



Brandenburg  
University of Technology  
Cottbus - Senftenberg

## **PhD THESIS**

# **The effects of habitat heterogeneity and human influences on the diversity, abundance, and distribution of large mammals: the case of Deng Deng National Park, Cameroon**

A thesis approved by the Faculty of Environmental Sciences and Process Engineering at the Brandenburg University of Technology in Cottbus-Senftenberg in partial fulfilment of the requirement for the award of the academic degree of Doctor of Philosophy (Ph.D.) in Environmental Sciences.

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Brandenburg  
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## **DOKTORARBEIT**

# **Die Auswirkungen von Habitatheterogenität und menschlicher Einflüsse auf die Vielfalt, Dichte und Verteilung von großen Säugetieren: der Fall Deng Deng National Park, Kamerun**

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## **Declaration**

I, Mercy Nambu Diangha hereby declare that this PhD thesis is the result of my personal academic research effort carried out within the structured PhD programme Environment and Resource Management, offered at Brandenburg University of Technology Cottbus-Senftenberg, Germany. Neither this thesis nor any part of its content has ever been submitted to any examination committee for the award of any academic qualification. Secondary sources used in this thesis are acknowledged and have been cited accordingly.

Mercy Nambu Diangha \_\_\_\_\_ Cottbus, \_\_\_\_\_ 2015

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## **Dedication**

*All Glory belongs to you oh Lord!*

This thesis is dedicated to my dearly loved children Frank Kafain Diangha and Matthew Diangha Young who remain my firm source of inspiration, and to my father Thomas Tingem Diangha and siblings Irene and Gabriel who went home to be with the Lord.



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## **Abstract**

Large mammals constitute an integral part of biological resources, and hence fundamental elements in many ecosystems. In view of the roles played by habitats and humans in structuring large mammal populations, research was conducted in the Deng Deng National Park, with the aim to identify and characterize the spatial and temporal patterns of habitats, determine the relationship between habitat heterogeneity and mammal abundance and also to investigate the types and extent of human pressure on various large mammal species in the park.

Distance sampling technique and kilometric index analyses approaches were applied to determine species presence, frequency and abundance, with dung, nests, and tracks used as proxy for species presence. Using a spatio-temporal analysis approach in Geographic Information System, species distribution was analyzed. Small and medium sized duikers, red river hog and gorilla were most frequently encountered. Important is the record of elephant for the first time in the park, emphasizing the importance of the park for large mammal conservation.

Diverse land cover types that constitute habitats for flora and fauna were distinguished and characterized as dense forest, mature secondary forest, young secondary forest, tree and grassland savanna, settlement and degraded areas, and water bodies. Area, mean patch size, shape, density and richness metrics of these land cover types varied, emphasizing the heterogeneity of the park landscape. No significant differences ( $0.2 \leq p \leq 0.8$ ) were observed in species abundance due to diverse habitat characteristics in the park. Species exhibited generalist habits with preference mostly for the dense and mature secondary forest habitat types. Temporal pattern over a 23 years' time lag projected a 6.19 % increase in dense forest cover, suggesting future shelter opportunities for large mammals in the park.

The park is experiencing threats that are changing the physical environment in simple and reversible manner but also threats that have changed the parks environment in permanent ways; all from impacts of adjacent human settlements and development activities. Generally, species abundance was significantly high ( $p = 0.03$ ) in habitats where threats encounter rates were low, and low in habitats affected by high human activity; a clear indication that these activities have eventually created depressing effects on the habitats of large mammal species in the park.

Actions aimed to limit human activities around the park, and aiming to sustain the large mammals and their habitats, especially within the hotspots identified in this study, are therefore proposed to ensure a more sustainable future for large mammals in the Deng Deng National Park.

**Keywords:** Large mammals, habitat heterogeneity, human influence, Deng Deng National Park, Cameroon

## **Zusammenfassung**

Große Säugetiere bilden einen integralen Bestandteil der biologischen Ressourcen und sind daher ein wichtige Elemente in vielen Ökosystemen. Angesichts der Bedeutung, die Lebensräume und Aktivitäten der Menschen bei der Strukturierung großer Populationen von Säugetieren spielen, wurden im Deng-Deng-Nationalpark Untersuchungen mit dem Ziel durchgeführt, die räumlichen und zeitlichen Muster von Lebensräumen zu identifizieren und zu charakterisieren, den Zusammenhang zwischen der Heterogenität der Lebensräume und der Abundanz von Säugetieren zu bestimmen bzw. die unterschiedlichen Arten und das Ausmaß des durch Menschen ausgeübten Drucks auf verschiedene große Säugetierpopulationen im Nationalpark zu untersuchen.

Ansätze der ›distance-sampling-technique‹ und der ›kilometric-index-analysis‹ wurden angewandt, um die Präsenz der Arten zu bestimmen. Die Häufigkeit und Intensität von Dung und Spuren wurde stellvertretend für Informationen über die Anwesenheit von Arten genutzt. Die ›spatio-temporal‹-Analyse mit einem GIS wurde herangezogen, um die Verteilung der Arten zu weitergehend zu analysieren. Kleine und mittlere Ducker, Pinselohrschweine und Gorillas traten am häufigsten auf. Bedeutsam ist der erstmalige Nachweis des Elefanten im Park, was den Stellenwert des Parks für den Schutz großer Säugetiere hervorhebt.

Verschiedene Flurarten, die Lebensräume für Tiere und Pflanzen bieten, wurden unterschieden und als dichter Wald, alter Sekundärwald, junger Sekundärwald, Baum- und Graslandsavanne, Siedlung, Gebiete mit Bodendegradation und Wasserflächen typisiert. Die Flächengröße der Gebiete, die durchschnittlichen Reviergrößen, der Zustand, die Dichte sowie die Fruchtbarkeit der Flurarten waren durch hohe Variabilität geprägt und betonen die hohe Heterogenität der Nationalparklandschaft in verschiedener Hinsicht.

Der National Park unterliegt Gefährdungen, die die physische Umgebung in einfacher und umkehrbarer Weise verändern, aber auch Veränderungen, die Biotope des National Parks dauerhaft und irreversibel verändern. Dies sind die, die durch angrenzende menschliche Besiedlungen ausgelöst werden. Allgemein war der Artenreichtum in den Lebensräumen besonders groß ( $p = 0.03$ ), wo die Berührungspunkte gering waren, und niedrig in denjenigen Lebensräumen, die sich durch vielfache menschliche Aktivitäten auszeichneten. Dies war ein

klarer Indikator dafür, dass diese Aktivitäten letztlich einen negativen Effekt auf die Lebensräume von großen Säugetierarten im National Park ausübten.

**Schlagworte:** Große Säugetiere, Habitatheterogenität, menschliche Einflüsse, Deng-Deng National Park, Kamerun

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## **List of abbreviations**

AFDB	African Development Bank
AFD	Agence Française du Développement
AOI	Area of Interest
CBD	Convention on Biological Diversity
CDS	Conventional Distance Sampling
CIFOR	Center for International Forestry Research
COTCO	Cameroon Oil Transportation Company
DBH	Diameter at Best height
DDNP	Deng Deng National Park
ECOFAC	Ecosystem Forestier d'Afrique Centrale (Forest Ecosystem in Central Africa)
EDC	Electricity Development Cooperation
EIA	Environmental Impact Assessment
ETM+	Enhance thematic map
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GFW	Global Forest Watch
GLCF	Global Land Cover Facility
GIS	Geographic Information System
GTG	Geospatial Technical Group
GTZ	Gesellschaft für Technische Zusammenarbeit
GVC	Global Village Cameroon
IUCN	International Union for the Conservation of Nature
MEA	Millennium Ecosystem Assessment
MIKE	Monitoring of Illegal Killing of Elephant
MINEF	Ministry of Environment and Forestry
MINFOF	Ministry of Forestry and Wildlife



# 1 Introduction

The effects of habitat heterogeneity and human influences on biodiversity, particularly on large mammals take many dimensions and has brought large mammal into the conservation spotlight. The unique characteristic of many large mammal species including their charismatic nature has attracted international, national and local concerns and has been one of the major rationales for establishing conservation areas in Cameroon. Large mammals naturally constitute an integral part of biological resources and are fundamental elements in many ecosystems (Morrison et al. 2007). They are known to influence the environment in diverse ways. Their inherently low densities, large dietary requirement, large home range and slow rates of recruitment render them vulnerable (Madhusudan and Karanth 2002). Among all wildlife taxa, they are the most prone to local extirpation as they are differentially hunted by humans for consumption (Morrison et al. 2007) and for supplying the expanding bush meat market (Bowen-Jones and Pendry 1999). As important as the large mammals are to ecosystem functioning (Wunderle 1997), the population and ranges of individual species are reportedly declining because of human activities, including direct exploitation and habitat alteration (Craigie et al. 2010, Morrison et al. 2007). There is therefore an urgent need to secure and maintain sites containing assemblages of large mammals. However, for any comprehensible conservation and effective management action to be adopted for large mammals, accurate knowledge of population densities, diversity, distribution and their habitat preferences have to be known (Cassey 1999) and constantly monitored (Varman and Sukumar 1995) in order to avoid extermination and to secure the richness of biodiversity.

Habitat heterogeneity, referring to the horizontal variation or patchiness in habitat physiognomy (August 1983), is of paramount importance for determining species habitat relationship. It is sometimes referred to as habitat diversity or habitat complexity, and considered an important mechanism influencing diversity patterns in spatially structured habitats (Tews et al. 2004). In spite of the importance of habitat to species, habitats around the globe and in Cameroon in particular are currently experiencing alterations and transformation (Alemagi and Kozak 2010, Ndoye 2000, Gartlan 1992) that in turn threatens the large mammal species that live in them. Maintaining habitat heterogeneity has been proposed as a means of conserving species diversity in habitats threatened by human activities (Cramer and Willig 2005). However, spatial heterogeneity is not static and can change along temporal scales, but any change in habitat composition or structure whether in small or large scale, slow or rapid, needs to be understood in

order to advance actions that may lead to conservation. Increase in habitat heterogeneity is assumed will increase species diversity by providing more niches in a unit of space for new species to colonize (Augustus 1983). However, the extent to which habitat heterogeneity influences the diversity and abundance of large mammals and the understanding of how conservation of wildlife can be fully effected in heterogeneous environment remains less clear.

Humans have long established their dependence on natural resources for essential life requisites and concurrently demonstrating limited consideration for impending changes that may affect the supply of these resources. The continuous reliance of humans on natural resources has been exacerbated by recorded increase in population growth and diverse activities of distinct human societies on the available natural resources (Conway-Gomez et al. 2010). Human influences particularly affecting ecosystem processes are causing unusual changes such as changing spatial extent, composition and configuration of habitats and species, and are depleting species population (Goudie 2013). Human linked threats on habitat and species, particularly large mammals, have motivated the inclusive and increasing consideration of humans in conservation planning. Yet, it is not fully known how the abundance and distribution of different large mammal species are related to different human activities, and how large mammal species respond to different habitats and habitat alterations caused by humans.

The Deng Deng National Park located in the eastern region of Cameroon was selected for this research to showcase the roles that habitat forms and humans play in structuring large mammal population. Cameroon is well-known for its rich biodiversity and encompasses unique and diverse flora, fauna and ecosystems (GFW 2000, Fomete and Tchanou 1998, Cheek et al. 1996, MINEF 1995, Vivien 1991). These rich biodiversity is unfortunately experiencing pressures from national socio-economic development actions and mainly from the country's ever increasing and dynamic human population that have continued to penetrate natural and remote ecosystems to satisfy social and economic needs, thereby threatening biodiversity. Forest degradation, habitat fragmentation, habitat loss and overexploitation of wildlife through hunting are some of the consequences (GFW 2000). One of the government's approaches to curb underlying and proximate national environmental stresses on biodiversity has been through the delimitation and implementation of in-situ protection strategies in protected areas (Tchigio 2007). The realization of Deng Deng National Park is one of the many ongoing strategies established to protect unique biodiversity particularly the western population of lowland gorilla (*Gorilla gorilla gorilla*) and other large mammals. Nonetheless, diverse land use and fragmentation from illegal hunting,

grazing, agricultural extension, gathering for subsistence and complete conversion of areas to meet settlement and other developmental needs, such as railway, oil pipeline and hydroelectricity dam construction are evident in the Deng Deng National Park even though it is a category II protected area that prohibits consumptive use of resources. Environmental Impact Assessments (EIA) conducted for the construction of a portion of the Chad-Cameroon oil pipeline crossing through the park (Poncelet et al. 2011, Dames and Moore 1999) and a hydroelectricity dam, i.e. Lom-Pangar Dam (COTCO 2011, IR and GVC 2005, WB 2005), adjacent the park did marginalize important habitats and wildlife in this area. Large area constituting habitat for flora and fauna in and adjacent this park has been clear-cut, dug up and flooded for the realization of these projects. Other contrary uses that followed these major projects has been the clearing and opening of large forest tracks for the construction of roads to facilitate transportation of project equipment and the construction of settlement camps for workers at the detriment of biodiversity.

Inherent to these problems, management of ecosystem supporting large mammal population in Cameroon is often challenged by insufficient underlining knowledge on human societies, their activities and the effects of their activities on habitat and biodiversity that may allow projections and direct policies. Specifically, conservation strategies laid down to manage the Deng Deng National Park's resources are facing implementation challenges due to the lack of adequate ecological information on which effective conservation and management strategies could be based. Since the establishment of the park, activities focused on mammals and anti-poaching have been the main concern. Limited surveys conducted in the park have reported the presence of large mammals and pressure from the growing human population living around it (Ambahe et al. 2011, Maisels et al. 2008, WCS 2008, Monfort et al. 2007, Fotso et al. 2002, Dames and Moore 1999). These studies highlight some human threats and attempted to quantify large mammal abundance and densities in the park with enormous emphasis on apes (i.e. gorilla and chimpanzee populations). Though these results motivated the upgrading of the park's status, they did not provide detailed evidence on the spatial pattern of its landscape and the associations between species and the spatial pattern of habitats nor the effects of human influences on large mammals that the park was established to protect. It also remains unclear how management is going to integrate results given that there is a lack of a defined management model that could help direct activities and management decisions that affect the park's integrity. In this light, this study attempts to define the roles of habitat forms and humans in structuring large mammal population in the Deng Deng National Park, and further highlights the ecological importance of the park.

The aim of this study is to define a framework where the roles of three major components in the park's landscape, that is habitats, humans and large mammals could be recognized together in defining focus conservation actions for the park. The study seeks to measure how the activities of human and heterogeneity of habitat in the park's diverse landscape are influencing the abundance and distribution of eleven large mammal species within the park.

Specific objectives of this study are:

- To identify and characterize the spatial and temporary patterns of habitat types present within Deng Deng National Park.
- To determine the relationship and variation between the identified habitats and the diversity, density and distribution of large mammals within the National Park.
- To determine where anthropogenic influences or human caused threats are occurring and their corresponding intensities and how strongly they impact the large mammal species in the study area.
- To make recommendations based on research results for the sustainable management of the Deng Deng National Park.

Research questions formulated for this research are:

- Is Deng Deng National Park a heterogeneous landscape?
- What are the habitats or land cover types present in the park?
- What are the characteristics of the land cover types?
- Has land cover changed over time?
- What is the future state of land cover?
- What are the human factors threatening the ecological integrity of the Deng Deng National Park?
- Where are the threats occurring and at what intensities?

It is hypothesized that the abundance, frequency, and distribution of mammal species will vary with land cover types and land cover characteristics. Land cover with larger extent or area, higher richness, and lower shape indices will be preferred by mammals. Human threat intensities in the study area will vary with habitat types. Diversity, abundance, and distribution of large mammal species will vary between habitats due to human influences. Areas with intensive human caused threats will hold low densities of large mammal species.

## **2 Conceptual background on the relationship between habitat, species and human interferences**

### **2.1 Landscape and habitat heterogeneity**

The term 'habitat', refers to an ecological area or environment where plants, animals and other organisms live (Tagliapietra and Sigovin 2010, Krausman 1999, Hall et al. 1997, Block and Brennan 1993). Habitat as defined by Tews et al. (2004) is a vegetation formation. Various vegetation formations occur around the globe and even within small areas resulting to heterogeneity in landscapes. The heterogeneity of a landscape is viewed as an environmental mosaic or the horizontal arrangement of diverse vegetation formations in space within a landscape (Forman and Godron 1986, August 1983). Complex interactions among many factors including human activities and natural processes (e.g. climatic variation and variation in landscape topography) are responsible for heterogeneity of landscape at different scales (Colligne 2010, Turner 2005, Fischer et al. 2004). Human presence as indicated by their activities on natural landscape (managed and unmanaged) has been largely acknowledged as the major source of habitat alteration and spatial heterogeneity (Walker 2012, Chapin III et al. 2011, Colligne 2010, Riitters et al. 2000, Turner et al. 1990). Among the multiple natural factors causing heterogeneity, habitat disturbance from natural factors such as floods, fire, wind storms and droughts are central, for the reason that they can cause devastation of flora and fauna and can leave legacies that may persist for a very long time depending on their intensities and spatial scale (Pickett 1985). However, some ecosystems depend on natural disturbance for their growth and development (Canham and Marks 1995).

In Cameroon, natural landscapes are dominated by diverse land-use and land-cover that constitute heterogeneous habitats for flora and fauna communities. Landscapes on the country are experiencing alterations from extensive logging, agriculture and other human manipulations (Mertens et al. 2001, Mertens et al. 2000, MINEF and UNEP 1997) that has actually changed the physiognomy of once vast landscape and are responsible for declines and changes in species composition. In the northern part of Cameroon for instance, vast lands within and outside protected areas are often exposed to wild and sometimes controlled fires that have left the savanna landscape in this part of the country fragmented (Klop and van-Goethem 2008). Wind storms in the forest zone have caused many small and large tree fall gabs, giving opportunity for the growth of species that need disturbance to grow and for invasive species to colonize such

areas. Nonetheless, it may take decades of succession for such areas to develop into mature canopy forest.

The dynamic nature of natural landscapes has attracted a lot of interest with ecologists seeking to understand the importance of landscape dynamics and its associated significances on flora and fauna communities (Smith et al. 2011, McGarigal 2010, Schultz and Crone 2008, Fischer and Lindenmayer 2007, Turner 2005, Fischer et al. 2004, Tews et al. 2004, Fischer and Lindenmayer 2002, Kerr and Packer 1997). While efforts are being made, the term landscape itself is perceived from different perspectives and has remained a dilemma to natural resource managers. The diverse views on landscape have made it even more complicated for managers to establish reliable policies that could address all elements in a landscape. The definitions of landscape (Box 1) however, consistently include an area of land with mosaic of heterogeneous patches or landscape elements (McGarigal 2010, Turner et al. 2001, Dunning et al. 1992, Forman and Godron 1986). Landscapes occupy spatial scale (Dunning et al. 1992) and are also defined based on scale. Landscape scale ranging from a few kilometres to 300 km<sup>2</sup> or any higher value has been suggested by Fischer and Lindenmayer (2007) and Forman and Godron (1986) but a landscape may be termed homogenous at one scale and heterogeneous at another (Biswas and Wagner 2012, Antwi 2009). Therefore, a clear definition of the landscape perspective under management is relevant to the understanding of the processes that occur within them. Box 1 presents some views of proponents, on the term 'landscape'

## **2.2 Interaction between landscape heterogeneity and animal species**

The selection and use of habitat by individual animal species in a heterogeneous landscape is influenced by several interacting factors including the provision of adequate habitat requirement such as shelter, cover, nesting site, and foraging grounds (Kruasman 1999, Litvaitis et al. 1994), and the special social systems, and dispersal patterns of animals (Yackulic et al. 2011).

Altering landscapes and habitats therefore may influence the persistence of species in a given habitat and may affect the supply of basic requirements for species the lack of which may lead to species decline, isolation or extirpation (Yackulic et al. 2011, Bennett and Saunders 2010, Kadmon and Allouche 2007).

## Box 1: Defining landscape

### **Ecological perspective**

- *An area that is spatially heterogeneous in at least one factor of interest (Turner et al. 2001).*
- *A heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout (Forman and Godron 1986).*
- *An area of land (at any scale) containing an interesting pattern that affects and is affected by an ecological process of interest (McGarigal 2010).*

### **Wildlife perspective**

- *An area of land containing a mosaic of habitat patches, often within which a particular “focal” or “target” habitat patch is embedded (Johnson and Hunn 2010, McGarigal 2010).*

### **Management perspective**

- *An area covering a large extent corresponding to an area of land equal to or larger than, say large basin (1,000's-10,000's of hectares), composed of an interacting mosaic of ecosystems and encompassing populations of many species (McGarigal 2010).*
- *A human-defined area ranging in size from c. 3 km<sup>2</sup> to c. 300 km<sup>2</sup> (Fischer and Lindenmayer 2007).*

### **Social perspective**

- *Symbolic environments created by human acts of conferring meaning to nature and the environment, of giving the environment definition and form from a particular angle of vision and through a special filter of values and beliefs (Greider and Garkovich 1994).*

Species however, vary in their tolerance for different habitat types, and for exogenous<sup>1</sup>, endogenous<sup>2</sup> and stochastic<sup>3</sup> factors defining habitats and species (Fischer and Lindenmayer 2007, Morrison et al. 2006). While some species show preference reflected by their presence, high abundances and continuous distribution patterns, others are restricted in their distribution and may rather decline or become locally extirpated or extinct (Bennett and Saunders 2010, Fischer and Lindenmayer 2007, Freckleton et al. 2005).

Large mammal species in particular, exhibit individualistic pattern of distribution, which can either be restricted in very small areas, continuous and randomly distributed over a large area or

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<sup>1</sup> Exogenous factors i.e. external factor such as habitat loss, degradation and habitat isolation.

<sup>2</sup> Endogenous factors i.e. internal factors that are part of species biology i.e. species growth, reproduction, special social system and dispersal patterns.

<sup>3</sup> Stochastic factors i.e. factors driven by chance or random events such as environment change (e.g. climate), natural catastrophe, and demography.

disjunctively distributed, in their habitat extent (Fetene et al. 2011). The distribution of large mammals has also been attributed to habitat pattern, composition<sup>4</sup>, and configuration<sup>5</sup> of landscape, and habitat structure (Bennett and Saunders 2010). In addition, the special social systems and dispersal patterns of large mammal species (Yackulic et al. 2011) as well as disturbance regimes, defines the interactions of large mammals with a heterogeneous landscape (Peterson et al. 2010).

### **2.3 Human interaction with biodiversity and landscape**

The relationship between humans, biodiversity and ecosystem has been a subject of ecological, social and political interest in the past decades (Yackulic et al. 2011, Van-der-Ree et al. 2011, Giulio et al. 2009, Díaz et al. 2006, MEA 2005). Many studies have presented humans as a threat factor and human activities as detrimental to both species and ecosystems (McKee et al. 2004, Loreau et al. 2001, Chapin III et al. 2000). Humans have favorably settled in areas of high biodiversity over area with low biodiversity (McKinney 2008). Owing to their cultural adaptations, humans have colonized nearly all ecosystems on earth (Liu 2001) exploiting and using natural resources from them to improve their wellbeing (Hoogeveen et al. 2013, MEA 2005). In the course of improving wellbeing, humans have reversibly or irreversibly altered habitats forms and species concentrations. Studies have indicated that human activities may reduce habitat patch size (Marzluff and Donnelly 2006), create new habitats (Fahrig 2003) and increase fragmentation (Fahrig 2003, Diamond et al. 1989), which are all detrimental to species especially specialist, that may not quickly adapt to the human imposed changes. However human alteration may have little effect on plants that may persist or recolonize within a short time (Pickett and White 1985) and on generalist species of animals that have the ability to roam over large areas, and may survive under various habitat conditions. This however, depends on the scale and intensity of human action.

Trends in wildlife population has followed changes associated with human interventions such as expanding urbanization (McKinney 2002), extraction from logging (Struhsaker 1997), land conversion to agriculture (Gordon 2009, Bulte and Horan 2003) and hunting of species (Corlett 2007, Willcox and Nambu 2007). Typically human interference on wildlife habitats and the

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<sup>4</sup> Composition of landscape as defined by Li and Reynolds (1993) and Gustafson (1998) refers to both the total number of patch types or categories or classes and their proportions relative to the entire area of landscape of concern and their diversity

<sup>5</sup> Configuration of landscape refers to the spatial pattern of patches in the landscape as reflected by size, number and density of patches



exploitation of wildlife species has rendered large mammal species vulnerable (Erb et al. 2012, Brashares et al. 2004, Milner-Gulland and Bennett 2003, Auzel and Wilkie 2000)

### **2.3.1 Social factors influencing human interaction with species and habitats**

Besides human imposed ecological processes affecting species and their habitats, human social factors such as demography, socioeconomic and attitude towards nature (Liu 2001) and diversity in human societies (Orland 2004, Nielsen 2004) are also contributing to the loss of habitats and species (Lee and Priston 2005, Hens and Boon 2003, McNeely and Ness 1996).

On a global scale, human demographic growth has stimulated more pressure on habitat and species. Unlike humans who can cope in a wide variety of environments through cultural adaptations (Richerson et al. 1996), natural resources are somewhat finite or exhaustible in nature (Baland and Platteau, 1996) and are threatened by the growing human population (Ciment and Ness 2014, World Bank 2014, MEA 2005, McKee et al. 2004) especially in developing Sub-Saharan Africa (Zuberi and Thomas 2012, Balmford et al. 2001) and particularly in Cameroon where the key resources are becoming vulnerable, triggered by the ever increasing human population (Marais and Femessy 2013, Alemagi et al. 2006, Burnham 2000). With an estimated national population density of about 44 persons per square km and a birth rate of about 36.2 % in 2010 (World Bank 2014, UN 2012), the demand for fertile land, forest and the diversity of biological resources particularly wildlife are on the rise in Cameroon. The costs of increasing dependence by the increasing Cameroonian population on the use of natural landscape and wildlife are already overwhelming and are expected to increase in future. Therefore adequate policies or monitoring framework for habitat, wildlife and human activities are vital and may halt extensive damages on landscapes and species communities. Though demography is not fully analyzed in this study, it is an important human factor that directly affects ecosystem and biodiversity.

Socioeconomically, humans depend on natural ecosystem and biodiversity for food security, income and the array of ecosystem services it provide for their welfare (Brussaard et al. 2010, Díaz et al. 2006). The trends in the use and exploitation of natural resource for economic improvement are already unsustainable and costing more than it is worth. In most part of Cameroon, large expanse of natural habitat has been converted to agricultural land not only to ensure food security but also for export (Sunderlin et al. 2000). Large areas of forest have also been logged mainly for export to boost the country's economy (Molnar et al. 2011, Bikié et al.

2000). Wildlife and other natural resources are being hunted, harvested and traded to secure food supply and household income (Abugiche 2008, Willcox and Nambu 2007). These socioeconomic activities are depleting habitats and species and have led to perceptible variations and changes in some landscape pattern and species abundance. Though the socioeconomic status of the communities around the Deng Deng National Park is not fully analyzed in this study, it forms an additional basis for the understanding of human influence on the habitat and large mammal species in the Park.

### **2.3.2 Human society and attitude towards nature**

The type of activities humans carry out on natural environment are directly linked with the type of human society they belong to, and the type of environment they live in (Nolan and Lenski 1999, Hanna and Jentoft 1996). The evolution of human societies and the increasing demand for resources has encouraged modification of technologies for the use of natural resources. The evolution of the level of technology applied in exploiting species and habitat, and the attitude of humans towards nature prompted the classification of humans into different types of conventional societies (Box 2) including; hunting and gathering, horticultural, pastoral, fishing, agrarian and industrial society (Nielsen 2004, Orland 2004, Nolan and Lenski 1999). Defining the types of human societies is therefore relevant for understanding the effect of human activities on species and habitat.

The human society in Cameroon is diverse and has emerged from various ethnic and cultural backgrounds (Sharpe 1998). Three main human societies in which others are embedded in Cameroon include; hunter-gatherer, agrarian, and industrial societies. The human society, cultures and attitude of the Cameroonian people are tightly associated with the ecosystem around them and have actually influenced the ways people relate with and use natural resources. While some tradition or local cultures promote the conservation of sacred places and species through traditional binding laws and taboos (Etiendem et al. 2011) some are encouraging the exploitation and use of natural resources for either traditional medicine, decoration, consumption and commercialization (Ambrose-Oji 2003, Ndoye et al. 1998) that to a larger extent has led to depletion of resources. The increasing need for natural resources for wellbeing by the Cameroonian society has triggered modification of old technology and the introduction of new techniques for resource collection. Manipulation of landscapes with advance technology has contributed more to the already widespread deterioration in the condition and productivity of

natural resources. Box 2 defines typology of human society and focuses on those obtained in Cameroon and the Deng Deng National Park area in particular.

#### Box 2: Human society typology

**Hunter and gatherer:** *are diverse group of people living in a wide range of ecological, social or political conditions whose subsistence are based on hunting of wild animals, fishing and collection of wild edible plants materials (Richerson et al.1996). This group of people share intimate relationship with nature and view themselves as inseparable from the natural ecosystems and wildlife around them (Hill et al. 2011, Bettinger 1991). They are sometimes not involved in cultivation of crops or domestication of animals except dogs that may assist in the hunting of wild animals (Lee and Daly 1999).*

**Horticultural societies:** *major portion of the dietary intake of the members is obtained from crops which are grown on land. They cultivate crops but do not use advance ploughs. They rely on the use of wood and stone tools. However, advanced horticultural societies use metal tools and weapons to execute their activities (Grenier 2002).*

**Pastoral societies:** *are societies in which the major portion of the livelihood of members is derived from the products obtained from herds of domesticated animals ('Societies' n.d.).*

**Agrarian society:**

- a) Simple agrarian societies: cultivate crops and often use affordable and less expensive materials.*
- b) Advanced agrarian societies: use weapons and tools made from a bit expensive but affordable materials (e.g. iron) (Grenier 2002).*

**Industrial society:**

*The most advanced human society; rely heavily on machine technology and inanimate sources of energy. They combine science and technology to run machines for the execution of their activities (Grenier 2002).*

## 2.4 Conceptual model of research

With insight drawn from the above background concepts on the interactions between habitats, humans and species and with respect to the problems and justification for this study, a conceptual model was developed to emphasize the link between habitat heterogeneity, human activities and large mammal species. The model particularly emphasizes the conservation needs of large mammals in the Deng Deng National Park (Figure 1). This model emphasizes the importance of the complex vegetation formation (habitats) within the park to the large mammal and took into account the fact that management of this park cannot be effectively implemented in isolation from the surrounding human landscape.

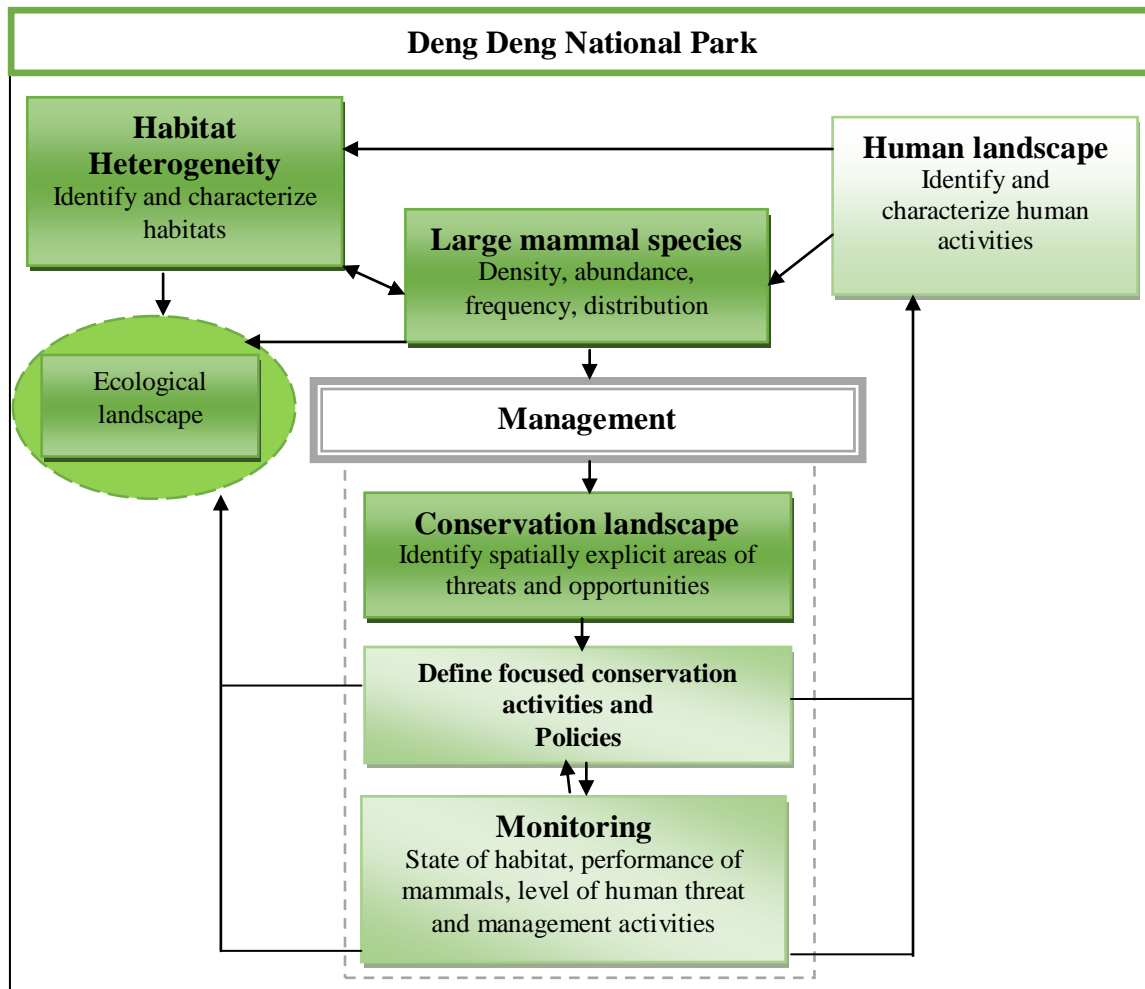


Figure 1: Conceptual model of research (adapted from Sanderson et al. 2002, Liu et al. 2001, WCS 2001)

It places large mammal survival in the park in the context of its potential success in utilizing the entire park landscape. The model delimits four major components including habitat, large mammal, human and a management component, and show how they are related to each other.

First of all, defining a conservation landscape for large mammal in the Deng Deng National Park requires meeting the diverse habitat needs of the mammal species present. This model allowed for the identification and characterization of the habitat of large mammals within the park. The type and characteristic of habitats, discloses the physical state of the park's landscape within which large mammal population are embedded. Geographic Information System and remote sensing techniques as well as landscape metrics were applied for habitat delimitation. Landscape metrics (e.g. richness, area, size) set broad limits in habitat opportunity for large mammals and may exert direct habitat selection pressure on the large mammal populations. An

understanding of the park's landscape physiognomy, pattern and characteristic metrics are therefore vital in the understanding of its landscape opportunities and capacity for large mammals.

Secondly, defining a conservation landscape also requires defining the human society around the park and identifying their activities in its landscape. This model contends that the types and intensity of human activities may have an overriding influence on the concentrations of large mammal species and the capacity of habitats to support high concentrations of species in the park. Therefore by understanding the type of human society, the type of human activities carried out, why activities are carried out and where there are carried out, actions to minimize key conflict between humans and wildlife would be quickly implemented to ensure species survival. Also policies could be derived for a long term conservation of the park.

Defining the roles that habitat and humans play in structuring the large mammal in the park also requires assessment of the performance of large mammal population. Definitive measures of large mammal species performance such as density, abundance, frequencies of occurrence, and distribution within the diverse habitats in the park were essential for the definition of the conservation landscape.

With regards to the management component of the research framework, the model explains that, by meeting the diverse habitat needs of large mammal, understanding the performance of large mammal species in the park's landscape, and identifying direct and indirect human threats on the park, a conservation landscape could be defined showing areas of threats and opportunities where focused conservation actions could be implemented to minimize threats to the survival of large mammal species in the park. Inbuilt in this concept, a geographic information system modeling approach is applied for the spatial presentation of areas of threats and opportunities.

Monitoring of the performance of large mammal species and habitats in the park and effectiveness in the implementation of conservation actions are fundamental part of the management component of this framework. Routine monitoring of the different component of the research model will advance the relevance of the park for the conservation of biodiversity with selected large mammals serving as 'umbrella species'<sup>6</sup>.

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<sup>6</sup> 'Umbrella species' is defined as 'charismatic species, the conservation of which also confer protection to a large number of naturally co-occurring species (Spitzer et al. 2009, Roberge and Angelstam 2004)

### 3 Description of study region

This study was carried out in Cameroon precisely in the Eastern Region of the country and specifically in the Deng Deng National Park. This chapter provides an overview of Cameroon's biophysical environment and the conservation status of the country. It briefly describes the Eastern Region and its conservation status, followed by a presentation and detailed description of the Deng Deng National Park where this study was conducted.

#### 3.1 Cameroon's biophysical environment

Cameroon is situated on the west coast of Africa. It lies between latitudes 2 ° and 13 ° north of the equator and longitudes 8 ° and 16 ° east of the Greenwich Meridian. It is bordered by six nations including Nigeria to the west, Chad to the northeast, Central African Republic to the east, Congo, Gabon, Equatorial Guinea, and a stretch of the Atlantic Ocean coastline of about 402 km to the south. The country covers a total area of 475,440 km<sup>2</sup> divided into 469,440 km<sup>2</sup> of land and 6,000 km<sup>2</sup> of water (Kouega 2007). It is administratively divided into ten regions being; Extreme North, North, Adamawa, North-West, South-West, West, Littoral, Centre, South and the East Regions (Figure 2).

Ecologically, Cameroon is characterized by six ecosystems (Figure 3) responsible for its extraordinary biodiversity including marine and coastal ecosystems, tropical humid dense forest dominating in the south and south west, tropical wooded savanna, semi-arid ecosystems in the extreme north, fresh water, and montane ecosystems (UNEP/GEF/CBD 2009, Molua and Lambi 2007, UNEP/MINEF 1997). Cameroon's flora biodiversity constitutes about 9000 species of plants, about 160 of which are endemic (Sunderland et al. 2003, Essama-Nssah and Gockowski 2000). The flora constitute important plant groups such as lichens, ferns, fungi, angiosperms and gymnosperms, spread across the countries diverse ecosystems. Cameroon harbors about 409 different species of mammals (Tchigio 2007, UNDP/UNEP/GEF 2001), among which are about 26 species of primates (Usongo 1998). Charismatic wildlife species in the country including the western lowland gorilla (*Gorilla gorilla gorilla*), the common chimpanzee (*Pan troglodytes troglodytes*), African forest elephant (*Loxodonta cyclotis*), African forest buffalo (*Syncerus caffer nanus*), black rhinoceros (*Diceros bicornis longipes*) and lion (*Panthera leo*) are central to the conservation of biodiversity in the country.



Figure 2: Political map of Cameroon showing the ten administrative regions and neighboring countries (Source: Page 2002)

Bird community is represented by about 928 bird species of which about 52 are hosted in the montane area and 8 are endemic (UNDP/UNEP/GEF 2001). About 190 amphibians have been recorded in the country, 63 of which are endemic to the Cameroon highlands (Jenkins 1990). The country also hosts about 542 species of fish and 330 species of reptiles with highest diversity of reptiles occurring on Mount Manengouba (Tchigio 2007, Gonwouo et al. 2006). Cameroon is possibly the richest country for butterflies in Africa, hosting about 45 % of known Afrotropical butterflies (Stork et al. 2003). In all these, the full potentials of the country's biodiversity is yet unknown and remains an opportunity for more investigations.

### **3.2 Conservation status of Cameroon**

Cameroon's flora and fauna are experiencing various threats. Main factors posing serious threats to the country's ecosystems and biodiversity include habitat destruction, degradation, and modification from deforestation through logging, agricultural expansion and the unsustainable extraction of non-timber forest products (Alemagi and Kozak 2010, Franzen and Mulder 2007, Ichikawa 2006, MINFOF and FAO 2005, Alpert 1993).

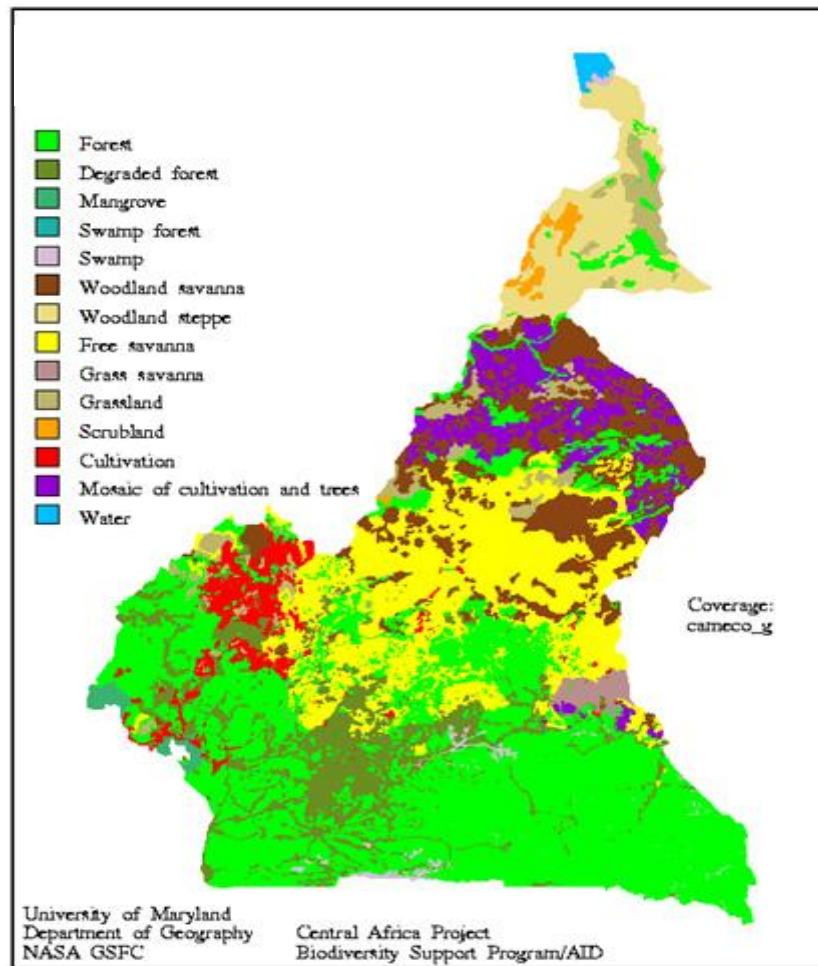


Figure 3: Ecological map of Cameroon (Source: CENADEFOR 1985)

About 47 % of the previous extent of the country's rainforest has been lost due to these factors (UNDP/UNEP/GEF 2001). Over-exploitation of biological resources through hunting (Abugiche 2008, Willcox and Nambu 2007, Wolfe et al. 2005) and unsustainable harvesting practices (Sunderland et al. 2004), has also depleted stocks of flora and fauna in the different ecological zones, rendering species vulnerable. Though very current estimates are not available for all threatened flora and fauna groups in the country, many more species have been listed as threatened (Table 1), thus calls for protection measures.



Table 1: Estimated number of threatened flora and fauna in Cameroon

<b>Taxon</b>	<b>Threatened species</b>
Vascular plants	335
Mammals (small and large inclusive)	43
Birds	47
Amphibians	55
Reptiles	4
Fish	35

(Sources: Egute 2012, Eyebe et al. 2012, Tchigio 2007, UNDP/UNEP/GEF 2001)

The goals to preserve and to fully document the potentials of Cameroon's flora and fauna has stimulated national commitment to further explore and protect extraordinary areas hosting unique ecosystems and biodiversity within the country. Protected areas currently cover about 20 % of the national territory, about 56 % of which lie in the tropical forest zone, 30 % in tropical wooded savanna and 7 % in the montane ecosystems (Mbi and Ndi 2013).

Besides the World Conservation Union (IUCN) categories of protected areas (i.e. I, II, IV, VI) (Phillips 2004), Cameroon has six national categories, classified based on different protection levels confer on them. Some of Cameroon's protection levels directly correspond with the IUCN categories (Table 2). Types of protected areas in the country include National Parks, Zoological Gardens, Wildlife Sanctuaries, Wildlife Reserves, Forest Reserves, Community Forest, Community Wildlife Hunting Zones, and Botanical Gardens (Egute 2012, Takem et al. 2010, Tchnindjang et al. 2003, UNEP/GEF/CBD 2009). Since Cameroon's commitment to respect the Convention on Biodiversity (CBD) in 1994, the government has been making efforts to have up to 30 % of its national territory protected. Deng Deng National Park is one of recently (2010) established protected areas in the Eastern Region of Cameroon. Table 2 presents Cameroon's protected area categories and associated IUCN equivalent as well as the respective management objectives, while figure 4 presents the protected area network in Cameroon including Deng Deng National Park.

Table 2: Cameroon protected area categories, IUCN equivalents and management objectives

<b>National protected area category</b>	<b>Equivalent IUNC category</b>	<b>Main Objectives</b>
National park	II	Managed mainly for biodiversity and ecosystem protection, conservation and recreation
Wildlife sanctuary	VI	Managed mainly for sustainable use of natural resources
Wildlife reserve	IV	Managed mainly for conservation through management intervention
Zoological gardens	Not available	Managed for the protection and breeding of wildlife ex-situ
Community forest	Not available	Managed for conservation and economic benefit of forest resources particularly timber
Community wildlife hunting zones	Not available	Managed for controlled sport hunting of wildlife
Botanical gardens	Not available	Managed for the maintenance of genetic resources

(Source: Adapted from various internet sources including Dudley (2008), Phillips (2004)

### 3.3 Overview of the Eastern Region

The East Region occupies the South-Eastern portion of the country (Figure 5), and is the largest in terms of area. It is however, the most sparsely populated region in the country with a density of about 7 persons per square km (Sonwa and Weise 2006, Mertens et al. 2000). It covers an area of 109,002 km<sup>2</sup> (Statoids 2013, Sonwa and Weise 2006) and is bordered by Adamawa region to the North, Center and South Regions to the West, Central African Republic to the East and Congo (Kinshasa) to the south. The region is politically partitioned into four divisions including; Boumba-et-Ngoko, Haut-Nyong, Kadey and Lom-et-Djerem division that supports a large stretch of the Cameroon's lowland rainforest, and humid wooded and grassland savanna ecosystems within its frontiers. The East Region is remote but exceptionally rich in natural resources, encompassing rich diversity of flora and fauna. Primates and other large mammals including, gorilla, chimpanzee, buffalo, elephants, Nile crocodile, hippopotamus, together with diverse species of birds, fish, reptiles, amphibians, diverse timber species and mineral resources are present in the region in high numbers (Birdlife International 2014, Sonwa and Weise 2006, Usongo 2003, Werdenich et al. 2003, Mertens et al. 2001, Mertens et al. 2000). These rich resources have attracted a lot of external interventions from logging, bushmeat hunting and the harvesting and trade of timber and non-timber forest products (Mertens et al. 2001, Muchaal and Ngandjui 1999) in this part of the country.

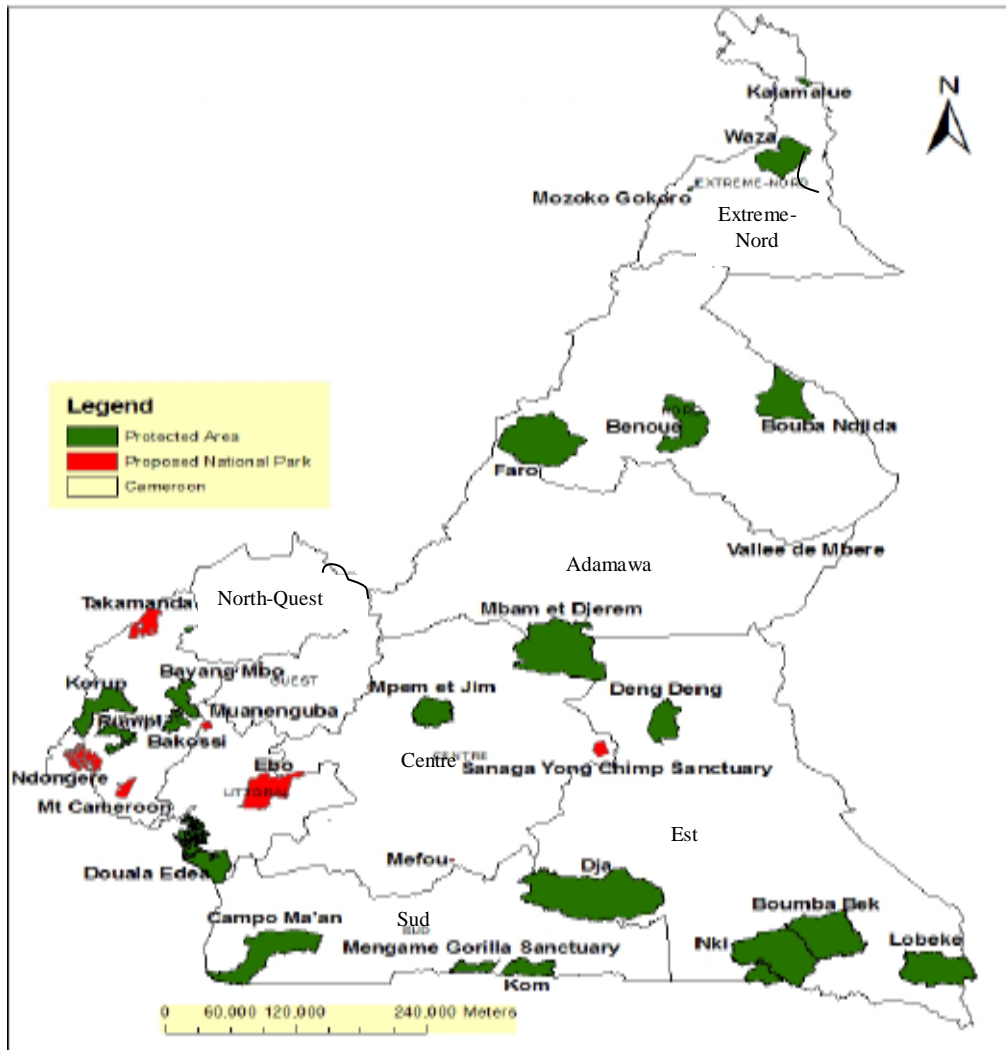


Figure 4: Map of protected areas network in Cameroon (Source: Ndeh 2010)

The Eastern Region provides about 57 % of Cameroon log production (Sonwa and Weise, 2006) and a very large percentage of household sources of protein to the communities living within this region (Usongo and Curran 1996). The remote East Region is experiencing threats from agricultural expansion, deforestation, settlement expansion and other human uses that are adversely affecting the region's biodiversity. These threats attracted government support to protect and manage the region's biodiversity through the endorsement of five protected areas (Table 3) being Dja Fauna Reserve (a world heritage site) in the South-West of the region, Deng Deng National Park in the North-West, Lobéké, Boumba-Bek and Nki National Parks in the southeast of the region (Figure 5).

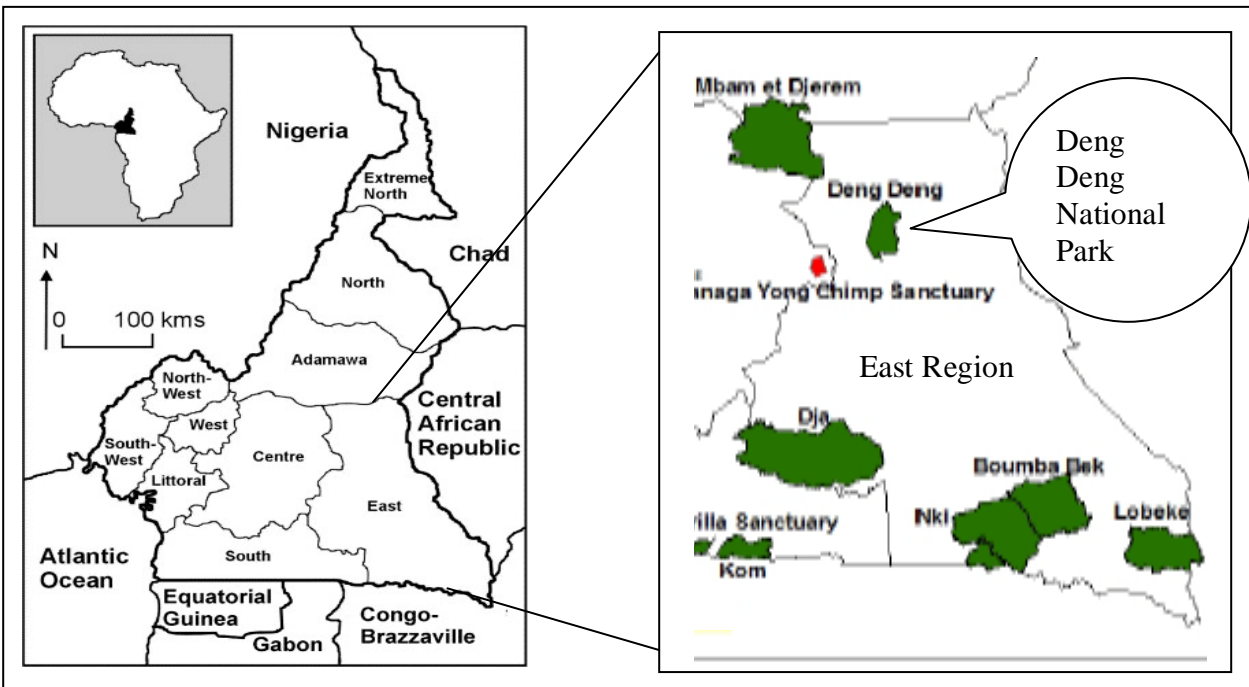


Figure 5: Location of the East Region and the Deng Deng National Park in Cameroon (Source: Page 2002, Ndeh 2010)

Table 3: Area covered by protected areas in the East Region of Cameroon

Protected areas	Area (km <sup>2</sup> )
Deng Deng National Park	523
Lobeke National Park	2,000
Boumba-bek National Park	2,382
Nki National Park	3,093
Dja Fauna Reserve (world heritage site)	5,260
Total area	13,258

(Source: Ambahe et al. 2011, Geßner 2008, UNESCO 2006, Dowsett-Lemaire and Dowsett 2000, Whitney et al. 1998)

These protected areas together occupy over 13,000 km<sup>2</sup> and constitute about 16 % expanse of the East Region's territory. Despite these efforts, the east region remains a challenging region for conservation. It has very little industry and its main economic source consists of logging of timber and mining (Essama-Nssah and Gockowski 2000). The bulk of its inhabitants are

subsistence farmers who rely on forest for their livelihood. Poaching is taking toll on the protected areas in this region (Njounan-Tegomo et al. 2012, Fimbel et al. 2002, Fotso et al. 2002, Muchaal and Ngandjui 1999) and patrolling the protected areas has been difficult due to the tough terrain, inadequate skills and lack of finance to cover monitoring cost. With the creation of National Parks and Reserves, international non-governmental organizations, e.g. World Wide Fund for Nature (WWF) and the Wildlife Conservation Society (WCS)<sup>7</sup> have increased their presence in the East Region and are providing technical support to the government through its Ministry of Forest and Wildlife (MINFOF) to manage the protected areas.

