also takes into account both browse availability and landscape fragmentation (Gara, *et al.*, 2017). Therefore the combined effect of forage availability and landscape fragmentation on elephant movement should be considered in predicting distribution and elephant response of elephant to anthropogenic landscape changes (de Boer *et al.*, 2013)., this is because the selection of foraging areas by elephants is mostly influenced by plant phenology which approximates the nutritional quality of the forage (Fryxell, 1991). And forage quality is known to decline with an increase in patchiness of landscape (Hebblewhite, Merrill and McDermid, 2008).

Land use /land cover change also increases risk of an elephant to motor accidents and poaching, in that, land use land cover changes including road constructions open up elephant habitat and increases human proximity to elephants (Whitehouse and Kerley, 2002) road increasing poaching activities.

## 2.2 The Elephant

The Savannah elephant (*Loxodonta africana africana*) is native to the Savannah ecosystem and is one of the subspecies of the African elephant. It is the biggest remaining terrestrial living mammal on earth (Asare, 2017). And an ecological flagship species with an incredible protection consideration (Blanc *et al.*, 2008). Previous genetic information suggested two subspecies of African Elephant, thus the Savannah elephant (*Loxodonta africana*) and the Forest Elephant (*Loxodonta cyclotis*) (Roca *et al*., 2001, 2005). These two subspecies vary in morphology and in ecology. The body size of the forest elephants is more compact and smaller compared with the savannah elephant, with long, thin and a straight tusk that is slightly yellowish in colour. It has a stretched lips and nose that is hairier than the savannah type. As opposed to the above evaluation, a third species is being postulated, suggesting to be West African Elephant (Selier *et al*., 2016). However, the IUCN/ SSC African Elephant Specialist Group currently acknowledge the single species proposition and has indicated that extensive research is required before any decision on the re-classification of the elephant is made (IUCN, 2005). Savanna elephant lives in smaller groups of families an average family size is five individuals led by a female who forms a clan (Vidya, and Sukumar, 2005) and their diet includes a higher proportion of fruits, leaves and a lower proportion of grasses (Adjewodah, 2010). Generally, the African savanna elephant is a herbivore benefitting on a wide range of vegetative materials such as leaves, fruits, grass and tree barks, (Feleha, 2018). Though a higher proportion of its feed is leaves and fruit with occasional salt licks. Elephants are social animals (Moss *et al.*, 1983) and exhibit several social interactions including greetings. The adult male African elephant is solitary and joins with others on certain occasion e.g. during mating season (Kangwana, 1996). The relationship between the male and female is largely sexual with no responsibilities (Maria, 2014).

### 2.2.1 Spatial Distribution and Trend of the African elephant

In classical time, the African elephant used to range freely throughout Africa, south of the Sahara in almost all habitats from savannas to rain forests, swamps to deserts, and seashores to high mountains (Cumming *et al.*, 1990). The savannah elephant (*Loxodonta africana africana*), occupies the grassy and woody savannah landscape while the smaller forest elephant (*Loxodonta africana cyclotis*), lives in the equatorial forests of central and western Africa (Barnes, Blom and Alers, 1995). According to the great elephant census (GEC), the African elephant was estimated around 26,000,000 individuals scatted around the continent in the early 19th century and by the turn of the 20th century, although the population has decreased there were still as many as 3-5 million African elephants in the continent(WWF). However, when the first continental elephant census was carried out in 1976 an estimated population of 1.34 million elephants was recorded in about 7,300,000 $km^2$ habitat range (Stiles, 2004). Presently, their range has shrunk and the population declined following the colonial invasion due principally to hunting for the ivory (Cumming, 1990). But there are now estimated around

415,000 individuals (WWF, 2018). The African elephant today is distributed in 37 range states with most of the population of the concentrated in eastern and southern Africa, with the highest densities found in Botswana, Tanzania, Zimbabwe, Kenya, Zambia and South Africa and few other populations in West Africa (Thouless et al., 2016). In 2016, 415,428 ± 20,111 African elephants were estimated in areas surveyed in the last ten years. With a possible additional 117,127 to 135,384 elephants which could be in areas not systematically surveyed in a total estimated range of 1,932,732 km², representing 62% of the estimated known and possible elephant range in Africa (Thouless *et al.*, 2016).

### 2.2.2 Spatial Distribution and trend of the Savannah Elephant

The Savannah elephant (*Loxodonta africana africana*) is the largest of the two subspecies and a native to the Savannah ecosystem. It is the biggest remaining terrestrial living mammal on earth (Asare, 2017). The range of the Savanna elephants falls under the savannah ecosystem with woody and grassy landscape which is largely found in eastern, southern Africa and in West Africa. The Great Elephant Census of 2016 estimated the savannah elephant populations of 352,271individuals, an indication of an estimated decline of 30% in seven years (WWF, 2018). Elephant's population is not even in the continent, southern Africa inhabits the largest population contributing about 39 % of range size containing 50% of the continent's population (Blanc *et al.,* 2007) whiles West Africa contributes about 5% of the range and eastern and central Africa constituting the remaining range. (Riddle, 2009). Currently, there are 350,000 individuals left in the continent according to Saigal, (2018). In West Africa, the savannah Elephants are distributed in 13 countries of Guinea Bissau, Guinea, Niger, Nigeria, Ghana,

Togo, Cameroon, Benin, Mali, Burkina Faso, cote d' Ivo ire and Liberia (Blanc *et al.*, 2003). Elephant ranges in West Africa are mostly patches of protected areas and populations are small, fragmented and isolated (IUCN, 2015). Elephants habitats are contracting and many authors are associating it to increases in human populations with its subsequent land requirement for housing and agriculture (Bouche, 2007; Sach *et al.*, 2019) and other human activities including poaching. For instance, Schlossberg, 2018 noted that, collared elephants avoiding close proximity < 6 while utilising habitat 4-40 km from human activity sites (Schlossberg, 2018). However the savannah elephant, particularly, the West African Ranges, has lost a greater percentage of its elephant range to habitat loss, degradation and fragmentation (barns, 1999) due to increasing population growth. Nevertheless, there is a strong will among West African wildlife managers to turn the table around and ensure that their children benefit from elephants in the future (Thouless *et al.*, 2016). However, with increasing population growth and infrastructural development in West Africa, there is increased pressure on natural areas from mining, logging and rapid transformation of land to agriculture (Thouless *et al.*, 2016) implying elephant habitat appropriation will be exacerbated. The elephant current range is estimated to covers 143000 $km^2$ with an estimated population of 11,489 ± 2,583 individuals in surveyed areas (Thouless *et al.*, 2016).

At the national level, Ghana has an estimated elephant population of 2500 individuals in eight reserve sites across the country covering an area of 31,796 $km^2$ thus about 13% of the land. Of these numbers, the savannah elephant has the highest population (Blanc *et al.*, 2003). The savannah elephant is distributed in two protected areas within the savanna ecosystem (i.e. the Mole National park and the Gbele Reserve) (GWD, 2000) and its extended enclave (a transfrontier complex that straddles the borders between Ghana and Burkina Faso) thus the PONASIRED complex (Sam 1994, Blancs, 2007). The Red Volta Valley is an extension of the PONASIRED complex. Sam, (1994), first estimated its elephant population, around 100-150 individuals a subsequent survey Sam *et al.*, (1996) estimated, a reduced number of 45 individuals. It is also important to note that the methods (uses of footprint to identify groups) employed by Sam and others were considered guesses by IUCN standards hence the number could be higher or lower. Okoumassou *et al.*, (1998), Adjewodah (2003, 2010) documented that, elephants in the Red Volta Corridor were not permanent but migrate from season to season in search quality forage resources consequently destroying crop produce.

### 2.2.3 Factors affecting Elephant Population in the RVV

The Red Volta Valley system has served as a refuge for the savannah elephant for an unknown period of time (Douglas-Hamilton 1979; Roth and Douglas-Hamilton 1991). In the early parts of the 20th-century elephant residence in the corridor was permanent, however towards the mid1970s upwards elephant residence became sporadic (Bouche and Lungren, 2004). Elephant distribution at any landscape is driven by many factors including physio-ecological landscape, browse, water, anthropogenic activities (Barnes *et al*., 1991; Sam *et al.*, 2002; Ashiagbor and Danquqh, 2017; Tikhile *et al.*, 2013). But in the Red Volta Valley socio-political decisions were noted as part of important factors that affected elephant distribution in the area (Sebogo, and Barnes, 2003). Although Prior to gazettement of the area as forest reserves in the 1940s and 1950 there were already elephant and other wildlife including Roan Antelopes and monkeys, the main aim the reserve was for watershed and timber resource protection not wildlife hence it did not get any attention (Adjewodah, 2010) before 1970 the Red Volta Valley was infested with Vectors of livestock and human disease (*Glossina*) and (*Simulium damnosum*) vectors causing (trypanosomiasis) Sleeping sickness and (Onchocerciasis) river blindness respectively. As a result the lands along the riverine vegetation was left unoccupied (fallow) or abandoned by previous settlers. Human population and agricultural activities in the area were low (Wardell *et al.*, 2003) making the area a safe haven for wildlife species such as the savannah elephant, Roan antelope and monkeys (Hilton, 1968). Elephants were permanently resident in the area and raiding crops at upland communities resulting in serious human-elephant conflicts. Under pressure from, farmers and local authorities, the GWD in 1970 decided to cull the elephant population in order to end the crop-raiding menace. The exercise eradicated the elephant population in the area at the time (Adjewodah, 2010).

However, the eradication of river blindness in the area by the Onchocerciasis control project which started in the mid-1970s in up till late1990s open-up the affected landscape for more economic activities (Kim, Benton and Mundial, 1995) and increases in human population density particularly following the last decade of the project in affected areas (Van Warren, Mariez- currena and Balma, 2007). The elephant eradication program by the GWD did not achieve its aim because by eary1990s elephants were back in the area (Adjewodah, 2010). Possibly migrating across the borders from habitat in Burkina Faso and Togo. Increased in human population in the Onchocerciasis freed zone (OFZ) resulted in appropriation of elephant habitats for settlement, farming activities and mining (Mcmillan, 1993) for instance in neighbouring Burkina Faso, the government had set up settlement programme which demarcated more than 30000 $km^2$ of land for the established of new communities (Mcmillan, 1993). The conversion of the elephant habitat into agricultural lands reignited the humanelephant conflict, this time farmer employed hunters to protect communal cropland and causing devastating loss to elephant population (Adjewodah *et al.,* 2003). The effect of agriculture expansion on elephants is not limited to reduced forage availability from their natural landscape because of land cover conversion, but increased human-wildlife conflict also with, the potential of causing serious mortality for both wildlife and humans (Hoare and Du Toit 1999) The negative relationship between elephant population density and human population density is similarly demonstrated in the studies of (Parker and graham 1986; Hoare, 1999). For instance population increase in a rural setting goes increase logging for housing construction and fuelwood (charcoal burning). The effects of logging on elephants are both direct, through the loss of elephant browse, and indirect through disturbance and the 'after month effects'. Felling trees for fuelwood (charcoal) may result in fragmentation of the landscape, degradation of habitat to a point that will be unfavorable to elephants. Although, certain types of logging can open up the thick forest into secondary forest favorable to elephants (Dudley *et al.*, 1992).

Draught which reported in the literature to limits the movement and causes elephant habitat loss (Roth and Douglas-Hamilton, 1991) is hypothesized to be effects of human activities resulting in climate change and change in rainfall pattern.

Annual wild bushfire is also common in the Red Volta valley (Adjewodah, 2010; Bouche 2007) and usually occur at the beginning of the dry season (started by farmers as a preventive measure to protect their own crops from same wildfire or mid dry season by hunters to smock out small mammal). Uncontrolled wildfires are intensive and have a serious impact on vegetation.

Habitat Fragmentation and degradation is also a serious issue in the Red Volta Valley. The studies of Okoumassou *et al.,* (1998) as well as Bouche, (2007) reported several establishments of farmland, farm and mining camps along the valley resultantly fragmenting the landscape. For instance, in 2002, the Forestry Services introduced a Taungya farming System in the Read Volta Valley. By this system farmers were given a piece of land in degraded parts of the reserve to grow their food crops in exchange for caring for newly planted tree seedlings integrated with their crops. With the hope that when the trees mature, and the canopy closes, farmers will abandon their plots. The intervention failed because the system was not compatible with the socio-cultural norms of the area. In that, it was a disincentive for farmers to ensure the success of the growing trees, besides human presence in the area have negative effects on the elephant. Also lessons from Eastern Africa show that, the Taungya System, could rather result in further degradation of the forests when it not well structured and monitored. (Adjewodah *et al*., 2003)

Currently, there is new hope and vision towards elephant conservation in the area since the government in 2005, with the assistance of IUCN agreed to re-established the area as an international wildlife migratory corridor (transfrontier corridor) and ensure the protection of wildlife particularly elephants. But management in the form of law enforcement in the area would have to be strengthened to reverse the current decline in the elephant population. Over the years, agricultural expansion, surface and alluvial mining, livestock grazing, charcoal burning and annual bushfires have left the place degraded and depleted of wildlife (Barnes *et al*., 2006a; Bouche,2007).

### 2.2.4 Eco-cultural significance of the African elephant

Wildlife ecology is a branch of science dealing with the interrelationships of wildlife with their own species, with other species, and with their non- living environment (Begone *et al.,* 2006). Conservation of species is achieved solely with a correct understanding of the ecology and relevance of the species (Tallis *et al.,* 2008).

