The WILD Foundation – Save the Elephants -
The Environment & Development Group

The Mali elephant initiative: synthesis of knowledge, research and recommendations about the population, its range and the threats to the elephants of the Gourma

Susan Canney, Keith Lindsey, Emmanuel Hema,
Iain Douglas-Hamilton, Vance Martin
December 2007

THE WILD FOUNDATION

SAVE THE ELEPHANTS

The Environment & Development Group

AFRICAN PARKS CONSERVATION

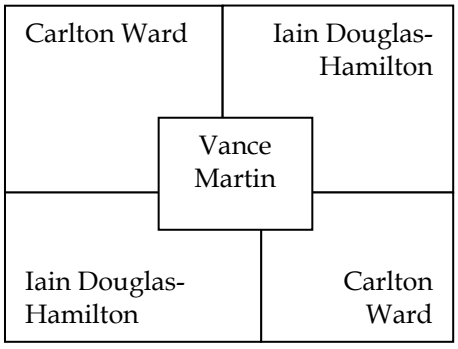
EAU & FORETS

DIRECTION DE LA CONSERVATION DE LA NATURE

Address for correspondence:

The WILD Foundation
PO Box 20527
Boulder, CO 80308, USA

Cover photo credits



Acknowledgements

The Mali Elephant Project team -- The WILD Foundation, Save the Elephants, and Environment and Development Group -- are very pleased to submit the report on Phase One (2003-2006). The project built on earlier work of Save the Elephants and others, and consisted of original scientific field research and compilation of archival information in order to work towards the basis of a management plan for the survival of the Gourma elephants.

This project was made possible by the financial, technical, and in-kind support of numerous agencies, organizations and individuals.

The Government of Mali -- The project had the distinct advantage of explicit endorsement from the Honorable State President(s) of the Republic of Mali, Alpha Oumar Konare and his successor, Amadou Toumani Toure. The Director and staff of the Direction Nationale de la Conservation de la Nature (DNCN) continue to provide superb in-country hosting and technical assistance, and our special appreciation goes to Directeur Felix Dakouo, Colonel Baikoro Fofana, Mamadou Samake, El Mehdi Doumbia and we appreciate the collaboration of the Projet de Conservation et de Valorization de la Biodiversite du Gourma et de ses Elephants (PCVBG-E), notably Biramou Sissoko and Nomba Ganame.

The Government of the United States -- The Embassy of the United States in Mali has been the bedrock support of this project in-country, and the Department of State (DOS) and the Agency for International Development provided considerable financial, logistical and equipment support that made everything possible. Assistant Secretary of State for Africa Walter Kansteiner, and James Dunlap at DOS understand the importance of wildlife for the people of Africa, and provided the initial grants. We especially thank the succession of ambassadors in Bamako who were unwavering in their support and back-up -- Ambassador Michael Rannenberger, Ambassador Vicki Huddleston, and Ambassador Terrence McCulley. A very special thanks and fond personal wishes to Political Officer Oumar M. Konipo, whose unfailing professional services and personal good humour saved the day consistently.

The Africa Parks Foundation (People and Parks Fund), through the vision of (the late) Paul van Vlissingen and the remarkable Caroline Tisdall, have been staunch and continuing financial supporters and project participants. Mrs Magalen Bryant and the Ohrstrom Foundation were key financial supporters and believers from the beginning. We also thank The Conservation, Food & Health Foundation for their financial assistance. Ambassador Timothy Towell made some of the political connections that helped set the course. Last but certainly not least, Carlton Ward Jr, the outstanding conservation photographer, donated his time, considerable talent, a bank of superb images, and significant promotional help.

All of these people and organizations, and others, made Phase One of the Mali Elephant Project an important step towards securing a future for the Gourma elephants. As we extend our sincere appreciation to all these supporters, and apologize if we have neglected to mention anyone, we confirm our enthusiasm and anticipation for Phase Two!

Table of contents

Executive Summary

The Gourma elephant population is unique in Africa for three reasons: it is the northernmost population on the continent, it occupies an exceptionally harsh, arid environment and it owes its existence to historical co-existence with the people of the region.

The people and government of Mali have much to be proud of, in their preservation of this valuable cultural and biological treasure. However, pressures on both people and elephants are growing, and accurate knowledge is essential for the development of well-informed strategies if this population of elephants is to have a long-term future.

The aim of the initiative was to better understand:

- the current size, composition and status of the elephant population
- the ecological requirements of the elephants
- patterns of human activity and their influence on the human-elephant relationship/elephant livelihoods
- the location and severity of threats to their future

It is vital to understand the migration as a whole because events or changes occurring in one part of the elephant range have knock-on effects that impact elsewhere, and are therefore invisible to those focusing on solutions in a small part of the range. Understanding the themes determining elephant survival is vital to be able to foresee these impacts and ensure effective policies, plans and activities.

Context of the Gourma elephants

Elephants once occupied a largely continuous range across West Africa, from the coastal forests to the Sahara, but are now restricted to small, highly fragmented, geographically isolated populations, with over half containing fewer than 100 individuals. The elephants of the Gourma region in Mali are a notable remnant population, representing 12% of all West African elephants. Possibly because of the tolerance of local people, the isolation of the region, and their small, low-quality tusks, the population largely escaped the intense poaching of the 1980s, which extirpated all populations that once existed across the Sahel.

This population is the most northerly in existence since the extinction of the Mauritanian elephants in the Assaba mountains in the 1980s. As one of the most important in the West African region, it is accorded a high priority in the regional elephant strategy of the World Conservation Union.