### **3.4 Deng Deng National Park**

#### **3.4.1 Location and legal status**

The Deng Deng National Park is located in the East Region of Cameroon, precisely in the Lom-et-Djerem division (Figure 6). The park covers an area of about 523 km<sup>2</sup> and lies between latitude 13° 23 to 13° 34 East and longitude 05° 5 to 05° 25 North, in the North-Eastern part of the lower Guinean forest. The Park is bounded by the Lom-Pangar River to the east, a segment of the Cameroon railway line and settlement (villages) to the west, by a continuous stretch of natural forest and savanna mosaic to the north and by roads and settlement to the south. Deng Deng National Park covers the least area among the protected areas in the east region, but one with high priority for conservation as it is situated within a zone where social and economic operations from logging, construction of petrol pipeline and hydroelectricity dam, are exerting enormous pressure on the landscape.

Deng Deng National Park was declared a category II, IUCN protected area in 2010 by prime ministerial Decree N° 2010/0482 PM of 18 March 2010, after years of conservation planning and research (WCS 2008, Monfort et al. 2007, Fotso et al. 2002), to protect great apes, particularly the most northern population of the western lowland gorilla (*Gorilla gorilla gorilla*) that was reported to be present in this area, but threatened by anthropogenic activities within and around the Deng Deng forest reserve (Maisels et al. 2010, Maisels et al. 2008, Fotso et al. 2002). In view of the need to protect the great apes, other specific objectives of the park are to conserve the wide

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<sup>7</sup> Wildlife conservation society (WCS) is an American based Non Governmental Organization with head quarters in Bronx, New York. WCS is working worldwide to save wildlife and wild places through science, field conservation programmes, education and the management of the world's largest system of urban wildlife parks.

range of flora and fauna and to collaborate with other stakeholders towards attaining the protection of key fauna species in the park.

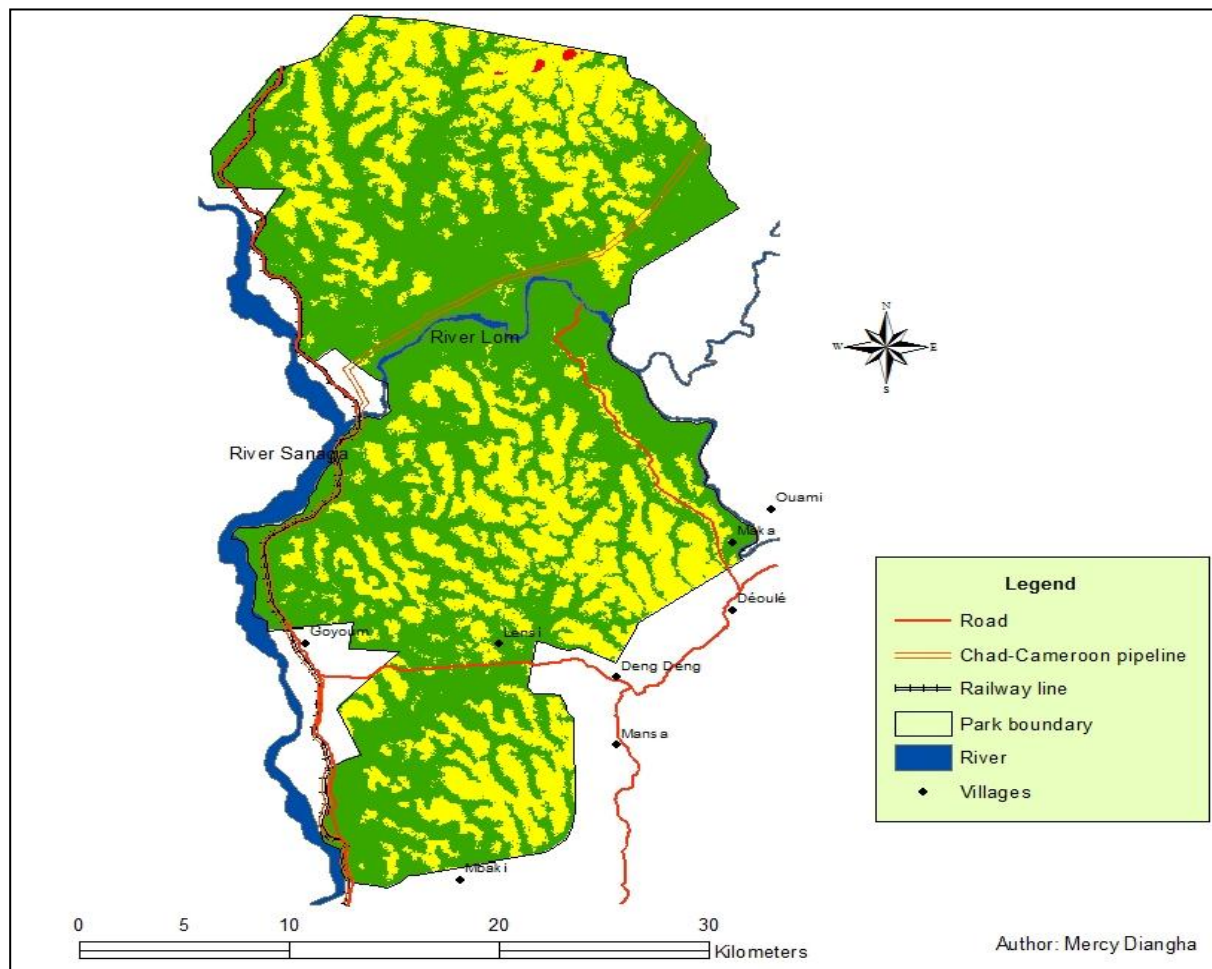


Figure 6: Map of Deng Deng National Park

### 3.4.2 Biophysical environment

The biophysical environment of Deng Deng National Park is described by its characteristics climate, relief, vegetation types and hydrology. Annual rainfall in the park ranged from 1500 mm to 1600 mm (COTCO 2011, GVC 2007). The park area features a typical equatorial and humid climate (Fotso et al. 2002) defined by the rainfall regime in this area. Seasonal pattern in the park area is characterized by distinct but unequal dry and wet season periods. Heavy wet season starts from August to November, a light wet season from April to June, a long dry season from December to March and a short dry season from July to mid-August. With a mean annual

temperature of 23° C, annual minimum and maximum temperatures within the park area ranged from 15° C and 31° C (COTCO 2011, Fotso et al. 2002). The park consists largely of flat and gently undulating terrain. Elevation within the park varies from 100 m in the south to 920 m above sea level in the north. Granitic and basalt rock outcrops (Plate 1) particularly in the north and northeast corner of the park characterizes the park's relief and also makes it an important geological site.



Plate 1: Views of rock outcrop in the Deng Deng National Park

Deng Deng National Park hydro-resources form a significant network within the boundaries of the park (Figure 7). Availability of water in the park is highly influenced by climatic variability and precipitation. Rivers and streams in the park are fed by rainfall and seasonal runoff during the wet season but experience drop in level, decrease in area or go dry during the dry season. Muyual, Mbanpkwa, Mbactoua, Mbibetana are main water sources flowing throughout the year, supplying water to downstream population living around the park. These streams discharge into River Lom, which eventually empty in the Sanaga River. River Lom flows westward through the park and is the main hydro-resource that divides the park into two i.e. northern and southern portions. The capacity of River Lom and its location 8 miles upstream of River Sanaga attracted the construction of a dam to boost hydroelectricity production in Cameroon.

Owing to the favorable climate, relief, significant water resources and diverse ecosystems within the boundaries of the park, the park is refuge to a rich diversity of flora and fauna. The park accommodates the wet equatorial vegetation and belongs to the lower Guinean forest block considered to be the largest in the Congo Basin (Letouzey 1985). The vegetation within the park



is characterized by dense evergreen and semi-deciduous rainforest (Fotso et al. 2002), mixed with patches of wooded and grassland savanna that spreads to the neighboring Adamawa region. The presence of forest savanna transition zones especially makes the park's flora unique with both savanna and forest species co-existing as the forest transitions into savanna and vice versa. The uniqueness of the flora of the park is further expressed by a small expanse of rock outcrops (Plate 1) that support plant species unique to this habitat type. The park's forest flora is however, dominated by commercially valuable *Triplochiton scleroxylon* (Sterculiaceae), which are heavily targeted for exploitation throughout their range in the east region. Some important economic plant resources present in the park include; *Triplochiton scleroxylon* ('ayus'), *Entandophragma cylindricum* ('sapelli'), *Terminalia superba* ('frake'), *Entandophragma utile* ('sipo'), *Erythrophleum suaveolens* ('tali'), *Eriobroma oblonga* ('èyong'), *Guarea cedrata* ('bosse'), *Pterocarpus soyauxii* ('padouk'), *Xylopia aethiopica*, and *Enantia chlorantha*. Appendix 1 presents a provisional list of plant species present in the park.

The Deng Deng National Park is refuge for important fauna community in the East Region (Maisels et al. 2010, Maisels et al. 2008, Monfort et al. 2007, Fotso et al. 2002). Among the species, the northern population of western lowland gorilla inhabits this area and occurs at higher density than in most sites in the East Region of Cameroon (Ambahe et al. 2011). Census conducted in the Deng Deng Forest and adjacent logging concessions estimated a total of between 300 to 500 gorillas with about half this population, estimated to be living in the park (Ambahe et al. 2011, Stautner and Delaney 2011). The park also shields additional large mammal population of chimpanzees, monkeys and ungulates including buffalo, bay duiker, blue duiker, yellow-backed duiker, red-flanked duiker, bongo and sitatunga. Water dwelling mammals including hippopotamus and swamp otter has also been confirmed in this area (Fotso et al. 2002). At least 40 large mammal species have been recorded in the park and are presented in Appendix 2. In addition to mammals, sixty species of fish belonging to 16 families and mostly *Mormyridae* and the *Cyprinidae* are common in the Lom River (COTCO 2012). Surveys are yet to be completed for the avifauna, reptiles, amphibians, fish and other fauna communities of the Deng Deng National Park.



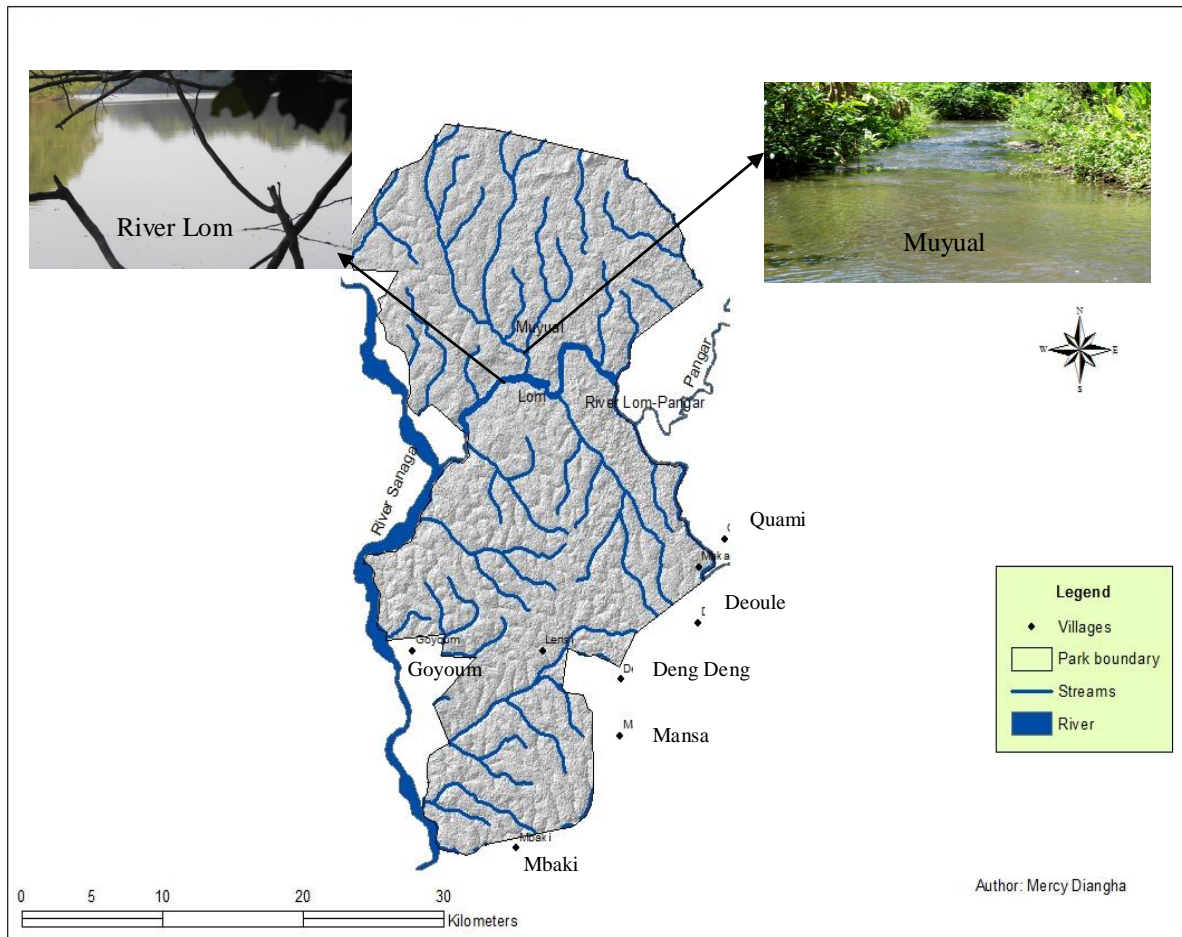


Figure 7: Hydrological network of the Deng Deng National Park

### 3.4.3 Demography and ethnicity

Though no detailed census has been conducted, coarse estimates suggest small population sizes in the villages around the park ranging from no individual in abandoned and relocated villages such as Lom-Bord, Muyual (abandoned villages), Deolé and Lom-Pangar (relocated villages) to about 574 persons per village in Tête d'éléphant (EDC 2011) with an estimated population density of about 1300 inhabitants in 16 villages (Fotso et al. 2002). The population of relatively big villages located along main road and railway like Deng Deng (about 250), Mbaki II (350), Goyoum (400) and Tête d'éléphant (574) are higher (EDC 2011, Fotso et al. 2002), suggesting the importance of rural development for population growth. The presence of Government, non governmental organizations (NGOs), Economic Operators and external development bodies (Cameroon Oil Transportation Company - COTCO and Electricity Development Cooperation - EDC) in the area has together promoted influx of human population (both employees and job seekers) into the

park's area. On the other hand villages are experiencing rural to urban exodus of population seeking to improve their wellbeing from employment opportunities, medical facilities and education for their children in neighboring urban centers (Fotso et al. 2002). In addition the increasing birth rate in the rural areas in Cameroon (Nana-Fabu 2001) which may also be the case in the villages around the park has contributed to the demographic fluctuations in the park's villages. Catholic Christians, Muslims, Protestants and believers of local traditions are the main religious groups in the area.

Livelihood of the indigenous population around the park has evolved closely with the natural resources within their vicinity. The indigenous population in the villages adjacent to the park belongs to four ethnic groups being Kepere, Bobolis, Pols and Gbaya (ABD 2011, WCS 2010, GVC 2007, Fotso et al. 2002). Among the main ethnic groups in the region, Kepere and Gbaya constitute the highest population and are the most dominant ethnic group. Culture and tradition of the ethnic groups in the region are closely linked with the forest and have since ancient times, regulated their use of natural resources. Recently, people from other ethnic groups including; Bassa, Eton, Kakou, Bavele, Ewondo, Hausa, have migrated to the park's region. Like the indigenous ethnic group, they are also depending on the natural resources within the park and its environ for their livelihood.

#### **3.4.4 Socioeconomic potentials**

The role which the Deng Deng National Park area plays both socially and economically is derived from the complex set of functions offered by the diverse ecosystems, flora and fauna therein, to the indigenous, national and international stakeholders.

Subsistence agriculture, basically farming is the main activity of the indigenous people of the Deng Deng National Park area (WCS 2008, GVC 2007). Shifting cultivation where large areas of land are slashed and burned for crop cultivation (Plate 2) and intercropping, are widely practiced in the area. Food crops such as cassava, plantain, cocoyam, banana, maize, peanut, cucumber, okra and pepper are cultivated mainly for household consumption. However, groundnuts and cucumber are cultivated for sale. Coffee is an economic crop in the area but very few people are engaged in coffee farming probably because of market failures associated with low prices, lack of good farm to market roads and limited market information (Fotso et al. 2002). Capital input is rarely used in agriculture thus weeds, insect pest and plant disease are common.



Plate 2: Slash and burnt agricultural fields in the Deng Deng National Park (Source: Author)

The indigenous people living around the park have secured their livelihood through farming along with rearing of livestock and poultry. Local breeds of animals such as goats, sheep, pigs and domestic fowls are reared in the region for subsistence, but mostly for sale to raise household income (GVC 2007). Protein supply from livestock consumption and income from sales of livestock have failed to satisfy people's needs thus have aggravated the extraction of resources from the park.

Forest resources are also an important source of livelihood to the human population living adjacent the park. Driven by the high cost of domestic livestock reared in this area and the lack of cheaper alternative sources of protein (GVC 2007), bush-meat resources (considered to be readily available and cheap) mainly acquired through hunting and poaching, now constitute an essential source of protein and main source of income for these local inhabitants (GVC 2007). Fauna taxa mainly targeted for bush-meat and alternative source of protein are the ungulates, primates, fish, reptiles and rodents common in the area. Hunting activity has mainly employed traditional trapping techniques but with the increasing demand for bush-meat (aggravated by the influx of population into the park area), modern techniques requiring the use of wire snares, modified den guns and rifles are now being used for hunting especially when primates are also targeted. Markets for bush-meat within the park area are found in Goyoum and Deng Deng villages. Buyers include local residents who buy for consumption and middlemen from neighboring cities who on the other hand buy mainly for sale in the urban markets of Bertoua, Yaounde or beyond (Fotso et al. 2002).



Plate 3: Smoked and fresh bushmeat harvested from Deng Deng National Park (Source: WCS Cameroon archive)



Plate 4: Basket load of smoked fish and bush-meat ready for urban market (Source: Forestry Post Deng Deng)

The hydrological network within Deng Deng National Park provides a good source of fish to the population living around the park. The River Lom and other small persistent streams like Mouyal, Mbactoua and Mbibetana supply water to downstream communities of Lom I, Liguim, Tête d'éléphant and Mbitom villages, who also install along the banks of these river and streams during the wet and dry season to fish. Like bushmeat, fish is also an important source of protein and income to the population living around Deng Deng National Park. Fishing in the Lom River is done using floating nets placed in lines and in the small stream by creating barriers. Large quantities of fish collected from the river and streams are often smoked along the banks of the river in huts from where they are then transported by head or as backloads to village. Fish is sold locally to residents for home consumption or to middle men who buy mainly for sale in neighboring urban markets.

Besides hunting and fishing, local residents around the park are also collecting plant resources from the park for medicine, for sale, for construction and also to supplement food supply from agriculture. Plant part such as leaves and bark, roots are collected for treatment of illnesses. Being an impoverished society with limited medical facilities, the indigenous communities living around the park area mostly rely on traditional medicines and herbs for treatment of illness. The bark of *Enantia chloranthia* for example is used for the treatment of malaria and common stomach pains. *Piper umbellatum* and *Xylopi aethiopica* are important plant species collected mainly for sale and also for home consumption. Thatches and bamboo are used for roof and chair construction and also for weaving of mat (personal communication with village assistants). The increase dependency of rural people on medicinal plant and other plant resource in the park is a course for more detailed investigation.

In addition to income from sales of agricultural and forest products in the Deng Deng National Park area, residents are also involved in other temporarily or permanent activities that contribute to their livelihood. Petty businesses such as provision stores in big villages like Deng Deng, Goyoum and Mbaki are providing residents with basic needs and also fueling hunters with cartridges, torches and other material used for hunting. Small restaurants and off-license bars in big villages serving mostly the immigrant population with bushmeat meals and other traditional meals are also additional sources of income. External bodies (logging companies, pipeline and dam construction companies) provide temporary employment and income to some local resident in the park area.

### **3.4.5 Conservation and management**

Prior to the creation of Deng Deng National Park, forest in the Lom-et-Djerem division constituted other management unit such as the Deng Deng Wildlife Sanctuary, Belabo Communal Forest and the Deng Deng Forest Reserve. Despite the presence of these management units, several anthropogenic activities including; logging, cattle grazing, dependence of community on forest resources to satisfy social and economic needs, and the irrational consideration of areas within the landscape for infrastructural development (Monfort et al. 2007, Fotso et al. 2002) took to the rise and therefore jeopardized the protection of species and ecosystems in the area. In view of the need to protect the great apes population in the Deng Deng forest, the National Park was established. The park is a compensatory strategy by the government of Cameroon, encouraged by the World Bank to cover damages caused during the construction of the Chad-Cameroon pipeline

in 2003 (Thomas et al. 1999) in portions of the Deng Deng Forest. It is also considered a compensation for damages that may adversely affect wildlife during and after the construction of the Lom Pangar Dam (EDC 2011). The establishment of park saw the extension of the Wildlife Sanctuary including important area south of the sanctuary boundary that needed more intense protection.

The management of Deng Deng National Park is mainly led by the government of Cameroon through its Ministry of Forestry and Wildlife (MINFOF), in partnership with Wildlife Conservation Society (WCS). The Ministry of Forestry and Wildlife, and the Wildlife Conservation Society's commitment in managing Deng Deng National Park has received significant support from international cooperation and partners such as the Agence Française du Développement (AFD), African Development Bank (AFDB), and the World Bank.

The Ministry of Forestry and Wildlife is the main stakeholder responsible for main administrative duties and for overseeing the overall management of the park. Management at the level of ministry has been supported by the appointment of a conservator to lead the implementation of government policies on park management. The ministry through its Conservator is responsible for the proper delimitation of the park's boundary, the training and equipping of eco-guards and the implementation of law enforcement patrols to monitor illegal activities in and around the park. Characterized by often limited and inadequate technical capacity and finance, the Ministry of Forestry and Wildlife is totally depending on the Wildlife Conservation Society for technical and financial support to execute its activities in the park. Recent efforts involved placing of joint MINFOF and WCS sign post at strategic points (areas where the possibility of encroachment is high) to mark the limits of the park, training of eco-guards in the school of Forestry and Wildlife Garoua (AFD 2011) and monitoring of illegal activities around the park. The joint effort has yielded seizures of bush-meat and arms from several hunters (Plate 5) and has reduced the level of illegal hunting in the park.

The Wildlife Conservation Society through the Cameroon Biodiversity Programme (CBP) is have been working in close collaboration with the government Ministry of Forestry and Wildlife in the management of Deng Deng National Park. It was through the leading research efforts and recommendations made by the Wildlife Conservation Society that the park was created (WCS 2008, Fotso et al. 2002). The Wildlife Conservation Society's main interest in the park is to protect the wealth of biodiversity it supports. With main funding from Agence Française du Développement (AFD), WCS is conducting research (ecological and socioeconomic research) to



provide relevant data require for management purposes. At an operational level, WCS has established a project “Deng Deng National Park project”, headed by a director to further the park’s objectives and is providing technical and research support to MINFOF (e.g. vehicles, research equipment and finance).



Plate 5: Bushmeat seized from hunters by joint Wildlife Conservation Society and Ministry of Forestry and Wildlife anti-poaching team (Source: WCS archive 2011)

The Wildlife Conservation Society through the Deng Deng National Park project is committed to ensuring a proper delimitation of the park’s boundary, training of eco-guards, monitoring of illegal activities, fundraising for the management of the park and sensitization of stakeholders operating in the park area on the importance of protecting the park’s biodiversity. WCS has realized several field surveys and sensitization campaigns, and is working in collaboration with external researchers, academic institutions, and development institutions (e.g. COTCO and EDC) to conduct further research, sensitization, and monitoring in and around the park.

Characterized by their economic interest and aware of the negative impacts of their project activities from the point of view of species and habitat conservation, economic operators in the park area such as the Electricity Development Cooperation (EDC) and the Chad-Cameroon petrol pipeline project (managed by the Cameroon Oil Transportation Company - COTCO), are working in collaboration with the Ministry of Forestry and Wildlife, The Wildlife Conservation Society, and the local communities towards the protection of the park (COTCO 2011, EDC 2011). In view of this collaboration, a memorandum of understanding was signed between the Ministry of Forestry and Wildlife and the Electricity Development Cooperation to further protect the park (EDC 2011). The roles of these projects are indicated in the areas of funding, control of access

into the park and adjacent areas, anti-poaching and the minimization of risk in the implementation of the respective projects' activities. The Electricity Development Cooperation and the Chad-Cameroon petrol pipeline project have supported the conservation of the park through limited financial support for anti-poaching activities and control of access into the park. They have assisted with short term control post near Ouami, Lom Pangar and Lom villages and a long-term control post north of the pipeline to halt easy access to the north-east of the park (EDC 2011b). Control posts are fortified with both Wildlife Conservation Society and the Ministry of Forestry and Wildlife trained eco-guards ready to enforce law in case of illegal activities. The Electricity Development Cooperation and the Chad-Cameroon oil pipeline project in their support for led anti-poaching campaigns, have taken internal measures through the implementation of strict anti-poaching laws to curb killing and commercialization of bushmeat among employees and contract staff. Employees are prohibited to hunt, buy bushmeat or live game. They are also prohibited to possess any hunting weapon (COTCO 2011). Despite these efforts, the activities of these projects are still detrimental to the biodiversity in and around the park.

Local communities living around the park are yet not fully involved in the management process. However, their culture and traditional beliefs are indirectly contributing to the management of resources within their vicinity (Fotso et al. 2002).

In the absence of a management plan for Deng Deng National Park, management so far has been guided by a set of short-term and long-term objectives. Main focus has been to ensure the survival and protection of great apes population through concerted actions with stakeholders. Short term management goals are to ensure the elimination of illegal activities, minimize the impact of developmental activities and ensure the participation and wellbeing of local populations around the park (EDC 2011, Maisels et al. 2010).



## **4 Research methods and data analysis procedures**

For the purpose of this study, both primary and secondary data were collected. Procedures for the collection and analyses of research data are elaborated in the respective and subsequent sections. First steps that were taken to acquire the necessary primary data included obtaining authorization to conduct study in the chosen study area (i.e. Deng Deng National Park) and assembling of major resources (human and material resources) needed for field surveys. Both written and verbal authorization to conduct research was obtained from the Ministry of Scientific Research and Technical Innovation, Yaounde, Ministry of Forest and Wildlife, Yaounde, and the Wildlife Conservation Society / Cameroon Biodiversity Programme, Yaounde. Field work was conducted between the periods November 2012 - March 2013 that coincided with the dry season period of the study area. During this period, administrative and training activities as well as actual field survey was completed. Administrative meetings were held with responsible authorities to finalize approval of research permits and to secure technical and logistic support needed to execute research. In this regard, meetings were held with the Society for Conservation Geographic Information System Cameroon (SCGIS), IUCN/World Resource Institute Cameroon, Wildlife Conservation Society/Cameroon Biodiversity Programme and the Ministry of Forest and Wildlife contact persons. Training of research team was conducted in December 2012 followed by field surveys that ran from January to March of 2013.

### **4.1 Organization of research team**

With the understanding that data collection entails sufficient knowledge on the subject under research and skills for specific task, a research team was developed and trained during the month of December 2012. Twelve research assistants made up of eight staff of the Geospatial Technical Group and three university graduates were offered a short introductory training course, detailing the types of ecological data and data collection procedures relevant for this research. Research assistants were trained on the use of field equipment such as Global Positioning System hipchain<sup>8</sup>, compass, altimeter, measuring tapes (simple measuring tapes and diameter tapes) and clinometer that were necessary for data collection. Assistants were also trained on good data

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<sup>8</sup> A convenient resettable counter with biodegradable string (topophil), attached to an in-build meter that unwraps and turns the meter when the string is pulled.

handling practices and on the use of field guides for mammals and plants identification (Kingdon 1997, White and Abernethy 1997). Templates detailing habitat requirement (Appendix 3), photos of selected large mammal species (Appendix 4), and field signs of the mammal species such as dung, foot prints and tracks were important training resources introduced to trainees. With the exception of the university graduate who participated in the training, all other trainees had field experience but needed additional skills to assist in data collection. Plate 6 shows some training activities conducted with the research team.



Plate 6: Research team during training and field surveys in the Deng Deng National Park (Source: Author)

In addition to technical field assistants, eight local assistants from villages around the park including Deng Deng (4), Goyoum (1), and Tête d'éléphant (3), participated in the study as field

guides and porters. Village assistants were also trained on the recommended techniques for minimally cutting transects and establishing plots in the field (White and Edwards 2000). They were also introduced to the use of less technical field equipment such as sighting compasses and hipchains. At the end of the training period, trainees were well equipped with knowledge and skills needed to assist with data collection following defined protocols for the study. All training sessions and field surveys were participatory and were led by the principal investigator (me).

## **4.2 Measuring habitat heterogeneity: classification of habitats**

Prior to field survey, the first part of this research was focused on identifying and characterizing the spatial and temporal patterns of habitat types present within the Deng Deng National Park landscape. To achieve this objective, Geographic Information System (GIS) and remote sensing techniques were applied for the classification and quantification of land cover or vegetation cover within the park, which in this study constitutes habitat for mammal species. For the purpose of spatial analysis, satellite imageries, topographic maps and digital elevation model were used to establish a spatial database to aid classification and characterization of habitat, as well as to facilitate change detection over time. It was also vital for the organization of field surveys in the study area.

### **4.2.1 Spatial database**

Satellite imagery including Landsat 7 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper (ETM+), Aster and Google Earth resources were used for spatial identification and classification of land cover types present within the park. Landsat 7 TM and ETM+ were obtained from the Global Land Cover Facility online portal, while Aster imagery was obtained from the World Resource Institute, Cameroon office database. Two scenes of Aster imagery of 15 m resolution each, taken during 2009 (during same season) and partially covering different portions of the study area, were mosaicked to obtain a complete extent of the study area. Single scenes of Landsat 7, TM and ETM+ of path 184 and row 56, and of 30 m in resolution, taken during 1987 and 2000 respectively, and the mosaicked Aster image taken in 2009 were used for change detection analyses. Recent Google Earth resource (IKonos) of 15 m in resolution, taken during November 2012 and 2013 were used for the confirmation of expert knowledge of the different cover types in the study area.

Topographic maps of 1978 and of scale 1:200,000 (covering the study area), obtained from the Geospatial Technical Group database were important sources of geographical data on drainage, road network, villages and land cover of the study area, in the absence of other historical and most recent data. Polygon of the protected area was obtained from the Interactive Forest Atlas of Cameroon version 3.0 (WRI and MINFOF 2011). Digital Elevation Model obtained from the Geospatial Technical Group database was vital for elevation, slope, and aspects analyses of the study area.

#### 4.2.2 Image pre-processing

Pre-processing and processing of spatial data (imagery and maps) were done using geographic information system software including; ERDAS IMAGINE 2011, ArcGIS 10 and ArcView 3.2.

To facilitate image classification, two Aster imagery of 15 m resolution for the period 2009 (taken during the same season) were mosaicked and pre-processed in ERDAS IMAGINE 2011 to produce a single composite coverage view of the study area. Images were mosaicked because single scenes obtained did not cover the entire study area.

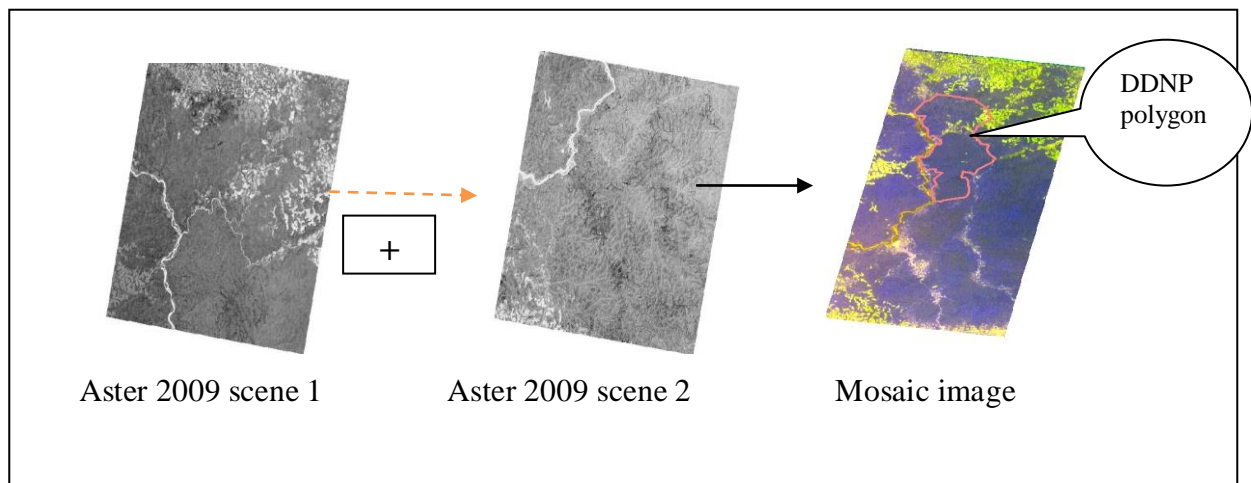


Figure 8: Mosaicked Aster image showing complete boundary of Deng Deng National Park

An 'area of interest' defined beyond the boundary of the study area was then subset from the mosaic image using ERDAS 2011 for further pre-processing. Using three basic bands 1, 2 and 3N in the visible and near visible Infrared part of the electromagnetic spectrum of Aster imagery, a single composite of green, red and near infra-red image was produced. The composite image

produced, aided the enhancement and visualization of the main feature classes or cover types possible in the study area.

Given that supervised image classification requires expert prior knowledge of the possible types of land cover or habitats in a given area (Richards 1999), common habitats present in Cameroon and in the study area including forest, savanna, aquatic habitat, soils, sub-montane and settlement areas as indicated in literature sources (Mertens et al. 2012, UNEP/GEF/CBD 2004, Fotso et al. 2002), served as guide or priori knowledge for the determination of the statistical criteria (training sites) for image processing and classification. An interactive forest atlas of Cameroon (Mertens et al. 2012), Google checks on the present status of land cover of the study area, and detailed visualization of pre-processed images were relevant for the determination of training sites for digitization.

#### **4.2.3 Image processing: Digitization of homogenous areas for selected land cover**

Training pixels was selected from several homogenous areas randomly distributed over the study area and digitized on screen in ERDAS IMAGINE 2011 such that they were representative of the predefined land cover classes. Training site selection was random but ensured that each pixel had equal chance of being selected. On-screen digitization of training site was done such that it covered a minimum of 50 pixels for each training site and a minimum of 100 pixels for each land cover type. Minimum pixel selection was recorded for classes that were not widespread but represented in the study area. Digitization accuracy was assured by adequate zooming in to ensure that only homogenous areas of interest representing a particular predefined cover type were digitized to generate training data for the land cover type. At least five training sites were digitized for each predefined cover type. Training data for each signature were later merged in the signature editor window in ERDAS IMAGINE 2011 and then labelled for a particular class.

#### **4.2.4 Image classification: supervised classification**

Imagery classification was finalized by the ERDAS IMAGINE software recognition algorithms by sorting and matching the remaining undigitized (unknown) pixels into individual classes or categories based on maximum likelihood classifier i.e. input data values (training class signatures), to generate supervised signatures of classes or categories. The classified image was then converted to shape file for further processing and analyses in ArcGIS 10.

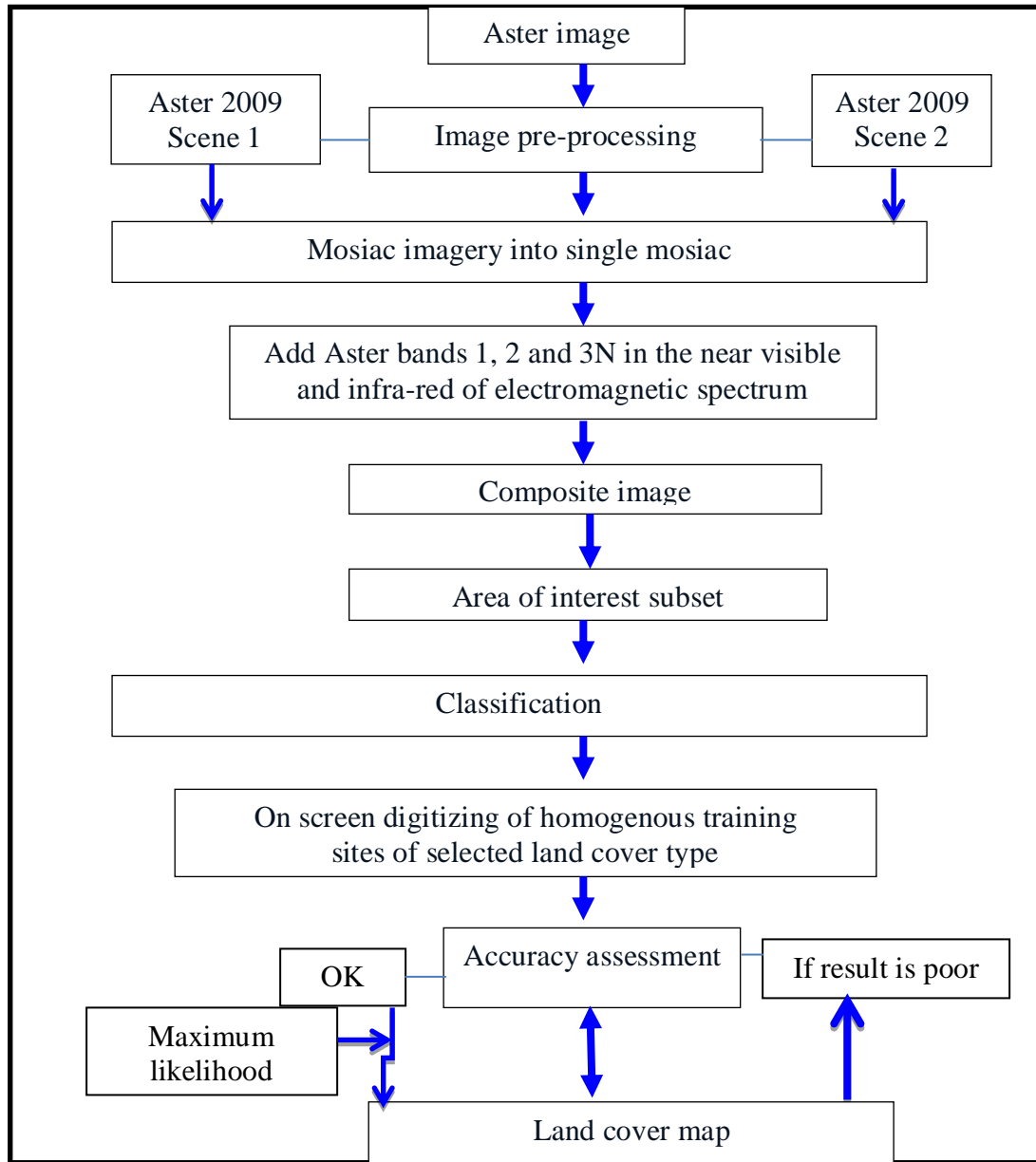


Figure 9: General procedure for the supervised classification of Aster imagery in ERDAS IMAGINE 2011

#### 4.2.5 Classification accuracy assessment

Accuracy assessment was done to check for remote sensing classification errors or to quantify the accuracy of the classification. An error matrix was generated in ERDAS IMAGINE 2011 to check if signatures for predefined cover classes were confused or mixed up with each other and also to determine the level of representativeness of training sites for a particular class. Overall



accuracy percentage, excluding omission (users accuracy) or commission errors (producer accuracy) was estimated by summing the total number of correct pixel for each class type (D) divided by the total number of cells in the error matrix (N), multiplied by 100.

Using the formula (1) below adopted from Ridd and Liu 1998, Kappa Coefficient for each class was calculated first, to compare or check if classes were significantly different and also to ensure that the final classification output is not a result of chance.

$$K = \frac{N \sum_{i=1}^r X_{ii} - \sum_{i=1}^r (X_{i+} \times X_{+i})}{N^2 - \sum_{i=1}^r (X_{i+} \times X_{+i})} \dots\dots\dots(1)$$

Where :

K = Kappa Coefficient

N = Total number of observation included in the matrix

r = Number of rows in the matrix

$X_{i+}$  = Marginal total of row i (right of the matrix),

$X_{ii}$  = Number of observations in row i column i (along the major diagonal),

$X_{+i}$  = Marginal total of column i (bottom of the matrix).

The spectral characteristics of the different signatures from the training data formed the basis for the classification of the total satellite image using the maximum likelihood classifier in ERDAS IMAGINE 2011.

#### 4.2.6 Field validation of geograhic information system / remote sensing classification

To further increase the accuracy of classification, field surveys were conducted to validate the GIS based classification. A simple stratified random sampling technique was applied. This technique has been recommended (Congalton 1991) for the validation of designated stratum or class in the field after remote sensing classification. Ground control points representing the different cover types were selected from 884 grids cells of 1 km x 1 km established over the classified map of the study area with the aid of ArcView 3.2 to facilitate the selection of field sampling points. Forty point (waypoints) were randomly and objectively selected over the study area with the aid of a random number table and entered into hand held Geographic Positioning System units (Garmin 60 and 62), for later location in the field. Figure 10 and Table 4 show the distribution of selected field survey points for each designated cover class over the study area.

Prior to final classification, two broad class categories including savanna and secondary mixed forest (Table 4) were masked pending field validation. After field validation, they were then further classified into tree savanna and grassland savanna, and to secondary mature forest and young secondary forest respectively, as vegetation types were confirmed more precisely from field surveys. These classes were later incorporated in the knowledge base map of the park.

Due to time, logistic and administrative constraints, only 32 points were actually validated in the field. Field validation ensured that all land cover classes were validated. At each field point (excluding points on water bodies and settlement areas), plots of 10 m x 10 m were established within which observations of vegetation cover was conducted based on selected criteria for the confirmation of previously defined classes. Criteria for validation included upper canopy cover density defined as 'non' from 0 - 20 %, 'low' from 20 – 60 % or 'high' from 61 - 100 %, based on stage of development of vegetation defined by additional criteria including, size and height of trees present (e.g. large tree diameter for mature forest and vice versa), tree species present, topography, undergrowth vegetation density and disturbances. Additional data of important field features, which could not be distinguished from the visualization of pre-processed images or were not clearly distinguished on maps but were observed in the field, were recorded. Photographs of each cover type at selected survey points were taken. All field observations were geo-referenced and later used for the validation of the remote-sensing based supervised classified map of the study area.

Table 4: Number of sampling points per land cover type

<b>Cover type</b>	<b>Number of sampling points selected</b>	<b>Number of sampling points validated</b>
Dense forest	11	10
Savanna	10	7
Secondary mixed forest	15	12
Settlement	2	2
Water surface	2	1
Total	40	32



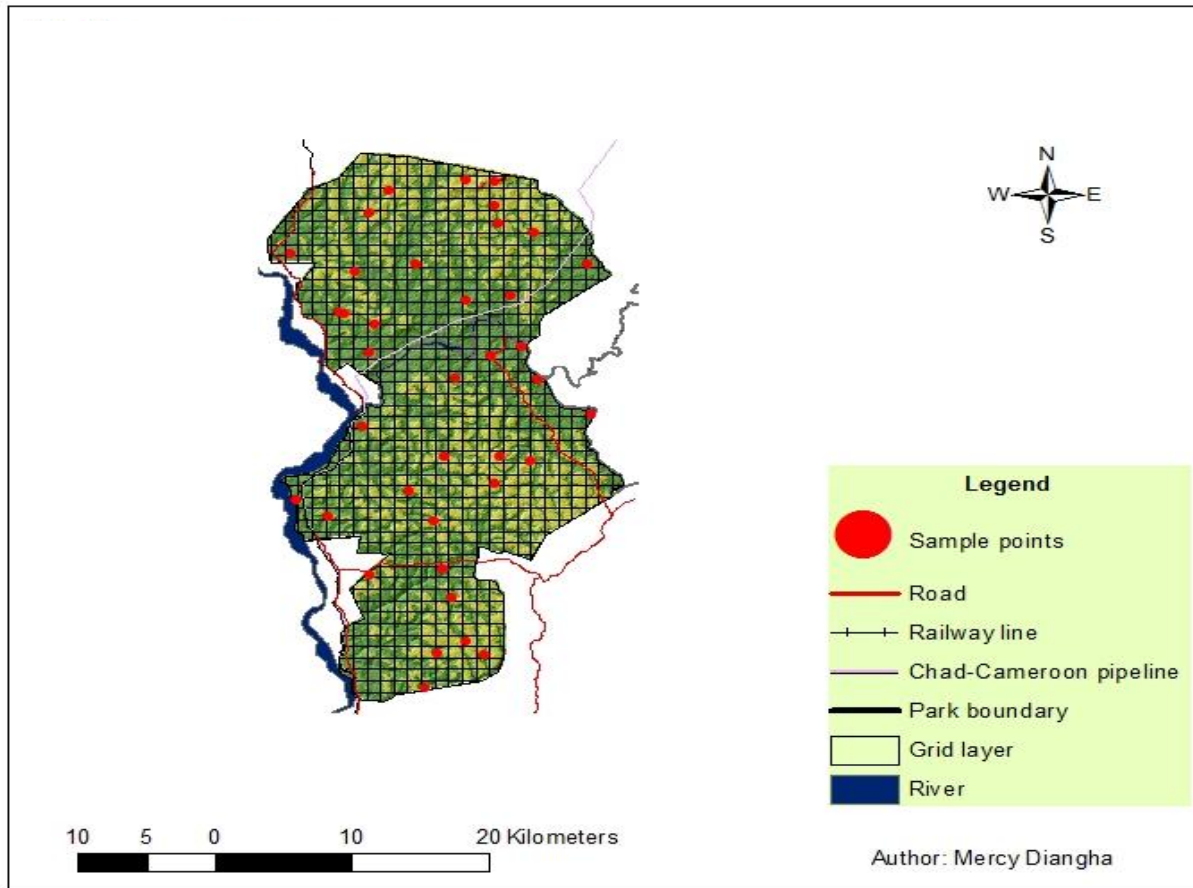


Figure 10: Field survey map showing grids and the distribution of field validation points

#### 4.2.7 Habitat characterization

Habitat characterization was done mainly in ArcGIS 10 with the aid of Patch Analyst 5.1 tool (Rempel et al. 2012) and also in ERDAS IMAGINE 2011. Specifically selected landscape metrics (Table 5) of interest to this research were analysed for the quantification and description of habitat composition and configuration within the park. Figure 11 illustrates the procedure for the analysis of landscape metrics for the characterization of the Deng Deng National Park.

Table 5: Landscape metric adopted for land cover analyses

Metric group	Landscape class level metrics	Analysis approach
Area	Area or extent of a class	Calculated as area covered by each class type.
	Mean class size	Calculated as cumulative average size of patches of a single class.
	Mean patch size	Average area of all patches.
Percentage of landscape	Percentage of area cover by each class	Calculated as the proportion of area covered by each cover type with respect to the total landscape area.
Diversity / Richness	Number of land cover classes and number of patches within a class (NumP)	Counts of the number of subdivisions in the landscape and also the number subdivisions of each class type.
Density	Frequency of occurrence of a habitat class	Computed by dividing the number of patches in a class (richness) by the total area (extent) of that class.
Shape index	Mean shape index (MSI)	It measures the average patch shape or perimeter-to-area ratio, for a patch type or patches in the landscape.
	Mean Fractal dimension (MFD)	Measures the level of complexity of patches by comparing with standard shape (e.g. square) Calculated as patch perimeter divided by patch perimeter for a patch square of same size.

(Sources: McGarigal 2002, Wu et al. 2002)

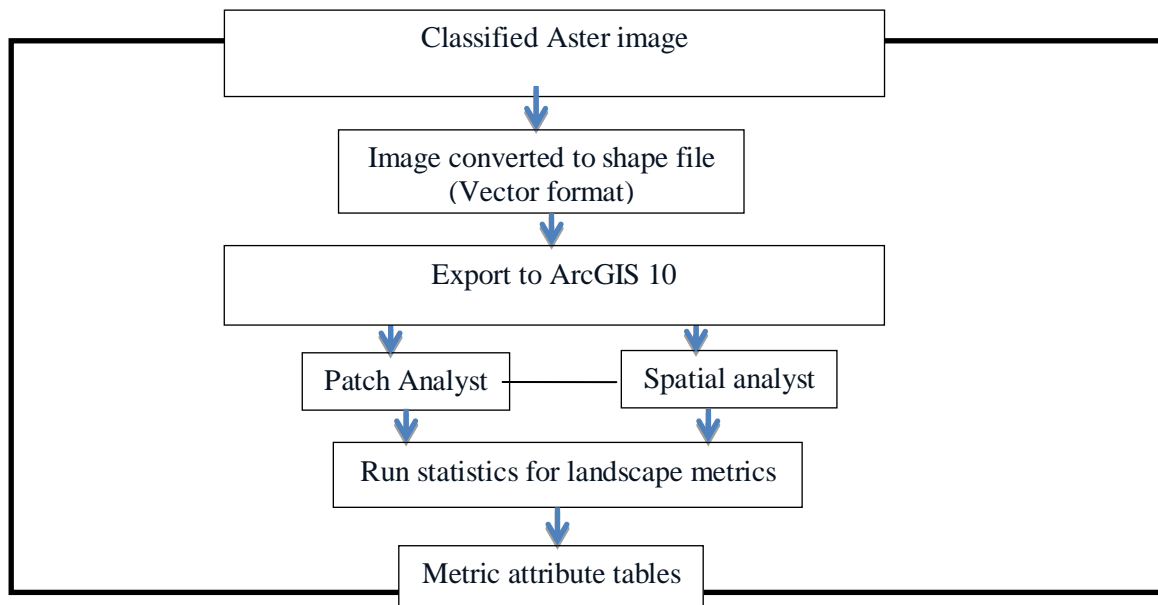


Figure 11: Flowchart of habitat characterization approach in ArcGIS

#### 4.2.8 Temporary patterns of habitats within the Deng Deng National Park

##### Change detection

Analyses of change in land cover over time for any given area are possible through the application of different approaches (Lu et al. 2004, Macleod and Congalton 1998) including image differencing, which can be achieved by subtracting spatial characteristic of images acquired at two different periods (Tardie and Congalton 2004, Mertens and Lambin 1997), normalized vegetation index (NDVI) image differencing, based on estimating the productivity (green biomass) of vegetation cover at two or more contrasting period (Hayes and Sader 2001), image rationing and regression, which ration images of different periods via pixel by pixel or band by band to evaluate the differences (i.e. the mean and variance) between them (Ilsever and Ünsalan 2012, Singh 1989), and a post classification comparison approach, which entails the comparison of two or more independently classified images (Singh 1989).

For the purpose of this study, both the Normalized Difference Vegetation Index (NDVI) and the post classification comparison approaches were applied in determining the temporary patterns of land cover within the Deng Deng National Park landscape. Three images including Landsat 7 TM and ETM+ and ASTER, covering the study area for the contrasting periods, 1987, 2000, and 2009 were subjected to NDVI analysis, supervised classification and post classification comparisons to determine change over time. NDVI was computed from these multispectral remotely sensed images in ERDAS IMAGINE using formula (2) below:

$$NDVI = \frac{(NIR - R)}{(NIR + R)} \dots\dots\dots (2)$$

Where NIR is the near infrared band and R is red band of the electromagnetic spectrum.

Due to the different sources of images used for image analysis, bands used for analysis were also different. For Landsat 7 TM and ETM+ images, NDVI was calculated using bands 3 and 2 of the electromagnetic spectrum as presented in the following formula (3):

$$NDVI = \frac{(Band\ 3 - band\ 2)}{(Band\ 3 + band\ 2)} \dots\dots\dots (3)$$

While NDVI for the Aster image was calculated using bands 4 and 2 of the electromagnetic spectrum as follows:

$$\text{NDVI} = \frac{(\text{Band 4} - \text{band 2})}{(\text{Band 4} + \text{band 2})} \dots\dots\dots (4)$$

Following image processing procedures illustrated above (Figure 9, page 39), Landsat 7 TM and ETM+ images of the respective contrasting periods 1987 and 2000 were also pre-processed in ERDAS IMAGINE 2011 using band combination 7, 4, and 2 of the electromagnetic spectrum to produce composites images, which were then subjected to supervised classification using the maximum likelihood approach. Classifications of all images (i.e. Aster, Landsat 7 TM and Landsat ETM+) of the contrasting periods (1987, 2000, and 2009) were simplified into identical seven classes. Classification outputs of the contrasting years were then examined for overall accuracy and Kappa Coefficient levels.

Post classification comparison approach was applied mainly by differencing landscape metrics (analysed in ArcGIS 10, Patch analyst) of the respective cover aggregates of the contrasting periods.

#### **Rate of change and habitat modification projection over a 23 years' time lag**

Habitat change and projections were analysed following George et al. (2004) methods and materials of demography approach. Annual rate of change of the habitat classes identified in the Deng Deng National Park landscape was computed using the formula:

$$\text{Annual rate of change} = \frac{(\text{Area in period 2} - \text{Area in period 1})}{(\text{Number of years})} \dots\dots\dots (5)$$

Habitat modification projection over a 23 years' time lag for each cover type was estimated based on exponential extrapolation, which assumes that the area covered by each land cover type will increase or decrease at a very similar trend to the annual percentage rate throughout the projection horizon. The following formula was applied:

$$\text{Projection} = (\text{Area of period 2}) * e^{rz} \dots\dots\dots (6)$$

Where e = exponential, r = ln (area of period 2 / area of period 1) / number of years in the base period, and z = number of years in the projection horizon.

### 4.3 Surveys of large mammals in the Deng Deng National Park

An important focus in this study to assess the effects of habitat heterogeneity on large mammals in the Deng Deng National Park was to determine the relationship and variation between the identified habitats and the diversity, abundance and distribution of large mammals within the National Park landscape. The following methodical steps were taken to achieve this objective.

#### 4.3.1 Selection of large mammal study species

Survey conducted prior to and after the creation of Deng Deng National Park reported the presence of diverse large mammal species in the area (Appendix 2). Based on the ecological and conservation status of species, eleven large mammal species, mainly ungulates and primates belonging to 3 orders and 4 distinct families (Table 6) were selected for this study.

