CROP RAIDING PATTERN OF THE SAVANNA ELEPHANT
Loxodonta africana
AND ITS ASSOCIATION WITH SOME KEY HABITAT VARIABLES IN THE RED VOLTA VALLEY OF NORTH-EASTERN GHANA

by

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Certification

I hereby declare that the material presented in this thesis is my original work, except where specific acknowledgements are made. All sources of information are acknowledged by reference to authors and year of publication and any quotations are distinguished by quotation marks. This thesis has not been submitted in whole or part for a degree at this or any other university.

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Plate 1: A family of elephants in the Red Volta

Abstract

This study investigated the degree to which crop-raiding by elephants in localities of the Red Volta Valley is a function of the density/diversity of their natural browse, extent of degradation of their habitat, their local abundance, size of crop field, and the proximity of crop enclaves to the forest reserve. Farm enumerators estimated the size of crop fields and the area damaged by elephants, and graded the growth and quality of affected crops. Incidents were plotted along a 12 month time series, and the location of fields was recorded with a GPS. Quadrats (50mx5m) were assessed for the density, diversity, and distribution of elephant browse. Quadrat area clear-felled, damaged by fire, and mined was estimated to measure habitat degradation. Elephant dung-piles within 1,000m x 10m transects were assessed for the abundance of elephants. Interviews and periodic monitoring of transects along the Ghana-Togo and the Ghana-Burkina Faso frontiers were used to determine trans-frontier movement of elephants. The relationship between crop raiding, and the density and diversity of browse, extent of habitat degradation, size of crop fields, local abundance of elephants, and distance of affected crop enclaves from the forest reserve for each locality was determined using correlation and regression analyses. A functional relationship between crop raiding and habitat variables was determined using stepwise regression. Majority (56%) of raided fields suffered damage to < 21% of the field, and 2-3% of farmers were affected each year. There was no marked variation in the rate and extent of crop damage among locales of the Red Volta Valley (Friedman test: d.f=6, P=0.128). Incidents peaked in October, with about 72% occurring in the harvest season. About 16% of woody species in the Red Volta Valley were categorized as potential elephant browse. Second order jackknife and Michaelis-Menten asymptotic estimators showed that the density and diversity of woody stems was near optimum. About 99% of the vegetation area sampled was burned, and 0.35ha

of vegetation was clear-felled. The area holds a small population of elephants that seasonally migrate between Ghana and Burkina Faso. The number of elephants per locale ranged between 0 and 3. A significant inverse association between crop raiding and distance of affected crop enclaves from the forest reserve was observed. But the association between crop raiding and density and diversity of browse, and the extent of degradation was not significant. A Stepwise regression model defined the relationship between rate of incident and proximity of fields to the forest as: $Y = 25.105 + 3.2 - 9.73X$ (Y= rate of incident and X= distance of field to the forest boundary). Contrarily to speculations, crop-raiding in the study area is not influenced by the status of browse, extent of degradation, or by the number of farmers (or size of land area cultivated). Thus mitigation measures should include relocating farms away from the forest reserves, while those aimed at reducing the density of farms, or replanting of degraded patches of the forest should be de-emphasized as they will not necessarily reduce crop raiding.

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List of Acronyms

AfESG	African Elephant Specialist Group
FSD	Forestry Services Division
GPS	Geographical Position System
HEC	Human Elephant Conflict
HETF	Human Elephant Conflict Taskforce
IUCN	World Conservation Union
KNUST	Kwame Nkrumah Univ. of Science and Technology
NCRC	Nature Conservation Research Centre
SSC	Species Survival Commission
PONASI	Po-Nazinga- Sissili

CHAPTER ONE

1.0 Introduction

Elephant crop raiding, and its correlation with some key habitat variables of the Red Volta Valley, was investigated. The study examined how the pattern of crop raiding in a locality of the Red Volta Valley relates to the density and diversity of elephant browse, extent of habitat degradation, and the local abundance of elephants. It further examined how the size of crop field, and the proximity of fields to the forest reserves, relates to crop raiding by elephants. The study provides an estimate of the elephants in the Red Volta Valley, and evaluates their trans-frontier movement across the Ghana -Burkina Faso, and Ghana- Togo frontiers.

Sam (1994) first studied the Red Volta elephants, and estimated between 100 –150 individuals for the area. A follow-up survey a couple of years after provided a reduced estimate of 45 elephants (Blanc *et al.* 2007) and since then policy makers and managers have relied on these population figures for planning and implementation of elephant conservation in the Red Volta Valley.

The Red Volta Valley forms part of a proposed international wildlife corridor (Sebogo and Barnes 2003), and is connected by trans-frontier elephant migratory routes which link it with the Kabore-Tambi National Park, and the Nazinga Game Reserve (both in south central Burkina Faso), and to the Fosse aux Lions National Park (in northern Togo) (Okoumassou *et al.* 1998). The trans-frontier movement of elephants along these routes has severally been reported (Jachmann 1998, Stalmans and Anderson 1992, Sam 1994, Sam *et. al.* 1996; 1997; 1998; 2002, Okoumassou *et al.* 1998, Sebogo and Barnes 2003, Adjewodah *et al.* 2003, Barnes *et al.* 2006a, 2006b). However the current status of the movement of elephants across the two frontiers is unclear (Barnes *et al.* 2006a, 2006b). Except Okoumassou *et al.* 1998 most of the above studies simply call attention to the phenomenon, or highlighted the threats confronting the elephant migratory routes.

Human- elephant conflict is an important conservation issue in the Red Volta Valley (Sam *et al.* 1997, Adjewodah 2004, Barnes *et al.* 2006a). Elephants use the Red Volta forest reserves as a natural refuge and raid crops in fields adjacent to the reserves (Jachmann 1992, Stalmans and Aderson 1992, Sam 1994, Okoumassou *et al.* 1998). Knowledge of habitat variables that significantly influence the rate of incidents, broadly speaking, is scanty and speculative. Some workers have suggested that the rate of incidents could be associated with degradation of the elephant's natural habitat and to dwindling browse resources (Ayigsi 1997, Okoumassou *et al.* 1998, Sam *et al.* 1998, Adjewodah *et al.* 2003, Adjewodah 2004), but fell short of providing empirical data in support of this assertion. It is believed that in localities where the natural vegetation is cleared for crops or burned, fewer browse resources are likely to be available (Sam *et al.* 1998, Okoumassou *et al.* 1998), and this compels elephants to seek for alternative sources of food within crop fields (Sukumar 2003).

With an exponential growth in human population, the need for more farmlands has caused further degradation of the habitats of elephants and the shifting of crop fields further into wild areas previously occupied by elephants (Sam *et al.* 1998, Hoare *et al.* 1999, Sukumar 2003). As a result, crop raiding incidents have intensified where crop fields are widespread, and where enclaves of cultivation have shifted closer into the elephant's range (Oppong *et al.* 2008, Sukumar 1990 and 2003).

Habitat degradation caused by fire, mining, and clear-felling of the vegetation is thought to be important underlying cause of crop raiding in the study area. Wildfire in the Red Volta Valley is not controlled or used as a management tool (as prescribed for wildlife protected areas in the climaxed savannas) (Mcshane 1987, Spinage 1994). Burning of vegetation is common even at the latter part of the dry season (Ayigsi 1997, NCRC 1999, 2000) when fires are most intense, and thus kill rather than support the growth of seedlings in the recruitment class (Oteng-Yeboah and Asase 2001). This is suspected to have an adverse impact on browse and cover for elephants. Artisanal mining is common in the dry season, and during this activity vegetation cover is removed and the several pits filled with water and left behind are a potential barrier to elephants.

The scientific study of crop damage by elephants in the Red Volta Valley has received very little attention. With the exception of a publication by Sam *et al.* (1997) most reports simply call attention to the issue (Ayigsi 1997, NCRC 1999, 2000; Adjewodah *et al.* 2003, Barnes *et al.* 2006a and 2006b), and fall short of a rigorous assessment of its pattern. None of the previous reports provide a statistical model for determining the factors (unique to the Red Volta Valley) that markedly influence elephant crop raiding in the area. The limited available literature on the subject are based on interviews with farmers (Ayigsi 1997, NCRC 1999, 2000), and are thus prone to inaccuracies, as farmers most often exaggerate the severity and rate of incidents anytime interviews form the basis of crop raiding data (Sukumar 2003).

This is the first study to identify from a set of potential cause factors variables that influence elephant crop raiding at the local scale, and the first to develop a cost–effective statistical model relating to crop raiding in the Red Volta Valley. The results will enable resource managers to predict the rate of incident, and allow them to have in place informed mitigation measures against the ragging human-elephant conflict in the Red Volta Valley.

1.1 Background

Elephant crop raiding occurs when they cause damaged to an agricultural field, either through trampling (as they walk through), or by directly foraging on crops (Hoare 1999). This is the most common form of human-elephant conflict in the study area, as the gazetted core habitat for elephants (i.e. the forest reserves), adjoins communal enclaves of crop and fallow fields (Ayigsi 1997, Sam 1994, NCRC 1999, 2000 and Adjewodah *et al.* 2003). Elephants use the forest reserves as a natural refuge and raid crop fields near and away from the forest boundary (Jachmann 1992, Stalmans and Aderson 1992, Sam 1994, Okoumassou *et. al.* 1998).

A large proportion of the elephant's natural diet is from browse. Browse forms more than 50% of their diet (Bell 1985), and elephants need to take in 4-6% of their weight in browse each day (Sukumar 2003). The density and diversity of woody plants browsed by elephants provides a quantitative assessment of the quantity and quality of natural elephant browse in a local area (Sukumar 2003). In localities where the natural vegetation is cleared for crops, or burned, fewer browse resources are likely to be available (Sam *et al.* 1998, Okoumassou *et al.* 1998), and it is assumed that elephants will seek for alternative sources of food within crop fields (Sukumar 2003). In light of the above crop raiding is generally expected to correlate inversely with the density and diversity of natural browse (Sukumar 2003). In contrast, however, the optimum feeding theorem (Sukumar 2003) suggests that palatability of cultivated crops over natural browse (rather than availability of browse), is what drives elephants to crop fields. It suggests the high calories and minerals value of most agricultural crops compared to their wild counterparts (Sukumar 1990) means that elephants will be attracted to cultivation even if natural sources are not lacking.

Also, the rate and severity of crop damage by elephants is said to be influenced by the number of fields (or the population of farms), and sometimes by the size of the cultivated area (Barnes 2002, Barnes *et al.* 1995, Oppong *et al* 2008). Localities where crop fields are widespread are generally expected to experience increased rate of crop-raiding relative to sites with less fields or fewer farmers (Sukumar, 1990 and 2003).

Whilst there are many similarities in crop-raiding patterns among conflict sites in Africa, there are also many differences, particularly at the local scale, and this is attributable to the uniqueness characteristics of each site (Parker and Osborn 2001, Sukumar 2003). The unique setting of the Red Volta Valley thus deserves that the key habitat variables that significantly influence the pattern of elephant crop raiding be independently investigated.

1.2 Justification

Elephant crop raiding remains undoubtedly the most important topic in the Red Volta Valley (Ayigsi 1997, NCRC 1999, 2000, Adjewodah *et al.* 2003, Adjewodah 2004, Barnes *et al.* 2006a and 2006b), yet very limited empirical data specific to the study area and central to the issue is available. With the exception of a paper by Sam *et al.* (1997) that systematically collected and analyzed quantitative data on elephant crop raiding in the Red Volta Valley, other studies only called attention to the problem, or relied on post-mortem interview of affected farmers to pass comments on the issue (Ayigsi 1997, NCRC 1999, 2000; Adjewodah *et al.* 2003, Barnes *et al.* 2006a, 2006b).

Several attempts by wildlife authorities to mitigate the perennial crop raiding problem in the Red Volta Valley have shown only limited success (Ayigsi 1997; NCRC 1999, 2000, Adjewodah *et al.* 2003), a situation which can be blamed on insufficient scientific data specific to the conflict area. Because crop raiding patterns are known to vary at the local scale (Sukumar 2003), site specific data is required by managers for fashioning of effective mitigation measures. Thus the need to deepen scientific knowledge of the Red Volta elephants and to provide recommendations to inform future mitigation efforts cannot be over emphasized.

Trans-frontier migration of elephants in and out of the Red Volta Valley have severally been reported (Sam 1994, Sam *et. al.* 1996; 1997; 1998; 2002, Sebogo and Barnes 2003, Barnes *et al.* 2006a, 2006b) yet most of the studies in literature simply draw attention to the phenomenon, and the current status of the elephant population and their movement across the Ghana-Togo, and the Ghana-Burkina Faso frontiers is not clear. Data relating to the abundance, distribution and movement of elephant is critically necessary for effective planning and management.

Crop raiding by elephants in the Red Volta merits a careful measurement of its variables. Considering the potential cost of management options and the importance of the subject to local communities and for the conservation of elephants, the variables which significantly affect the rate of incident at the local scale should be determined to help the authorities to predict incidents and to fashion appropriate site specific mitigation measures.

1.3` Research Problem

Though elephant crop raiding is the most important concern in the Red Volta Valley, not much scientific data exist in literature about the pattern of damage. Geographical and temporal patterns of elephant crop raiding incidents in the study area are not well understood, and have been a subject of much speculation. It is not clear whether the pattern of elephant crop raiding differ markedly among localities of the Red Volta Valley, and how it is influenced by potential cause factors and habitat variables including local abundance of elephants, the extent of crop field (or enclave), or by the proximity of farmed enclaves to the core elephant area. An authoritative pronouncement on these issues is critical for any successful mitigation/conservation measures for the Red Volta elephants.

The Red Volta Valley is thought to host the third most important savanna elephant population in Ghana (Wildlife Division 2000). However, the current status of the Red Volta elephant population is not known. The area contains international elephant migratory routes, which allows seasonal migration of elephants between the study area and adjoining habitats in Togo and Burkina Faso. The current status of the trans-frontier movement of elephants is not known.

Of the studies on the Red Volta to date (Ayigsi 1997, Sam *et al.* 1998, Okoumassou *et al.* 1998, NCRC 1999, 2000, Adjewodah *et al.* 2003, Adjewodah 2004, Barnes *et al.* 2006a, 2006b), none provides a model for predicting the extent of damage. Knowledge of the key variables underlying elephant crop raiding in the study area is lacking though critical for any successful conservation measures.

1.4 Goal and Objectives

The study aimed to investigate the extent to which elephant damage to crop fields is a function of the density and diversity of natural elephant browse, habitat degradation, abundance of elephants, the size of crop field or enclave, and the location of crop enclaves with respect to the core elephant habitat (protected forest reserves). The specific research objectives were:

Objective 1: Determine the pattern of crop raiding by elephants in the Red Volta Valley

Objective 2: Determine the extent of elephant browse and habitat degradation in the Red Volta Valley;

Objective 3: Estimate the population and distribution of elephants in the Red Volta Valley and evaluate the importance of trans-frontier migration of elephants between the Red Volta Valley and neighbouring south-central Burkina Faso and northern Togo;

Objective 4: Determine the association between crop raiding and extent of natural browse, habitat degradation, local elephant population, size of crop enclave, and location of crop field.

Objective 5: Determine the functional relationship between crop raiding and all the key variables of the Red Volta elephant habitat

Six localities of the Red Volta Valley were selected as the focal area of the study.

1.5 Hypotheses

1. The pattern of elephant crop raiding incident differ markedly among localities of the Red Volta Valley
2. The rate and extent of elephant crop raiding in a locality of the Red Volta Valley is markedly influenced by the density and diversity of natural elephant browse
3. The rate and extent of elephant crop raiding in a locality of the Red Volta Valley is markedly influenced by the extent of degradation of the elephant's habitat
4. The rate and extent of elephant crop raiding in a locality of the Red Volta Valley is markedly influenced by the local abundance of elephants
5. Elephants in the Red Volta Valley seasonally migrate across the Ghana-Burkina, and Ghana-Togo frontiers
6. Elephants in the Red Volta Valley seasonally migrate across the Ghana-Togo frontier
7. The severity of elephant crop damage in the Red Volta Valley is markedly determined by the size of crop enclave
8. The rate and extent of elephant crop raiding are markedly influenced by the distance of crop enclave from the core elephant habitat

CHAPTER TWO

2.0 Literature Review

2.1 The African Elephant

There are currently two subspecies of African elephants, the savanna elephant *Loxodonta africana africana* and the forest elephant *Loxodonta africana cyclotis* (Ansell 1971). They differ substantially in morphology and ecology. Forest elephants are smaller than bush elephants, with long, thin, straight tusks. They live in smaller groups, and their diet includes a higher proportion of fruit and a lower proportion of grass. There appear to be intermediate forms, with some individuals having physical characteristics of bush elephants, but living in forest areas. The genetic relationship between the two forms, and the extent of interbreeding is still not well understood (Roth & Douglas-Hamilton 1991). There are recent suggestions that the West African elephant may be an entirely different species (Eggert *et al.* 2000). However there is not yet enough data to substantiate this suggestion.

2.1.1 Ecological significance of the African elephant

The elephant is believed to be a crucial 'keystone' species for African savanna and forest ecosystems (Western, 1989). 'Keystone' species play a major role in maintaining the linkages in a food web, and the extermination of these species is expected to cause dramatic changes or extinctions in ecosystems (Blanc *et al.* 2003). Elephants do have a dominant role within ecosystems due to their huge size, large food requirements, their effect on plant species composition, and their importance for dispersing seeds and fruits. However, because of the lack of historical evidence on changes in African vegetation and wildlife, there is little direct evidence to show whether the loss of elephants from particular areas has actually led to the loss of other species.

Regardless of whether elephants actually are a keystone species, they do have an important impact on vegetation structure through their feeding behaviour (Tchamber and Mahamat . 1993, Jachmann and Croest 1991). It has been suggested that they play an important ecological role in tropical forests through the creation of clearings, creating niches for specialized disturbance-adapted species, and allowing tree regeneration (Sukumar 2003).

When they occur at high densities in savanna areas, elephants create open habitats by eating from, and killing, large numbers of trees and bushes (Barnes, 1996). Elephants affect the structure of vegetation through physical damage to trees and plants, including bark -stripping, pulling off branches and vines, and trampling. Conversely, the loss or reduction in numbers of elephants can lead to an increase in bush cover in forest areas (Spinage 1994, Sukumar 2003).

When elephants in savannas occur at high densities relative to the regenerative capacity of woodlands, they reduce canopy cover. This occurs through browsing and bark-stripping, and by bull elephants pushing down mature trees (Cumming 1982). The effects may be enhanced by an increased frequency of tree-damaging fires as the amount of grass fuel increases in more open woodland (Sukumar 2003). Loss of woodland may be fastest around permanent water-sources, as elephants concentrate there in the dry season (Sukumar 2003). High elephant densities are also likely to have a negative effect on species and structural diversity (Western 1989).

Elephants' long gut retention time, combined with their daily movement across long distances promotes wide seed dispersal. Their low digestive efficiency means that elephant dung contains a good supply of nutrients for early growth. There is some evidence that germination of certain East African savanna tree species is enhanced by passage through elephant guts (Spinage 1994).

Three studies have provided support for the idea that rain forest trees may also be adapted to dispersal by elephants. Seeds of *Balanites wilsoniana* dispersed by elephants showed improved germination as a result of having passed through the guts of elephants (Spinage 1994). Because of the dominant role of elephants in some ecosystems, they have an important effect on nutrient cycling, making nutrients found in woody material available to other species (Spinage 1994, Sukumar 2003). They may also make additional food available to smaller browsers by breaking down branches and trees (Viljoen 1988). Through defecation they may redistribute nutrients into bare areas around waterholes (Sukumar *et al.* 1987). Elephants also dig to get underground water in river beds, and this may make water available to species which would not otherwise have access to it (Viljoen 1988). They are also believed to play an important role in the formation of waterholes (Cumming 1982).

2.1.2 Status and distribution of the African elephant

The African elephant may have once inhabited most of the continent (Cumming *et al.* 1990). They were exterminated from North Africa in the Roman era, probably as a result of capturing large numbers for domestication and the circus, although climate change may also have played a role (Scullard 1974). Elephants were also hunted to extinction in much of Southern Africa in the 18th and 19th century (Campbell 1991; Hall-Martin 1992). During the latter part of the 20^{th} century their range has been fragmented as a result of increasing agricultural development, but they are still widespread in sub-Saharan Africa, occurring in 37 countries (Said *et al.* 1995).

Sub-Saharan Africa can be divided into four regions - Central, Eastern, Southern and Western Africa - that differ considerably in vegetation and human density. Within each region, countries share important characteristics that affect elephant conservation efforts. Central Africa has relatively sparse human populations, and includes the largest remaining forest areas on the continent. About 45% of remaining African elephants are believed to occur in Central Africa (Said *et al.* 1995), and the majority of these are the forest subspecies.

However, the status of elephants in the rain forest is not well known, since few surveys have been done. The largest populations of forest elephants are believed to exist in the Democratic Republic of Congo, Gabon, and Cameroon (Alers *et al.* 1992). Human population densities and croplands are higher in West Africa, and there is correspondingly little remaining natural habitat. Elephant populations in West Africa are confined to fragmented pockets, both in forest and savanna, and amount to only about 2% of the continental total. The largest numbers are in Burkina Faso and the Ivory Coast (Roth & Douglas-Hamilton 1991; Said *et al.* 1995). In West Africa, where the elephant habitat is much encroached upon and fragmented by agricultural fields, availability of natural habitat and forage for elephants has been much concern and has been linked to elephant depredation of farms abutting the elephant core habitat (Sukumar 2003).

In Southern Africa there are still large areas of low human density, where wide-ranging elephant populations occur. Approximately 33% of the continental population is believed to live in this region (Said *et al.* 1995). Numbers have been stable or increasing in South Africa, Botswana, Namibia, and Zimbabwe. However, civil wars in Angola and Mozambique have probably resulted in the decline of previously substantial populations in those countries (Chambal 1993).

The Eastern African highlands have very high human densities, and few elephants remain in these areas. There are still elephants in the lowland areas, but the region was heavily affected by waves of poaching in the 1970s and 1980s (Blanc *et al.* 2003). The only country with a substantial population currently is Tanzania, with over 90,000 elephants. Overall the region accounts for about 20% of the continental total (Said *et al.* 1995). Very little is known about the status of elephants in Somalia, or in Sudan, which still has a large area of potential elephant habitat with low human densities.

2.1.3 Status of elephants in West Africa

The twentieth century witnessed a decline of 90% of elephant range in West Africa primarily because of ivory hunting and the rapid expansion of human activities (Roth & Douglas-Hamilton 1991). Roads, railways, and settlement split the remaining range into isolated fragments, so that today West African elephants are found for the most part in small isolated populations. Because the remaining elephant refuges are surrounded by dense human populations, crop-raiding and other forms of human elephant conflict are frequent. The remaining habitats are often degraded and encroachment by farmers and grazers is common (IUCN/AfESG 1999). Poaching for both ivory and meat is a constant risk.