This population of elephants has evolved a nomadic strategy that includes a unique migration circuit of 600km to cope with the widely dispersed and variable nature of the Gourma's resources. The elephants lived in relative harmony with the peoples of the

Gourma until the 1990s, but the recent trends of reduced rainfall, along with the spread of agriculture, ranched livestock, and settled human communities and water development programs, have changed the relationship between elephants, humans and the Sahelian ecosystem. Humans and elephants are now competing more heavily for the same resources (land, crops and water), and this is increasing conflict.

The Elephant Range

Gourma elephants range throughout the year broadly within the bend of the Niger River in Mali southward to the border region with Burkina Faso, generally between 14.30°N and 16.50°N, and 0.55°W and 2.55°W. The elephant range can be thought of as being in two halves: the wet (south) and the dry (north) season ranges. The border between them roughly follows the RN16 between Sevare and Gao, the only metalled road in the region. The north is characterized by open sandy steppe and savannah with sparse trees, sparsely vegetated dune formations, and shrubby woodland stands occurring in bottomlands and drainage-ways. The south is dominated by bands of low and relatively thick 'tiger bush' complex alternating with dune, open steppe and vegetated dune formations.

The Elephant Population

Individual elephants were identified by the nicks and tears in their ears and the characteristic shape of their tusks. The population size is estimated at 550-700 animals. It appears to have remained more or less stable since the 1970s, and is neither increasing nor decreasing significantly at present. Compared to other populations throughout Africa, it is an old population with over 50% of the population composed of adults. It has a fairly high fertility rate but very high rates of mortality in newborns and young animals that are probably due to the harsh environment and long migration.

Such a population is vulnerable to anything that obliges the elephants to search further afield for food or water, and in particular to prolonged stresses such as drying climate or increased pressure from humans.

Elephant GPS collar data

Three elephants were collared by Save the Elephants: two females and one male. This information showed how the elephants used their range over the period 2000/2001, where they went and how long they stayed there. We do not know for sure how representative these elephants were of the whole elephant population, but we have combined these findings with a variety of other information gleaned from reports, personal accounts, and field work, in an attempt to shed some light on the elephants' world.

Corridors and concentration areas

The GPS collar data indicate that elephants spend around 95% of their time in "concentration areas", where they congregate for periods of time, and that they move rapidly between these areas along "corridors".

Concentration areas are likely to possess resources of interest to elephants while corridors represent areas where elephants do not want to linger, either because there is nothing of interest or because they feel harassed or threatened. By examining and comparing concentration and corridor areas, we can understand what these important resources are, at what time of year they are important, and ensure that development does not inadvertently block elephant movement and create further problems for elephants and people.

The need to migrate

Migration is a strategy for coping with variation in abundance and quality of food and water. In the harsh and variable environment of the Sahel, the ability to migrate and move is critical to elephant survival. Migration allows higher populations to exist than if the same animals are sedentary, and this applies for both wild and domestic species. Where such migrations have been impeded, animal numbers have declined drastically, often to a level where the population is no longer viable and dwindles to zero.

Key resources of the north – water, thicket & the importance of Benzena

Although the south of the elephant range supports more food resources, the water-holes are small and ephemeral, and the elephants are obliged to spend the dry season in the north where they can find water. The elephants move from lake to lake which dry out as the dry season progresses, eventually converging on Benzene, the last accessible permanent water.

Adequate food is also required to survive the long dry periods and the elephants rely heavily on the woody vegetation of the thicketed drainage ways and bottomlands spending the vast majority of their time there, and mostly avoiding the dunes and plains. These vegetated bottomlands provide water, food, shade and cover making this a key habitat for their survival.

Studies of browsing pressure around Benzena raise questions about the trend in the woody vegetation, and the degree to which elephants, droughts, and human activities are contributing to its decline. This is important because a lack of food within reach of water can cause elephants to die of starvation at the end of the dry season. Anything that increases their reliance on Benzena, or causes them to retreat there sooner in the dry season, will also increase the pressure on the vegetation here, and increase their vulnerability to starvation.

Key resources of the south – food

At the onset of the rains the elephants migrate south where the forest, bush and grass, temporary pools and drainage lines and salt pans provide a rich variety of grazing, browsing, cover and salt. They need to eat enough to replenish their fat reserves that will enable them to survive on the meagre food of the long dry season, while the females need adequate fat reserves for reproduction and lactation. The Boni-Serma concentration area is of particular importance, particularly for the family herds, as is the passage through the Aire de Protection de Faune de Nassaoumbou in Burkina Faso.

Elephant movement in relation to human presence and activity

Human presence, settlement and cultivation in the elephant range have had a significant impact on the elephants by:

- Displacing elephants from the centre of the range

- Impeding their access to water where, since the late 1980s, market gardens and settled infrastructure have been established around water-points in their dry-season range such as Gossi, Dimamou, Adiora, Hekia, and Inadiatafane. The family herds have not visited Gossi since the late 1980s, and the loss of access is likely to have increased the pressure on other water points, especially Benzena.

- Confining the elephants to small patches of critical habitat during the wet season.

  This is particularly evident in the south-west. The Boni-Serma concentration area is virtually the only remaining area of their preferred habitat between the RN16 and the Seno sand dune that is relatively free of cultivation. If this area is closed to them, there is very little other place for them to use and conflict will increase dramatically. The quieter border area with Burkina Faso is also favoured but to reach it requires passing through cultivated areas.

- Blocking passage through the Gandamia hills to the food resources of the south.