Table 6: Large mammal species selected for survey

Order	Family	Scientific Name	English names
Artiodactyla	Bovidae	<i>Syncerus caffer nanus</i> (Boddaert 1785)	Forest buffalo
Artiodactyla	Bovidae	<i>Tragelaphus eurycerus</i> (Ogilbyi 1837)	Bongo
Artiodactyla	Bovidae	<i>Tragelaphus spekii</i> (Speke 1863)	Sitatunga
Artiodactyla	Suidae	<i>Potamochoerus porcus</i> (Linnaeus 1758)	Red River Hog
Artiodactyla	Bovidae	<i>Cephalophus dorsalis</i> (Gray 1846)	Bay Duiker
Artiodactyla	Bovidae	<i>Cephalophus monticola</i> (Thunberg 1789)	Blue Duiker
Artiodactyla	Bovidae	<i>Cephalophus rufilatus</i> (Gray 1846)	Red-flanked duiker
Artiodactyla	Bovidae	<i>Cephalophus silvicultor</i> (Afzelius 1815)	Yellow-backed duiker
Primates	Hominidae	<i>Gorilla gorilla gorilla</i> (Savage 1847)	Gorilla
Primates	Hominidae	<i>Pan troglodytes troglodytes</i> (Blumenbach 1799)	Chimpanzee
Proboscidae	Elephantidae	<i>Loxodonta cyclotis</i> (Matschie 1900)	Forest Elephant

**Ecological status of species:** Ecologically, the species listed in table 6 (above) were selected because, they leave visible signs, notably dung, nests, footprint (tracks) and characteristic feeding marks and residues that could (with some degree of precision) be identified. Large mammal groups like duikers, whose pellets have similar morphological characteristics and often are sources of identification accuracy problems (Hibert et al. 2008, Van-Vliet et al. 2008), pellets

were distinguished into groups of large, medium and small to represent the different species of duikers in the study area. Large pellets represented yellow-backed duiker, medium size pellets represented all medium sized duikers in the park particularly the bay duiker and red-flanked duiker, while small size duikers were represented by the common blue duiker (Table 6).

**Conservation status of species:** The conservation status of species particularly the international, national and local importance attached to individual species was relevant for the selection of study species.

With respect to the IUCN red list, species selected for the study represented six categories of threats (Table 7) including species that are critically endangered (e.g. gorilla), endangered (e.g. buffalo and chimpanzee), threatened (e.g. sitatunga), vulnerable (e.g. elephant), low risk and near threatened (e.g. bongo) and of least concern (e.g. all duikers and red river hog).

At the national level species selection was guided by the Cameroon wildlife law (Government of Cameroon Law No. 94/01 of 20 January 1994 to lay down forestry, wildlife and fishery regulations: section 78) that has classified wildlife species into three management categories 'A', 'B' and 'C' (Djeukam 2012). Category 'A' comprises rare species or species threatened with local extinction. Species selected from this category were gorilla, chimpanzee, elephant, and the yellow-backed duiker. Category 'B' comprises species that benefit from partial protection but can be hunted, captured or killed only after obtaining license. Species selected from category 'B' were buffalo, bongo, sitatunga, bay duiker and red river hog. Category 'C' describes species with high proliferation rates that are partially protected and are not in 'A' and 'B'. Species selected from category 'C' group was the common blue duiker.

Lastly, species selection was also guided by the local cultural and economic importance assigned to species (Table 7). All species selected were either killed for their meat as a source of protein or sold in the form of bush-meat to generate household income. Species such as gorilla and chimpanzee, yellow-backed duiker were selected because of their additional cultural and traditional values (taboo) to the local population around Deng Deng National Park (GVC 2007, Fotso et al. 2002). Table 7 presents the conservation status that prompted the selection of study species.

Table 7: Conservation statuses and community values of selected study species

(CR-critically endangered, EN-Endangered, TH-Threatened, LR-Low Risk, NT-Near threatened, LC-Least Concern), A, B, and C are described in text above.

Large mammal species			IUCN category	National category	Value to community
Bongo			LR/NT	B	<ul style="list-style-type: none"><li>• Not common</li></ul>
Chimpanzee			EN	A	<ul style="list-style-type: none"><li>• Protein from meat</li><li>• Income from bush-meat sales</li><li>• Cultural taboo</li></ul>
Duikers	Large size	Yellow backed	LC	A	<ul style="list-style-type: none"><li>• Protein from meat</li><li>• Income from bush-meat sales</li><li>• Cultural taboo</li><li>• Common</li></ul>
	Small size	Blue	LC	C	<ul style="list-style-type: none"><li>• Protein from meat</li><li>• Income from bush-meat sales</li><li>• Very common</li></ul>
	Medium size	Bay	LC	B	<ul style="list-style-type: none"><li>• Protein from meat</li><li>• Income from bush-meat sales</li><li>• Very common</li></ul>
		Red-flanked	LC	C	<ul style="list-style-type: none"><li>• Not Common</li><li>• Income from bush-meat sales</li></ul>
Forest buffalo			EN	B	<ul style="list-style-type: none"><li>• Protein from meat</li><li>• Income from bush-meat sales</li></ul>
Forest elephant			VU	A	<ul style="list-style-type: none"><li>• Protein from meat</li><li>• Income from bush-meat sales</li><li>• Not common</li></ul>
Gorilla			CR	A	<ul style="list-style-type: none"><li>• Protein from meat</li><li>• Income from bush-meat sales</li><li>• Cultural taboo</li></ul>
Red River Hog			Common (LC)	B	<ul style="list-style-type: none"><li>• Main source of bush-meat</li><li>• Income from sales</li><li>• Common</li></ul>
Sitatunga			TH LR/NT (2002)	B	<ul style="list-style-type: none"><li>• Protein from meat</li><li>• Income from bush-meat sales</li><li>• Not common</li></ul>

Source: The IUCN Red List of Threatened Species version 2014.3, Djeukam 2012, Fotso et al. 2002, IUCN 2001)

#### 4.3.2 Selection of method for large mammal survey

Estimating population of large mammals through direct observation or direct sighting of animals in the tropical dense forest has been problematic (Borchers et al. 2002) because of the shy, elusive and sometimes cryptic nature of large mammal species (Noss et al. 2012) and also because of the poor visibility in dense tropical forest (Varman and Sukumar 1995). Several

indirect approaches have been developed to address these problems including the use of indirect signs of animals such as animal dung, animal nest, animal tracks and trails (Barnes 2001, Plumptre 2000) as proxy for the estimation of animal presence and population. Advance systematic methods of indirect estimation of large mammals densities are currently being explored such as the use of camera traps (Noss et al. 2012, Tobler et al. 2008), video recording (Scheibe et al. 2008), and line transect method (Plumptre 2000, Walsh and White 1999, Varman and Sukumar 1995). For the purpose of this study, mainly the line transects method (section 4.3.4, page 50) was adopted for the survey of large mammals in the park. Standing crop method (Section 4.3.4, page 52) was applied to assess the presence of primate nest (Plumptre and Reynolds 1996) in the study area. Additional reconnaissance data were collected along reconnaissance walk from one transect point to another to further confirm the presence of selected species in the study area.

#### **4.3.3 Selection of field sampling sites**

Following classification of habitats in the park, geo-referenced square grid of 1 km x 1 km were generated in ArcView 3.2 and then overlaid on the classified surface of the map to facilitate the selection of sampling points, for large mammal monitoring in the field. Field points for the establishment of line transect, representing the different habitats or land cover types identified in the study were generated using a random number table. Twenty-nine sampling points were then randomly selected for the survey but ensured that all habitat types present in the study area were represented. Figure 12 shows the location of sampling points of large mammals in the study area.

Once sampling points were selected, geographical coordinates in Universal Transverse Mercator (UTM) of each point were then referred from the map and entered into hand held GPS units (Garmin 60 and Garmin 62) for later location in the field. Each UTM point coordinate, was considered as starting point for each transect in the field.



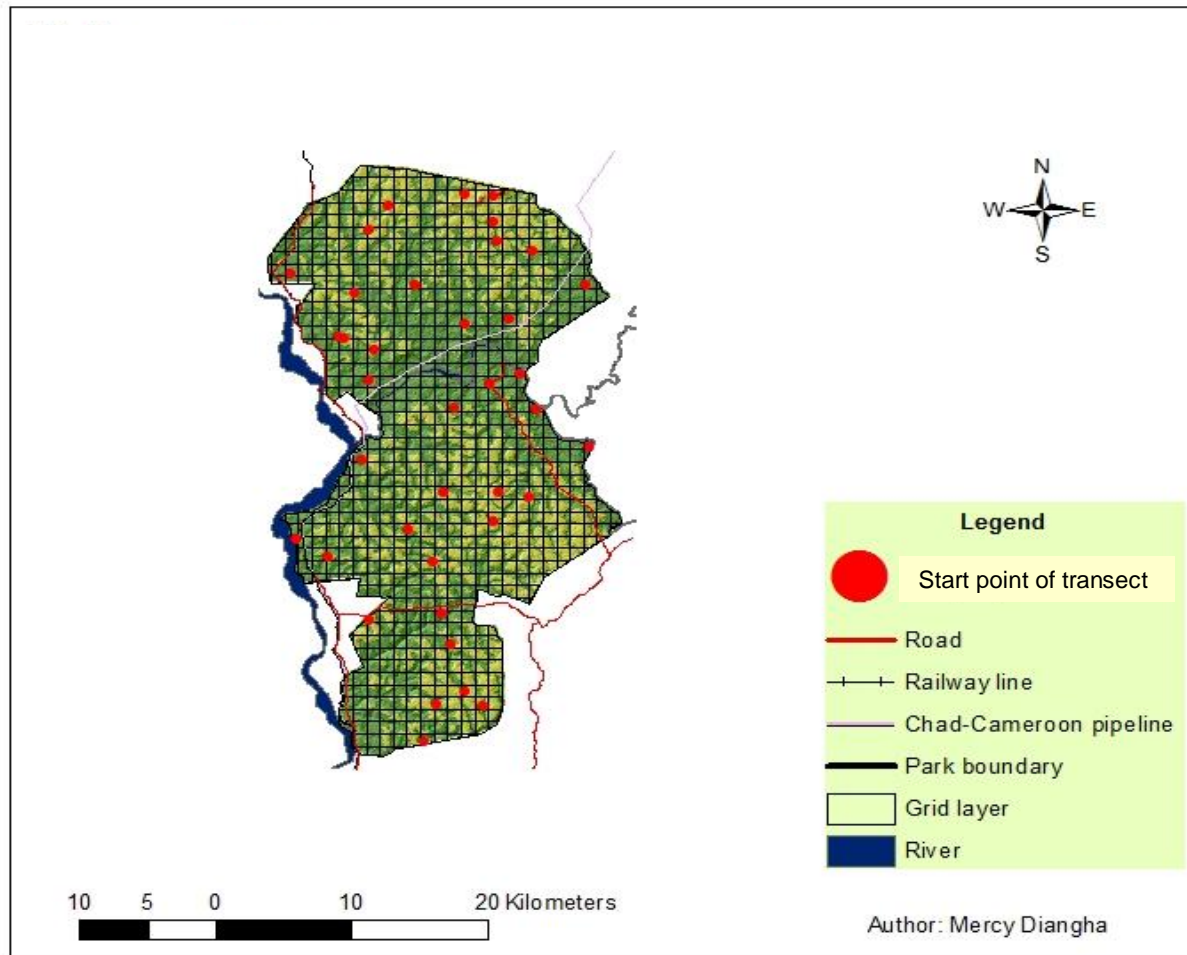


Figure 12: Map of study area showing distribution of sampling sites for large mammal surveys

#### 4.3.4 Field survey and data collection

##### Line transect method

The establishment of transect followed protocols of line transect recommended by (Barnes and Jensen 1987) and Buckland et al. (1993). Materials used for the establishment of transects included machetes for cutting, compasses for defining bearing and directions of transects, hipchain for transect length measurement, and measuring tapes for perpendicular distance measurement.

At each selected sampling point (Figure 12), line transects of 2 km each were minimally cut following defined compass bearings objectively oriented tangential to set considerations including park boundary, elevation and drainage. Transects were cut and walked by two survey teams of five persons each, composed of one compass bearer, a “Macheteur” or cutter, two

observers one data recorder and hipchain bearer. Two persons were strictly assigned duty to observe for the presence of dung and tracks of mammals along transect. All team members however participated in the observation and identification of direct and indirect signs of mammals species encountered along transect, thus increasing precision.

Along each transect route, the type of data collected for analyses included the direct (e.g. seen, heard) and indirect (e.g. dung, track, nest, heard, feeding residue) signs of individual study species. For each observation of dung pile, data type such as distances along transects, perpendicular distance from line to object (Figure 13), name of species and the forest type where dung were observed were recorded.

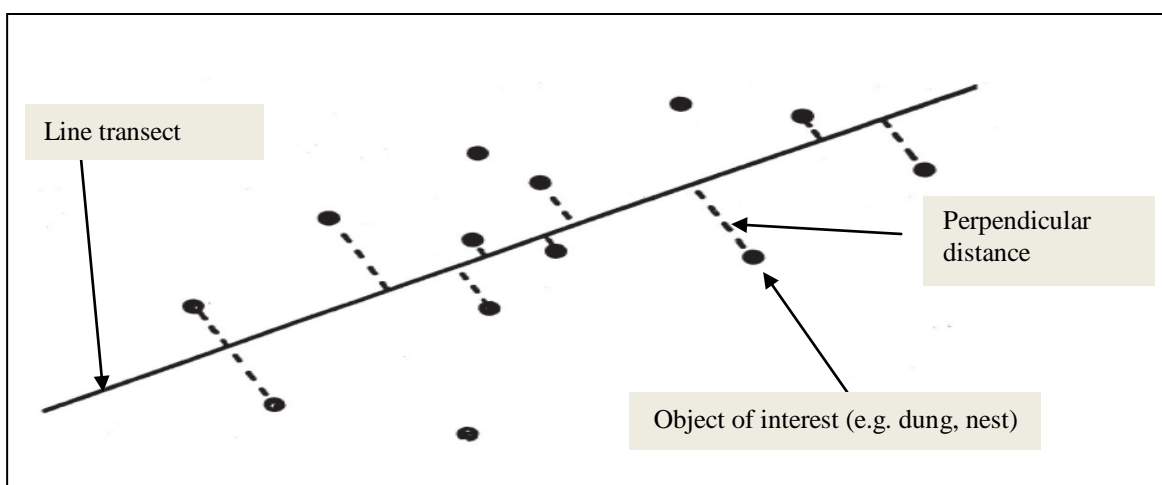


Figure 13: Illustration of line transects method showing transect line, perpendicular distances and objects of interest

Forest type was assigned mainly based on forest structure (above and understory canopy, tree height and size, disturbance and landform). Figure 13 illustrates the line transect approach while plate 7 show the practical establishment of transects in the field.

**Assumptions of line transect method:** There are several assumptions established for the line transect method (White and Edwards 2000), but among them, this study adopted the assumptions that all objects of interest on the transect line are never missed and are detected with a probability of one ( $p = 1$ ). It also assumed the non-detection of some objects especially those that are further away from the transect line, where probability of detection was expected to decrease with increasing distance from the transect line ( $p < 1$ ).

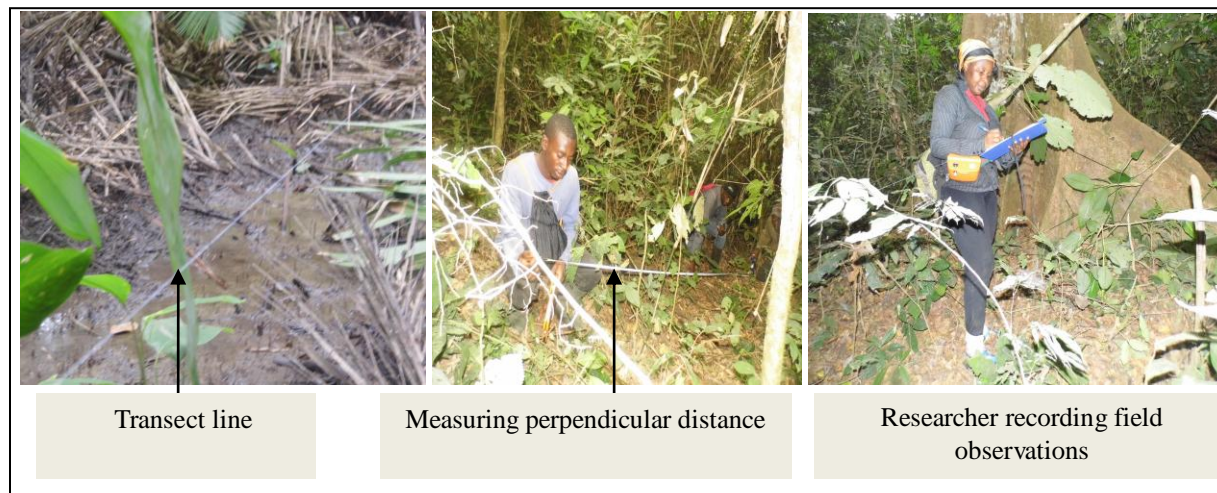


Plate 7: Field demonstration of line transect establishment and data recording

### **Standing crop method**

The standing crop count method which involves counting nest of all ages found along transects (Plumptre and Reynolds 1996), was applied in this study to estimate the apes (gorilla and chimpanzee) nest group density. For each nest encountered, data including the distance along transect, forest type where it was found, perpendicular distances from center of transect to nest and tree height in the case of tree nest were recorded.

Mainly spatial data (UTM coordinates) of species presence were recorded along reconnaissance walk between sampling sites. Spatial data on nest, dung piles of individual species found were mapped using hand held GPS devices to facilitate visual analysis of species distribution.

#### **4.3.5 Sampling effort**

Field trips of a minimum of 20 days each were completed during the actual data collection period of January and March 2013. Given the remoteness of the study site, a minimum of one day was spent establishing one or two transects in the field and one day for changing camp sites from one transect location to another since transect points were sparsely located. At each predetermined location (Figure 12), line transects of length 2 km each were established. Sampling effort was distributed over the study area to cover all land cover types identified from classification analysis. Layers such as settlement and water bodies where study species were not expected to be present

were not considered for the survey. Transect length totalling 58 km was walked during the survey for the collection of required data. Table 7 shows the distribution of sampling efforts within the different types of land cover in the Deng Deng National Park.

Table 8: Distribution of sampling effort for large mammal surveys in the study area

Cover type	Number of sampling points selected	Number of sampling points for large mammal survey	Total length of transect (km)
Dense forest	11	10	20
Savanna	10	7	14
Secondary mixed forest	15	12	24
Settlement	2	-	-
water surface	2	-	-
Total	40	29	58

#### 4.3.6 Analysis of species diversity, abundance, density, and distribution

**Analyses of species richness and diversity:** Data collected from transects and in the respective land cover types were analyzed to assess the diversity and richness of the selected study species. Species richness was simply analyzed as the number of species present on transects and in the respective habitats. Shannon-Wiener index of diversity (formula 7) was used for the analysis of species diversity in the sampled area.

$$\text{Diversity index} = (H' = - \sum p_i \ln p_i) \dots \dots \dots (7)$$

Where  $p_i$  = the proportion of species  $i$  and  $\ln$  = the natural logarithm.

**Estimating absolute density of species:** Indirect signs (dung or nest) of species presence were used for the quantitative estimation of density per unit area. Densities of species with at least 40 field observations were estimated in DISTANCE 6.0 computer software (Thomas et al. 2010). The software was preferred over other methods of analysis because it has been designed to recognize the fact that the ability to detect objects (detection function or detection probability) in the field, declines with increasing distance from transect line. By estimating how detection probability declines with distance from line transect, DISTANCE 6.0 calculated the effective strip width (ESW) and area of transect (2Lw). Area of transect was then used in the formula below, to convert the number of signs counted per species (n), to an estimate of the species

density in the sampled area. Detection probability (p) was estimated in DISTANCE 6.0 by assuming that object detection distances are normally distributed with values ranging from 0 to 1.  $p = 1$  when object is at zero distance (directly on line transect) and is very visible.  $p = 0$  when object is further away from transect and not visible. Density was calculated using the following formula:

$$D = n / (2Lwp) = D_s \dots\dots\dots (8)$$

Where  $D$  = Density,  $n$  = number of objects observed (i.e. number of dung piles or number of nest),  $L$  = length of transect,  $w$  = critical observation width of transect,  $p$  = detection probability of object (dung or nest),  $2Lw$  = effective survey area of transect where all objects were detected.

Estimating density of dung and nest also required converting the result ( $D_s$ ) by known factors such as rate of dung deposition and decay, or rate of nest production and decay using the following formula:

$$D_a = D_s / P \times t \dots\dots\dots (9)$$

Where  $D_a$  = density,  $D_s$  = estimated density of animal signs in the study area,  $P$  = production rate of signs,  $t$  = estimated mean time for signs to decay.

Given the above approach, dung and nest data collected from field were prepared in rows and column then converted to text tab delimited compatible with DISTANCE software, and then exported into the software for analysis. Analysis in DISTANCE 6.0 employed the conventional distance sampling (CDS) engine where data were filtered to right truncation at largest observed distance, to analyse the critical observation width ( $W$ ). Normal cosine adjustments of observation, and detection function ( $g(x)$ ) analysis model were also selected for the analysis in DISTANCE 6.0

In addition to field data, known dung and nest decay rates of selected species (Table 9) were entered in DISTANCE 6.0 to run density calculations of the individual selected species. The dung production and duration rates of forest duiker obtained from Koster and Hart (1988), nest production and duration rates of gorilla and chimpanzee obtained from Todd et al. (2008), Tutin, et al. (1991) and Tutin and Fernandez (1984) were used for density estimations.

Table 9: Dung decay and production rates of selected large mammal species

NA = not available, NNS = non nesting species

Species	Dung defecation rate	Dung decay rates (days)	Nest decay rate (days)
Blue duiker	4.9	18	NNS
Medium sized duiker	4.4	21	NNS
Gorilla	3 -5	NA	221
Chimpanzee	NA	NA	120

Adopted from Todd et al., (2008), Koster and Hart (1994), Tutin et al., (1991), Tutin and Fernandez (1984)

**Estimating relative abundance:** Kilometric Abundance Index (KAI) or encounter rates referring to the number of observations of a study object encountered per kilometer (Preatoni et al. 2012, Nasi and Van-Vliet 2011, Mathot and Doucet 2006, Buckland et al. 1993, Vincent et al. 1991) was applied for the estimation of the abundance of study species in the study area. This approach was also important for the comparisons of species abundances between transect and land cover types within the study area. KAI was assessed based on the ratio of the total number of signs (dung, tracks, and nest) present or observed along transect to the total distance (transect length) travelled.

$$KAI = \frac{\text{Number of signs observed}}{\text{Transect length covered}} \dots\dots\dots (10)$$

Three indices including index of abundance per transect, index of abundance per land cover or habitat type, and index of abundance for the entire study area were analyzed per study species.

Encounter rates of species calculated separately for each habitat type were extrapolated for the entire park area since the proportion of area sampled for each habitat type was far less than the area covered by the habitat type in the entire park landscape. Estimates of abundance for each species present in the respective habitat types within the park entire area was calculated using formula (11), adopted from Choudhury 1991.

$$\text{Abundance} = \frac{\text{Sampled area encounter rate for each species within each habitat type}}{\text{Total area occupied by the vegetation type in the park}} \dots\dots\dots (11)$$

**Species habitat association:** Spearman's rank correlation was analyzed in SPSS to determine the strength and direction of the association between large mammal species richness and abundance with the respective habitat types in the study area using the following formula (12). Significance of the correlation was also computed to validate the hypotheses established for the associations.

$$r_s = 1 - \frac{6 (\sum d^2)}{n (n^2 - 1)} \dots\dots\dots(12)$$

Where  $r_s$  = Spearman's rank coefficient  
 $d$  = Difference between ranks and  
 $n$  = Number of samples (pairs)

**Mapping abundance and distribution of species:** Presence and absence data collected for each species along transects and in the respective habitat types were vital for the determination of the species distribution in the study area. Species presence and encounter rates were spatially mapped in ArcGIS 10 to show areas of species concentrations (hotspots) in the study area.

#### **4.4 Assessment of human influence on large mammals**

Another focus of this study was to assess the effects of human influences on large mammals in the Deng Deng National Park. Methodological steps taken to achieve this objective involved identification of the human factors threatening the sustainability of the park, determination of where threats are occurring and their corresponding extent, and determination of the relationship and variation between identified threats and the abundance and distribution of large mammals within the National Park landscape.

##### **4.4.1 Identification of human factors threatening Deng Deng National Park**

Both secondary and primary data were collected to identify types of human factors threatening the park. Various literature sources of previous studies conducted in the park area, archived in the Wildlife Conservation Society / Cameroon Biodiversity Programme office library were important secondary sources. Also historical topographic and land use maps, and satellite images detailing land use such as settlement and presence of infrastructural features in and around the study area were important secondary sources used for the identification of some human factors. Field surveys along transects and reconnaissance walks were elucidated to complement and update the types of human threats occurring in the park.

#### 4.4.2 Field surveys of human threats in the Deng Deng National Park

Line transects and reconnaissance surveys approaches were used in this study to assess human intrusion in the park. Same line transects established for large mammal surveys (explained in section 4.3.4, page 50) were also walked by the research team to record observations of human presence or signs left by humans (users) in the study area. For every observation of human sign along transects, the type of sign and the habitat type where signs were observed, were recorded on data sheets designed for the purpose. Opportunistic observations of human signs were also recorded from reconnaissance walks conducted when walking between transects (i.e. from one transects to the next) in the field.

#### 4.4.3 Analyses of the occurrence and distribution of human threats

To facilitate the analysis of the effects of human factors on mammal species, signs recorded along transects were grouped into eight categories. Categorization of signs ensured that all signs observed as pertains to the study area were included. Analysis of the encounter rates of human threat categories in the park, and analysis to show the relationship or association between threats and large mammal encounter rates in the study area were done using Excel 2010 and SPSS, respectively. The distribution of threats in the study area was analysed with the aid of ArcGIS 10.

**Encounter rate of human signs:** For each sign category, indices of human pressure including index of abundance of human threat category for the entire sampled area, index of abundance of human threat category per transect, and index of abundance of human threat category per land cover or habitat type were analyzed to show the intensity of human intrusion in the park and to ease contrasting between large mammal encounter rates with each human threat categories. Encounter rates (ER) or Kilometric Index of Abundance (KAI) of signs recorded from sampled area were calculated as:

$$ER = \frac{\text{Counts of each sign category}}{\text{Transect length covered (km)}} \dots\dots\dots (13)$$

Encounter rates of signs of human intrusion recorded from reconnaissance survey were also analysed and then were compared with results analysed from transect data. Confidence intervals were also computed to determine the level of precision of the encounter rates.



**Mapping distribution and extent of human intrusion in the park:** Frequencies of occurrence of the different human threat categories were analysed to determine distribution of threats. Spatial data collected with the aid of Garmin 60 and 62 GPS hand held devices on the various human signs that were noted in the park were later entered into ArcGIS 10 as attribute for further visual analysis to show the distribution and intensity of human activities. Shape files of different infrastructural developmental features, such as settlement (villages), roads network, petrol pipeline and railway were established and then overlaid on the map surface of the park, to show where they are located and to show how their locations threatens the park's integrity. Further spatial analysis to show the intensity and location of the others and different categories of human signs in the park were done in ArcGIS 10, using geo-referenced data points and encounter rates of threats indicators recorded in the sampled area. GPS locations of human signs collected during reconnaissance walks were also integrated in the spatial surface. An overall spatial landscape showing the spread and concentrations of human threat indicators in the park was then analysed with the aid of ArcGIS 10.

#### **4.5 Secondary data**

Secondary data including the socio-economic and biophysical state of the survey area, satellite images, topographic maps and digital elevation model of the study area were obtained from different sources which include the University of Maryland, World Research Institute / Cameroon office, and the Geospatial Technical Group database in Cameroon. Secondary data on large mammal species occurring in the park area and types of human imposed threats faced by the park were obtained mainly from the Wildlife Conservation Society / Cameroon main office library and from various internet sources.

## 5 Results: Spatial and temporal patterns of habitats in Deng Deng National Park

### 5.1 Land cover types in the Deng Deng National Park

This study marks the first detailed land cover classification of the Deng Deng National Park derived from the application of both geospatial technology (GIS and remote sensing) and ground validation approaches to confirm the presence of predefined and distinct classes. Output from spatial analyses derived from supervised classification of satellite images (the mosaicked Aster image, Landsat 7 TM and ETM images of 1987, 2000, and 2009 respectively) and from field validation of habitat types in the study area, revealed and confirmed the presence of seven distinct land cover or habitat classes. Landscape features including rivers, streams, settlement area, park boundary polygon, digital elevation model and slopes that were also factored into the knowledge based supervised maps of the study area gave a clearer view of the physical state of the park. Figure 14 shows the land cover map of Deng Deng National Park while figure 15 presents a general land use map of the park derived from this study. Section 5.2 describes the seven habitat classes identified in the study area from the from image analysis and from field surveys.

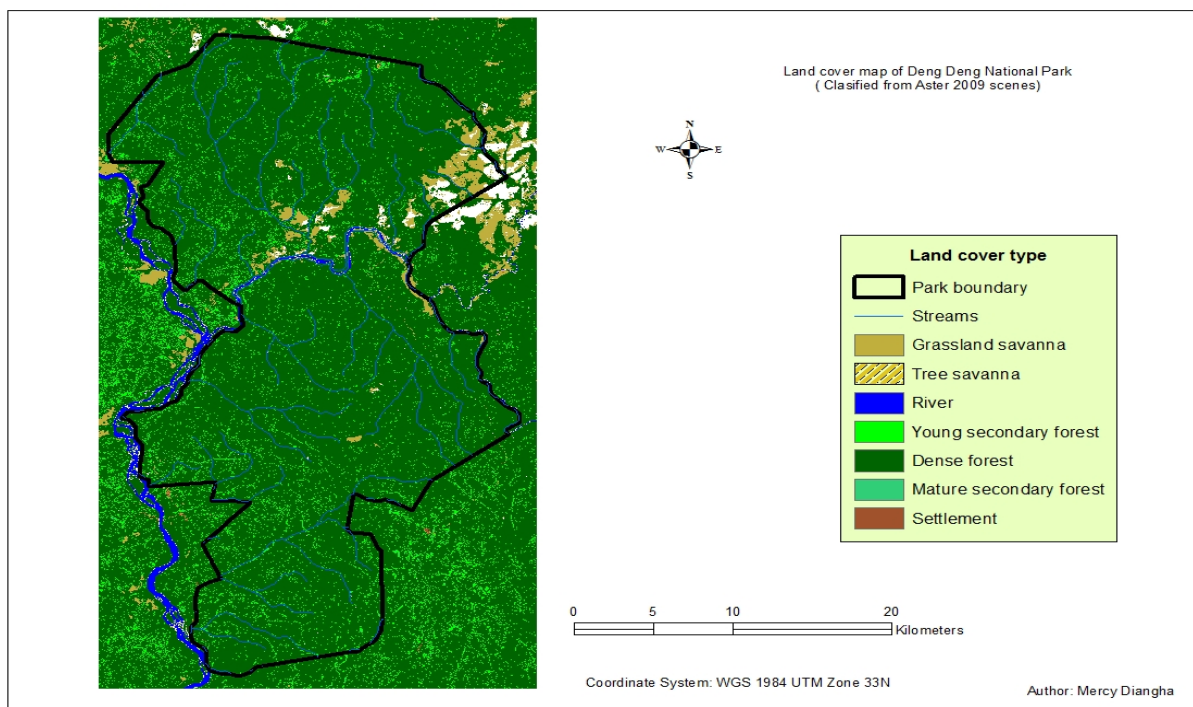


Figure 14: Land cover map of Deng Deng National Park derived from Aster scene composite

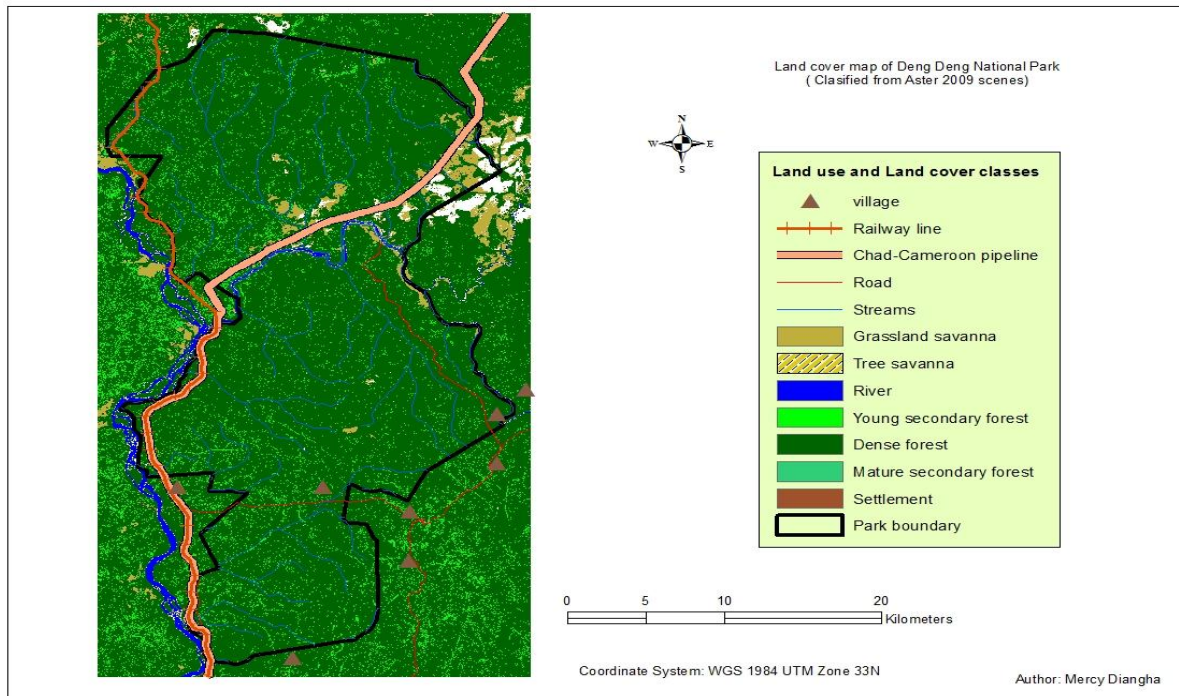


Figure 15: Map showing land use and land cover classes obtained in Deng Deng National Park

## 5.2 Description of habitat classes identified in the Deng Deng National Park

1) **Dense forest:** Includes areas of the image (Figures 14 and 15, pages 59 and 60) identified by their dark green colour and physically covered by natural humid tropical trees (Plate 8). It structurally consists of two to three floristic layers with upper canopy reaching 85 % and understorey open (Plate 8). Tree heights of the superior layer in this habitat ranged between 35 m to 50 m, while tree diameter at breast height was estimated within the range of 80cm to 250 cm.



Plate 8: Dense forest cover in Deng Deng National Park (Source: Author)

Trees in this habitat retain their leaves throughout the year. Some common tree species recorded in this habitat included *Entandophragma cylindricum*, *Erythrophyllum ivoriensis*, *Hylocodendron gabonensis*, *Pycnanthus angolensis*, *Triplochiton scleroxylon*, *Sterculia oblonga*, and *Greenwaydendron suaveolens*.

2) **Mature secondary forest:** Includes areas of the image (Figures 14 and 15, pages 59 and 60) that are uniformly green and are not near any other type of land cover. This habitat is closely similar to the dense forest habitat but for the fact that the upper canopy is less dense (about 75 %) and undergrowth denser but clearer when compared with the young secondary forest (Plate 9). Tree height of the superior layer ranged between 25 m to 35 m while tree diameters ranged from 20 cm to 80 cm. Species composition was similar with those in the dense forest habitat. This habitat type occurred in small patches spread all over the study area and was more conspicuous on gentle slope of about 10 to 20 % in all directions. Some common species included *Mansonia altissima*, *Xylopia aethiopica*, *Tricalysis pallens*, and *Strebleus kamerunensis*.



Plate 9: Mature secondary forest cover in Deng Deng National Park (Source: Author)

3) **Young secondary forest:** Includes areas of the image (Figures 14 and 15, pages 59 and 60) that are uniformly light green and were not near any other type of land cover. This habitat type was differentiated by its irregular but moderate canopy condition with cover density of about 60 %. It has dense undergrowth and mostly present around forest areas that have witnessed disturbance (Plate 10). Tree heights in this habitat ranged from 15 m to 25 m while tree diameters ranged from 10 cm to 50 cm. Some common plant species included *Uapaca guinenensis*, *Musanga cercropioides*, *Albizia zygia*, *Bateria fistulosa*, *Macaranga* sp, and *Myranthus aboreus*.





Plate 10: Young secondary forest cover in Deng Deng National Park (Source: Author)

4) **Grassland savanna:** Included areas of the image (Figures 14 and 15, pages 59 and 60) that are uniformly dense orange and are not near any other land cover. It is characterized mainly by herbaceous grassland with grass height reaching 3 m (Plate 11). Dotted individual of shrub plants of not more than 5 m tall were also observed in this habitat. It is dominated by plants belonging to the plant family Gramineae



Plate 11: Grassland savanna cover in Deng Deng National Park (Source: Author)

5) **Tree savanna:** Includes areas of the image (Figures 14 and 15, pages 59 and 60) that are light yellow mixed with white. This habitat forms a transition between forest and grassland habitat type. Uppers canopy in this habitat was low and ranged from about 45 % to 55 % closed. Trees in this habitat reached heights of about 12 m but tree diameter is averagely low and could reach 15 cm. Some common species include *Terminalia glauscesens*, *Hymenocardia* sp, *Vitex doniana*, *Monotes kerstingii*, *Piliostigma thonningii*, *Lohpira lanceolata*, *Prosopis africana*, *Lannea fructicosa*, and *Imperata cylindrica*.



Plate 12: Grassland savanna cover in Deng Deng National Park (Source: Author)

6) **Water:** Includes areas of the image (Figures 14 and 15, pages 59 and 60) that are blue and are not close to any other color representing open water bodies of different sizes (Plate 13).



Plate 13: Water sources in Deng Deng National Park (Source: Author)

7) **Settlement:** Includes areas of the image (Figures 14 and 15, pages 59 and 60) that are uniquely brown. These habitat types were mostly observed along roads (main road and railway line) and along the oil pipeline. It is characterized by the presence of active or abandoned villages, permanent hut, other disturbances that has eroded vegetation cover



Plate 14: Village settlement in Deng Deng National Park area (Source: Author)

### 5.3 Accuracy assessment

Training pixels were positively separated and commissioned to predefined classes with an overall accuracy of 84.3 %. For the purpose of this study, this accuracy value was sufficient to continue with the supervised classification of images to produce land cover map of the study area. Classification accuracy derived from error matrix statistics of individual classes ranged from 98 % for the dense forest class to 100 % for settlement as shown along the diagonal line on table 10. Kappa coefficient calculated for the classification output was 0.98 (98 %) indicating that the maximum likelihood classification of the respective land cover classes was almost perfect and that pixel grouping for the respective land cover types was not due to chance.

Table 10: Error matrix derived from thematic classification of land cover in the Deng Deng National Park

Reference data									
Classified data	Habitat classes	Grassland savanna	Tree savanna	River	Young secondary forest	Dense forest	Mature Secondary forest	Settlement	Omission accuracy %
	Grassland savanna	<b>99.6</b>	0.66	0	0	0	0	0	<b>98</b>
	Tree savanna	0.3	<b>99.27</b>	0.64	0	0	0	0	<b>99.8</b>
	Water bodies	0	0	<b>99.3</b>	0	0	0	0	<b>100</b>
	Young secondary forest	0	0		<b>99.06</b>	0.82	0	0	<b>88.2</b>
	Dense forest	0	0.03	0	0.94	<b>98.94</b>	1.14	0	<b>99.8</b>
	Mature secondary forest	0	0	0	0	0	<b>98.86</b>	0	<b>100</b>
	Settlement	0.1	0.03	0	0	0.24	0	<b>100</b>	<b>87.2</b>
	<b>Commission accuracy %</b>	<b>99.6</b>	<b>99.3</b>	<b>99.3</b>	<b>99</b>	<b>98.9</b>	<b>98.8</b>	<b>100</b>	
Kappa coefficient = 0.98					Overall accuracy = 84.3%				

## 5.4 Land cover characteristic derived from landscape metrics analysis

Results from the characterization of large mammal habitats represented by five land cover classes in the park, including the dense forest, mature secondary forest, young secondary forest, tree savanna and grassland savanna area presented.

### 5.4.1 Habitat richness metrics

From classification analysis, seven classes are revealed in the park emphasizing the richness and diversity of land cover types within the park. To further elucidate the heterogeneity of the large mammal habitats in the park, it was important to think of heterogeneity in terms of number of individual habitat patches within each habitat category. Results derived from vector analysis in ArcGIS 10 aided by patch analyst tool as shown on figure 16 indicates that the mature secondary forest is the richest habitat type in terms of the number of patches within this land cover class (57,002 patches). In order of richness, the mature secondary forest is followed by the young secondary forest (5,779 patches), grassland savanna (1,931 patches), dense forest (1,447 patches), and tree savanna cover class (118 patches) in that decreasing order.

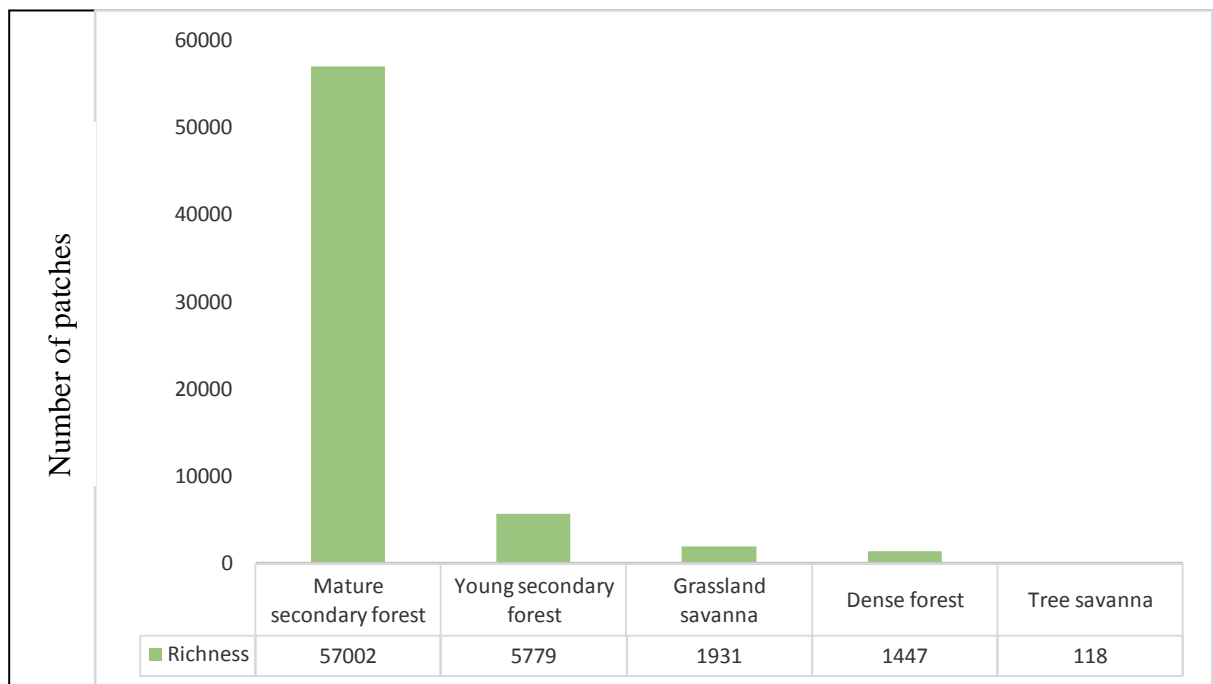


Figure 16: Habitat richness illustrated by number of patches of each habitat type in the Deng Deng National Park



### 5.4.2 Class area and size metrics

The extent of the different land cover types in the park were defined by the area and size metrics, which basically calculated the area covered by each class and also the total area of interest, subset for the analysis. Area covered by individual habitat classes ranged from 261 ha of settlement areas to 67,693 ha of dense forest habitat calculated from an area subset of 74,827 ha covering the entire park landscape and an additional area beyond the park polygon. Table 11 presents the area and size metrics of the seven habitat classes analyzed from the 2009 mosaicked Aster image of the study area.

Table 11: Land cover class area and size metrics

Habitat class/type	Habitat area (ha)	Habitat percentage area (%)	Number of patches (NumP)	Mean class patch size (MPS) (ha)	Median class patch size (MedPS) (ha)
Dense forest	67693	90.5	1447	46.7	0.02
Mature secondary forest	3351	4.5	57002	0.05	0.03
Tree savanna	1494	2.0	118	0.8	0.02
Grassland savanna	1340	1.8	1931	0.8	0.02
Water	391	0.5	2273	0.09	0.02
Young secondary forest	297.5	0.4	5779	0.05	0.02
Settlement	261	0.35	323	1.2	0.03

A further habitat extent analysis that was strictly limited within the boundary of the park and focused on terrestrial large mammal habitats (i.e. excluding settlement areas and water bodies), showed that the park's landscape is occupied mainly by the dense forest habitat class covering 52,852 ha of the total landscape area. Results from the analysis of percentage area covered by each habitat type in the park indicated that the park landscape is dominated by dense forest cover, occupying over 90.5 % of the total park's territory. Dense forest cover also represents the class with the largest cumulative mean patch size (MPS) of 46.7 ha (Table 11). Figure 17 shows a graphical presentation of the area proportion of the respective habitat classes in the park.

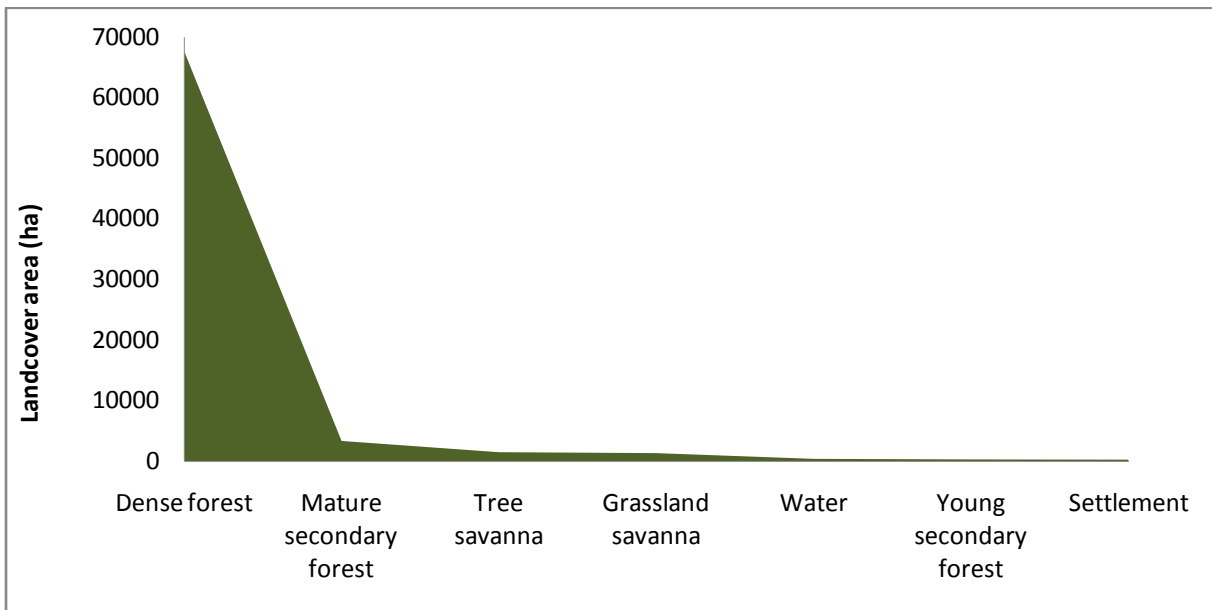


Figure 17: Graphical presentation of the area proportion of habitat classes in the Deng Deng National Park

#### 5.4.3 Land cover density

Densities of the respective land cover of the study area which was calculated by dividing the number of patches (richness) in each habitat class by the total area of the class are presented on table 12. Result show a decrease in cover density from the young secondary forest, which showed the highest density (19.4) and a mean patch size of (0.05 ha), to the dense forest, which showed the least density of 0.02 and a mean patch size of 46.7 ha (Table 12).

Table 12: Land cover density metrics

Habitat class/type	Dense forest	Mature forest	Young secondary forest	Tree savanna	Grassland savanna	Settlement	Water
Density metrics	0.02	7.0	19.4	0.08	1.4	1.2	5.8
Mean class patch size (MPS) (ha)	46.7	0.05	0.05	0.8	0.8	1.2	0.09

#### 5.4.4 Habitat shape index

Shape metrics analyzed for the park summarises the complexity of the configuration of habitat patches of the different habitat types in the park's landscape. Mean shape index (MSI) and mean patch fractal dimension (MPFD) of the individual habitat classes in the park are presented in table 13. MSI indicated similarly simple but irregular shape patterns of all the respective habitat classes

in the park ranging from 1.2 for the young secondary forest cover to 1.4 for the dense forest and grassland savanna habitat, respectively (Table 13). MPFD, which ranged from 1.4 for grassland savanna cover to 1.54 for tree savanna (Table 13), also confirms that habitats within the Deng Deng National Park have very irregular and complex shapes accounting for the park's heterogeneity.

Table 13: Habitat shape metrics

Habitat class / type	Dense forest	Mature secondary forest	Young secondary forest	Tree savanna	Grassland savanna
Mean shape index (MSI)	1.4	1.3	1.2	1.3	1.4
Mean patch fractal dimension(MPFD)	1.52	1.53	1.51	1.54	1.4

### 5.5 Spatial distribution of land cover types in the Deng Deng National Park

The spatial patterns of the respective land cover types as analyzed from the mosaicked Aster 2009 image of the park are illustrated (Figures 18 – 23). An overall overlay of the thematic spatial layers of the respective individual land cover and land use pattern of the park's landscape are presented above (Figure14, page 59 and Figure 15, page 60). The dense forest cover is continuously distributed and widely spread all over the park's landscape (Figure 18). It forms the major land cover in the park, occupying the largest proportion (i.e. 90.5 %) of the park landscape.

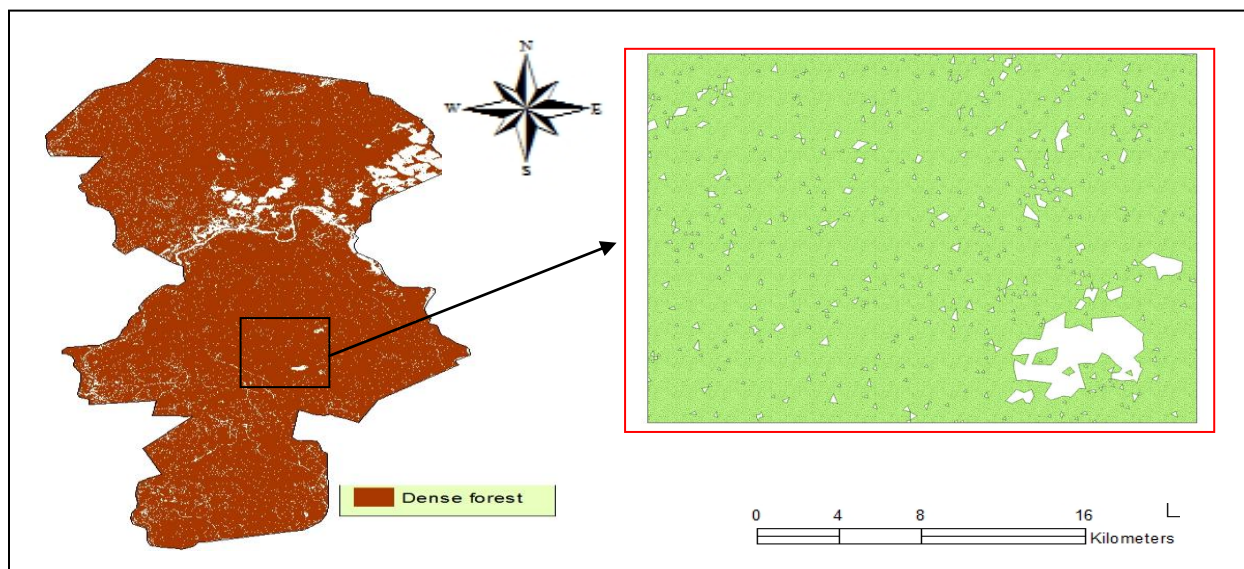


Figure 18: Spatial distribution of dense forest cover in the Deng Deng National Park

The mature secondary forest, which formed 4.4 % of cover, is widely but disjunctively scattered all over the park landscape with more concentrations in the western half than the eastern half of the park (Figure 19).

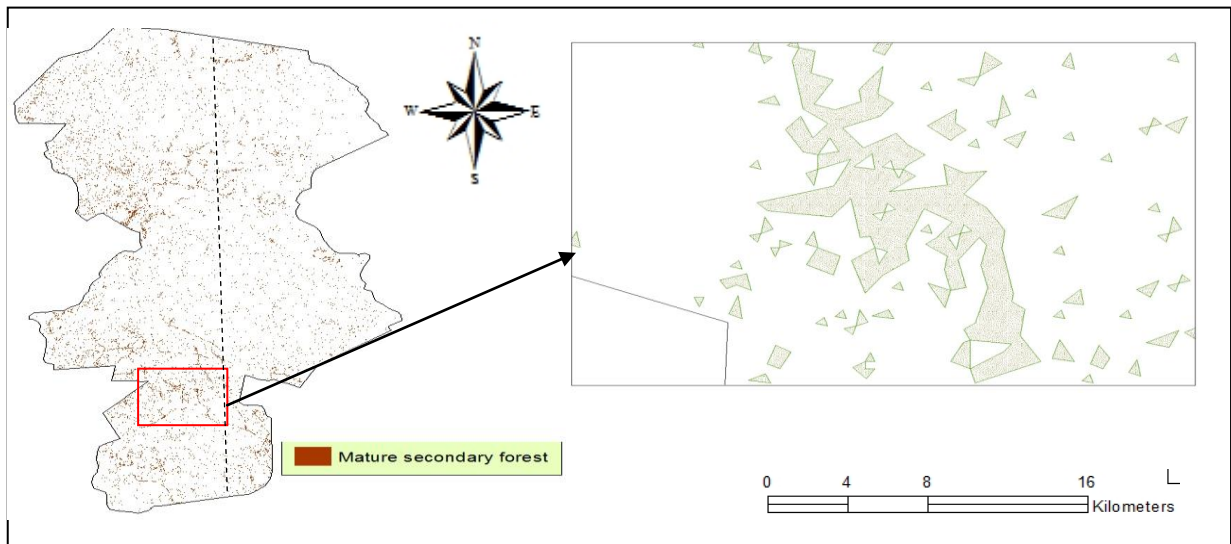


Figure 19: Spatial distribution of mature secondary forest in the Deng Deng National Park

Like the mature secondary forest, the young secondary forest is also widely scattered all over the park's landscape occupying 0.4 % of area (Figure 20). It shows areas of concentration mostly in the western half of the park.