The elephant is believed to be an important 'keystone' species for African savanna and forest ecosystems (Western, 1989). 'Keystone' species play a significant role in maintaining the linkages in a food web, despite the West African elephant has lost a greater proportion of its range to habitat degradation and fragmentation (Thouless *et al.,* 2013). And therefore the extermination of these species is predicted to cause dramatic changes or extinctions in ecosystems (Blanc *et al.,* 2003). Because Elephants show a dominant role in shaping ecosystems due to their immense size, large food needs, their impact on plant species composition, and their importance through their daily movement across long distances promotes wide seed and fruit dispersal. Their low digestive efficiency implies that elephant dung contains a decent supply of nutrients for early growth (Campos-Arceiz Steve and Blake, 2011). However, due to the lack of historical evidence on changes in African vegetation and wildlife, there is very little evidence to indicate whether or not the loss of some plant species from a specific landscape is actually associated with loss of elephants from of elephant from that landscape or the other way around. Whether elephants are really a keystone species or not, they do have a significant impact on vegetation structure through their feeding behaviour (Jachmann and Croest 1991; Tchamber and Mahamat. 1993). It is also reported that they play a very important ecological role in tropical forests through the creation of clearings and creating niches for specialised disturbance-adapted species, and allowing tree regeneration which is favoured by some species (Sukumar, 2003). Additionally, it creates important effect on nutrient cycling, making nutrients found in woody material available to different species (Spinage, 1994; Sukumar 2003) and distribute nutrients into clean areas around waterholes (Sukumar *et al*., 1987) however, when they occur in high densities in grassland areas, elephants create open habitats by eating from, and killing, large numbers of trees plants (Barnes, 1996). On the other way round, the loss or reduction in numbers of elephants can lead to an increase in bush cover in forest areas (Spinage, 1994; Sukumar, 2003). Also, the loss of woodland is also the fastest around permanent water sources, as elephants concentrate there within the dry season (Sukumar, 2003). High elephant densities are also likely to pose a negative impact on species and structural diversity (Western, 1989).

Socio- Culturally, the African elephant is fascinated by many different cultures in African society due to the huge physical stature and magnificence. It is viewed as a symbol of strength, power and peace. For instance, within the Moaga traditional society (one of the largest ethnic groups in Burkina Faso), the elephant is a symbol of strength and power for ancient chiefs (IUCN, 2005). Indeed, chiefs who were the most popular and powerful fighters of their time bore the name "NabaWobgo" (literally meaning Chief Elephant) which they acquire during their enskinment (IUCN, 2005). In other societies, their activities, and movement with respect to direction are indicative of a particular event. For example, in the northern part of Mali, people believe that elephants moving from north to south signifies the start of the rainy season in the Sahel (Niagate, 1998). In Ghana, the paramount chiefs of Denkyira, Eguafo, Abura, Ajumaku, and Abeaze have an elephant as their stools symbols (Reindorf, 1889, quoted in kwarteng, 2006). whiles the Asante’s have many cultural/ritual uses of the elephant tail including one designed with a golden handle and used by the Asantehene to signify the wealth and power of the Asante state (kwarteng, 2006). Ravenhill and Blackmun, (1992) also reported many other beliefs associated with elephants including featuring in fairy tales and inspirational talks, sculpture and painting and in many traditional ceremonies.

### 2.2.5 Drivers of elephant habitat selection

Understanding animal population ecology and habitat selection within a dynamic landscape play a pivotal role in conservation ecology (Hull *et al.*, 2016). Elephants move around in search of food, water, and possible mates from one forest patch to the other and they do so, by typically following a predefined path and this happens as a result of hereditary behaviour (Maria, 2010). Contrary to the above, some scholars also documented that, elephant habitat selection is motivated by several environmental variables including energy constraints, abundance and distribution of resources and social factors (Ashigbor and Danquah 2007; Shannon, 2012). Forage availability, topographic characteristics of a landscape, water, land cover (shelter), are considered basic factors in influencing habitat selection by elephants (Kumar, Mudappa, and Raman, 2014; Sukumar, 2003; Ashiagbor and Danquah 2017). Although these factors remain evident in the literature, the extent to which a variable defines elephant ranging is a function of seasonal variation, and local conditions according to (Sukumar, 2003). Until recently when the Red Volta corridor was invaded by a myriad of human activities (Bouche, 2007) it had provided favourable landscape for elephant occupation and migration (Jachmann, 1998).

### 2.2.6 Elephant transboundary migration and use of the Red Volta Corridor

Migration is defined here as a repeated seasonal movement between two non-overlapping habitats chiefly as a result of the adaptive response to the spatiotemporal distribution of resources (Purdon, 2018). Both African and Asian elephants yearly embark on this kind of movement. Usually in response to seasonal rainfall distribution and patterns (Purdon *et al.*, 2018). The distance involves depends on its habitat condition and the intensity of dryness or wetness (Grabbe, 2018). They are capable of moving hundreds of miles from their usual range to new habitats where they are less regular (Bouche, 1974) He similarly documented elephant's annual seasonal migration from Burkina Faso towards the western state of Niger in the latter part of the dry season. Elephant seasonal migration occurs along historic path (Purdon *et al.*, 2018) of some of these routes are now currently maintained as conservation corridors. Today, corridors play an important role in maintaining the elephant population, particularly in West Africa (Bouche, 2007), because the population in West Africa is isolated in small patches of protected areas. Corridors help to maintain gene flow between different populations. And allows the elephant to leave overused habitat and access underused habitat whiles allowing their key habitat to regenerate. Besides elephants are wandering animals hence corridors allows them to wander freely and connecting up with different habitat.

In Ghana, migration is well documented in some parts of the elephant's ranges (Jackmann, 1979; Parren and Sam, 2003). Elephants movement in and out of Ghana is via three historical route now conservation corridors thus the Bia-Goaso-Djambarakou (Ghana-Cote D'Ivoire), Nazinga - Sissili - Fumbissi - Mole (Burkina Faso - Ghana) and the Kabore Tambi- Zabre - Red Volta -Dough (Burkina Faso- Ghana- Togo) Corridor. Trans-frontiers elephant movement in the Red Volta valley was first reported by (Jackmann, 1979). okoumassou *et al.*, 1992 also reported the movement of elephants between the Red Volta corridor in of Ghana and northwestern part Togo. He received accounts of elephant's sightings during the wet season particularly towards harvest season and seems to move northwards to Burkina Faso during dry. In his study of 'crop-raiding pattern of the savanna elephant' in the Red Volta Corridor Adjewodah, 2010 also narrated that, elephant occasionally migrates to the Red Volta valley when crops were matured in order raid farms and go back to their key habitat during the dry season and harvest was over. Movement between Ghana, Togo and Burkina Faso is also reported by other authors such as (Sam *et al.*, 1996; 1997; 1998). Presently, the present status of elephant presence and migration in the Red Volta Valley is known (Bouche, 2007; Adjewodah, 2010). Back in the late 80s, Okoumassou *et al.*, (1988), indicated that, the expansion of farms into some portion of the corridor both in Ghana and the Togo side of the border was major obstacles to the elephant migration between the two borders. And in less than a decade the studies Bouche, (2007) concluded that the Red Volta Corridor was no longer used by an elephant. He cited human activities such as farming, surface mining, and indiscriminate harvesting of fuelwood, Fulani Herdsman ship, and weak law enforcement as the major cause of elephant absence in the corridor as the corridor was littered with patches of farms Fulani cattle herds, and surface mining activities.

**2.3 Species distribution and corridor modeling**

MaxEnt is a machine learning technique designed to make predictions from uncompleted data. The approach estimates the most uniform distribution (maximum entropy) of sampling points compared to background locations given the constraints derived from the data (Hernandez *et al*., 2006) MaxEnt has great potential in determining the  distributions and habitat selection by wildlife due to its capacity  to work with only presence locations( Baldwin, 2009). MaxEnt has the ability to predict species distribution with certainty with only five locations data, although the more location data, the better the expected accuracy (Maria, 2014)

There are several traditional species geospatial distribution analysis tools designed to make predictions on the relationship between spatial variables and species distributions, with presence-absence data (e.g., logistic regression, discriminant function analysis Genetic algorithm for rule-set prediction (GARP), CART etc. (Baldwin, 2009). However, since the development of MaxEnt in 2004 by Philip *et al*., (2004) its predictive performance is consistently competitive against others models given its capacity to predict with only presence given that most of the time absence data is difficult to come by (Elith, *et al.*, 2006 and Hernandez *et al.,* 2006). Since its development in 2004, MaxEnt has been used extensively in the species distribution, published examples cover diverse situations such as finding correlates of species occurrences, mapping present distributions, and predicting to new times and places across many ecological, conservation and biosecurity applications (Elith *et al.,* 2010). the publications of Ashiagbor and Danquah, 2017 uses MaxEnt in determining Seasonal habitat use by Elephants (Loxodonta africana) in the Mole National Park of Ghana with Vegetation cover, NDVI, Proximity to settlement, water source, Roy et al. adopted a similar technique to connect fourteen protected areas in Orissa by introducing a potential corridor model. Using vegetation map along with an impedance and preference layers as inputs. (Roy *et al.*, in Maria 2014).

To explore anthropogenic and physical factors influence on habitat selection of elephants and buffalo in the Zambezi Valley, Southern African, the probability of elephants and buffalo presence in different land use system were compared using MaxEnt species distribution modeling technique with elephant and buffalo observation data and vegetation cover, distance to surface water, distance to agricultural fields, and terrain slope as an environmental variable. A jack-knife of variable importance analysis was used as a means of illustrating the importance of variables to the model. The AUC of ROC is used as a means of validating the model (Matawa *et al.,* 2012).

**2.3.1 Corridors modeling.**

Corridors are habitat linkages that allow wildlife species to migrate freely from one habitat patch to another. Conservation biologist are of the view that construction of such linkage structures for wildlife between isolated habitat patches could increase or at least maintain flow of gene and possibly mitigate human-wildlife conflict (Green *et al.*, 2018) and crucial to conservation efforts (Liu *et al.,* 2018), particularly for wide-ranging and migratory species such as the African elephant (Loxodonta africana) (Green *et al.,* 2018). It has been an important geographic feature for biological conservation and biodiversity assessment (Vogt *et al.*, 2007). In their study of 2018, Huang *et al*., identified a suitable habitat for Asian elephants using the maximum entropy modeling algorithm (MaxEnt) and illustrated the socio-economic impact of the habitat. Maria, 2014. Also adopted a similar approach together distance least cost path analysis to identify potential elephant corridor between forest patches in Lower Shivaliks area of Uttarakhand.

As it is applied to model wildlife linkages or corridors, 'least-cost distance models assume that organisms have perfect knowledge of the landscape and therefore will choose paths that minimize cumulative ecological cost across the entire path' (wade *et al.*, 2015). The least cost analysis approached is based on the fact that the landscape presents certain barriers or encouragement (Ecological Cost) to wildlife that use the landscape.

Least-cost modeling is a highly versatile, and had been used in modeling of ecological corridors in landscapes (Wade *et al.*, 2015), modeling the spread of some phenomenon from a point, such as animal dispersal distance from their habitat, the spreading of a wildfire (Mitchell, 2012). And it's becoming popular ecological functional linkages due to its availability in most modeling software such as ArcGIS and others (GRASS Available in Development Team, 2016). (Wade *et al.*, 2015).

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1. Study area

The study was conducted in the Red Volta valley (North eastern Ghana), a trans-frontier wildlife corridor that links Reserves in Southern Burkina Faso, Niger, Benin Togo and Ghana.

It is located between Latitude 10º 30′ to 11º 00′ North, longitude 0º 00′ West to 0º 45′, Covering an estimated area of 1,049 km$^2$ (Figure 1).

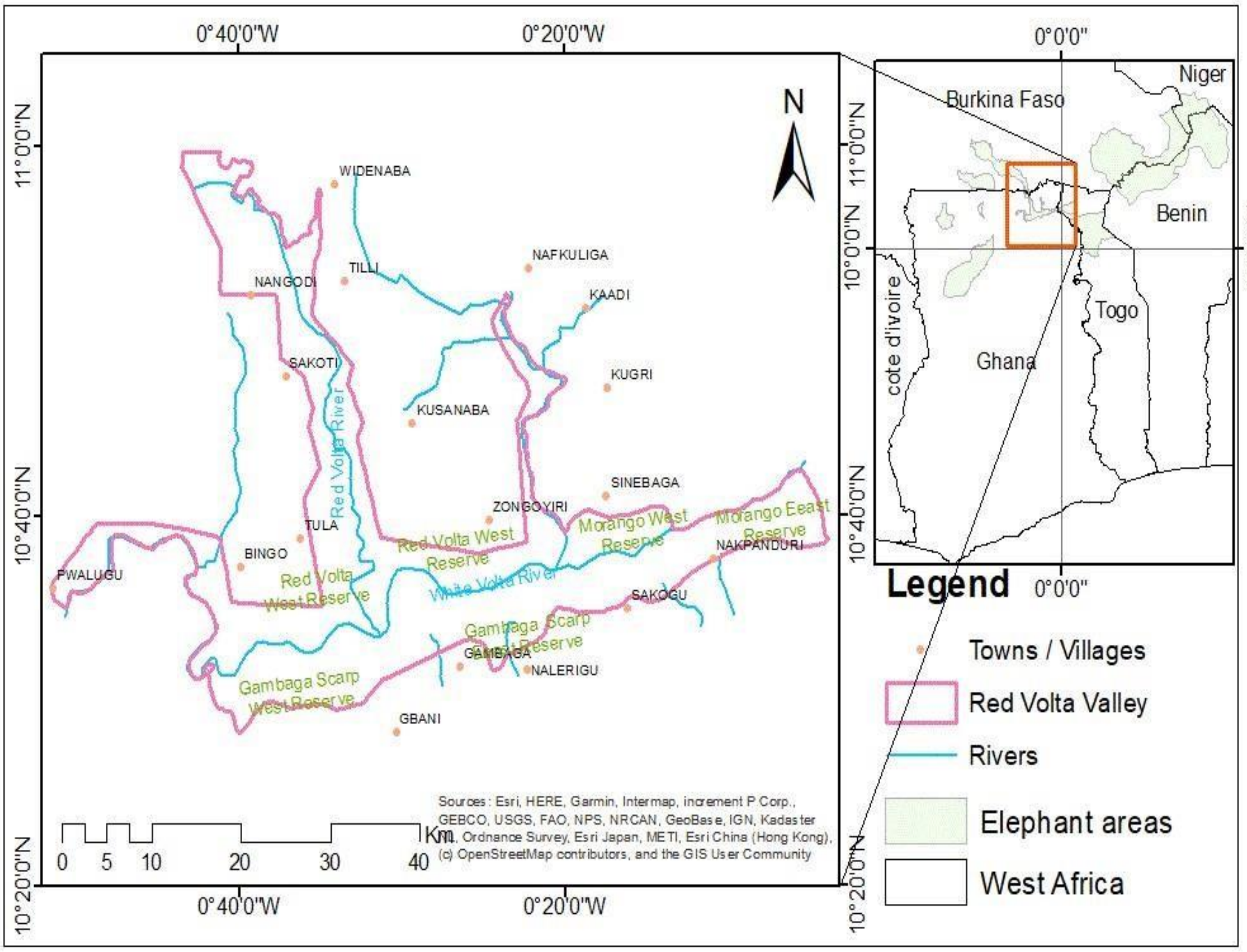


Figure 1: Map of the Red Volta corridor (study Area) showing major roads towns and streams

The Red Volta valley is located in the Upper East Region, the north eastern part of Ghana. It is made up of a network of riverine forest reserves; Red Volta west, Red Volta East, Morago East, Morango West, Gambaga Scarp East, and Gambaga Scarp East Forest Reserves (Adjewodah, 2010). It has two major climatic seasons thus; Rainy season which starts in April or May and ends in October and the cool and hot dry season from November to March. And an annual average rainfall data of between 1000mm to 1100 mm MOFA (2016). The vegetation is described as Guinea savanna (Okoumassou 1999). It consists of deciduous short trees, tall grasses and shrubs (Barnes *et al.*, 2006a). It is home to important economic tree species such as *Vetellaria paradox, Khaya senegalensis Terminalia* Spp, and *combretum Sep*. (pers obs.).