  At the beginning of the wet season, the elephants need to pass through the Gandamia hills to their wet season range. Records from the 1970s indicate that elephants used several passes through the hills at this time, but by 1990 they were mostly using only one of these - the 'Porte des Elephants' - due to increased settlement and cultivation in the other corridors. The Porte des Elephants thus represents a 'choke-point' in the migration and it is vital to keep it open to elephant movement.

In the pastoral areas, there is sometimes conflict over access to water and accidents that occur when humans, livestock and elephants are concentrated around water. This is exacerbated by large numbers of livestock causing the semi-permanent lakes to dry earlier

in the dry season thus increasing the dependence of the elephants on fewer water-points for longer, and on Benzena in particular.

The impact of small, incremental increases in stress is difficult to detect but reduces the ability of the elephant population to recover from a more acute stress such as a succession of drought years or the blockage of a key elephant corridor. Studies in other parts of Africa indicate that an incremental expansion of human impact reaches a threshold, at which point elephants move away. In this part of Mali, it is not clear that the elephants would have anywhere to move to that could provide all their requirements. As the options for the elephants are reduced, there is the risk that sudden increases in conflict will occur. Once this happens the scope for reducing it are limited, and solutions are much more difficult to implement.

1. Introduction and Background

1.1 Background to the project

The Gourma elephant population is unique in Africa for three reasons: it is the northernmost population on the continent, it occupies an exceptionally harsh, arid environment and, most importantly, it owes its existence to historical co-existence with the people of the region. The people and government of Mali have much to be proud of, in their preservation of this valuable cultural and biological treasure. However, pressures on both people and elephants are growing, and accurate knowledge is essential for the development of well-informed strategies if this population of elephants is to have a long-term future.

The Mali Elephant Project (MEP) comprises the Wild Foundation, Save the Elephants (STE), and The Environment and Development Group (EDG). The initiative began in 2002 when, because of the field research work being done by Dr Iain Douglas-Hamilton, WILD's attention was drawn to this last surviving Sahelian population. Concerned about the herd's prospects for survival, and alarmed that such an unusual and important group of elephants had received no attention from the large international conservation organizations, Vance Martin, President of The WILD Foundation, worked with STE and the then US Ambassador to Mali, Michael Rannenberger, and raised the profile of these elephants in meetings with DNCN and the President of Mali. Then, with the initial assistance of the Assistant Secretary of State for Africa, Walter Kansteiner, WILD raised $300,000 to begin a conservation programme. Closely following, through WILD's work with the subsequent Ambassador, Vicki Huddleston, the US Fish and Wildlife Service, and private foundations, an additional $125,000 was raised, two field vehicles donated, and so on. In 2003, STE, an NGO dedicated to conservation of African elephants, joined with WILD and together they invited the participation of EDG, a consultancy with long-standing experience in both elephant conservation and natural resource management in Mali.

This project represents the first, long-term sustained effort to conserve this elephant population in the field. Prior to this initiative, there had been a variety of surveys but little systematic scientific data had been collected, and knowledge of the elephant migration and the chief threats to it was patchy and largely anecdotal. The Gourma Elephant Initiative has provided the basic knowledge required to enable advocacy and engagement with stakeholders, and provided a solid basis for future conservation activity.

This document reports on the work undertaken by the consortium between November 2003 and May 2006, and sets out the conclusions and management recommendations that result.

1.2 Aims

The aim of the initiative was to develop a reliable dataset on the conservation status of these elephants through rigorous scientific research and, on the strength of this knowledge, to

make recommendations for management guidelines. The first phase of the project involved estimating the size of the population, and understanding more about their movement and behaviour to assess their needs and their prospects. Specifically this involved:

1. Studies and analyses to better understand the population composition and ecological requirements of the elephants.

2. A review and synthesis of data on human land use to better understand the patterns of human activity and their influence on the elephant population.

This information would allow us to answer the following questions:

- What is the current status of the population: how many are there; is it increasing or decreasing?
- Why do the elephants move in their seasonal migrations?
- How much space do they need, what key habitat features are important and are there alternative areas they could use?
- What needs to be done to ensure their future?

3. The communication of results and recommendations so that the importance of conserving this elephant population is appreciated at different levels of government and society.
4. A review of tourism potential in the light of the value of the elephants to local communities.

1.3 Approach

1.3.1 Consultative process

Initial meetings and discussions - The Mali Elephant Project team has made a series of consultative visits to Mali over the past three years. A visit was made by Steve Cobb (EDG) and Francis Lauginie in November 2003 to make contact with 45 officials from the Ministry of the Environment, aid agencies and civil society organizations to introduce the Mali Elephant Project, and assess the level of support and interest, identify any obstacles, and gather information that would be useful for the successful implementation of the project. This was essential preparation for the beginning of any intervention on the ground. A second visit by Francis Lauginie and Mahamane Maiga in January 2004 continued this process both in Bamako and in the region of the Gourma, visiting officials, organizations and individuals in Sévaré, Douentza, Hombori, Gossi and Gao.

The field team maintained close contact with DNCN and local government officers at national and local levels, providing updates on their progress and giving presentations of the work, approach, methodology and results so far, as did members of the consortium visiting from Europe and the US. Emmanuel Hema, the field team leader, sustained and

extended relations between the MEP and DNCN and with the local people throughout the Gourma.

Progress reports were produced and distributed to officials within DNCN and other interested parties at the end of 2004 and 2005, together with a photo-kit of elephant identities.