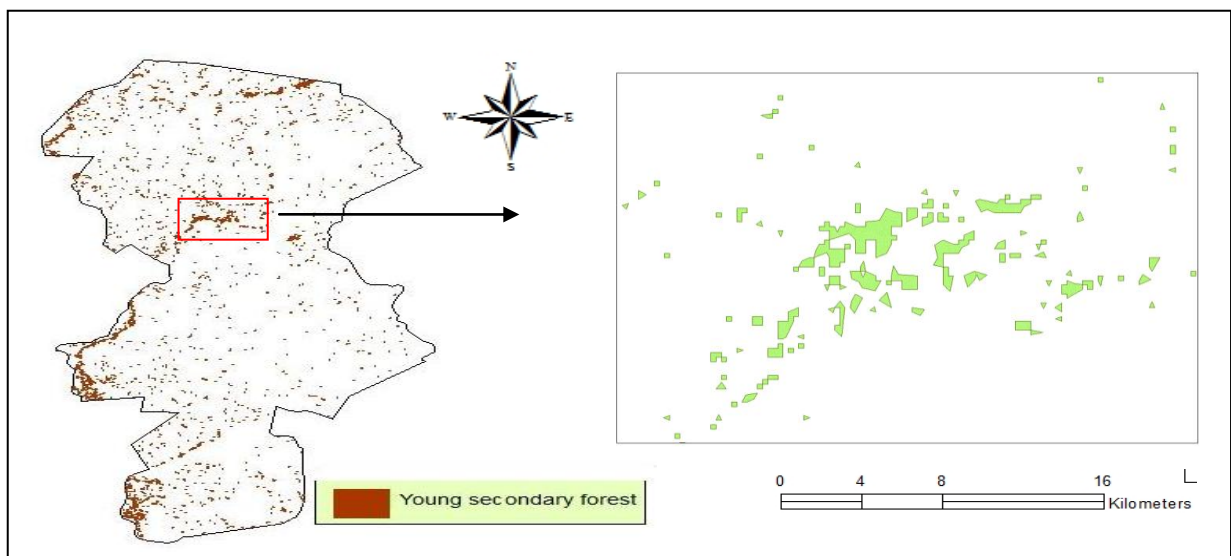


Figure 20: Spatial distribution of young secondary forest in the Deng Deng National Park

The tree and grassland savanna cover types occupying 2.6 % and 0.4 % respectively, of the park's area in the north eastern portion, showed similar spatial distribution patterns in two zones (1 and 3, and 1 and 2, respectively) in the eastern portion of the park (Figures 21 and 22).

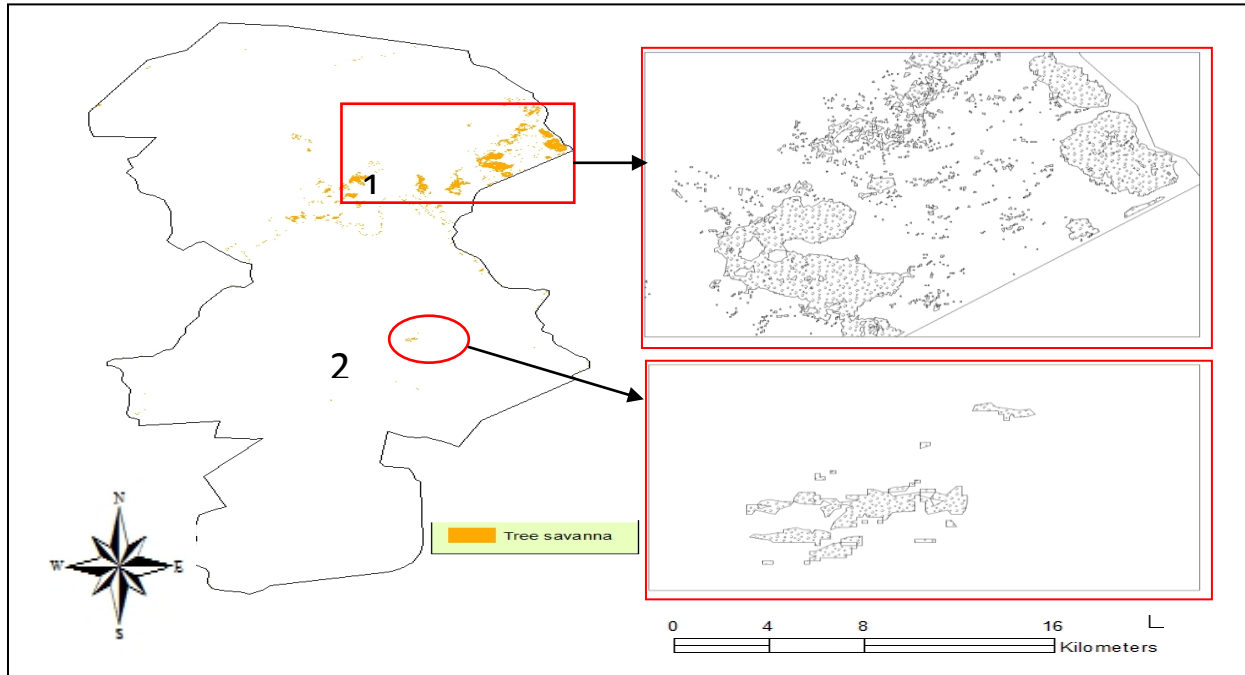


Figure 21: Spatial distribution of tree savanna habitat type in Deng Deng National Park

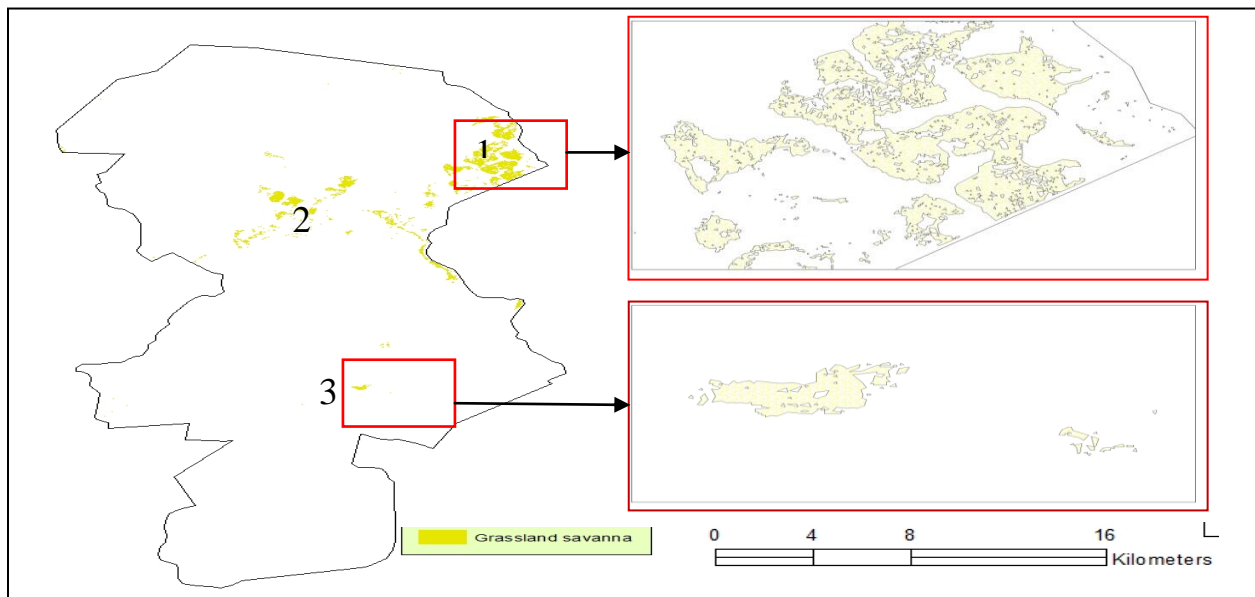


Figure 22: Spatial distribution of grassland savanna habitat type in Deng Deng National Park.

The spatial distribution of settlement and other degraded areas are presented in figure 23. Active villages were mostly located outside the boundary of the park, but abandoned villages and other degraded areas including areas along petrol pipeline tracks (1) roads (2), and railway line (3) are concentrated around zones 1, 2, and 3 as illustrated in figure 23.

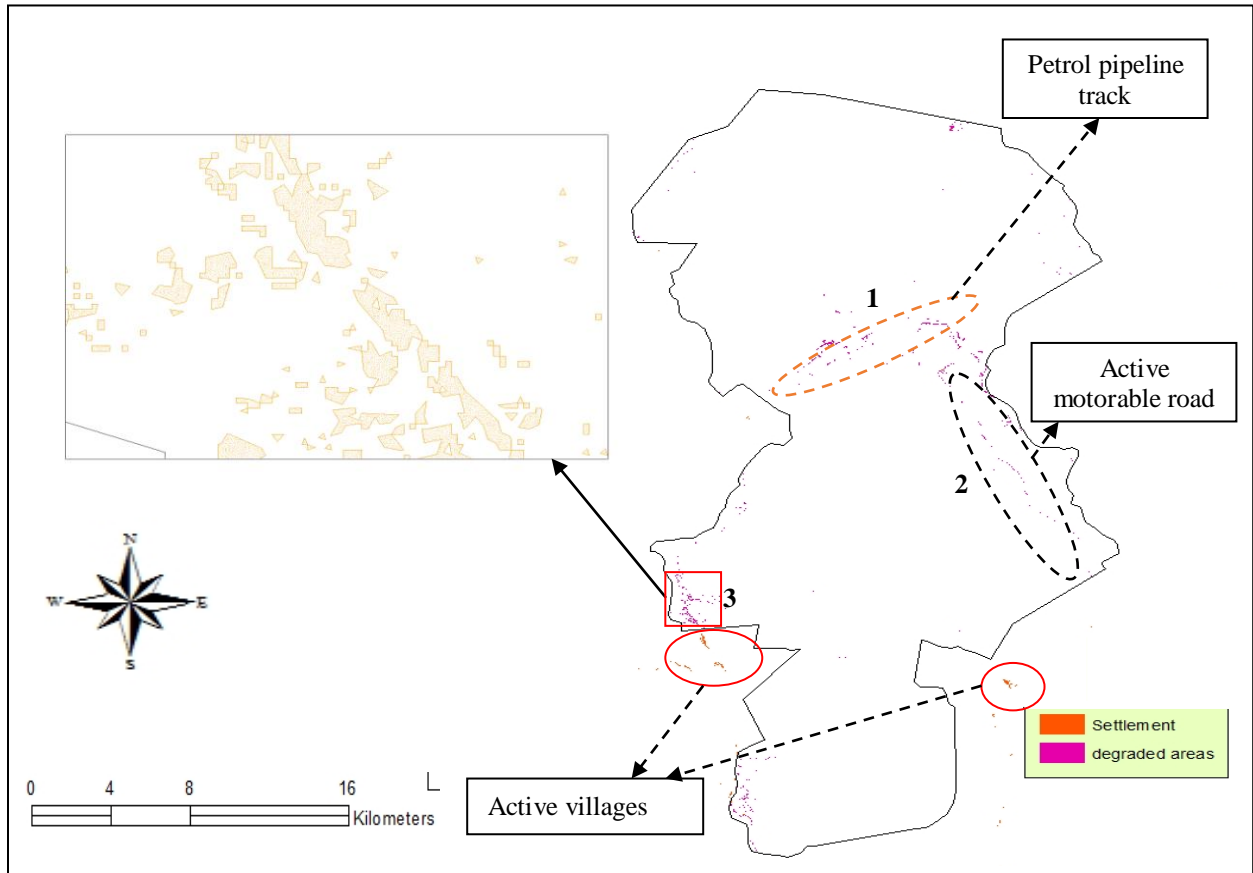


Figure 23: Spatial distribution of settlement and other degraded areas in the Deng Deng National Park

The spatial hydrological pattern of the park presented in figure 7 is rich. Analyses of the surface area covered by water, excluding areas covered by little streams in the park, represented 0.2 % coverage of the park's surface area.

## 5.6 Temporal pattern of land cover in the Deng Deng National Park

### 5.6.1 Land cover distribution during the periods 1987, 2000, and 2009

Results from the supervised classification of images of the contrasting years 1987, 2000, and 2009 are represented in figures 24, 25, and 26. For each contrasting year, seven similar predefined land-cover classes defined as dense forest, mature and young secondary forest, tree



and grassland savanna, settlement, and water surfaces were identified. Overall classification accuracy assessment and Kappa coefficient calculated for the contrasting years are presented in table 14.

Table 14: Land cover accuracy assessment and Kappa coefficient of images of the years 1987, 2000 and 2009

Image year	Overall accuracy (%)	Overall Kappa coefficient (%)
1987	92.5	90
2000	87.8	84
2009	84	98

Overall classification accuracy of each image year (Table 15) indicated a high level of commission of training pixels to the respective land cover classes. The overall Kappa coefficients of each image year (Table 15) also indicated that the peculiarity of the individual land cover classes identified from image analysis was not by chance, where ( $84 \% \leq \text{Kappa values} \leq 90 \%$ ).

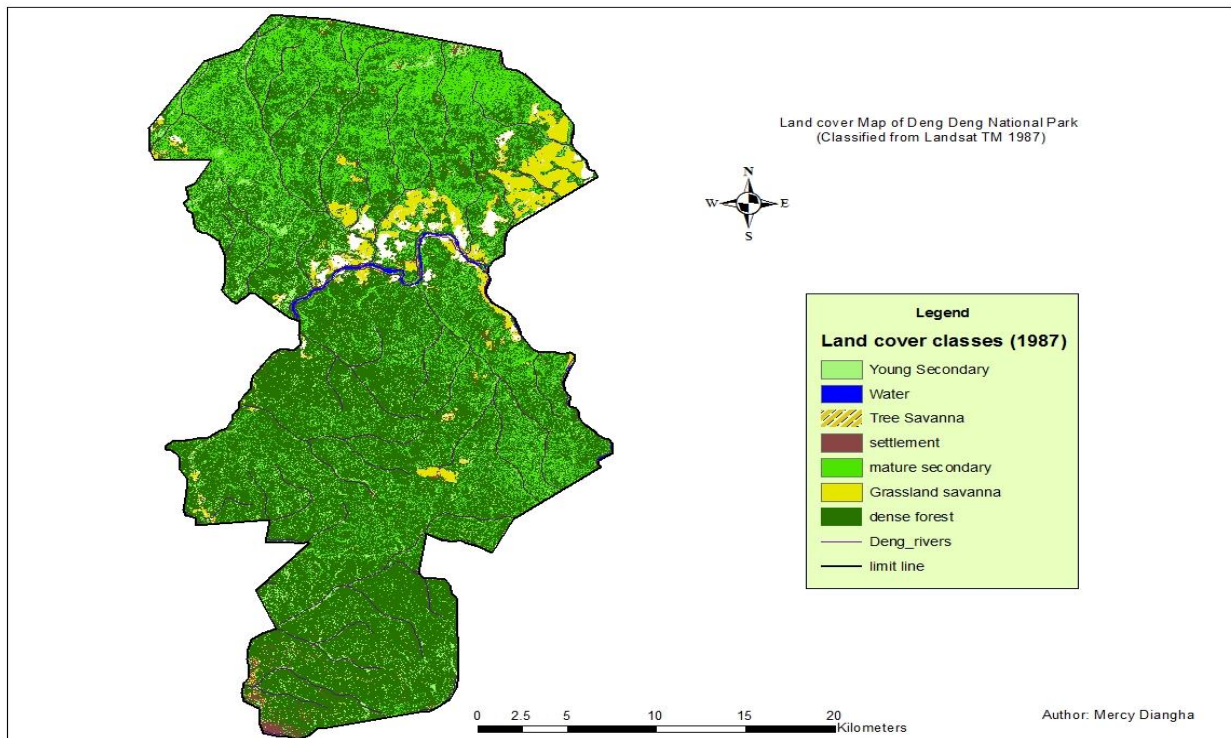


Figure 24: Land cover map of Deng Deng National Park derived from Landsat 7 TM 1987

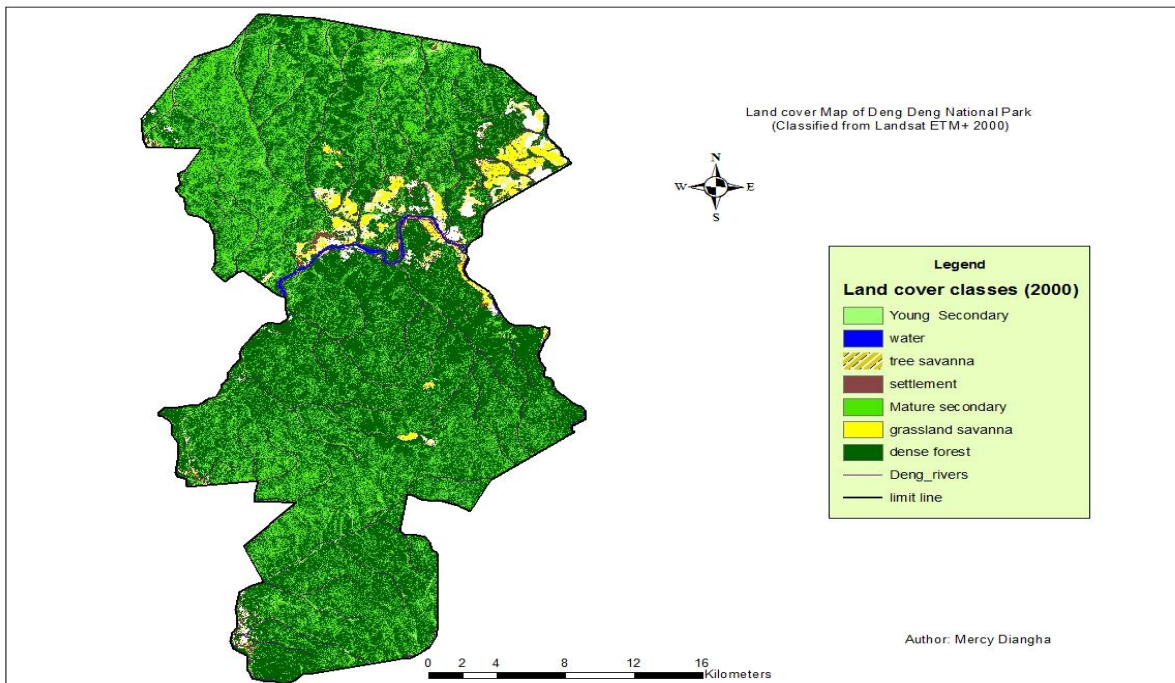


Figure 25: Land cover map of Deng Deng National Park derived from Landsat ETM+ 2000

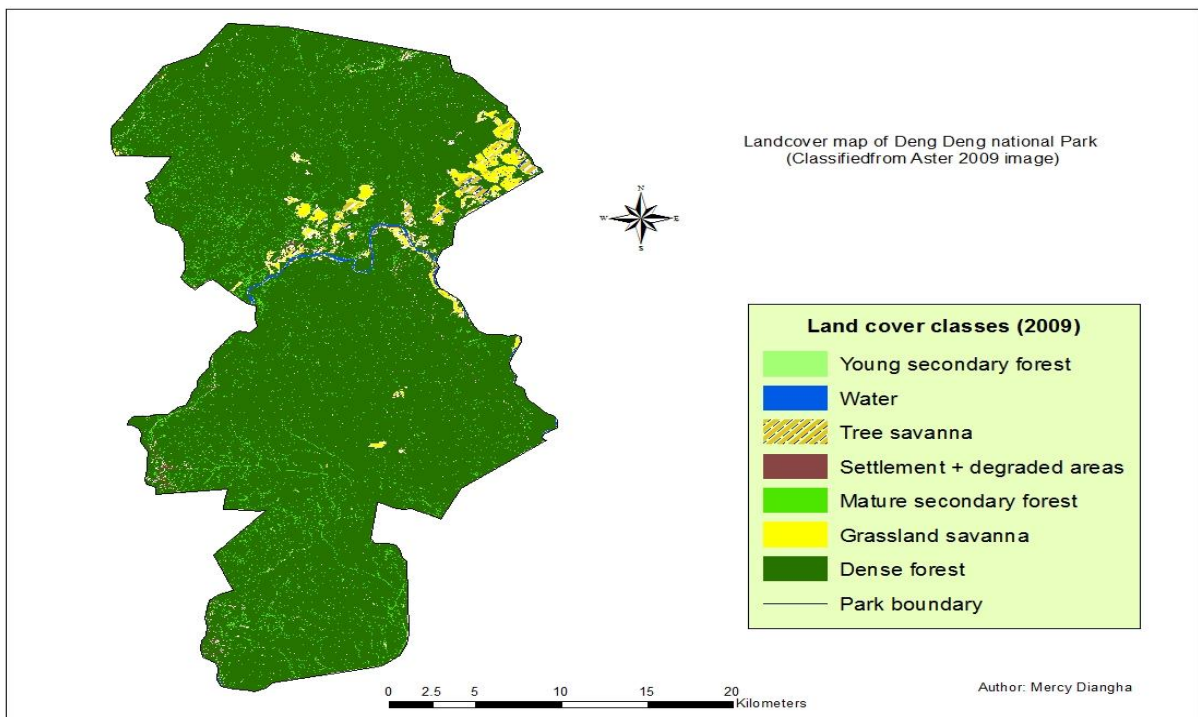


Figure 26: Land cover map of Deng Deng National Park derived from Aster 2009



### 5.6.2 Change detection estimated using normalized difference vegetation index

Primary production of the Deng Deng National Park landscape spanning three time intervals and covering a total time lag of 23 years showed difference in the contrasting years. Table 15 and figure 27 show the Normalize Difference Vegetaion Index (NDVI) values of land cover in the park for the years 1987, 2000, and 2009. Estimated NDVI values for the contrasting periods ranged between -0.23 to 0.62 (Table 15).

Table 15: Minimum, maximum, mean, and standard deviation of the Normalize Difference Vegetation Index for the periods 1987, 2000 and 2009

Period	Minimum NDVI	Maximum NDVI	Mean	Standard deviation
1987	- 0.57	0.5	- 0.2	0.17
2000	- 0.23	0.47	- 0.01	0.05
2009	- 0.27	0.62	0.23	0.19

NDVI values close to minus 1 indicate low vegetation content and values close to one indicate high vegetation content. NDVI analysis shows a slight drop in maximum value between the years 1987 and 2000 (Figure 27). It also shows an increase in the maximum value from the year 2000 to 2009 (Figure 27). Maximum NDVI value was lowest in the year 2000.

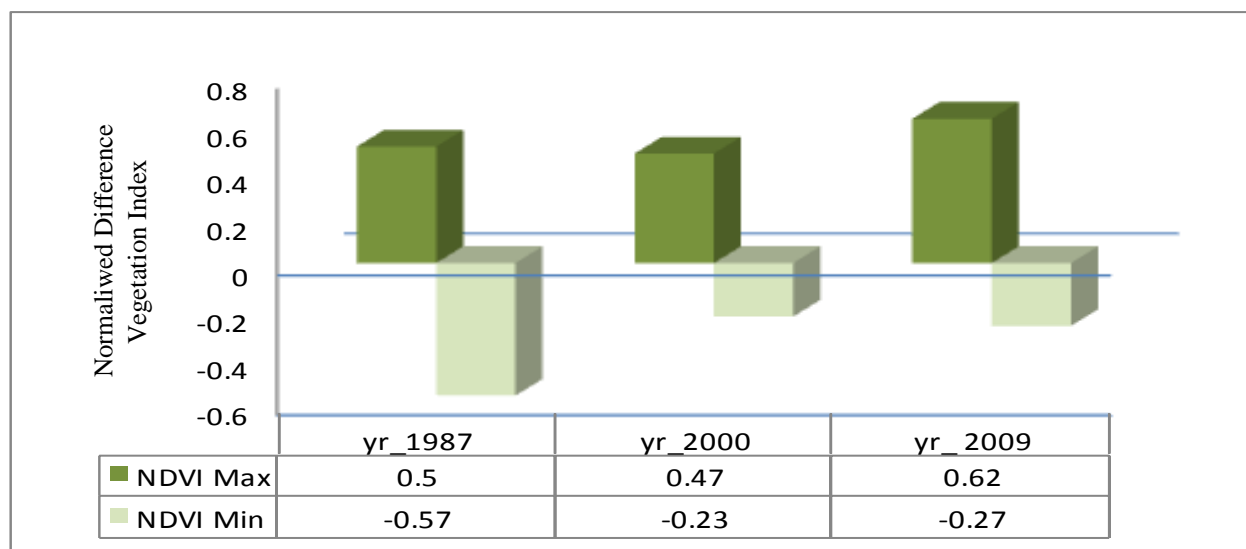


Figure 27: Change in the Normalize Difference Vegetation Index during the contrasting periods 1987, 2000, and 2009

### 5.6.3 Change detection from post classification comparison: Periods 1987, 2000, 2009

Results from temporal change analyses of land cover characteristics (total area, percentage area, mean patch size and richness) during the periods 1987, 2000, and 2009 are presented in table 16. Results showed that the dense forest cover has been the most dominant land cover type during the 23 years contrasting period (1987-2009), indicated by the highest proportion of area of this cover type in the respective years (Table 17 and Figure 28). On the other hand, tree savanna (in 1987), grassland savanna (in 2000) and young secondary forest (in 2009) were the least dominant land cover classes during the periods 1987, 2000, and 2009, respectively (Table 17). The percentage area of landcover types showed a slight decrease in the area of the dense forest cover from 1987 (64.9 %) to 2000 (63 %) and a remarkable increase in 2009 covering about 90 % of the landscape.

Table 16: Change in land cover characteristic of Deng Deng National Park during the periods 1987, 2000, and 2009

Land cover type	Landscape metrics	Contrasting period		
		1987	2000	2009
Dense forest	Area (ha)	48950	47098	67693
	Percentage area	64.9	63.0	90.5
	Number of patches	14100	16990	1447
	Mean patch size	3.47	2.7	46.7
Mature secondary forest	Area (ha)	16724	19789	3351
	Percentage area	22.2	26.5	4.5
	Number of patches	40085	55109	57002
	Mean patch size	0.4	0.35	0.05
Young secondary	Area (ha)	3467	1989	297.5
	Percentage area	4.60	0.03	0.4
	Number of patches	23468	15844	5779
	Mean patch size	0.1	0.1	0.05
Tree savanna	Area (ha)	1313	2072	1494
	Percentage area	1.7	2.8	2.00
	Number of patches	1430	3107	118
	Mean patch size	0.9	0.7	0.8
Grassland savanna	Area (ha)	3178	1744	1340
	Percentage area	4.2	2.3	1.8
	Number of patches	1798	1435	1931
	Mean patch size	1.7	1.2	0.8
Settlement	Area (ha)	852	1750	261
	Percentage area	1.1	2.3	0.35
	Number of patches	4808	14635	2273
	Mean patch size	0.1	0.1	1.2
Water	Area (ha)	920	330	391
	Percentage area	1.2	0.4	0.5
	Number of patches	72	153	323
	Mean patch size	4.03	2.1	1.2

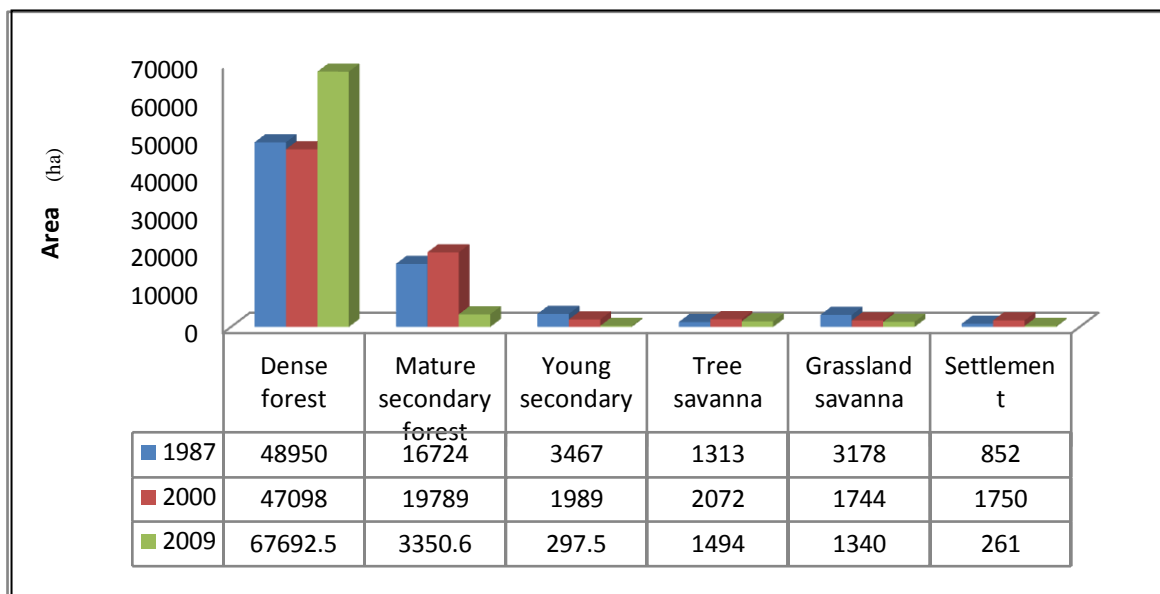


Figure 28: Area of land cover in the years 1987, 2000, and 2009

The mature secondary forest represented the richest land cover in terms of the number of patches present in all of the contrasting years (Table 16 and Figure 29). However, the number of patches or patch richness was highest in the year 2009 (57,002), followed by the year 2000 (55,109) and then 1987 (43,085) in that order.

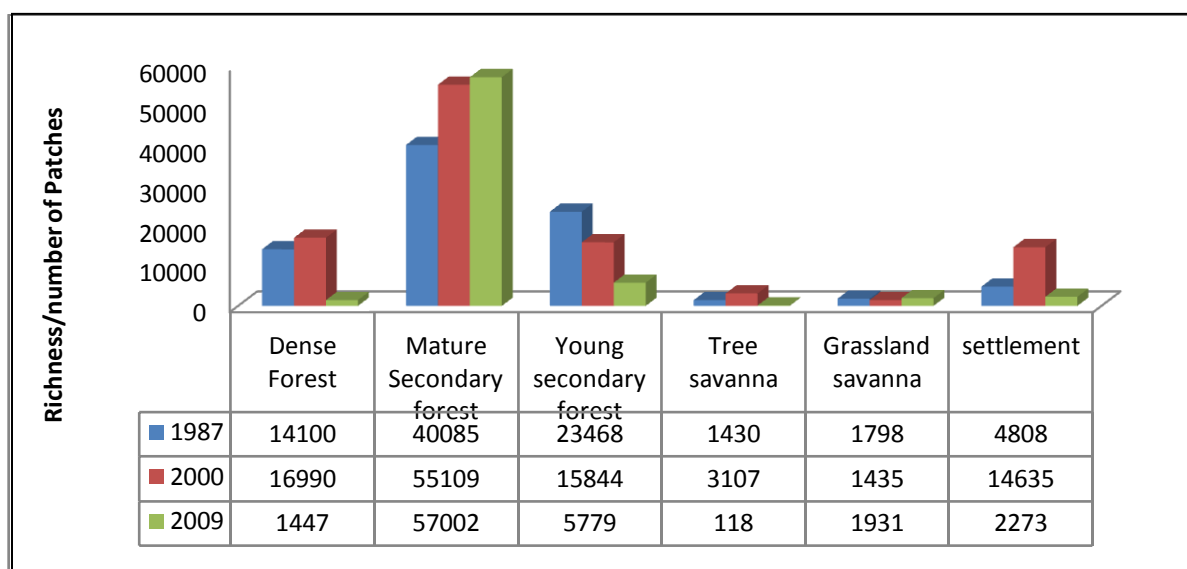


Figure 29: Richness of landcover in years 1987, 2000, and 2009

Figure 30 presents the distribution of land cover mean patch size during the contrasting years. The young secondary forest cover showed smaller mean patch sizes compared to the mean patch sizes within the other land cover types during the contrasting years. The dense forest cover recorded the largest mean patch sizes in all the contrasting years (Figure 30). A mean patch size of 46.7 ha of the dense forest cover was observed in 2009 indicating a better patch connectivity compared to the previous years.

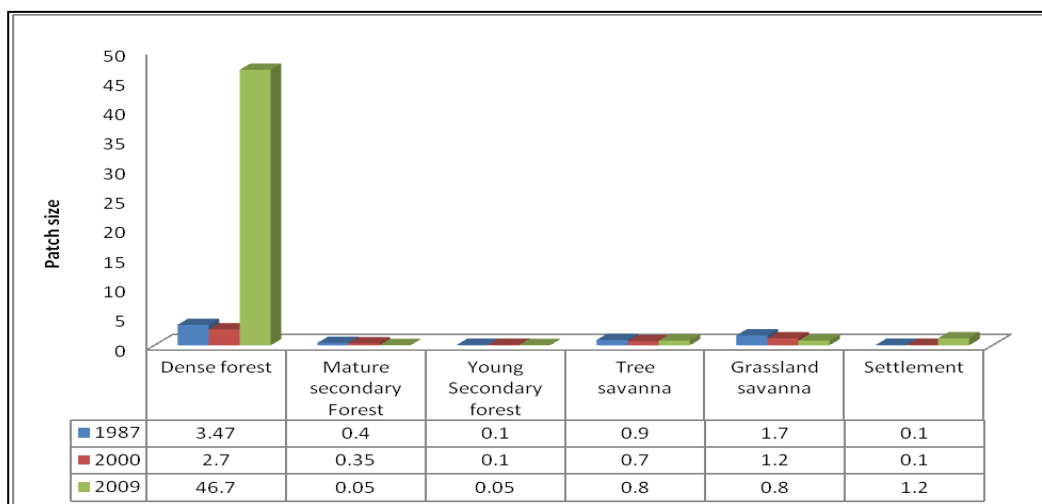


Figure 30: Mean patch size of land cover in the Deng Deng National Park for the periods 1987, 2000, and 2009

#### 5.6.4 Rate of land cover change

Post classification comparison of the park's land cover characteristics during 1987 and 2000 showed that there was a 1.9 % decrease in area of the dense forest, 4.6 % decrease in area of the young secondary forest, a 1.9 % decrease in the previous extent of grassland savanna, and a 0.8 % decrease in water surface (Figure 31). These cover extents were mainly replaced by other land cover types such as the mature secondary forest, tree savanna, and settlement including degraded areas, which showed positive changes in extent (Figure 31) and increases in the number of patches during this time span (Table 16, page 75). Despite the drop in extent, there was also an increase in number of patches of the dense forest cover between 1987 and 2000 (Table 16, page 75).

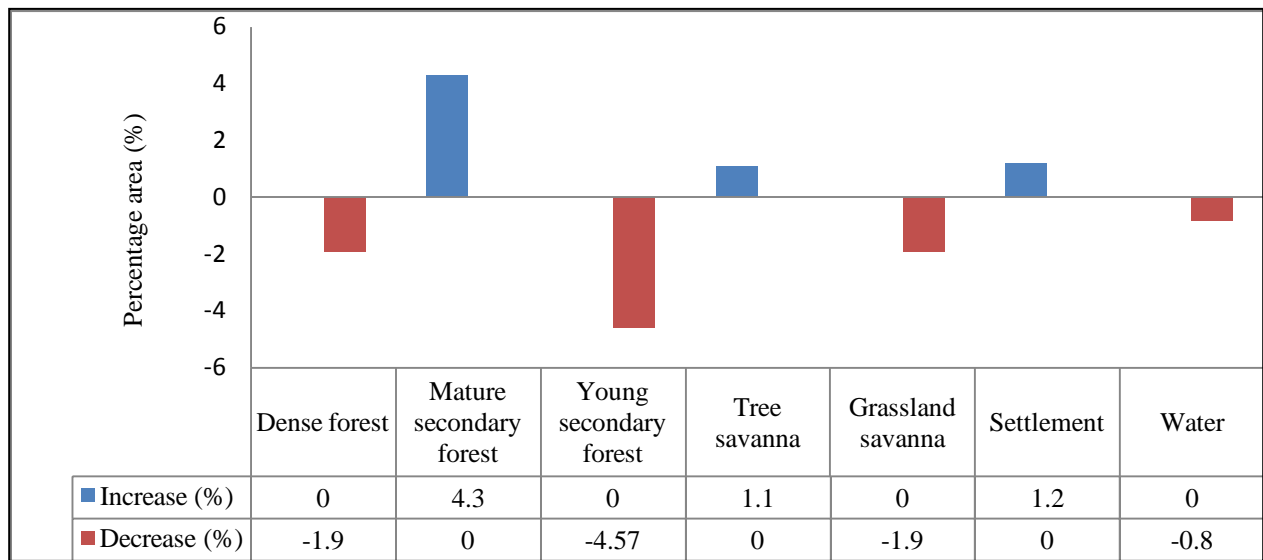


Figure 31: Percentage of cover change between 1987 and 2000

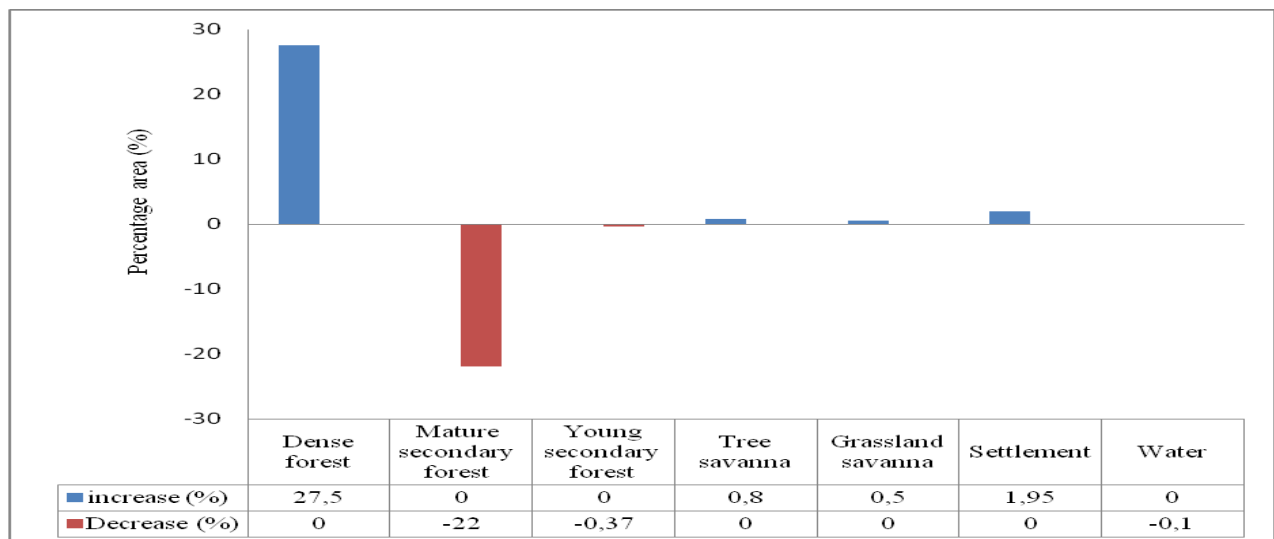


Figure 32: Percentage of cover change between 2000 and 2009

Change detection analyses for the period 2000-2009, showed a remarkable increase in the extent (27.5 %) and mean patch size (44 ha) of the dense forest cover. It also showed a slight increase of 0.4 % (Figure 32) in the extent of the young secondary forest.

Decrease in the extent of land cover was observed of the mature secondary forest, tree savanna, grassland savanna, and settlement areas (Figure 32). A great decrease in the extent of the mature secondary forest cover was observed during this period (i.e. 2000 and 2009). However, the number of patches within this cover type remained comparatively higher (Table

17). There was an observed 1.1 % increase in the mean patch size of settlement area during this time span (Table 17).

Table 17: Change analysis for the period 1987 and 2009

<b>Class</b>	<b>Landscape metrics</b>	<b>Change detection (1987 - 2000)</b>	<b>Change detection (2000 - 2009)</b>	<b>Change detection (1987 - 2009)</b>
Dense forest	Area (ha)	-1852	20595	18743
	Percentage area	-1.9	27.5	25.6
	Number of patches	2890	-15543	-12653
	Mean patch size	-0.8	44.0	43.2
Mature secondary forest	Area (ha)	3065	-16438	-13373
	Percentage area	4.3	-22	-17.7
	Number of patches	15024	1893	16917
	Mean patch size	-0.1	-0.3	-0.4
Young secondary	Area (ha)	-1478	-1692	-3170
	Percentage area	-4.6	0.4	-4.2
	Number of patches	-7624	-10065	-17689
	Mean patch size	0.0	-0.1	-0.1
Tree savanna	Area (ha)	759	-578	181
	Percentage area	1.0	-0.8	0.3
	Number of patches	1677	-2989	-1312
	Mean patch size	-0.2	0.1	-0.1
Grassland savanna	Area (ha)	-1434	-404	-1838
	Percentage area	-1.9	-0.5	-2.4
	Number of patches	-363	496.0	133
	Mean patch size	-0.5	-0.4	-0.9
Settlement	Area (ha)	898	-1489	-591
	Percentage area	1.2	-2	-0.8
	Number of patches	9827	-12362	-2535
	Mean patch size	0.0	1.1	1.1
Water	Area (ha)	-590	61	-529
	Percentage area	-0.8	0.1	-0.7
	Number of patches	81.0	170	251
	Mean patch size	-1.9	-0.9	-2.8

Figure 33 shows results of change detection analysis for the entire 23 years contrasting period (i.e. 1987- 2009). The dense forest and tree savanna land cover increased by 25.6 % and 0.3 %, respectively during this period. Overall mean patch size of the dense forest also increased by 43.2 ha during this period. Decrease in the extent of land cover was observed for the mature secondary forest, young secondary forest, grassland savanna, and settlement areas (Figure 33).

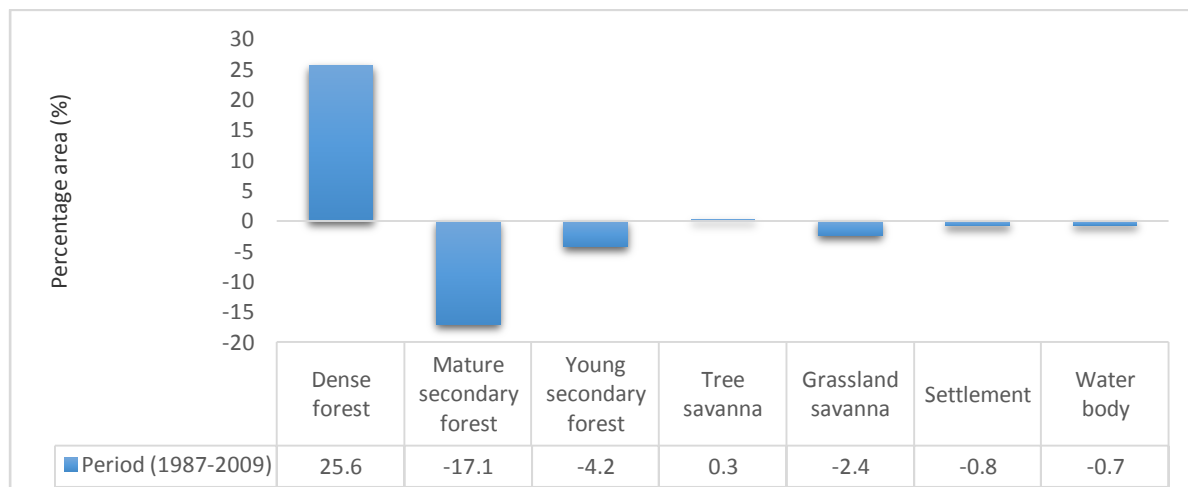


Figure 33: Percentage of cover change in Deng Deng National Park during the 1987-2009

### 5.6.5 Land cover change prediction for the next 23 year time lag

Annual rates of change of habitat classes in the Deng Deng National Park for the 23 years analysis period 1987 to 2009 are presented (Figure 34). Results are indicating that the dense forest and tree savanna habitat types increased by 1.1 % (814.8 ha) and 0.01 % (7.8 ha) respectively every successive year, while the other habitat types decreased (Figure 33). The matured forest area represented the highest decrease in area (0.77 %) during the 23 years period probably as a result of increases shown by the dense forest cover in the study area.

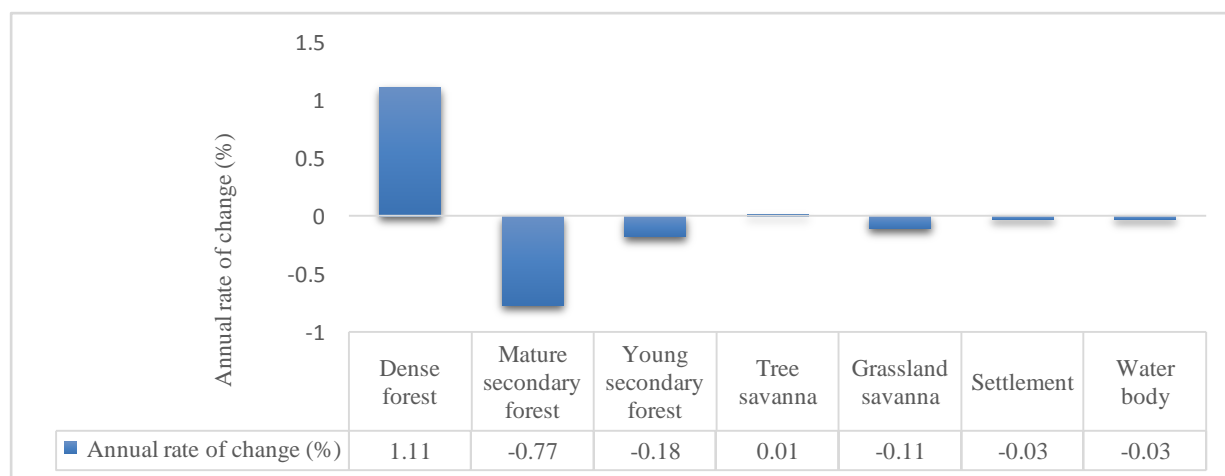


Figure 34: Annual rate of change of landcover types in the Deng Deng National Park for the period 1987 to 2009

A projection of the future land cover area of the respective habitat types within Deng Deng National Park was analyzed (Figure 35) based mainly on the assumption that land cover area will increase or decrease at a very similar trend to the annual percentage rate (Figure 34) throughout a

23 years projection horizon (2009 to 2032). Results showed an expected increase of about 6.1 % of the dense forest area (i.e. from 90.5 % in 2009 to 96.6 % in 2032) and expected decreases in the areas of the mature secondary forest by 3.80 % (i.e. from 4.5 % in 2009 to 0.69 % in 2032), young secondary forest by 0.37 % (i.e. from 0.4 % in 2009 to 0.03 % 2032), tree savanna by 0.24 % (i.e. from 2 % in 2009 to 1.76 % in 2032), and grassland savanna by 0.17 % (i.e. from 0.35 % in 2009 to 0.08 % in 2032). Figure 35 shows the past and projected trends of land cover succession of the Deng Deng National Park for the periods 1987, 2009 and 2032 spanning 23years interval.

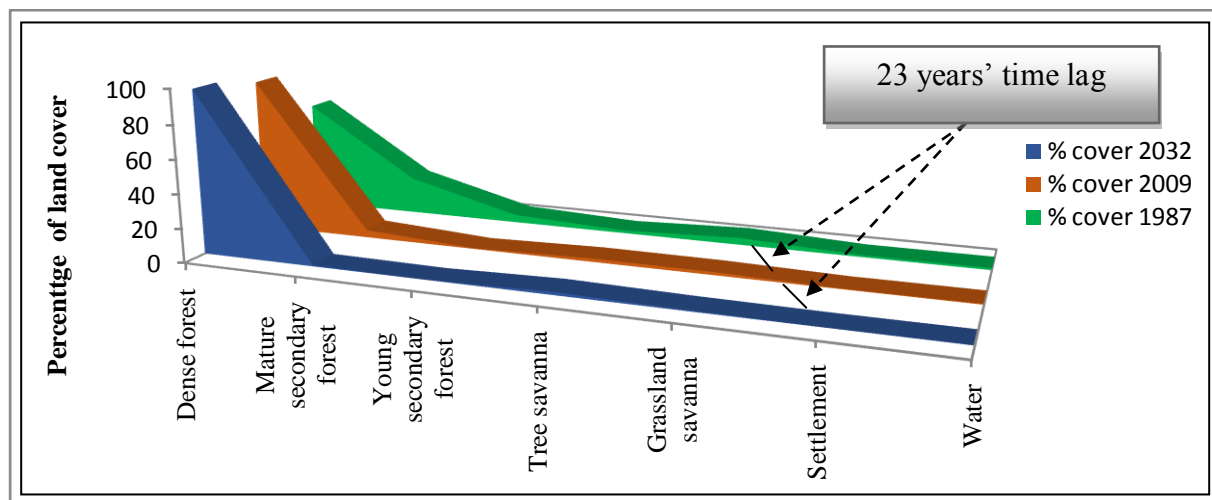


Figure 35: Past and projected trends of land cover of Deng Deng National Park for the periods 1987, 2009, and 2032

## 5.7 Discussion

### 5.7.1 Physiognomy of Deng Deng National Park

The application of supervised classification and the resulting differences in spectral signatures obtained in this study, emphasized distinction in land cover type in the park. Through classification and ground truth validation, seven distinct classes of land cover were identified, confirming the spatial heterogeneity or the non-homogenous pattern of the park's landscape. This results highlighting the level of habitat diversity in the Deng Deng National Park, partly conforms to previous results (Fotso et al. 2002) that also specified the presence of diverse habitats including farmland, clearings, primary forest, mature savanna, adult secondary forest, young secondary forest, and marsh forest, in the park area. However, habitat such as clearings, marsh forest, mature savanna, emphasized by Fotso et al. (2002) were also record in this study, but were



classified as niches within the broad habitat types classified in this study. Important land cover such as settlement area and water bodies analysed from this study, add to the physiognomy of the park's landscape.

Various landscape patterns occur today as a result of complex relationships among multiple factors (Turner 2005). In the specific case of Deng Deng National Park, spatial heterogeneity is directly attributed to the presence of diverse land cover types and diverse niches (field observations) within the park. Differences in structural characteristic and species composition of the different habitat types identified in this study (field observations) are also responsible for the non-homogenous pattern of land cover in the park. Natural processes such as wind, storm, fires, climatic variation (Collign 2010, Kaufmann and Regan 1992), and human activities on landscape (managed and unmanaged) have been largely acknowledged as the main causes of spatial heterogeneity (Walker 2012, Chapin III et al. 2011, Colligne 2010, Riitters et al. 2002). Land covers in the park are and have played significant role in influencing and linking human with the park's physical environment. Human land use from previous and current logging activities, agricultural expansion and infrastructural development from construction of road, oil pipeline and railway line, occurred in this area because of the evaluated suitability of the park's landscape for this activities. However, these activities have changed the face of the once vast to a more or less fragmented landscape at different stages of regrowth, and have eventually contributed to the heterogenous state of the park's environment.

From an ecological and wildlife point of view, results from land cover classification of the Deng Deng National Park established that the park is a heterogenous landscape containing a mosaic of habitats in which species of flora and fauna are embedded.

### **5.7.2 Estimation of habitat richness, area, size, density, and shape indices**

The argument that habitat metric is relevant to population dispersal and occupancy, and that species respond differentially to spatial characteristics of habitats (Wilson 2007, Gardner et al. 1987) encouraged the analysis of habitat metrics in the Deng Deng National Park. Habitat metrics analysed in this study were important for the analysis of the effects of habitat characteristics on large mammal species abundance and distribution in the park. In this study, the characterization of habitats identified in the park was done mainly in ArcGIS 10 with the aid of Patch Analyst 5.1 (Rempel et al. 2012) and in ERDAS IMAGINE 2011.

Key aspects of landscape metrics including habitat richness, area of habitat, and percentage area cover by each habitat type, density shape index and degree of dominance were important characteristics considered to further emphasize the physical heterogeneity of the park.

The presence of seven habitat types in the park as mentioned above, emphasize the habitat richness status of the park. The park is rich in habitat types owing partly to the wet equatorial climate and the spread of two broad vegetation formations in the park's area i.e. the dense evergreen forest and savanna vegetation formation (Fotso et al. 2002, Letouzy 1985), in which the seven habitat types are embedded. The number of patches (Habitat richness)<sup>9</sup> of individual habitat types were comparatively higher in the mature secondary forest type than the other habitat types in the park implying that the mature secondary forest is the most fragmented (i.e broken up into smaller patches) of the habitat types in the park.

The size of habitat (be it extensive or restricted) is important for the dispersal of species in a landscape (Wilson 2007, Connor and McCoy 1979), thus an important metric in conservation. In this study, area of land cover was analyzed at both landscape (referring to the entire park) and class level (referring to individual land cover types in the park). At the landscape level, the dense forest cover was the most extensive cover (90.5 %) in the park probably due to the spread of the wet equatorial climate in the area that supports large expanse of dense forest. The proportion occupied by the other habitats types (mature secondary forest (4.5 %), tree savanna (2.0 %), and grassland savanna (1.8 %), young secondary forest (0.4 %) in the park was comparatively small and likely to have been established through natural and human disturbances of the once vast dense evergreen and semi-deciduous rainforest that covered most of the park region.

Habitat heterogeneity has been associated to sizes of patches within land cover types. Differences in mean patch sizes of land cover types were clearly visible in the park. The largest mean patch size of the dense forest cover (46.7 ha) coupled with the extent covered by dense forest cover are clear indications of the dominance of this habitat type in the park. Nonetheless the health and extent (be it small or large) of each habitat in the park is important for large species conservation in the park

Density metric which consider the frequency of occurrence of habitat type within a landscape is an important indicator of the spatial heterogeneity in a landscape (Berry 1999). It was analyzed

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<sup>9</sup> Habitat richness : The number of habitat types or number of individual patches in a landscape (McGarigal 2010)

in this study to further characterize the habitat types within the park. It is supposed that if patch density is large and mean patch size is small, then the greater the heterogeneity (Berry 1999). In this study, density metrics of the habitat types in the park indicated that the young secondary forest is the most dense cover type in the park. Density results of the young secondary forest did not only show a larger density (19.4) but also held the smallest mean patch size (0.05 ha), emphasizing the spatial heterogeneity of this habitat and the spatial heterogeneity of entire the park's landscape.

The shape of habitat is an important landscape attribute that determines the dispersal patterns of species in a landscape (Urban 2006) and summarises the complexity of boundary configuration within or between patches or habitat types (Berry 1999). The often numerous patches in a landscape have made the analysis of shape metric difficult (McGarigal 2002). However, patch analyst in ArcGIS 10, facilitated the shape analyses in this study. Shape analysis was focused on measuring the complexity of habitats, defined by two shape indices, mean shape index and mean patch fractal dimension. Calculated values of both Mean Shape Index and Mean Patch Fractal Dimension of the respective habitats indicated that habitats within Deng Deng National Park are characterized by mostly irregular and complex shape patterns (i.e  $MSI > 1$ , and  $MFFD > 1$ ) accounting for the parks heterogeneity. Mean Shape Index is 1 or less when patch shape is less complex (i.e. circular or square). Higher value of Mean Shape Index indicates that habitat shape is more irregular and complex (Antwi 2009). Mean Patch Fractal Dimension has values ranging from a lower limit of 1 indicating shapes with less complex perimeters (e.g. rectangle and circles) to an upper limit of 2 indicating very irregular and complex shape patterns (McGarigal and Marks 1994). Irregular and complex shape pattern of habitats are common in the Deng Deng National Park.