Historically, a good number of wild fauna such as Roan *(Hippotragus equinus*), Kob (*kubus kob*), oribi (*Ourebia ourebi*), bushbuck (*Tragelaphus scriptus*), and Red-flanked duiker (*Cephalophus rufilatus*) were found in the area, although the studies of Okoumassou (1999) recorded the only oribi. The Red Volta corridor also has a fertile soil (Wardell, 2003) perhaps due to its proximity to the three drainage systems; Red, White Volta and Morango River Most recently, the discovery of mineral deposits in the area (per observation). All these factors make it attractive to farmers and small scale miners alike.

### 3.2. Data requirement

Landsat 5 for the epoch 1988 (15-10-1988) was downloaded from (https://earthex plorer .usgs .gov) scenes 194 / 052 and 194 / 053 and sentinel 2B image of October 2018, from (https://scihub.copernicus.eu/dhus/#/home) and used for the analysis of NDVI and LULC classification. Landsat images for the study area for 2018 had high cloud cover and therefore, was not preferred for the analysis NDVI and LULC Classification of 2018. SRTM (DEM) data set was obtained from (https://remotepixel.ca/.) GPS waypoints for elephant presence location, farmlands, mining site, water holes, and rivers were recorded during field survey using handheld GPS. Roads, path, Settlement and water line/ holes shapefiles within the corridor were digitized from google earth and existing shapefile from the Department of Wildlife and Range, GIS laboratory and validated through field visits.

### 3.3. Software requirement

*Table 1: Software requirement and purpose in the study*

| S/N | Software | purpose |
|---|---|---|
| **1** | ArcGIS | Data preparation and creation / digitizing of shapefiles/NDVI |
| **2** | ERDAS | Preparation, classification of images and accuracy assessment |
| **3** | MaxEnt | Model training |

### 3.3. Methods  Flow diagram of processes

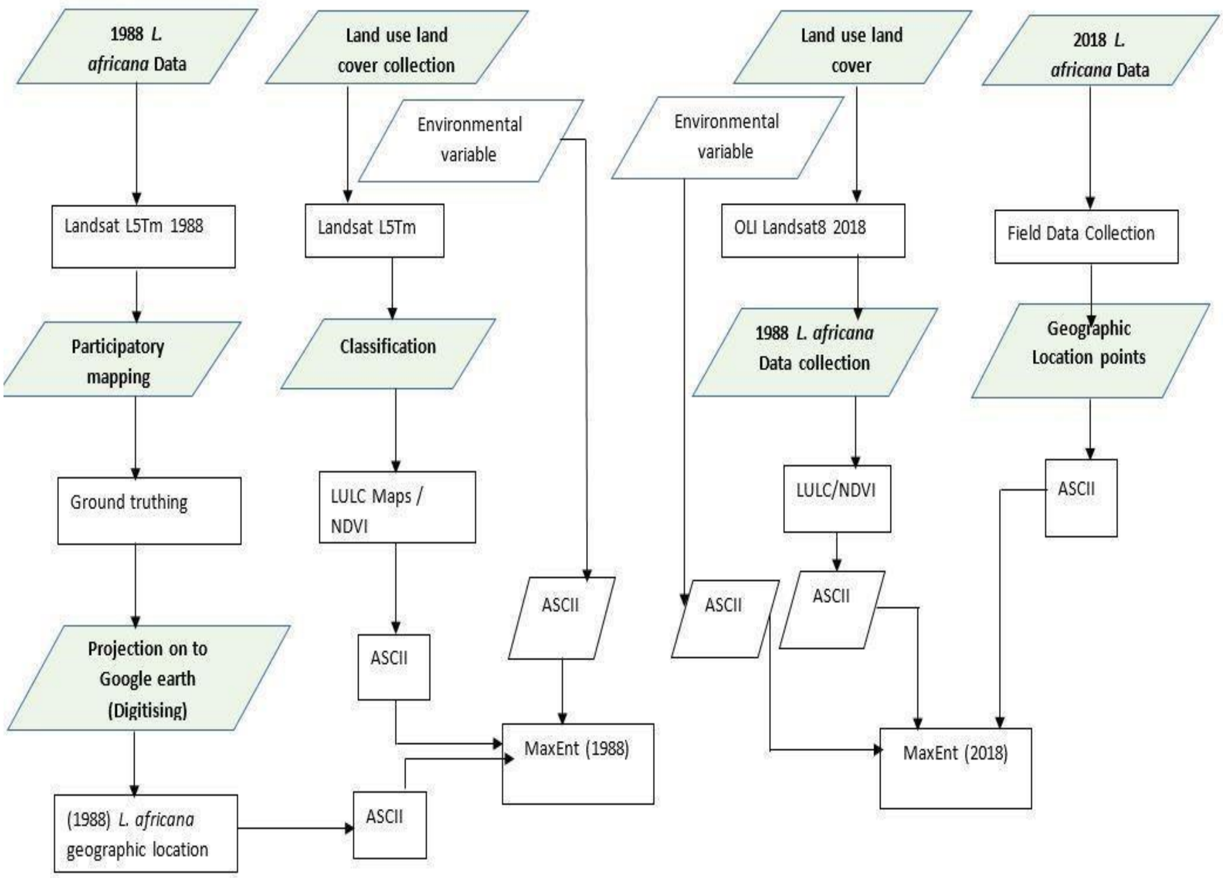

*Figure 2: flow chart of a process for generating L. africana distribution using Entropy algorithm in the Red Volta valley*



The processes of generating a distribution of suitable areas of use (corridor) for *L. africana* is summarised using a flow chart.

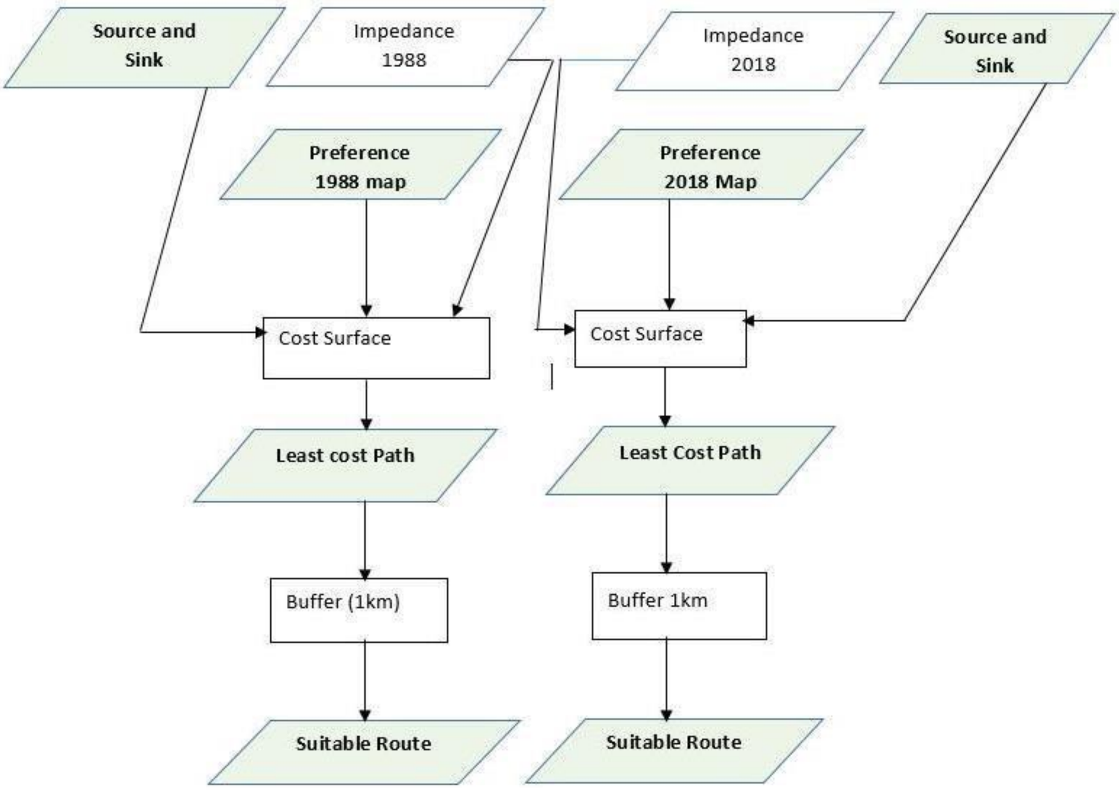


*Figure 3: Flow chart processes summarizing methodology for arriving at design Corridor*

### 3.4 Data Collection

#### 3.4.1. Field Visits

A reconnaissance survey was carried out from the 21st of October to the 1st of November, 2018 to get a good understanding of the study area and to plan the sampling design. The reconnaissance team visited all the different forest reserves that form the study area, following wildlife trails and searching for signs of elephant's presence (i.e. dung piles, footprint, feeding activities, etc.). The reconnaissance team also used key informant interviews and information from farmers and wildlife officers stationed at fringe villages of the forest reserve to access elephant presence location and activities. All elephant activities that were located such as dung pill etc. were marked using a handheld GPS. Other environmental variables such as streams, mining, and farming camp were also recorded at each elephant presence location if possible. The reconnaissance survey provided baseline information on the presence and spatial distribution of the elephant at that period in time. (Figure 4) shows photographs of the field data collection process.

A B **C** **D**

*Figure 4: Photographs of observations at fieldwork, 2018 in the Red Volta valley Corridor, northeastern Ghana.* (**A**) = Elephant raided rice field; (**B**) = Elephants raided rice field; (**C**) =

Elephants dung pile on river bed of the Red Volta; (**D**) = Elephants dung pile

### 3.4.2. Sampling design

The study area was divided into four zones and named upper zone, middle zone, Eastern and western zones based on the reconnaissance survey Figure 5. Longitudinal and latitudinal lines were overlaid on the study area to generate a 1 km square grids, called cells. 15 cells were randomly used for transect in each zone, making a total of 60 transect cells. A GPS was then used to locate each transect cell. A transect line of length 1 km was placed midpoint the cells length and oriented perpendicular to major rivers (Norton-Griffiths, 1978). The transect was walked on and searched thoroughly for elephant presence (direct sighting, footprints, feeding activates, dung pile, etc.) and the location marked with a handheld GPS. Environmental variables such as vegetation type, land use class, conspicuous water channel or any other structure were recorded at each elephant's present location. Secondary data (31 GPS coordinates of elephant's presence location) were also obtained from the Wildlife district officer to supplement the field efforts. 190 ground truth points were also collected for accuracy assessment of the 2018 land used map.