Phase I Workshop - A workshop was held in conjunction with DNCN in February 2006 to present the findings of Phase I to interested stakeholders. This was preceded by a visit to Bamako by Susan Canney in January 2006 to review the arrangements for the workshop with DNCN. Approximately 30 participants were actively involved including MEP members Vance Martin, Iain Douglas-Hamilton, Susan Canney, and Caroline Tisdall of African Parks Foundation, a prospective donor to the project. The US Ambassador Terrence McCulley opened the meeting and stayed for the presentations. The Minister was called away at the last moment, and was represented by Mr. Diallo (the Minister's long-term senior advisor). The National Director, Felix Dakouo was also called away with the Minister, and the DNCN was ably represented by the Deputy Director, Lt.-Col. Baikoro Fofana, who chaired the meeting.

The MEP team presented the major findings from Phase I, answered questions, and then presented three suggested aspects for Phase II of the MEP to solicit comments. This entertained considerable discussion from all participants, and provided a focus for follow up meetings with the Minister of the Environment, Nancoman Keita, the French Ambassador Norman, and Dr Faye of IUCN. Each participant received colour copies of the summary report and colour wall maps were presented to DNCN together with a complete set of photographs (100 in hardcopy and 1,000 on CD) taken by the professional photographer, Carlton Ward, during his 2004 visit to the Gourma.

1.3.2 Communication of results:

The results of phase I have been communicated to the relevant stakeholders and interested parties in a variety of ways.

- **Reports and other materials**: full colour progress reports on the GIS work were produced at the end of 2004 and 2005; and the following donated to DNCN:

    - full colour wall-maps
    - a set of elephant photo-Ids
    - A set of 100 hard copy elephant photographs and a CD of 1000 elephant photographs of professional quality.

- **Presentations**: these were made within Mali to DNCN at the end of each field season by the team leader. Presentations have also been made at major international congresses including the 8th WWC in Alaska in 2005; the International Congress for

Conservation Biology in California in 2006, and the British Ecological Society Annual Meeting in Oxford, 2006.

- **Stakeholder workshop**: this was held in February 2006.

- **Brochure**: this has been produced in English for international audiences to inform them about the elephants and the work to conserve them. The French language version to be distributed in Mali is in its final stages.

- **Communication at local level**: Emmanuel Hema, the field team leader, has maintained close contact with local government officers and with the populations encountered along the elephant route, describing the work and the reason for it. In the process he has enhanced relations between the MEP and DNCN and with the local people throughout the Gourma.

1.3.3 Capacity building

In 2004 Richard Barnes, Emmanuel Hema and Elmehdi Doumbia spent two weeks with the Save the Elephants team in Samburu, Kenya, to learn the techniques of elephant photo-identification before embarking on the field season in Mali. Emmanuel Hema returned to Samburu for 5 months after the 2004 field season to work on the photo identification files and again for one month in 2005 to continue this work.

During 2005 the field team received technical support visits from Susan Canney (GIS, field data collection, and ground-truthing methodology) and Keith Lindsay (elephant identification methods).

Daniel Lentipo from the STE team spent 2 months during 2005 in the Gourma assisting the field team with age-determination and the recognition of individual elephants, as well as helping to train two groups of interested stakeholders from local communities in elephant observation and recognition. This built on the outreach work by Emmanuel Hema in introducing the elephant project to local populations along the elephant route.

At the request of DNCN, a Malian student from Bordeaux University also accompanied the field team for 2 weeks in May 2005 as part of her Masters course.

The project has also paid Emmanuel Hema's university fees to enable him to enrol for a doctorate at the University of Ouagadougou. His research will compare the elephant population of the Gourma with that of Nazinga in Burkina Faso.

1.3.3 Field seasons

In 2004, the field team led by Richard Barnes, and supported by Emmanuel Hema and Elmehdi Doumbia, and accompanied by Mamadou Samake (Chef d'Antenne for Douentza

at that time), spent two months between March and May in the Gourma at the end of the dry season following elephants and photographing them to identify as many individuals as possible in the time available. The first month was spent in reconnaissance of the north-eastern part of the elephants' range, while during the second month the team was based at Benzena, where most of the elephants had concentrated. During this field season 40 transects were run to evaluate the elephants' use of space around Benzena at the end of the dry season, using the number of dung-piles to assess the level of elephant use in relation to measures of woody vegetation density and species diversity, and livestock abundance. Emmanuel Hema then spent July - December in Samburu sorting the photographs and assembling the ID file. .

In 2005 the field team, led by Emmanuel HEMA and supported by Elmehdi DOUMBIA and Mamadou SAMAKE of DNCN, began their work in March 2005. The focus of the field work was elephant identification, determining the boundaries of the elephant range and collecting ground-truth data to assist satellite image interpretation. The team began in the north-east, following the elephants through the northern part of the Gourma to Inadiatafane-Indamane-Benzena over the next 3 months. The months of June to August were spent in the south-west sector of the elephant range, followed by a break in September when the team leader left to debrief at STE's headquarters in Kenya before presenting the project internationally at the 8^{tth} World Wilderness Congress in Anchorage, Alaska. Field work resumed in the Gourma in October in the south-east of the elephant range and continued there until November, followed by a final excursion to the north during December. The photo-ID files were revised and updated.

In 2006, the field team based themselves at Banzena for two months at the end of the dry season to continue the elephant ID work. During this field season, the photo-ID file was refined once again and the age structure of 23 family units, comprising females and juveniles, was positively determined, with and 83 additional adult females catalogued. For the independent males, 67 were positively identified.