### **5.7.3 Landscape diversity and change during the time lag 1987, 2000, and 2009**

The use and analyses of satellite images covering the Deng Deng National Park area, registered during three contrasting years 1987, 2000, and 2009; revealed the land cover change processes that have taken place in the park in these time span. Firstly, Normalized Difference Vegetation

Indices (NDVI)<sup>10</sup> were analysed for each image year and later compared. Differences in the maximum and minimum NDVI values were observed in the contrasting years indicating that change in vegetation cover had occurred during the time span. NDVI has values ranging between +1.0 and – 1.0. NDVI values close to – 1 indicates low or no vegetation content and values close to 1 indicate high vegetation content (Anonymous 2002). From analysis maximum estimates of NDVI values for the contrasting period ranged from 0.23 in 2000 to 0.62 in 2009 indicating that the overall primary production or vegetation content of the park in 2009 was healthy and greener than the vegetation cover in the previous years. A drop in primary production was observed from 1987 to 2000 during which time, areas within and around the park experienced logging and agricultural expansion that changed the landscape and caused reduction in the reflection of radiation from vegetation at the time when the satellite data was recorded in the year 2000. Increase in vegetation cover in the year 2009 came probably as a result of increase in forest protection and management efforts of the Deng Deng forest, through the Deng Deng forest reserve, the Belabo communal forest, and the Deng Deng sanctuary that were established within this time (i.e. from 1987 – 2009) in the region, which might have enhanced the development of more green plant biomass.

Normalize Difference Vegetation Index rarely defines the characteristics of single vegetation cover (Anonymous 2002) thus, a post classification approach was applied to further determine possible changes in the diversity and characteristics of land cover in the park. The types of land cover identified in the park were similar during the contrasting years. However, changes were observed when land cover metrics (e.g. percentage area, number of patches, mean patch size) were analysed. Both positive (increase) and negative (decrease) changes in landscape metrics observed during the period 1987 to 2000, 2000 to 2009, and 1987 to 2009 ( 23 years), emphasize the dynamics or the unstable state of the park's natural environment, attributed to both human and natural factors. Results indicate that a decrease in the area of one land cover type during the contrasting periods meant increases in areas of one or more of the other land cover. The year 2000 for instance showed reduction in the areas of the dense forest cover, young secondary forest

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<sup>10</sup> Normalized vegetation index (NDVI) is a good indicator of overall vegetation change. It is the sum of radiation reflected from all land use types but aspects such as roads, building, water surface, bare ground can possibly be singled out from NDVI analyses with some difficulties (Anonymous 2002)

grassland savanna and water surface. The reduced portions of the previous extent of the dense and young secondary forest cover were replaced mainly by mature secondary forest and settlement areas, which increased during the time. The area occupied by the tree savanna habitat also increased consuming portions of the previous extent of the young secondary forest, and grassland savanna habitats. Between the periods 2000 to 2009, portions of the mature and young secondary forest were outgrown by the other vegetation types. The expanse of the dense forest, tree savanna, grassland savanna and settlement areas increased but there was a remarkable increase in area covered particularly by the dense forest, which increased by 27.5 %. While extent of dense forest, tree savanna and settlement areas increased, throughout the 23 years contrasting period, the surface area covered by water decreased. The increase in area covered by plant biomass during this period conforms to results from NDVI analysis (this study) that indicated an increase in the park's plant biomass (NDVI maximum value of 0.62) in the year 2009. It is also linked to the increase in forest management effort in the Deng Deng forest that saw the establishment of management units as mentioned above. Increase in settlement area during the period confirms the activities of humans as proximate drivers (presence of road, individual farms, bush huts, communities or villages) to changes in landscape especially the case of Deng Deng National Park. Decrease in water surface could possibly be attributed to the long and hot dry season in the region, which probably has led to high evapotranspiration of the small streams in the park leaving visible water trenches that are gradually being replaced by green vegetation.

All the land cover identified in the study area experienced change in area, richness (patchiness) and patch size during the 23 years contrasting period. However, throughout the contrasting years, the mature forest has held the largest number of patches while the dense forest has held the largest area and mean patch size, thus explain the dominance of these habitat types in the park.

#### **5.7.4 Projection of land cover change in Deng Deng National Park**

It was of interest to this research to determine the future potentials of the habitats within the Deng Deng National Park for the survival of large mammal species. Annual rate of change of habitat from the period 1987 to 2009 (23 years) was the key factor employed in projecting the potentials of the land cover in the park. Projected changes in land cover for the next 23 year time interval were different across land cover types. Increase in dense forest habitat accounted for the greatest amount of projected change in the park. The secondary forest, savanna and settlement areas and

other habitats identified in this study (especially those within the limit of the park) were projected, will be outgrown by 2032, by the dense forest habitat type, which has demonstrated dominance in area and mean patch size since 1987. In addition, the forest cover was once vastly spread covering most of the park's region. Underlying factors<sup>11</sup> (e.g. population density, urbanization and industrialization, agriculture technical changes, policies on land use, public attitude and behavior) and proximate factors<sup>12</sup> (e.g. infrastructural extension, agricultural expansion, extraction of resources (wood) as well as natural drivers of land use and land cover changes (e.g. flood, drought and fire) (Geist and Lambin 2002) were not assigned in the projection analyses. It is however assumed that if management measures are not fortified to ensure the maintenance of habitats within the park, some proximate factors that are already evident in the park area such as infrastructural expansion, agricultural expansion and resource extraction from logging, fire wood and spices may escalate and instead of the anticipated growth and expansion of the dense forest cover, depletion of vegetation may occur that will rather be detrimental to the large mammals residing in the park.

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<sup>11</sup> Underlying causes of land use and land cover changes are fundamental and indirect forces that trigger proximate causes of land use and land cover changes. They include demographic, technological, economic and cultural factors (Geist and Lambin 2002)

<sup>12</sup> Proximate causes of land use and land cover changes are direct manifestation of underlying causes of change through direct actions and activities such as infrastructural expansion, agricultural extension and wood extraction (Geist and Lambin 2002)

## **6 Results: Richness, density, and distribution of large mammal species**

### **6.1 Large mammal species richness**

Analyses of both primary and secondary data confirmed the presence of all selected species in the study area (Table 18). A total of 1,185 observations of both direct and indirect signs of species presence were recorded in the survey area along transects, majority (98.65 %) of which were indirect observations. Only 16 direct sightings of four species, which are blue duiker (3), bay duiker (10), yellow-backed duiker (2) and sitatunga (1), were recorded. This study marks the first record of elephants in the Deng Deng National Park. Table 18 lists the mammal species and type of observations recorded for each species.

### **6.2 Frequency distribution of large mammal species**

Frequency analysis showed variations in the occurrence and distribution of species in the sampled area (Figures 36 and 37). The most often recorded species in the sampled area were the small duikers (blue duiker) and the medium sized duikers (bay and red-flanked duikers). These species were recorded in all of the twenty nine transects (Figure 36) and five habitat types (Figure 38) surveyed. Indicators of bongo and elephants presences were less frequent.

Shannon-Wiener Index of diversity ( $H'$ ) calculated for all study species in the sampled area was 1.6 (typical value is mostly between 1.5 and 3.5 in most ecological studies but rarely greater than 4).

Table 18: Study species documented from secondary and primary sources

D = dung, T = track, N = nest, SN = seen, Fr = feeding residue, H = heard, P = primary source, SC = secondary source

Order	Family and species	English names	Direct signs	Indirect signs	Sources
Artiodactyla	<b>Bovidae</b>				
	<i>Cephalophus dorsalis</i> (Gray 1846)	Bay duiker	SN	T, D, H	SC, P
	<i>Cephalophus monticola</i> (Thunberg 1789)	Blue duiker	SN	T, D, H	SC, P
	<i>Cephalophus rufilatus</i> (Gray 1846)	Red-flanked duiker		T, D	SC, P
	<i>Cephalophus silvicultor</i> (Afzelius 1815)	Yellow backed duiker	SN	T, D, H	SC, P
	<i>Syncerus caffer nanus</i> (Boddaert 1785)	Buffalo		T, D	SC, P
	<i>Tragelaphus eurycerus</i> (Ogilby 1837)	Bongo		D	SC, P
	<i>Tragelaphus spekii</i> (Speke 1863)	Sitatunga	SN	T, D	SC, P
Proboscidae	<b>Suidae</b>				
	<i>Potamochoerus porcus</i> (Linnaeus 1758)	Red river hog (bush pig)		T, D	SC, P
Primates	<b>Elephantidae</b>				
	<i>Loxodonta cyclotis</i> (Matschie 1900)	Elephant		T, D, Fr	SC, P
	<b>Hominidae</b>				
	<i>Gorilla gorilla gorilla</i> (Savage 1847)	Gorilla		T, D, Fr, N	P
	<i>Pan troglodytes troglodytes</i> (Blumenbach 1799)	Chimpanzee		N	SC, P



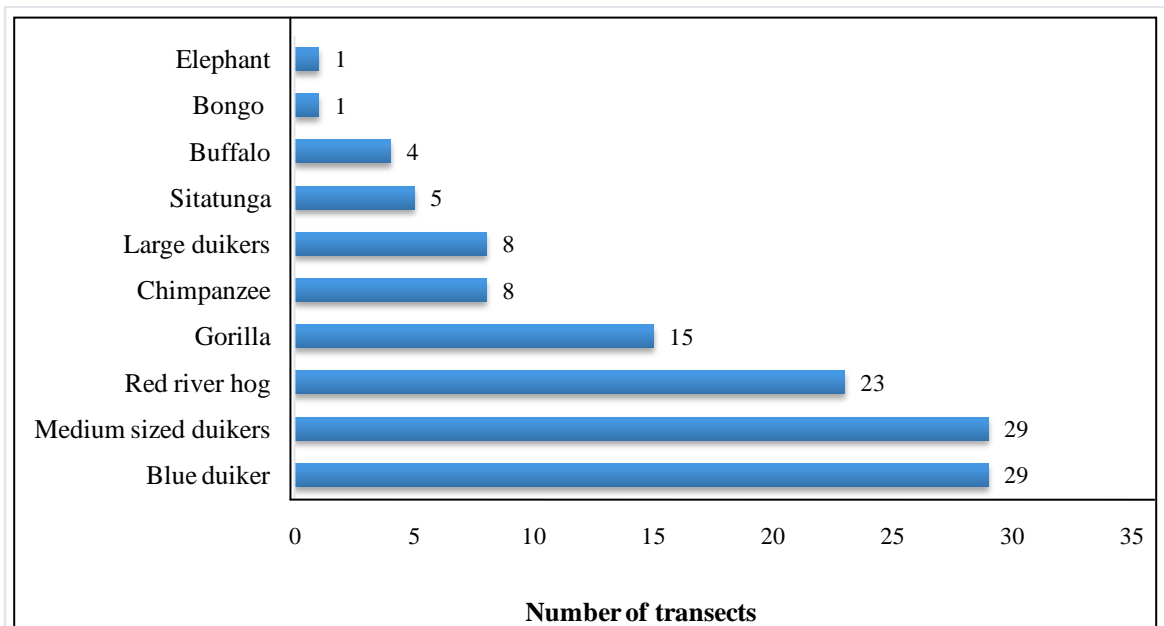


Figure 36: Frequency of occurrence of study species on transects (including direct and indirect indicators)

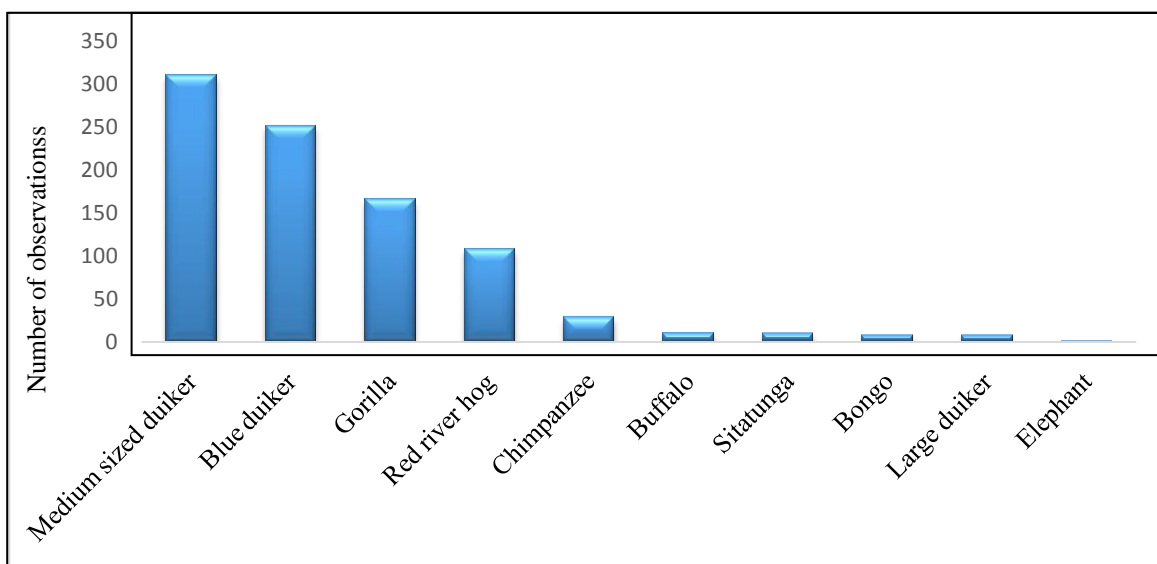


Figure 37: Number of observations of species in the sampled area

Considering results from habitat analyses (Chapter 5), five terrestrial habitats identified in the park including the dense forest, mature secondary forest, young secondary forest, tree savanna and grassland savanna were further analysed for large mammal presence and frequencies. Data recorded from transects that fell within the same habitat type were grouped and analysed

separately to facilitate comparison between habitats. Four species including small sized duiker (blue duiker) red river hog, gorilla and medium sized duikers (bay duiker and red-flanked duiker) were recorded in all five habitat types (Figure 38). Other species were recorded in at least one habitat types present in the park. For instance, bongo and elephant were recorded in only one habitat i.e. the dense forest habitat. Buffalo was recorded in the dense forest and grassland savanna. Chimpanzee presence was recorded in the dense forest, secondary mature forest and tree savanna. Large duiker occurred in the dense forest, secondary mature forest and tree savanna, and sitatunga was recorded in the dense forest, secondary mature forest and tree savanna, respectively (Figure 38).

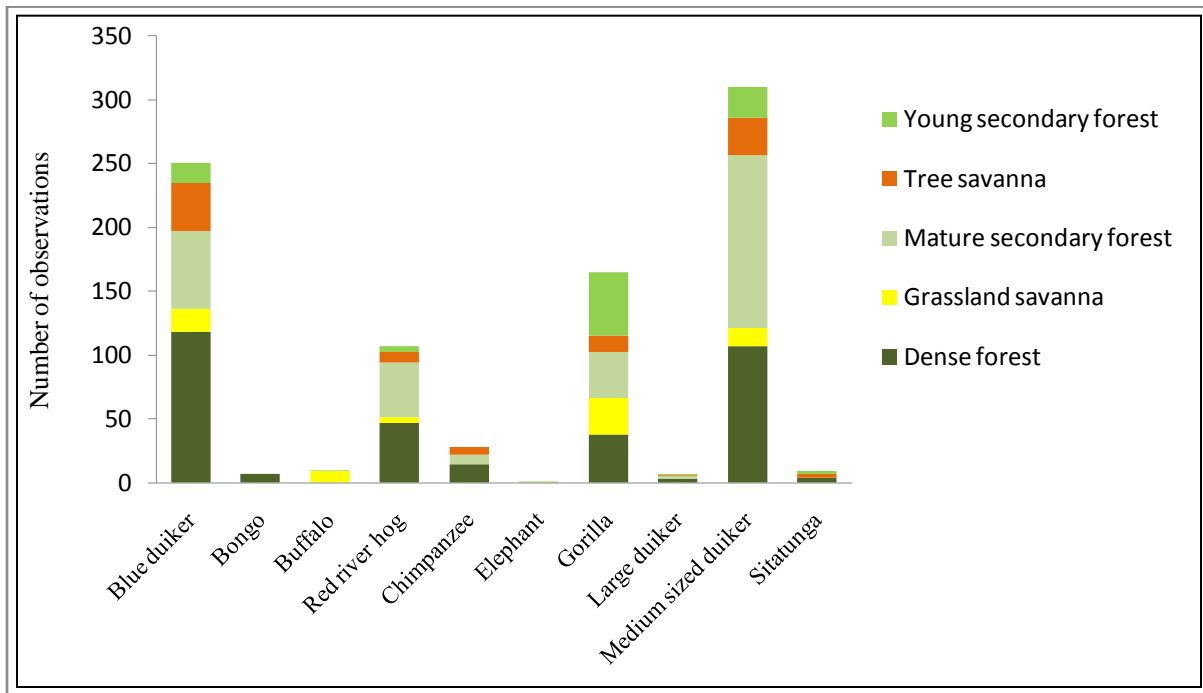


Figure 38: Presence and absence distribution of species in the sampled habitat types.

The number of species present in the respective habitat types increased from grassland savanna where five of the study species were recorded, to the dense forest habitat where up to eight of the study species were recorded and vice versa (Figure 39).



Figure 39: Species richness per habitat type sampled.

The number of species in each habitat type showed a positive correlation ( $r_s = 0.65$ ) with the area sampled. However, there was no significant difference in the number of species between habitats ( $p \geq 0.24$ ). Species diversity on the other hand showed a gradual increasing pattern from the young secondary forest (1.31) to the dense forest (1.56) (Figure 40). Correlation between large mammal species diversity indices of the various habitat types and the area of the respective habitats surveyed, showed no significant relationship ( $p \geq 0.4$ ).

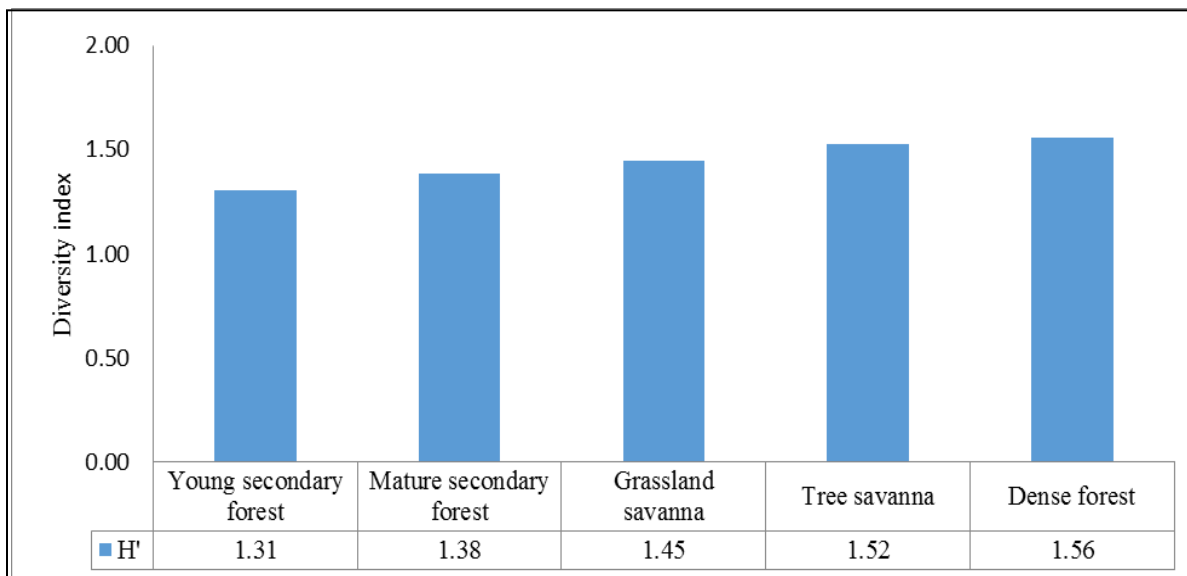


Figure 40: Large mammal species diversity indices of the habitat types sampled.

## 6.3 Density and relative abundance of study species

### 6.3.1 Estimated density

Density calculation using DISTANCE 6.0 was done for four species that met distance sample size criteria of at least 40 observations from transect surveys. These species included small duiker (blue duiker), medium sized duiker (bay and red-flanked duikers) and gorilla. The first step in the estimation of the density of duiker dung and gorilla nest encountered on transect was to model the probability of detection<sup>13</sup> and the detection function<sup>14</sup> of the respective species indicators (Thomas et al. 2010). Detectability of blue duiker dung was attained within an effective strip width (ESW) of 1.54 m and at a probability of  $p = (0 \geq 0.23 \leq 1)$  (Table 19). An overall transect width of 6.5 m (Figure 41) was estimated and then used for duiker density analysis.

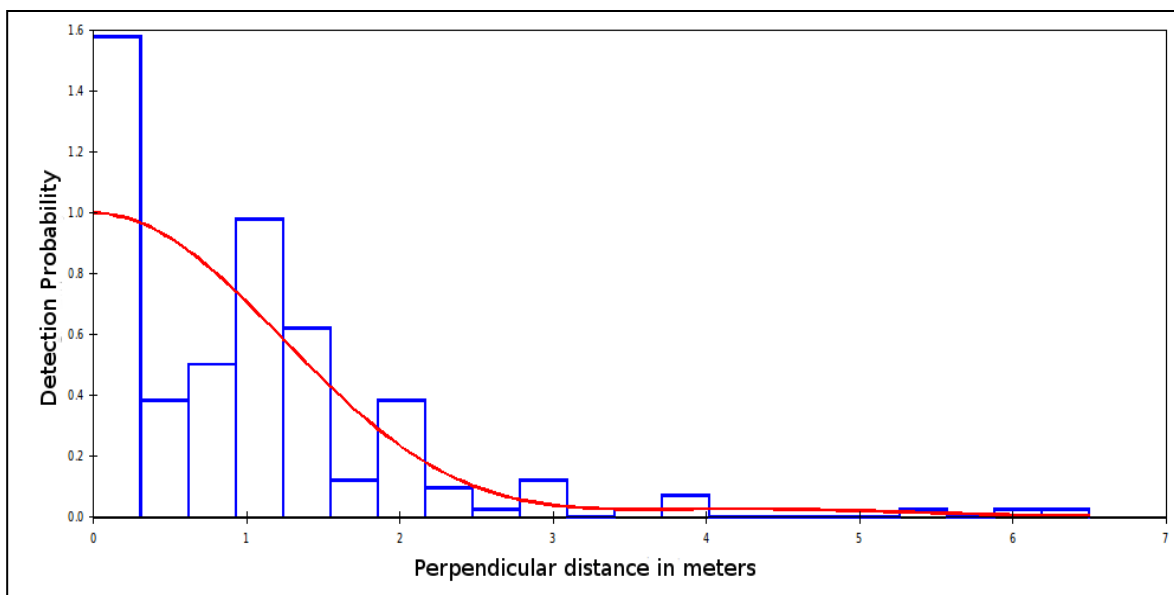


Figure 41: Detection probability of blue duiker dung in the Deng Deng National Park

<sup>13</sup> Detection probability ( $p$ ) = the probability of detecting an object, given that it is at perpendicular distance ( $x$ ) from the centre of transect line. It is usually decreasing from the center line and assumed to start at 1 on the line (Buckland et al. 1993).

<sup>14</sup> Detection function =  $g(x)$ , is a function which is fitted to the observed distances to estimate the proportion of objects missed during the survey. It facilitates obtaining point and interval estimates of density and abundance (Thomas et al. 2013).

A total of 208 dung of blue duiker were recorded in the surveyed area. Using the standard dung decay rate of 18 days and defecation rate of 4.9 days determined by Koster and Harts (1994), density of blue duikers was estimated at 13.3 individuals per km<sup>2</sup> (coefficient of variation = 12.3 %), amounting to between 598 to 983 blue duikers in the area sampled.

Table 19: Estimated density and detection probability of blue duiker in the sampled area

	Parameters	Point estimate	Confidence interval (95 %)	
			LCL	UCL
Density estimate	D	13.3	10.3	16
Detectability	g(x)	0.65	0.6	0.69
	p	0.23	0.22	0.25
	ESW	1.54	1.42	1.65
	W	6.5	-	-

(D = density, p = probability of detection, g (x) = detection function, LCL= lower confidence level, UCL= upper confidence level, ESW = Effective strip width, W = Transect width)

Detectability of medium sized duikers was obtained within an effective strip width (ESW) of 2.1 m at a probability of  $p = (0 \geq 0.26 \leq 1)$  (Table 20). An overall transect width of 8 m was estimated (Figure 42) and then used for density analyses. A total of 224 dung of medium sized duiker were recorded in the surveyed area. Using the standard dung decay rate of 18 days and defecation rate of 4.9 days determined by Koster and Harts (1994), medium sized duiker density was estimated at 10.3 / km<sup>2</sup> (17.6 %) amounting to between 417 to 848 medium sized duikers in the area sampled.

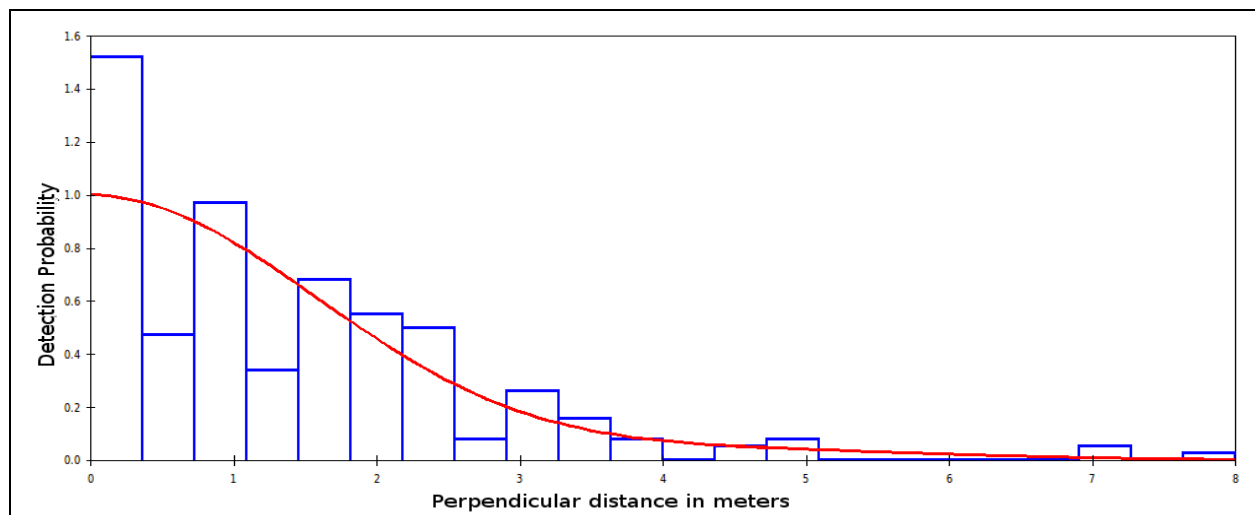


Figure 42: Detection probability of medium sized duiker in the Deng Deng National Park

Table 20: Estimated density and detection probability of medium sized duikers in the sampled area

	Parameters	Point estimate	DF	Confidence interval (95 %)	
				LCL	UCL
Density estimate	D	10.3	33.2	7.2	14.7
	g(x)	0.47	220	0.42	0.52
	P	0.26	220	0.23	0.29
Detectability	ESW	2.1	220	1.91	2.34
	W	8	-	-	-

(D = density, p = probability of detection, g (x) = detection function, LCL= lower confidence level, UCL= upper confidence level, ESW = Effective strip width, W = Transect width)

Detectability of gorilla nest was obtained within an effective strip width (ESW) of 5.6 m, at a probability of  $p = (0 \geq 0.6 \leq 1)$ . An overall transect width of 9 m (Figure 43) was estimated.

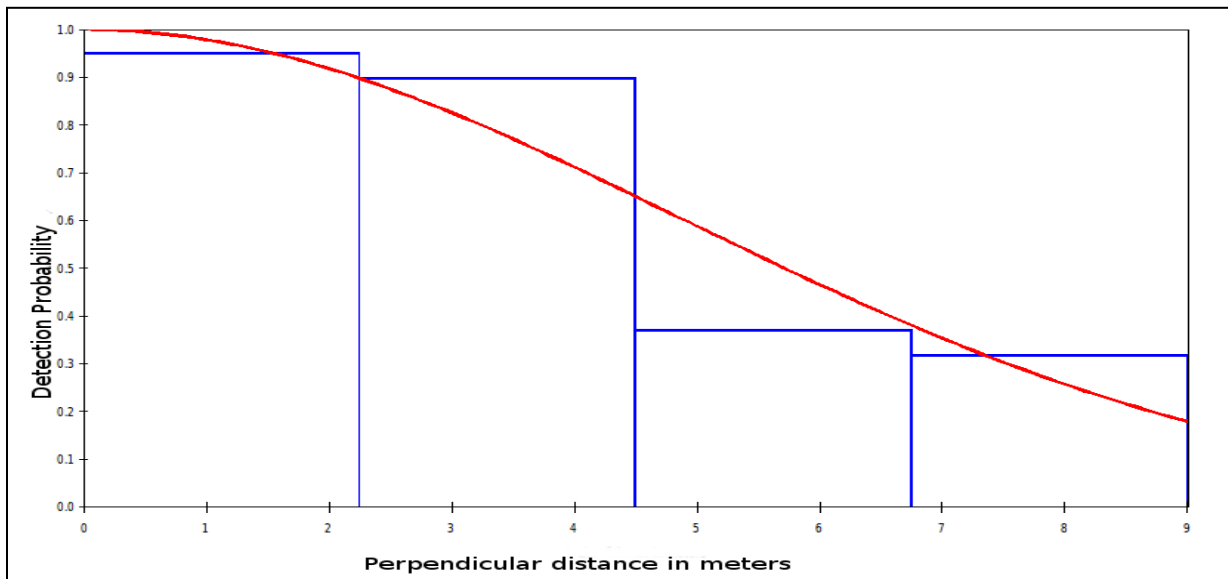


Figure 43: Detection probability of gorilla in the Deng Deng National Park

A total of 48 gorilla nest sites were recorded in the surveyed area. An average of  $5.2 \pm 0.8$  individual nest per group was estimated from data. Gorilla density was estimated at 7.6 nest site /  $\text{km}^2$  (CV= 54.3 %), however, using 221 nest days decay rate (Maisels et al. 2010), gorilla density was estimated at 1.6 weaned gorilla per  $\text{km}^2$  amounting to a population of about 836 gorillas in the entire park area ( $523 \text{ km}^2$ ).

A total of 26 chimpanzee nest groups were recorded. An average of  $2.2 \pm 0.4$  individual nest per nest group was estimated. Using 120 nest days decay rate, chimpanzee density was estimated at 0.74 weaned chimpanzee per  $\text{km}^2$  amounting to a population of about 390 chimpanzee living within the Deng Deng National park.

### 6.3.2 Relative abundance of study species

Mostly dungs, tracks and nests were used to calculate individual species encounter rates and estimates of relative densities of species in the sampled area. Appendix 5 and 6 presents detailed encounter rates of dung, tracks and nests of all study species per transect (2 km) in the sampled area.

**Encounter rates of dung and tracks:** The overall mean relative abundance of dung and track signs of the study species in the sampled area was estimated at 1.11 dung signs and 0.36 track signs per kilometre, respectively. This result implies that one would record at least one dung sign or less than one track signs of the study species in the sampled area per kilometre walk. Table 21 presents the encounter rates of dung and tracks of the respective study species, per kilometre of the total transect length surveyed in the Deng Deng National Park.

Table 21: Encounter rates of dung and tracks of large mammal species in the Deng Deng National Park

Species	Transect length (km)	Number of dung	Encounter rate (dung)	Number of tracks	Encounter rate (tracks)
Blue duiker	58	208	3.59	39	0.67
Bongo	58	7	0.12	-	-
Buffalo	58	1	0.02	9	0.16
Red river hog	58	-	-	79	1.36
Elephant	58	1	0.02	1	0.02
Large duiker	58	3	0.05	2	0.04
Medium sized duiker	58	225	3.88	10	0.17
Sitatunga	58	6	0.10	2	0.04
Min			0.02		0.02
Max			3.88		1.36
Mean			1.11		0.35

As shown in table 21, medium sized duikers (bay and red flanked duiker) and small duikers (blue duiker) are the most abundant species in the sampled area indicated by their comparatively higher mean dung encounter rates of 3.8 / km and 3.5 / km, respectively. For most species, the encounter rates of tracks were rather lower than those of dung throughout the study period with the exception of red river hog (bush pig) whose presence was mainly indicated by records of tracks thus showed a comparatively higher tracks encounter rate (1.3 / km). Of the number of individual indicators recorded (i.e. dung and tracks), elephant signs were the least encountered (0.02 / km) in the area sampled.

**Encounter rates of dung and tracks per habitat type:** By dividing the number of dung and tracks recorded on transect within a given habitat type by the total length (actual sampled area) of transects within the sampled habitat type, encounter rates of dung and tracks were calculated. The actual sampled area per habitat type ranged from 6 km in the grassland savanna to 20 km in the dense forest. Table 22 and 23 presents the encounter rates of dung and tracks of the respective study species, per kilometre of habitat type surveyed in the Deng Deng National Park.

Table 22: Encounter rates of dung per habitat type surveyed in Deng Deng National Park

	Dense forest	Mature secondary forest	Young secondary forest	Tree savanna	Grassland savanna
Total length	20 km	16 km	8 km	8 km	6 km
Species					
Blue duiker	4.8	2.94	1.88	4	3
Bongo	0.35	0	0	0	0
Buffalo	0	0	0	0	0.17
Red river hog	0.45	0.25	0.13	0	0.5
Gorilla	0.25	0.63	1.88	0.25	3
Large duiker	0.05	0.06	0	0.13	0
Medium duiker	3.2	6.7	2	3	2.17
Sitatunga	0.1	0	0.25	0.25	0
Min	0	0	0	0	0
Max	4.8	6.7	2	4	3
Mean	1.15	1.32	0.77	0.95	1.10

On average, the encounter rates of dung of the respective study species were higher in the mature secondary forest with a mean encounter rate of 1.32 / km, followed by high mean abundances in



the dense forest (1.15 / km) and grassland savanna (1.10 / km) respectively. Results suggest that for every kilometre walked in the respective habitat types of the sampled area, one would find between 0.17 to 0.55 more dung per kilometre in the mature secondary forest habitat than in other habitat types. Dungs of blue duiker and the medium sized duikers were the first and second commonly encountered in all habitat types surveyed, indicated by higher relative densities per km (Table 21 above). Mean dung encounter rates in the young secondary forest (0.77) and tree savanna (0.95) showed less than one dung / km. A positive correlation ( $r_s = 0.6$ ) was observed between mean dung encounter rates and area / km of habitat surveyed. The correlation, however, showed no significant effect due to the association ( $p = 0.3$ ).

The mean encounter rates of mammal tracks / kilometre / habitat type sampled ranged from 0.19 tracks per kilometre in the grassland savanna to 0.59 tracks per kilometre in the dense forest (Table 23). Tracks of red river hog and medium sized duikers (bay and red flanked duikers) were the most encountered in the dense forest habitat at a rate of 1.75 tracks per kilometre (red river hog) and 1.65 track per kilometre (medium sized duikers), respectively (Table 23). Red river hog tracks were also the most encountered in the secondary mature forest (2.06 / km) and the tree savanna (0.75 / km). Buffalo tracks were encountered in both the grassland savanna and mature secondary forest habitats, but showed a comparatively higher encounter rate in the grassland savanna (1.33 / km) (Table 23).

Table 23: Encounter rates of mammal tracks per habitat type in Deng Deng National Park

	Dense forest	Mature secondary forest	Young Secondary forest	Tree savanna	Grassland savanna
Total length	20 km	16 km	8 km	8 km	6 km
Species					
Blue duiker	1	0.75	0.13	0.75	0
Buffalo	0	0.06	0	0	1.33
Red river hog	1.75	2.06	0.5	0.75	0.17
Chimpanzee	0	0	0	0.25	0
Elephant	0	0	0.13	0	0
Gorilla	0.8	0.81	1	0.5	0.17
Large duiker	0.05	0.06	0	0	0
Medium duiker	1.65	1.38	0.75	0.63	0
Sitatunga	0.05	0	0	0.13	0
Min	0	0	0	0	0
Max	1.75	2.06	1.00	0.75	1.33
Mean	0.59	0.57	0.28	0.33	0.19

There was a strong positive correlation and a significant relationship between the mean encounter rates of tracks and area km of habitat in the sampled area ( $r_s = 0.97$ ,  $p = 0.005$ ).

**Encounter rates of ape nests:** Apes nests comprising 48 gorilla nest sites with 252 individual gorilla nests, and 26 chimpanzee nest sites with 56 individual chimpanzee nests, respectively, were encountered during field surveys. Apes nests found in tree canopy were assigned as chimpanzee nests, in the absence of signs that could indicate the nests were constructed by gorilla. Analyses of ape nest encounter rate on transect and within the respective habitat types are presented in tables 24 and 25.

Table 24: Overall encounter rates of apes nests in the sampled area

	Total length (km)	Number of nest sites on transect	No of individual nest	Encounter rate (nest sites) / km	Encounter rates of individual nest / km
Chimpanzee	58	26	56	0.45	0.97
Gorilla	58	48	252	0.83	4.34

Among the apes, gorilla nest sites encounter rate (0.83 nests per km) and individual nests count encounter rate (4.34 individual nests per km), were comparatively higher than the encounter rate of chimpanzee nest sites (0.45 nests per km) and individual nest counts (0.97 individual nests per km) in the total sampled area (Table 24).

Differences in mean nests encounter rates were also observed between both species in the respective habitats types in the study area (Table 25). The mean encounter rates of gorilla nest / km / habitat type sampled, ranged from 0.44 nest sites / km and 2.25 / km individual nests in the secondary mature forest to 2.13 nests / km and 10.2 / km individual nests in the dense forest (Table 25). On the other hand, the mean encounter rate of chimpanzee nest / km / habitat type sampled ranged from none in the young secondary forest and grassland savanna habitats respectively, to 0.7 nest sites / km and 1.5 individual nests / km in the dense forest (Table 25). Test relationship between mean nest encounter rate of gorilla nests with the actual area sampled in the respective habitats, showed no significant difference ( $r_s = 0.4$ ,  $p = 0.4$ ). On the other hand, test relationship between mean nest encounter rate of chimpanzee nests with the actual area sampled in the respective habitats showed significant and strong positive correlation with the area of the habitat surveyed. ( $r_s = 0.9$ ,  $p = 0.02$ ).

Table 25: Encounter rates of apes (gorilla and chimpanzee) nests per habitat type surveyed

Species	Habitat type	Total length	Nest site	Individual nest	Encounter rate (nest sites)	Encounter rate of individual nest
Gorilla	Dense forest	20	15	86	0.75	4.30
	Mature secondary forest	16	7	36	0.44	2.25
	Young secondary forest	8	17	82	2.13	10.2
	Tree savanna	8	4	22	0.50	2.75
	Grassland savanna	6	5	26	0.83	4.00
Total		58	48	252		
	Mean				0.92	4.7
Chimpanzee	Dense forest	20	14	30	0.7	1.50
	Mature secondary forest	16	8	15	0.56	0.94
	Young secondary forest	8	0	0	0.00	0.00
	Tree savanna	8	4	11	0.50	1.38
	Grassland savanna	6	0	0	0.00	0.00
Total		58	26	56		
	Mean				0.35	0.76

Average ape nests group size, which was calculated by dividing the number of individual nests by the number of nest sites per habitat type, is presented in table 26. Results show a comparatively larger gorilla group size in the dense forest (5.73) and a comparatively larger chimpanzee group size in the tree savanna (2.8) habitats, respectively (Table 26). Gorilla nest group size was generally larger than chimpanzee nest group size in all the habitat types surveyed.

Table 26: Mean group size of apes per habitat type

Habitat type	Gorilla mean group size	Chimpanzee mean group size
Dense forest	5.73	2.1
Mature secondary forest	5.14	1.9
Young secondary forest	4.82	0.0
Tree savanna	5.50	2.8
Grassland savanna	5.20	0.0

Estimated populations of study species extrapolated from the calculated encounter rates of dung and nest sites in the respective habitat types and for the entire park area are presented on Appendix 7 and 8. Extrapolated densities of all study species were comparatively highest in the dense forest habitat than in other habitat types in the study area (Appendix 7). The most common species in the park in terms of relative density is the blue duiker with an extrapolated abundance

of 2415, for the entire park landscape (523 km<sup>2</sup>). Analyses of ape abundance showed an estimated population of approximately 384 gorillas and 350 chimpanzees in the Deng Deng National Park.

#### **6.4 Species habitat relationship**

The relationship between species abundance and diversity of large mammals with habitat characteristics including area, richness, mean patch size (MPS) and mean shape index (MSI) of the respective habitat types in the study area were analyzed. Graphical representations of the associations are presented in Figures 44 to 46.

The dense forest habitat occupying the largest area in the park and the largest proportion of the area sampled, showed the presence and comparatively higher richness of up to eight of the selected mammal species census in this study. There was a positive correlation between the area of the respective habitat types surveyed with the number of species of large mammal ( $r_s = 0.65$ ,  $p = 0.2$ ) and dung encounter rates ( $r_s = 0.56$ ,  $p = 0.3$ ) in the survey area but these relationships were not statistically significant.

Overall mean encounter rate of all study species was highest in the mature secondary forest (1.32 species per kilometre), which also is the habitat with the highest number of patches in the study area. However, habitat richness was weakly correlated with mammal species abundance. No significant difference was observed in this association ( $r_s = 0.3$ ,  $p = 0.6$ ).

Large mammal species diversity (Shannon-Wiener: 1.38 – 1.56) was negatively correlated with habitat richness ( $r_s = - 0.6$ ) implying species diversity did not increase following increase in number of patches per habitat. While habitat richness declined from mature secondary forest through to the tree savanna habitat type, there was a gradual increase in species diversity following the same habitat gradient. The correlation between habitat richness and species diversity indices of the respective habitat types was not statistically significant ( $r_s = - 0.6$ ,  $p = 0.2$ )

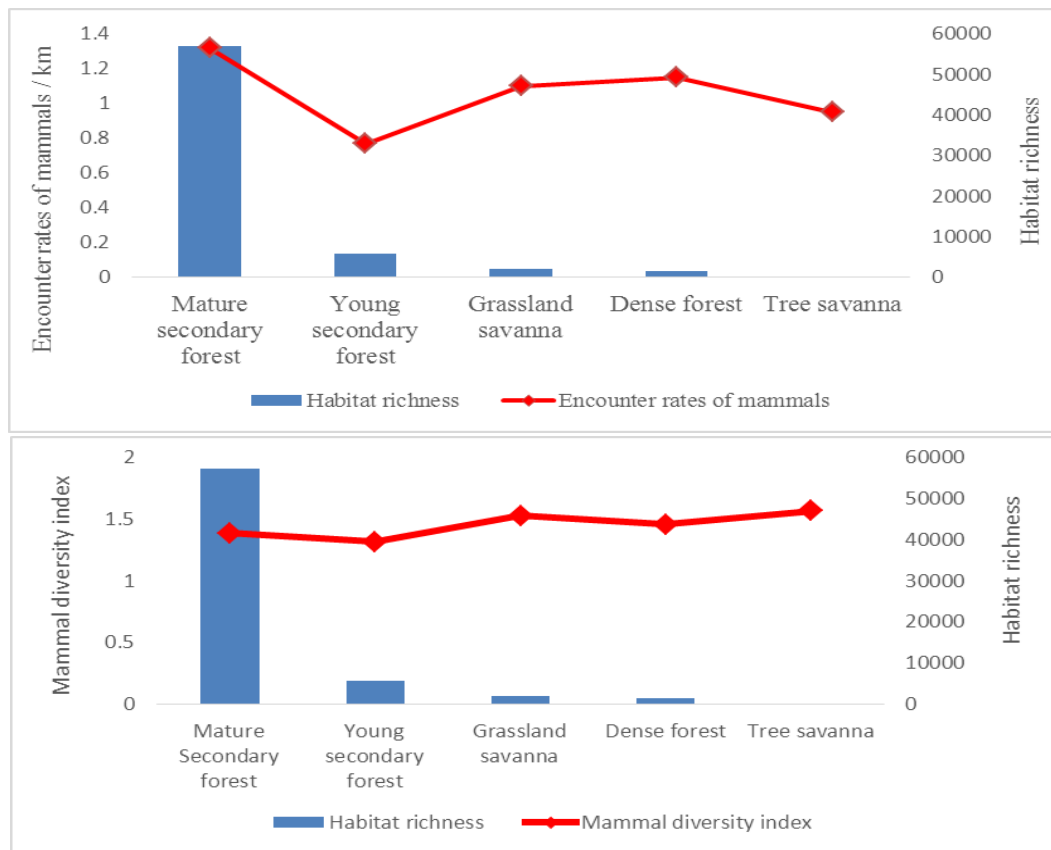


Figure 44: Relationships between the encounter rates (above) and diversity (below) of species in the respective habitats with overall habitat richness.

Mammal diversity index was higher in the dense forest habitat (1.56) which of course hold the largest mean patch size (46.7 ha) in the study area. Mean patch size of habitats analyzed in the study area showed no significant correlation with both the encounter rates ( $r_s = 0.1$ ,  $p = 0.8$ ) and diversity ( $r_s = 0.6$ ,  $p = 0.2$ ) of large mammal species in the respective habitat types. The correlation values ( $r_s$ ) were positive implying that the larger the patch size the greater the encounter rates of species in the patch. However, an exception was observed in this study where the overall encounter rates of large mammal species in the mature secondary forest with mean patch size of 0.05 ha, was higher (1.32 per km) than the overall encounter rates of large mammals in the dense forest habitat (1.15 per km) with a mean patch size of 46.7 ha (Figure 45).

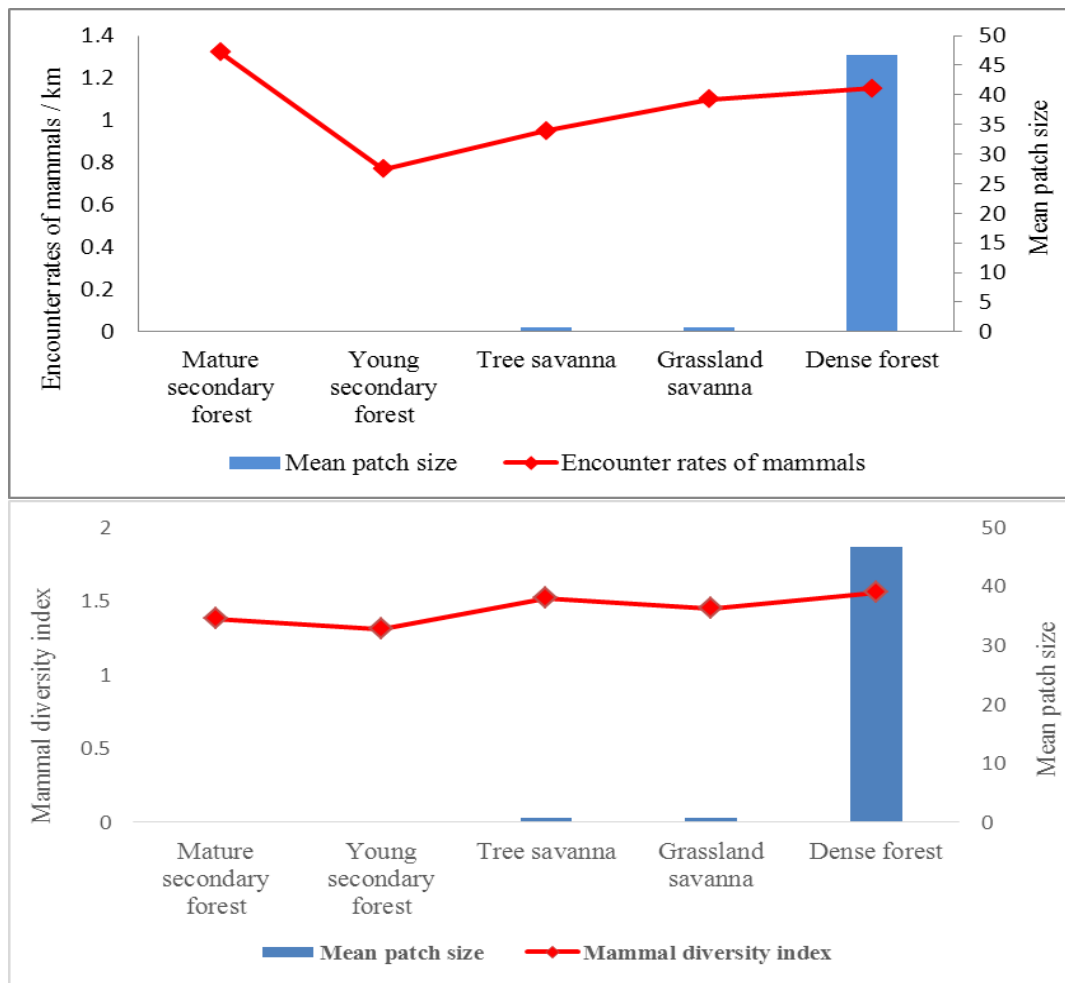


Figure 45: Graphical presentation of the relationships between the encounter rate of mammals and diversity of large mammals with mean patch size of habitats.

Mean shape indices calculated for the respective habitats in the study area did not show any significant difference when compared with the encounter rates ( $r_s = 0.5$ ,  $p = 0.3$ ) and diversity ( $r_s = 0.7$ ,  $p = 0.2$ ) of large mammals in the respective habitats. However, high encounter rates and higher species diversity were observed in the more complex habitats i.e. in habitats with irregular shaped patterns indicated by their high mean shape index values and vice versa (Figure 46). The young secondary forest comparatively showed the least mean shape index value (1.2) and also recorded the least overall encounter rate of mammal species (0.77) and also lowest mammal species diversity index (1.2) (Figure 46).

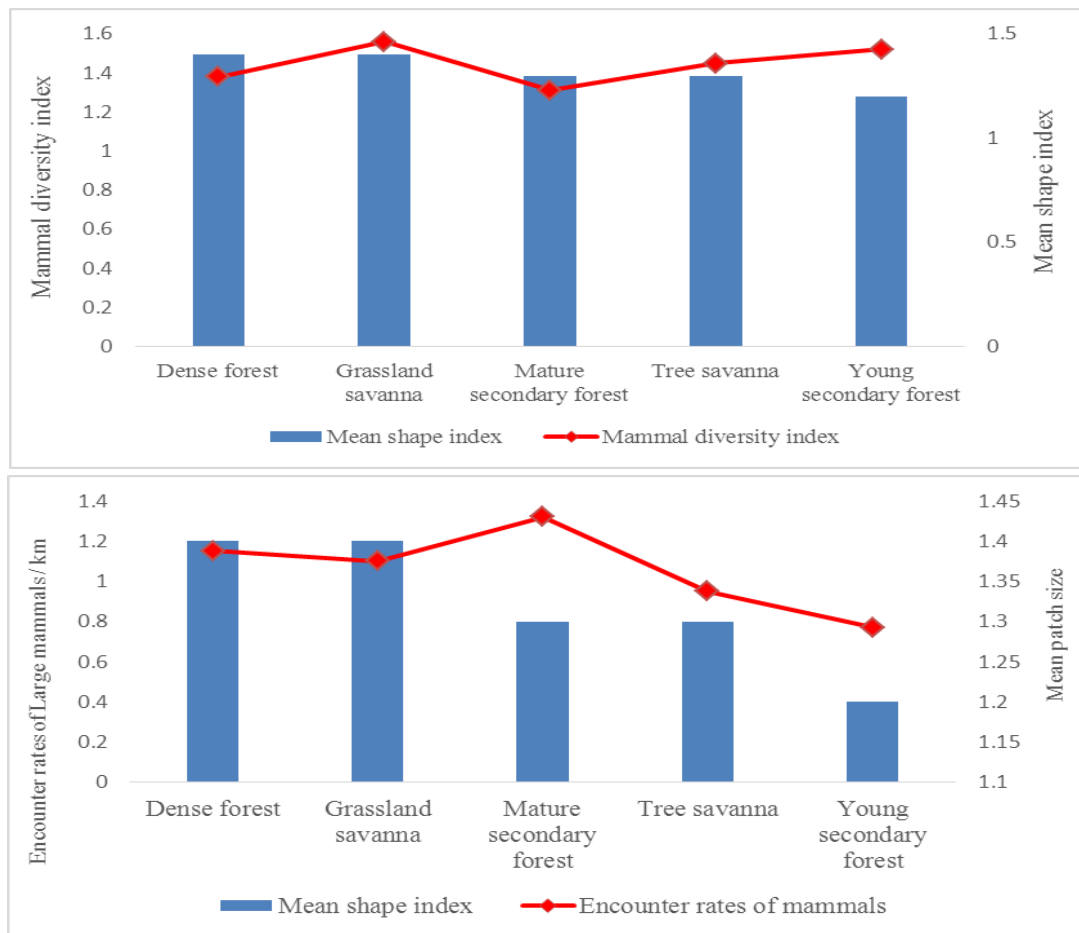


Figure 46: Graphical presentations of the relationships between the encounter rate of mammals and diversity of large mammals with mean shape index of habitats.

### 6.5 Distribution of large mammal species in the Deng Deng National Park

In addition to frequency distribution, spatial patterns of large mammal species distribution in the study area were also analyzed. Spatial data collected from both reconnaissance and transect surveys were used for mapping. Graduated dot symbols ranging from smallest (for low encounter rates) to larger sizes (for higher encounter rates) of the respective species dung or tracks encounter rates, were applied to show areas of species concentration. Results revealed both irregular (and random) and more or less clumped distribution patterns of species in the study area. Figures 47 to 51 present the presence and absence as well as the abundance distribution patterns of species in the sampled area.

Duikers, particularly the blue and medium sized duikers (bay and red-flanked duiker) are wide spread and distributed in a random and irregular pattern all over the study area (Figure 47).