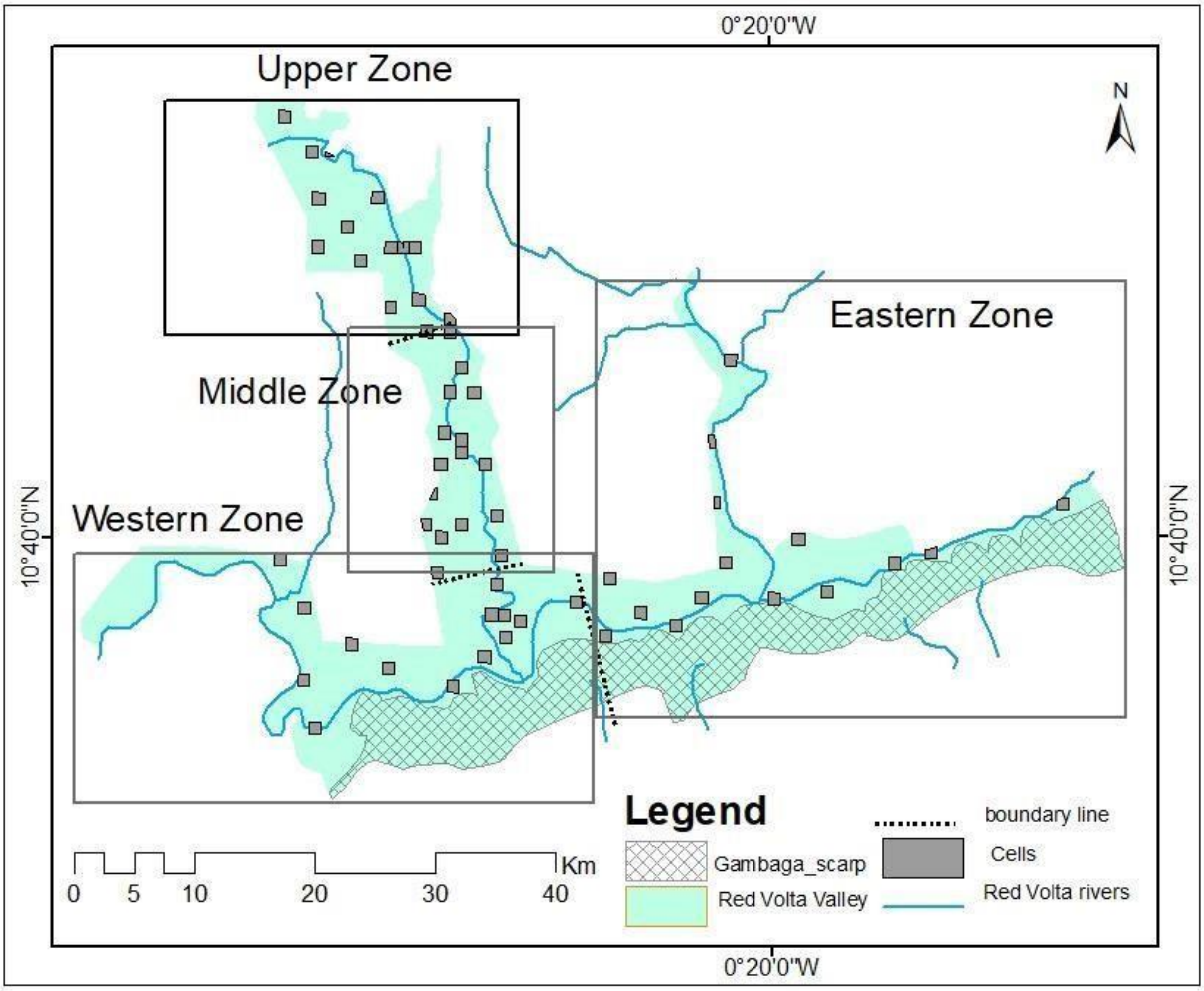


*Figure 5: Map of the study area showing Transect locations and distribution.*

### 3.4.3 Participatory mapping of elephant's location and land use / land cover types for 1988

A community participatory mapping approach (Aswani and Lauer, 2012; Luizza *et al*., 2016) was used to develop land use area maps and to collect data on elephant's presence location (presence location points) for the year 1988, Figure 6 and Figure 7. First, a focus group made up of 5-10 members above the age of 50 years who had engaged themselves in farming, hunting or herding and had lived in each of the six fringe communities since 1988 were organised.

The purpose of the participatory mapping exercise was then explained to them. A base map (satellite image) of the study area was introduced to members of the participatory mapping team and guided to identify landmarks such as Rivers, streams, paths and settlement areas on the map. This was done to allow them to understand the geographic orientation of the base map. In a focus group discussion, guided by a questioner (appendix 7), members were then asked to mark on the base map, areas they once sight an elephants in the year 1988. If participants agree with the position marked by a team member in reference to a known and identified landmark, then the marked point is transferred to google earth base map, Figure 7. These points then serve as a georeferenced elephant presence location for 1988. The same process is repeated for other features such as roads, settlement and water-holes, and land use type. A total of 86 Geographic coordinate locations of elephants were collected through the participatory mapping process and 120 ground truth points also marked for the assessment of the 1988.

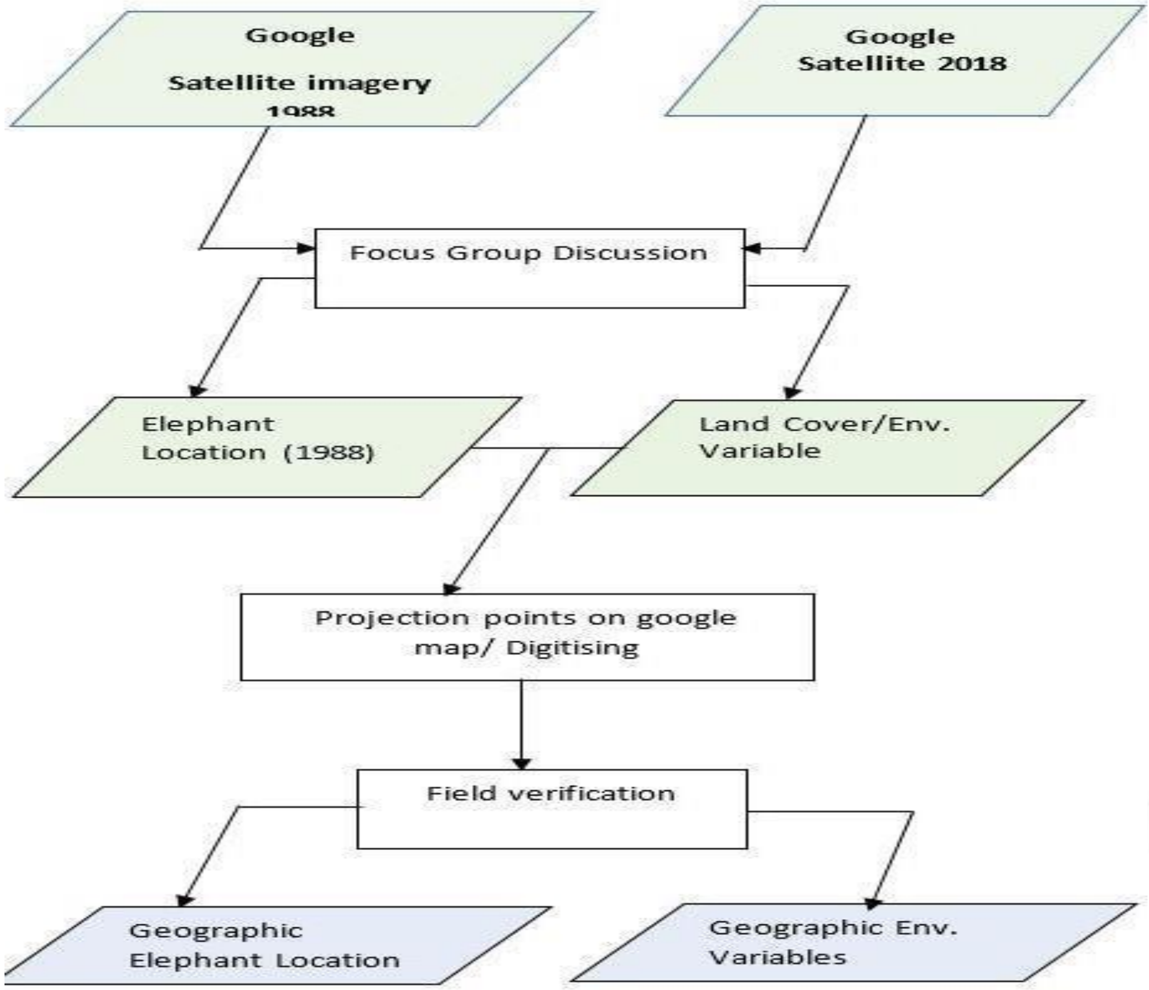


*Figure 6: Flow chart process of generating 1988 elephant and geographic information Red Volta using community participatory approach.*

**A** **B**

**C D**

*Figure 7: Photographs of Community Participatory mapping exercise at fringe communities of the Red Volta valley. (A &B) = Sakote; (C&D) Nangodi*



### 3.5. Data preparation and Analysis

Landsat image for 1988 and 2018 was used for this based cloud perrThe images of the study area were extracted from the Landsat and the Sentinel 2B scenes by subsetting, after stacking, mosaicking, and histogram equalisation. All the dataset were then re-projected to Ghana Metre grid Transverse Mercator. The Resolutions of the DEM and bands (2, 3, 4, and 8 of sentinel 2B data) were resampled to 30m x 30m to keep it at the same resolution with the Landsat datasets. LULC map, NDVI, Slope, Terrain ruggedness Index, Proximity water lines/holes Raster, Proximity to settlement raster, proximity to roads raster were selected as predictive environmental variables based on literature (Ashiagbor *et al.*, 2017; Maria, 2014; Chamaille-Jammes *et al.*, 2007; Xu *et al.*, 2016; Harris *et al.*, 2008).

#### 3.5.1. Land use Mapping

Land use land cover classification scheme of the Red Volta was developed based on a reconnaissance survey and literature from (Basommi *et al.,* 2015). Bare soil/ Build-up, Close savannah open savannah /Agricultural land, Riverine vegetation and Waterbody were identified as the main LULC system in the study area (Table 2). Supervised classification was done (Basommi *et al.,* 2015; Yeboah *et al.,* 2017). And Post classification Change matrix was developed to assess the changes in LULC type. In all, 120 and 190 ground truth points were used for the accuracy assessment of the land used/land cover map of 1988 and 2018 respectively. Kappa statistic were calculated for the accuracy assessment.

*Table 2: Description of Vegetation types in the Red Volta valley Corridor of Northeastern Ghana (2018)*

| Type | Description |
|---|---|
| **Bare soil/ build-up** | This is areas with no vegetation cover or minimum vegetation cover thus barren farmland rocky areas, build-up, etc. |
| **Savanna grassland** | This type of cover is predominantly grass with few scattered trees between 80 to 150 tree population density per hectare |
| **Close Savanna** | This type of cover has a relatively higher tree population density. It has more than 150 trees per hectare |
| **Riverine vegetation** | Relatively thick forest cover at the  edges of water bodies and wetland areas |
| **Water** | This includes rivers, streams, and ponds |

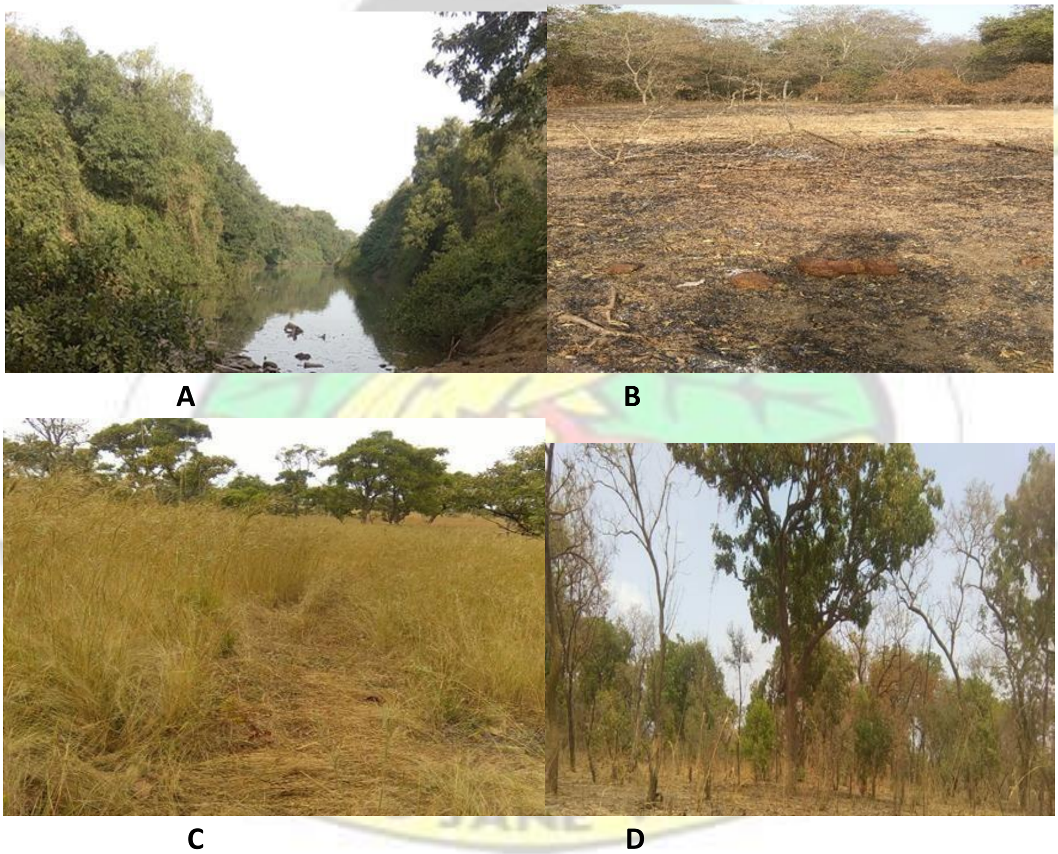


*Figure 8: photographs of vegetation types observed in the Red Volta Valley Corridor, North Eastern Ghana: (A) = Riverine; (B) = Bare Soil; (C) = Open Savannah; (D) = Close Savannah*

### 3.5.2. NDVI Calculations for Landsat $5^{TM}$

NDVI here is considered as a measure of forage quality and availability to the species the in study area (Murwira, *et al*., 2005; Duffy *et al*., 2012 and Bohrer, *et al*., 2014). In deriving the NDVI of the study area, the approaches of Firl *et al.*, (2011) was followed. The Landsat ($L5^{TM}$) image for 1988 was reclassified so that, all 0 DN value is changed to NODATA during the Mosaicking and subsetting process. The DN values are then converted to top of reflectance (TOA) using the US Geological Survey equations (2016) adopted by of Firl et al., (2011)

$$\rho_{\lambda} = \frac{M_{\rho} Q_{cal} + A_{\rho}}{\sin(\theta)} \qquad equation\ 1: Top\ of\ (TOA)\ reflectance$$

Where

$\rho_{L5TMBand\ i}$ = TOA Reflectance for $L5^{TM}$Bandi

$M_{\rho}$ = Reflectance multiplicative scaling factor for the band $\rho_{L5TM}$

= Band4 (0.0025); Band3 (0.0022)

$A_{\rho}$ = Reflectance additive scaling factor for the band

$A_{\rho L5TM}$= Band4 (0.0072); Band3 (0.0046)
$Q_{cal}$= Quantized and calibrated standard product pixel values (DN)

$\theta$ =Local sun angle elevationL5TM = (54.75)

$L5TMBand4 = NIR \quad L5TMBand3 = Red$

NDVI values were then calculated using the TOA reflectance for Band 3 Band 4 using the following formula.