Elephants were found over much of Ghana up to the early part of the twentieth century, when their range began to contract in response to human expansion and agriculture (Roth & Douglas-Hamilton 1991). Elephant population estimates for most ranges in Ghana are largely based on guess work, with the total population placed between 1,000 and 2,000 (Blank *et al.* 2002). There are limited or no data on population trends and no estimates have ever been made of age structure, sex ratio, natality, or mortality. The first attempt to study the elephants of north-eastern Ghana was made by Sam (1994). He estimated between 100 and 150 elephants for the Red Volta valley. A longer survey, which included northern Togo, was carried out by Sam *et al.* (1996) and Okoumassou *et al.* (1998). These were the first studies to describe the contraction of elephant range in the northern savannas, including the Red Volta Valley.

2.1.4 Factors influencing the distribution of elephants

Douglas-Hamilton *et al.* (1992) analyzed the range of African elephants by habitat types and the extent to which they occur within different vegetation types and found that the most significant factors influencing distribution include habitat availability (i.e. browse density and structure), and human induced disturbance (wildfire and human presence in particular). Even in the remotest and least disturbed habitat, Barnes *et al.,* (1991), found that the distribution of the forest elephant is governed by the distribution of both past and present human settlements. Though the biology of the Red Volta elephants is not fully understood, it is preliminarily assumed that their distribution and habitat selection are driven by the availability of browse and the need to avoid human disturbance (Sam *et al.* 1997, and Okoumassou *et. al.* 1998). Sam *et al.* (1998) associated crop raiding incidents in this area with the lack of natural habitat for elephants.

Mcshane (1987) found that elephant prevalence in the Niger was markedly affected by burning and was higher at areas of unburned vegetation where floral density and structural diversity is superior to burned localities. In particular, browse availability was thought to have a direct influence on the distribution of elephants at the local scale. In an area where fire was used as a management tool, it was found that foraging elephants selected burned areas with re-sprout induced by early dry season fire, which provided a fresh source of food (McShane 1987). Beside fire, the elephant habitat in the Red Volta Valley is threatened by illegal mining, and clear-felling of trees for firewood (Adjewodah 2004). An added factor of disturbance to elephants comes from the presence of humans in the forest reserves as this could influence the distribution and prevalence of elephants. The relationship between the distribution of elephants and human presence is vividly captured by an aerial survey of elephants in south central Burkina Faso (Bouché *et al.* 2004). The survey found that elephant numbers increased as one flew further from fields and from villages. Eighty-five per cent of the elephants were seen at a distance greater than 6 km from villages. This form of association between elephant distribution and human presences was also articulated by Sam *et al.* (1997, 2002) and Barnes et al.(1991).

Seasonal dispersal is a strategy for coping with variations in the abundance and quality of food (Sukumar 2003). Most herbivores disperse to areas where the quality of food (e.g. protein content) is higher. But elephants are large bodied animals and, in contrast to most herbivores, they have evolved a non-ruminant digestive system (Barnes *et al.* 2006b, Sukumar 2003). The combination of large body size and the lack of a rumen mean that they may seek food that is more abundant rather than higher in quality. In light of the above, one would expect a greater abundance of elephants in localities of high browse density where the vegetation is preferable.

Seasonal fruits sought after by elephant do influence their distribution, and they migrate to distant ranges to take advantage of seasonal resources (Sukumar 2003). The elephants in the Red Volta were attracted by a stand of *Lannea sp.* in fruiting (Adjewodah 2004). Fruits of *Lannea sp.* are a delicacy for elephants. At Nangodi, Sakote, and Kusanaba villagers reported that elephants were attracted to localities with stands of Borassus palm *Borassus aethiopium*, *Detarium sp*., and *Vitellaria paradoxa* bearing ripe fruits.

2.2 Crop Raiding by Elephants

Crop raiding occurs throughout the range of elephants, and probably began with the advent of agriculture 10,000 years ago. It has intensified as agriculture continue to spread throughout the elephant's range. However, scientific study of crop damage by elephants began only in the 1970's in Asia and in the 1980's in Africa (Sukumar 2003). Since then, a number of deterrent methods have been developed, including disturbance shooting and electric fencing (Thouless and Sakwa. 1995; Kangwana 1995). Electric fencing was considered to be the best solution to crop-raiding elephants in the 1970s, but not all fences have worked (Thouless and Sakwa 1995). The high cost of construction and maintenance of electric fences is unrealistic for many elephant conflict sites in West Africa. Disturbance shooting has been widely applied since the colonial era, despite suggestions that it also has only minimal success in mitigating crop raiding (Osborn and Parker, 2002; Ayigsi, 1997).

In 1970, the Ghana Wildlife Division under pressure about crop-raiding complaints from the Red Volta Valley undertook a severe cull operation with the aim of eliminating the elephant problem from the area. Reportedly the cull continued until no further evidence of elephants remained. By the mid 1990s the elephant population bounced back and the Wildlife Division used disturbance shooting to attempt scaring elephants away from farms.

Because the Wildlife Division has no permanent presence in the Red Volta elephant range, the authorities dispatched deterrent teams from the Mole National Parks and Gbele Resource Reserve in response to complaints from farmers and local politicians. These ad hoc interventions were limited by budgetary constraints and had little impact on the conflict (NCRC 1999, Ayigsi 1997). In 1999, a community-based approach, which collaborated with local people to implement low cost deterrent measures was initiated and has since been more effective in mitigating the problem (Adjewodah *et al.*2003).

The rate of crop-raiding is believed to be a function of the abundance of elephants (Okoumassou *et al.* 1998, Sam *et al.* 1998, 2002). But it is also thought to be a function of the number of farms in a given area (Barnes 2002, Oppong *et al.* 2008). Thus growth of the rural population and the increasing proportion of the landscape that is cultivated will lead inevitably towards intensified conflict. It is necessary to examine the factors that increase the risk of crop damage by elephants, so that farmers and conservationists can take the necessary measures to reduce risk.

2.2.1 Association between crop raiding by the elephant and variables of its habitat

Observations at some human-elephant conflict sites have shown that several environmental variables can potentially affect elephant crop raiding at the local scale. Sukumar (1990, 2003) found seasonal elephant movement, and degradation of natural habitat to be associated with increased crop-raiding in India. In Africa, seasonal movements of elephants bring them into contact with crop fields, which have encroached and fragmented their traditional range (Hoare 1999, Sam *et al.* 2003). Okoumassou *et al.* (1998) attributed a surge in the incidence of elephant crop-raiding in the Red Volta Valley, during the mid 1990s, to encroachment and degradation of protected areas in northern Togo (Lowry and Donahue 1994). Parker and Osborn (2001) found a negative non-linear relationship between the rate of crop-raiding by elephants and distance from major perennial rivers.

Degradation and fragmentation of elephant used areas by humans contribute to elephant crop-raiding in the Upper Guinean forest zone of West Africa (Barnes 2002). Barnes *et al.* (1995) found a correlation between crop raiding and habitat status, and reported that increased crop raiding levels in Ghana are a direct result of felling of trees. Within forested habitats, logging causes an increase in secondary growth which is a preferred habitat of elephants. Furthermore, logging on the periphery causes a decrease in the forest radius which consequently causes an increase in elephant density, resulting in more elephants occurring on the forest boundary and near fields. Barnes *et al.* (1995) found a significant association between crop raiding and field size. However, Hoare *et al.* (1999) found no association between crop raiding and the total area transformed by human settlement, including fields and villages. Oppong *et al.* (2008) found that the risk of crop-raiding positively correlated with the number of crops grown.

Barnes *et al.* (2006a) stated that the intensity of crop-raiding is a function of the abundance of elephants and the number of farms. They argued that as the human population grows and the number of elephants and farms increase over time the incident of crop damage would naturally increase. It is anticipated that the growing human population and the need for new farmland will cause an increase in human-elephant conflict in the Red Volta Valley (Sam *et al.* 1998).

Sukumar (1990, 2003) found that the higher nutritive value of cultivated crops (compared to natural food) is associated with increased crop-raiding. The traditional land use system of shifting cultivation practiced in the adjoining communities to elephant ranges creates a mosaic of vegetation patches in different stages of re-growth, mixed with the original vegetation and productive fields. Elephants are extremely attracted to this kind of habitat (Sukumar 2003).

Elephants have a non-ruminant digestive system, which means that they are not able to detoxify the secondary toxins that many plants produce to deter browsers (Sukumar 2003). Domestic crops however lack this natural adaptation to browsers and are thus more palatable. Therefore it is expected that elephants will be attracted to the mosaics of -farm-fallow-natural vegetation usually found in farm enclaves.

2.2.2 Mitigation of crop-raiding by elephants

Elephant crop raiding in the Red Volta Valley dates back at least to the 1940s (Wheelan 1950). The problem has been cyclical but has most probably worsened overtime in response to habitat loss and expanding agriculture. In the mid-1990's, crop raiding by elephants was perceived as an important problem by farmers in the Red Volta range (NCRC 1999). Okoumassou, *et al.* (1998) reported the risk of crop losses caused by elephants as intolerable by farmers, and suggested that the hostility of local people was the most important short-term threat facing elephants there. Indeed, farmers' intolerance for crop damage encouraged poaching of elephants by hunters employed to protect communal farms enclaves (Adjewodah *et al.* 2003; NCRC 1999, 2000).

In response, a Red Volta Valley Conservation Project was initiated in 1998 to mitigate crop raiding by elephants. The project involved the collaboration of the Nature Conservation Research Centre (NCRC – a Ghanaian conservation NGO), the project communities and Traditional Authorities, the Wildlife Division, the Bolgatanga and Bawku West District Assemblies among others. The project provided training to farmers on quick response to information on elephant movement towards their area and the uses of a locally made blaster to deter invading elephants. The blaster carries no missile, and is not harmful to elephants. It is packed with sand and gunpowder which is ignited at funeral grounds to create a loud booming sound in honour of the deceased.

Farmers were taught how to respond to elephant raids using the blasters and to coordinate pre-emptive blasts in the early mornings and evening when elephants were believed to be in the vicinity. Making use of information coming through the early warning system, farmers who had cultivated bush farms in the crop-raiding zone took greater protection of their farms than previously. The farmers stayed overnight in farming zones, often accompanied by Wildlife Division staff stationed in the area for the crop-raiding season, and applied the blasters when elephants were approaching their area. The sound effect from the blast (which could be heard 4-km away) provided an interim measure effective at scaring elephants from farms (NCRC 1999, 2000).

Some traditional agricultural practices, may have contributed to an increased risk of crop damage in the Red Volta Valley. Prior to the project interventions, many farmers lost their harvests to elephants as a result of prolonged stockpiling of harvest on their farms. The project encouraged the farm monitoring groups to provide labour for communal harvest of peer farms. This enabled farmers who were hitherto not able to harvest and cart produce the same day to avoid stockpiling and reduce the risk of elephant crop raiding.

2.3 Elephant natural browse

2.3.1 The elephant's diet

The elephant's diet includes grass, forbs, fruits, roots, leaves, bark, and twigs of several shrubs, trees and lianas (Sukumar 2003). But it consists of at least 50% browse on year round basis (Bell 1998). Adult elephants spend about 75% of their time browsing. Browse constitutes about 59% of the elephant's diet during the dry season. In Tanzania, it was found that leaves, woody material, and bark constituted 77%-91% of the diet of bulls (Sukumar 2003). Some 80% of woody stems in the diet were from slender species of tree which rarely attain a diameter of more than ½m at maturity.

Certain plant families consistently provide much of the elephant's diet and they include *Fabaceae* (*leguminosae*- legume family), *Palmae* (the palm family), *Combretaceae* (combretum family), the *Anacardiaceae* (the cashew family), and the *Sterculiaceae* (Sukumar 2003). In Uganda, an examination of 71 elephant stomach revealed that 35% of the content was woody vegetation particularly *Combretum* spp, a favoured species for elephants in central and southern Africa. Because a particular plant item is consumed frequently does not necessarily mean it is a preferred food plant (Sukumar 2003). A positive or negative preference for a particular food item has to be scored in relation to its availability in relation to other plant species. In one of the early studies of elephant browsing in Zimbabwe, tree density and or canopy volumes were estimated to measure availability of potential food plants (Sukumar 2003).

The number of plant species browsed by elephants in their savanna habitat has been severally placed in literature. In one of the earliest scientific studies of feeding in elephants the examination of stomach contents revealed 25 plant species in diet (Sukumar 2003). Similarly, examination of culled elephants in Zimbabwe identified 61 browse species (Sukumar 2003). Fruits are an important component of the elephant's diet. It is known that fruits constitute up to 35% of the dry weight of elephant droppings during the fruiting season (Sukumar 2003). Most fruit species, however, were recorded only over a month, indicating that elephants were consuming whatever was available seasonally (Sukumar 2003).

According to Spinage (1994), elephants prefer to feed from 1 to 2 m above ground level. Taking foliage from shrubs and trees is the most common way of browsing. Preferred trees whose foliage is high may be pushed over. Different plant parts are taken in. From Acacia, the leaves, bark, and fruits are often consumed (Sukumar 2003). Elephants strip off leaves and break off branchlets to consume the soft growing terminal twigs of trees. In the dry season more bark, woody stems, and roots are taken in (Sukumar 2003). Bark stripping is most noticeable at the onset of the rains, when the bark is rich in sap (Spinage 1994). Unpalatable species are pushed over according to their relative occurrence in an area.

2.3.2 The impact of elephant browsing on the vegetation

Elephants can adversely affect their own habitat (Tchamba and Mahamat 1993, Jachmann and Croest 1991). To fill their stomach, elephants need to take in 5-6% wet weight of their total body weight. This amounts to about 162-240 kg of fresh plant material each day, of which a majority comes from woody vegetation. Elephants cause havoc to their habitat when feeding, as they up-root and break branches of trees. To reach to roots and crown, elephants break or bend trees by butting with their forehead (Sukumar, 2003). They first shook and tested a tree to see whether it was possible to overturn (Spinage, 1994).

Elephant habitat contraction or expansion is critical to their population trend. The general rule however is that elephant damage to vegetation is proportional to their density in a given area. High elephant densities affect vegetation considerably, transforming it from woodland savanna to open grassland. Elephant use of an area is related to the status of the vegetation. Spinage (1994) found that elephant densities are low in mature miombo woodland (found in East African) because food availability is low, concentrated at the top of the trees. The association between elephant density and their impact on vegetation in the Red Volta valley is however yet to be fully understood.

2.4 Elephant Habitat Degradation

Human expansion has largely been blamed for the shrinking of the elephants' range (Ford, 1971). As human populations rose throughout Africa and land-use patterns changed, there was a general contraction of elephant range. The negative relationship between human population density and elephant numbers was demonstrated by Parker and Graham (1989b), and similarly in a study by Hoare and Du Toit (1999). Other factors may have also caused the loss of elephant range, including climate change, particularly in North Africa (Roth & Douglas-Hamilton 1991). Elephants can also adversely affect their own habitat (Tchamber *et al.* 1993, Jachmann *et al.* 1991).

The extent of habitat degradation has differed throughout Africa. West African rain forests have been greatly reduced in area, and forest elephants are now confined to a few isolated patches. There is still much elephant habitat in Central African rain forests, although this is being rapidly lost as forestry operations open up previously inaccessible areas, allowing human settlement and growth (Said *et al.* 1995). West and Central African savannah populations have probably been more influenced by hunting than by habitat loss (Roth & Douglas-Hamilton 1991).

Habitat loss in the fertile highland areas of East Africa has been extensive with the expanding human population, and this process is spreading to the less productive lowland areas (Said *et al.* 1995). It has been less severe in Southern Africa, and in some parts of that region elephant range has expanded in recent years (Anderson 1993, Campbell 1991). The major types of habitat loss that can occur are conversion of natural vegetation to farmland, exclusion of elephants from pastoralist areas, and logging (Sukumar 2003).

2.4.1 Cultivation as an agent of degradation of elephant habitat

Conversion of natural vegetation to crop field has been the most significant form of degradation to elephant habitat (Sukumar 1990). Cultivation around sources of permanent water may prevent the use of larger areas by elephants (Pringle & Diakite 1992). The impact of agriculture comes not just from reduced availability of natural food, but also increased conflict with humans, leading to increased mortality of both species (Hoare and Du Toit 1999)

The implications of habitat degradation through shifting agriculture in tropical forests are more complex. The secondary vegetation created by slash-and-burn cultivation may increase food availability for elephants in forested habitats (Barnes, *et al.* 2003). However, the effect of disturbance seems to over-ride this benefit, and thus elephant densities are low in the vicinity of humans including crop fields and settlements (Barnes *et al.* 1991). For instance, the rise in the cultivation of the cocoa crop in the forest regions of Ghana has led to a sharp decline in elephants in those areas. Wildlife officials were pressured to shoot elephants to mitigate damage to the crop, and local hunters collaborated with wildlife and forest guards to poach elephants for their ivory under the pretext of protecting cocoa farms (Barnes *et al.*, 1995).

2.4.2 Clear felling as an agent of degradation of the elephant habitat

The impact of logging on elephants is both direct, through loss of habitat, and indirect through the effects of disturbance. Clear-felling may result in a habitat that is unacceptable to elephants for a number of years. However, some forms of logging can create patches of secondary vegetation favoured by elephants (Dudley *et al.* 1992). In general, elephants are likely to move away from forestry operations while there is disturbance.

Logging roads provide access routes into previously inaccessible forest for farmers, hunters, and prospectors (all of whom cause disturbance) in addition to commercial poachers (Fay & Agnagna 1991). Furthermore, logging company employees may engage in poaching (Wilkie *et al.* 1992). Subsistence hunters or immigrant workers may have damaging effects on elephant populations by setting traps and snares set for other large animals that can cause fatal injuries to elephants. It is important to determine which form of logging is least damaging in tropical forests.

2.4.3 Wildfire and mining as agents of degradation

Uncontrolled fires are common in the study area and occur annually in the dry season (NCRC 2000), and are said to pose the greatest constraint on habitat and resource availability for elephants. In the Red Volta Valley, bushfires are not managed or used as a management tool (as prescribed for wildlife protected areas in the fire climaxed savannas). Rather, bush burning is uncontrolled and extensive, and occurs even at the latter part of the dry season when it is known to have a negative impact on vegetation (NCRC 2000).

Because bush fires at the peak of the dry season are intense, they kill rather than support the growth of seedlings in the recruitment class (Oteng-Yeboah and Asase 2001). They eliminate species in gallery forest which have no or little adaptation to fire (Mcshane 1987). The long term implication for elephants is loss of natural browse and cover. Adjewodah (2004), found that a high percentage of plants in the Red Volta are within the recruitment size of less than 5cm, and attributed it to the effect of uncontrolled bushfires on the vegetation structure.

Two methods of mining are used in the area. In the first, local artisans with handheld implements create pits in the vegetation for gold ore. The vegetation cover is removed in the process, and several pits filled with water are left behind (Plate 2). The pits crated could be as deep as 10m (personal observation) and could trap a calf of an elephant. Pit mining is common to a locality around Tilli at small scale mining camp called Zomella within the Red Volta West Reserve. A second method of mining involved collecting alluvial silt from the Red Volta River. The practice is sporadic along sections of the river during the dry season. In both methods, the presence of workers will repel elephants as the animals are known to avoid human presence (Bouche 2003). Because elephants avoid humans, the presence of miners in the river basin means that elephants will stay away.

Plate 2: Degradation of the habitat from mining

2.5 Elephant Seasonal Migration and Corridors

2.5.1 Elephant migration in the Red Volta valley

Elephants are long ranging animals, and may travel hundreds of miles from their regular range to areas why they are less regular (Barnes *et al.* 2006a, Poche 1974). This type of movement is well documented for some elephant sites. In Burkina Faso, elephants in the Nazinga Game Ranch were reported leaving their usual dry-season range entirely and not returning for several months (Jachmann 1988). Similarly in the Niger, elephants exhibit yearly seasonal migration in the latter part of the dry season (Poche 1974). Prior to their migration, elephant clans gather in a large group led by a senior bull or a matriarch (Moss, 2000) and some groups are known to travel over 150 km away from the regular home.

The seasonal and migratory movements of elephants in and out of the Red Volta Valley have severally been reported (Sam 1994, Sam *et. al.* 1996; 1997; 1998; 2002, Sebogo and Barnes 2003, Barnes *et al.* 2006a, 2006b) but most studies simply draw attention to the phenomenon, and the current status of migration across the Ghana-Togo, and the Ghana-Burkina Faso frontiers is not clear. The current status of the Red Volta elephant range as a year round elephant habitat is also not clear. In the past elephants were permanent residents of the Red Volta Valley (Sam 1994, Sam *et al.* 1996). However, a drastic shift in presence of elephants in the Red Volta may have recently occurred, and attention was drawn to these changes by Adjewodah (2004). He attributed the change in elephant occupancy in the Red Volta to migration of the population.

The shift in occupancy by elephants of the Red Volta has been noted by other authors too, and the causes have severally been ascribed. For instance, Barnes *et al.* (2006a) provided two possible explanations for the recent absence of elephants from the Red Volta, and said conservation work in the adjoining Kabore Tambi National Park (in Burkina Faso) may have made the park more attractive for elephants and they do not feel the need to move southwards into the Red Volta Valley. It was also speculated their migration route might be blocked by Fulani settlements within the corridor (Barnes *et al.* 2006a).

Accounts of regular movement of elephants across the Ghana-Togo can be found in literature (Stalmans and Aderson 1992, and Okoumassou *et al.* 1998). Okoumassou *et al.* (1998) noted that elephants seem to move northwards from the Red Volta into Burkina Faso for the dry season and southwards again in the early wet season. At one time there was an influx of elephants in the Fosse aux Lions National Park due to disturbance of elephants by hunters on the Ghana side of the border (Stalmans and Aderson 1992).

In the early 1990s, elephants were common and resident in northern Togo, but political unrest during 1990-1992 in that country encouraged encroachment of protected areas and the displaced elephants into neighbouring Benin, Ghana, and Burkina Faso (Lowry and Donahue 1994, Okoumassou *et al.* 1998). Since then the over 130 elephants inhabiting the Togo end of the corridor are believed to have disappeared (Okoumassou *et al.* 1998), and the seasonal migration of elephants across the border between Red Volta Valley and northern Togo is now in doubt (Adjewodah 2004). Okoumassou *et al.* (1998), observed natural bottlenecks at some portions of the corridor within Togo and predicted that expansion of farms in those areas of the corridor could partially block it.