1.4 The Gourma and its elephants

1.4.1 Context of the Gourma elephants

Elephants once occupied a largely continuous range across West Africa, from the coastal forests to the Sahara, but are now restricted to small, highly fragmented, geographically isolated populations, with over half containing fewer than 100 individuals (Roth and Douglas-Hamilton 1991; Said et al. 1995; Barnes et al. 1998; Barnes 1999). Their collapse, caused by poaching for the ivory trade, human encroachment and the concurrent lack of conservation and scientific attention, has been alarming. Remaining populations are small, highly fragmented and geographically isolated, with over half now containing fewer than 100 individuals (Roth and Douglas-Hamilton 1991; Said et al. 1995; Barnes et al. 1998; Barnes 1999). The elephants of the Gourma region in Mali are a notable remnant population, representing 12% of all West African elephants. Poaching by local nomadic peoples has traditionally been very low; however, until the 1980s, illegal hunting by urban

Malians from vehicles was a threat to the Gourma elephants (Olivier 1983). Possibly because of the tolerance of local people, the isolation of the region, and their small, low-quality tusks, the population largely escaped the intense poaching of the 1980s, which extirpated all populations that once existed across the Sahel. This population is the most northerly in existence since the extinction of the Mauritanian elephants in the Assaba mountains in the 1980s (Douglas-Hamilton, 1979). As one of the most important in the West African region, it is accorded a high priority in the regional elephant strategy of the World Conservation Union.

This population of elephants has evolved a nomadic strategy that includes a unique migration circuit of 600km to cope with the widely dispersed and variable nature of the Gourma's resources. According to La Marche (1978) the elephants lived in relative harmony with the peoples of the Gourma, a coexistence that continued into the 1980s and 1990s (Douglas-Hamilton and Douglas-Hamilton 1992; Olivier 1983; Jachmannn 1991; Youssef 2001; Maiga, 1996), but the recent trends of reduced rainfall, along with the spread of agriculture, ranched livestock, and settled human communities and water development programs, are changing the relationship between elephants, humans and the Sahelian ecosystem (Jachmannn 1991). Humans and elephants are competing more heavily for the same resources (land, crops and water), which is increasing conflict (Olivier 1984; Jachmannn 1991; Pringle and Diakité 1992).

1.4.2 The Country

The Republic of Mali in west Africa, is a land-locked country of 1.241,238 million km^2 bordered by Algeria, Burkina Faso, Guinea, Ivory Coast, Mauritania, Niger and Senegal. Vegetation ranges from extreme desert in the north, through Sahelian and Sudanian savannah, to Sudano-Guinean savannah in the extreme southwest. The climate in the north is arid, becoming sub-tropical in the south. Mean annual rainfall is ca. 1350 mm in the south-west decreasing to negligible levels in the north. A distinct wet season in the south and centre of the country goes from June until October; November to February is dry and mild. The late dry season from February until June is also the hottest period of the year, and mean monthly maximum temperatures reach up to 46^{o} C.

The human population of 13.8 million is expanding at an estimated 3.0% per year (FAO, 2005). Nearly 45% of the population is under 15 years of age. Despite this, the human population density of Mali remains one of the lowest on earth with most Malians living in the south of the country. Climatic conditions mean that primary productivity is highest in the south, and much of the north is too arid for humans and mammalian wildlife to exist. The growing demands of the human population have exacerbated the negative effects of an increasingly dry climate, and desertification, deforestation, erosion and lack of drinking water are major environmental concerns (Kone 2001).

1.4.3 The Gourma

Gourma elephants range throughout the year broadly within the bend of the Niger River in Mali southward to the border region with Burkina Faso, generally between 14.30°N and 16.50°N, and 0.55°W and 2.55°W (fig. 1). Other large wild mammalian species are rare (listed by Jachmannn, 1991), and the status of many is unknown. Still commonly seen are Dorcas gazelle (*Gazelle dorcas*), common jackal (*Canis aureus*) and Africa wild cat (*Felis libyca*).

The Gourma is an extensive undulating Sahelian landscape with annual grasses, especially *Cenchrus biflorus,* or bare sandy substrate. The area is dominated by dunes that cover 50% of the area, laterite plateaus 25%, plains 19%, and sandstone buttes and escarpments 6% of the region (PIRT, 1983 cited in Blake et al., 2003).

The elephant range can be thought of as being in two halves: the wet (south) and the dry (north) season ranges. The border between them roughly follows the RN16 between Sevare and Gao, the only metalled road in the region. The north is characterized by open sandy steppe and savannah with sparse trees (mainly *Balanites aegyptiaca* and *Acacia* spp.), sparsely vegetated dune formations, and shrubby woodland stands occurring in bottomlands and drainage-ways. The south is dominated by bands of low and relatively thick 'tiger bush' complex, dominated by *Grewia bicolor, B. aegyptiaca* and *Acacia* spp., alternating with dune, open steppe and vegetated dune formations (Jachmannn 1991). Throughout the study region, trees are small, and their density and height increase from north to south. Isolated woodland stands, usually surrounding waterholes and following drainage lines, provide the main elephant habitat. Erosion by wind and water occurs throughout the study region and is particularly pronounced in devegetated areas heavily used by livestock.

The west of the region is delimited by a chain of lakes previously fed by the flood of the Niger River and used by elephants and humans, but these have been mostly dry for the past 25 years. A series of small semi-permanent lakes runs through the northern half of the region, fed by surface water run-off from local rainfall. Only two of these lakes – Benzena and Gossi - tend to retain water throughout the entire dry season, and human populations and elephants now heavily rely on them. Even these lakes have dried completely twice during the past 20 years, which has affected the elephant range. Water sources in the southern half of the region tend to be ephemeral persisting only during the wet and early dry season.