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad \text{equation 2: Normalised Difference Vegetation Index.} \quad \text{(Firl et al, 2011)}$$

### 3.5.3. NDVI Calculations for Sentinel Data

Sentinel 2B/A (Level-1c Product) Data released after much 2018 comes with TOA Calculated values (ESA, 2018)

*NDVI for Sentinel data was calculated using the formula,* $\frac{band\ 8 - band\ 4}{band\ 8 + band\ 4}$ *ESA, 2018 Table 3: Summary Statistics of NDVI Values of 1988 and 2018*

| **Summary Statistics of NDVI Values** | | |
|---|---|---|
| **Values** | 1988 | 2018 |
| **Maximum** | 0.664 | 0.391 |
| **Minimum** | -0.31 | -0.006 |
| **Mean** | 0.434 | 0.193 |
| **Standard Deviation** | 0.083 | 0.032 |

### 3.5.3. Slope, Terrain Ruggedness and Euclidean Distance Raster Calculations

DEM, the extracted DEM of the study area (RVV) ranges from 120 m above mean sea level for most parts of the corridor, and increasing sharply to form a scarp at 532 m above mean sea level towards the southern end the study area 'the Gambaga scarp'. The DEM was resampled to 30 * 30 to ensure that it has the same extent as the other variables selected for the model. Using the ArcGIS Raster conversion tool, the DEM was converted to slope gradient raster surfaces ranging from 0 degrees to 68 degrees. Terrain ruggedness index (TIR) is calculated by first calculating the average, minimum and maximum focal statistic using the spatial analyst neighbourhood toolbox. Then using raster calculator TIR= Average focal statistic (DEM) - minimum focal statistic (DEM) / maximum focal statistic (DEM) + minimum focal statistic (DEM) Riley, DeGloria, and Elliot (1999). Euclidean distance raster was calculated in meters for Roads, Settlement and Waterline from their shapefiles using the Euclidean distance analysis tool in GIS to obtain proximity rasters.

### 3.5.4 Preference and Impedance Raster Calculations

The use of any landscape by wildlife species to extend dependent upon the local environmental factors in the area. Some of the factors are friendly and inviting (preference) others discouraging and obstacle (impedance).A choice on impedance and preference variables for generating landscape 'resistance' in the Red Volta valley is guided by the following literature (Foley, 2012; Wall *et al.*, 2006; Maria, 2014; Ashiagbor, 2017). The preference and impedance rasters (Euclidean distance raster calculated for settlement, roads and river shapefiles, and slope, terrain ruggedness, DEM, LULC ) are then normalised by reclassifying them to between 0 and 1, with 1 being the most preferred suitability value and 0 is the worst preferred suitability value. An analytical hierarchy process (AHP) was done to assign a weight to all variables based on their relative contribution to the models (Appendix 6). A weighted overlay analysis was performed using the raster calculator in ArcGIS to obtain a single raster layer (cost layer).

### 3.5.6. Test for Multi collinearity between Variables

ArcGIS Band Collection Statistics tool in Spatial Analysis Tool Box was used to compute the band covariance matrix of all environmental variables 9 DEM, Slope, Terrain Ruggedness, Land use /land cover maps, NDVI, proximity to water, proximity settlement and proximity to roads) and to check multicollinearity. The strong correlation between variables may violate statistical assumptions which could alter model predictions (Heikkinen and Luoto, 2006; Fourcade *et al.*, 2014).

### 3.5.5. Elephant Habitat use (Distribution) Modeling using MaxEnt

All the Geographic coordinate location of elephant collected as presence data served as input for the MaxEnt Software after converting it into CSV format. The predictive environmental variables, of NDVI, DEM, Slope, Terrain ruggedness, land use Land cover type data, proximity to Waterlines / holes, proximity to roads and proximity to settlement, were all converted into a common extent, projection and saved in (ASCII) file format for the generation the MaxEnt distribution of *L africana*. The result is a logistic response curve and probability map ranging from 0 - 1 representing the presence of the elephant. The probability map was then reclassified to two classes showing presence (suitable) or absent (Not Suitable) map, using 10 percentile training presence logistic threshold value of 0.239 and 0.284 for 1988 and 2018 models respect



**3.5.6. Model Validation**

The binary distributions map suitability and non-suitability were validated using the Area Under the Curve (AUC) of Receiver Operating Characteristics (ROC). The 30% of the presence data that MAXENT set aside was used for validating the model. AUC value >0.9 is considered very a good fit, AUC between 0.7– 0.9 good and AUC less than 0.7 is considered not better than random (Swets, 1988; Van de Pearson *et al.*, 2011).Overall accuracy, sensitivity (Se), specificity (Sp) were used to check model validity.

True skill statistic (TSS), was also calculated to check the model validity. (Allouche, Tsoar, and Kadmon, 2006; Liu, White, and Newell, 2011, 2013). TSS was employed as a second measure of accuracy given that its value is not affected by the size of the validation set and prevalence also, as it combines sensitivity and specificity, both and omission and commission errors are accounted for (Allouche *et al.*, 2006; LI *et al.*, 2016).

**3.5.7 Core habitats and suitable route of elephants (Least cost path)**

To understand the impact of land use/land cover change on elephant use of the corridor, an intersection analysis was performed to identify habitat overlap between 1988 and 2018. And mark out areas that were predicted suitable for used only during the 1988 and 2018 period respectively (Maria, 2014).

A Least Cost path (suitable route), is further generated four times for 1988 and 2018 an intersection the suitable route and land cover map was performed to obtain land use/land cover changes on the paths. To model the least cost path, a preference and impedance raster (Cost layer) were prepared using, Cost distance tool from ArcGIS. Two points source and sinks were selected in areas with high elephants presence probability and closest to ranges (forest patches) in the MaxEnt threshold map. Cost distance is calculated with its backlink using ArcGIS spatial analyst cost distance tool. With the cost layer as 'cost surface' (landscape resistance), source (starting) and sink (destination) points. The least cost path is then calculated by selecting distance raster and its backlink raster in ArcGIS (Arijit *et al.*, 2010). The least cost path is calculated four times and overlaid with the current land use land cover map.

**Statistical Analysis**

To test for significant differences in habitat use by elephants in 1988 and in 2008, Schoener's D and Hellinger's-based I was calculated using ENMTools (Warren, Glor, and Turelli, 2008; Zhang et al., 2014).

A student T-test unpaired two tail test was used to compare the differences between the lengths of the four suitable route and to test for any significant differences between land use/land cover types on the four estimated paths in 1988 and 2018.

# CHAPTER FOUR
# RESULTS

## 4.1 Land cover/land use changes from 1988 to 2018 in the Red Volta Valley

The results of the land use/land cover change map of the Red Volta corridor from 1988 to 2018 is shown in Figure 9. From the maps, the predominant land cover/land use type during 1988 as can visually be observed is open Savannah/ Agricultural land followed by close Savannah and then riverine vegetation. In 2018, open Savannah/ Agricultural continuous to dominate the land scape followed by Bare Soil/ Buil-up and then close Savannah. The results of the areas covered by the various land cover/land use type in 1988 and 2018 is shown in Table 4. From the Table, open savannah/agricultural land occupies the largest area with 636.2km$^2$ followed by close savannah with an area of 155km$^2$ and 141.7km$^2$ of riverine vegetation for 1988. In 2018, open savannah covers 467.1 km$^2$, bare soil/build-up covers 2467.1 km$^2$ whiles close savannah was 207.2 km$^2$. Table 5 shows the land use/land cover change matrix between 1988 and 2018. Prominent among the land cover changes are: Bare soil / Build-up increased from an area of 74.56 km$^2$ to 248.96 km$^2$ representing an increment of 174.4 km$^2$ thus (233.8%). From the cover change conversion matrix, 151km$^2$ of the increment was converted from open savannah, 26.69 km$^2$ from riverine 20.83km$^2$ from closed savannah whiles 7.78 km2 was from the water body.

Closed savannah also increased from 155.9 km$^2$ to 207 km$^2$ representing an increment of 51km$^2$ (32%). From the matrix, 116.7km$^2$ was converted from open savannah or build-up, 33.55 km$^2$ from riverine and 6.89 from bare soil, whiles 2.0 km$^2$ was converted from the water body.

Open savannah declined from 636.2 km$^2$ to 467.1 km$^2$ representing an increment of 169.0 km$^2$ (26.6%). From the matrix, 68.71 km$^2$ was converted to bare soil, 50.38 km$^2$ to riverine vegetation, 22.3 km$^2$ to bare soil and 2.0 to water bodies. Riverine vegetation and water also declined by 55.1 (38%) and 2.3 km$^2$ (8.81%) respectively. Figure 10 shows the changes in LULC types for both 1988 and 2018.

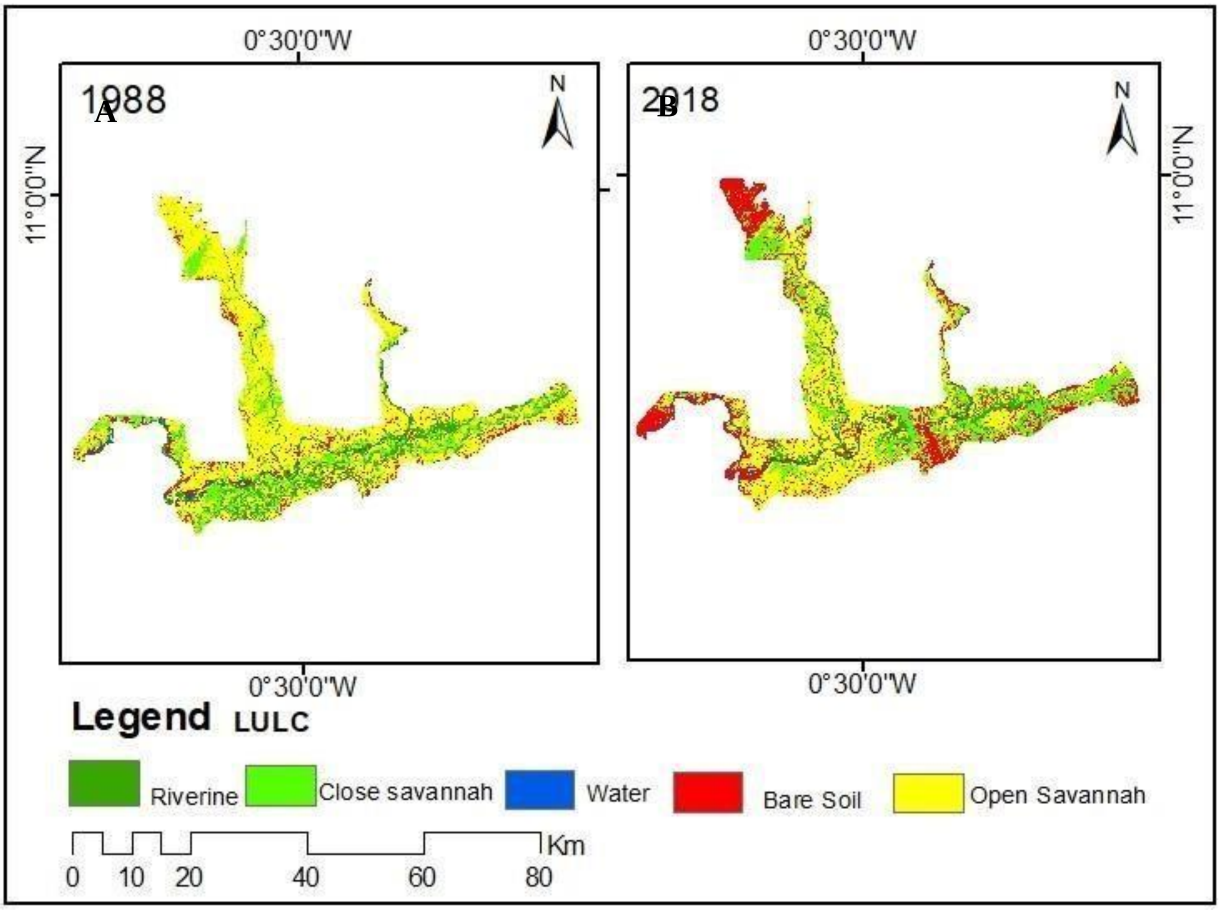


*Figure 9: LULC Map of Red Volta corridor for (**A**) =1988 and (**B**) = 2018*

*Table 4: Results LULC types in the study area for 1988 and 2018*

| | LULC 1988 | | LULC 2018 | |
|---|---|---|---|---|
| **LULC** | Area km$^2$ | Percentage (%) | Area km$^2$ | Percentage (%) |
| **Bare Soil** | 74.8 | 7.2 | 249.7 | 24.1 |
| **Open savannah / G** | 636.2 | 61.5 | 467.1 | 45.2 |
| **Close Savana** | 155.9 | 15.1 | 207.2 | 20 |
| **Riverine** | 141.7 | 13.7 | 86.6 | 8.4 |
| **Water Bodies** | 26.1 | 2.5 | 23.8 | 2.3 |
| **Grand Total** | 1034.5 | 100 | 1034.5 | 100 |