2.5.2 Why elephants migrate

Elephants have considerable variation in habitat use (Jachmann 1992), and migration may be necessitated by one or a multiple of human induced or natural factors that impact on elephants directly or on their habitat (Sukumar 2003). For instance, climatic conditions affect the resources that elephants need and may cause a whole population or clans to migrate to elsewhere to assess seasonal resources. Seasonal changes in the availability of resources, particularly water and food, are long known to necessitate migration (Jachmann, 1992).

Elephants also move out of their regular range in response to security and safety, and poaching can cause or halt seasonal migration in elephants (Jachmann 1988). In the DR Congo, elephant movement and distribution was strongly influenced by poaching. Similarly in northern Togo, elephants migrated across the frontier into the Red Volta in response to hunting and encroachment of their range (Stalmans and Anderson 1992, Lowry and Donahue 1994). Jachmann (1992) noted that elephant numbers in Nazinga Game Ranch had drastically increased and speculated that it was due to immigration from the Red Volta Valley in Ghana.

Improved conservation measures (provision of water holes, anti-poaching patrols) might have made the ranch conducive to the migrant elephants and they did not find the need to migrate back into the Red Volta (Barnes *et al.* 2006a, Poche 1974). Elephant migration elsewhere in West Africa is influenced by rain, the fruiting circle of seasonal fruit trees, human disturbance, and the availability of cultivated crops (Sukumar 2003, Spinage 1994). The prevalence of elephants in the Red Volta has been linked with crop maturation (Sam *et al*, 2002, and Adjewodah 2004).

2.5.3 West African elephant corridors

The IUCN/SSC African Elephant Specialist Group (AfESG) recognizes the urgent need for trans-frontier corridors in the conservation of the remaining elephant populations of the sub-region (Barnes *et al.*, 2006a and 2006b).

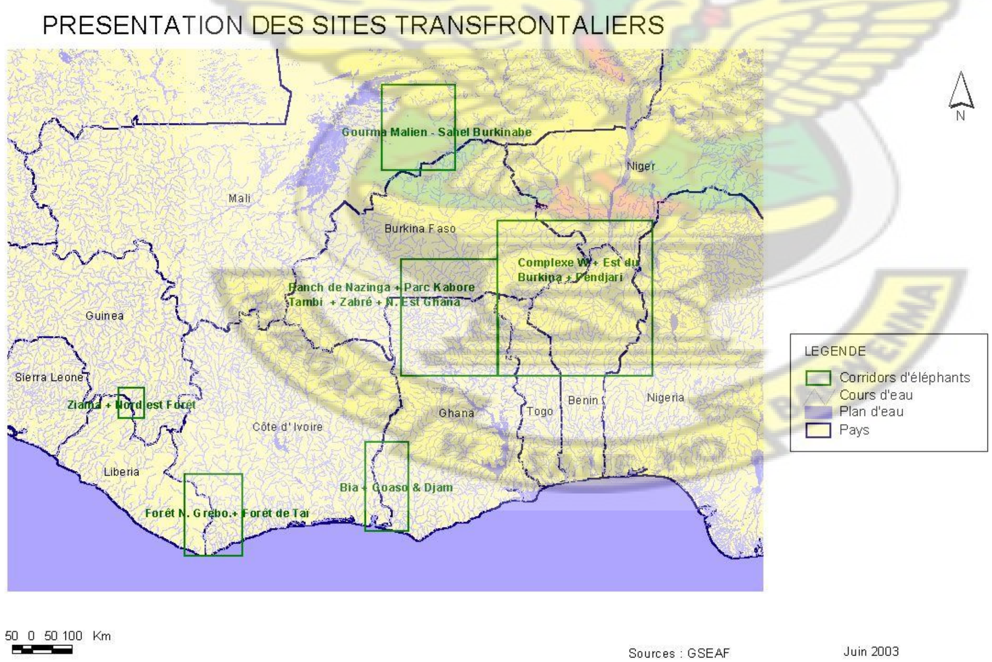

Figure 1: Trans-frontier corridors proposed by IUCN for West Africa. Source: AfESG.

Five elephant corridors were proposed for immediate development (Figure 1). The Red Volta range is included in one of the proposed corridors: the Po-Nazinga-Sissili- Red Volta (PONASI-RED VOLTA) complex. The other West African corridors proposed for development are the: Pendjari /Parc W/East-Burkina Faso complex (shared by Burkina Faso, Benin and Niger), Gourma area (Mali and Burkina Faso), Bia/ Goaso and Djam (Ghana and Cote d'Ivoire), and the Grebo N. Forest/ Tai Forest shared by Liberia and Cote d'Ivoire (Sebogo and Barnes 2003).

2.5.4 PONASI-RED VOLTA Corridor Complex

The PONASI-RED VOLTA corridor complex falls within north-eastern Ghana, northern Togo and south-central Burkina Faso (Sebogo and Barnes 2003), covering a land area of about 18,035 km^2 (Figure 2).

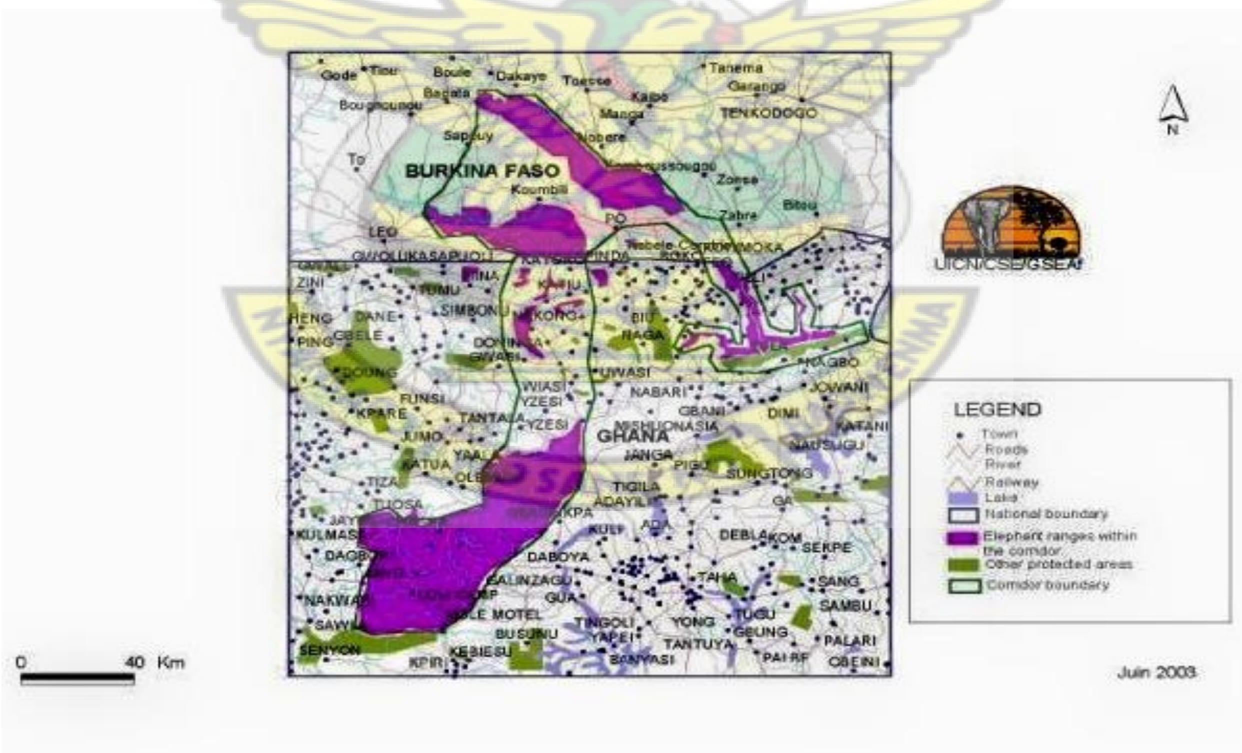

Figure 2: The PONASI-Red Volta Corridor Complex.
Source: AfESG.

The Ghana portion of the complex is formed by the Red Volta Valley ecosystem, the Sissili area, and the Mole National Park. In Burkina Faso the protected areas connected in the complex are the Kabore Tambi National Park (PNKT), the Nazinga Game Ranch, and an adjoining community dedicated area called *la Zone de Chasse de Sissili* (or Sissili Hunting Area).

2.5.5 Current land uses

The land is mainly used for arable cropping and livestock grazing but there are also some natural and plantation forest reserves. Cereal crops such as millet, sorghum, maize and rice and livestock production predominate in the area (Ayigsi 1997). Agriculture in the area is however plagued by many problems. Typical crop production problems include low soil fertility due to continuous cropping, soil erosion, and inadequate application of organic fertilizer, unavailability of improved seeds, weeds, pests and diseases, erratic rainfall, lack of credit and irrigation facilities. These challenges have led to low crop yields generally and heightened food insecurity (Ayigsi 1997).

Regarding typical animal production problems, high rate of animal mortality due to diseases, lack of adequate water and food, inbreeding, inadequate veterinary services, high cost of veterinary drugs and animal theft are common in most of the communities. The growing human and livestock populations, have placed increasing pressure on the land, and could be contributing to the declining productivity of crops, and the encroachment of the corridors (NCRC 2000).

2.5.6 Conservation significance of corridors

The benefits of corridors to conservation efforts are undisputable. They provide a continuum or a link between two patches of isolated habitats and in so doing allow animals access to seasonal resources outside their core home range (IUCN/AfESG 2003). It reduces the risk of genetic isolation, and promotes viability of the population concerned (Barnes *et al.* 2006b). Elephants in fragmented and isolated populations face an imminent risk of inbreeding, low birth-rates which together with other factors could result in the population dwindling to extinction. This danger is illustrated by several populations in Mauritania, Mali, and Cote d'Ivoire which have gone extinct over the past 25 years (Barnes, 1999; Blanc *et al.*, 2003).

Corridors are most needed for the conservation of elephants in West Africa. This is so because a majority of the populations occur in isolated habitat fragments, and are small relative to populations in other regions of the continent (Sebogo and Barnes 2003). In both forest and savanna, one quarter of the elephant populations are thought to consist of only 20 animals (Blanc *et al.* 2003). Because there is a high proportion of a small elephant population in West Africa, the sub-region risks losing many of its elephants without active management that integrates the isolated pockets of habitats (Barnes *et al.* 2006a).

Corridors are needed where human expansion has encroached on natural migratory routes. For instance accounts by communities in the northern Mole area suggest that the Mole elephant population has historic genetic links with the populations in southern Burkina Faso (Adjewodah *et al.* 2006a, 2006b), but farming along the banks of the Sissili River along which migratory routes are found means that elephant movement would be severely hampered unless an artificial corridor is created.

CHAPTER THREE

3.0 Materials and Methods

3.1 Study Area

The Red Volta Valley comprises of a network of adjoining forest reserves: Red Volta East, Red Volta West, Gambaga Scarp East, Gambaga Scarp West, and Morago East Forest Reserves and adjacent off reserve woodlands and fallow/crop fields (latitude 10° 30' to 11° 00' North, longitude 0° 45' to 0 ° 00' West) laying within the Talensi-Nabdam, Bawku West, and Bongo Districts of the Upper East Region of Ghana (Fig. 3). The vegetation is savanna woodland and consists of deciduous short trees and shrubs (Barnes *et al.* 2006a), and gallery forest is found along the banks of the Red Volta River, the White Volta River, and the Morago River. The canopy is not closed and there is dense medium or long grass layer in the late wet season. The common plant species include communities of *Combretum sp.* and *Vitellaria paradoxa*. Cutting of trees for firewood, charcoal burning, and natural mortality may be reducing the density of large trees because they are not being replaced through natural succession. Areas that hold more water, such as near streams and rivers, tend to have bigger size trees.

The forest reserves harbour trans-frontier elephant migratory routes, which link the Red Volta Valley to the Kabore-Tambe National Park and the Nazinga Game Ranch in south central Burkina Faso, and to the Fosse aux Lions National Park in northern Togo (Sebogo and Barnes 2003). About 1,049 km^2 of the Red Volta Valley, comprising of the above forest reserves and adjoining fallow woodlands, is uninhabited and thus potentially available for elephants.

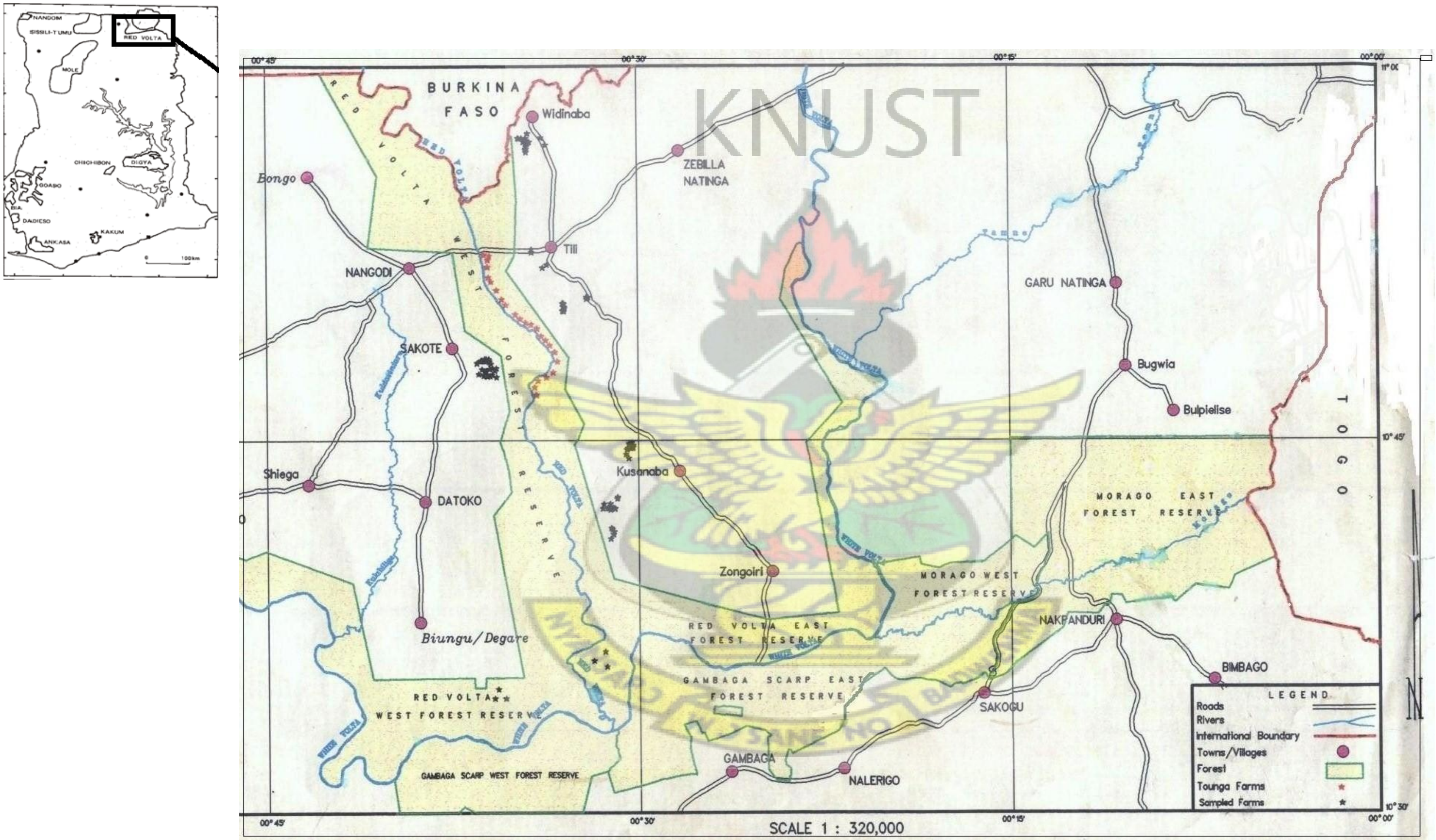

Figure 3: Location of the Red Volta Valley and research area in north-eastern Ghana indicating major rivers, forest reserves, enclaves of cultivation and main villages.

The Red Volta forest reserves are managed by the Forestry Services Division of the Forestry Commission for watershed protection. Wildlife management is not a major priority. The area experiences two climatic seasons, namely, dry and wet seasons. The wet season extends from May to November, and the dry season from December to April. Mean annual rainfall is about 896 mm with an annual peak in July, August, and September. The dry period is characterized by desiccating northeast winds known as harmattan, which bring dust and haze from the Sahara desert. The dry season is also characterized by high incidents of wildfire between December and February, and during this period wildfire damage to the vegetation extends over a large portion of the study area (Adjewodah 2004).

The main economic activity of the people is rain-fed subsistence agriculture. Farm sizes are small and ranged from 0.1 ha to 7.3 ha (Adjewodah 2004). Crops common to the area include millet, maize, and groundnut.

3.1.1 Recent management history

Most of the forest reserves in Ghana were created primarily to protect the catchment of water bodies. Now however, management of most forest reserves are particularly focused on their timber value (Kotey *et al.* 1998). Because the Red Volta Valley forest reserves are the savanna type where most trees do not have commercial timber value, the forest there is not given same level of attention as those in the high forest zone.

Prior to central government's takeover and management of the forest reserves in the Red Volta Valley, the local traditional authorities (Chiefs and tindana) had controlled and managed the area. Mainly cultivation and hunting were the common land use forms, and certain cultural practices which were strongly adhered to (and the low human population at the time) may have allowed sustainable use of the area. However, upon gazettement, they relinquished control to the government, and since that time the inhabitants have relied upon officials to manage and conserve the fragile lands. While some adjoining villages to the reserve look on with apathy as resources in the reserves decline, others contribute to the decline through their illegal activities (cultivation, alluvial mining, and overgrazing of livestock) within the forest (NCRC 2000, Adjewodah *et al.* 2003, Adjewodah 2004).

In the 1970s, the Forestry Department (now the Forestry Services Division) undertook plantation development in some of the forest reserves. Mainly exotic species were introduced in degraded areas of the forests (Adjewodah *et al.* 2003). Forest guards patrolled the boundaries of the reserves and regulated entry by villagers. They also cleared and maintained the boundaries of the forest.

In 2002, the Forestry Services Division re-introduced the Taungya System in the Red Volta and Sissili Valley Forest Reserves. In this system, farmers are given an acre of land in degraded areas of the forest and are allowed to plant food crops in exchange for caring for newly planted tree seedlings on their plot. The idea is that as the trees mature, and the canopy closes, the farming will phase out. The intervention raises many questions and may not be compatible with the current status of the forests as conservation areas. First of all, what impact does this human presence in the reserve have on elephant movement? Secondly, what incentive do farmers really have to ensure the success of the growing trees? Lessons from Eastern Africa show the Taungya System, when not well monitored, could rather lead to further degradation of the forests it is meant to save (Adjewodah *et al.* 2003).

The management and protection of the forest reserves in the study area would have to be strengthened to reverse the current decline in their resources. Over the years tree cover has declined, species diversity decreased, erosion and soil surface exposure increased and annual bushfires occurred uncontrolled each dry season (Barnes *et al*. 2006a). Poaching, mining, farming, grazing and tree felling are common in some areas of the reserves though these activities were prohibited upon gazettement.

The Northern Savanna Biodiversity Conservation Project (NSBCP) has carried out assessment of the Red Volta Valley to determine its feasibility for an international wildlife corridor with neighbouring Burkina Faso and Togo (Ministry of Lands and Forestry 2002). The IUCN is providing technical support to Ghana and Burkina Faso for implementation of the wildlife corridor project.

3.2 Methods

3.2.1 Selection of sample area

This section describes the sampling process used for selecting the focal research area (locales), followed by the methods used in gathering data during the fieldwork.

The Red Volta Valley, as defined by Sam et al. (1997), was captured on topographical sheets (1:50,000) having the following codes: 1001A4, 1001A2, and 1001B3. The uninhabited natural area was delineated and divided into 18 localities, each measuring about 58.3 km2 (and here after referred to as locales). Each of the locales extended 7.63 km x 7.63 km and encompassed the gallery forest along the major rivers in the study area, and adjoining savanna fallow lands. Six of the locales named after the nearest community: Tilli, Kusanaba, Morago, Bongo, Sakote, and Buing were randomly selected (Fig. 4) to give a sampling intensity of 33% of the potential elephant habitat. The selected locales were gridded at 5 minutes intervals (on both the longitudinal and latitudinal axes), and this resulted in sub-divisions of the locales referred cells. A locale consisted of about 18 cells, each measuring 1.8km x 1.8km. Ten cells were randomly selected from each locale for the placement of 50m x 5m quadrats, along 1,000m long transects. The position of the 1,000 m transect within each cell was determined with the help of a random table. The random table generated one of the terminal coordinates, and the second terminal was located by placing it 2 cm (equivalent to 1,000m on the ground) east or west of the first terminal. A straight line was ruled to join the two terminal points on the map. Each of these lines (referred to as map transects) defines a 1-km transect.

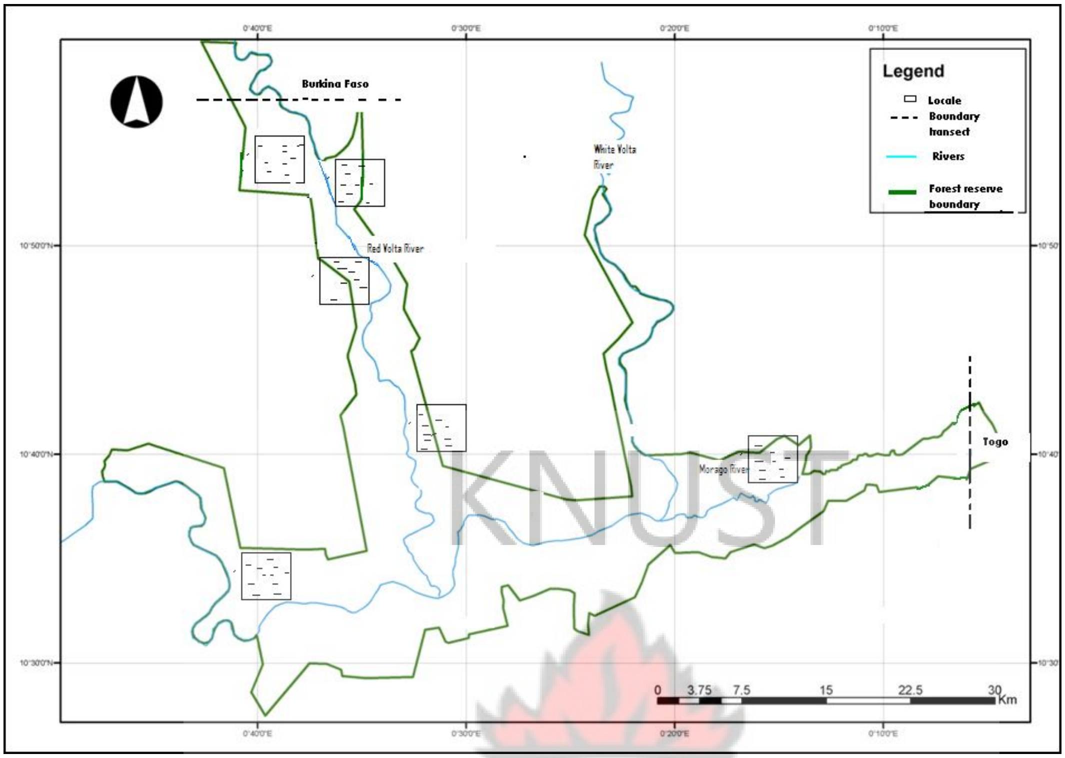

Figure 4: The Red Volta ecosystem indicating the research locales and transects.