A marked rainfall gradient spans the Gourma, with average annual rainfall of 450 mm in the extreme southern range, progressively declining to 150 mm in the extreme north. The region experiences a single rainy season with most precipitation falling between late June and late August followed by a dry season lasting from 8 to10 months (fig. 1.1) (PIRT 1983). Rainfall isohyets have shifted to the south in recent years, because of a series of below-average rainfall seasons. Long-term rainfall data for this region that exist from the 1920s reveal droughts and a series of years with above-average rainfall occurring at unpredictable intervals (Leeuw et al. 1993). Whether the current prolonged period of low rainfall is part of

normal long-term rainfall cycles, a long-term drying trend, or the result of drought induced by human use or other factors is not known, but the droughts of the 1970s and particularly the 1980s resulted in a significant migration into the Gourma of pastoralists from the north, many of whom still regard themselves as waiting to return when conditions improve.

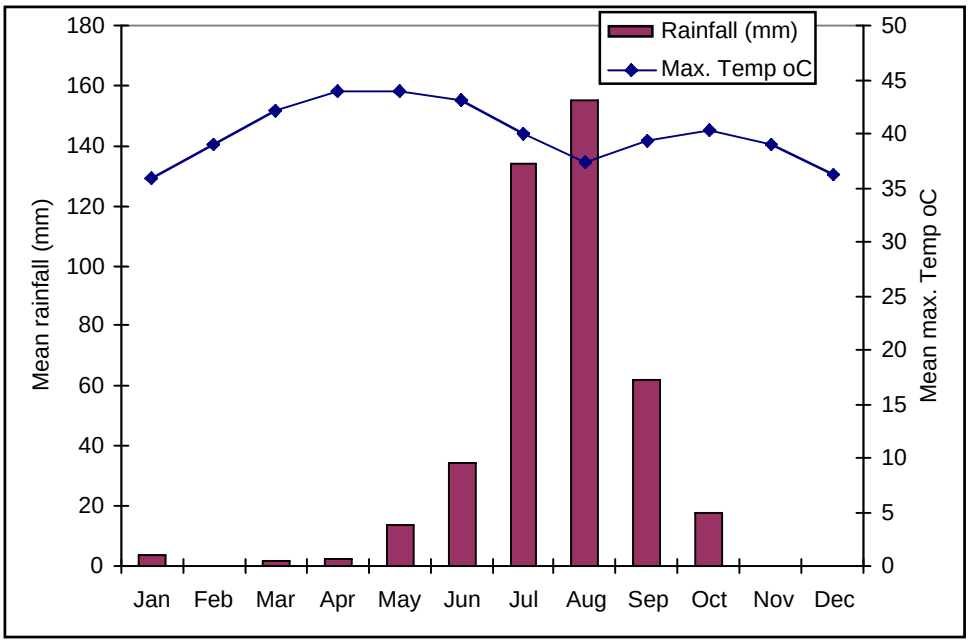


Figure 1.1 Rainfall and temperature data from the Gourma region of Mali (Blake, 2003)

Associated with the gradient of rainfall, there is a north-south gradient of vegetation biomass that is part of a more general trend shown in figure 1.2. This shows the area under study in the white box superimposed on a satellite derived measure (NDVI) of green biomass for West Africa with the darkest green representing higher biomass.

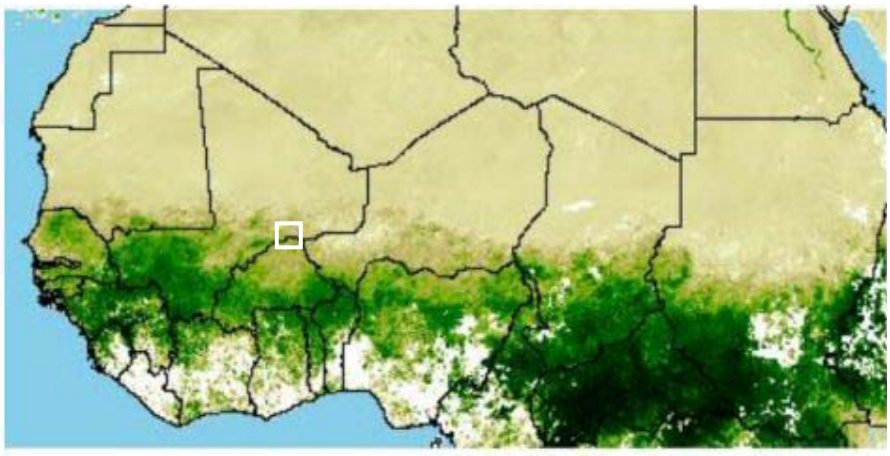


Figure 1.2 NDVI for West Africa (source http://www.fews.net)

2. The Elephant Population

2.1 Methods

Elephants were located mostly by obtaining information on their whereabouts from the nomads, and then searching for their tracks. Elephants can be most easily identified by the nicks and tears in their ears and the characteristic shape of their tusks, and so photo-IDs were compiled by photographing the elephants' heads from each side profile and head on, although it was not always possible to obtain photographs of both ears nor to see the full body of the animal. Photographic ID ensures that elephants are not counted twice and enables the collection of data on behaviour, social organization, age structure and, with time, demographic events. Bulls were catalogued as individuals and family groups were catalogued together and could be recognized if at least one of the group had a photo ID.

The collection and examination of ID photos allows an estimate of the population size. At the start of the study, the number of photographed animals will represent a small proportion of the total population, but over time the catalogue of photographed animals will increase and should stabilize. In a small population, the number of known animals identified by photographs and located through comprehensive search patterns informed by local knowledge, will fairly quickly approach the total population size.