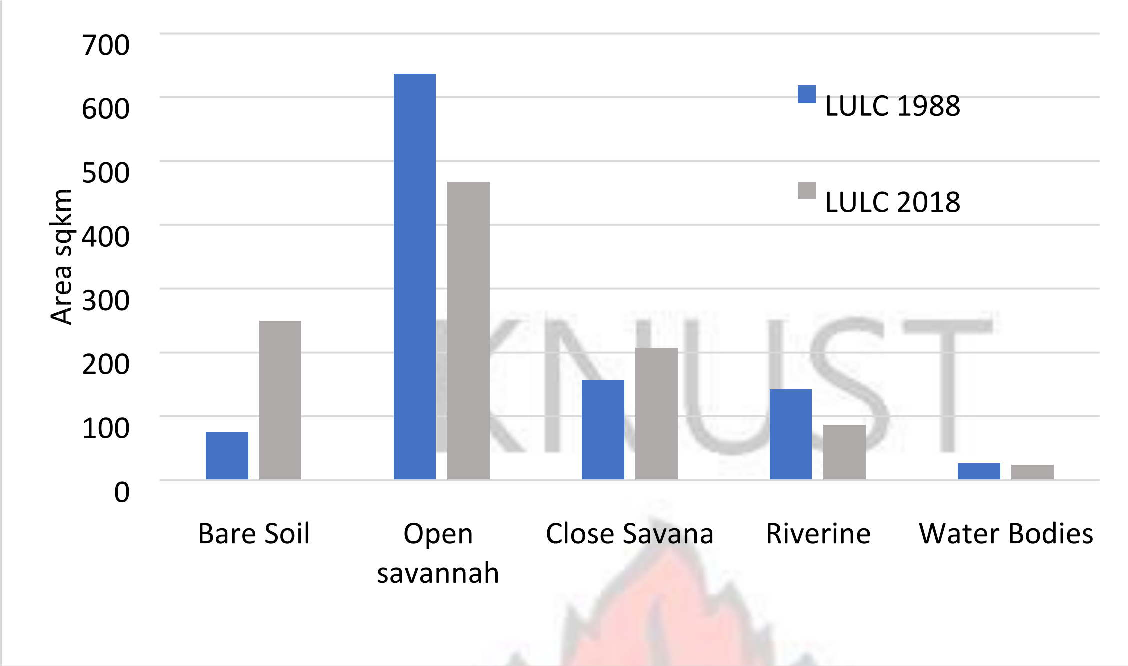


*Figure 10: a bar chart of land use land cover types for 1988 and 2018*

*Table 5: Results LULC type transition from 1988 to 2018*

| | | | **LULC CLASS 2018** | | | |
|---|---|---|---|---|---|---|
| **LULC CLASS 1988** LULC | Bare Soil | Grass/Agricultural | Close Savana | Riverine | Water | Total |
| Bare Soil | **42.31** | 22.31 | 6.89 | 1.83 | 1.22 | 74.56 |
| Open savannah | 151.36 | **322.98** | 116.72 | 41 | 2.81 | 634.88 |
| Close Savana | 20.83 | 68.71 | **49.22** | 15.49 | 1.41 | 155.66 |
| Riverine | 26.69 7.78 | 50.38 | 33.55 | **26.58** | 4.3 | 141.5 |
| Water | 248.96 | 2.01 | 0.53 | 1.67 | **13.63** | 25.62 |
| Total | | 466.4 | 206.9 | 86.57 | 23.38 | 1032.22 |

**Bold** figures = persisted land cover

### 4.1.1 Accuracy Report of the LULC map of 1988 and 2018 respectively

The accuracy report of land cover change for 1988 and 2018 is shown in Appendix 3 and 4. The overall accuracy and kappa statistic respectively for 1988 and 2018 is 83.33%, 78.17% and 80.00% and 74.76%. Accuracy statistics computed for producer's accuracy, user's accuracy kappa statistics for each class is summarised

*Table 6 Accuracy assessment of LULC change classification of the red Volta report for 1988*

**Over All Accuracy = 83.33**

**Kappa Statistics = 78.17**

| **LULC 2018** | Reference Totals | Classified Totals | Correctly Classified | Producer Accuracy | User Accuracy |
|---|---|---|---|---|---|
| **Bare Soil** | 25 | 32 | 24 | 96.00 | 75.00 |
| **Close Savana** | 20 | 17 | 14 | 70.00 | 82.35 |
| **Riverine** | 15 | 16 | 13 | 86.67 | 81.25 |
| **Water** | 15 | 15 | 14 | 93.33 | 93.33 |
| **Open savannah/** | 45 | 40 | 35 | 77.78 | 87.50 |
| **Grand Total** | 120 | 120 | 100 | | |

| **LULC Class** | **Reference Total** | **Classified total** | **Correct number** | **Producer Accuracy (%)** | **User Accuracy (%)** |
|---|---|---|---|---|---|
| **Bare Soil** | **30** | **38** | **35** | **87.50** | **92.11** |
| **Close Savana** | **40** | **32** | **22** | **55.00** | **68.75** |
| **Riverine** | **30** | **36** | **23** | **76.67** | **63.89** |
| **Water** | **30** | **29** | **29** | **96.67** | **100** |
| **Open Savannah/Agric** | **50** | **55** | **43** | **86.00** | **78.18** |
| **Total** | **190** | **190** | **152** | | |

**Over all Accuracy = 80%**

**Kappa Coefficient = 74.76%**

*Table 7 Accuracy assessment of LULC change classification of the red Volta report for 2018*

### 4.2 Results of Multicollinearity Test

The results collinearity among predictor variables using ArcGIS Band collection statistic shows no correlation (r > .8) (Fourcade *et al*., 2014; Jarnevich and Reynolds, 2010) among the environmental variables. Hence all variables were maintained for model training see (Appendix 1) for the report.

### 4.3 Spatial distribution and habitat use of elephants in the Red Volta Valley using Maximum Entropy algorithms.

The results of the final logistic model, threshold to binary predictions of suitable and unsuitable corridor areas of use by *L. africana*, using 10 percent training and sensitivity values are shown in Figure 10 and Table 8. From Table 8. The area predicted suitable for use by elephants in 1988 is 510 $km^2$ which reduced to 355.05 in 2018. Areas predicted suitable in 1988 is 155.51 $km^2$ more than in 2018. The common habitat areas predicted suitable in both 1988 and 2018 is 279.86$km^2$ representing 27%.

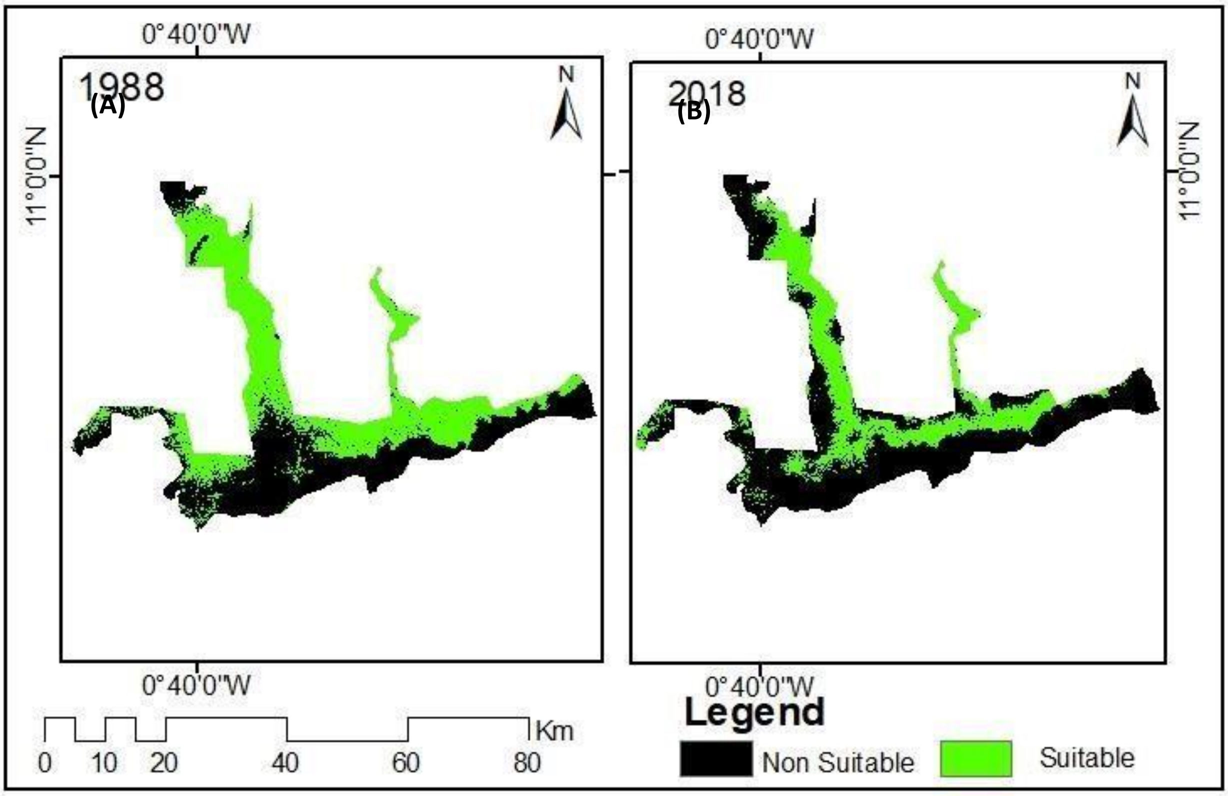


*Figure 11: Binary distribution Map of Savana elephant (L. africana) (A)=1988 and (B)2018*

*Table 8: table Suitable Habitat area*

| MaxEnt distribution Elephant use areas | | |
|---|---|---|
| **Year** | Areas (Km2) | Percentages (%) |
| **1988** | 510.59 | 49.3 |
| **2018** | 355.05 | 34.4 |
| **Intersection** | 279 | 26.3 |

From Table 8, *L. africana* MaxEnt spatial distribution Model of the red Volta Valley was well within the acceptable level as revealed by the mean AUC values of ROC. A mean AUC value of 0.7545 and a standard deviation of 0.023, and a mean AUC Value of 0.7982, and a standard deviation of 0.023 were respectively recorded for 1988 and 2018 year.

*Table 9: Summary of model validation scores on habitat suitability distribution for both 1988 and 2018 period*

| Year | AUC | Overall Accuracy | Sensitivity | Specificity | TSS |
|---|---|---|---|---|---|
| **1988** | 0.755 | 0.524 | 0.881 | 0.521 | 0.402 |
| **2018** | 0.798 | 0.679 | 0.846 | 0.678 | 0.524 |

The relative contribution of the eight predictors (environmental) variables for the elephant's spatial distribution in the RVV corridor by MaxEnt SDM is shown in Appendix 5. DEM, proximity to water lines and proximity to settlement are considered the most significant predictors to elephant spatial distribution in the RVV as of 1988. DEM contributed 40.2%, proximity to water lines 24.5%, Proximity to Settlement 15.8% and the other seven variables contributing a total of 19.5% to the elephant spatial distribution. Also, DEM, Proximity to roads and Proximity to Settlement and Slope shows significant contribution to elephant's distribution in 2018. With, DEM contributed 48.10%, proximity to Roads 18%, Slope 11.8 and Proximity to Settlement 10.1%, the others contributing a total of 12%. Appendix 5 shows the percentage contribution of all environmental variables to the model.

### 4.4 Results of Least cost Path (LCP) (suitable elephant route)

The results of the least cost path generated is shown on Figure 11. The least cost path can visually be seen as a line from Ghana Togo boarder closest to Fossie Lions Park meandering on its way through the banks the white and Red Volta to the Ghana- Burkina Faso boarder.

Table 10 and 11 show the results of the length of least cost path and length of land use/ land cover type for 1988 and 2018 respectively. In 1988, path (3) covers the longest distance with 99.59 km followed by path (4) with 99. 48 km, path (2) and Path (1) is 91.83 and 91.91 km respectively. In 2018 path (3) covers the longest distance with 100.1 km followed by path (4) with 100. Km, path (2) and Path (1) is 92.6 and 92.7 km. Major proportion of the routes both 1988 and 2018 period were largely covered by open savannah/agricultural land followed by close savannah Figure 10 and 11. The paths show the probably suitable routes for the elephant given the challenges presented by environmental barriers and land cover/ land use practices, as the elephant traverses between other forest patches.

**4.5 Results of the Student t-test (unpaired two tail test)**

Results of independent student t-test (unpaired two-tail) show that there are no significant differences between the means of the four least cost paths $p < 0\ 0.456$ at 0.05 confidence level. However, a comparison of the land cover/land use types on the means shows that there is a statistically significant difference between land use land cover types on the suitable route of 1988 and 2018. With $P < 0.0001$ for riverine, $P < 0.0001$ for water, $P < 0.0001$ for Grassland/ agriculture, $P < 0.0004$ for Close Savannah and $P < 0.0001$ for Bare soil. (Appendix 6)

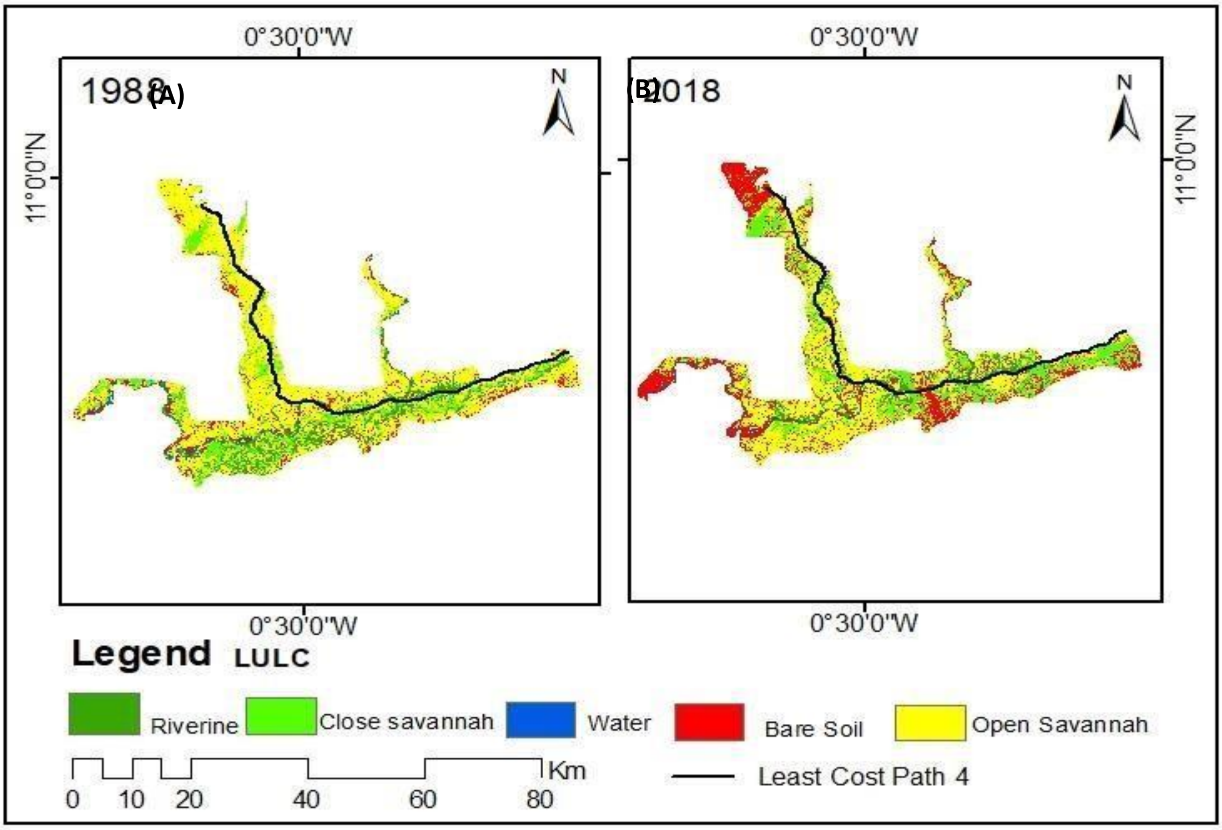


*Figure 12: suitable route for the elephant in (A) =1988 and (B) =2018 respectively*