3.2.2 Elephant crop-raiding pattern

Elephant crop damage during 1999-2003 was assessed using a standardized format developed by the IUCN Human Elephant Working Group of the African Elephant Specialist Group (Hoare 1999). An incident was defined as an event where one or more elephants caused damaged to a crop field. In the IUCN format, the proportion of the affected field destroyed by elephant(s) provided a measure of the severity of the incident (Parker and Osborn 2001).

Local enumerators estimated the field size and the area (in m^2) damaged by pacing both. They categorized crop stage as seedling (pre-inflorescence stage), intermediate (early inflorescence stage), or mature (crop ready for harvest); and graded the quality of crops affected as poor (crop with stunted vegetative growth; and or failed harvest with less than a quarter of the expected yield), medium (crop has neither failed nor blossomed; or yield is about half of the expected harvest), or good (crop blossoming, or reached full yield potential).

This assessment was subjective because it relied on the judgment of the enumerator and opportunistic because it relied on farmers to report incidents. However, these limitations were minimized through regular training and supervision of the enumerators. The author conducted regular and intensive field supervision to standardize data collection techniques and to minimize biased reporting by enumerators. Furthermore, the limited bias due to subjective judgment was outweighed by affording large coverage of the elephant range, low cost and sustainability of approach.

Crop raiding incidents were plotted along a 12 months' time series to determine temporal distribution. Geographical patterns were determined by comparing number of incidents among locals, and by correlating incidents with the location of affected fields with respects to the nearest forest reserve boundary. The geographical location of cultivated enclaves and affected fields was determined using GIS.

Starting in 1999, farmers in the study area were organized into associations called farm-monitoring groups. A series of meetings was held to introduce them to a monitoring programme and a companion programme to reduce the incidents of elephant crop-raiding. Each of the 33 groups participating in the programme in 1999 elected two representatives: a leader and an enumerator. Members of the farm groups and associations registered their farms with their respective enumerators during the planting seasons (May/June) of 1999 to 2003. A project team led by the author supervised these exercises and made sure the following farm variables as reported by the farmer were recorded: name of farmer, sex, general location of farm, size of farm, crops planted and date of sowing.

The farm groups cooperated to implement a set of measures against crop raiding by elephants. Details of these measures are provided elsewhere (Adjewodah *et al.* 2003). Group members shared information on elephant damage and movement among themselves and with the project team, and group members formed cooperatives to enable them to harvest crops in a timely manner. The project team held periodic meetings with the groups to prepare them for the crop raiding season. When an incident occurred, the affected farmer reported it to the leader or enumerator of his farm group. The enumerator then visited the affected farm to assess and record the damage using the standardized IUCN format described above.

A total of 996 farmers were registered in 1999, the first year of the study. The number of participating farmers increased to 1500 in 2000 following a reduction in crop-raiding incidents (NCRC 2000). In 2003, 1030 farmers were registered. Registration was voluntary. Enclaves where crop raiding was not an issue (and farms inside the forest reserves) were not included. Although the entire farming population was not enumerated, it is casually estimated over 80% of farmers cultivating farmlands with raiding history participated in the project each year.

3.2.2.1 Farming practices

Farming in the study area involved seasonal, rain-fed subsistence agriculture. Farming activities started with land preparation beginning in the late dry season (March-April), followed by planting in May-June. Farm sizes are small and ranged from 0.1 ha to 7.3 ha (mean 0.7 ha, *n* = 104) (Adjewodah 2004). Crops grown in order of decreasing area cultivated include millet, maize, groundnut, beans, guinea corn, rice, and yam (Ayigsi 1997). In 2003, monocultures of millet, maize, and groundnut comprised 33%, 30% and 12% (n = 104 farms) respectively of the area of crops grown (Adjewodah 2004). A variety of early-maturing millet, usually grown in June (in the courtyard of the farmer) takes about two months to mature (Adjewodah 2004). A second variety of millet known as "late millet" is sown after June on bush farms (farms closer to the forest reserves than settlements). This variety is harvested between September and November (Adjewodah 2004).

3.2.2.2 Data analysis

Data forms were retrieved from the group leaders at the end of the crop-raiding season in November for analysis. Because records for 1999 were incomplete, 1999 data were not used in some analyses. An index of damage developed by Hoare (1999) was adopted. The damage score is the sum of the age score of crop (1 = seedling, 2 = intermediate, 3 = mature), the quality score (1 = poor, 2 = medium, and 3 = good) and the damage category (1 = ≤5% of farm area damaged, 2 = 6–10%, 3 = 11–20%, 4 = 21–50%, 5 = 51– 80%, and 6 = >80%). Damage scores were interpreted as low (1–5), medium (6–8), or high (9–12).

Descriptive statistics were used to quantity the extent and frequency of crop raiding by elephants, and to assess the severity of damage caused to affected fields, and the proportion of farmers affected (Sukumar 2003). Friedman test (for repeated measures), and analyses of variance (ANOVA) were carried out for variations in the extent, severity and frequency of elephant crop raiding among the locales, and among years. Crop raiding incidents were plotted along a 12 month time series for temporal distribution.

3.2.3 Elephant browse and habitat degradation in the Red Volta Valley

In all, 52 one-km transects were surveyed for elephant natural browse and for the extent of bush burn, artisanal gold mining, and clear felled vegetation. Using a tape measure, 2.5 m were measured on both sides of the transect line. Each transects consisted of 20 adjoining 50m x 5m quadrats, of which 4 were sampled. Counting from the start of the transect, the third, eighth, thirteenth, and eighteenth quadrats were systematically sampled. In all, 208 quadrats were sampled.

All individual tree and shrub, ≥10cm tall, were enumerated and identified to the species level. The girth size of all trees and shrubs above 5 cm was measured at breast height. The largest branch or stem was measured for forked plants. The enumerated plants were examined for elephant feeding signs, by looking out for broken stems and branches, knocked down tree and shrubs, debarking etc (Spinage, 1994). Because there were too few elephant feeding signs, trees and shrubs selectively browsed by elephants of the neighbouring Kabore-Tambi National Park (Spinage 1985) provided the bases of identifying browse species among the enumerated plants. Unidentified plant species were collected and pressed for identification at the University of Ghana herbarium, Accra. Notes were also made of any elephant signs found in the plots.

In order to assess the extent of degradation, the cross sectional area (in m^2) of mining pits within each of the 50m x 5m quadrats were measured with a tape. Size measurements (in m^2) were also taken for the area of the quadrat clear felled, and also for the quadrat area burned by wildfire from the previous season.

3.2.3.1 Data analysis

The statistical programme EstimateS (Colwell, 2005), was used for a rigorous extrapolation and interpolations of the empirical sample-based dataset. Sample-based rarefaction curves of the diversity and density of browse were computed by repeated re-sampling (Gotelli and Colwell, 2001). Extrapolation of the browse rarefaction curves allowed an estimate, with 95% confidence interval, of how many species occur in a larger set of samples from the same assemblage. The second order-jackknife, and Michaelis-Menten species richness/diversity indices were calculated for each locale.

ANOVA was used to compare the density of browse and non-browse species among locales. Density of browse species was compared with the density of all other enumerated species using the independent *t*-test. Species diversity indices including observed species richness, second order-jackknife, and Michaelis-Menten estimators (Gotelli and Colwell 2001) provided a test for homogeneity or otherwise of the habitat in the six locales in relation to distribution and diversity of trees and shrubs. Lastly, the independent sample *t*-test was used to test for difference between observed species richness and the projected Michaelis-Menten asymptote. Descriptive statistics were used to assess the habitat structure and the level of disturbance.

3.2.4 Distribution of the Red Volta elephant and its trans-frontier migration

3.2.4.1 Abundance and distribution of the Red Volta elephant population

With modifications, the elephant dung count method (Barnes and Jensen 1987) was adopted for an estimate of the elephant population. This method is widely applied and favoured over aerial and direct counts (Barnes and Jensen 1987), particularly in settings where visibility is limited, and where the population in question is small and cryptic (McClanahan, 1986). The latter conditions (small and cryptic population) apply to the Red Volta elephant population, thus the choice of the indirect count method over the direct method. For the indirect method, elephant dung decay rate, and deposition rate are required for deducing population estimates from dung pile counts. Dung decay and deposition rates from the Nazinga Game Ranch (which falls within the same ecosystem as the Red Volta Valley) were thus adopted for this study.

A total of 58 transects (each 1,000m x 10m) were randomly established within the six selected locales and surveyed for elephant dung-piles. Two individuals cleared the path of a tape measure to lay a dead straight centre line. Two other persons walked on either side of the tape and counted elephant dung piles within 5m on either side of the tape. Dung piles on the boundaries of the 1,000m x 10m belts were counted in. Fixed width transects are unreliable if dung piles in the outer edge are less likely to be detected than those in the middle (Barnes and Jensen, 1987). This pitfall was avoided by using two observers walking abreast to inspect 100% of the transect area. Visibility was excellent in most transects except for a few areas adjacent to streams.

This approach followed the fixed width transect method (Jachmann and Bell, 1979), rather than the more favoured distance-sampling method (Barnes and Jensen 1987). The distance-sampling method requires a minimum of 60 dung pile counts for estimating elephants (Barnes and Jensen 1987). At the unset it was not certain that the minimum dung population could be achieved because a reconnaissance survey suggested a low elephant dung abundance in the area. Fixed width transects are unreliable if dung piles in the outer edge of the transect are less likely to be detected than those in the middle, and are biased if detectability is much less than 100% (Barnes and Jensen, 1987). These pitfalls were avoided by using two observers walking abreast to inspect 100% of the transect area. Furthermore, visibility was excellent in most transects except for few area adjacent to streams.

3.2.4.2 Trans-frontier migration of the Red Volta elephant

Elephant distribution maps generated from the research in different months and seasons was compared. Additionally, migratory cattle herders and farmers were interviewed for elephant's seasonal movement, particularly for trans-border movement of elephants between Ghana and Togo and between Ghana and Burkina Faso. Interviewees provided information on elephant movement, location of elephant sightings in the Red Volta, group size, and sex-age composition. A minimum of 5 key informants were identified from each of the project locale and interviewed.

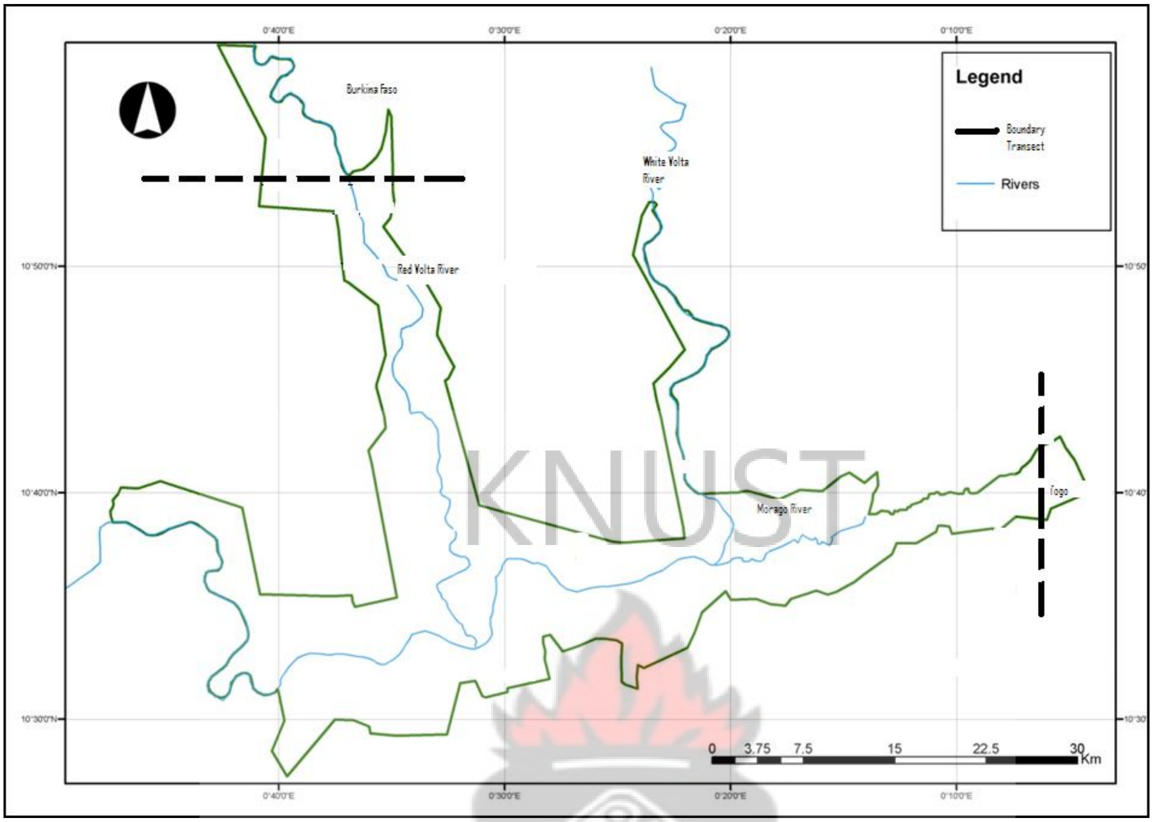

Figure 5: Red Volta ecosystem showing trans-boundary transects

Information from the community interviews was validated with direct inspection of straight line transects along Ghana-Togo, and the Ghana-Burkina Faso international boundary within the Red Volta valley (Fig. 5). The transects were monitored once every month from May 2003 to February 2004 for elephant signs (prints, dung pile, and damage to vegetation). Hunters, farmers and gold miners encountered on the transects were interviewed.

The Ghana-Burkina Faso boundary transect consisted of two sections, one on the west side of the Red Volta River and the other on the east bank. Both sections were oriented east-west, at a near perpendicular angle to the Red Volta River (Fig. 5). The two sections passed across the woodland reserves (along the banks of the river) and adjacent land. The section on the east of the Red Volta started from the feeder road between Tilli and Widnaba and extends 7 km to the Red Volta River. The west side section started near a village called Apatanga in the Bongo District and extended for about 13 km. The boundary transect near the Ghana-Togo border consisted of only one section and extended for about 15 km north of the Gambaga Scarp into the Garu area.

3.2.5 Association between elephant crop-raiding and habitat variables of the Red Volta Valley

3.2.5.1 Association between crop raiding, extent of browse, habitat degradation and abundance of elephant

The association between crop raiding by elephants, and the extent of natural elephant browse, habitat degradation, and local abundance of elephant was determined using correlation analysis. Variables of elephant crop raiding included in the analysis are: size of crop field destroyed, and rate of crop raiding incident. Density of woody stem and species diversity (weighed by the Michaelis-Menten species richness) provide an estimate of browse (Gotelli and Colwell 2001, Sukumar 2003). Quadrat area (in m^2), burned, clear felled or mined provided an estimate of degradation, and the number of elephant per locale provided an estimate of abundance.

Pearson moment product correlation test (Zar 1999) was used to determine the association between browse density and the annual frequency of elephant crop raiding, and then to test for the association between the size of crop field damaged by elephants, and diversity of woody plants. The association between crop raiding and the number of elephants for the locales was determined using Spearman rank-order correlation of the area of crop field damaged, with the number of elephants.

3.2.5.2 Association between crop raiding and the extent of crop field

The relationship between crop raiding and extent of crop field cultivated each year is determined using correlations. In this analysis, the size of crop field destroyed, or the annual frequency of crop raiding incidents per locale denote variables of elephant raiding, while the size of land under cultivation, or the number of registered farmers, denote extent of cropland.

Spearman correlation was applied to determine the association between the annual frequency of incidents and size of cropland. The number of registered farmers each year provides an index of the area under cultivation. Spearman rank-order correlation was used to determine the association between the number of registered farmers and the number of incidents each year.

3.2.5.3 Association between crop raiding and geographical location of affected enclaves

Distances of enclaves of cultivation to the nearest forest boundary, and to the nearest village (human settlement), and to the Red Volta River were determined using GIS. For each of the six locales, the distance of the enclave of cultivation was obtained by estimating the mean distance of a random sample of farms from the reserve boundary. The geographical coordinates of the sampled farms were recorded with a handheld GPS and fed into the GIS analysis.

Standard linear regression was used to determine the type and strength of the relationship between the distance separating cultivated enclaves from the core elephant habitat (forest reserves) on one hand, and frequency of incidents on the other. Linear regression was also applied to test the type and strength of the relationship between distance of farm enclave from the nearest village and frequency of incidents. In a parallel analysis, the association between rate of incidents and distance to the forest reserve was determined by Pearson product-moment correlation.

3.2.5.4 Functional relationship between elephant crop raiding and key variables of the Red Volta elephant habitat

A functional relationship between crop raiding and the key variables of the elephant habitat was determined using a Model. The statistical program SPSS (SPSS Inc. 2007), was used to build the model, and following the Stepwise Strategy (Dytham 2003). It identified the key factor(s) of rate of crop raiding (dependent variable) in a locale from a set of variables: (a) size of cropland cultivated in the locale, (b) local elephant abundance, (c) density of woody stem (d) density of browse (e) distance of enclave from the forest boundary, (f) distance of enclave from the Red Volta River, (g) and distance of the locale's enclave from settlement. The analysis produced a function between crop raiding and the selected cause factor(s). The variables listed above were added and subtracted in steps only using those combinations and slopes that generate a better fit (Dytham 2003). This allowed Stepwise algorithm to choose the most important factor(s), and to select a "best" model for predicting the rate of crop raiding for the locales.

The abundance of elephant data was excluded from the list of potential factors since it was thought that the zero records for most of the locales will introduce extremities in the analysis. When this was done, stepwise algorithm chose only "distance of enclave from the forest boundary" as the predictor of the rate of incident. ANOVA was used to test the acceptability of the model from a statistical perspective. A histogram and normality plot of the residuals was used to check the assumption of normality of the error term. The model was based on the equation (Zar 1999): $Y_j = a + b_1X_{1j} + b_2X_{2j} + b_3X_{3j} + \ldots + b_mX_{mj} + e_j$

Where Y_j= Number of incidents in the j^{th} locale

a = the intercept (the value of Y when X_1, X_2 and X_3 are zero)

m= number of predictors (or independent variables)

b_1 = correlation coefficient of the 1^{st} variable

X_{1j} = denotes the jth observation of variable X_1

e_j= is the error in the observed value for the j^{th} case

3.2.6 Amendments

Out of the 60 planned transects, 58 were surveyed for dung piles. The locale in Sakote could not accommodate more than 9 transects without a significant change in the sampling intensity relative to the other locales. This was due to the relatively small uninhabited land area in Sakote. A transect at Morago was inaccessible during the rains and was not surveyed.

During the initial stage of the fieldwork, a vegetation belt of 10m x 200m was randomly laid on the one km transects to sample the vegetation and habitat status of locales. In the course of the fieldwork however, this design was amended. Instead four 50m x 5m plots (equivalent to one vegetation belt), were systematically laid on the third, eighth, thirteenth and eighteenth segments of the 1-km transects. The change was necessary to allow micro differences in the vegetation and habitat status of the transects to be captured.

C HAPTER FOUR

4.0 Results

4.1 Elephant Crop-raiding Pattern in the Red Volta Valley

4.1.1 Extent of damage and crops affected

The extent of crop damage (i.e. size of crop field destroyed, and the rate of incident) and the proportion of the farmer population affected were low. When the crop raiding incidents for the six locales were pooled, the mean area of crop field destroyed by elephants each year was less than 1.5 ha (Table 1).

Table 1: Number of farmers registered, number affected by elephant crop-raiding, and the mean annual damage score for 1999–2003.

Year	Number of registered farmers	Number affected	Percent of farmers affected	Average number of hectares damaged per annum	Mean damage score per raided field (on scale of 1-12)***
1999	996	30	3	Not available	Not available
2000	1500	32	2	1.29	1.39
2001	1500	24	2	0.53	1.31
2002	859	25	3	0.98	1.25
2003	1030	0	0	--	-
Mean	1177.0	111(±22.2)	2.0	0.93(±0.7)	1.32(±0.1)

***The damage score is the sum of the age score of crop (1 = seedling, 2 = intermediate, 3 = mature), the quality score (1 = poor, 2 = medium, and 3 = good) and the damage category (1 = ≤5% of farm area damaged, 2 = 6–10%, 3 = 11–20%, 4 = 21–50%, 5 = 51– 80%, and 6 = >80%). Damage scores are interpreted as low (1–5), medium (6–8), or high (9–12).

During 1999-2002, elephants raided the fields of 111 registered farmers (n=4,855), representing only 2.3% of the farmers registered during this period (Table 2). There were no incidents in 2003. The proportion of farmers affected per year ranged between 2-3%, with little change among years until 2003 when elephants were absent in the Red Volta during harvest. The mean damage score of affected farms was low (Table 2).