As noted above, pictures of left and right ears may be taken on separate occasions and for positive identification it is necessary to determine which pairs belong to the same animal, Until this is done, there will be pictures of the left or right ears alone, with the matching-up not established. The extent to which left and right ear photos form a matched pair serves as the basis for upper and lower estimates of known animals, ranging from a minimum, with all left and right ear photos matching, to a maximum, with none matching. As identification of the study elephants progressively improves, the estimated total may actually decrease as the degree of matching increases.

While it is possible to recognize adult animals from their photographs, it is harder to identify juveniles because their ears have had few years to develop distinctive folds and cuts. However, since juveniles associate closely with adult females until sexual maturity at 10-15 years old in the case of males, or for their whole lives in the case of females, these other animals can be registered by their association with the known adult females. In family groups where we do not have accurate counts of the number of juveniles, but do know the number of adult females, we can use known ratios of adults to juveniles to estimate the total group size. In 2004 and 2005, we used estimates from other populations, where the number of juveniles associated with adult females has ranged from 1.31 to 2.00 per adult. In 2006, we used the observed ratio in Gourma elephant families, 1.703. If these ratios are applied to the number of identified females, then an estimate of the total numbers of animals in family units can be calculated.

The age of the elephants was determined by body shape and proportions, particularly height at the shoulder, and the eruption of tusks. Five classes were identified: New-borns (<

1 year old), Young (1 to 3 years old), Sub-adults (4 to 10 years old), Young-adults (11 to 19 years old) and Adults (20+ years old).

2.2 Results

The number of elephants identified by the photographic method, and the population estimated, in the three field seasons 2004-2006 are summarized in the table below.

Year	Adult females identified	Associated family unit members	Adult males identified	Total population size
2004	124-169	162-338	97-149	383-656
2005	173-227	227-454	104-132	504-813
2006	164-214	215-428	104-132	547-710

The fact that both the number of females identified and the +- range of the estimate, decreased slightly from 2005 to 2006 does not indicate a decline in the true population size but an improvement in the accuracy of the estimate, and the increased matching of left and right ear photographs. It should be noted that the upper estimate of population size, at some 700 animals in 2006, is at most the absolute maximum number and the lower estimate of some 550 animals may be closer to the true figure.

By 2006, the composition and age structure of 23 family units had been established. These family groups compromised 207 individual animals, classified into estimated age classes of which 37% (or 77 animals) were adult females. Another 83 adult females were firmly identified but could not be grouped into families; with the same proportion of sub-adult animals, their families would have totaled 224. There were thus some 431 animals in family units. There were 67 adult males that were identified and assigned to age classes. These numbers produce a total of 498 elephants in the population that were both identified and classified. As the table above notes, there remains an additional number of animals for which there are left or right ear photographs but which were not counted in family units or classified by age.

The population age structure was calculated from 207 animals identified and classified in family units and is shown in the graphs below. The first graph shows the distribution of female elephants in the broad age categories described above. Since these categories include different numbers of years, the second graph shows the distribution of elephant numbers across yearly age classes. Compared to elephant age structures elsewhere in Africa, the Gourma population appears to have a relatively high proportion of adult, compared to juvenile animals.