*Table 10: Changes in LULC types along elephant suitable route (paths in the corridor) between 1988 and 2018 scenarios*

| LULC | Path(1)km | Path(2)km | Path(3)km | Path(4)km |
|---|---|---|---|---|
| **Water** | 1.96 | 1.99 | 2.02 | 2.05 |
| **Bare Soil** | 2.97 | 2.82 | 3.17 | 3.02 |
| **Open Savannah /Grassland** | 53.33 | 51.98 | 60.60 | 59.24 |
| **Close Savannah** | 13.60 | 13.97 | 13.66 | 14.02 |
| **Riverine** | 20.04 | 21.08 | 20.11 | 21.14 |
| **Grand Total** | 91.91 | 91.83 | 99.57 | 99.48 |

*Table 11: LULC type and length of the suitable route through its 2018 scenario*

| LULC | Path(1) Km | Path(2) Km | Path(3)km | Path(4)km |
|---|---|---|---|---|
| **Water** | 4.4 | 4.5 | 4.5 | 4.6 |
| **Bare Soil** | 13.6 | 13.4 | 16.5 | 16.3 |
| **Open Savannah /Grassland** | 42.2 | 40.2 | 46.2 | 44.2 |
| **Close Savannah** | 17.1 | 19.2 | 17.5 | 19.6 |
| **Riverine** | 15.4 | 15.4 | 15.4 | 15.4 |
| **Grand Total** | 92.7 | 92.6 | 100.1 | 100.0 |

# CHAPTER FIVE

# DISCUSSION

## 5.1. Changes in land use land cover from 1988 to 2018 for the Red Volta valley

LULC changes is a global, regional and local environmental issue of concern, including land conversion from one cover to another. Land cover modification through land use practices has greatly altered significant proportions of the earth's surface to satisfy humans' immediate resources needs. (Rahman *et al*., 2012). This phenomenon was equally observed in Red Volta Valley (eastern wildlife corridor)

The Results of the study revealed an increment of bare soil/build-up and open Savannah, close Savannah at the expense of Riverine vegetation, and water from 1988 to 2018. These results can be associated with the increase in human population growth in the corridors catchment area of the corridor. For instance from 1946 to 2003 the population in the region has increased by a factor of 2 with an average population density (excluding protected lands) rise to 126 people per $km^2$ as against national figure of 82 persons per $km^2$ (Wardell *et al.*, 2003) and the fact that about 80% of the population are subsistence farmer (Sarpong, 2001). Also, the cultural farming practices of the areas, thus ploughing the land bare and removing tree covers to open-up crops to sunlight encourages degradation of the soil (Baatuwie, 2015).

The forestry commission policies with regards to the management of the area also led to increasing human activities (cultivation) in the reserve. For instance, the forestry service division introduced a Taungya farming System in the area. By this system farmers were given plots of land in degraded parts of the reserve to cultivate food crops in exchange for caring for newly planted tree seedlings among their crops, the idea was that, as the trees mature, and the canopy closes, farmers will be facing out.

These results also agree with the findings of Boatin *et al*., (1997) who noted significant changes in the forest cover of some part of the Red Volta Valley (Biung, a village along the southwestern boundaries of the study area). And similarly attributed it to an increase in human population in the area resulting from an influx of ‘galamsey’ (surface mining) miners since 1995. He also noted that, ten thousand prospectous have occupied temporary settlements south of Datoku a fringe community in the western border of the reserve.

In his survey of elephant population, Bouche, (2007) asserted human activities such as Agricultural cultivation, farm and mining camps, surface mining, wood logging, and bushfire had left the corridor degraded and no longer support elephant use.

Also, Baatuuwie, (2015) 'multi-dimensional approach for evaluating land degradation in the savanna belt of the White Volta basin White Volta basin' which covers the study area. Confirms degradation of the as a result of Basin result pressure on the land, bad farming practices, logging, bush burning and surface mining.

It is important to note that the current levels of vegetation cover loss will seriously impact on elephant use of the corridor because, trenches and tunnels that are left after mining activities pose serious health risks and impedance to elephant movement. The elephant has been reported in literature to avoid rugged terrain and trenches due to risk to injuries and to maximize their energy use (Youngpoy, 2012; Ashiagbor and Danquah, 2017) due to their body size.

Young trees and Shrubs are important dry season fresh forage for elephants while they feed on grasses during the wet season (Sukumar, 1990). However, annual wildfire during the dry season in the Red Volta Valley, completely burns grasses leaving the ground bare. A prolonged and repeated occurrence of wildfires may also lead to vegetation shift towards fire-resistant plants species and which may not be good fodder for elephants (Lenin and Sukumar, 2011). Limited vegetation cover also exposes elephants to the risk of poaching since poachers can easily be track and spotted even at a farther distance.

Afforestation project that was carried out in the 1970s, by the Forestry Department now called Forestry Services Division in degraded areas of some forest reserves and the re-introduced Taungya System in 2002 (Adjewodah *et al*. 2003 in Adjewodah 2010) may have also accounted for the increase in close savannah. The forest species that were planted were exotic types as a result, local dwellers were not logging for fuelwood.

## 5.2. Elephant spatial distribution and landscape use

Elephant spatial distribution and landscape use are driven by biophysical and anthropogenic factors within the locality (Mukeka, 2010; Jathanna *et al.,* 2015; Xu *et al.,* 2016). This study modeled the spatial distribution and habitat use of *L. africana* keeping in mind the impact of land use land cover change in the Red Volta valley (Red Volta corridor) from 1988 to 2018 using Maximum Entropy algorithms. The habitat suitability analysis revealed a decrease in the spatial distribution of suitable habitat for the elephant from 510.59 $km^2$ in 1988 to 355.05 $km^2$ 2018, a decrease in habitat size of 155.54$km^2$ (15%) of the total corridor in just 30 years. In comparison with the maximum home range (40km) of the savannah elephant (Leuthold and Sale, 1973; Schlossberg 2018) the observed difference is significant. A measure of habitat overlap (276.  $km^2$) representing 26.8% between 1988 and 2018 habitats was observed with (Schoener's D = 0.924 and Hellinger's-based I = 0.719).

The decreased in habitat size (Table 5) may be attributed to the loss of forage, water bodies and vegetative cover resulting from anthropogenic activities. As the core habitat the (overlapping areas) visually, is positively correlated with water line and highly productive vegetative zones in the generated model, (Figure 9) agreeing with the findings of Rood and Ganie (2010).

Proximity to a water source is reported in several studies as environmental variables that determine elephant habitat selection (Ashiagbor and Danquah 20017; Cushman, Chase and Griffin, 2005). In this study water availability significantly determines the distribution of elephants. The Red Volta corridor, as the name clearly suggests drains into two main tributaries of the Volta River; White Volta and Red Volta with a network of other streams like the Tamde and Morango stream. These network of river bodies forms relatively thicket of savannah forest with fresh vegetation ideal for elephant use hence the predicted suitability areas of use was observed to positively correlate with permanent water bodies and quality vegetation for forage. Similar to the findings of (Cushman *et al.*, 2010; Van de Perre *et al.*, (2014).

According to Western, (2006) vegetation changes in landscape particularly for a long period of time significantly reduces habitat diversity and impact greatly on large mammal diversity, with an abrupt decrease in browsing ungulates and large mammal species. Ottichilo, (2000) also noted that agricultural expansion in the Sai Mara National Reserve, coupled with drought significantly reduces wildebeest range and their population by 81% while resident zebra population by declined by 50% facts that can be applied to the Red Volta wildlife corridor. The studies of Bouche, (2007) in the Red Volta earlier question the integrity and the ability of the Red Volta Corridor to serve as an elephant migratory route a fact that is supported by this study.

Elevation and proximity to Human settlement were other major predictive variables in the model. DEM showed a single maximum individual contribution of (48%) and (40%) in predicting elephant distribution in 1988 and 2018 model respectively with Terrain ruggedness contributing the least to the model as shown in the jackknife analysis of regularized training and test gain graph appendix I. According to the studies of Ochieng (2015), Ashiagbor and Danquah (2017) elevation on restricted elephant use of landscape, Ashiagbor and Danquah (2017) noted that elephant distribution in the Mole National Park of Ghana was strictly restricted to the lower elevation of between 121.9 and 192.2 m within flat terrain. In the Red Volta valley, the effect of DEM on the model was pronounced due to the very sharp difference in DEM within the study area creating a steep slope of up to 68 degrees towards the southern end of the corridor. This restrains elephant movement in the areas (corridors) to a narrow strip of low flat terrains along the edges of the main rivers where the elevation of the area was between 120 and 270m above sea level and forms flat terrains with gentle Slope of <10° for both the 1988 and 2018, similar to the studies of (Douglas-Hamilton, and Vollrath 2006; Ashiagbor and Danquah, 2017).

The effect of settlement in predicting elephant distribution in the Red Volta Valley was minimal in contrast to the observation of some scholars (Lee and Graham, 2006)

Terrain ruggedness and proximity to the road did not minimally to elephant distribution in the Red Volta valley because the terrain was generally flat except some few areas in high elevated areas. Also, highly rugged terrain areas occurred on the high elevated areas that were excluded from the model.

**5.3 Least cost paths (suitable route) of an elephant in the Red Volta valley for 1988 and 2018**

The least cost paths can visually be seen restricted into the narrow valley through areas with high vegetative productivity, along the banks of the main rivers (White Volta, Red Volta and the Morango River), sometimes crossing rivers and streams in the study area, depicting the description of (Jackmann, 1988; Sam 1994 and Sam *et al*., 1996) elephant route in the area.

A student t-test comparison between the least cost path of 1988 and 2018 shows that, there is no significant difference between the mean lengths of the paths $p<0.456$. However, it showed statistically significant differences between the means of the land use/land cover types of four least cost paths $P < 0.0001$ for riverine, $P < 0.0001$ for water, $P < 0.0001$ for Grassland/ agriculture, $P < 0.0004$ for Close Savannah and $P < 0.0001$ for Bare soil/build-up at 95% confidence level. Hence the hypothesis that, there is no change in the most suitable path used by elephants from 1988 to 2018 is rejected.

This result agrees with the findings of (Sam *et al* 1998; Bouche 2007; Adjewodah, 2010) on land use /land cover changes observed in the study area. Attributable to the increased in agricultural activities, surface mining and bushfires in the area. The results also confirms (Baatuuwie, 2015) regional scale 'Multi-dimensional approach for evaluating land degradation in the Savanna belt of the White Volta Basin' which confirmed that the White Volta basin and its catchment areas face persistent problem of soil loss and land degradation resulting from extensive agricultural cultivation, wood harvest surface mining and charcoal burning. He stated that, 82% of the basin is degraded due to negative land use/cover conversion and 33% of the basin's landscape is experiencing severe degradation and soil loss.

The contrasting statistical difference observed between the land use/land types and the average lengths of the paths may confirm the notion that, elephants show a strong attachment to certain localities that prevent them using other areas even if there are better resources there than their present habitat (Lunstrum, 2010). This explanation, more or less agrees with the hypothesis stated by Laws, (1969) that, elephant population in the Tsavo national park were subdivided into 'unit populations' occupying discrete areas and undertaking seasonal movements only on limited.

Other scholars have also acknowledged the intellectual ability of the older mother elephant (matriarchs) to memorise details of features, events and historic route and can also recall places where there is better resources and water in the past, an instinct that partially guides their path selection on the occasion of migration (Van Moorter *et al.*, 2009).

It is also suggestive that elephant may be able to compete with humans and other animals for space and resources although available literature has shown that elephant avoids human activity areas due to perceived risk of human confrontation and poaching as they are reported to adopt to speedy movement strategy whiles using suspected human activity areas or exposed landscape such low covered vegetation types. (Lara, 2002; Douglas-Hamilton *et al*., 2005; Douglas-Hamilton *et al.*, 2009).

The impact of land use /land cover change on the savannah elephant stems from the loss of habitat resources as a result of increasing agricultural lands wildfires and surface mining. Agricultural activities fragments elephant habitat by divides the landscape space into different discontinues units thereby impeding elephant movement as well as reducing the total range size. Apart from reducing elephant habitat, the notorious crop planted on agricultural lands is attracted by elephant resulting in an increase in human-elephant conflicts where both elephant and farmers at risk of serious mortality. Continuous cropping in the area which practice in the (Wood, 2013) also impacts negatively on the soil fertility reducing its ability to support plant growth. Cattle rearing which also characterizes in the study area (Bouche, 2007) also threatens elephant use of the habitat as they compete with the elephant for resources such as forage and water

Wildfires set by farmers and hunters have contributed to significant loss of elephant browse in the corridor (Adjewodah, 2010) and subsequently reducing elephant population (Bouche, 2007). Apart from destroying elephant browse, wildfire renders the land incapable of supporting tree/plant growth, it reduces the soil fertility by consuming a commutated litter that would have decomposed and nutrients to the soil. Especially when it occurs for a long period of time.

Surface mining leaves trenches on the landscape that impedes elephant movement. Also, surface mining removes the landscape of its cover exposing the land to agents of erosion and subsequently resulting in the degradation of the habitat.