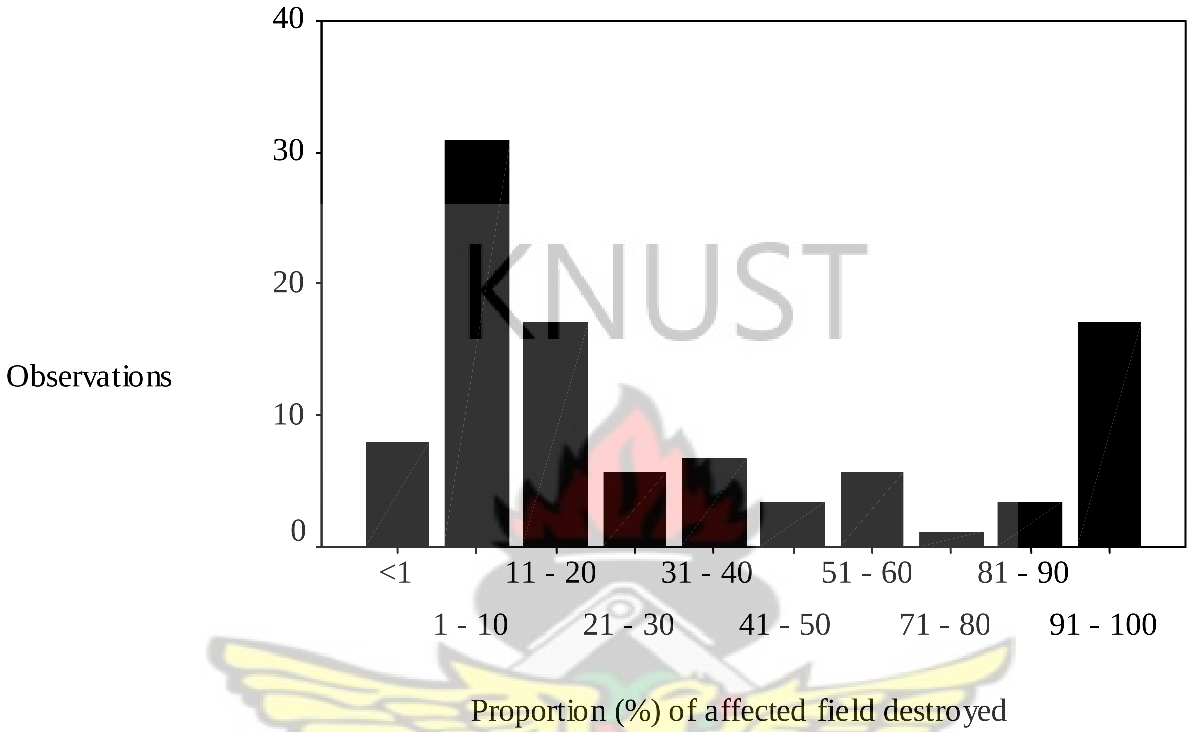

Figure 6: Frequency distribution of percentage of farm damage for 87 farms raided during 2000-2002.

The proportion of an affected field destroyed was highly variable and ranged from <1 to 100% (Figure 7). However, a majority (56%) of raided fields suffered damage to < 21% of the cultivated area, and only about 27% of raided fields experienced damage to >50% of the cultivated area (Figure 6).

Elephants showed preference for selected crops that had reached maturity. From 2000 to 2002, millet was the most frequently raided crop, followed by Guinea corn, groundnut, and rice (Table 3). The affected crops were raided during mature stages when they were ready for harvest, or when the crops had reached the intermediate stage (Table 2). Most raiding incidents involved crops of medium to good quality, with considerable variation among crops (Table 2).

Table 2: Composition of damaged area for 105 fields raided by elephants during 2000-2002.

Crop	Percent of damaged crop area	Percent of crop in			Percent of crop of		
		mature stage	intermediate stage	seedling stage	good quality	medium quality	poor quality
Millet	31	71	29	0	38	44	18
Guinea corn	27	42	58	0	56	40	4
Groundnut	17	100	0	0	94	0	6
Rice	16	16	79	5	32	37	31
Maize	8	68	32	0	43	43	14
Beans	1	100	0	0	100	0	0
Mean	16.7	66.2	33.0	0.8	60.5	27.3	12.2

Monocultures of millet, maize, groundnut form 33%, 30% and 12% (n=104) respectively of crops raised. In order to relate choice of crops by elephants to availability of those crops in the cultivated landscape, the area of millet, guinea corn, maize and rice cultivated (Table 3) were compared across locales to determine variation in the availability of preferred crops. Kruskal-Wallis test for differences in means, indicates there was no significant difference in hectares of millet, Guinea corn, maize and rice cultivated (x^2=0.41, *P*=0.98). In a related analysis, field size of the two most affected crops (millet and Guinea corn) available in five locales were compared, and the analysis indicates the differences were not significant (Chi-square=0.39, *P*=0.98).

Table 3: Size (ha) of affected crops cultivated

Locale	Area (ha)	Millet (ha)	Maize (ha)	G.corn (ha)	G.nut (ha)	Rice (ha)	Beans (ha)
Tilli	56	1	54	14	1	0	0
Bongo	91	74	4	8	22	1	7
Kusanaba	114	0	70	105	8	0	0
Sakote	158	1	14	17	106	20	5
Morago	607	468	125	0	27	0	0
Total	1027	544	267	144	164	20	12

4.1.2 Geographic and temporal variations

There was no marked variation in the rate and extent of elephant crop damage among the study locales (Table 4). Friedman test (for repeated measures) finds no significant difference in the number of crop raiding incidents per annum among the study locales (d.f=6, P=0.128).

Table 4: Frequency and extent of elephant crop-raiding in six localities of the Red Volta range during 2000-2002.

	Number of incidents				Mean area damaged (ha)			
Locale	2000	2001	2002	Total	2000	2001	2002	Total
Tilli	0	1	2	3	0.00	0.05	0.02	0.07
Kusanaba	2	12	4	18	1.04	0.09	0.01	1.14
Morago	0	6	0	6	0.00	0.21	0.00	0.21
Bongo	0	2	7	9	0.00	0.15	0.75	0.90
Sakote	28	5	12	45	0.16	0.02	0.11	0.29
Biungu	8	0	1	9	0.09	0.00	0.00	0.09
Total	38	26	26		1.29	0.52	0.89	

When the cultivated area destroyed by elephants each year was compared across locales (Table 4), the analysis indicates a non-significant difference in the size of damage (2-way ANOVA: $F_{5,10}$=0.591, P> 0.1), and neither was there an indication that the size of cultivation destroyed each year varied significantly during 2000-2002 ($F_{2,10}$=0.136, P> 0.1). Furthermore, and as indicated in Table 5, there was no significant difference, among locales, in the proportion of raided field destroyed (Friedman test: d.f = 5, P= 0.454).

Table 5: Size of cropland destroyed, and the proportion of affected fields damaged by elephants within six localities of the Red Volta Valley during 2000-2002.

	Size (ha) of damage				% of field damaged		
Locale	2000	2001	2002	Total	2000	2001	2002
Tilli	0.0000	0.0493	0.5847	0.6340	0.00	1.15	100.0
Kusanaba	2.1480	0.9868	0.0496	3.1844	25.01	64.65	5.00
Morago	0.0000	2.6534	0.0000	2.6534	0.00	37.00	0.00
Bongo	0.0000	0.2105	5.2270	5.4375	0.00	12.00	35.00
Sakote	4.3646	0.3336	1.1796	5.8778	46.62	23.01	37.00
Biungu	0.5954	0.0000	0.0050	0.6004	1.39	0.00	5.00
Total	7.108	4.2336	7.0459	18.3875			

Regarding temporal variations, crop raiding incidents usually occurred from June to November. October was the peak crop-raiding month in each year with about 72% of the raiding cases occurring in that month alone (Fig. 7). The peak period coincided with the time when fields were ready for harvest. However, in 2002, crop raiding by elephants was reported as early as June (28% of the annual cases) and ended in November (4% of cases).

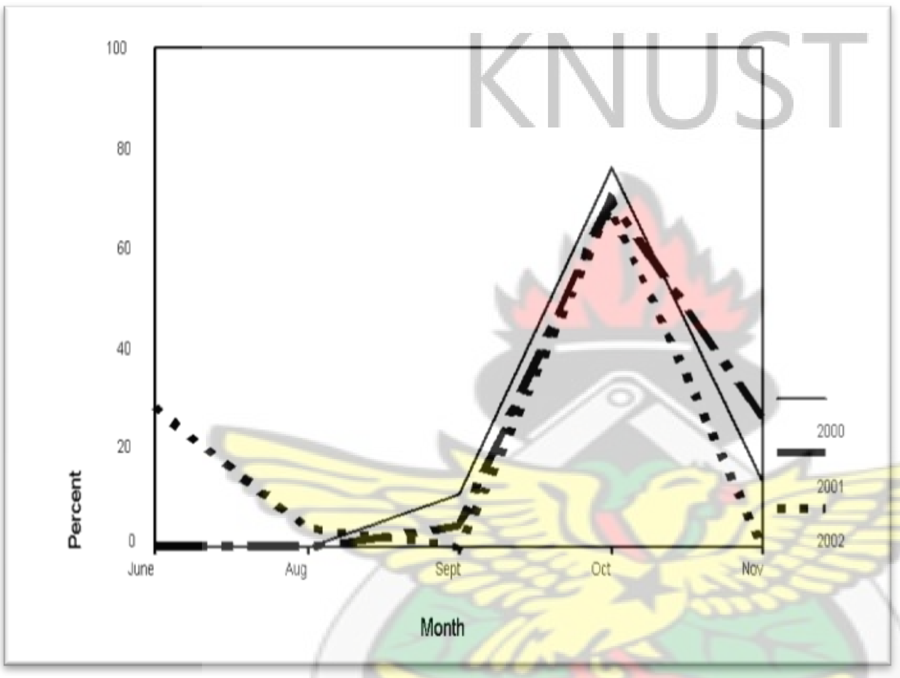

Figure 7: Frequency of monthly crop raiding incidents during 2000 – 2002.

4.2 Elephant browse and habitat degradation in the Red Volta Valley

4.2.1 Density and diversity of browse

A total of 12,948 trees and shrubs were enumerated in the 208 vegetation quadrats. About 16% (n=67) of the species enumerated (Table 6) were categorized as elephant browse species, based on observations of foraging elephants at the Kabore-Tambi National Park (Spinage 1994). Elephant browse species were found across all the six locales, except for *Borassus aethiopum* which was present in only Sakote (Table 6).

Table 6: Density and distribution of elephant browse in the Red Volta Valley.

Browse species	Density (stem/m^2)					
	Tilli	Kusanaba	Morago	Bongo	Sakote	Biung
Acacia hockii	0.093	0.252	0.093	0.288	0.207	0.042
Acacia nilotica	0.013	0.218	0.013	0.372	0.464	0.002
Borassus aethiopum	0.000	0.000	0.000	0.000	0.001	0.000
Combretum sp.	0.231	0.473	0.231	0.264	0.126	0.129
Detarium microcarpum	0.032	0.070	0.032	0.057	0.006	0.652
Gardenia ternifolia	0.017	0.013	0.017	0.082	0.010	0.032
Lannea acida	0.005	0.006	0.005	0.011	0.002	0.004
Mitragyna sp.	0.013	0.001	0.000	0.028	0.00	0.021
Piliostigma thonningi	0.042	0.117	0.042	0.050	0.019	0.018
Pteleopsis subarosa	0.156	0.137	0.156	0.155	0.142	0.351
Terminalia macroptera	0.288	0.196	0.288	0.235	0.198	0.218
Vitellaria paradoxa	0.073	0.161	0.073	0.098	0.087	0.136

Analysis of variance (ANOVA) indicates density of browse species was not significantly different between locales ($F_{5,66}$=0.5.2, P=0.774, Homogeneity of variances, P=0.487). When the density of all enumerated plants (Table 7) were compared, ANOVA indicated there was no significant difference among the locales ($F_{5,46}$=0.44, P=0.818).

Table 7: Density of woody plants enumerated in six localities of the Red Volta valley

Locale	Density (stem/m^2)									
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
Tilli	0.227	0.249	0.205	0.334	0.408	0.061	0.202	0.238	0.138	0.162
Kusanaba	0.327	0.244	0.336	0.257	0.233	0.187	0.131	0.233	0.188	0.152
Morago	0.389	0.290	0.188	0.174	0.085	0.362	0.143	x	x	x
Bongo	0.381	0.296	0.235	0.340	0.357	0.251	0.153	0.293	0.092	x
Sakote	0.328	0.450	0.340	0.060	0.340	0.115	x	x	x	x
Biungu	0.195	0.195	0.263	0.400	0.367	0.289	0.326	0.325	0.268	0.052

T_x=Transect , X= missing data

However, a higher number of stems per unit area was recorded in Bongo, Sakote, and Buingu (Fig. 8). To further explore the data for any differences among locales, the density of browse species was compared with the density of all other enumerated species to determine relative abundance. In this instance independent *t*-test indicates there is a significant difference between browse and non-browse species, and thus affirmed the dominance of the former group of plants (Levene's test of equality of variances: $P>0.05$, *t*-test, d.f.=10, $P<0.05$).

Table 8: Number of stem per m^2 of plant species in six locales of the Red Volta valley.

Locale	Density (stem/ m^2)		
	Non-browse woody plants (Range)	Non-browse woody plants (Mean)	Browse (Mean)
Tilli	0.06-0.41	0.222	0.080
Kusanaba	0.15-0.33	0.229	0.137
Morago	0.14-0.39	0.233	0.079
Bongo	0.09-0.38	0.266	0.137
Sakote	0.06-0.45	0.272	0.105
Biungu	0.05-0.40	0.268	0.134

Because species composition and diversity of a locale could influence its utilization by elephants, diversity indices for the locales were computed and compared.

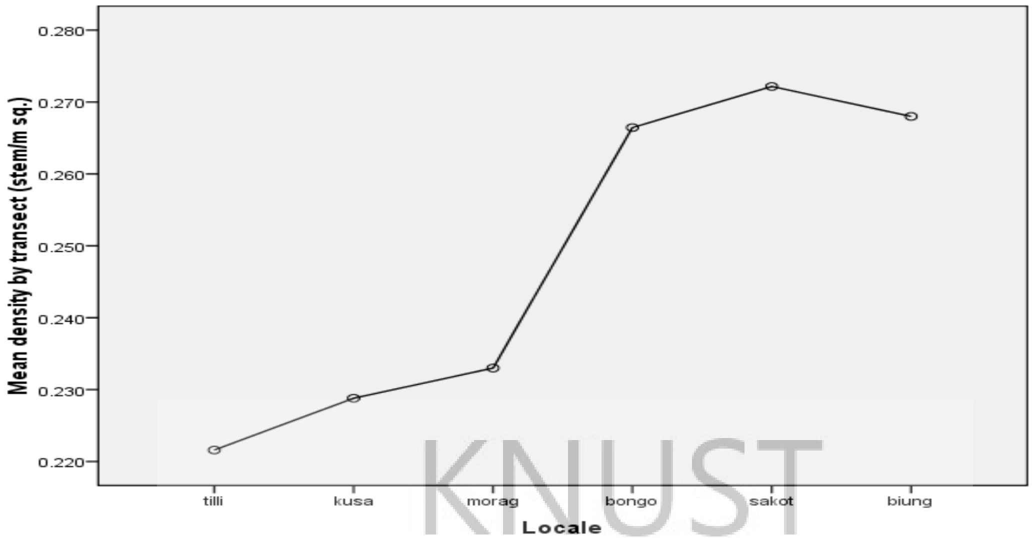

Figure 8: Mean density (stem/ unit area) of trees and shrubs in six locales within the Red Volta elephant range.

When species diversity indices, (observed species richness, second order-jackknife, and Michaelis-Menten estimators) of the locales were compared, Kruskal-Wallis test indicates homogeneity of the habitat in relation to woody plant diversity (species richness: Chi-square = 5, P>0.05, second order jackknife: P>0.05, Michaelis-Menten: Chi-square =5, P>0.05)(Table 9).

Table 9: The density and diversity estimates for 208 vegetation quadrats within the six research locales (with standard deviations in parenthesis).

Estimator	Locale					
	Tilli	Kusanaba	Morago	Bongo	Sakote	Biung
Observed species richness(S_{ob})[1]	34	42	48	32	39	37
Density(SD)[2]	0.23(0.09)	0.23(0.07)	0.23(0.12)	0.38(0.09)	0.27(0.15)	0.20 (0.10)
Michaelis-Menten estimate[3]	37.92	48.37	58.14	33.38	47.61	42.04
2[nd]-order Jackknife estimate[4]	40.65	50.16	49.51	37.42	42.51	48.03
Singletone (SD)[5]	1.84(1.48)	4.01(2.34)	3.05(3.37)	1.71(1.06)	4.64(2.4)	4.15(2.15)
Doubletons (SD)[6]	2.76(1.68)	4.52(1.88)	4.01(3.57)	2.35(0.90)	4.60(2.11)	3.49 (2.10)

1[Sob] Observed species richness estimated as number of species expected in the pooled samples given the empirical data.
[2]Stem density (of all diameter classes) per square meter.
[3]Michaelis-Menten estimate of species richness: an asymptote estimator.
[4]Second-order Jackknife richness estimator (mean among runs).
[5]Singletone Mean: number of species with only one individual in the pooled quadrats.
[6]Doubletone Mean: number of species with only two individuals in the pooled data.

There was spatial variation in the density of woody plants with a coefficient of variation reaching 55% in Sakote (Table 10).

In order to determine how the observed woody plant richness (or diversity) compares with the optimum species richness for the area, the observed species richness for the locales were compared with the Michaelis-Menten asymptotic estimate. An independent sample *t*-test showed no significant difference between the observed species richness (S_{ob}) and the projected Michaelis-Menten asymptote (Levene's test of equality of variances: P>0.05, t-test for equality of means *P*= 0.198).

Table 10: Coefficient of variation of stem density within locales

Locale	All transects	
	Variance	Coefficient of variation
Tilli	0.009	43.8%
Kusanaba	0.005	29.5%
Morago	0.013	49.5%
Bongo	0.010	35.8%
Sakote	0.022	55.5%
Biungu	0.010	37.6%

Likewise, the second order jackknife species richness estimator predicted a species richness that was not significantly different from the actual number of species observed (t-test, P>0.05).

When species rarefaction curves based on a series of 100 randomizations were generated for each locale by the freeware Estimate (Colwell, 2005), it showed close similarity of the vegetation within the locales (Fig 9).

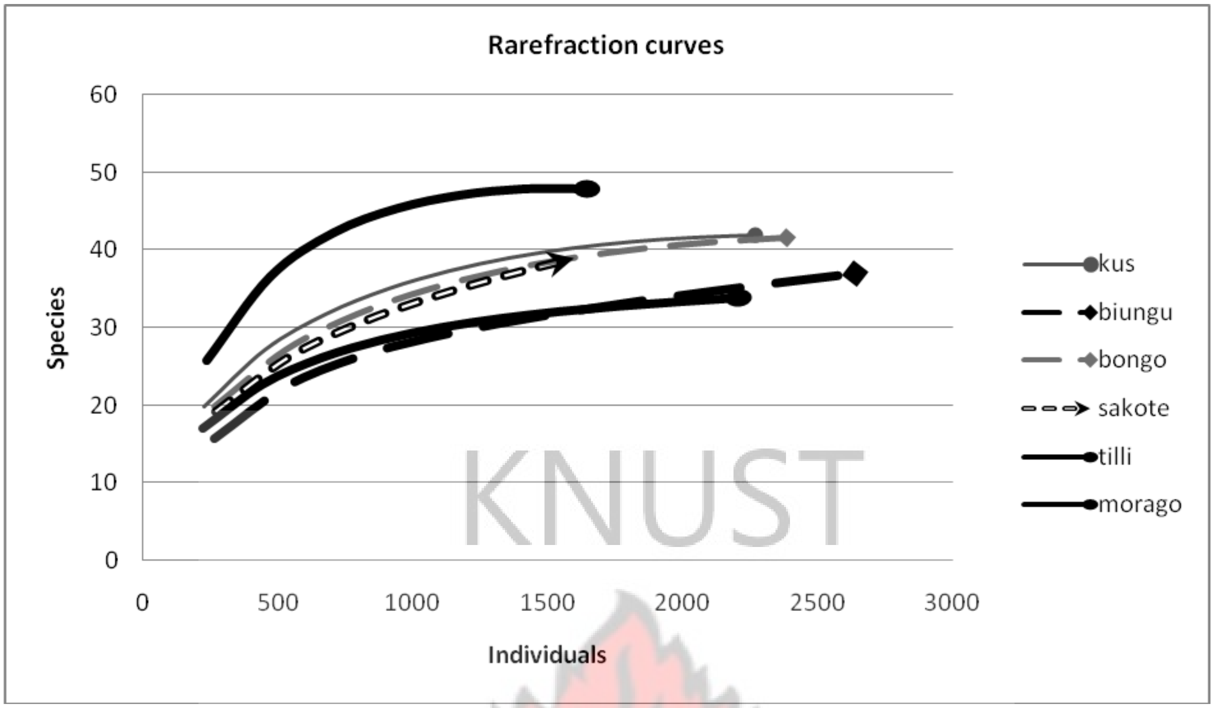

Figure 9: The mean species accumulation curve of woody stems within six locales of the Red Volta elephant range.

4.2.2 Extent of habitat degradation in the Red Volta Valley

Evidence of wildfire was recorded in most of the quadrats sampled, and about 99% of the vegetation area sampled was severely burned (Table 12) (Plate 2). There was no evidence of mining in any of the vegetation plots, and of 0.35ha involving 14 quadrats (n=208) was clear felled for firewood (Table 11).

Only one plot, out of the 208 enumerated had elephant damage to vegetation. The plot was located in Sakote and damage was on *Acacia gourmaensis*, with broken branches as a result of elephants feeding on the leaves and branches. Though there were elephant foot prints in some of the vegetation plots, no other obvious sign of elephant feeding activity was seen.

Table 11: The number of 50 m x 5 m quadrats, and quadrat area in m^2, burned, and clear-felled.

Locale	Veg. burned by fire			Veg. clear-felled	
	# of quadrats burned	Area (m^2)	% of area sample	# of quadrats	Area (m^2)
Till	32	8000	100	0	0
Kusanaba	36	9000	100	8	2000
Morago	28	7000	100	2	500
Bongo	36	9000	100	0	0
Sakote	24	6000	100	1	250
Biungu	34	8500	100	3	750

The vegetation was dominated (73-82%) by small plants with girth size less than 5cm diameter (Table 6), typical of a fire pro-climax habitat. Plants within size 25cm – 35cm were the least common, making up only 3% of total plants enumerated. Five percent (5%) of plants were within a size class 15cm – 25cm, and 4% were greater than 35cm in girth size (Table 12).

Table 12: Distribution of vegetation among five diameter classes in 6 locales within the Red Volta Valley

Diameter Class	Locale					
	Tilli	Kusanaba	Morago	Bongo	Sakote	Biungu
< 5cm	76%	79%	73%	82%	81%	73%
5 - 15cm	10%	8%	16%	7%	10%	12%
15 - 25cm	7%	6%	5%	3%	4%	7%
25 - 35cm	4%	3%	2%	4%	2%	4%
> 35cm	3%	4%	4%	4%	3%	4%
n plants	2239	2294	1696	2400	1635	2684
n transects	10	10	7	9	6	10
Trees/ha	537	481	654	804	518	724

Plate 2: Habitat clearing for cultivation

4.3 Distribution of the Red Volta elephant and its trans-frontier migration

4.3.1 Abundance and distribution of the Red Volta elephant population

Out of the six locales surveyed, only one (Sakote) registered elephant dung piles. Elephant dung piles were found on two of the nine Sakote transects. Transect number 11 registered two dung piles, and transect 12 registered eight dung piles (Table 13). Both transects fell within the Red Volta West Forest Reserve. All the dung piles were recorded in June. They were deposited by elephants after the annual bushfires (which occurred during November - 2002 through February 2003).