The concentrations of these species (blue and medium sized duikers) are greatest in the northern block of the park where higher encounter rates (i.e. encounter rates ranging from 4.5 to 15 per km) were recorded. The large duiker (yellow backed duiker) on the other hand, was the least

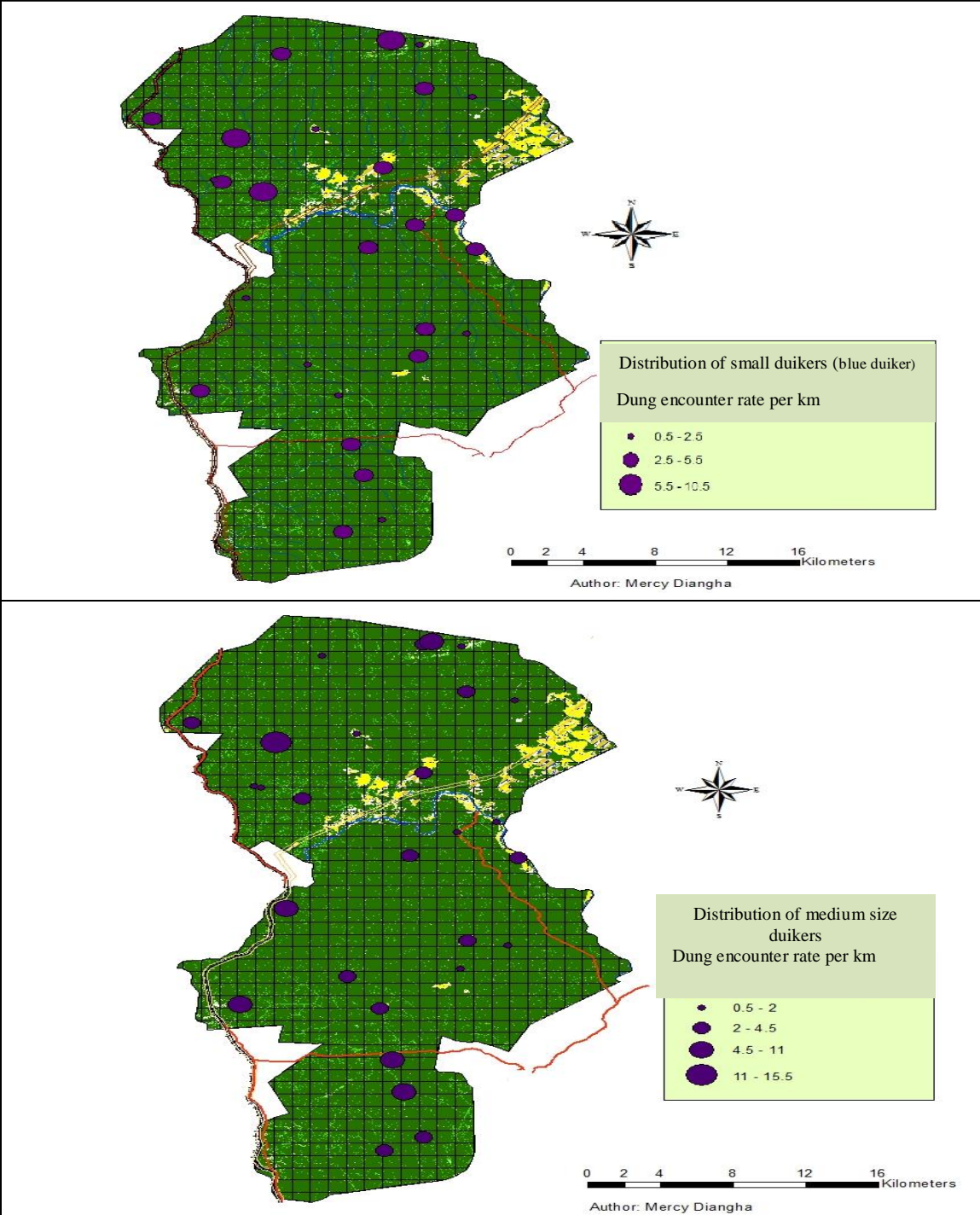


Figure 47: Distribution of small duiker (above) and medium sized duiker (below) in the Deng Deng National Park



encountered (encounter rates 0.5 - 1 / km) of the duikers and was recorded at three locations in the North (dense forest, tree savanna) and Southeast (mature secondary forest) of the park

Elephant tracks and dungs were rarely encountered in the study area but few records along transects and reconnaissance walks, mainly in the extreme northern portion of the park, at several locations across the dense forest, mature secondary and young secondary forest (Figure 48)

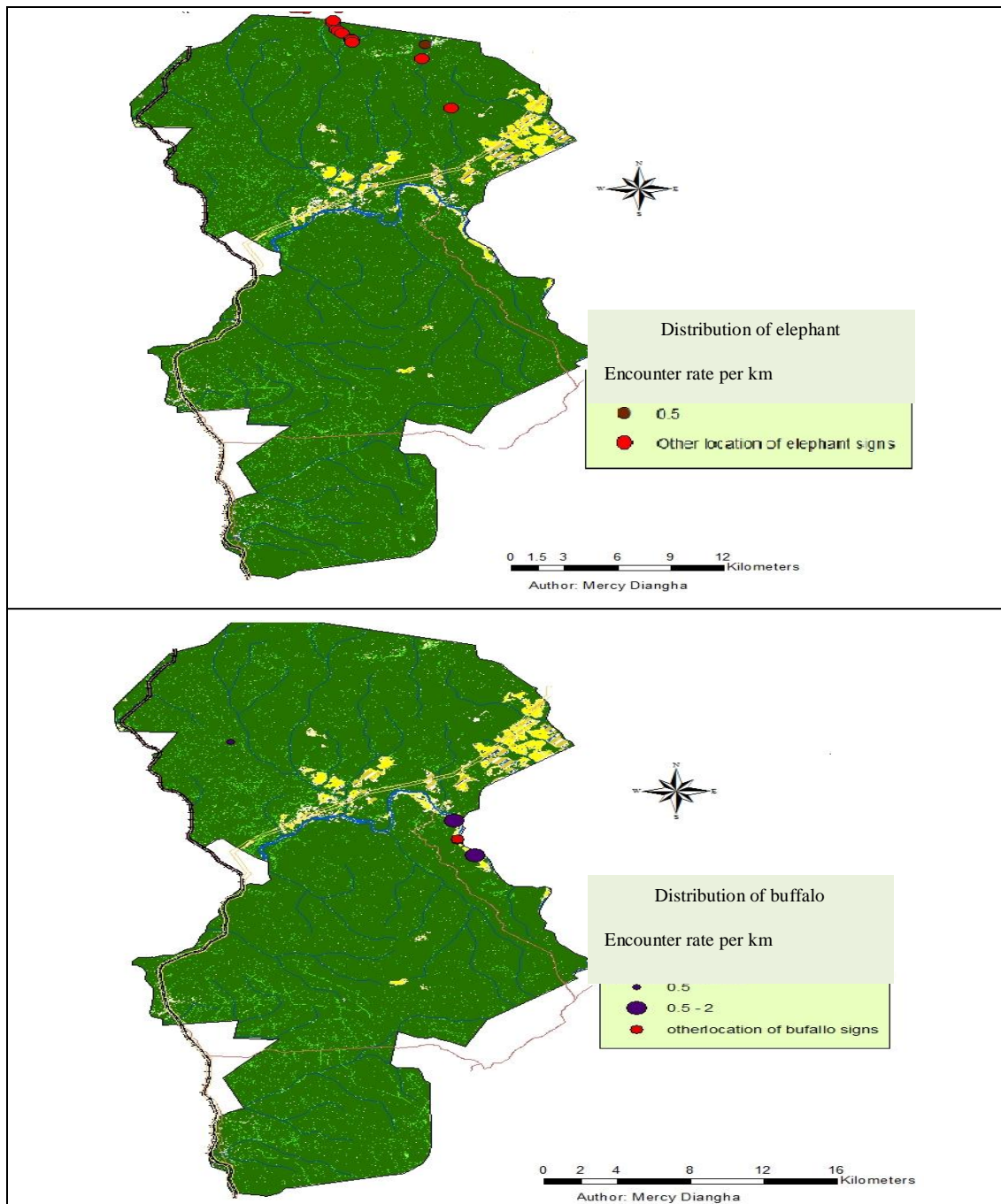


Figure 48: Distribution of elephant (above) and Buffalo (below) in the Deng Deng National Park

confirmed the presence of elephants in the park. Encounter rates of elephants tracks analyzed from a single transect (0.5 tracks per km) and for the entire study area (0.02 tracks per km) were very low (Figure 48 – small dots). Forest buffalo were recorded in the eastern portion of the park in areas dominated by grassland savanna, south of the Lom River (Figure 48).

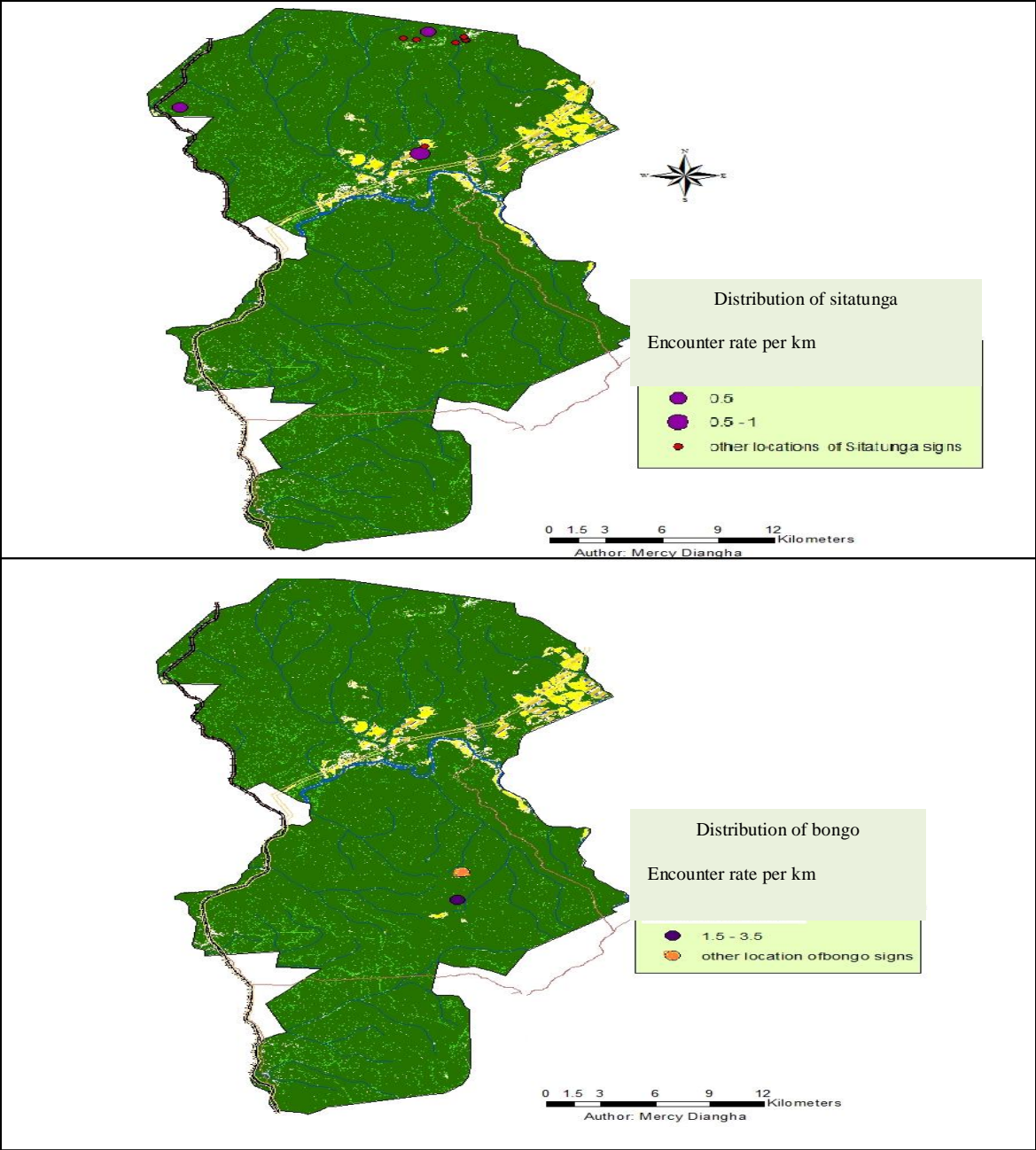


Figure 49: Distribution of sitatunga (above) and bongo (below) in the Deng Deng National Park

Indicators of sitatunga and bongo presence were recorded in very few locations in the park (Figure 49). Signs of sitatunga for instance, were recorded in the dense forest with open understory, in the young secondary forest and tree savanna habitats, in the north of the park. Higher encounter rates of sitatunga were observed within forest savanna transition zones and along stream courses in the park, indicating its preference for these habitat conditions. Very few signs of bongo presence were recorded in the core area of the park (around 5 km to the park boundary) in the dense forest habitat type. It was also noted in a forest- savanna transition zone (Figure 49) indicating its preference for these habitats. Encounters of bongo presence were rare, ranging from 1.5 - 3.5 dung per km per transect (transect length = 2 km) and 0.12 dung per km in their preferred habitats, in the entire sampled area.

The distribution of red river hog in the study area followed a random and irregular spatial pattern (Figure 50). Encounters of red river hogs tracks were common but showed higher concentrations in the section south of River Lom (Figure 50). Tracks of this species were recorded in all the habitat types present in the park but particularly in the dense forest habitat and precisely in inundated or swampy niches where most of its tracks were easily noticed.

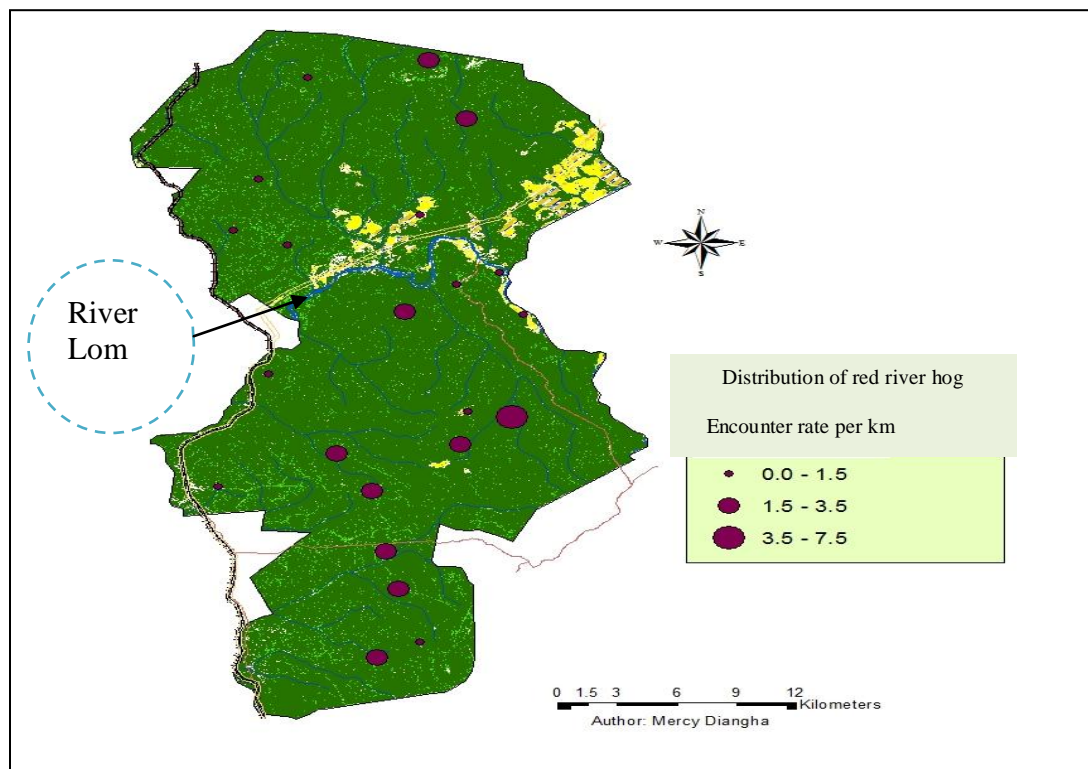


Figure 50: Distribution of red river hog in the Deng Deng National Park

The mapped distribution of apes including gorilla and chimpanzee in the study area show that the range of occurrence of both species is limited to the south of the Lom River and particularly in the center block of the park (Figure 51). Gorilla signs were mostly observed beyond (but inward) a 2 km buffer from the border of the park towards the core area, in forest fragments dominated by the dense forest habitat type. It was also represented in the young and mature secondary forest and in the tree and grassland savanna habitat in the study area. Encounter rates of gorilla nest sites were lowest in areas close to roads in the east of the park (Figure 52) but were higher at the east boundary where concentrations ranging from 3.5 to 7.5 nest sites per km (transect length = 2 km) were recorded. Gorilla showed preference for the young secondary forest and grassland savanna habitat patches (precisely at the edge between dense forest and grassland savanna) that are located adjoining the Lom Pangar River (Figure 51).

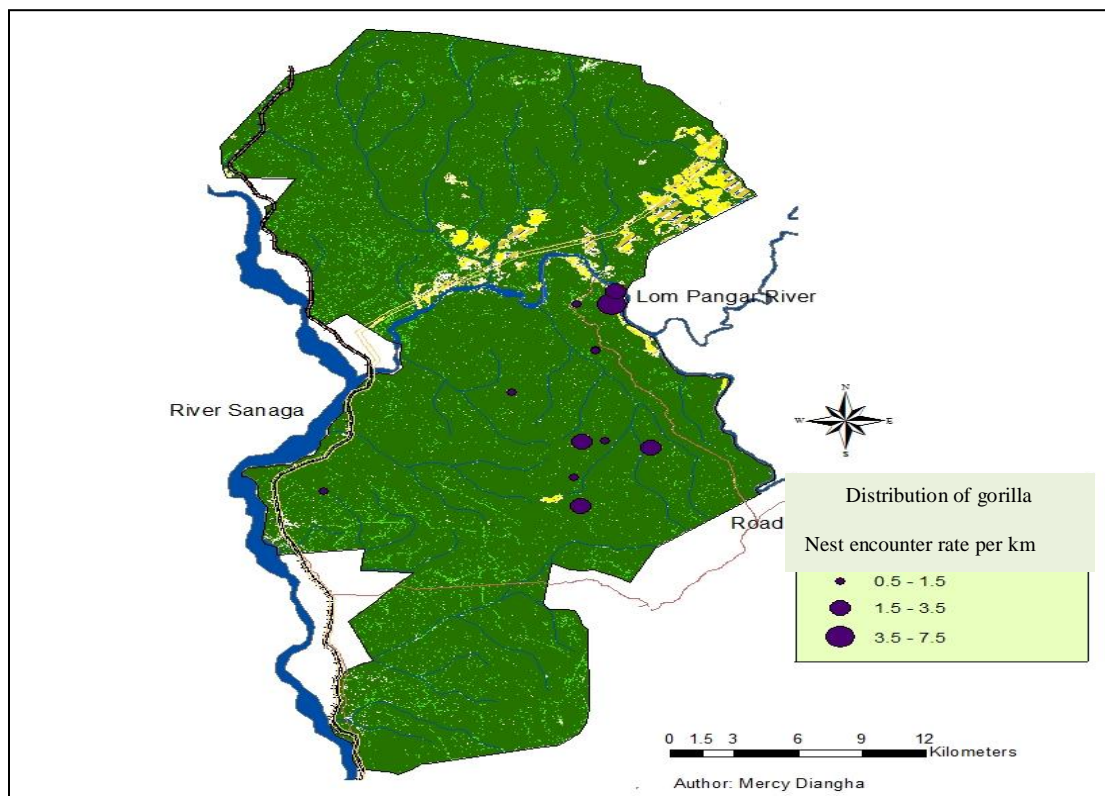


Figure 51: Distribution of gorilla in the Deng Deng National Park

Signs of chimpanzee presence in the study area were mainly recorded in the southern block of the park. The species was conspicuously absent or not recorded in the grassland savanna but occurred



in the dense forest, tree savanna and secondary mature forest habitat types and showed high abundances toward the core zone of the park (Figure 52). The pattern of distribution of this species was however, irregular or random in the park (Figure 52).

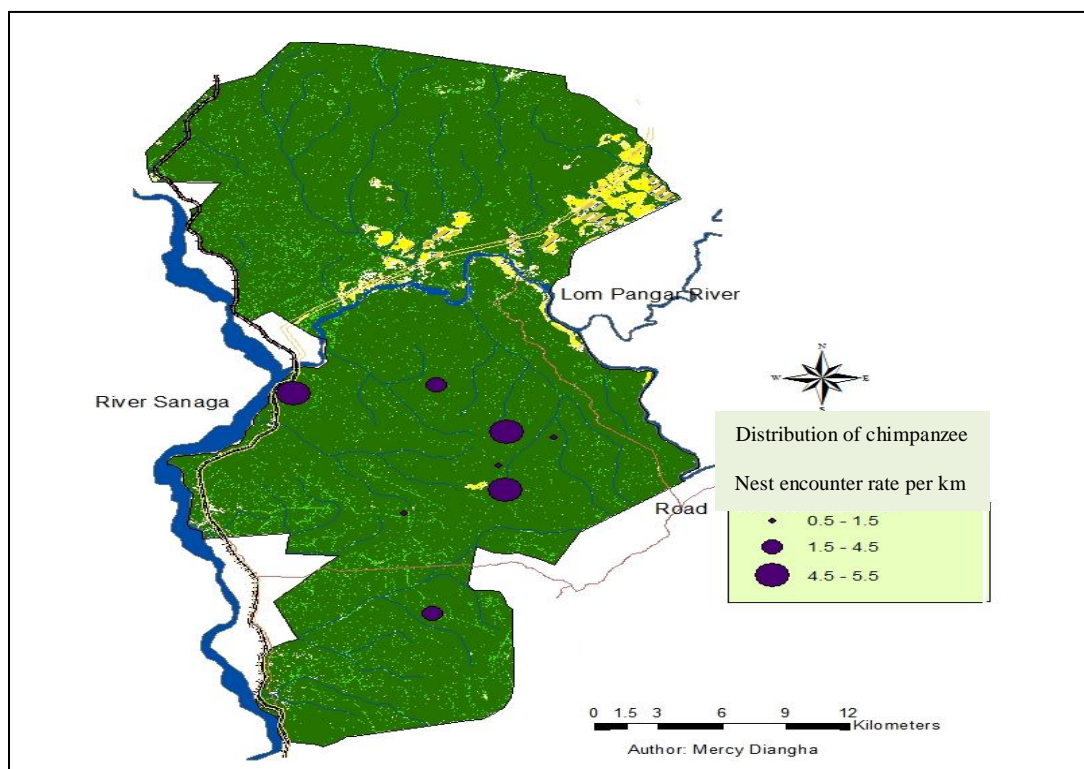


Figure 52: Distribution of chimpanzee in the Deng Deng National Park

## 6.6 Discussion

### 6.6.1 Large mammal species presence and richness

The Deng Deng National Park supports populations of large mammal species within its boundary similar in composition to those of adjacent protected areas in the east region of Cameroon (Bobo et al. 2014, Geßner 2008, Bene and Nzooh 2005). Large mammal species selected for this study (11) represents about 24 % – 27 % of the total population indicated to be present in the park. Previous surveys and reports on large mammals in the park indicated the presence of about 40 to 50 species (WCS 2008, Fotso et al. 2002). Data collected from field surveys confirmed the presence and resident of all selected species in the study area, emphasizing the importance of the park for large mammal conservation. Particularly important from this study is the first record of

elephant which has been conspicuously absent in the park, but occur in adjacent protected areas such as in Lobeke, Dja, Boumba Bek and Nki (Bobo et al. 2014, Geßner 2008, Bene and Nzooh, 2005, Ekobo 1995) and neighboring Mbam et Djerem (Maisels et al. 2000) National Parks. Whether the elephants simply used the park as a corridor or are now fully resident in the park could not be absolutely determined from this study. They are assumed to have migrated from the neighboring Mbam et Djerem National Park where they are present in high abundance and threatened by hunting (Maisels et al. 2000) to the northern section of the Deng Deng National Park, which equally offers similar shelter characteristics and other life requisites for their survival. Plate 15 shows dung of elephant recorded from this study in the Deng Deng National Park.



Plate 15: Dung of elephant marked in the Deng Deng National Park (Source: Author)

All species in the park had equal chances of being selected for this study but a special consideration was given to species with significant values at international, national and local levels. Besides the duikers and red river hog indicated as species of least concern (LC) and category C species following IUCN criteria (IUCN 2008) and Cameroon Forestry law classification, respectively, most of the species selected for this study, are either endangered, threatened or vulnerable (IUCN criteria) and belonged to categories A and B following Cameroon's forestry law classification, comprising of species that are rare and threatened (A) and species that benefits from partial protection (B) (Djeukam 2012). All of the selected species are sources of protein, income and some are of cultural importance (taboo species) to the local

communities. The belief that gorilla and chimpanzee helped local ancestors in the past out of difficult (local war) situations, that killing of bongo brings ill-luck, that eating meat of yellow-backed duikers and sitatunga is a taboo for pregnant women (may result to epilepsy) respectively (Fotso et al. 2002) has promoted the protection of these species in the Deng Deng National Park.

#### **6.6.2 Frequency, density, and abundance of species**

Very few direct sighting of large mammals were obtained from this study mainly due to the elusive, shy and sometimes cryptic nature of these taxa (Noss et al. 2012). However, indirect signs (indicators) including dung, tracks, nest, sounds, and feeding residues recommended as proxy for the presence of large mammal species in the absence of direct sightings (Barnes 2001, Plumptre 2000, White and Edwards 2000) were applied to determine species presence and abundance. Estimate of density was analysed for only three species group (Gorilla, blue duiker and medium sized duikers (bay and red-flanked duiker) that met the distance criteria of at least 40 observations (Thomas et al. 2010). However, density estimate using the described formula was used to analyse the density of chimpanzee (about 390 individuals) in the park to further emphasize the importance of the park for primate protection.

Density and abundance of large mammal species from this study were comparatively higher than results from previous surveys in the Deng Deng forest (Ambahe et al. 2011, Fotso et al., 2002). Calculated density and extrapolated abundance of gorilla from this study, which suggested the presence of between 350 and 850 gorillas in the park, is higher but also consistent with findings from previous surveys (Ambahe et al. 2011, Fotso et al. 2002) that estimated a gorilla density range of between 300 to 500 gorilla in the park. The higher density and abundance of species observed in this study could be attributed to possible immigration of species from nearby unprotected and disturbed areas into the park. Estimated density of medium sized and blue duikers were also higher compared to estimates obtained from surveys conducted in adjacent Lobeke, Boumba bek and Nki National Parks and in the northern periphery of Boumba Bek National Park (Bobo et al. 2014). The comparatively high density and abundance estimates of large mammal species (particularly of gorilla) in the park emphasize the importance of the park for the conservation of large mammals in Cameroon.

The high frequency of occurrence of blue duiker and medium sized duikers (bays and red-flanked duiker) indicators (particularly dung) recorded from this study suggest their commonness in the study area. Records of buffalo presence in this study was comparatively higher than was observed in 2008 probably due to immigration of this species into the park and encouraged by the protection level that the park has gained since 2010. Species such as elephant, bongo, sitatunga, buffalo and yellow-backed duiker were recorded fewer times in their typical habitats in the sampled area, suggesting their rarity in the park. Among the rare species in the park, the yellow-back duiker is particularly rare in most part of its expected range in the east region and is thought to be locally extirpated in some parts of Cameroon (Bobo et al. 2014). Among the primate species, gorilla was the most frequently encountered in the park suggesting its free roaming habit and the fact that they construct mostly ground nest unlike chimpanzee that occurred mostly in forested area and construct mostly tree nest.

### **6.6.3 Large mammal species habitat association and distribution in the Deng Deng National Park**

Animal species generally vary in their tolerance for different habitat types, and for exogenous<sup>15</sup>, endogenous<sup>16</sup> and stochastic<sup>17</sup> factors defining habitats and species (Morrison et al., 2006, Fischer and Lindenmayer 2007). As observed in this study species richness of the selected mammal species differed among the five main terrestrial habitats in the park. Only four common species in this study were represented in all habitat types i.e. gorilla, red river hog, blue and medium sized duiker. However, further results established that all species selected for this study are mostly forest dwellers with generalist habit implying they use all habitat types in the park to obtain necessary life requisite such as forage, shelter, nesting sites and refuge from external threats. Given the generalist habit of species, their absences or presence in specific habitat in the park simply provided knowledge on their area of occupance and possible extent of occurrence within the limits of the park.

Differences in mean dung and tracks encounter rates of the respective species in this study were observed within and between habitats. However, preference was shown mostly for the dense

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<sup>15</sup> Exogenous factors i.e. external factor such as habitat loss, degradation and isolation.

<sup>16</sup> Endogenous factors i.e. internal factors that are part of species biological, e.g. special social system and dispersal patterns.

<sup>17</sup> Stochastic factors i.e. factors driven by chance or random events such as environmental change (e.g. climate), natural catastrophe, and demography.



and mature secondary forest habitats where high abundances of indicators of all species were recorded. Although encounter rates of gorilla nest sites was high in the young secondary forest, the number of nest sites was particularly higher in the dense forest but mainly in regenerating tree fall gaps characteristic of young secondary regrowth with close forest understorey. Chimpanzee which normally prefers rich canopy habitats (because of their tree nest preference) increased its habitat preference to the tree savanna area where a higher mean group size was observed.

In addition to their specific associations with the respective habitats in the park, the large mammal species exhibited individualistic spatial pattern of distribution over the park landscape. The abundance and spatial distribution patterns of large mammal in the park also reflects the species dispersal as well as their interaction ability with the diverse habitats in the park. Apes were mostly concentrated in the southern block of the park, south of the Lom Pangar River. Their absence in the northern block (which offers similar habitats as found in the southern block) is attributed to the wide width and depth of the Lom River, restricting their spread. The clumped distribution of elephants, buffalo, bongo, and sitatunga shown in the park, is attributed to the rarity of these species and to other external factors including hunting for meat and trophies, logging for timber and the presence of roads in the areas that might have caused emigration or isolation of these species, restricting them to very few locations in the park. Signs of buffalo presence, previously recorded in both the southern and northern block of the park, south and north of the Lom River (WCS 2008) were recorded only in the south of the Lom River in this study. The absence of this species in the southern block where it was once recorded raises concern of possible external influences that might have resulted to hunting or emigration of this species.

The random distribution of the common species (mostly duikers with the exception of yellow-backed duiker) in the park demonstrates species adaptability and the presence of suitable habitat conditions for large mammal survival in the National Park.

Given the observed association and distribution of large mammal species with respect to habitat physiognomy and characteristics in the park, altering the park's landscape may influence the persistence of species in a given habitat and may also affect the supply of basic requirements for species, the lack of which may lead to species decline, isolation or extirpation (Yackulic et al. 2011, Bennett and Saunders 2010, Kadmon and Allouche 2007).

#### **6.6.4 The impact of habitat characteristics on large mammal species**

Large mammals show various responses to habitat diversity and metrics some of which are advantageous and others disadvantageous to species population. Though no significant differences were observed in the relationship between habitat characteristics i.e. area, mean patch size, habitat richness and shape index, and the diversity and abundance of large mammal species in this study, for many species of large mammals, the characteristics of their habitats is very important for their survival.

The area occupied by the different habitats in the park was important for the study species and was positively correlated with species diversity and abundance though the relationship was not significant. The land cover with the largest extent in the park (i.e. dense forest cover), held high abundances and was mostly preferred by most species. This observation in the dense forest habitat in the park confirms the suggestion that larger area captures more environmental conditions (e.g. diverse niches) and provides more space required by species to survive (Fischer and Lindenmayer 2007). Large area also provides opportunity for escape from threats when part of species habitat extent is disturbed, accounting for the high abundance of species in this habitat. Nonetheless, small size vegetation cover such as the young secondary forest and grassland savanna in the park were also important for large mammal species and their role in complementing the larger dense forest cover area in the park can not be neglected.

Habitat richness (number of patches per habitat type) in this study showed no significant relationship with species diversity nor abundance per habitat. However, higher mean encounter rates of large mammal species especially in mature secondary forest (richest habitat in terms of number of fragments) suggest the advantage of habitat richness over habitat patch size for species abundance and distribution in the park. According to Ziv (1998) habitat patchiness affects species communities because sub-population may escape threats in a few patches and then recolonise those patches later, thus maintaining species population. But relative to a single patch with large size, habitat richness may result in a lower per patch population size susceptible to threats.

As observed in this study, most species utilized multiple habitat types and habitat patches in the park landscape probably due to the characteristic generalist habits of the large mammal species that allowed them to survive under diverse habitat conditions. But also the importance of habitat complexity (defined by shape) in determining species abundance, mobility and home range has been emphasized (Bennett and Saunders 2010, Bowyer and Kie 2006, Covich 1976).

Though no significant differences were observed between mean shape indices of the respective habitats and the diversity and abundance of study species, habitat complexity may over time result to species isolation. For a small area like Deng Deng national Park where individual habitat types are already very complex (i.e. having high mean shape index values), and where human incursion is already on the rise, any further increase in habitat fragmentation or complexity of habitats may alter species mobility between habitats and habitat patches within the park's landscape as well as may alter the large mammal population composition and structure in park.

## **7 Results: Human influences in the Deng Deng National Park; types, intensity, and distribution**

### **7.1 Human factors threatening the sustainability of Deng Deng National Park**

Both primary and secondary data analyzed from this study revealed various human activities taking place within and adjacent the Deng Deng National Park that are affecting the large mammal species population in the park. A list of eight human factors and possible consequences of these factors on the ecosystem within the park compiled from secondary sources is presented (Table 29). About 224 (from transect survey) and 105 (from recce surveys) individual indicators of human pressure including mainly the presence of used gun cartridge shells, hunter snares (i.e. wire snares and local traps), hunting and fishing huts (or camps), foot path (human tracks), burnt scars, agricultural fields (farmland), logged area, signs of cattle grazing, dam construction traces and petrol pipeline tracks, were recorded along transects and reconnaissance walks, respectively, in the surveyed area. Some examples of threats recorded in the park are illustrated (Plate 16). Individual threat indicators recorded from field surveys were grouped into eight categories (Table 30) to facilitate analyses. Table 30 presents and describes the different categories of threats recorded in the park.

Table 27: List of threats and possible consequences for the conservation of Deng Deng National Park

Threats	Some consequences
Chad-Cameroon oil pipeline	Habitat destruction Soil pollution from oil spills Facilitate access to remote areas
Railway	Habitat destruction Source of environmental noise Facilitate access to remote areas Facilitate bush-meat and fish transportation to urban markets
Dam construction	Habitat destruction Facilitate access to remote areas Increased influx of labor population hence increase demand for bush-meat
Cultivation fields-farmland	Habitat destruction Increase plant diversity
Bush-meat hunting	Overexploitation and loss of biodiversity
Grazing	Seasonal burnings Opportunity for bush-meat hunting Habitat destruction
Fishing	Overexploitation and loss of biodiversity
Mining	Habitat destruction

Sources: Ambahe et al. 2011, COTCO 2011, EDC 2011, Maisels et al. 2010, WCS 2008, GVC 2007, Fotso et al. 2002, Thomas et al. 1999, Author's assessment

Table 28: Description of human threat categories recorded in the Deng Deng National Park

Category	Description
Hunting	Includes all signs of hunting such as gun-shells, wire snares, pit and stick traps, small fire places and cuttings.
Logging	Includes all signs of logging such as old and active logging tracks, abandoned logs, old felled tree stumps and felled logs.
Farmland	Includes all active and abandoned crop fields, new forest clearings and burnt areas for cultivation.
Camps	Includes permanent and temporary huts, abandon and active villages and construction camps.
Livestock	Includes the presence of cow, sheep, goat and signs of livestock presence including dung and tracks.
Extraction	Includes signs associated with removal of resources such as removal of tree bark, and felling of trees for the fruits and leaves
Tracks	Includes all foot paths and roads.
Fishing	Includes locally closed fishing points, fish parts, local fish drying stand.

Source: Field survey by author



Plate 16: Some examples of threat indicators in the Deng Deng National Park (Source: Author)

## 7.2 Frequency distribution of threats categories

The eight categories of human presence indicators in the park as summarized in table 30 were analyzed for their frequency of occurrence in the study area. Human presence indicators were absent in 10.3 % (i.e. 3 of 29) of transects surveyed. Frequency analysis of threats showed high

occurrences of hunting signs, which accounted for 73.7 % (i.e. 165 of 224 records) of all records of human pressure on transect, trailed by logging signs, which accounted for 12.5 % (Figure 53). Frequency of occurrence of threats along reconnaissance walks (Figure 53) also showed high occurrences of hunting signs, accounting for 90.5 % (i.e. 95 of 105 occurrences) of all human signs recorded from reconnaissance survey.

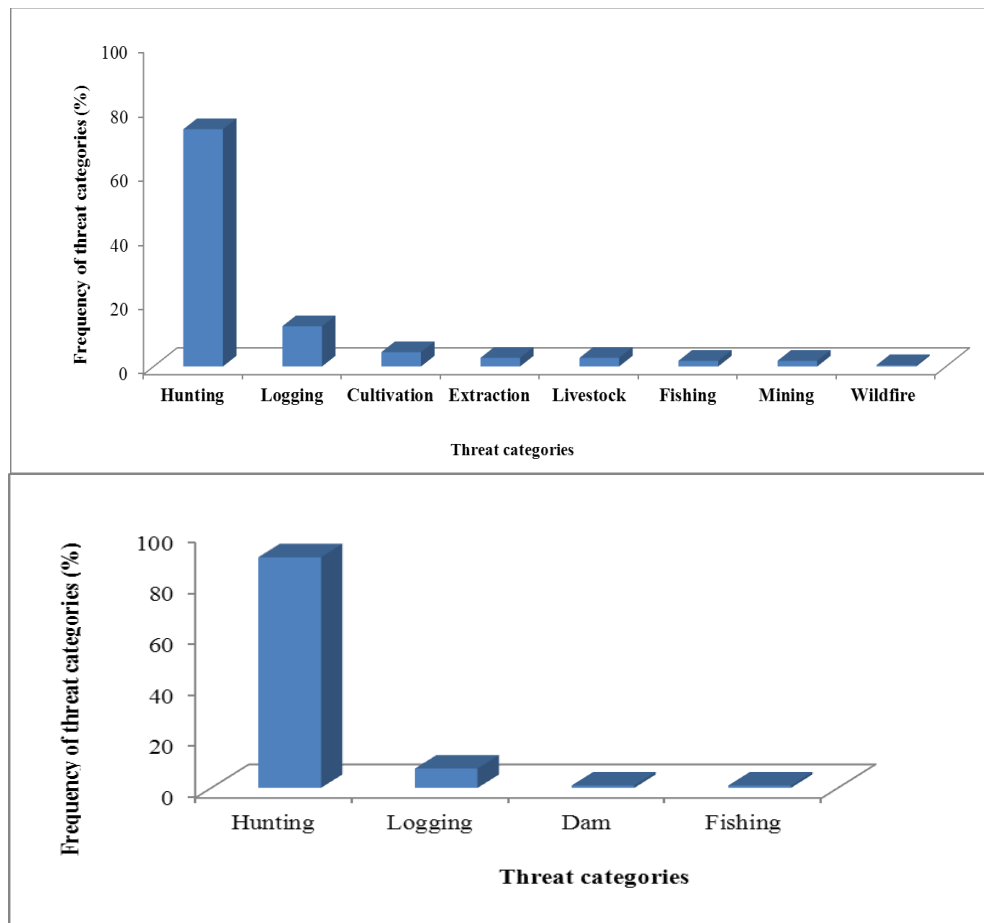


Figure 53: Frequency distribution of threats from transect (above) and reconnaissance (below) surveys

Further analysis to specify the spread of threats within the hunting category showed a high representation of human tracks (43.6 %, 72 records) and a minimum representation of hunting huts (1.8 %, 3 records) along transects. Additional hunting indicators including burnt scars from fire, and cigarette packets assumed to have been dropped by hunters were recorded during reconnaissance walks. Analyses of the spread of threats within the hunting category from reconnaissance data showed a high occurrence of used cartridge shell (41.9 %, 39 records)

followed by human tracks (28.5 %). Figure 54 presents the percentage distribution of the various hunting threats in the sampled area.

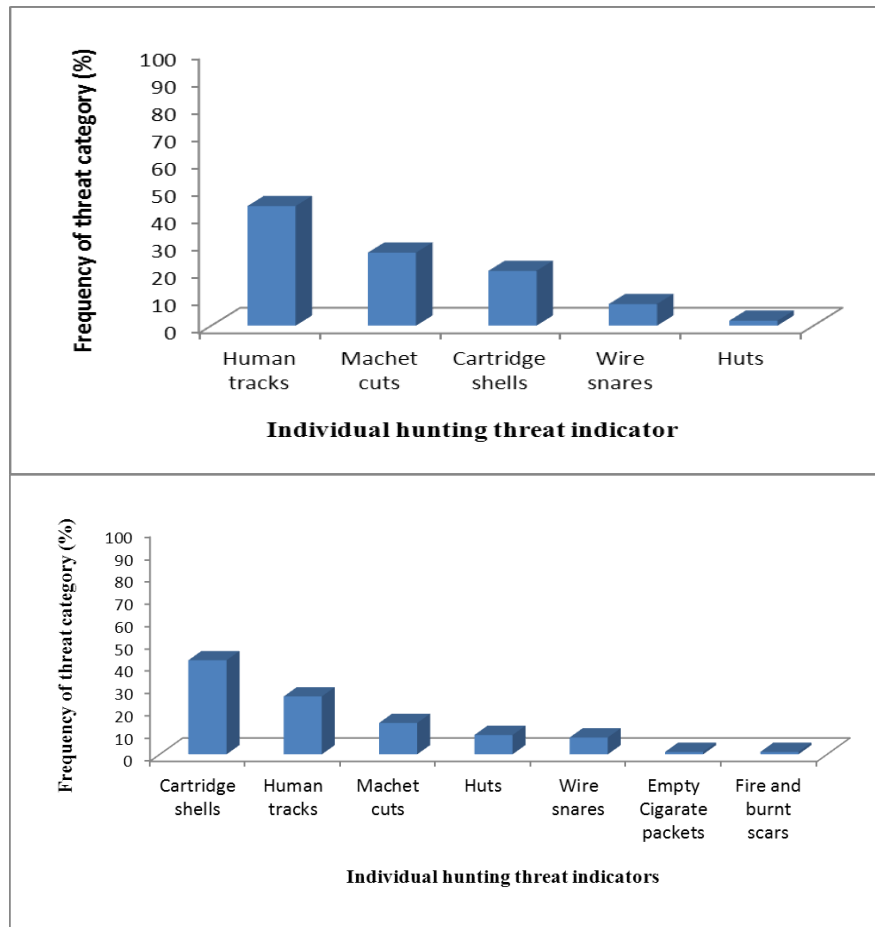


Figure 54: Frequency distribution of individual hunting indicators from transect (above) and reconnaissance (below) surveys

The frequency of occurrence of the different threat categories (Table 30, page 118) in the respective habitat types of the study area varied from at least one category of threat per habitat to five in the sampled area (Figure 55). Habitat analyses showed an increasing pattern in the occurrence of threats from the dense forest where mostly hunting signs were observed, to the tree savanna, where in addition to the presence of hunting signs, signs of fishing, extraction of resources (especially tree parts), burnt scar from wildfire, and livestock grazing were also recorded (Figure 55). Frequency variations were also observed within the composition of the various categories of threats in the respective habitats.



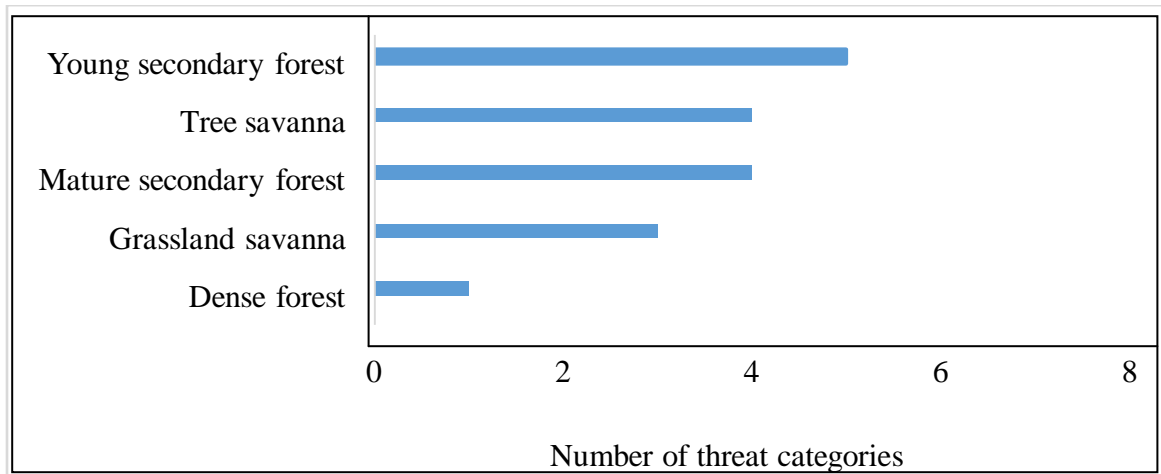


Figure 55: The number of threats category recorded in the different habitats surveyed

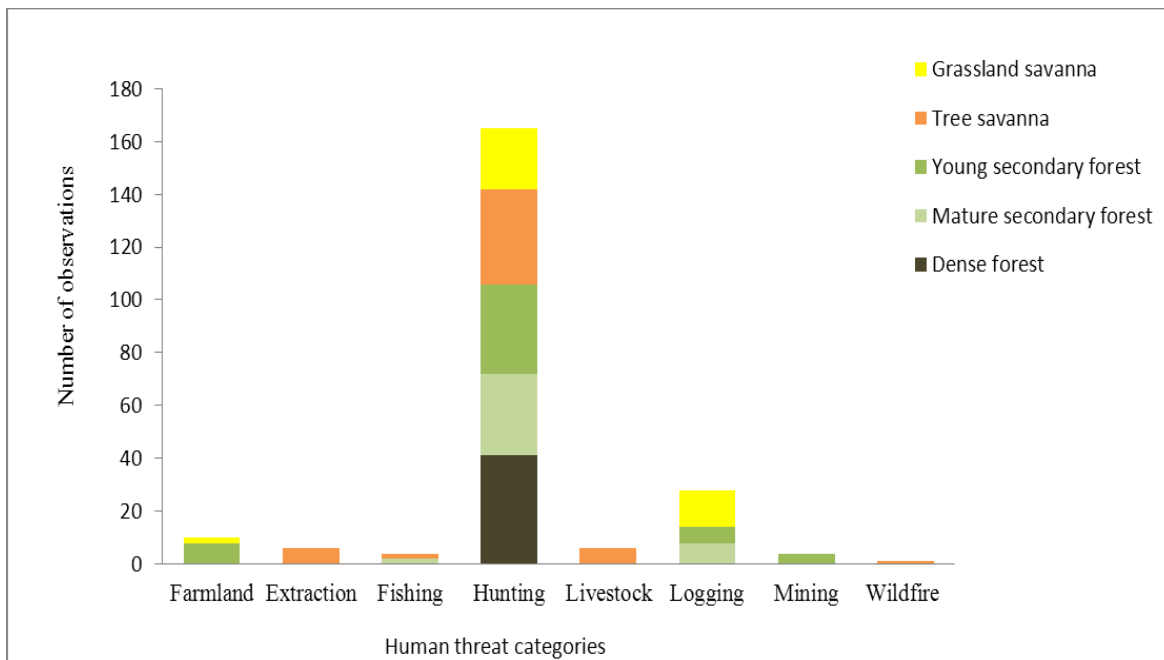


Figure 56: Presence and absence distribution of threat categories per habitat

Hunting indicators were the most common and frequent threats recorded in all the habitat types. Logging indicators such as the presence of logs piles, logging road and tracks were also recorded in the grassland habitat accounting for the high number of logging signs in this habitat (Figure 56). However, the act of logging (i.e. felling of trees) itself was not recorded in this habitat as it is mainly characterized and dominated by grasses. Threats such as mining, wildfire, and farmland were least common and occurred at low intensities.



### 7.3 Relative density of threat categories in the Deng Deng National Park

The accumulated encounter rates and mean encounter rate of all the categories of threats are shown in table 31. Accumulated encounter rate was estimated at 3.86 signs / km while overall mean encounter rate was estimated at  $0.5 \pm 0.3$  signs / km (at 95% confidence level), respectively. These results suggest that for every kilometre walked in the sampled area, about 0.5 signs of each of the category of threats were recorded. The encounter rate of hunting signs (2.84 signs / km) as shown in table 31 is comparatively higher than the encounter rate of other threats in the sampled area.

Table 29: Overall encounter rates of threat categories in the Deng Deng National Park

Threat category	Encounter rate
Cultivation	0.17
Extraction	0.10
Fishing	0.07
Hunting	2.84
Livestock	0.10
Logging	0.48
Mining	0.07
Wildfire	0.02
Overall encounter rate	3.85
Max	2.84
Mean	0.48

Encounter rates of each threat categories per habitat type were estimated by dividing the sum of each threat category encountered on transect within the respective habitat types by the total length of transects sampled within each habitat. The area sampled per habitat ranged from 6 km in the grassland savanna to 20 km in the dense forest. Table 32 presents the encounter rates of threats, per kilometre of habitat type surveyed in the study area. The overall encounter rates of threats per habitat ranged from 2.1 signs / km in the dense forest to 6.5 signs / km in the young secondary forest and grassland savanna respectively (Table 32). The high overall encounter rates of threat in the grassland savanna and young secondary forest implies that these habitats are more prone or exposed to threats than other habitats in the study area.

Table 30: Encounter rates of threats per kilometer per habitat type in Deng Deng National Park

Threat categories	Dense forest	Mature secondary forest	Young secondary forest	Tree savanna	Grassland savanna
Farmland	0	0	1	0	0.3
Extraction	0	0	0	0.8	0
Fishing	0	0.13	0	0.3	0
Hunting	2.1	1.9	4.3	4.5	3.8
Livestock	0	0	0	0.8	0
Logging	0	0.5	0.8	0	2.3
Mining	0	0	0.5	0	0
Wildfire	0	0	0	0.13	0
Overall encounter rate	2.1	2.7	6.5	6.3	6.5
Min	0	0	0	0	0
Max	2.1	1.9	4.3	4.5	3.8
Mean	0.3	0.32	0.81	0.79	0.81

Individual mean encounter rates of threats in the respective habitat types ranged from 0.3 threat signs / km in the dense and mature secondary forests to 0.81 threat sign / km in the young secondary and grassland savanna respectively (Table 32). There was a positive and significant correlation ( $r_s = 0.9$ ,  $p = 0.03$ ) in the mean threat encounter rates per habitat surveyed. The intensity of hunting threat was evidently higher than the intensity of other threats in all habitat types and ranged from 1.9 hunting signs / km in the mature secondary forest to 4.5 hunting signs / km in the tree savanna (Table 32). There was, however, no significant correlation between the encounter rates of hunting threats and the area of the respective habitats ( $r_s = 0.8$ ,  $p = 0.3$ ).

Further analysis to specify the relative abundance of individual threat indicators within the hunting category showed higher encounter rates of human tracks ranging from 0.8 tracks / km in the dense forest to 2.3 tracks / km in the grassland savanna. This was followed by the number of machete cuts per km, which ranged from 0.6 machete cuts per km in the tree savanna to 1.1 machete cuts per km in the young secondary forest. The encounter rate of used cartridge shells, ranged from 0.13 used cartridge shell / km in the mature secondary forest to 1.6 used cartridge shell / km in the tree savanna (Figure 57). Wire snares were the least encountered of the hunting indicators from transect surveys and ranged from 0.1 wire snare per km in the dense forest to 0.5 wire snare per km in the young secondary forest.

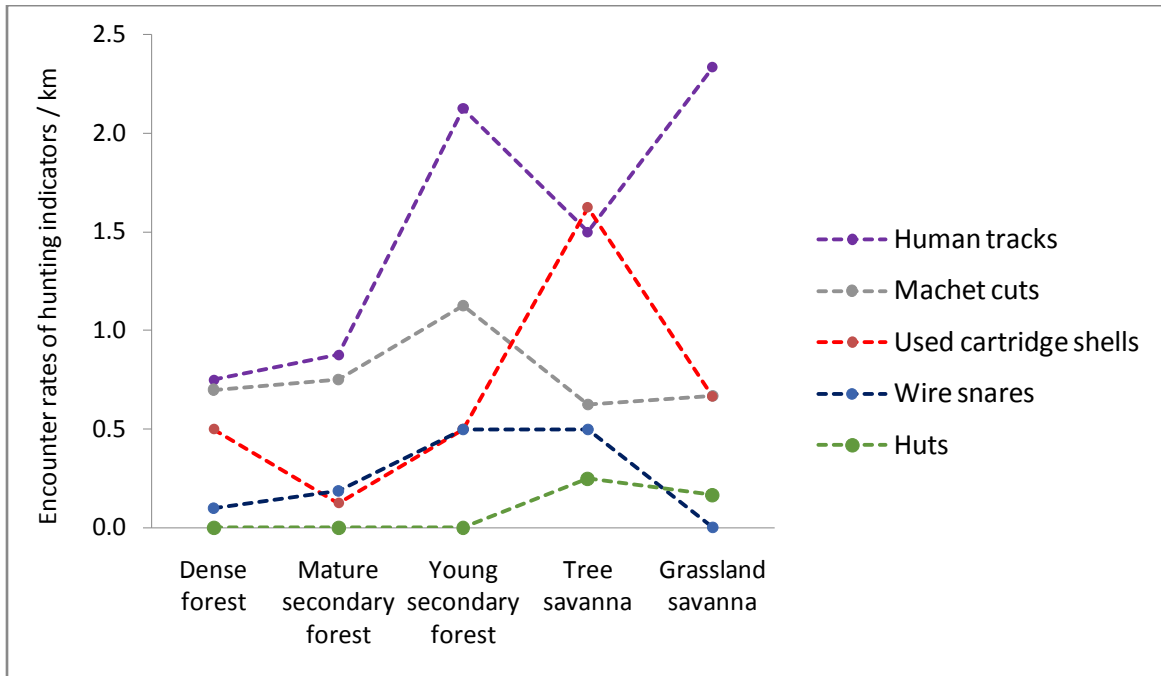


Figure 57: Encounter rates of individual hunting indicators in the study area

Hunting huts were scarcely encountered along transects but were found in the tree and grassland savanna, in areas located close to or at the edge of dense forest habitat type. Figure 57 presents the encounter rates of the respective hunting indicators in the area sampled.

#### 7.4 Distribution of human threat factors in the Deng Deng National Park

Spatial patterns of the distribution of threat categories being hunting, logging, fishing, mining, livestock; wildfire, farmland, and extraction of resources in the park were analyzed. Graduated dot symbols were used for the spatial presentation of the encounter rates of threat signs to show the intensity and extent of threats in the sampled area. Dot sizes were chosen such that the smallest dots represented areas with low encounter rates and larger sizes for areas with higher encounter rates. Spatial analyses revealed both random (and irregular) and more or less clumped distribution patterns of threat categories in the study area (Figures 58 – 61). Other point locations of threats recorded from reconnaissance surveys were also analyzed to further show the extent of human activities in the park (Figures 58-61).