# CHAPTER SIX

# CONCLUSION AND RECOMMENDATIONS

## 6.1 Conclusion

The Red Volta Valley (eastern wildlife corridor) was gazetted as a biodiversity and wildlife corridor. However, as the population in the catchment areas grows, demand for agriculture land, settlement and other human immediate needs increases, forcing human encroachment into the corridor. This has, however, caused changes in the landscape of the corridor posing questions on the integrity of the corridor as a wildlife trans-frontier migratory route. This ignited the desire to assess and determine the land use /land cover changes and spatial distribution of elephant in the Red Volta corridor from 1988 to 2018 as well as generate elephant most suitable migratory path using the least cost path analysis algorithm. This allows for the identification of those land use system that interferes with elephant movement.

From the results of the spatial distribution map of the elephant, suitable areas of use as a corridor have significantly decreased by 15% of the total corridor size, thus from 151.36 $km^2$ to 355.05$km^2$. And 279.86$km^2$ was also observed to have persisted since 1988 as a suitable habitat (core habitat). The observed core habitat and suitable areas of use were positively correlated to proximity to a water source, low elevation of less than 20ms below sea level and the gentle slope of fewer than 10 degrees.

The reduction in the suitable areas is attributed to the land use/ land cover conversion observed in the area. Some of the significant land cover/land cover transformation that has taken place in the landscape of the Red Volta corridor since 1988 are; open savannah reduced by 26.6%, riverine vegetation by 38.9% paving way for an increase in bare land by 233.8%. Although there was a slight increase in close savannah by 32.9%. This was a result management program in the form of afforestation that was implemented to revegetate the barren land.

There was also some significant land use /land cover changes on the along with the most suitable route use by elephants in the corridor since 1988.

**6.2 Recommendation**

Evidence gathered from the field survey indicates few number of law enforcement officer stationed at the area hence they are unable to effectively enforce the protection of the area. As several of cultivation field, surface and alluvial mining temporal and permanent human residential camps were observed in the study area. Wild bush fires and farming on the banks of the rivers was also persistent. Therefore, it is recommended that management should provide enough law enforcement staff to end the menace of these illegal activities and ensure that, there is strict protection of the Red Volta valley and its resources.

It is also recommended that there should be a development and implementation of a community resources management strategy that will include training local community members on best elephant deterrent methods so as to be deployed in their farms to help minimize elephant cropraiding and as well as reduce HEC.

The status of the Fossie Lions Park in terms of elephant occupancy in Neighbouring Togo is unknown. Therefore, studies that will unravel the status and potential of the Fossie Lions Park in serving as a transit corridor to the W Complex Park is recommended since information on the status of this park is relevant in the management strategies of its adjoining Red Volta Valley

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## APPENDICES

### Appendix 1: Collinearity between predictor variables

| | | | |
|---|---|---|---|
| Var2 | -0.07455 | | |
| Var3 | -0.01478 | -0.23549 | |
| Var4 | -0.08767 | 0.49549 | -0.03485 |

| layer | Var1 | Var2 | Var3 | Var4 | Var5 | Var6 | Var7 |
|---|---|---|---|---|---|---|---|
| Var5 | 0.00602 | 0.01968 | 0.24732 | -0.05484 | | | |
| Var6 | 0.01673 | 0.25555 | -0.07509 | 0.12516 | 0.07767 | | |
| Var7 | -0.02523 | 0.18493 | -0.07281 | 0.00544 | 0.00447 | 0.01054 | |
| Var8 | -0.14515 | 0.17144 | -0.17468 | 0.03496 | -0.00897 | 0.17259 | 0.03210 |



Var1, LULC; Var2, DEM; Var3, Proximity to Settlement; var4, Proximity to River; Var5, Proximity to Roads; Var6, NDVI; Var7, Terrain ruggedness, Var8, Slope.

**APPENDIX 2: AHP for assigning a weight to environmental variables employed in the landscape suitability analysis of the Red Volta Valley**.

| Variables | Weight Assign (%) |
|---|---|
| Proximity to settlement | 6 |
| Proximity to roads | 5 |
| Proximity water | 28 |
| Ruggedness | 11 |
| Slope | 8 |
| NDVI | 15 |
| LULC | 7 |
| DEM | 20 |
| **Total** | 100 |

**Appendix:3 Percentage contribution of to SDM 2018 and 1988 respectively**

| **Variable** | **2018 Contributions (%)** | **1988 Contributions (%)** |
|---|---|---|
| **DEM** | 40.2 | 48.1 |
| **Proximity to water** | 24.5 | 24.5 |

| | | |
|---|---|---|
| **Proximity Settlement** | 15.8 | 10.1 |
| **Proximity roads** | 7.9 | 18 |
| **Slope** | 7.6 | 11.8 |
| **LULC type** | 2.6 | 5.7 |
| **NDVI** | 0.9 | 1.8 |
| **Terrain ruggedness** | 0.5 | 2.1 |

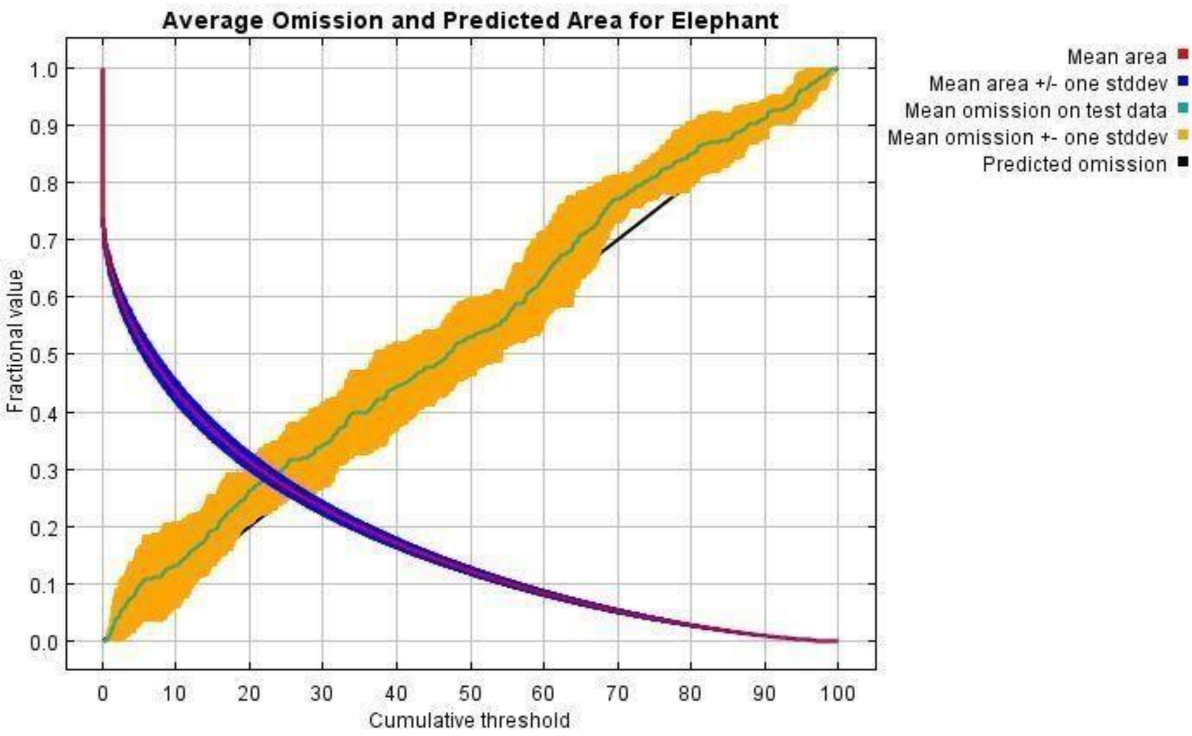


**Appendix 4. Summary Table of unpaired student t-test (two tail) for land use/ land cover on Suitable Paths 1988 and 2018**

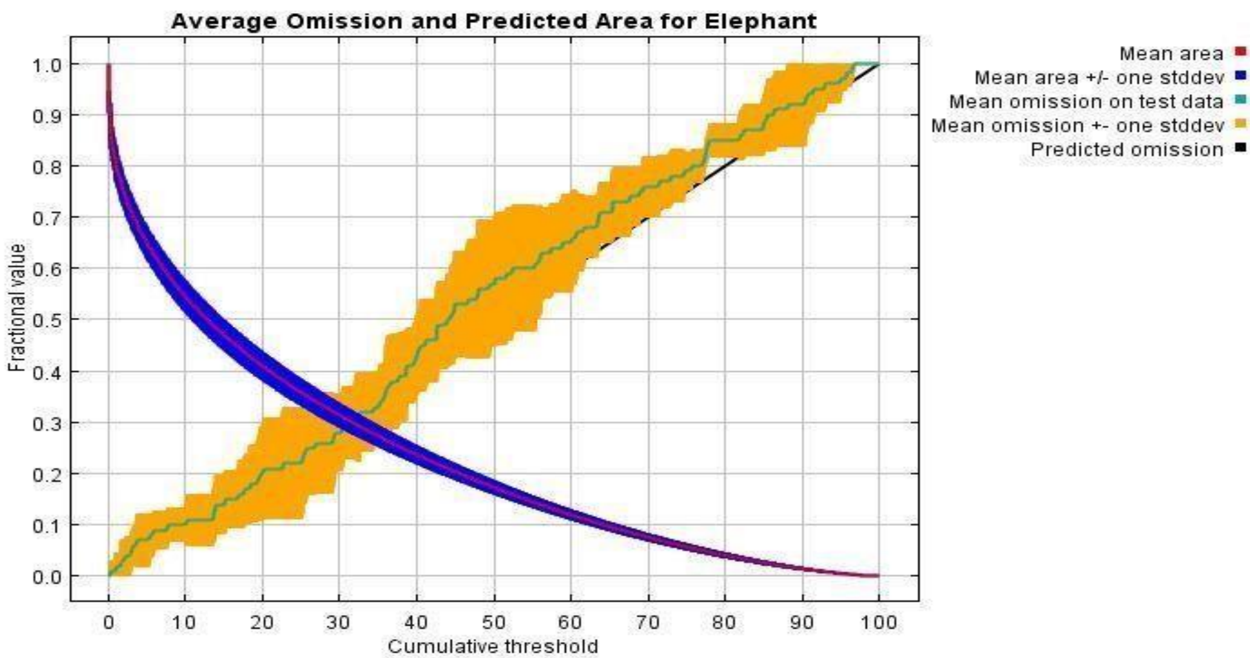
**COMPARISON OF DIFFERENCE BETWEEN LAND COVER TYPES OF 1988 AND 2018 USING UNPAIRED 'TWO TAIL' T-TEST**

| **Land cover Type** | Riverine | Water | Savannah Grassland | Close Savannah | Bare soil |
|---|---|---|---|---|---|
| P value | P<0.0001 | P<0.0001 | P<0.0001 | 0.0004 | P<0.0001 |
| P value summary | *** | *** | *** | *** | *** |
| Are means signif. different? (P < 0.05) | Yes | Yes | Yes | Yes | Yes |
| t | 17.37 | 55.22 | 17.08 | 7.246 | 14.19 |
| Df | 6 | 6 | 6 | 6 | 6 |
| R squared | 0.9805 | 0.998 | 0.9799 | 0.8974 | 0.9711 |
| **F test to compare variances** | | | | | |
| F | 143.4 | 4.444 | 11.95 | 33.54 | 135.2 |
| Df(1988) | 3 | 3 | 3 | 3 | 3 |
| Df(2018) | 3 | 3 | 3 | 3 | 3 |
| P value | 0.002 | 0.252 | 0.0711 | 0.0166 | 0.0021 |
| P value summary | ** | ns | ns | * | ** |
| Are variances significantly different? | Yes | No | No | Yes | Yes |

**Appendix 5. Omission and predicted areas for Elephant 1988 scenario**




**Appendix: 6 Omission and predicted areas for Elephant 2018 scenario**



**Appendix: 7**

**Community focus group discussion and interview protocol on deforestation elephant migration in the red Volta range**

Date: ……………………..

Name of community:………………………………………………………………………………………………………………….

Focus group list and age bracket:………………………………………………………………………………………….

Name of Interviewer:……………………………………………………………………………………………………………….

Place of interview:……………………………………………………………………………………………………………………..

**Elephant migration**

Occupation of informant (possible responses: fishing, herdsman, mining):………………………………..

Are there elephants in this forest throughout the year? (yes/No). Which period of the year are they available?……………………………………………………………………………..

Describe all encounters with elephants in this area during the last two years, starting with the most recent observation:

| Observ. No: | Year & Month | Numbers of elephant: | | | | | | Direction | | Duration of stay |
|---|---|---|---|---|---|---|---|---|---|---|
| | | M | F | Y | Unknown | Total | Location | From | To | (days) |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |

Notes: Obs
#1:…………………………………………………………………………………………………
……………………………………

Notes: Obs
#1:…………………………………………………………………………………………………
……………………………………

**Deforestation**

1. How long have you lived in this community?

……………………………………………………………………………………………………

2. Do you know of any forest in this area? (Yes/No)

3. If yes have you noticed any changes in the forest cover from 1988 to 2018? (Yes/ No)

4. If yes, what changes have you observed?

………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………

5. What was the forest in 1988?

………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………

6. What is the current forest cover?

………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………
…………………

7. From which year did you notice that the forest cover was changing?

………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………

8. What is responsible for the changes you have noticed?

………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………

9. Can you mention some of the tree species contributing to the changes observed?

…………………………………………………………………………………………………………

…

…………………………………………………………………………………………………………

…………………………………………………………………………………………………………

…………………………………………………………………………………………………………

10. If there have not been any changes, why do you think this area has remained the same whiles other areas are changing?

…………………………………………………………………………………………………………

…………………………………………………………………………………………………………

…………………………………………………………………………………………………………

…………………………………………………………………………………………………………



**APPENDIX 10: Photographs of field observations, taken during field survey 2018**


C D

**E**

**F**

**H**

**I**

**I**

**I**

**J**


**APPENDIX 5: Photographs of human activities in the Red Volta Valley Corridor, northeastern Ghana taken during the field survey. From 21st September to 28 January 2019.**