Table 13: Number of elephant dung piles counted in each locale, and estimated number of elephants in each 58.3-km^2 locale.

Locale	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Dung/ha	Elephant estimate
Tilli	0	0	0	0	0	0	0	0	0	0	0	0
Kusanaba	0	0	0	0	0	0	0	0	0	0	0	0
Morago	0	0	0	0	0	0	0	0	0	---	0	0
Bongo	0	0	0	0	0	0	0	0	0	0	0	0
Sakote	2	8	0	0	0	0	0	0	0	---	1.1	2.5
Biungu	0	0	0	0	0	0	0	0	0	0	0	0

--- = missing data

McClanahan (1986) and Barnes and Jensen (1987) have suggested methods for estimating elephant numbers from dung piles in areas where elephants are present year-round and dung piles are not destroyed by fire (i.e. removed only by decay). In the Red Volta Valley however, elephants were present only intermittently and fire removed dung piles in December, as over 90% of the habitat is burned by wildfire in the dry season. Instead, the following formula was adopted:

$E = N/D * A/t$, where:

E= Number of elephants in a locale,

N= Estimated number of dung-piles/ha,

D= Defecation rate per elephant per day

A = area in hectares, and

t = days since plot was cleared until day of observation.

No estimate of elephant defecation rate has been done in the Red Volta Valley, instead a defecation rate, D, of 14.1 dung piles elephant $^{-1}$ day^{-1} was adopted from the Nazinga Game

Ranch (Jachmann 1992). This figure was adopted for the Red Volta Valley since the Ranch and the study area fall within the same ecological zone, sharing similar vegetation and climatic conditions. The number of days elephants were present, *t*, was estimated to reach 180 days (i.e. fire date of 1 December and detection dates in early June). When the above formula is applied, 2.5 elephants in the Sakote locale, and 0 elephants in the other areas were estimated in the Red Volta Valley between December 2002 and June 2003.

As indicative from the dung survey results (Table 14), the elephant population was clumped around the Sakote area. No elephant signs were recorded on the Morago transects, indicating that elephants had not been in that locality in recent years. All the other locales had recent signs of elephant particularly footprints from 2002. Elephant footprints from the previous year were more obvious at Sakote/Datuku /Kusanaba (central portion), followed by Tilli, Bongo/Nangodi (in the north of the Red Volta), and Biungu/Degare in the south.

4.3.2 Trans-frontier movement of the Red Volta elephants

Cross border elephant movement was limited to the Ghana-Burkina Faso frontier. Observations from both the Ghana-Togo boundary transects (Table 14), and responses from key informants (Table 15), indicate that elephants did not migrate across the Ghana-Togo frontier in recent years. Parallel to the transect data, about 99% of local respondents said the last time any elephant activity was noted around the Morago River in the vicinity of the Ghana-Togo frontier, was in 1999.

Table 14: Presence (+) or absence (-) of fresh elephant signs (dung, print, and damage to vegetation) on transects along the Ghana-Burkina Faso (Gh-BF) and Ghana- Republic of Togo (Gh-RT) frontiers of the elephant migration corridor.

	Observation of fresh sign of elephant									
Boundary Transect	May 03	Jun 03	July 03	Aug. 03	Sept 03	Oct. 03	Nov 03	Dec 03	Jan 04	Feb 04
[1]Gh-BF	+	+	+	-	-	-	-	-	-	-
[2]Gh-RT	-	-	-	-	-	-	-	-	-	-

A clear majority of key informants (95%, n= 41) discerned that during 2000 and 2003, elephants were in the Red Volta at certain periods of the year only (Table 15). However, 2% of respondents provided a contrary view, and suggested elephants were in the research area year round.

Table 15: Periods of elephant prevalence in the Red Volta during 2000-2003.

Period	# of respondents	Percent	Cumulative Percent
Aug.-May	8	19.5	19.5
May-Dec.	8	19.5	30.0
Sept- Jan	7	17.1	75.6
May-Nov.	6	14.6	58.5
Jun-Aug.	6	14.6	90.2
Aug-Oct.	3	7.3	100.0
Jan.-Dec.	2	4.9	43.9
Apr.-May	1	2.4	92.7

When the responses were pooled into eight elephant prevalence period (Table 15), over 19% of the respondents cited August to May as the period elephants are common. Over 17% of respondents mentioned September to January as the most prevalent period. The average number of respondents who provided a positive indication of elephant presence during the eight prevalent period did not really differ (X^2 = 26.7, n=41, d.f=5, P=0.00).

4.4 Association between elephant crop-raiding and some key variables of the Red Volta Valley

4.4.1 Association between crop-raiding, extent of browse, habitat degradation and the abundance of elephant

The variables of elephant crop raiding included in the analysis are: size of crop field destroyed, and rate of crop raiding incident. Density of woody stem and species diversity (weighed by the Michaelis-Menten species richness) provide an estimate of browse. Quadrate area (in m^2), burned, clear felled or mined provided an estimate of degradation (Table 16).

Table 16: Rate of incident, extent of cultivation, extent of browse, habitat degradation and abundance elephants in six locales of the Red Volta valley during 2000-2002.

	Rate of incident	Extent of cultivation	Density and diversity of browse			Extent of degradation		Elephant
Locale	Rate of elephant crop raiding	Crop field cultivated (ha)	Mean density of browse species	Mean density of all species	Diversity index (Michaelis -Menten)	Quadrat area burned (ha)	Quad. area clear-felled (ha)	#/ locale
Tilli	3	250.6	0.080	0.222	37.92	8000	0.	0.0
Kusanaba	18	221.9	0.137	0.229	48.37	9000	2000	0.0
Morago	6	462.7	0.079	0.233	58.14	7000	500	0.0
Bongo	9	250.6	0.137	0.266	33.38	0	0	0.0
Sakote	45	1104.6	0.105	0.272	47.61	6000	250	2.5
Buing	9	585.2	0.134	0.268	42.04	8500	750	0.0

Overall, there was no evidence of a marked association between browse and crop raiding: Pearson moment product correlation indicates a non-significant association between the rate of incident and the density of browse species (r=0.806, d.f=5, *P*>0.05). When area of crop field destroyed by elephants was correlated with the density of browse species, Pearson moment indicated a positive but non-significant association between size of crop fields destroyed and browse density (r=0.25, d.f =5, P= 0.63). Pearson correlation indicates a negative association between the size of damage and diversity of browse. However this association is weak and not significant at the 0.05 level (r= - 0.007, d.f =5, P= 0.98).

Correlation analysis indicates a negative non-significant association between crop raiding and habitat degradation, i.e. the rate of crop raiding is not markedly associated with the extent wildfire (Pearson product-moment correlation: r= -0.557, d.f = 5, P= 0.329). Parallel to the above, the size of crop field destroyed by elephants correlated inversely with the extent of wildfire, however the association was not statistically significant (Pearson product-moment correlation: r= -0.780, d.f = 5, P= 0.119). Also correlation analysis indicate association between the rate of incidents and size of the habitat clear felled was not significant (Pearson product-moment correlation: r= -0.016, d.f = 5, P= 0.979).

Regarding a test for any association between crop raiding and the local abundance of elephant, Spearman rank-order correlation indicates a non significant positive association between size of crop land destroyed by elephants and local abundance of elephants (r_s=0.65, P= 0.16).

4.4.2 Association between crop raiding and the extent of crop field

The variables of elephant crop raiding used in the correlation analysis are: size of crop field destroyed, and rate of crop raiding by elephants; while extent of crop field is estimated by the land area under cultivation, and the number of registered farmers each year (Table 17).

Table 17: Rate of elephant crop raiding incidents, number of farmers cultivating in the crop raiding enclaves, and the extent of crop field in six localities of the Red Volta valley during 2000-2002.

	Number of incidents					Number of registered farmers					Crop field	
Locale	2000	2001	2002	Total	Mean	2000	2001	2002	Total	Mean	area cultivated (ha)	area damaged (ha)
Tilli	0	1	2	3	1	130	130	76	336	112	250.6	0.6340
Kusanaba	2	12	4	18	6	93	93	61	247	82	221.9	3.1844
Morago	0	6	0	6	2	180	180	121	481	160	462.7	2.6534
Bongo	0	2	7	9	3	143	143	57	343	114	250.6	5.4375
Sakote	28	5	12	45	15	401	401	392	1194	398	1104.6	5.8778
Biungu	8	0	1	9	3	251	251	83	585	195	585.2	0.6004
Total	38	26	26			1500	1500	859				

When the size of crop field destroyed by elephants was correlated with the total size of crop field cultivated in each of the locales, Pearson correlation indicates a positive association between the area under cultivation and the size of crop field, but this association is not strong enough at the 0.5 significance level (r=0.39, d.f.=5, P= 0.45).

Also, the rate of incident is tested against size of crop field cultivated in the respective locales: Spearman correlation (in parallel with the previous result), indicates a positive but weak association between size of cropland cultivated and rate of incident (r=0.25, d.f. =5, P= 0.63). When data for all the locales were pooled (Table 17), Spearman rank-order correlation indicates a positive association between the number of registered farmers and the number of incidents each year, but the association is not significant at the 0.05 level (r_s=0.51, P=0.935).

4.4.3 Association between crop raiding and geographical location of affected enclaves

The variables of elephant crop raiding included in the analysis are: size of cropland destroyed, and rate of crop raiding incident. The mean distance of affected fields from the nearest forest reserve boundary provide an estimate for proximity of an enclave to the forest reserve (core elephant habitat (Table 18).

Table 18: Proximity of cultivated enclaves to the nearest forest reserve boundary, the Red Volta River, and settlements, and the annual frequency of elephant crop raiding in the Red Volta range during 2000-2002.

	Mean distance of farm enclave from main village	Mean distance of farm enclave to Red Volta	Mean distance of affected farms from forest boundary	Number of incident			
Locale	Km	Km	Km	2000	2001	2002	Mean
Tilli	2.62	5.33	2.65	0	1	2	1
Kusanaba	7.10	8.26	2.23	2	12	4	6
Morago	4.24	14.45	3.00	0	6	0	2
Bongo	1.28	5.24	2.9	0	2	7	3
Sakote	1.58	4.81	1.27	28	5	12	15
Biung	4.36	7.99	2.50	8	0	1	3

Correlation analysis indicates a significant association between crop raiding and proximity of fields to the forest reserve. The number of crop raiding incident markedly increases with decreasing distance to the forest reserve (Pearson product-moment correlation: (r= -0.96, d.f = 5, *P*= 0.002) (Fig. 10). In line with the above, the size of crop field destroyed by elephants correlated inversely with distance of fields from the forest boundary, however the association was not statistically significant (Pearson product-moment correlation: r= -0.44, d.f = 5, *P*= 0.38).

Correlation analysis indicate an inverse association between the rate of incidents and distance of crop fields from the Red Volta River (Pearson product-moment correlation: r= -0.43, d.f = 5, P= 0.39), but the association was not significant. However, the association between the rate of incident and distance of the nearest village to the affected fields is not significant (r= -0.213, P = 0.68).

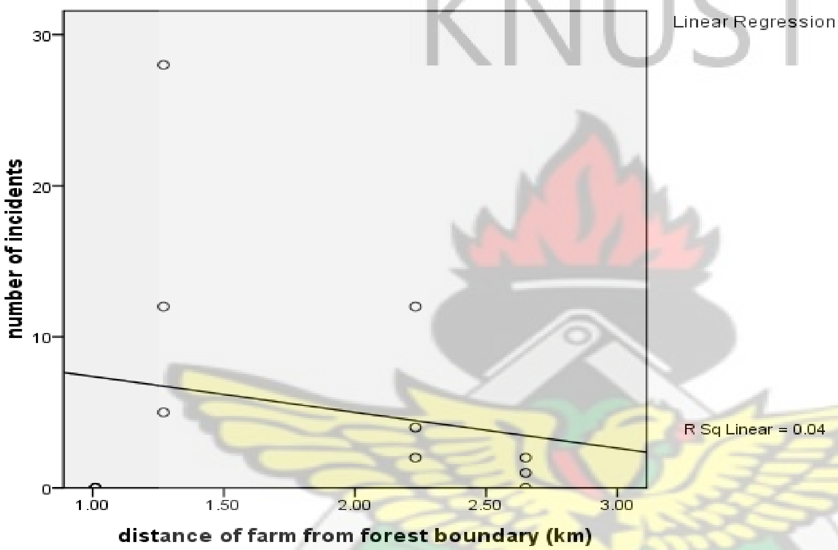

Figure 10: Relationship between distance of cultivated enclaves from the forest, and the annual rate of elephant crop raiding in six localities of the Red Volta valley in 2000-2002.

Linear regression of the distance of farm enclave from the nearest village and rate of incidents gave a best fit slope of zero, meaning there is no association between these variables (Fig 11).

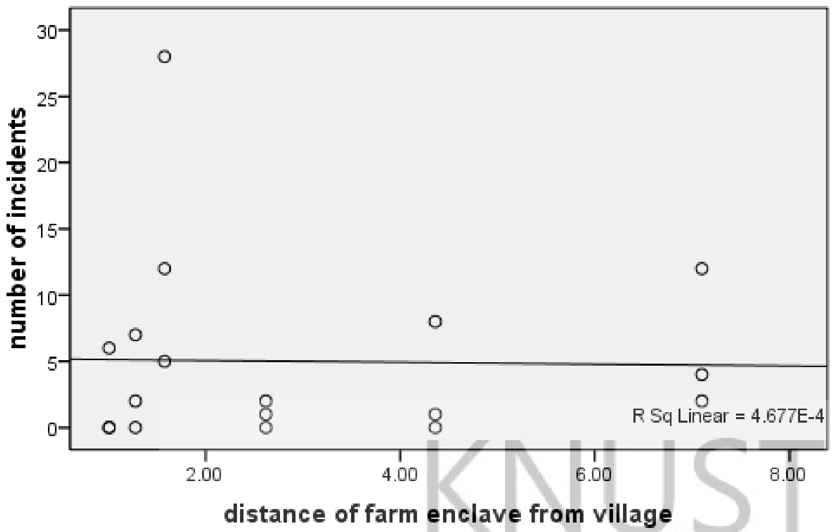

Figure 11: Relationship between distance of cultivated enclaves from the nearest community, and the annual rate of elephant crop raiding in six localities of the Red Volta valley in 2000-2002.

4.4.4 Functional relationship between crop-raiding and the key habitat variables of the Red Volta Valley

A functional relationship between the rate of crop raiding incident and some key habitat variables is determined using a Regression Model. In this analysis, twelve potential variable of the rate of crop raiding are considered (Table 19).

Table 19: Potential predictor variables of the rate of elephant crop raiding incidents in six localities of the Red Volta Valley

Locale	Crop area destroyed (ha)	density of woody plants (stm/m)	Diver-sity index	# raids/ yr	# of farmers	area cult (ha).	Dist. of enclave from village (km)	Dist. of enclave to River (km)	Dist. of enclave from Forest (km)	Area burn-ed (ha)	area cleared (ha)
Tilli	0.634	0.222	37.92	1	112	251	2.62	5.3	2.65	8000	0
Kusanab	3.184	0.229	48.37	6	82	222	7.1	8.3	2.33	9000	2000
Morago	2.653	0.233	58.14	1	160	463	4.24	14	x	7000	500
Bongo	5.438	0.266	33.38	3	114	251	1.28	5.2	x	x	x
Sakote	5.878	0.272	47.61	15	398	1105	1.58	4.8	1.27	6000	250
Buing	0.6	0.268	42.04	3	195	585	4.36	8	x	8500	750

x=missing data

Model

When the number of elephants per locale is exempted from the list of potential key factors entered for the regression analysis, stepwise algorithm chooses "distance of the affected farmed enclave to the forest boundary" as the only predictor of rate of elephant crop raiding in a locale. The relationship between the rate of incident and proximity of farmed enclave to the forest is provided by the model below (equation 1):

$Y = 25.105 + 3.2 – 9.73X$ -------------------------- **(Equation 1)**

Where Y= expected rate of incident

X= distance of the affected enclave from the nearest forest boundary

Rate of incident = Intercept + standard error of estimate + coefficient x distance of enclave from forest boundary ………. **(Equation 2)**

The model (Equation 1) is arrived at when the standard error estimate and coefficients of the regression (Table 20) are accounted for in equation 2. It indicates an inverse relationship between rate of incident and distance of the affected enclave from the forest boundary, and predicts a best guess of the rate of incident in a locality of the Red Volta to average 4.83± 2.75 inc. /annum. The model states that the expected rate of incident in a locale is equal to 25.1 x distance of enclave from the forest – 9.73. For Sakote, where the distance of enclave to forest boundary is 1.27km, the predicted rate of incident using Model 1 is 15.95 incidents/annum.

Table 20: Coefficients of regression and collinearlity statistics of Model 1

Model 1	Unstandardized Coefficients		Standardized Coefficients			Correlations			Collinearity Statistics	
	B	Std. Error	Beta	T	Sig.	Zero-order	Partial	Part	Tolerance	VIF
(Constant)	25.105	6.743		3.723	.020					
distance of farms from forest boundary	-9.730	3.174	-.838	-3.066	.037	-.838	-.838	-.838	1.000	1.000

The ratio of the regression and residual sums of squares indicate that 70% of the variation in incident is explained by the model (Regression sum of squares = 98.79, residual=42.04, total =140.8; R square= 0.72). Furthermore, ANOVA indicates that the variation explained by the model is not due to chance (F=9.40, *P*=0.037).

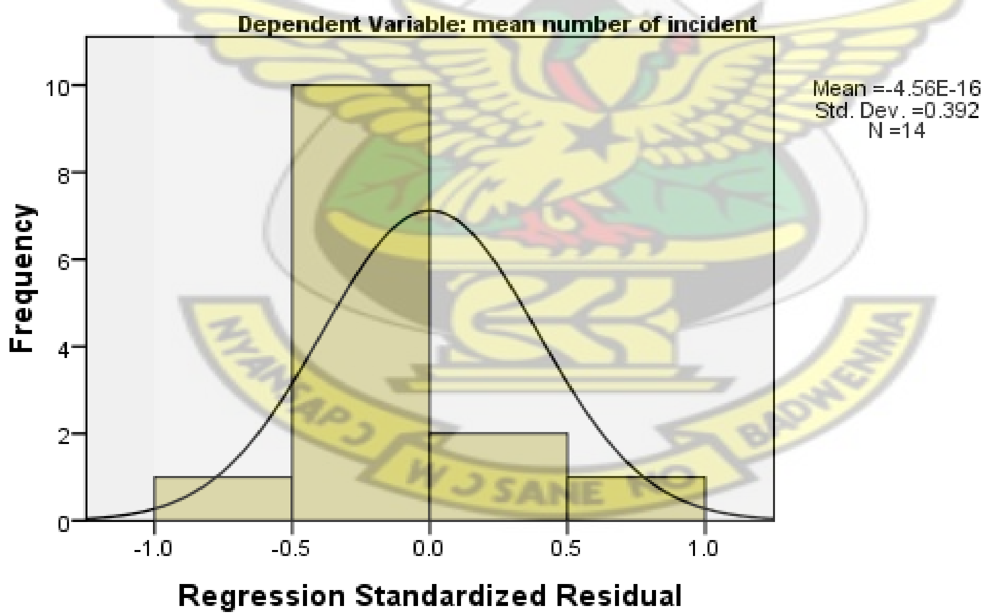

Figure 12: A histogram and normality plot of the residuals against frequency of elephant crop raiding incidents

The histogram and normality plot of the residuals fairly follows the shape of the normal curve (Figure 12). The difference between the observed and model-predicted rates of incident for each locale is shown below (Figure 13).

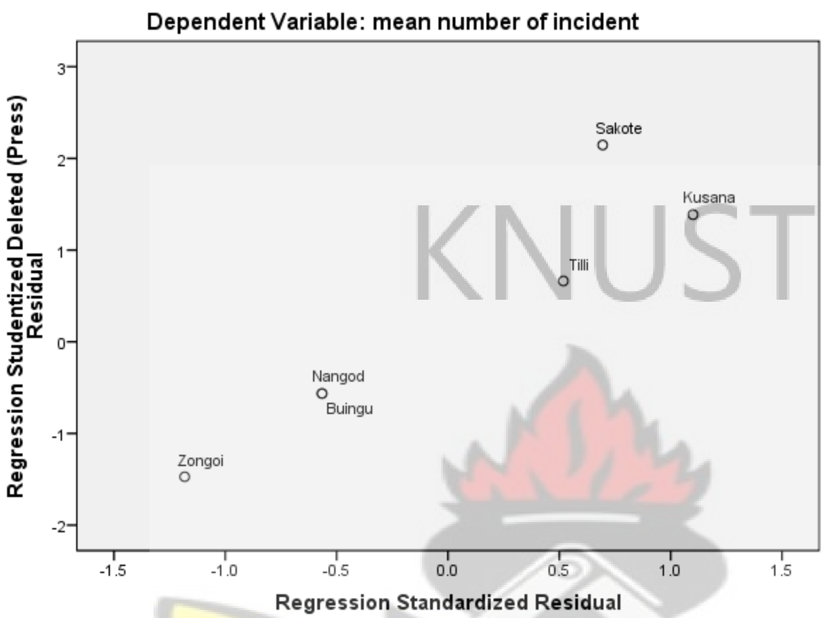

Figure 13: Scatter plot of the residuals against frequency of elephant crop raiding incidents

The multiple correlation coefficient (R) is examined for the strength of the relationship between the model predicted values and the observed rate of incident. When this was carried out, Stepwise regression indicates a high correlation coefficient (R=0.838), and a strong coefficient of determination (R^2= 0.702). As a further measure of the strength of the model fit, the standard error (2.24 incidents/annum) compare favourably with the standard deviation of incident (of 2.75 incidents/annum).

CHAPTER FIVE

5.0 Discussion

5.1 Elephant Crop Raiding Pattern

5.1.1 Extent of damage and crops affected

The percent of crop fields affected, and the proportion of the cultivated area destroyed per affected field were relatively low in the Red Volta Valley. Each year, a maximum of 3% of crop fields were affected. Because the study attracted and registered only farmers at risk (i.e. fields within enclaves prone to elephant raids), the overall incidence of crop-raiding is lower than 3% of farmers, as fields outside the crop raiding zone were not considered in this estimate. In light of the above, the extent of crop raiding observed (i.e. size of crop fields destroyed, and the rate of elephant crop raiding per locale) reflect the worse scenario. Furthermore, most raided fields suffered ≤ 20 % crop loss, and it is inferable from the results that in the event a field is raided, there is a 50% chance that less than half the cultivated area will be destroyed.