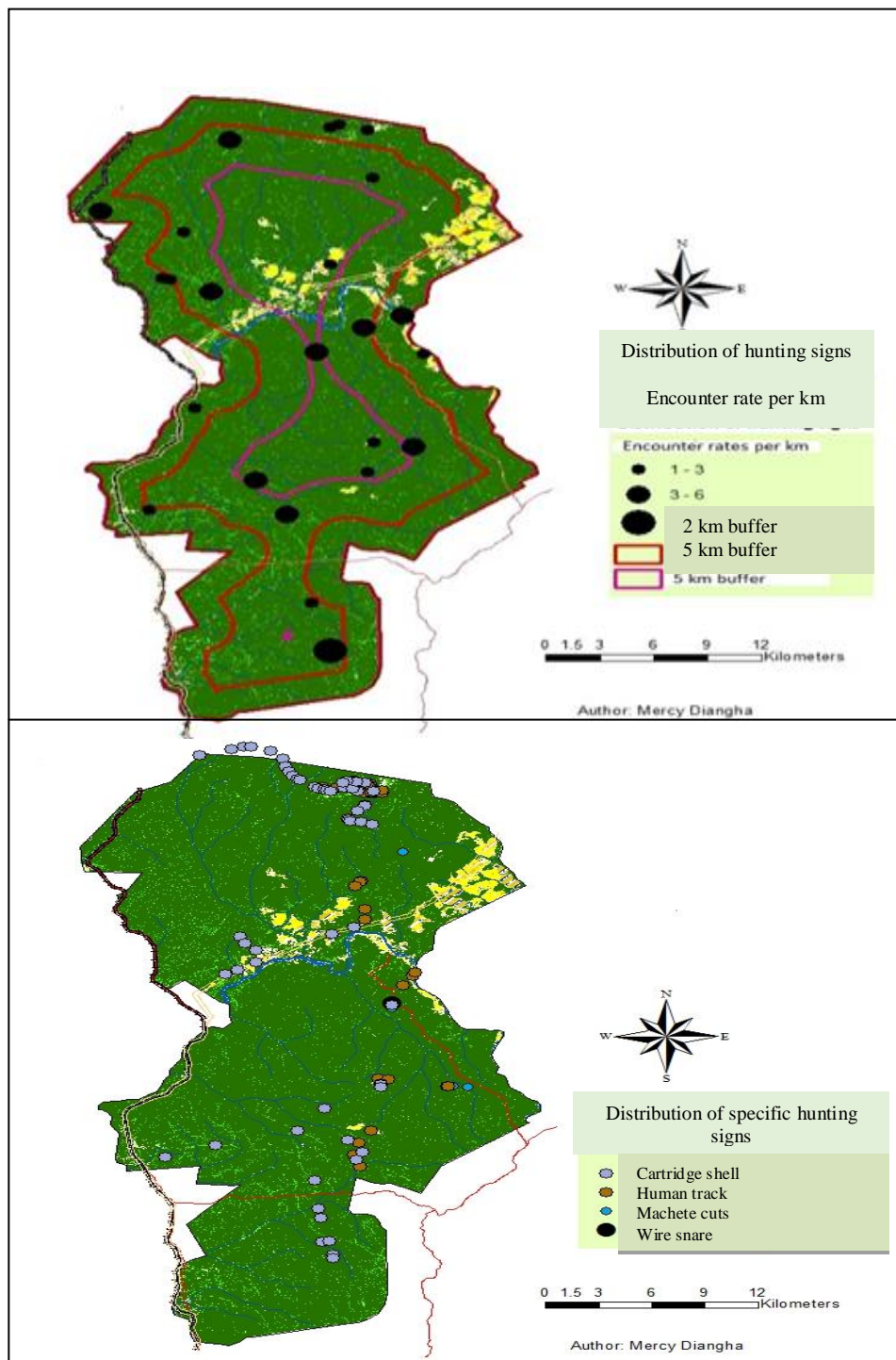


Figure 58: Distribution of hunting signs in the Deng Deng National Park analyzed from transect (above) and reconnaissance surveys (below)

Specifically, hunting indicators including wire traps, hunting huts, human tracks and cartridge shells, recorded on transects showed a random distribution pattern in the park. High concentrations of hunting indicators per transect (i.e. 6 - 10 signs / km) were recorded in the area

south of the Lom Pangar River particularly around the extreme southern boundary of the park (Figure 58). About 97 % of hunting signs recorded from transect surveys were within 5 km from the park boundary. Relatively fewer observations of hunting signs were recorded in the core area of the park. Randomly mapped GPS points of hunting threats (i.e. cartridge shell, human path, machete cuts and wire snares) showed high occurrence of cartridge shells and human tracks within 2 km from the boundary particularly, in the extreme northern zone of the park. Figure 58 (above) show mapped locations of hunting signs recorded during this study.

The distribution of logging signs in the park followed a clumped pattern. Logging signs were recorded from transects surveyed in the southern block. Higher encounter rates of logging signs (3 - 5 signs / km) were obtained from the southeast portion adjoining the Lom Pangar River (Figure 59). Random records of logging signs recorded from reconnaissance walks are also indicative of the occurrence and the extent of logging in this section of the park (Figure 59).

Signs of fishing, mining, cultivation, resource extraction and fire events were sparingly distributed and were also not frequently encountered along transect and reconnaissance surveys. Fire events were recorded mainly in the savanna, contiguous to a rock outcrop in the southern center portion of the park (Figure 60). Fishing signs including traditionally enclosed fishing pools, local fish drying stands and fish part remains (scales, fins, and bones) were recorded in two transects in the southern and northern blocks and along the banks of river Lom (Figure 60).

All signs of livestock grazing as shown in figure 59 were recorded in the northern block of the park, typically in the savanna habitat type along the Chad-Cameroon petrol pipeline.

Signs of extraction of forest resources in the park (such as tree fell for the extraction of fruits of *Xylopia ethiopica* and barks of medicinal tree plants) were noted in the mature secondary forest and tree savanna habitat types, located close to the Chad-Cameroon pipeline (Figure 60). Suspected mining sites were recorded mostly in the dense forest habitat in the southeastern portion adjoining the Lom River (Figure 60). Construction activities and camping sites of the Lom-Pangar dam project were observed within 2 km of the boundary east of the park (Figure 60). Lastly, agricultural lands (active and abandoned farmland) were noted in the southeast of the park (Figure 60).

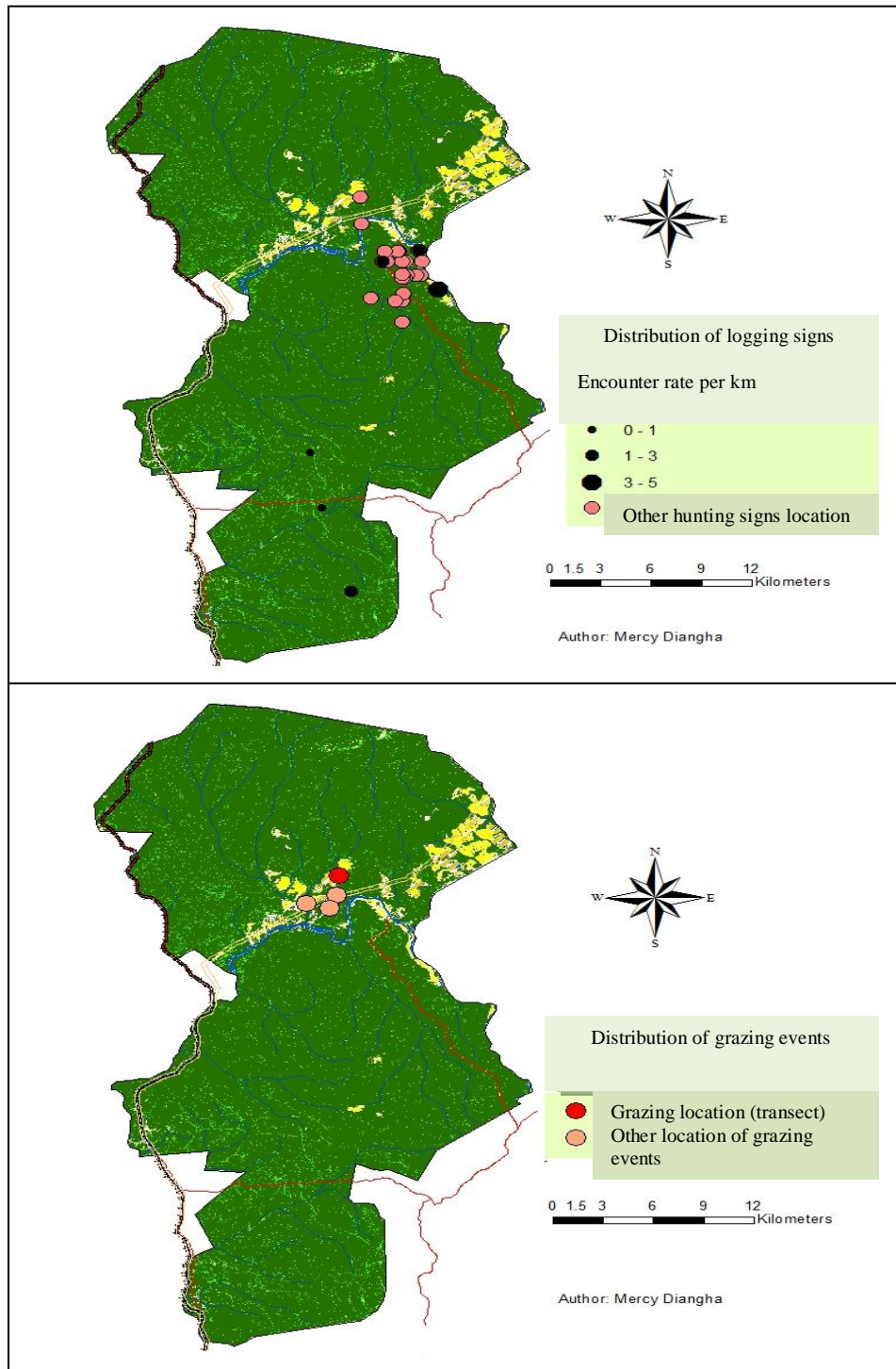


Figure 59: Distribution of logging signs (above) and grazing events (below) in the Deng Deng National Park landscape

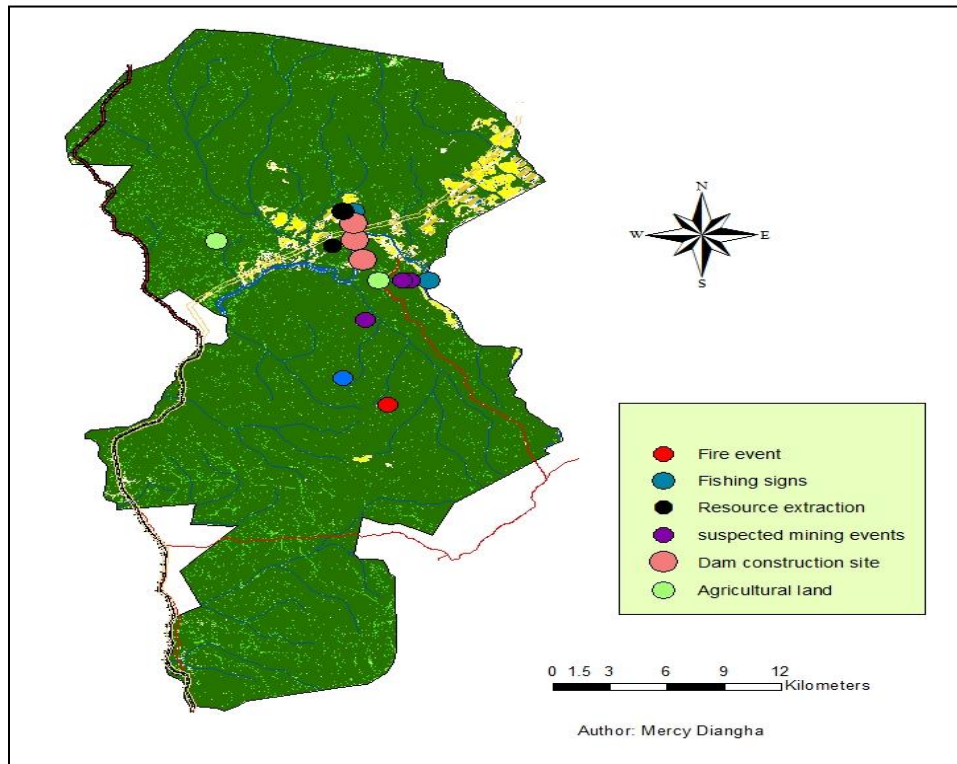


Figure 60: Distribution of fishing, forest resource extraction, fire events, and suspected mining sites in the Deng Deng National Park

In addition to spatial data collected from field surveys, other physical factors threatening the existence of the park such as the presence of infrastructure (e.g. railway, pipeline, roads) were extracted from several topographic maps and google earth source, and then integrated into the geo-database established for this study, for the analyses of a comprehensive human landscape of the park. An overall human landscape reflecting the spatial spread of human intervention in the Deng Deng National Park derived from this study is presented (Figure 61).



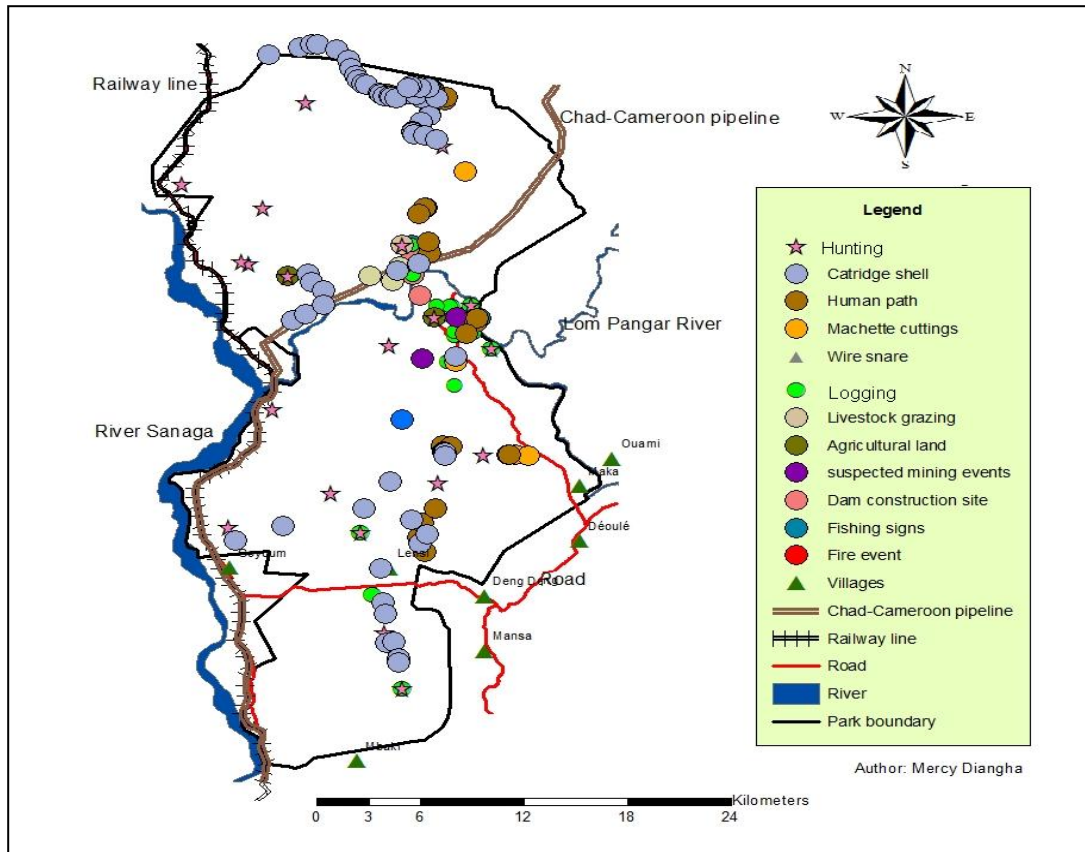


Figure 61: Human landscape of the Deng Deng National Park

## 7.5 Relationship and variation between human threat factors and mammals in the Deng Deng National Park

Comparative analysis computed to verify if observed variations in the encounter rates of the selected large mammal species in the sampled area was due to human influences showed an irregular pattern (Figure 62). However, higher encounter rates of large mammal signs were prominent in transect (Figure 62) and in habitats (Figure 63) where human threats intensity was low and vice versa. There was no significant correlation when the overall encounter rates of the categories of threats grouped in this study were compared with the overall encounter rates of the selected large mammal species in the respective 2 km transects surveyed ( $r_s = 0.001$ ,  $p = 0.9$ ). Nonetheless, a significant correlation was observed between the overall encounter rates of the categories of threats and the overall encounter rates of the selected mammal species in the respective habitats ( $r_s = - 0.9$ ,  $p = 0.03$ ). Figures 62 and 63 show the relationship between the encounter rates of the threats categories and the encounter rates of the selected large mammals per transect (Figure 62) and habitat types (Figure 63), respectively.



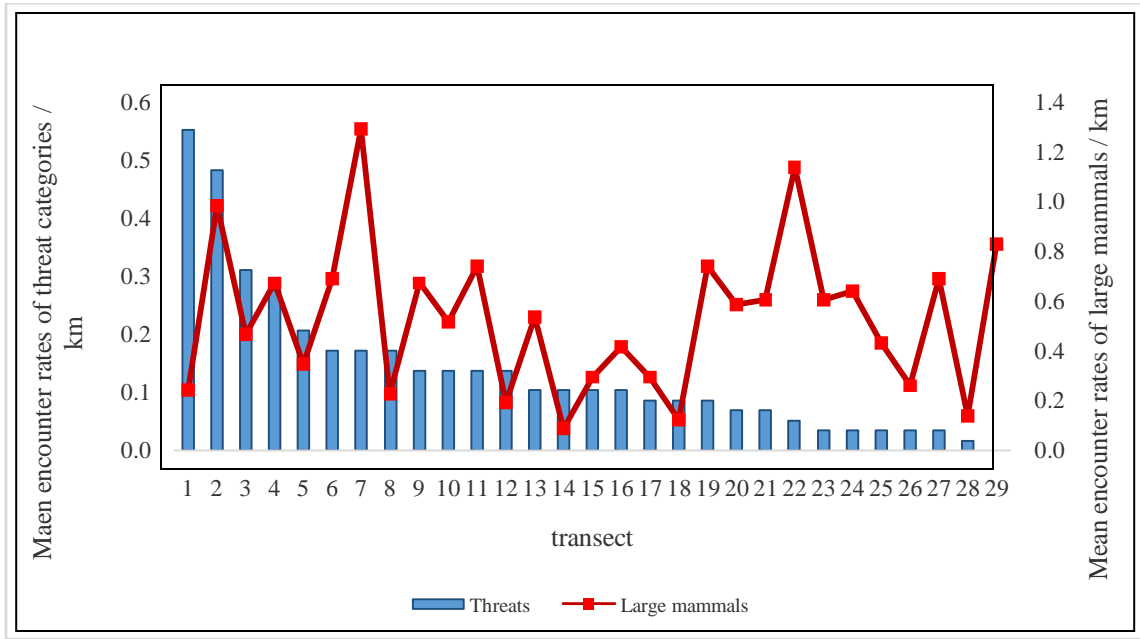


Figure 62: Relationship between the encounter rate of mammal and threat indicators per transect

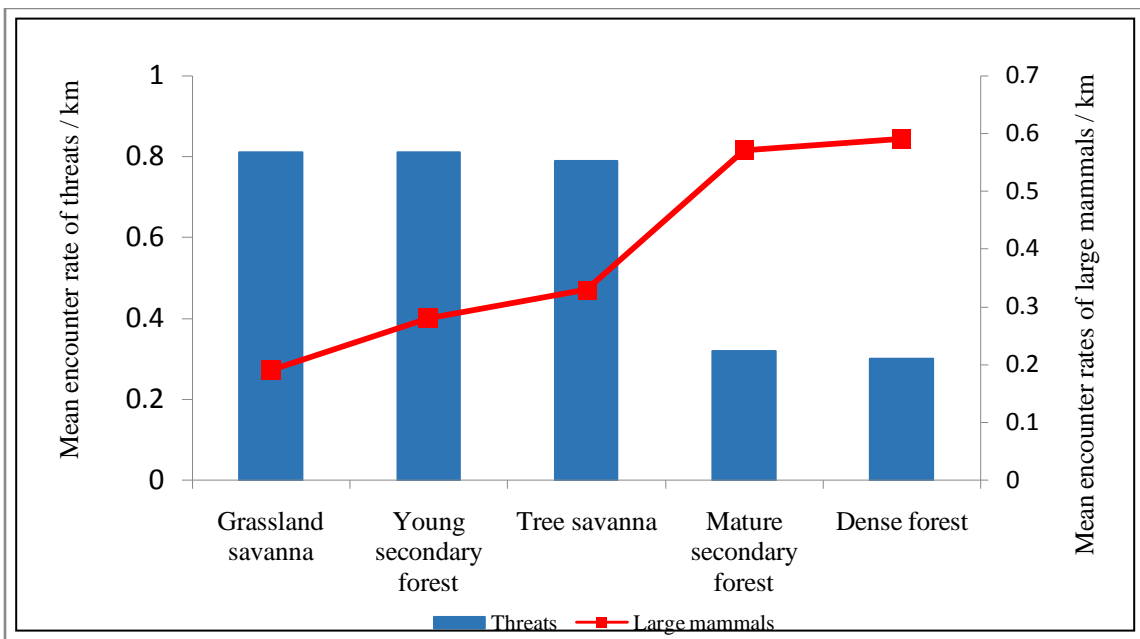


Figure 63: Relationship between the encounter rate of mammal and threat indicators per habitat

Generally, the encounter rates of threat indicators decreased from the grassland savanna to the dense forest habitat types in the sampled area (Figure 63). On the contrary the encounter rates of large mammal signs rather increased from the grassland savanna to the dense forest habitat type (Figure 63).

Further analysis of the two most important threats categories (with high records of occurrence) being hunting and logging were examined for their effects, first on the encounter rates of the four most encountered (with comparatively high encounter rates) large mammal species analysed in this study being the small duikers, medium sized duikers, red river hog, and apes (gorilla and chimpanzee) and second on the overall encounter rates of the selected large mammals presence indicators from transects and in the respective habitats.

### 7.5.1 Relationship and variation of hunting on selected mammal species.

Graphical presentations of the associations between the encounter rates of hunting indicators and the encounter rates of selected large mammal species per habitat in the Deng Deng National Park are presented in figures 64 – 69.

Generally, encounter rates of blue duiker species were high where hunting intensity was low along transects and in the respective habitats (Figure 64). However, there was no significant correlation when the encounter rate of hunting signs was compared with the encounter rates of blue duiker dung obtained from transect ( $r_s = -0.01$ ,  $p = 0.9$ ) and habitats ( $r_s = 0$ ,  $p = 1$ ) analyses.

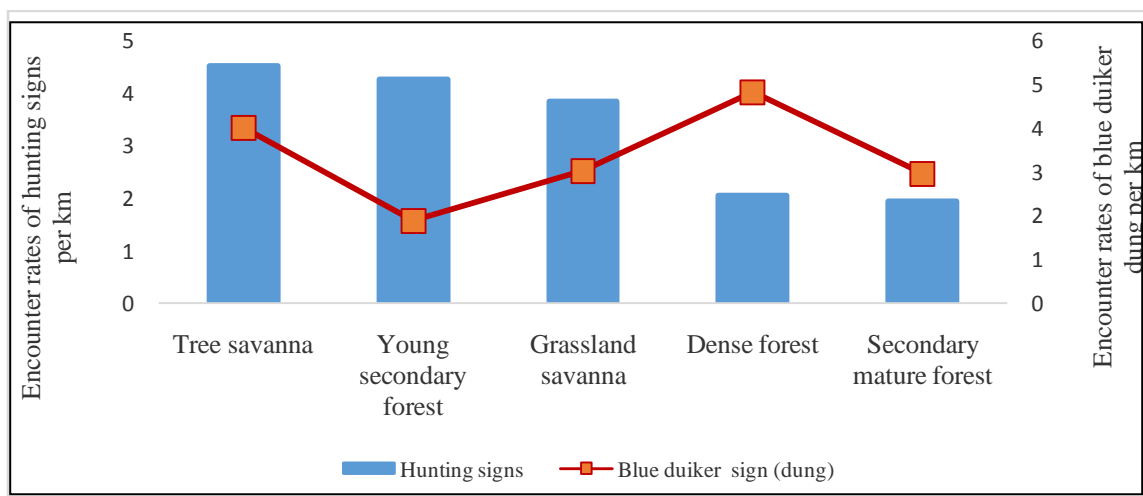


Figure 64: Relationship between the encounter rates of blue duiker and hunting per habitat

Result showed higher concentrations of medium size duiker in areas where hunting intensity was low in both transects and the respective habitats (Figure 65). Correlation analyses between the encounter rates of hunting indicators and medium size duiker dung on transects ( $r_s = -0.15$ ,  $p = 0.4$ ) and in the respective habitats ( $r_s = -0.7$ ,  $p = 0.2$ ) analysed were, however, not significant.

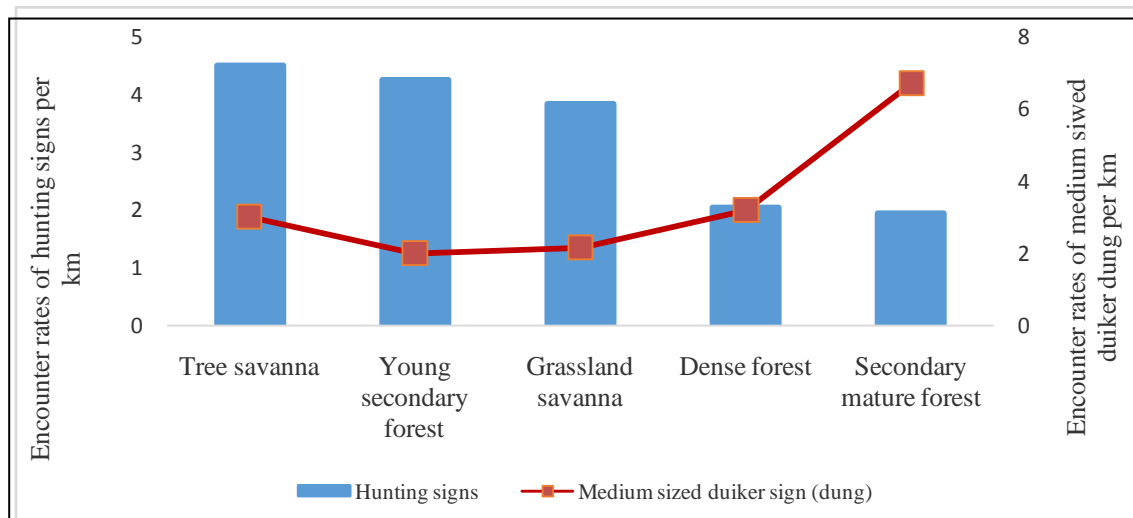


Figure 65: Relationship between the encounter rates of medium sized duiker and hunting per habitat

The encounter rate of red river hog in the sampled area was low in areas where hunting (i.e. hunting signs) intensity was high. Specifically, there was a steady decrease in the encounter rates of red river hog from tree savanna, through the young secondary forest to the grassland habitat, then followed by a sharp increase in the dense forest and mature secondary forest as hunting intensity dropped in these two habitats (Figure 66). Spearman correlation analyses showed no significant difference between the encounter rates of hunting indicators and the encounter rate of red river hog obtained from transect ( $r_s = -0.6$ ,  $p = 0.2$ ) and habitats analyses ( $r_s = 0.2$ ,  $p = 0.1$ ).

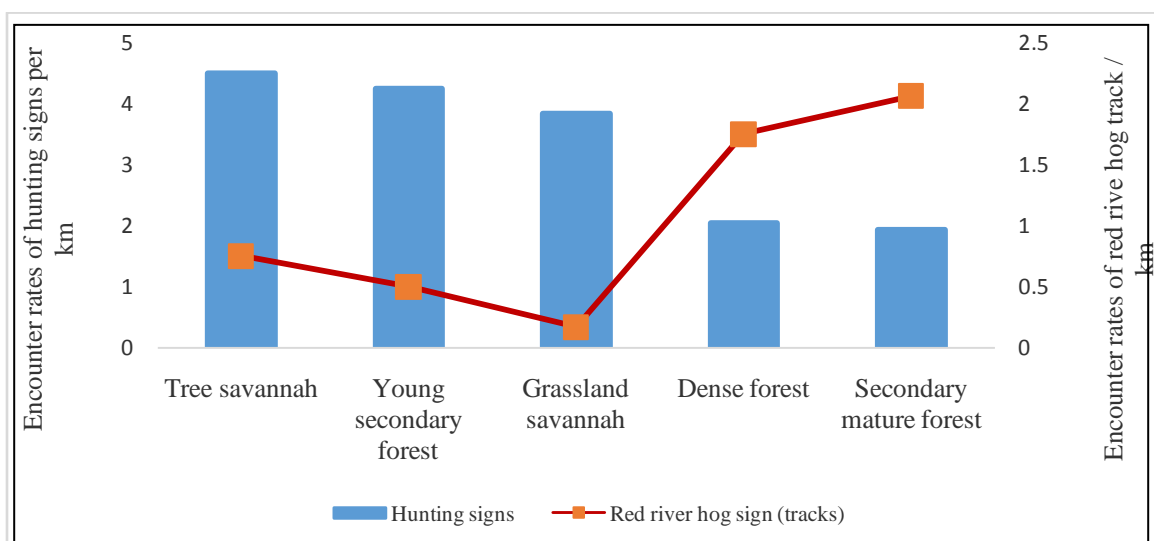


Figure 66: Relationship between the encounter rates of red river hog and hunting per habitat

Excluding areas where no gorilla nest were recorded, the encounter rates of both hunting indicators and gorilla nests in the respective sampled habitats showed a more or less similar change pattern (Figure 67). That is, habitats that held higher encounter rates of gorilla nest (e.g. young secondary forest) also showed higher intensity of hunting signs. Correlation analyses between the encounter rate of hunting indicators and the encounter rate of gorilla nests was significant when transects data was analysed ( $r_s = 0.4$ ,  $p = 0.01$ ). However, there was no significant correlation between the encounter rate of hunting indicators and the encounter rates of gorilla nest in the respective habitats ( $r_s = 0.4$ ,  $p = 0.5$ ).

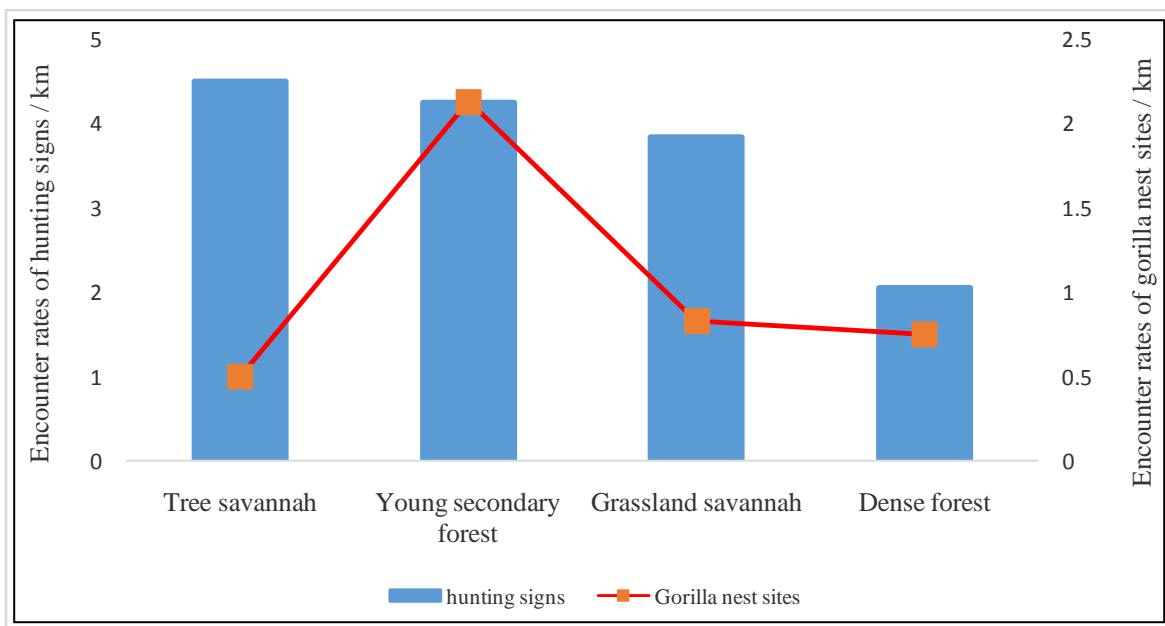


Figure 67: Relationship between the encounter rates of gorilla nest and hunting per habitat.

Excluding areas where no chimpanzee nests were recorded, the encounter rates of chimpanzee nest was generally low in areas where hunting intensity was high and vice versa. Higher encounter rates of chimpanzee nest were observed in the dense and mature secondary forest where hunting intensity was low in the sampled area (Figure 68). Correlation analyses between the encounter rates of chimpanzee nests and the encounter rates of hunting indicators was significant ( $r_s = 0.5$ ,  $p = 0.005$ ) when transect data was analysed, however, no significant correlation was observed when the encounter rates of hunting indicators was compared with the encounter rates of chimpanzee nest in the respective habitats ( $r_s = -0.5$ ,  $p = 0.3$ ).

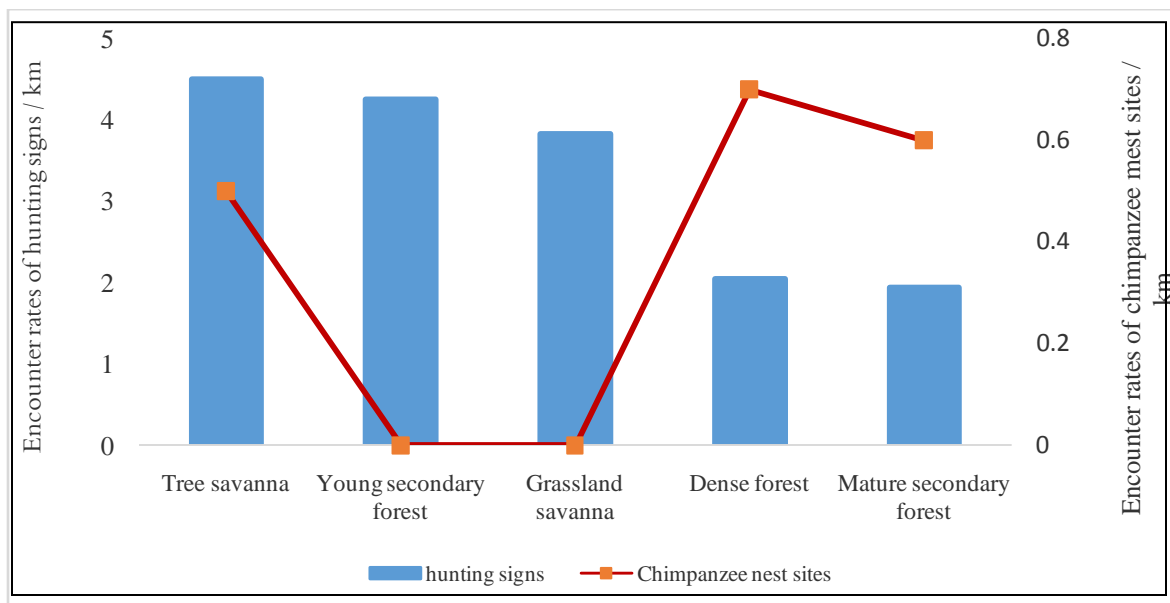


Figure 68: Relationship between the encounter rates of chimpanzee nest and hunting per habitat.

A comparison of the relationship between the overall encounter rates of hunting indicators with the overall dung encounter rates of the selected large mammal species (irrespective of species) in the respective habitats showed that habitats that held higher encounter rates of mammals (i.e. dense forest and mature secondary forest) also showed higher concentrations of hunting threats and vice versa (Figure 69). There was no significant correlation between the overall encounter rate of threats with the overall encounter rates of large mammals indicators recorded on transect ( $r_s = 0.2$ ,  $p = 0.2$ ). On the other hand, there was a significant correlation between the overall encounter rates of threats with the mean encounter rates of large mammals signs (including nests, dung, and tracks) in the respective habitats ( $r_s = -0.9$ ,  $p = 0.005$ ), implying higher concentration of large mammal in habitats where hunting intensity is low and vice versa. Nonetheless, there was no significant correlation between the overall encounter rates of large mammal dung (which was the most encountered signs of large mammal) with the encounter rate of threats in the sampled area ( $r_s = -0.7$ ,  $p = 0.1$ ).

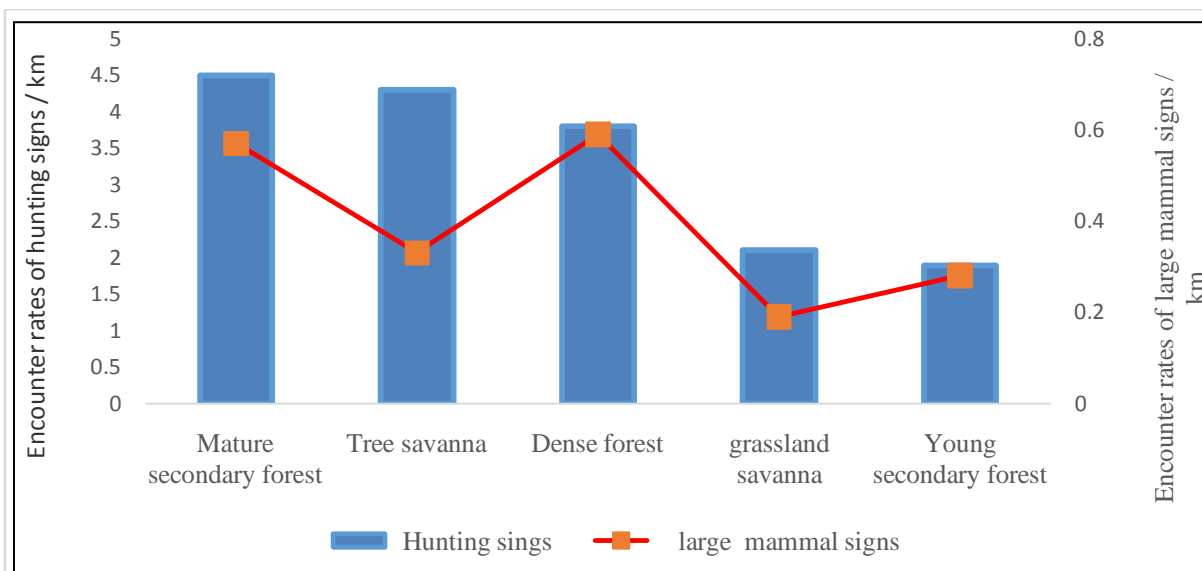


Figure 69: Relationship between the overall encounter rates of large mammal and overall hunting per habitat

### 7.5.2 Relationship and variation of logging on selected mammal species

To clearly present the effects of logging on the relative abundance of the selected large mammal species, analyses was limited to data collected from sampled areas where logging events (e.g. logging tracks, piles of logs, remains of logs, clear cut areas) were recorded. In all, logging events were recorded from 6 of 29 transects and 3 of 5 habitat types in the sampled area. The encounter rates of large mammals from these transect and habitats were compared for their variability with the encounter rates of logging signs recorded from the same transects and habitat types. Graphical presentations of the associations are presented in figures 70 – 74.

The relationship between logging intensity and the encounter rates of blue duikers illustrates a gradual decrease in encounter rates of blue duikers as logging intensity decreased in both transect and the respective habitats. However, a sudden peak was observed in the dense forest habitat (where signs of this species were most frequently encountered) showing a high encounter rate of blue duiker sign (4.7 signs / km) (Figure 70). Generally, the encounter rate of blue duiker signs was higher in habitats where logging intensity was lowest (Figure 70). Nonetheless, there was no significant correlation between the encounter rates of logging event and the encounter rates of blue duiker signs both in transect ( $r_s = 0.1$ ,  $p = 0.8$ ) and in the habitat types where logging events were recorded ( $r_s = -0.6$ ,  $p = 0.2$ ).

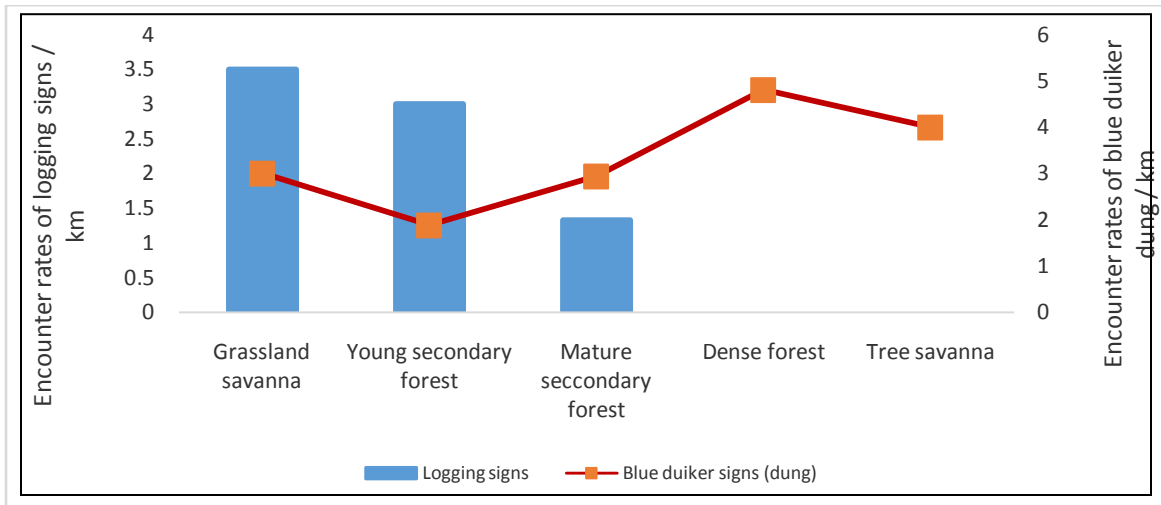


Figure 70: Relationship between the encounter rates of blue duiker and logging per habitat

The encounter rates of signs of medium sized duikers in the sampled area were high in areas where logging intensity was low. The encounter rate of this species in the respective habitats presents a sharp peak and immediate drop effect with peak in the mature secondary forest where the highest encounters of this species were recorded (Figure 71) specifically in areas where old logging tracks had developed into mature forest. However, there was no significant correlation between the encounter rates of medium sized duikers and the encounter rates of logging signs obtained from both transect ( $r_s = -0.6$ ,  $p = 0.1$ ) and habitats ( $r_s = -0.5$ ,  $p = 0.3$ ) where logging signs occurred in the sampled area.

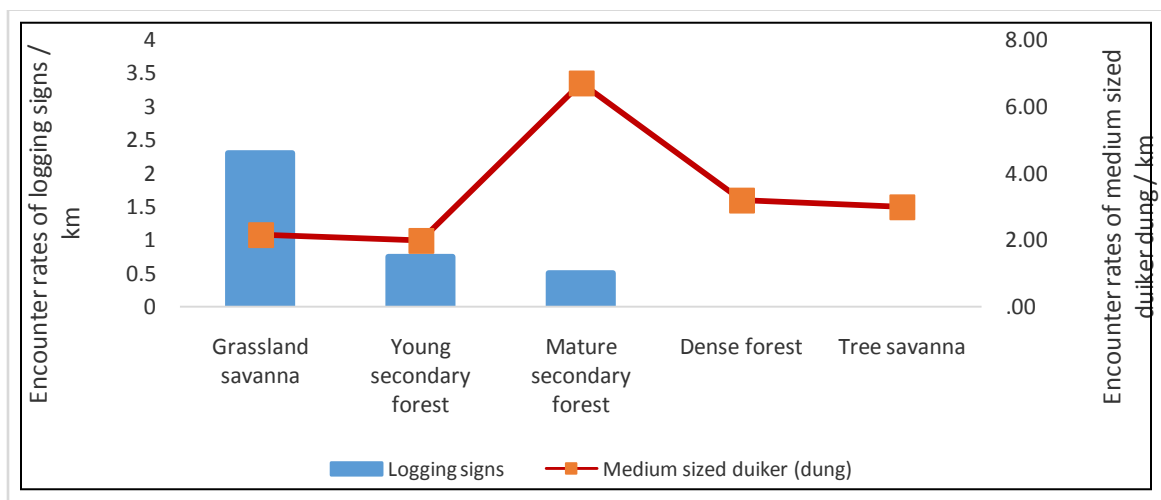


Figure 71: Relationship between the encounter rates of medium sized duikers and logging per habitat

Concentrations of red river hog tracks in the sampled area were generally higher in areas where logging signs were absent or less encountered (Figure 72). The encounter rates of red river hog, however, showed no significant correlation with the occurrence of logging incidences in both transect ( $r_s = -0.5$ ,  $p = 0.2$ ) and the respective habitats ( $r_s = -0.6$ ,  $p = 0.2$ ) analysed.

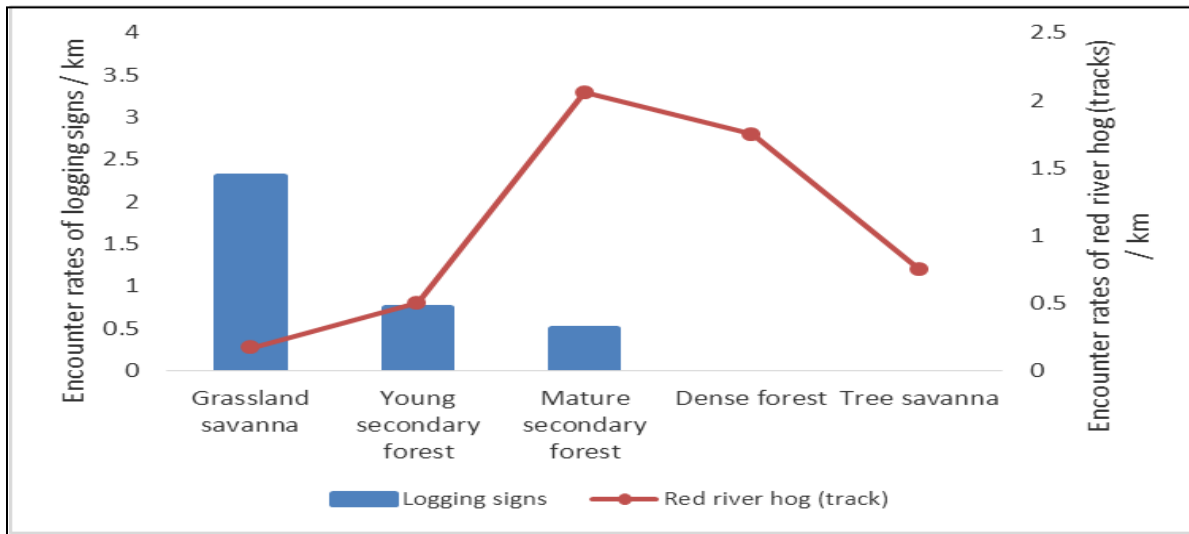


Figure 72: Relationship between the encounter rates of red river hog and logging per habitat.

Excluding areas where no gorilla signs (nests, tracks, dung) and no logging signs were encountered from the analyses, the encounter rates of gorilla and logging signs in the sampled area where they both occurred generally followed a more similar pattern (Figure 73). For example, habitats analyses showed higher encounter rates of gorilla nest in the young secondary forest where logging signs were also common (Figure 73). However, no significant correlation in the relationship between the concentration of logging events and the encounter rates of gorilla nests in both transect ( $r_s = 0.1$ ,  $p = 0.8$ ) and habitats ( $r_s = 0.5$ ,  $p = 0.3$ ) where logging events were recorded was observed.



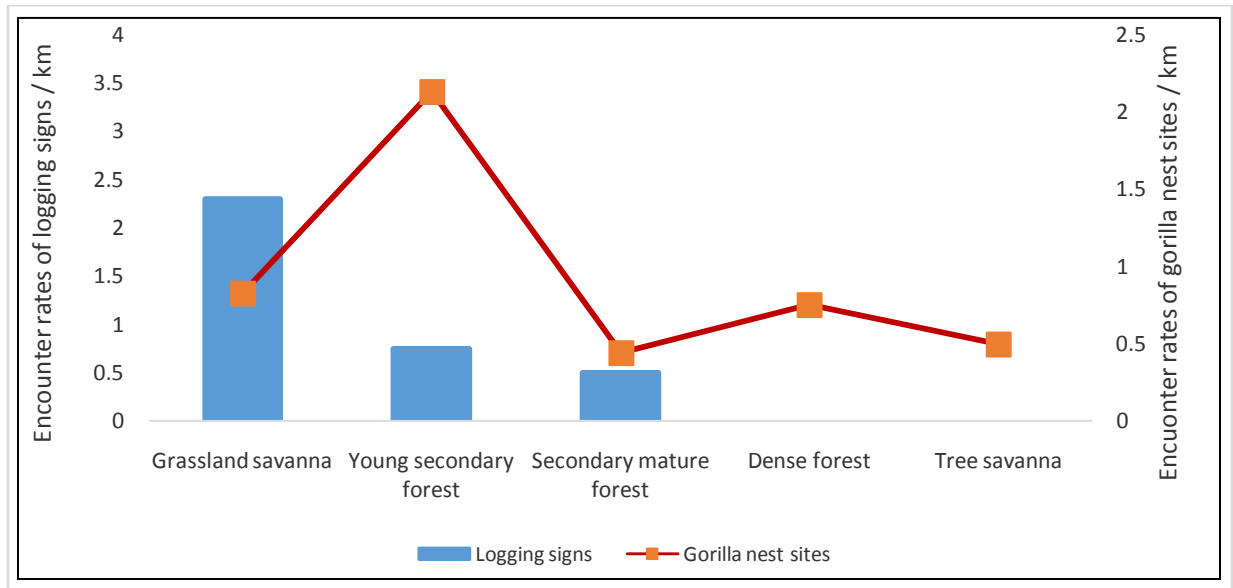


Figure 73: Relationship between the encounter rate of gorilla nests and logging per habitat.

Excluding areas where no chimpanzee signs (nests) were encountered from the analyses, encounter rates of chimpanzee nest was generally low in areas where logging intensity was high and vice versa (Figure 74). Higher encounter rates of chimpanzee nest were observed in the dense forest, mature secondary forest and tree savanna habitats, where encounter rates of logging signs was comparatively low. There was no significant correlation between the presence of logging sign and the encounter rates of chimpanzee nest on transect ( $r_s = -0.5$ ,  $p = 0.2$ ). There was also no significant correlation between the presence of logging signs and the occurrence of chimpanzee nests in the respective habitat types ( $r_s = -0.7$ ,  $p = 0.1$ ).

Overall, a negative correlation was observed when encounter rates of logging signs was compared with the encounter rates of large mammal signs in the entire area sampled (i.e. including data from sampled area where logging signs were not recorded) implying higher encounter rates of mammals in areas where concentrations of logging events were low and vice versa. However, no significant difference was observed ( $r_s = -0.3$ ,  $p = 0.5$ ).

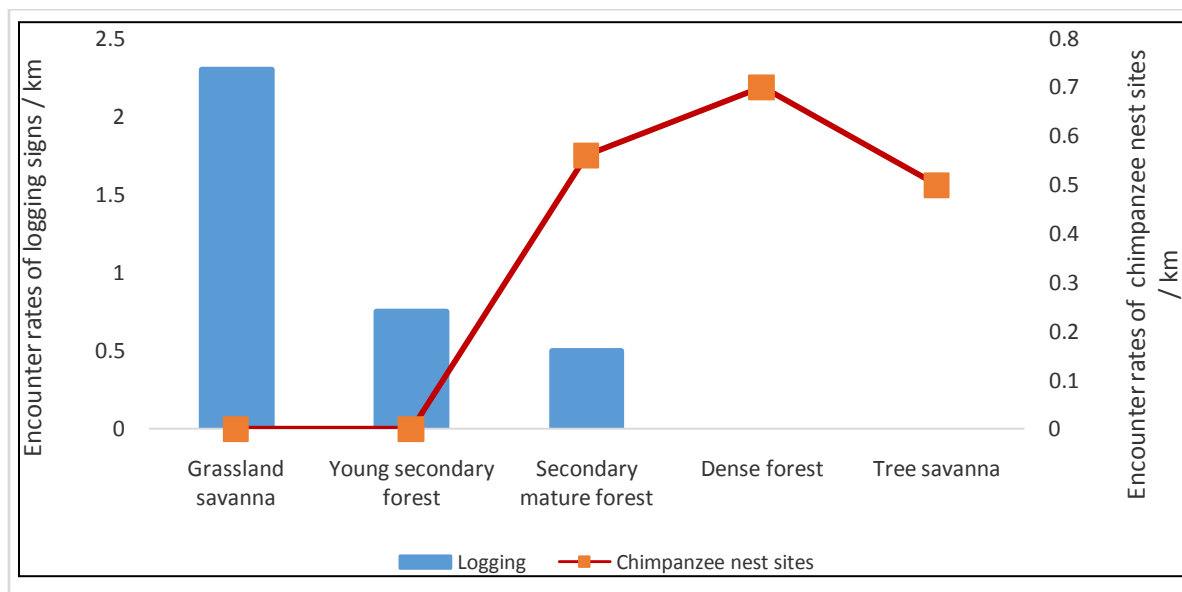


Figure 74: Relationship between the encounter rate of chimpanzee nest and logging per habitat.

## 7.6 Discussion

### 7.6.1 Characteristics and intensity of threats in the Deng Deng National Park

The integrity of the Deng Deng National Park has been at risk as wildlife, ecosystems, and ecological processes within the park have continued to experience threats from the diverse human societies (including the local ethnic groups, immigrants, and exploitation as well as developmental groups) living around the area, and mainly from the increasing dependence of the park's community on resources therein for their sustenance. Human pressure is a common phenomenon in most of Cameroon's protected areas but the case of Deng Deng National Park is unique given that it occupies a comparatively small area accommodating flagship fauna (e.g gorilla and chimpanzee), but is at the same time experiencing diverse external pressure some of which have caused physical and permanent changes in the park's structure (e.g. road, railway, and dam), and may have continuous effect on the park's biodiversity.

Threat categories recorded in the park including signs of hunting, logging, farming, livestock, settlement, extraction of plant and fish resources, and the presence of roads confirm previous reports (Ambahe et al. 2011, Maisels et al. 2010, WCS 2008, Fotso et al. 2002) of human caused threats in the park. Among the categories of threats, hunting signs occupied the largest proportion in which human tracks, cartridge shells, and machete cuts were the most encountered. Few records of hunting huts in the study area observed in this study are similar with results reported

by Fotso et al. (2002). This observation is attributed to the dry season period during which this study was conducted and during which time hunters spend less effort in constructing huts as observed in most of Central African forest (Plate 17).