Although reliable baseline data are lacking for an objective comparison of the observed crop raiding pattern with historic records gathered prior to 1999, anecdotal records suggest a decline in the size of crop field destroyed, and rate of incidents from previous highs. Using interviews with farmers, NCRC (2000) estimated as much as 400ha of crop fields was destroyed by elephants over a 2-year period (1995-1996). Compared to a documented total of 18ha of cropland destroyed during 2000-2002 (Adjewodah 2004), this translates to about 95% decline.

Relative to other conflict sites, the size of crop field damage, and rate of incident experienced by farmers in the Red Volta are on the low side. Around the Maputo elephant reserve in Mozambique, elephants destroyed over 100ha of crop fields within 30 days (de Boer and Ntumi 2001). In the Zambezi valley (an area of about 2774 km^2) over 300 crop raiding incidents were reported within a two year period involving both wet and dry season crops (Parker and Osborn 2001). In southern Ghana, around the Kakum National Park, the affected farmers on the average lost as much 50% of their farm and as many as 140 fields were affected within a year (Barnes *et al.* 1995).

Elephant crop raids were less frequent in periods when crops are still immature, and the more productive fields had a relatively greater damage. This agrees with observed patterns in most conflicts sites in Africa. In the Zambezi valley, over 75% of raided crops were in the advance (mature) stage, and only 2% of incidents involved crops at the seedlings stage (Parker and Osborn 2001). Similarly, elephants at the Maputo reserve in Mozambique selected fields with mature crops ready for harvest (de Boer and Ntumi, 2001). Elephant in the Bia Conservation Area raided mainly mature crops (Oppong *et al.* 2008).

Although elephants are generalist feeders, they chose certain crop species over others (Sukumar 2003). The Red Volta elephants were extremely attracted to mature finger millet, as millet fields recorded the highest proportion of damage of 30% (Table 3). Parallel to the observed pattern in the Red Volta Valley, Sukumar (1990) found that finger millet makes the highest contribution among crops raided by the Asian elephant, and showed that selection of fields was biased towards high quality crops in inflorescence or grain stage. It was found that elephants' preference for millet in the mature stage is in line with optimum foraging strategy of a mega browser (Sukumar 1990, 1994). Choice of millet could be due to the sensory properties of elephants, succulent nature of the vegetative crop, level of calories and minerals (Sukumar 2003).

The relative abundance or availability of crops is important, as this could also explain the observed preference for some crops. Because a particular plant item is consumed frequently does not necessarily mean it is a preferred food plant, as a positive or negative preference for a particular food item has to be scored in relation to its availability in relation to other plant species. In light of this the size of field of the crops cultivated were compared across locales to determine variation in the availability, but the test indicates there was no significant difference availability of crops. Although millet as the most common crop within the affected landscape, the hectares of this crop was not significantly different from that of the other crops. This argument further enforces the importance of the superior nutritional value of millet as the main factor in the elephants' preference for this crop.

5.1.2 Geographic and temporal variations

The results indicate that the risk of elephant crop raiding did not differ significantly between the six locales. In other words, the burden of crop damage was evenly spread among affected localities. The geographic location of the locale had no significant influence on the observed crop raiding pattern and no one locale had a relative disadvantage of increased raiding incidents as a result of its location.

The observed raiding pattern underscores the wide ranging habits of elephants. Elephants range widely and they sort farms with preferred crops irrespective of the locale where the crops occurred (Sukumar 2003). Because the crops they preferred were evenly available across the six locales (Section 4.1.1), the lack of variation in incident pattern among the locales is expected to be the case, and the even distribution of incidents reflects the lack of significant difference in the availability of affected crops.

Annual variation in incident was not significant. Rather, crop raiding incidents relates to the presence of elephants in the study area. For example, the lack of incidents in 2003 was because elephants apparently did not cross into the Red Volta from their dry season range in Burkina Faso (Adjewodah 2004). In that year, migratory herds of elephants on the Burkina Faso side of the border moved to as close as 7 km to the Ghana border but did not cross into the Red Volta (Sawadogo 2003).

Crop raiding in the Red Volta peaked during harvest, parallel to observed patterns elsewhere on the continent (Sukumar 2003, Barnes 2002, and Sawadogo 2003). In the savanna of Zimbabwe, elephant crop raiding occurred mostly in the wet-season and peaked with maturation of crops (Parker and Osborn 2001). Because elephants were in the Red Volta seasonally and crop raiding incidents were concentrated in a few months close to the time crops are harvested, managers can up mitigation measures during this period to maximize the impact of mitigation measures.

5.2 Elephant browse and habitat degradation in the Red Volta Valley

5.2.1 Density and diversity of elephant browse

There was no evidence to suggest that elephant browse was limiting within the Red Volta valley, as potential browse constitute about a quarter of the woody plants recorded. Woody stems (in both browse and non-browse categories) were homogeneously distributed among locales. The abundance, diversity, and richness of browse were near the asymptotic estimates or optimum values expected for a savanna ecosystem. The second order jackknife species richness (diversity) estimator predicted a species diversity that was not significantly different from the actual number of species observed. This observation implies browse (with respect to density and diversity of trees and shrubs) was near the optimum. This inference is based on the fact that Michaelis-Menten and Jackknife estimates are asymptotic values (Colwell 2005, Gotelli and Colwell 2001).

The results indicate that two in every ten woody plant species are edible to elephants. In parallel, a study in Zimbabwe found that a bulk of the browse intake by elephants relates to only a few species. In the savanna of Uganda, examination of the stomach content of elephants revealed only 25 species in their diet, which compares with the 11 browse species recorded in the Red Volta. Some previous studies (NCRC, 2000, Sam *et al.,* 1998, Okoumassou *et al.* 1998) of the Red Volta elephants speculated lack of natural browse in the core habitat of the Red Volta elephants, and had gone further to link crop raiding to lack of browse. Inferring from the results however, this present study did not find the evidence to show that density and diversity of browse is markedly different from the optimum.

5.2.2 Extent of habitat degradation in the Red Volta Valley

Over 90% of the vegetation area sampled showed sign of fire burn. Elsewhere in West Africa, it was observed that elephant prefer unburned vegetation when standing/resting, i.e. for cover (Mcshane 1987). But it is also reported that elephants when feeding select burned areas with re-sprout induced by early dry season fire, which provide a fresh source of food (McShane 1987).

Though the direct impact of uncontrolled fire on elephants in the Red Volta Valley was beyond the scope of this study, evidence of the impact of uncontrolled fire on vegetation elsewhere in Ghana indicates that over a long period, uncontrolled fire could lead to irreversible degradation (Oteng-Yeboah and Asase 2001), which could become a major constraint on habitat and resource availability for elephants.

This is because wildfire has an influence on the distribution of woody stems, in this case browse, among diameter classes (Oteng-Yeboah and Asase 2001). Typical of a fire-proclimax habitat a majority of the stems enumerated in the Red Volta fall within the recruitment class of < 5cm dbh and may not be readily available to elephants. However some 80% of woody stems in the diet of savanna elephants were found to come from woody plants larger than 5cm dbh (Spinage 1994). Elephants prefer to browse from 1 to 2 m above ground level (Spinage 1994), and trees in the recruitment class fall outside this range. This imply the plants observed in the recruitment class in the Red Volta, even when they are categorized as browse species, may temporarily be overlooked by elephants.

There is no evidence however that the 20-30% of the enumerated plants which are larger than the recruitment is inadequate source of browse for the Red Volta elephants. At a given time and season, only a fraction of the plant population is required to provide the needed resources for elephants (Sukumar 2003, and Spinage 1994). Plants in the recruitment class serve as a vital reservoir for restocking the upper classes through succession, provided they grow beyond the threshold above which most savanna trees acquire adaptation to fire damage (Oteng-Yeboah and Asase 2001).

Though pit mining and clear felling of vegetation were reported by the field team these activities were limited in spread, and this explains why they were not recorded in any of the vegetation quadrats.

The impact of elephants on the woody vegetation of the Red Volta was not significant, as only 2 out of the enumerated plants showed any sign of damage caused by elephants. The absence of elephant feeding sign/activity was a reflection of the seasonal status of the elephant population as outlined in section 4.3 (which described the elephant population and seasonal migration). Absence of feeding related damage to vegetation in the sampled plots also supported findings that elephants were absent for most of the period during 2003. By inference, the low elephant numbers observed (section 4.3) as well as seasonal migration and clumped distribution provide the most tangible explanation for the absence of any significant impact of elephants on the vegetation.

5.3 Distribution of the Red Volta elephant and its trans-frontier migration

5.3.1 Abundance and distribution of the Red Volta elephant population

This study estimated about 2.5 elephants in the Sakote locale, and none in the other areas, during December 2002-June 2003. Sam *et al.* (1994) used footprint measurements to identify groups and estimated 100-150 resident elephants for the Red Volta; a much higher abundance than observed during this current study. The relatively low elephant estimate observed in the locales reflects the seasonal migration of elephant population. The results thus suggest elephants used the Red Volta valley as a seasonal range. The estimates provided by this study captured a small group of animals that remained in the Red Volta valley from December 2002-June 2003, and moved into Burkina Faso later in the year. It is inferable from the results that the population of elephants in the Red Volta is low during a greater part of the year, and the elephant range can no longer maintain its position as holding the third largest savanna elephant population in Ghana (Wildlife Services Division, 2000). A revision of the relative importance of the Red Volta valley for conservation of elephant in Ghana is thus necessary.

5.3.2 Trans-frontier migration of the Red Volta elephant population

Trans-frontier movement of elephants was observed across the Ghana-Burkina Faso boundary only, and there was no evidence of the movement of elephants across the Ghana-Togo frontier. During 2000 and 2003, elephants were in the Red Volta occasionally, and their stay overlapped the period when crop were ready for harvest (August-Nov).

The lack of any evidence of elephant movement across the Ghana-Togo boundary agrees with the estimate of zero elephants for the Zongoiri/Morago locale, as this locale is the nearest among the six to the Ghana-Togo frontier. The lack of elephant signs on the Ghana-Togo elephant migration route is further supported by zero crop-raiding reports for this locale and adjoining communities.

The results however contrast with anecdotal records of brisk elephant activity along the Ghana-Togo frontier. It was reported that in the 1980s and 1990s, elephants made regular movement across border, and at one time there was an influx of elephants in the Fosse aux Lions National Park (in Togo) due to disturbance of elephants by hunters on the Ghana side of the border (Stalmans and Anderson, 1992 and Okoumassou *et al.* 1998). There are also records of elephants moving in large herds from Togo into the Red Volta area in the 1980s and 1990s. Stalmans and Anderson (1992) and Lowry and Donahue (1994), reported of migration of large herds of elephants from Togo across the frontier into the Red Volta apparently in response to hunting and encroachment.

The relatively low number of elephants observed during 2003, and the evidence of migration of elephants across the border into Burkina Faso suggest that elephants used the Red Volta valley as a seasonal range. Seasonal migration of elephants in and out their regular range could be either a response to changes in the ecosystem or catalyzed by an internal biological clock (Sukumar, 2003 and Spinage 1985). The prevalence of elephants in June noted during this study overlaps with the availability of wild fruits sort after by elephants. In particularly, the fruits of *Vitellaria paradoxa*, *Borassus palm, and Lannea sp* ripe and common between March and June (Adjewodah 2004). Seasonal migration of elephants elsewhere in West Africa is influenced by rain, the fruiting circle of seasonal fruit trees, human disturbance, and the availability of sufficient food and cover (Barnes *et al.* 1991, Jachmann 1988, Sam *et al.* 2002, and Osborn 2003).

The migratory movements of elephants between Ghana and Burkina Faso have been in existence for several years now. Jachmann (1992) observed an apparent increase in the abundance of elephants in the Nazinga Game Reserve, and suspected this was due to immigration of elephants resulting from improved law enforcement and increased availability of permanent water provided by dams newly constructed in the Reserve. Sam (1994) reported of the movement of elephants across Ghana-Burkina Faso frontier.

The seasonal movement in and out of the study area across the Ghana-Burkina Faso frontier did not follow a regular pattern during the study period. In 2003, there was no evidence of elephants migrating into the study area during the harvest period (from August to November), in a clear departure from the routine observed from 2000 to 2002 when elephants migrated from Burkina Faso and damaged harvestable crops.

No efforts were made to trace elephants into Burkina Faso, as it is beyond the scope of this study. However, it is suggested in available literature that the study area shares the same elephant population with the Kabore-Tambi National Park in south central Burkina Faso (Jachmann 1988, Sawadogo 2003). The conservation of the Red Volta thus of utmost importance for the conservation of the shared elephant population with Burkina Faso.

5.4 Association between elephant crop-raiding and some key variables of the Red Volta Valley

5.4.1 Association between crop-raiding, extent of browse, habitat degradation and abundance of elephant

This study did not observe any marked association between crop-raiding by elephants and the status of their natural habitat. In other words the rate of incident and the size of cropland destroyed by elephant are not significantly related to either the density or diversity of the woody trees and shrubs that form the bulk of the elephant's food requirement. It is also not related significantly to the extent of degradation observed in the locales.

For most of the analyses by this study, the outcome indicated a weak positive association between crop raiding and the extent of browse and habitat degradation. This reflects observations from some conflict sites on the continent where it was found that crop enclaves situated near superior habitat rather experienced increased raids than those near resource poor habitats. Parallel to the results Sukumar (2003) found no clear relationship between crop raiding and the status of elephant habitat in the immediate vicinity of the cultivated track. He found that crop raiding by elephants was influenced by several attributes of their habitat which were not mutually exclusive, but interrelated in a complex fashion that was poorly understood.

On a related note, the variation observed in the local abundance of elephants did not reflect in any significant way in the rate of incidents. Elephants range widely when foraging (Sukumar 2003), and this could account for the lack of correlation between elephant abundance and crop raiding on a local scale.

As there was not sufficient evidence to suggest that browse density and diversity, and habitat degradation in the Red Volta Valley relate significantly with the abundance of elephants and with frequency (rate) of incident, any mitigation measures that target reforestation of the forest reserves to improve stocking of browse for elephant will not leave the desired impact, as elephant will still crop raid.

5.4.2 Association between crop raiding and the extent of crop field

This study did not observe any marked association between crop raiding by elephants, and the extent of field cultivated in the six study locales. Though some level of association was found between the size of cultivated crop field destroyed by elephants and the total size of the enclave cultivated, this was weak and lacked statistical significant. In parallel, the rate of incidents also showed a weak association with size of crop field cultivated. However, in line with general principle and expectation, the rate and extent of crop raiding has a positive association with the extent of cropland in all cases.

Barnes *et al.* (2003) found that the rate of crop raiding was proportional to the density of farms. Sukumar (1990) also found that the frequency of crop raiding during different months in the years was proportional to the area of land under cultivation. However, they made these observations at conflict sites where elephants are present year round. In the Red Volta, the elephant population is seasonal and the extent and rate of crop raiding is more dependent on the seasonal migration of elephants. For instance, in 2003 there was no reported incident even though the size of cultivated land and crop availability had not changed markedly. This was because that year, there was a marked change in the migration pattern (Section 4.3), and elephants were not in the Red Volta during the crop raiding season (Sawadogo 2003) and Section 4.1.2. Parallel to the observed pattern in the Red Volta, Sukumar (2003) noted contact of elephants with agriculture fields in their course movement, and he found a correlation between crop raiding and migration.

5.4.3 Association between crop raiding and geographical location of affected enclaves

In line with general principle and observations from some other conflict sites on the continent, this study reports a marked association between proximity of fields to the nearest forest reserve boundary and the rate of incidents. Within the Zambezi valley, Parker and Osborn (2001) found a strong non-linear relationship between distance classes and frequency of incidents, and rate of incidents increased rapidly with decreasing distance from the core elephant habitat. Also around the Kakum National Park (Barnes *et al.* 2003) and the Bia Conservation Area in Ghana (Oppong *et al* 2008), the risk of crop-raiding was highest for those farms immediately adjacent to the park.

The results provide a scientific basis for argument by previous works in the Red Volta (NCRC 1999; 2000 and Sam *et al.* 1997) that preference of elephants for the forest reserves means farms nearer the forest are at greater risk of being affected. This study does provide scientific evidence in support of the recommendation to relocate farms away from the forest reserve for reduced crop raiding.

5.4.4. Functional relationship between crop raiding and habitat variables

Stepwise algorithm chose the factor "distance of affected enclave to the forest boundary" as the only important habitat variable influencing the rate of incident. It was selected by the algorithm from the list of potential variables because it best accounted for the rate of elephant crop raiding. The other potential variables were ignored by the stepwise algorithm, because after adding "distance of enclave to the forest" none of the remaining variables made any significant addition to the model.

The observed rate of incident and the predicted rates generated by the model compares closely. Taking Sakote for instance, where the distance of the locale's farmed enclave is only 1.27km from the forest boundary, the predicted rate of incident generated by the model is 15.948 incidents/annum, which compares closely with the observed rate of 15 incidents/annum. The model does a good job of modelling the rate of incident in a locale as the R square value of 0.72 means that about 70% of the variation in rate of incident is explained by the model. The significant F statistic further indicates that the prediction of rate of incident using the model is statistically reliable.

CHAPTER SIX

6.0 Conclusion and Recommendations

6.1 Conclusion

The Red Volta area provides habitat for a small population of elephants that seasonally migrate between Ghana and Burkina Faso, and raid crops fields in the Red Volta Valley during the harvest season. The rate of elephant crop raiding incident and the extent of destruction to affected farms are low in the Red Volta Valley. There is only about a 3% chance that a farmer cropping anywhere within the affected zone will lose crops to elephants. Even for the unfortunate farmers who are affected, there is a 50% chance that the crops within more than half of the affected farm will be spared from destruction, and thus could still be harvested. Incidents peaked in October when the most affected crops (millet, Guinea corn, groundnut, and rice) have reached the harvest stage. The pattern of elephant crop raiding was not markedly different among locales, and neither did it vary annually among the cropping seasons.

The Red Volta Valley holds adequate browse resources for elephants, as two in every ten of the woody plants recorded are edible to elephants. The diversity of woody plants is near the optimum expected value for the area. Wildfires were extensive, and poses the greatest threat to elephant browse resources relative to pit mining and clear felling of vegetation. The high percentage of enumerated plants within the recruitment size is a manifestation of the effect of fires on the vegetation.

The rate of crop loss can be predicted from the proximity of cultivation to the nearest forest boundary, but it is not markedly influenced by abundance of elephants, extent of degradation and the diversity of woody plants. Thus a mitigation plan targeted at relocating fields away from the forest reserves will yield positive results. The notion that elephants will seek for alternative sources of food within croplands if natural browse resources are poor is not upheld. In this regard any mitigation measure aimed at reforestation of the Red Volta reserves to improve stocking of browse for elephant will not leave the desired impact, as elephant will still crop-raid. Because incidents peaked during harvest in October each year, managers can up mitigation measures during this month to maximize the impact of mitigation measures.

Some of the findings for the Red Volta contrasts with observations at some other elephant conflict sites and underscore the unique characteristics of the Red Volta range. Rather than relying on general rules based on observations from other conflict sites, the observations from this study should inform the fashioning a site specific mitigation plan for the Red Volta. Even though the extent of damage and raiding frequencies are low, it is still necessary to help farmers reduce lose of crop to elephant, as a single former affected can cause animosity against elephant by the whole community.

6.2 Recommendations

This study gives the following specific recommendations:

- Moving some farms away from the reserve boundary will help reduce elephant raiding, and is recommended as a mitigation strategy for the Red Volta range.
- The status of the Red Volta/Nazinon River Valley between the Ghana-Burkina Faso boundary (i.e. the northern end of the Ghana range of the elephant corridor) and the southern end of the Kabore-Tambi National Park within Burkina Faso should be investigated, through a joint Ghana-Burkina Faso initiative
- A study should be conducted on the current status of elephant migration along the complete range of the Nazinga-Kabore Tambi-Red Volta- Doung Corridor which includes the Sissili Valley and Mole NP. There is very little information on migration along the Sissili River between Mole National Park in Ghana and Nazinga Ranch in Burkina Faso. This will support ongoing efforts to establish a corridor to link these ranges.
- The elephant population is seasonal, and the elephant range can no longer maintain its position as holding the third largest savanna elephant population in Ghana. A revision of the relative importance of the Red Volta valley for conservation of elephant in Ghana is thus necessary.
- The key to successful management of the Red Volta elephant range lies in collaborative effort of all stakeholders in-country and across the border. A collaborative community reserve approach, which will make the local communities decision makers (and not outsiders) on the resources and benefactors from elephants and not victims of its activities hold a promising future for elephants and their habitat in the Red Volta Range.

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Appendices

Appendix 1 Species frequency and abundance tables

1.1 # Species frequency and abundance table for Biung

Locale: Biungu				**Transects**							
Transect	*15*	*1*	*6*	*19*	*2*	*12*	*13*	*18*	*4*	*9*	
Species	Freq.	Freq.	Freq.	Freq.	Freq.	Freq.	Freq.	Freq.	Freq.	Freq.	#/ha
Acacia hockii	3	0	0	14	3	0	6	10	6	0	42
Acacia nilotica	0	0	0	2	0	0	0	0	0	0	2
Annona senegalensis	0	1	8	6	7	1	18	9	4	0	54
Anogeissus leiocarpus	0	0	0	0	0	0	0	0	0	1	1
Bombax costatum	0	0	1	0	2	0	0	0	0	0	3
Cissus populnea	0	7	0	0	0	0	0	0	0	0	7
Cochlospermum planchoni	2	0	0	1	5	0	3	3	0	0	14
Combretum sp.	12	9	14	11	13	24	9	12	15	10	129
Crossopteryx febrifuga	2	5	11	3	20	12	12	1	10	1	77
Daniellia oliveri	0	0	0	0	0	3	1	0	0	0	4
Detarium microcarpum	36	39	21	71	153	40	98	130	64	0	652
Detarium senegalensis	14	39	4	10	14	0	29	3	36	0	149
Dichrostachys cinera	0	6	0	0	0	55	0	0	11	5	77
Dichrostachys glomerata	0	1	0	0	0	90	0	0	0	0	91
Diospyros mespiliformis	0	0	0	0	3	0	0	0	0	0	3
Entada africana	1	0	0	0	2	.	0	0	0	0	3
Ficus platyphylla	0	0	0	0	0	1	0	0	0	0	1
gardenia aqualla	5	0	0	2	1	0	2	0	1	0	11
Gardenia ternifolia	4	1	2	2	2	1	8	10	2	0	32
Grewia mollis	0	2	1	1	0	2	0	5	5	1	17
Hymenocardia acida	1	1	0	0	0	0	0	0	0	0	2
Khaya senegalensis	0	1	0	0	0	0	0	0	0	0	1
Kusangsiring	0	0	0	50	0	0	0	0	0	0	50
Lannea kerstingii	0	0	1	0	0	0	0	0	0	0	1
Lannea acida	0	0	0	0	0	0	0	3	1	0	4
Lannea Acida	0	0	0	0	1	0	0	0	0	0	1
Maytenus senegalensis	0	0	0	3	0	0	0	1	0	0	4
Mitragyna inermis	0	0	0	0	1	0	0	0	0	20	21
Mitragyna sp.	0	5	0	0	0	2	0	0	0	0	7
Nauclea latifolia	0	1	0	0	0	0	0	0	0	0	1
Pericopsis laxiflora	4	32	0	0	0	0	0	0	0	0	36
Piliostigma thonningi	0	1	1	1	0	9	0	3	0	3	18
Prosopis africana	8	0	6	0	0	1	1	0	0	0	16
Pteleopsis subarosa	28	0	23	112	84	0	63	9	32	0	351
Pterocarpus erinaceus	6	3	2	3	1	1	4	4	0	0	24
Securidaca longepeduncul	3	0	0	2	0	0	0	0	1	0	6
Securinega virosa	0	1	0	2	0	19	0	1	0	8	31
species 25	0	0	0	0	0	1	0	0	0	0	1
Species 6	0	0	0	0	5	0	0	0	0	0	5
Species 8	3	0	0	0	0	0	4	0	0	0	7
Stereospermum kunthianum	6	0	2	19	5	1	4	7	4	0	48
Strychnos spinosa	33	25	49	33	40	12	28	46	55	0	321
Tamarindus indica	0	1	0	0	0	0	0	0	0	0	1
Terminalia macroptera	20	14	113	12	3	3	22	18	13	0	218
Vitellaria paradoxa	4	0	4	40	2	11	14	50	8	3	136

1.2 Species frequency and abundance table for Kusanaba

Locale: Kusanaba

Transect #:	*18*	*14*	*9*	*13*	*4*	*7*	*5*	*8*	*17*	*3*	
Species	*Freq.*	*Freq.*	*Freq.*	*Freq.*	*Freq.*	*Freq.*	*Freq.*	*Freq.*	*Freq.*	*Freq.*	*#/ha*
Combretum sp.	59	81	25	8	49	69	27	72	40	43	473
Piliostigma thonningi	3	8	1	12	26	9	13	8	17	20	117
Annona senegalensis	22	3	9	6	3	2	4	3	11	0	63
Vitellaria paradoxa	44	15	20	33	3	5	26	7	8	0	161
Acacia hockii	14	21	25	0	0	33	26	31	33	69	252
Acacia nilotica	56	13	0	5	18	43	3	78	0	2	218
Entada africana	6	0	0	1	6	1	5	1	4	13	37
Terminalia macroptera	11	4	71	95	3	3	3	.	6	0	196
Acacia gourmaensis	21	33	0	0	1	0	1	17	15	0	88
Cochlospermum planchoni	10	5	1	0	11	1	0	0	46	2	76
Gardenia ternifolia	2	1	1	4	1	0	0	1	3	0	13
Maytenus senegalensis	11	0	7	0	1	1	1	1	3	0	25
Grewia mollis	5	1	4	0	11	1	0	3	0	0	25
Pterocarpus erinaceus	3	1	3	19	1	0	0	7	0	0	34
Detarium microcarpum	2	.	65	1	1	0	0	1	0	0	70
Stereospermum kunthianum	28	8	21	3	0	0	0	3	0	0	63
Cissus populnea	8	6	6	.	0	2	0	0	0	0	22
gardenia aqualla	2	3	.	2	0	.	1	0	0	0	8
Strychnos spinosa	2	10	22	0	0	1	0	0	0	0	35
Bombax costatum	2	.	3	0	0	13	0	0	0	0	18
Crossopteryx febrifuga	2	2	0	0	0	0	0	0	0	0	4
Lannea kerstingii	0	.	0	0	0	0	1	0	1	1	3
Lannea acida	0	2	3	0	0	1	0	0	0	0	6
Pteleopsis subarosa	3	0	40	0	94	0	0	0	0	0	137
Anogeissus leiocarpus	4	0	3	0	0	0	0	0	0	0	7
Kusangsiring	3	4	0	0	0	0	0	0	0	0	7
Lannea microcarpa	0	0	0	0	3	0	0	0	0	0	3
Parinari curatellifolia	0	0	0	7	0	0	0	0	0	0	7
Prosopis africana	0	0	0	12	0	1	0	0	0	0	13
Species 8	0	9	5	0	0	0	0	0	0	0	14
(Omah)	0	0	0	0	0	0	5	0	0	0	5
Cissus sp.	0	0	0	0	0	0	2	0	0	0	2
Daniellia oliveri	0	0	0	41	0	0	0	0	0	0	41
Detarium senegalensis	0	0	1	0	0	0	0	0	0	0	1
Dichrostachys cinera	0	0	0	0	0	0	0	0	0	2	2
Diospyros mespiliformis	0	12	0	0	0	0	0	0	0	0	12
Ficus platyphylla	1	0	0	0	0	0	0	0	0	0	1
Ficus sp.	0	0	0	1	0	0	0	0	0	0	1
Khaya senegalensis	0	0	0	0	0	1	0	0	0	0	1
Mitragyna inermis	1	0	0	0	0	0	0	0	0	0	1
Mitragyna sp.	0	2	0	0	0	0	0	0	0	0	2
Papilaenceae	0	0	0	0	0	0	11	0	0	0	11
Parkia biglobosa	0	0	0	5	0	0	0	0	0	0	5
Poabisim	2	0	0	0	0	0	0	0	0	0	2
Pseudocedrela kotschyi	0	0	0	0	0	0	0	0	1	0	1
Sclerocarya birrea	0	0	0	0	1	0	0	0	0	0	1
Securidaca longepeduncul	0	0	0	0	0	0	2	0	0	0	2
Securinega virosa	0	0	0	2	0	0	0	0	0	0	2

1.3 Species frequency and abundance for Tilli

Locale: Tilli

Transect	*4*	*6*	*5*	*14*	*13*	*9*	*18*	*15*	*11*	*2*	
Species	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***#/ha***
Acacia nilotica	1	3	66	14	84	24	46	31	55	54	378
Combretum sp.	64	12	41	80	31	1	68	35	54	57	443
Acacia hockii	4	8	3	0	22	1	10	29	16	40	133
Piliostigma thonningi	1	36	0	16	5	8	0	1	3	6	76
Acacia gourmaensis	18	2	16	10	11	0	13	9	0	0	79
Cochlospermum planchoni	10	8	0	8	0	4	2	6	1	0	39
Entada africana	2	1	0	5	3	0	0	5	6	3	25
Gardenia ternifolia	3	5	7	11	3	0	3	7	0	0	39
Lannea acida	3	1	0	2	0	0	3	1	1	0	11
Stereospermum kunthianum	60	1	25	7	0	2	9	18	0	0	122
Terminalia macroptera	24	84	6	120	0	7	2	9	0	0	252
Vitellaria paradoxa	4	39	0	22	3	5	1	18	0	0	92
Pterocarpus erinaceus	4	9	1	0	0	1	6	1	0	0	22
Annona senegalensis	2	3	2	6	0	0	0	0	1	0	14
Maytenus senegalensis	2	0	1	0	0	2	1	0	0	0	6
Anogeissus leiocarpus	0	0	1	0	13	2	0	0	0	0	16
Detarium microcarpum	13	2	0	2	0	0	0	0	0	0	17
gardenia aqualla	0	0	0	12	0	1	0	0	1	0	14
Hymenocardia acida	4	1	2	0	0	0	0	0	0	0	7
Strychnos spinosa	0	3	0	2	0	0	1	0	0	0	6
Species 8	2	0	5	0	0	0	0	0	0	0	7
Diospyros mespiliformis	0	0	14	0	10	0	0	0	0	0	24
Ficus platyphylla	0	0	0	0	0	1	34	0	0	0	35
Grewia mollis	0	0	6	0	1	0	0	0	0	0	7
Mitragyna inermis	0	0	4	0	191	0	0	0	0	0	195
Mitragyna sp.	0	0	3	15	0	0	0	0	0	0	18
Pteleopsis subarosa	2	30	0	0	0	0	0	0	0	0	32
Securinega virosa	0	1	0	0	6	0	0	0	0	0	7
Sterculia setigera	0	0	2	0	0	0	1	0	0	0	3
Tamarindus indica	0	0	0	2	7	0	0	0	0	0	9
Bombax costatum	4	0	0	0	0	0	0	0	0	0	4
Calotropis procera	0	0	0	0	0	0	0	0	0	2	2
Lannea microcarpa	0	0	0	0	1	0	0	0	0	0	1
Neem	0	0	0	0	15	0	0	0	0	0	15
Pakia biglobosa	0	0	0	0	0	1	0	0	0	0	1
Prosopis africana	0	0	0	0	0	0	2	0	0	0	2
Sclerocarya birrea	0	0	0	0	0	1	0	0	0	0	1
Teak	0	0	0	0	0	0	0	68	0	0	68
Vitex sp.	0		0	0	0 2	0	0	0	0	2	

1.4 Species frequency and abundance table for Bongo

Locale: Bongo

Transect	*12*	*7*	*13*	*14*	*5*	*6*	*20*	*15*	*18*	
Species	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***#/ha***
Terminalia macroptera	11	45	42	50	6	13	6	62	0	261
Cochlospermum planchoni	12	20	1	28	15	13	9	31	6	150
Combretum sp.	28	26	5	42	38	16	17	70	22	293
Entada Africana	3	10	1	7	13	1	16	11	3	72
Pterocarpus erinaceus	6	11	5	13	8	3	1	4	0	57
Vitellaria paradoxa	17	20	14	8	9	7	8	13	2	109
Acacia gourmaensis	26	2	0	5	31	1	13	10	2	100
Acacia nilotica	121	47	0	0	62	123	2	5	12	413
Detarium microcarpum	8	1	0	21	0	0	18	8	1	63
Pteleopsis subarosa	7	8	36	17	3	0	20	54	10	172
Acacia hockii	62	24	0	48	135	5	7	0	7	320
Annona senegalensis	4	2	1	11	0	2	8	0	13	46
Hymenocardia acida	26	0	4	1	7	0	1	2	1	47
Mitragyna sp.	6	2	4	2	2	1	11	0	0	31
Piliostigma thonningi	3	7	2	3	2	29	0	0	4	56
Strychnos spinosa	8	2	73	24	1	0	2	1	0	123
Detarium senegalensis	3	1	1	3	10	0	0	0	9	30
Gardenia ternifolia	2	24	15	24	0	5	0	12	0	91
Lannea acida	0	4	1	1	3	0	1	1	0	12
Stereospermum kunthianum	5	6	8	13	8	7	0	0	0	52
Anogeissus leiocarpus	0	0	1	3	0	3	0	1	0	9
Species 8	3	0	3	15	0	0	4	6	0	34
Grewia mollis	1	1	4	0	0	0	5	0	0	12
Sterculia setigera	0	1	0	1	1	0	0	1	0	4
gardenia aqualla	0	1	4	0	0	1	0	0	0	7
Maytenus senegalensis	1	0	2	0	0	0	0	1	0	4
Securinega virosa	5	5	0	0	0	19	0	0	0	32
Diospyros mespiliformis	0	1	0	0	0	0	3	0	0	4
Sclerocarya birrea	0	0	0	0	0	1	1	0	0	2
Securidaca longepeduncul	13	0	5	0	0	0	0	0	0	20
Afzelia Africana	0	0	2	0	0	0	0	0	0	2
Bombax costatum	0	0	0	0	2	0	0	0	0	2
Lannea microcarpa	0	0	0	0	0	1	0	0	0	1
Species 8	0	25	0	0	0	0	0	0	0	28
Species 11	0	0	1	0	0	0	0	0	0	1
Species 9	0	0	0	0	1	0	0	0	0	1

1.5 Species frequency and abundance table for Morago

Locale: Morago

Transect #:	*10*	*2*	*17*	*6*	*4*	*1*	*9*	
Species	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***#/ha***
Pteleopsis subarosa	38	34	0	0	8	26	50	223
Terminalia macroptera	115	40	14	0	12	107	0	411
Strychnos spinosa	11	76	8	5	0	10	10	171
Annona senegalensis	11	9	0	1	12	1	1	50
Combretum sp.	29	1	9	44	11	103	34	330
Pterocarpus erinaceus	6	2	2	8	0	17	3	54
Piliostigma thonningi	22	0	4	1	8	7	0	60
Crossopteryx febrifuga	1	1	1	13	0	1	3	29
Anogeissus leiocarpus	7	1	6	3	2	0	0	27
Cochlospermum planchoni	30	40	11	0	2	0	1	120
Diospyros mespiliformis	8	0	2	1	6	0	2	27
Gardenia ternifolia	0	1	4	0	6	3	3	24
Grewia mollis	0	1	15	6	0	1	1	34
Mitragyna sp.	26	0	0	0	3	0	1	43
Securidaca longepeduncul	6	5	1	0	0	0	1	19
Securinega virosa	5	0	6	2	0	0	1	20
Stereospermum kunthianum	6	0	6	1	1	5	1	29
Acacia hockii	11	30	23	0	0	28	1	133
Bombax costatum	1	1	0	8	1	0	1	17
Cissus populnea	4	3	2	2	0	0	1	17
Detarium microcarpum	0	21	0	1	3	6	1	46
gardenia aqualla	2	3	3	0	0	0	1	13
Nauclea latifolia	14	0	0	0	0	0	1	21
Pericopsis laxiflora	0	0	12	0	0	1	1	20
Vitellaria paradoxa	2	0	0	20	7	43	1	104
Dichrostachys glomerata	0	0	23	6	0	0	1	43
Entada africana	1	11	5	0	0	0	1	26
Lannea acida	0	0	1	1	2	0	1	7
Mitragyna inermis	1	0	0	11	0	0	1	19
Anogessius leiocarpus	0	0	0	16	0	0	1	24
Acacia gourmaensis	0	0	10	1	0	0	1	17
Daniellia oliveri	2	0	0	1	0	0	1	6
Detarium senegalensis	7	6	0	0	0	0	1	20
Dichrostachys cinera	17	3	0	0	0	0	1	30
Ficus platyphylla	3	0	0	0	0	0	1	6
Maytenus senegalensis	0	0	3	0	0	2	1	9
Acacia nilotica	0	0	12	0	0	0	1	19
Afzelia africana	0	1	0	0	0	0	1	3
Allophyllus africanus	0	0	0	12	0	0	1	19
Dalium guineensis	0	0	0	1	0	0	1	3
Haematostaphis barteri	2	0	0	0	0	0	1	4
Lannea microcarpa	1	0	0	0	0	0	1	3
O. Oweri	0	0	0	3	0	0	1	6
Oncoba spinosa	0	0	0	6	0	0	1	10
Parkia biglobosa	0	0	0	0	0	1	1	3
Prosopis africana	0	0	0	0	0	0	1	1
Setaria sp.	0	0	5	0	0	0	1	9
Seteria sp.		0	0	0	0 1	0	3	

1.6 Species frequency and abundance table for Sakote

Locale: Sakote

Transect #:	*12*	*6*	*11*	*2*	*7*	*5*	
Species	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	***Freq.***	#/ha
Annona senegalensis	5	34	15	2	19	2	128
Acacia nilotica	6	230	29	3	100	96	773
Combretum sp.	11	26	65	7	15	2	210
Terminalia macroptera	94	35	11	1	54	3	330
Vitellaria paradoxa	22	23	5	3	28	6	145
Entada africana	1	4	0	1	0	2	13
Gardenia ternifolia	3	2	3	1	1	0	17
Piliostigma thonningi	5	4	4	1	5	0	32
Prosopis africana	5	1	0	1	5	1	22
Acacia hockii	0	66	5	25	111	0	345
Cochlospermum planchoni	0	4	2	3	0	1	17
Detarium microcarpum	1	3	0	0	1	1	10
Stereospermum kunthianum	2	7	5	2	0	0	27
Asparagus flagellaris	0	0	2	2	0	0	7
Detarium senegalensis	0	1	0	0	1	1	5
Grewia mollis	1	0	1	2	0	0	7
Lannea acida	0	1	1	0	0	0	3
Maytenus senegalensis	7	1	4	0	0	0	20
Strychnos spinosa	3	3	1	0	0	0	12
Bombax costatum	0	0	1	1	0	0	3
Diospyros mespiliformis	1	0	0	1	0	0	3
gardenia aqualla	2	0	0	0	1	0	5
Pterocarpus erinaceus	0	4	0	0	0	0	7
Securidaca longepeduncul	1	2	0	0	0	0	5
Acacia gourmaensis	0	0	66	0	0	0	110
Borassus aethiopum	0	0	1	0	0	0	2
Cissus populnea	1	0	0	0	0	0	2
Cissus sp.	0	0	0	1	0	0	2
Daniellia oliveri	2	0	0	0	0	0	3
Dichrostachys glomerata	0	0	0	1	0	0	2
Hymenocardia acida	5	0	0	0	0	0	8
Kusangsiring	0	0	113	0	0	0	188
Pericopsis laxiflora	0	0	0	2	0	0	3
Pteleopsis subarosa	142	0	0	0	0	0	237
Securinega virosa	6	0	0	0	0	0	10
Syzygium guineense	0	0	1	0	0	0	2
Tamarindus indica	1	0	0	0	0	0	2
Vitex doniana	0	1	0	0	0	0	2
Vitex sp.	1	0	0	0	0	0	2

Appendix 2: Disturbance recorded in quadrats arranged by locale

2.1 Disturbance levels within Morago

Transect	# seg. burned	Area mined	# seg cleared	Savanna	S. woodland	Riverine	Farmed
A21 2	4	0	0	0	4	0	0
A21 10	4	0	0	2	0	2	0
A21 4	4	0	0	2	0	0	2
A21 17	4	0	0	3	1	0	0
A21 9	4	0	0	1	4	0	0
A21 6	4	0	0	0	3	1	0
A21 1	4	0	0	0	4	0	0

2.2: Disturbance level within Sakote

Transect	# seg. burned	Area mined	# seg cleared	Savanna	S. woodland	Riverine	Farm
A25 2	4	0	0	3	0	0	1
A25 11	4	0	0	0	0	4	0
A25 12	4	0	0	0	2	2	0
A25 7	4	0	0	0	4	0	0
A25 6	4	0	0	4	0	0	0
A25 5	4	0	0	4	0	0	0

2.3 Disturbance level within Kusanaba

Transect	# seg. burned	Area mined	# seg cleared	Savanna	S. woodland	Riverine	Farmed
41	4		0	4	0	0	0
8	4	0	0	4	3	0	0
4	4	0	0	4	0	0	0
7	4	0	0	0	4	0	0
9	4	0	0	0	4	0	0
18	4	0	0	0	3	0	0
17	4	0	0	4	0	0	0
5	4	0	0	0	0	0	4
13	4	0	0	0	0	0	4

2.4: Disturbance level within Bongo

Transect	# seg. burned	Area mined	# seg cleared	Savanna	S. woodld	Riverine	Farmed
A21 7	4	0	0	3	1	0	0
A21 6	4	0	0	4	0	0	0
A21 20	4	0	0	2	2	0	0
A21 14	4	0	0	0	4	0	0
A21 18	4	0	0	4	0	0	0
A21 12	4	0	0	0	0	4	0
A21 5	4	0	0	4	0	0	0
A21 13	4	0	0	0	3	1	0
A21 15	4	0	0	2	0	2	0

2.5: Disturbance level within Tilli

Transect	# seg. burned	Area mined	# seg cleared	Savanna	S. woodld	Riverine	Farmed
11	4	0	0	4	0	0	0
2	4	0	0	4	0	0	0
18	4	0	0	0	4	0	0
5	4	0	0	4	0	0	0
4	4	0	0	4	0	0	0
13	4	0	0	0	2	2	0
14	4	0	0	4	0	0	0
6	4	0	0	4	0	0	0

2.6: Disturbance level within Biungu

Transect	# seg. burned	Area mined	# seg cleared	Savanna	S. woodld	Riverine	Farmed
13	4	0	0	0	4	0	0
4	4	0	0	0	4	0	0
6	4	0	0	0	4	0	0
15	2	0	2	3	0	0	1
9	4	0	0	4	0	0	0
12	4	0	0	1	3	0	0
1	4	0	0	1	3	0	0
18	4	0	0	0	4	0	0
2	4	0	0	0	4	0	0

Appendix 3: Data forms

3.1 Data forms used for the dung pile (population and distribution) surveys

		IUCN Project: No SGO203					
		Dung pile surveys: Red Volta Range					
Date:			Cell #:				
Quadrat #:			Quadrat size:	Guide(s):			
Terminal coords. of transect:							
	# Cattle dung pile	Elephant dung pile		Habitat Status of segment			
Segment		Perpendi. Dist.	Location on transect	Cleared	Burned	Mine pits	Veg. Type

3.2: Vegetation and habitat surveys

			Vegetation Surveys/habitat studies																					
			IUCN Project #: SGO203																					
Date:		Cell #:	Season:					Ground ternimal coord:																
								Group leader:																
Quadrat #		Quadrat size:						Assistant:																
Terminal coords of quadrat:										Guide(s):														
	Species		Part eaten					Veg. Damage							Elephant signs							Habitat Status of segment		
Segment	Scientific name	Local name	GS	B.	BR.	F.	L.	R.	S.	BB.	BS.	BT.	DB.	OB.	PO.	UP.	D.	H.	P.	S.	Cleared	Burned	Mine pits	Veg. Type

Part eaten: B. (bark), BR. (branch), F. (fruit), L. (leave), S (stem), Veg. Damage: BB. (broken branch), BS. (broken stem), BT. (broken top), DB. (debarked), OB. (overbrowsed), PO (pushed over)

Elephant signs: D. (dung pile), F. (footprint), S. (sighted), H. (heard). UP. (uprooted) **GS:** girth size *= absent **=present

3.3: Data Protocol on Elephant Migration/Movement in the Red Volta Range

Date of interview……………………..

Interviewer and other persons present during interview:……………………….

Name of informant……………………

Village of informant…………………..

Place of interview…………………….

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

Are elephants here through out the year?…………………….

In which period of the year are they available?………………

Describe all encounters with elephants during the last year, starting with the most recent:

Observ. Number	Month & Year	Numbers of Males	Females	Young	Unknown	Total	Location	Direction From	To	Length of stay (days)
1										
2										
3										
4										
5										
6										
7										

Notes:
Obs #1:

Obs #2