Plate 17: Active hunting camp (typical style during dry season) in the Deng Deng National Park (Source: Author)

As observed in this study, well formed tracks or trails established by forest users are common in the park. The presence of trails and tracks in the park are facilitating walking access to the core area, thus threatening a vital refuge for many large mammal species in the park.

The use of dane guns (indicated by frequency and presence of cartridge shells), machetes, and wire snares for hunting in the park emphasizes the technological advancement of the human society around the park and the importance of bush meat in supplementing their household protein and income. Nonetheless, the local ethnic groups living around the park are mainly agrarians and depend on subsistence agriculture for their livelihood. Traditional agriculture characterized by shifting and “slash and burn” practices remains the main economic activity of the communities. While this activity is benefiting the community, it is expanding further into the park’s boundary. Records of farmland in the park were not frequent in this study but previous reports (WCS 2008) indicated wide spread and presence of farmlands in and adjacent the park.

Signs of extraction of resources especially plant parts or plant materials (such as bark and fruits) were comparatively low in the park. They occurred synonymously with the presence of hunting huts and along tracks or trails mainly used by hunters in the study area. Given this observations, it is assumed that the extraction of plant resources from the park is probably a secondary reason why the park is visited by users accounting for its low intensity. Example of

plant extraction in the park included the felling of *Xylopia ethiopica* trees for the harvest of fruits, commonly used as spice (Plate 18).



Plate 18: *Xylopia ethiopica* tree fell for fruits harvest (an important spice in the Deng Deng National Park area) (Source: Author)

The geographical scale of logging was not measured in this study rather, present and absence analyses of proxies for logging such as residues from fell tree, log piles, logging road, clear cut areas, and logging track were useful for evaluating logging intensity, spread, and impact on large mammals in the park. According to the law creating National Parks in Cameroon<sup>18</sup>, all activities meant to or that might alter the integrity of such areas are prohibited. Logging therefore is a prohibited activity in the Deng Deng National Park. Observation from this study, however, reveals that limited selective logging activities are taking place in and adjacent the park and is a cause for concern. Logging aimed towards recovering of timber from the Lom-Pangar dam reservoir and periphery has clear-cut and destroyed large areas of active habitats of large mammal within and adjacent the park boundary. The construction and rehabilitation of access road for logging inside the park and the presence of visible and active logging tracks found in this study, indicate the the gradual spread and intensity of this activity in the park. Selective logging conducted in parts of the park years back by a logging company (SOFIBEL) are still evident

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<sup>18</sup> Cameroon: Law No. 94/01 of January 20, 1994 to lay down Forestry, Wildlife and Fisheries regulations (Republic of Cameroon 1994)



(Fotso et al. 2002) reflecting the forest development history and the type of forest management that took place in parts of the Deng Deng forest area in the past. Frequency analysis ranks logging indicators the second most encountered threat category (after hunting), threatening the integrity of the park and affecting the large mammal communities in subtle and diffuse ways.



Plate 19: Evidence of old and active logging activities in the Deng Deng National Park (Source: Author)

Illegal and small scale mineral mining was reported taking place in the north-eastern part of the region (Fotso et al. 2002). Records of signs attributed to mining in this study were low implying uncertainty in the active exploitation of minerals in the park. However, few excavated pits supposedly meant for leads to possibly buried deposits of mineral (e.g. bauxite, uranium, diamonds, gold, rutile, zinc, iron ore, nickel, cobalt, and manganese) were recorded from this survey (Plate 20). The surface excavation of portions of the park for mining of minerals threatens both plants and mammal resources in the park. Open pits may cause the fall and death of free roaming large mammal species in the park.



Plate 20: Excavation (supposed) in search for minerals in Deng Deng National Park (Source: Author)

Different approaches have been applied in determining the intensity of livestock grazing in an area (Holechek et al. 1998). This study contrast with other approaches as it took into account and was focused on the number of times either tracks, dung, feeding residues of livestock as well as physical presence of livestock were encountered in the survey area. The encounter rates of livestock indicators in this study were low mainly because few people in the communities sharing territorial boundary with the park are involved in large scale cattle breeding. Grazing of livestock in the park, however, is mainly carried out by pastoralist from the northern region of the country who because of the characteristic long dry season and shortage of rainfall in this region, and also because of easy access made possible by the pipeline track, migrate into the park where they spend months (up to three months) grazing large herds of livestock.

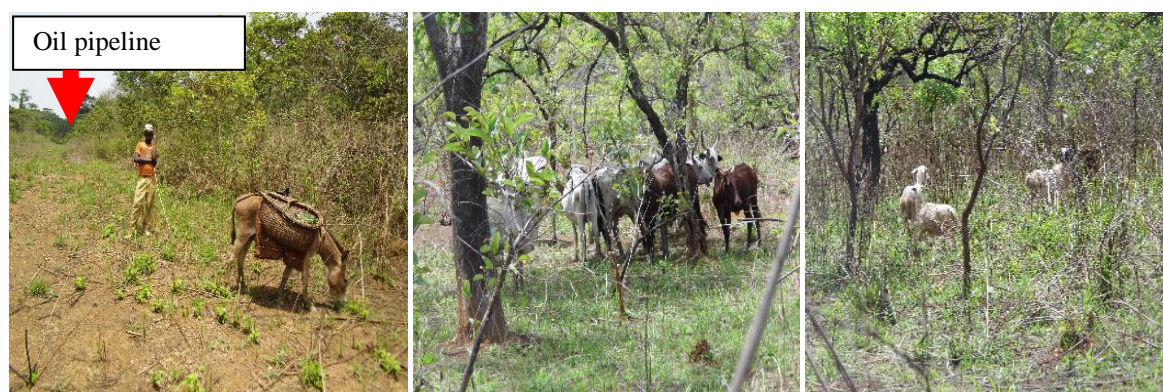


Plate 21: Evidence of grazing in Deng Deng National Park (Source: Author)

Fire events indicated by burnt scars was the least encounter of all threats identified in the sampled area. The scale of fire extent was not measured in this study, but was observed it has destroyed large area within the grassland savanna habitat in the park. The purpose and source of the fire event recorded in the park was not clear from this study. However, intentional situations frequently occur around the park where large areas are burnt for farming purposes. Already mentioned is the slash and burn agricultural practice in the area. The occurrence of fire event in the grassland savanna habitat in the park shows the vulnerability of this habitat type to forest fire.

The Chad-Cameroon oil pipeline that transverses approximately 12 km of one long track within the park (runs from oil fields in Doba in southern Chad to an off-loading vessel off-shore Kribi in Cameroon) is a threat to the park's integrity. Though it is a one long track (Plate 22) the consequences of it crossing through the park (e.g. habitat destruction, soil pollution from oil



spills, facilitate access to remote areas) are enormous to the habitats and large mammals community in the park. Numerous cartridge shells and also people (pastoralist and hunters) were encountered along the pipeline track during this study.



Plate 22: Chad-Cameroon pipeline track within the Deng Deng National Park (Source: Author)

Construction of the Lom-Pangar dam is ongoing (Plate 23) and is threatening the terrestrial and aquatic integrity of the Deng Deng National Park. As observed from this study, dam construction activities including clear cutting of forest, diverting water courses, flooding terrestrial surfaces, opening of access road, construction of settlement camps and work stations, have destroyed large area of wildlife habitat in and adjacent the park. Large portion of forest have been cleared and flooded in the East of the park without detailed evaluation of the importance of the zone for rare and endemic plant, hence a cause for concern.



Plate 23: Lom-Pangar Dam construction site and staff residential area (right) east of Deng Deng National Park (Source: Author)

The location of road infrastructure adjacent or cutting through protected areas in Cameroon is not uncommon. The presence of unpaved road and railway infrastructure inside and adjacent the Deng Deng National Park confirms this assertion. A segment of Cameroon railway line, which runs from the Center to the North region of the country, passes through the whole length of the western section of the park. The consequences of the presence of these infrastructures are enormous (e.g. habitat destruction, source of environmental noise, facilitate access to remote areas, facilitate bush-meat and fish transportation to urban markets) and threaten the ecological integrity of the park.



Plate 24: Segment of railway line (left) and main road access (right) within the Deng Deng National Park (Source: Author)

### **7.6.2 The extent and distribution of threats**

The extent of threats and the pattern of their distribution are very important for the allocation of management efforts in the Deng Deng National Park, thus require greater attention. In an attempt to measure the extent of threats in the study area, the approach used has been to identify threats and to relate their frequencies and encounter rates with the respective habitats in the park. Geographic Information System and remote sensing techniques were also applied in locating threat indicators. According to research results, all the habitat types analysed in this study (i.e. dense forest, mature secondary forest, young secondary forest, tree savanna, and grassland savanna) are exposed to and are experiencing various categories of threats, but the encounter rates and frequency of occurrence of the diverse categories of threats identified in this study (including hunting, logging, farmland, camps, extraction of resources, fishing, wildfire, livestock, and tracks) was significantly different ( $p = 0.03$ ) and were higher in the young secondary forest, tree savanna and mature secondary forest than was observed in the dense forest and grassland savanna



habitats. This result implies that these habitats are more prone to threats in the study area. Possible reasons for the difference and concentrations of threats in these habitats are accessibility, knowledge of the presence of objects of interest, e.g., knowledge of animal presence and home range, knowledge of the presence of plant resources (for food and timber extraction) in the park, and also the location and physical structure of the habitats, which coincidentally best fit some activities (e.g. for the construction of a hydroelectricity dam, pipeline and road infrastructure).

Pattern of threat distribution was both irregular and clumped over the study area as shown in the results. The high concentration of human tracks in most of the southern block of the park, the long extent of the Chad Cameroon pipeline cutting through the southern block of the park, the presence of a railway line extending the entire length of the western side of the park and the presence of timber tracks and unpaved motor-able road in the eastern block of the park, has made access to the different habitats in the park possible, especially in the young secondary forest, mature secondary forest and tree savanna where threat intensity was high, and also in the dense forest habitat where threats were recorded.

Hunting signs as observed from this study were randomly distributed over the study area and also occurred in all the habitats surveyed. From this observation, it is likely that hunters' knowledge of specialist as well as generalist habits of most species present in the park might have guided or directed hunting activities in the park accounting for the spread of hunting signs. Hunters' knowledge of species occurrence and distribution has been emphasized (Brinkman et al. 2009).

An overall human landscape reflecting the spatial spread of human interventions in the Deng Deng National Park derived from this study (Figure 61, page 130) shows that the park is multifunctional and holds four conservation hotspots characterized by the concentration of various categories of threats that are negatively affecting the ecological integrity of the park's landscape. The conservation hotspots identified from this study are distributed in the north east (where high concentration of hunting signs particularly cartridge shell were recorded), in the centre, mainly along the Chad-Cameroon pipeline (where hunting, farmland, livestock grazing and evidence of resource extraction were recorded) in the east (where the dam construction project is ongoing, and where hunting, logging, fishing event, and major roads were recorded) and in the southern block where multiple threat categories are concentrated, including fire events.

Considering a normal protected area zoning plan, the core of the park would have been more isolated from the surrounding human activities, but for a small area like the Deng Deng National

Park where the core is just slightly above 5 km east and west from human settlement or from its boundary, it was not excluded from threats. Evidence of hunting (mostly machete cuts and few cartridge shells), were also recorded in the core area of the park.

### **7.6.3 Impact of human pressure on large mammal richness and abundance in the Deng Deng National Park**

Virtually all human activities affect wildlife either positively or negatively (Steidl and Powell 2006, Lui et al. 2003), but most of the human activities on natural ecosystems are detrimental to wildlife (Happold 1995). Individual categories of threats posed by humans in the Deng Deng National Park are potentially reducing the population of species and disrupting species ecological processes in the park. Field observations actually confirmed alterations in the physical environment of large mammal species in the park caused by human interference in the area. Infrastructure located within and adjacent the park (i.e. the Chad-Cameroon petrol pipeline, railway, dam, and major access road) has limited the available habitat area and home range of large mammals in a relatively permanent way. Given that area of suitable habitat is proportionate to species number (Connor and McCoy 1979), the reduction of large mammal suitable habitat area through the construction of these infrastructures maybe, has negatively affected the richness and abundance of species in the park. It is possible that emigration of species and incidental exposure of species to hunting might have occurred as species sought for alternative refuge. No data exist or were found to compare the richness and abundance of large mammal before the construction of the railway. However, a study conducted before the construction of pipeline (Fotso et al. 2002) and this study confirms that species that were present before the construction of the pipeline are still present in the park. The presence of these infrastructures have also created opportunities for expansion of hunting and other human activities that are detrimental to both large mammal population and habitats in the park. These infrastructures for instance, have facilitated hunting access into remote areas (WCS 2008, Fotso et al. 2002) that were once enclave. It has also increased the transportation and commercialization of bush meat, which has now become a lucrative business to residents in the area. Other pressure including wildfire, the presence of farmland, grazing of livestock, and selective logging identified from this study have not only changed the quality of the natural habitats of large mammal in the park, but possibly have driven species to isolation in areas less exposed to external pressure. The positive roles played by these activities in structuring wildlife habitats are not undermined. Nonetheless,

transects and reconnaissance surveyed through areas where these pressure occurred, recorded fewer signs of large mammal presence, indicating the negative effect that these activities have on the large mammal species in the park.

This study investigated the possible relationship that the different categories of human pressure occurring in the park may cause on the population and possibly behavior of different large mammal species. No significant difference were observed when the overall encounter rates of the categories of threats were compared with the overall encounter rates of the selected large mammal species independent of habitat types where species were recorded. However, clear and significant variation in the encounter rates of species in the respective habitats in response to the concentration of the different categories of human activities taking place in the study were observed, emphasizing the importance of biome in the response of species to human pressure. The encounter rates of large mammal species were comparatively high in habitats where the encounter rates of human threats was low, e.g. the dense forest habitat, but the persistence of species in other habitats where threats concentrations were high, such as in the young secondary and mature secondary forest, marks the implication of species ecological attributes and community interaction (Rogala et al. 2011, Happold 1995). However, scale and intensity of human pressure may undermine such interaction and species ecological attributes, the consequence of which may be local extirpation, migration and possibly extinction. Happold (1995) and Rogala et al. (2011) observed that wildlife response to pressure is a function of several factors including the biome where species occur, the ecological attributes of the species and the intensity and type of human pressure.

It was evident from this study that there is a huge hunting pressure on large mammal species in the park, given the high frequencies of occurrence of hunting signs in both transect and reconnaissance surveys, and its comparatively high encounter rates in the respective habitat and in the entire sampled area. Hunting for subsistence and also for commercialization is threatening the large mammal population in Cameroon (Wood et al. 2013), and has caused decline in large mammal population (Muchaal and Ngandjui 1999) and local extirpation of species in some parts of the country (Willcox and Nambu 2007). The low encounter rates of both common and rare species in this park compared with the high encounter rates of hunting signs in the respective habitats in the study area suggest that hunting pressure has altered the structure of large mammal population in the park. The impact of hunting specifically analyzed to disclose its effect on specific large mammal species that were found to be relatively abundant in the park being blue

duiker, medium sized duiker (Bay and red-flanked duikers), red river hog, gorilla, and chimpanzee, showed differences in the response of these species to hunting. Though no significant differences were observed between the encounter rates of blue duiker, medium sized duiker (bay and red-flanked duiker), and chimpanzee when compared with the encounter rates of hunting indicators they were indeed not correlated in the case of blue duikers or negatively, but weakly correlated (i.e. exhibited low abundance where hunting intensity was high) with hunting pressure, suggesting that moderate hunting can also alter the structure and the behavior of large mammal species. Also the weak but positive correlation observed between the encounter rates of gorilla nest and encounter rates of hunting indicators in this study did not mean that gorillas are not affected by hunting. It could be attributed to the fact that gorillas in the park are often not main targets of local hunters (protected by local taboo), as such they partly avoid human modified habitats. Gorillas in the park are nonetheless experiencing hunting pressure from both resident and non-resident poachers who are capable of affording automatic shotgun (Ambahe and Bosco, personal communication).

Logging pressure has evidently reduced habitat and forage area of large mammal in the eastern section of the park and it is also possible that emigration of species and incidental exposure of species to hunting might have occurred as a result of logging. In fact, the response of blue duiker, medium sized duiker (bay and red-flanked duikers), red river hog, and chimpanzee, to the presence of logging indicators in the park was similar to their response to hunting emphasizing the contribution of logging to hunting. While the abundance of these species declined in areas where logging indicators were high, the abundance of gorilla nest was rather high in habitats disturbed by logging activities. Studies have shown that gorilla favors selectively logged and regrowth area (White and Tutin 2001, Tutin and Fernandes 1984), which might explain why gorilla population did not response negatively to the presence of logging event or why they persist in the relatively disturbed habitats in the study area. Large scale logging may, nonetheless, be detrimental to large mammal species and also to gorilla population in the Deng Deng National Park.

## **8 Conclusions and recommendations**

### **8.1 Conclusions**

#### **8.1.1 Spatial and temporal patterns of habitats in Deng Deng National Park**

The purpose of this part of my study was to bring out the characteristic of the Deng Deng National Park that has supported the survival of large mammals. It was also intended to use this characteristic to demonstrate interactive effects and consequences for large mammal species in the park. Through application of various analysis approaches including Geographic Information System and remote sensing, ground validation, and the comparisons of landscape metrics, habitats within the park were identified, characterized, and analyzed for their spatial and temporal patterns. Despite the small area of the park compared to the area of other protected areas in the East Region of Cameroon (e.g. Lobeke, Boumba - Bek and Nki National Parks and Dja reserve), the presence of seven distinct land cover within the limits of park and differences in characteristic landscape metrics (area, mean patch size, mean shape index, density and richness) of the individual land cover types clearly indicates the diverse and heterogeneous state of the park's landscape. Visible evidences of land use and fragmentation of habitats revealed from this study are some of the drivers responsible for the analyzed changes in the physical characteristics of individual habitats within the park over the years. However, the park has maintained its diverse land cover types throughout the contrasting period in this study (1987, 2000, 2009) with the dense forest cover and tree savanna expected to gradually expand over time to occupy most of the park's landscape. This prediction may be realized only in the absence of externalities and drastic ecological and climatic variations but given potential future changes in natural and anthropogenic factors that may arise, the future of individual habitats of large mammals in the park remains uncertain. By revealing and spatially presenting the physical configuration of habitats in the park, park management can focus policy or management intervention based on any land cover type of interest that needs attention. These findings revealing the physiognomy of the Deng Deng National Park are very important for the management of large mammal community living therein.

### **8.1.2 Effect of habitat heterogeneity on large mammals**

In this study, eleven large mammal species were selected to closely evaluate the relative importance of landscape physiognomy and human pressure on them. The selection of eleven species of large mammals for the purpose of this study does not reduce the importance of the park to these species as the park also supports other fauna that as well contributes to the ecological functioning, socioeconomic, and conservation, importance of its landscape. However, the presence of these species in the park emphasizes the large mammal species richness in this area and the extent of their occurrence in Cameroon.

Large mammal species analysed in this study portrayed generalist characteristic explained by their frequency of occurrence and distribution in multiple habitats types in the park. The heterogeneous state of the park's landscape is therefore an opportunity for the generalist species as it provides diverse habitat conditions required by many and particularly the selected large mammal species to survive. However, observed contractions due to differences in habitat complexity, habitat richness, habitat area, and habitat mean patch size, indicates that species respond differently to different habitat condition.

The dominance of dense forest cover, which was also found to be the most preferred habitat for most species, and the predicted shift towards more of dense forest cover in the park in the next 23 years, suggests the possibility of large mammals spreading and occupying other areas in the park where they were not recorded in this study or where survey was not conducted. This suggestion can materialize if all external pressures are brought under control. In a threatened and human dominated landscape like the Deng Deng National Park, bringing external pressure under control is unlikely. Nonetheless, maintaining habitat heterogeneity is generally important for large mammal species survival through out their range of occurrence and especially in the Deng Deng National Park where species demonstrated generalist habits.

### **8.1.3 Effects of human influence on large mammals in the Deng Deng National Park**

In this study, investigations were made in order to identify and characterize the types of human pressure the Deng Deng National Park is experiencing, to find out where there are occurring, and to analyse the intensities and the possible effects of identified human pressure on the large mammal population in the park.

Findings from this study revealed that the park is experiencing different categories of threats posed by the diverse human society living adjacent the area, ranging from threats that are

changing the physical environment in simple and reversible manner to threats that have changed the park's environment in more or less permanent ways.

Though the heterogeneous nature of the park's landscape is an opportunity for large mammal species resident in this area as found in this study, spatial distribution of threats revealed that human pressure within the park is wide spread and has affected all the habitat types therein thus detrimental to the large mammal population.

Statistical significance of associations calculated between encounter rates of threat categories (e.g hunting and logging) and the encounter rates of large mammals in the study area mostly showed no biological significance, but observed relationship patterns confirmed that large mammal encounter rates were indeed low in areas where threat intensity was high. Hunting signs (human tracks, cartridge shells, machete cuts, wire snares) represented the most common threat in the park and the low abundance of large mammal species in habitats where hunting and logging intensities were high is a clear indication that these activities have eventually created depressing effects on large mammal species and their habitat in the park. However, the persistence of species in the park despite the threats the park is experiencing is an indication of individual species specific ecological attribute and adaptations in the available habitats in the park.

Given the many threats that the park is experiencing as realized in this study, it is clear that the demand for natural resources is growing faster, in protected areas in Cameroon and the Deng Deng National Park is no exception. In order not to jeopardize the conservation status of this park, quick actions are therefore required to halt the risk that may follow further alteration of the park's landscape, which may not only disrupt the ecological interactions between large mammals and their habitats, but may increase species vulnerability in the area.

The identification of threat hotspots in this study concentrated in four areas around the extreme northeast section of the park (where hunting signs occurred), around the current damp construction sites in the east (where logging, hunting, human tracks are rampant), along the Cameroon-Chad pipeline cutting through the park (where grazing, hunting, human track, farmland, resource extraction were concentrated), and in the south where minor road or larger concentrations of human tracks are common provide opportunities for focused and concerted conservation actions in and around the Deng Deng National Park.

## **8.2 Recommendations**

The following recommendations have been made for the advancement of the conservation objectives of the Deng Deng National Park.

### **1. Maintain and improve physical landscape**

One of the main forces behind the establishment of the Deng Deng National Park has been to maintain the integrity of the site. As revealed from this study, the park's physical environment is still experiencing serious alterations from the expansion of permanent infrastructure (e.g. railway, pipeline, dam and road construction), agriculture, logging, and hunting activities that have variably diminished the structure and quality of the park landscape. It is therefore appropriate for the park management to put efforts towards ensuring that the park represents a reserve of the physical land cover types identified in this study and most especially ensure that the park provide sufficient habitat to support suitable populations of the large mammals species residing within its boundary.

- Actions to stop farming activities and the development of more farmland in the park, to promote forestry or habitat restoration through afforestation of degraded and logged areas and the establishment of barriers and visible boundary marks against illegal intrusion and expansion of these activities into the park are proposed.
- Efforts to maintain and improve the physical landscape of the park would be promising if management would engage in the national political process to limit expansion of existing infrastructure into the park, and to prevent further approvals of projects that may cause more exploitation and destruction of the park's physical landscape while offering little or no direct economic gains to the park's community.
- Without considering external stresses, this study predicts the growth and expansion of the dense forest cover extending over most of the entire area of the park in the next 23 years. This outcome could be realized under the conditions that humans are excluded from the park, stochastic factors are kept under control and the above proposed actions are adopted. In this regard, additional GIS and remote sensing monitoring of the land cover within the park is recommended for future management and quick management interventions in case of any observed changes in the physical landscape of the park. Provision of alternatives to the activities carried out by humans in the park may initiate the process of encouraging non-consumptive use of the park's resources by the neighbouring communities.



Addressing these suggestions may not be fully feasible in practice. However, it is crucial for management to make efforts towards these proposed directions and most especially efforts to retain and protect the natural heterogeneity of the habitats in the park.

## **2. Ecological monitoring of large mammals**

Findings from this study present the status of large mammal species as either common or rare in the park. The evidently and comparatively poor representation of species (i.e. abundance and frequency) in the different habitats in the park especially in areas where human activities particularly hunting and logging occurred at high intensities, suggest possible isolation, emigration, and future extirpation of species from the park if care is not taken. Though the extraction and gathering of resources from the park is prohibited, these activities have continued in order to supply basic needs to the communities around the park. Therefore, low abundance or extirpation of species from the park may also have serious consequences on the livelihoods of the hunter-gatherer community in the long run. The following actions could ensure the survival and protection of large mammal species in the park and are therefore proposed.

- Continuous monitoring to further point out the status of large mammal in the park for remedial conservation action is proposed. In this regard, both scientific and integrated (including stakeholders) long-term ecological monitoring programs are suggested. Scientific monitoring of large mammals on the transects that were surveyed during this study, particularly in the four threat hotspots that were identified in this study (Figure 75), and additional monitoring in other areas within the park that were not surveyed during this research is recommended.
- Application of monitoring methods such as camera trapping technique is proposed. This method will also determine the status of species in the park and will further validate this study and previous studies that assumed the presence of species from indirect signs.
- Integrated method using communities to participate in monitoring is recommended. This approach will be more cost effective (because communities are on site), will provide useful and reliable information about species (communities know best about species in their vicinity) and may amend the way communities exploit resources from the park.

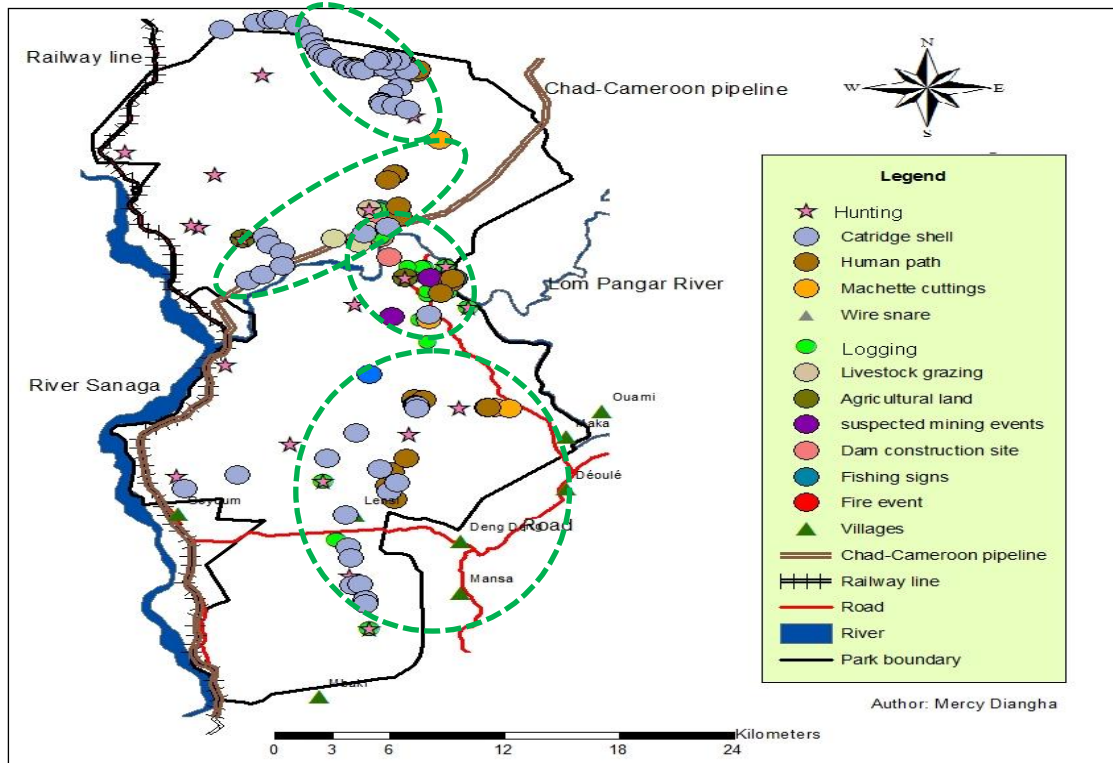


Figure 75: Human landscape showing recommended areas (in green circles) for focused monitoring actions in the Deng Deng National Park

### 3. Establish and protect wildlife corridors for animal movement

Movement of large mammals in the Deng Deng National Park was not tracked in this study but given the threats posed by human activities on large mammal species and their habitats in and around the park, it is likely that some species have migrated to or from the park for refuge. This study marks the first record of elephant in the park assumed to have migrated from areas outside the northern block of the park that are not under any kind of protection but share similar wildlife habitat with the park, or from adjoining protected areas, maybe Mbam et Djerem National Park where they have been recorded (Maisels et al. 2000). In this regard,

- The extension of protection measures to possible wildlife corridors<sup>19</sup> outside the northern block of the park is recommended to allow undisturbed movement of large mammal (particularly the case of elephants recorded in this block) between sites.

<sup>19</sup> Wildlife corridors are narrow strips of land that links two or more larger areas of similar wildlife habitats. Corridors can enhance species survival through increasing food sources, decreasing the chance of predation, providing suitable habitat, and provides opportunity for reconnecting isolated populations (DFW 2004).

- Survey activities to locate possible corridors through tracking of animal movement and actions to ensure that ecological processes and corridor functions are maximised are proposed.
- In the case where corridors may lie in public land, actions to extend the protection to such areas, and activities that may increase vegetation cover and improve habitat quality are recommended to enhance connection between patches of suitable habitats.
- In cases where corridors are located in areas dominated by farmlands owned by communities, human and wildlife conflicts may arise, hence policies to provide alternative farmland or compensation in case of crop damage by wildlife should be considered.

#### **4. Sensitisation and awareness campaigns**

Given the diverse categories of threats posed by the dynamic human society operating and living adjacent the Deng Deng National Park identified in this study, it is clear that sufficient protection and effective conservation of resources in the park can only occur when stakeholders understand the essence of conservation. Though efforts are currently being made by the Wildlife Conservation Society (WCS) and the Ministry of Forests and Wildlife (MINFOF) to sensitize the public, the park is still experiencing pressure from the diverse human society operating and living adjacent it. Therefore, more intense sensitization and awareness campaigns that might improve networking and collaboration between stakeholders and possibly attract their interest in the protection of the wealth of biodiversity in the park are recommended. In this regard, sensitization and awareness campaigns addressing the park's management policies, risks and benefits that may accrue from successful participation and conservation are recommended. Clearly defining and addressing the what, why, who, where, when and how conservation questions during sensitization campaigns to stakeholder is crucial and a core for a successful management of the park. Sensitization aids including poster, leaflet, radio and television announcement conveying important conservation issues about the park's natural resources are recommended. Frequent communication and sensitization meetings with target communities led by the responsible officers from the Ministry of Forests and Wildlife (MINFOF) and Wildlife Conservation Society (WCS) in whose hands the management of the park lies, will promote collaboration, thus recommended.

## **5. Partnership and stakeholder's involvement**

Findings from this study indicate that the activities of the local communities (particularly the traditional hunting community), logging institutions, and developmental (CAMRAIL) and economic groups (COTCO and EDC) are influencing the ecosystem processes, structure and functions within and adjacent the park in a manner contrary to meeting conservation objectives. Conflict between nature conservation on one hand and infrastructural development on the other hand, and conflict between nature conservation on one hand and the use of resources by local community on the other hand are obvious in the park. To prevent obvious and serious conflicts from arising, it is therefore recommended to

- Establish partnership and networking between stakeholders,
- Establish partnership agreement or memorandum of understanding in which win-win situations that may attract the participation and full commitment of all stakeholders in the park's conservation process are specified, and to
- Carry out routine monitoring of the respective stakeholder activities to check if partnership agreements and memorandum of understanding are being respected.

In the specific case of local communities, most protected areas management effort in Cameroon including the management of Deng Deng National Park has shown less recognition of this group. Given that the local communities are the ones (with high interest) living closest to the park and depend on resources from it to satisfy their needs in the absence of alternatives, the cumulative effect of their activities as already indicated from this study may be more detrimental to species and habitat in the park. Therefore, the involvement of local communities in the management of the Deng Deng National Park is imperative. However, successful partnership with local communities requires adequate recognition of their rights and local values, as well as the provision of alternatives to their activities. Recognition of the rights and local values, and the development of resource alternative schemes for the Deng Deng National Park community are therefore recommended. In this regard the following proposals are made;

- Establish a clear buffer zone for farming activities outside the boundary of the park,
- Introduce conservation friendly agricultural practice that will improve household crop yield for both the short and long term,
- Provide subsidy to encourage smallholder and improved subsistence farming practices,
- Carry out needs assessment for any adequate and dependable alternative,

- Provide alternatives that could deliver both household protein and improve the income conditions of locals. Alternatives such as piggery, poultry, fish farming and cattle rearing are recommended as they are already being practiced by individuals in the area.

Through these efforts political support from the local communities may increase and will further ensure an effective management of the park.

## **6. Law enforcement and patrols**

Law enforcement is crucial to curb the threats occurring in the Deng Deng National Park and remains an essential determinant for the conservation of large mammals in the park. The spread of the different category of threats over the entire park's landscape as found in this study is an indication that law enforcement in the past was not adequate enough to prevent these activities from taking place. An anti-poaching monitoring system for the park (set up through joint efforts of stakeholders i.e. MINFOF, WCS, COTCO, CAMRAIL and EDC) has recorded successes in arresting poaching activities. However, it was noticeable from field observations that anti-poaching efforts were mostly concentrated in accessible areas in villages located adjacent the park and south of the Lom River, along road infrastructures (main road and railway), and accessible paths where ecoguards could easily reach with patrol motorcycles. High concentrations of hunting signs in the park, particularly in the enclaved north eastern portion, north of the Lom River as observed in this study, highlights the limited law enforcement activities in this area. More rigorous law enforcement patrols deploy to the entire park area (easily accessible or not) both within and outside the park boundary is recommended. For a more focused policy action, patrols deploy to the strategic hotspots identified in this study (Figure 75, page 156) and in the northern block of the park are therefore recommended. Actions to discourage hunting such as confiscation of bush meat from defaulters and also prosecution and punishment in accordance with the wildlife law (Republic of Cameroon 1994) should be promoted. Routine and spontaneous patrols are proposed.

## **7. Proposals for further research**

This study analysed the characteristic of habitats in the Deng Deng National Park and made projection for possible change scenarios based on images from the contrasting years 1987, 2000, and 2009. Though one year interval does not make any much difference in vegetation change, it would have been perfect if satellite images taken after March 2010 (when the park was

established) were used in this study. Given this limitation, long term monitoring of the park using advance Geographic Information System and remote sensing techniques as well as current satellite images covering the park area are proposed for future research. Considering that change in vegetation need at least five years and longer period to be clearly evident, research to measure the impact of the establishment of the park on landscape composition and structure using images taken five years after the establishment of the park, and using the 2009 classified image in this research as a basis for judgement is recommended.

This study, which selected only eleven large mammal species residing in the park, has highlighted the importance of the park for the conservation of the selected species. However, knowledge on the status and distribution of other fauna community, i.e. both vertebrates and invertebrates present in the park may further boost the park's status. Further ecological studies to identify and assess the abundance and distribution of other fauna, and to determine their association with the land cover types in the park is therefore proposed. Research focused on investigating invertebrate communities is important as most invertebrate (e.g. butterflies or dragonflies) are good ecological indicators that may provide bases for urgent conservation actions.

Human social factors such as demography, socioeconomic and attitude are crucial determinants of the state of many ecosystems. In this study, focus was directed more on the type of pressure that may emerge as a result of the dynamics of these determining factors and the corresponding consequences of their occurrence on large mammals and their habitats. This study did not fully address the demography, socioeconomic and attitude of the human society around the park, which could have been very useful in explaining the observed intensity and extent of human caused threats in the park and also in projecting possible changes in the park's landcover. Previous studies had attempted to define the socioeconomic of the local communities but detail demography of the population, and knowledge on the attitudes and perception of stakeholders on resource and resource conservation in the park are lacking and therefore recommended for future research.

This study did not deal with hunting of bush meat per se but on the factors indicating that hunting has and is taking place in the park. Further research dealing with hunting of bushmeat in the park will additionally direct management intervention. In this regard, research addressing issues such as bush meat offtake and bushmeat marketing in the Deng Deng National Park area are recommended. Also monitoring to keep track of target species, where they are killed, and

hunters or porter itinerary in the park are important for management intervention, thus proposed for further research.

### **General conclusion**

Efforts placed on the establishment of protected areas in Cameroon is a clear indication of the recognized value of the wealth of biodiversity in the country, but the establishment of Deng Deng National Park for example, have not by itself totally ensured the survival of species and ecosystems within the park. Diversity and changes in the spatial and temporal composition of landscape features within the park, and the contrary and continuous use of the park by the diverse human societies living adjacent it as found in this study, are affecting fauna communities especially large mammals, in many ways some of which are detrimental to the species for which the park was established to protect. Specifically, the abundance, frequency, and distribution of mammal species varied with land cover types and land cover characteristics, with the large mammal species demonstrating generalist habit but also preference for the dense and mature forest cover types in the park, where high encounter of large mammal signs were recorded. Eight categories of human threats were recorded from this study and the intensity of each of these categories also varied with the landcover types in the park. The diversity, abundance, and distribution of large mammal species varied between habitats as a result of the presence of human threat indicators as shown in this study. Areas with intensive human caused threats actually held low abundance of large mammal species in the park. For these reasons, focused conservation actions and activities recognising three major components in the park's landscape being habitats, large mammal species, and humans are proposed to advance the park's management objectives and to ensure a more sustainable future for large mammals in the Deng Deng National Park.

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Appendix 1: Provisional list of common plants in the Deng Deng National Park

<i>Alconia</i> sp	<i>Diospyros crassiflora</i>
<i>Anthocleista nobilis</i>	<i>Diospyros</i> sp
<i>Aframomum</i> spp	<i>Discogyprigna</i>
<i>Afzelia africana</i>	<i>Ditarium macrocarpa</i>
<i>Afzelia bipendensis</i>	<i>Donella ubanguiensis</i>
<i>Albizia zygia</i>	<i>Drypetes staudtii</i>
<i>Albizia</i> sp	<i>Enantia chlorantha</i>
<i>Alstonia bonnie</i>	<i>Entandophragma cylindricum</i>
<i>Amphimas pterocarpoides</i>	<i>Entandophragma utile</i>
<i>Anonidium mannia</i>	<i>Erythrophleum suaveolens</i>
<i>Anthocleista vogelii</i>	<i>Erythrophyllum ivoriensis</i>
<i>Antonotha fragrance</i>	<i>Ficus</i> sp
<i>Antrocaryon micaster</i>	<i>Funtumia africana</i>
<i>Aorantho cladantha</i>	<i>Garcinia nobilis</i>
<i>Bafia nitida</i>	<i>Grewyodendron</i> sp
<i>Balanitis wilsonia</i>	<i>Grewia</i> sp
<i>Bateria fistolosa</i>	<i>Guarea cedrata</i>
<i>Bertiera lujae</i>	<i>Harungana</i> sp
<i>Bridelia grandis</i>	<i>Hylo dendron gabonensis</i>
<i>Bridelia</i> sp	<i>Hymenocardia</i> sp
<i>Calamus</i> sp	<i>Hyparrhenia</i> sp
<i>Canarium schweinfurthii</i>	<i>Irvingia gabonensis</i>
<i>Ceiba pentandra</i>	<i>Khaya grandifolia</i>
<i>Celtis conferta</i>	<i>Khaya ivorensis</i>
<i>Cola lateritia</i>	<i>Klanadoxa gabonensis</i>
<i>Cola verticillata</i>	<i>Landolphia</i> spp
<i>Cordia</i> sp	<i>Lannea welwitschii</i>
<i>Corynanthe pachyceras</i>	<i>Lasiodiscus mannii</i>
<i>Costus afer</i>	<i>Lepidobotrys staudtii</i>
<i>Costus englerianus</i>	<i>Leptactina involucrata</i>
<i>Croton oligandrus</i>	<i>Leptactina laurentiana</i>
<i>Cyathea manniana</i>	<i>Leptaulus</i> sp
<i>Dacryodes edulis</i>	<i>Lophira alata</i>
<i>Dacryodes edulis</i>	<i>Macaranga albescens</i>
<i>Desbordesia glaucescens</i>	<i>Macaranga anglensis</i>
<i>Desplatia dewevrei</i>	<i>Maesopsis eminii</i>
<i>Detarium macrocarpum</i>	<i>Magaritaria discoides</i>
<i>Dialium bipindensis</i>	<i>Mallotus</i> sp

<i>Maniophytum fluvum</i>	<i>Sorindeia grandifolia</i>
<i>Maranthes glabra</i>	<i>Sorindeia</i> sp
<i>Markhamia tomentosa</i>	<i>Spatodia campanulata</i>
<i>Meiocarpidium lepidotum</i>	<i>Sterculia oblonga</i>
<i>Melicia excelsa</i>	<i>Sterculia rhinopetala</i> ,
<i>Microdemis puberula</i>	<i>Sterculia tragacantha</i>
<i>Mitragyna stipulosa</i>	<i>Strebulus kamerunensis</i>
<i>Monodora myristica</i>	<i>Strombosiosis</i> sp
<i>Morinda lucida</i>	<i>Swartzia fistuloides</i>
<i>Musanga cecropioides</i>	<i>Synsepalum brevipes</i>
<i>Myrianthus aboreus</i>	<i>Synsepalum longicuneatum</i>
<i>Nauclea diderrichii</i>	<i>Syzygium rowlandii</i>
<i>Nesogordenia papaverifera</i>	<i>Tabernamontana crasa</i>
<i>Ongokea gore</i>	<i>Tapura africana</i>
<i>Oxyanthus speciosus</i>	<i>Terminalia glaucescens</i>
<i>Pachyelasma tessmannii</i>	<i>Terminalia superba</i>
<i>Pachypodianthum staudtia</i>	<i>Tessmannia africana</i>
<i>Pakia bicolor</i>	<i>Tetrapleura tetraptera</i>
<i>Pentaclethra macrophylla</i>	<i>Trechilia rubescens</i>
<i>Pentadesma butyraceae</i>	<i>Treculia africana</i>
<i>Piliostigma thonningii</i>	<i>Trelipisium</i> sp
<i>Piper guniense</i>	<i>Tricalysia pallens</i>
<i>Piper umbellatum.</i>	<i>Trichoscypha acuminate</i>
<i>Piptadenastrum africanum</i>	<i>Tridesmostemon omphalocarpoides</i>
<i>Poga oleosa</i>	<i>Trilepisium madagascarienses</i>
<i>Polyscias fulva</i>	<i>Triplochiton scleroxylon</i>
<i>Poststella johebe</i>	<i>Uapaca guineensis</i>
<i>Pteleopsis hylodendron</i>	<i>Uapaca paludosa</i>
<i>Pterocarpus soyauxii</i>	<i>Uapaca vanhouttei</i>
<i>Pterygota bequaertii</i>	<i>Uretia</i> sp
<i>Pycnanthus angolensis</i>	<i>Vitex</i> spp
<i>Rauvolfia vomitoria</i>	<i>Voacanga</i> sp
<i>Recinodendron heudelotii</i>	<i>Xanthophyllum zanthoxylum</i>
<i>Rinorea abbreviata</i>	<i>Xylopia ethiopica</i>
<i>Rothmannia</i> sp	<i>Xylopia quintasii</i>
<i>Santiria trimera</i>	<i>Xylopia stadtii</i>
<i>Scoteli trichiloides</i>	
<i>Scotelia</i> sp	

Source: Fotso et al., 2002, Author

Appendix 2: Provisional list of mammal species in the Deng Deng National Park

	<b>ScientificName</b>	<b>Common Name</b>
1	<i>Cephalophus callipygus</i>	Peter's duiker
2	<i>Antilax paludinosus</i>	Marsh mongoose
3	<i>Aonyx congica</i>	Swamp otter
4	<i>Babouin doguera</i>	Olive baboon
5	<i>Bdeogale jacksoni</i>	Jackson's mongoose
6	<i>Boocerus euryceros</i>	Bongo
7	<i>Bos indicus</i>	Zebu
8	<i>Cephalophus dorsalis</i>	Bay duiker
9	<i>Cephalophus leucogaster</i>	White-bellied duiker
10	<i>Cephalophus monticola</i>	Blue duiker
11	<i>Cephalophus nigrifrons</i>	black-fronted duiker
12	<i>Cephalophus ogilbyi</i>	Olgybi duiker
13	<i>Cephalophus rufilatus</i>	Red flanked duiker
14	<i>Cephalophus sylvicultor</i>	Yellow-backed duiker
15	<i>Cercocebus albigena</i>	Grey-cheeked mangabey
16	<i>Cercopithecus ascanius</i>	Red-tailed guenon,
17	<i>Cercopithecus cephus</i>	Moustached guenon
18	<i>Cercopithecus mona</i>	Mona monkey
19	<i>Cercopithecus neglectus</i>	De Brazza's monkey
20	<i>Cercopithecus nictitans</i>	Putty-nosed monkey
21	<i>Cercopithecus pogonias</i>	Crowned guenon
22	<i>Cercopithecus preussi</i>	Preuss's guenon
23	<i>Colobus guereza</i>	Black and white colobus
24	<i>Colobus Satanus</i>	Black Colobus
25	<i>Dendrohyrax dorsalis</i>	Western tree hyrax.
26	<i>Erythrocebus patas</i>	Patas monkey
27	<i>Galago cf alleni</i>	Allen's galago
28	<i>Gorilla gorilla gorilla</i>	Western lowland gorilla
29	<i>Hippopotamus amphibius</i>	Hippopotamus
30	<i>Hyemoschus aquaticus</i>	Water chevrotain
31	<i>Hylochoerus meinertzhageni</i>	Giant forest hog
32	<i>Hystrix cristata</i>	Crested porcupine
33	<i>Lophocebus albigena</i>	Grey cheeked mangaby
34	<i>Loxondota africana</i>	Elephant
35	<i>Manis gigantea</i>	Giant pangolin

36	<i>Manis tricuspis</i>	White bellied pangolin
37	<i>Neotragus batesi</i>	Bates's pygmy antelope
38	<i>Neotragus pygmaeus</i>	Royal antelope
39	<i>Orycteropus afer</i>	Aardvark
40	<i>Pan troglodytes ellioti</i>	Chimpanzee
41	<i>Papio anubis</i>	Olive baboon
42	<i>Phacochoerus africanus</i>	Warthog
43	<i>Potamochoerus porcus</i>	Red River Hog (Bush Pig)
44	<i>Procolobus badius</i>	Western red colobus
45	<i>Snustsia gigantea</i>	Giant pangolin
46	<i>Syncerus caffer</i>	Bufallo
47	<i>Thryonomys swinderianus</i>	Cane rat
48	<i>Tragelaphus scriptus</i>	Bush buck
49	<i>Tragelaphus spekei</i>	Sitatunga

Source: WCS 2008, Fotso et al. 2002, Author

#### Appendix 3: Training template 1: Guide notes on species habitat and habitat requirement

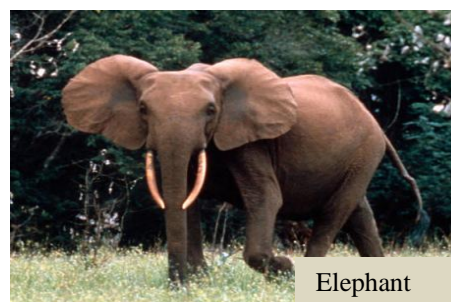
	<b>Species</b>	<b>Habitat and habitat requirement</b>
1	<b>Bay duiker</b> <i>Cephalophus dorsalis</i> (Gray 1846)	Prefer primary forest habitat but also occur in forest edge, relatively unmodified old secondary forest, and savannah mosaic. They also prefer farm bush.  Browser and forage more on ripe fruits.
2	<b>Blue duiker</b> <i>Cephalophus monticola</i> (Thunberg 1789)	Most common duiker. Occur in a wide range of habitats including primary and secondary forests, gallery forests, and savanna mosaic. They also use forest herbaceous regrowth and farmland.  Feed mainly on fallen leaves and seeds and seldom browses.
3	<b>Bongo</b> <i>Tragelaphus euryceros</i> (Ogilby 1837)	Bongos prefer primary forest and open secondary regrowth. They are primarily browser of forest edge and understorey plants.
4	<b>Buffalo</b> <i>Syncerus caffer nanus</i> (Boddaert 1785)	Main habitat is dense forest. Also dependent on clearings and open forest stands and forest edge characterized by large trees and open canopy.

5	<b>Chimpanzee</b> <i>Pan troglodytes troglodytes</i> (Blumenbach 1799)	<p>Prefer forest habitat and can be found in secondary regrowth forests, swamp forests, cleared patches.</p> <p>Also occur in open savanna where there are forested areas but rarely venture far into the savanna except to move from one forest patch to the next.</p> <p>Feed mostly on fruits but also on pith, buds, leaves, seeds (nuts) and insects.</p>
6	<b>Elephant</b> <i>Loxodonta cyclotis</i> (Matschie 1900)	<p>Prefer dense forest but also occur in open and closed savanna, grassland.</p> <p>Found over wide altitudinal range.</p>
7	<b>Gorilla</b> <i>Gorilla gorilla gorilla</i> (Savage 1847)	<p>Prefer lowland tropical forest, particularly niches where there is dense ground-level herbaceous growth and swampy forests.</p> <p>Staple foods are pith, leave and shoot e.g. pith, of plant family Maranthaceae and Zingerbaraceae.</p>
8	<b>Red-flanked duiker</b> <i>Cephalophus refulatus</i> (Gray 1846)	<p>Prefer relatively thick vegetation in rocky areas and near permanent sources of water. Also prefer areas along the forest edge within the savanna.</p> <p>They occur in secondary vegetation and in farm bush with shrubby undergrowth. Mainly browsers.</p>
9	<b>Red river hog (Bush pig)</b> <i>Potamochoerus porcus</i> (Linnaeus 1758)	<p>Prefer swampy forest, particularly with dense vegetation cover. They are associated with water and occur in swampy habitats but browse on available vegetation</p> <p>They also roam to agricultural land.</p>
10	<b>Sitatunga</b> <i>Tragelaphus spekii</i> (Speke 1863)	<p>Forest species and may prefer forest edge and swampy forest</p> <p>Feed mainly on herbs, sedges, grasses and shrubs. Food species include <i>Cyperus papyrus</i>, <i>Malenthera scandens</i> <i>Polygonum senegalense</i> <i>Polygonum pulchrum</i></p>
11	<b>Yellow-backed duiker</b> <i>Cephalophus silvicultor</i> (Afzelius 1815)	<p>Largest of duikers and prefer forested habitats. Occurs in moist lowland and montane forests especially in forest with dense undergrowth.</p> <p>Also prefer secondary forest, plantations and farm bush. They are also occur in forest-savanna mosaics.</p>

Source: Mainly from the IUCN redlist of threatened species (IUCN 2008), but also from numerous books reviews including Kingdon 1997, and internet sources



Appendix 4: Training template 2: Photos of selected mammal species





Bay duiker



Red-flanked duiker



Blue duiker



Olgiby duiker

Source: Obtained from assorted internet links but mainly from Arkive weblink:  
<http://www.arkive.org/>, <http://animaldiversity.org/accounts>

Appendix 5: Detailed encounter rates of dungs and tracks of mammal species per transect

	Blue duiker			Bongo	Buffalo	Red River Hog			Elephant	Large duiker		Medium size duiker		Sitatunga	
Transect length (km)	Transect code	Dung	Track	Dung	Dung	Track	Dung	Track	Track	Dung	Track	Dung	Track	Dung	Track
2	T1	4	4.5				1	3				0.5	0.5		
2	T2	4.5	1	3.5			1.5	3.5				3	2		
2	T3	3.5					0.5	2.5				2.5	0.5		
2	T4	1	1.5					7.5				1	1		
2	T5	4	0.5					1				1	0.5		
2	T6	2.5						1				11	1.5		
2	T7	6.5	0.5					1				3	1.5		
2	T8	7.5	0.5			0.5	1	1.5				15.5	3		
2	T9	1.5						2				4.5	1		
2	T10	3					0.5					1.5			
2	T11	3				2		0.5				2			
2	T12	4			0.5	2	1.5					3.5			
2	T13	0.5					1	0.5				2.5			
2	T14	3.5						0.5				2.5	0.5		
2	T15	5	0.5									3	1	0.5	
2	T16	5.5										1			
2	T17	1.5	1									4.5			
2	T18	4	2.5				0.5	2		0.5	0.5	2.5	6		
2	T19	1										0.5		1	
2	T20	2.5							0.5			2	2		
2	T21	0.5	2							0.5		3	0.5	1	0.5
2	T22	1 0.5	1				1	3				1	5.5	0.5	0.5
2	T23	2										1			
2	T24	2										2			
2	T25	1	0.5					2				4	1		
2	T26	5.5	0.5					1.5				3.5			
2	T27	5	2.5					3				7	1.5		
2	T28	4	0.5					1		0.5	0.5	7.5	3		
2	T29	5						2.5				7	0.5		

Appendix 6: Detailed encounter rates of nest, dungs and tracks of apes species (gorilla and chimpanzee) per transect

Length of transect (km)	Transect code	Gorilla				Chimpanzee		
		Number of nest site	Number of individual nest	Track	Dung	Number of nest site	Number of individual nest	Track
2	T1			3		0.5	1.5	
2	T2			0.5			0	
2	T3	2.5	14.5	2	0.5	2	5.5	
2	T4	1	8.5	3	0.5	0.5	0.5	
2	T5	3.5	22		1	2.5	4.5	
2	T6					2.5	5.5	
2	T7	2	11	1.5	1	2	5.5	1
2	T8	0.5	3	2	1.5		0	
2	T9	1.5	6	1	3	1	1.5	
2	T10	7.5	36	3.5	7			
2	T11	2	12		8			
2	T12	0.5	1	0.5	1			
2	T25	0.5	2	0.5	0.5			
2	T26			0.5				
2	T27	1	5	0.5				
2	T29	1.5	6.5	2.5	1	2	3.5	

Appendix 7: Estimated (extrapolated) population of mammals per habitat type in the Deng Deng National Park

Mammal species	Dense forest	Mature secondary forest	Young secondary forest	Tree savanna	Grassland savanna	Total estimated population
Blue duiker	2272	69.2	3.9	41.8	28.4	2415
Bongo	166	0.0	0.0	0.0	0.0	166
Buffalo	0.0	0.0	0.0	0.0	1.6	1.6
Red river hog	196	5.9	0.3	0.0	4.7	207
Gorilla	109	14.8	3.9	2.6	28.2	158.5
Large duiker	22	1.4	0.0	1.4	0.0	24.8
Medium duiker	1393	157.4	4.2	31.4	20.4	1606
Sitatunga	44	0.0	0.5	2.6	0.0	47

Appendix 8: Estimated (extrapolated) population of apes (gorilla and chimpanzee) in the Deng Deng National Park

Apes species	Habitat type	Estimated population
Gorilla	Dense forest	354.9
	Secondary mature forest	10.4
	Young secondary forest	4.5
	Tree savannah	5.2
	Grassland savannah	7.8
Total		383.8
Chimpanzee	Dense forest	331.3
	Secondary mature forest	13.2
	Young secondary forest	0
	Tree savannah	5.2
	Grassland savannah	0
Total		349.5