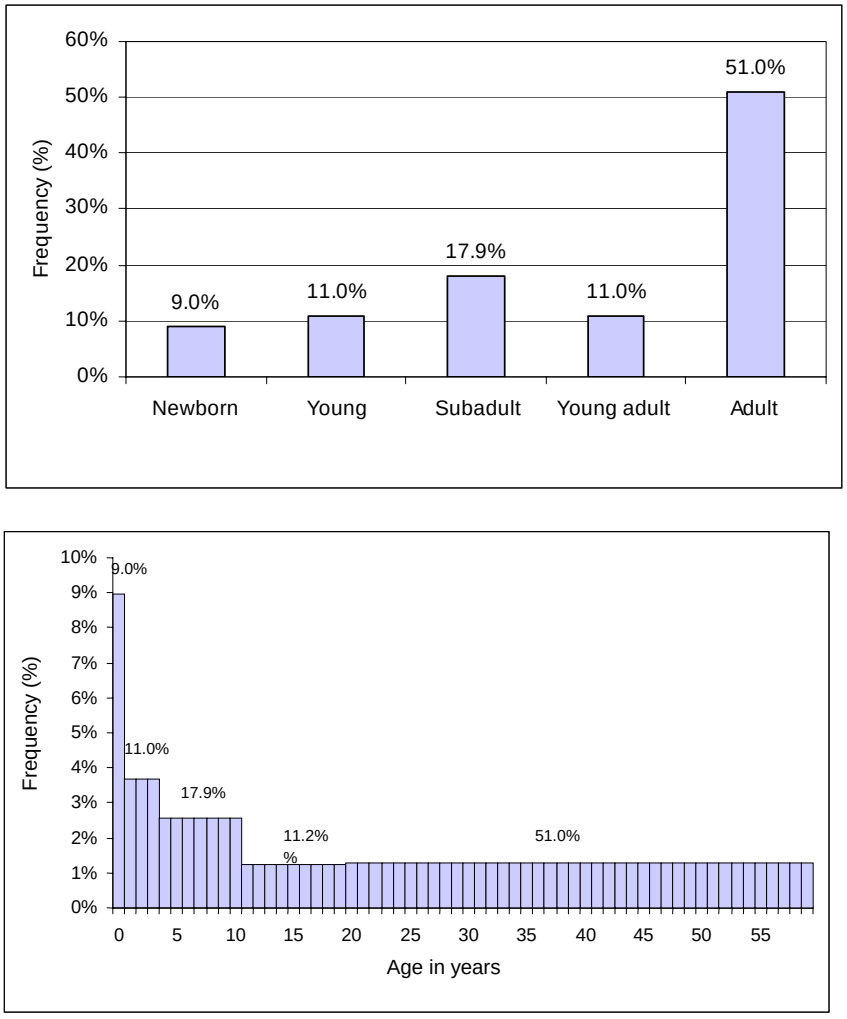


Figure 2.1 Age structure of the population

When the observed age structure is entered into a simple age structure population model, results suggest a fairly high birth rate of calves but also very high rates of mortality in Newborn and Young age classes. The best fit of the observed data with the population model was a rate of increase of about 1.4% per annum. This is a very low rate of increase, and given the uncertainty of age estimates and the assumptions of the model, which also produced scenarios of a slightly declining population, it is likely that the population can be considered, at best, stable. Certainly the high rates of juvenile mortality, most probably due to the harshness of the long dry season, suggest that the population is vulnerable to any disturbance of its dry season foraging resources, and very dependent on adequate nutrition during wet season migrations.

2.3 Discussion

The project has achieved some more precision on the size of the elephant population (550-700 individuals). These numbers must be treated as provisional, given the difficulty of finding and identifying the elephants in the field. This estimate is compared with other

published estimates of the elephant population over the last 35 years in the table below with the more reliable figures derived from rigorous census methods highlighted in bold, which control for problems of counting the same individuals more than once and extrapolating from incomplete samples. They suggest that since the late 1970s the population has remained more or less stable and this is supported by the data on the age structure which also suggests that the population is currently stable.

Year	Number	Source	Notes
1950	50-100	Zampaligre et al. 1997	Source unknown
1979	**500**	Douglas-Hamilton	Partial aerial reconnaissance
1989	**840**	Douglas-Hamilton	Partial aerial reconnaissance
1989-90	**300**	Barbier and Perrier	Partial aerial reconnaissance by microlight
1991	**500**	Jachmannn	Dung transects
1994	600	Cobb and Lapuyade	Source unknown
1996	1,000	Samake cited in (Maiga, 1996)	Estimate – basis unknown
1997	870	SCN cited in (PCVBG, 2001)	Estimate – basis unknown
2001	483-950	Local populations at Gogoro, Dadiem, Foutounde, Banzena cited in (PCVBG, 2001)	Estimate based on counting the numbers of elephants encountered at four locations.
2002	800-1000	Ganame and Lasbennes	Estimate – basis unknown
2003	**322**	Blake et al.	Partial aerial reconnaissance

There is a perception in some quarters that elephant numbers have increased (Zampaligre, 1997); that this is linked with the 80% decrease in cattle numbers over the last 30 years in the north of the Gourma; and mention that their increasing numbers may need to be controlled (Faure-Osei, 2002). Given the above figures, it is, however, more likely that this perception reflects the increasing incursion of humans into areas frequented by elephants, and in particular the increasing practice of clearing fields in bottomland areas on the elephant route (Maiga, 1996).

The low proportion of young-adults may be due to the difficulty in distinguishing between young-adults and adults, but despite this, the key finding is that the age structure of the Gourma elephants shows a relatively old population with over 50% of the population being adult. This is likely to be indicative of the harsh environment and long migration which causes high calf mortality, but means that the population is vulnerable to any increase in stress that affects their survival.

3. Elephant movement and range use

3.1 Data collection and generation

Field data were collected on the ground by the research team and integrated with a variety of existing data within a Geographical Information System. The latter, previously collected by other institutions, were sourced through existing contacts (including hard copy maps acquired by STE, satellite imagery from the US Geological Service) and during a data collection mission by Dr Susan Canney to Bamako in April 2005 (facilitated by Mahamane Maiga).

3.2 Elephant GPS collar data

The analyses described in the following sections use the location data gathered by STE's GPS collars over the period 2000/2001 (see Blake *et al.*, 2003). Data came from three elephants: two females and one male. Unfortunately one of the female collars recorded intermittently and the resulting dataset contains large gaps, and so these analyses have used 12 months of data from Ahni and El Mehdi between 1 April 2000 and 31 March 2001.

Elephant	Sex	Number of observations	
		18 months	12 months
Ahni	F	4,274	3,676
El Mehdi	M	4,778	3,554
Doppit Gromoppit	F	405	338
TOTAL		9,457	7,568

In interpreting these data it must be remembered that the collar data represent the movements of only three animals and the degree to which they are representative of the whole elephant population is unknown. We also do not know how variable the movements of an elephant are between years or in response to different patterns of rainfall. These are questions that can only be illuminated by further studies. Where possible we have tested these findings against a variety of other information gleaned from reports and personal accounts, and this is indicated in the report.

3.3 Contraction in range since the 1970s

The map below shows the elephant range as described by La Marche in the 1970s (in dark green); by Jachmannn in 1990 (light green); the STE GPS collar data in 2000-1 (orange line and yellow points); and the point data collected by the WILD-STE-EDG consortium in 2005 that recorded sightings at the outer edge of the elephant range (yellow line and stars). It

should be noted that these points are all outlying observations of bulls that, it appears, are testing the edge of the range. These data are superimposed on key landscape features: the lakes to the west, the Gandamia escarpments, the frontier with Burkina Faso, major settlements and the main road between Mopti and Gao.

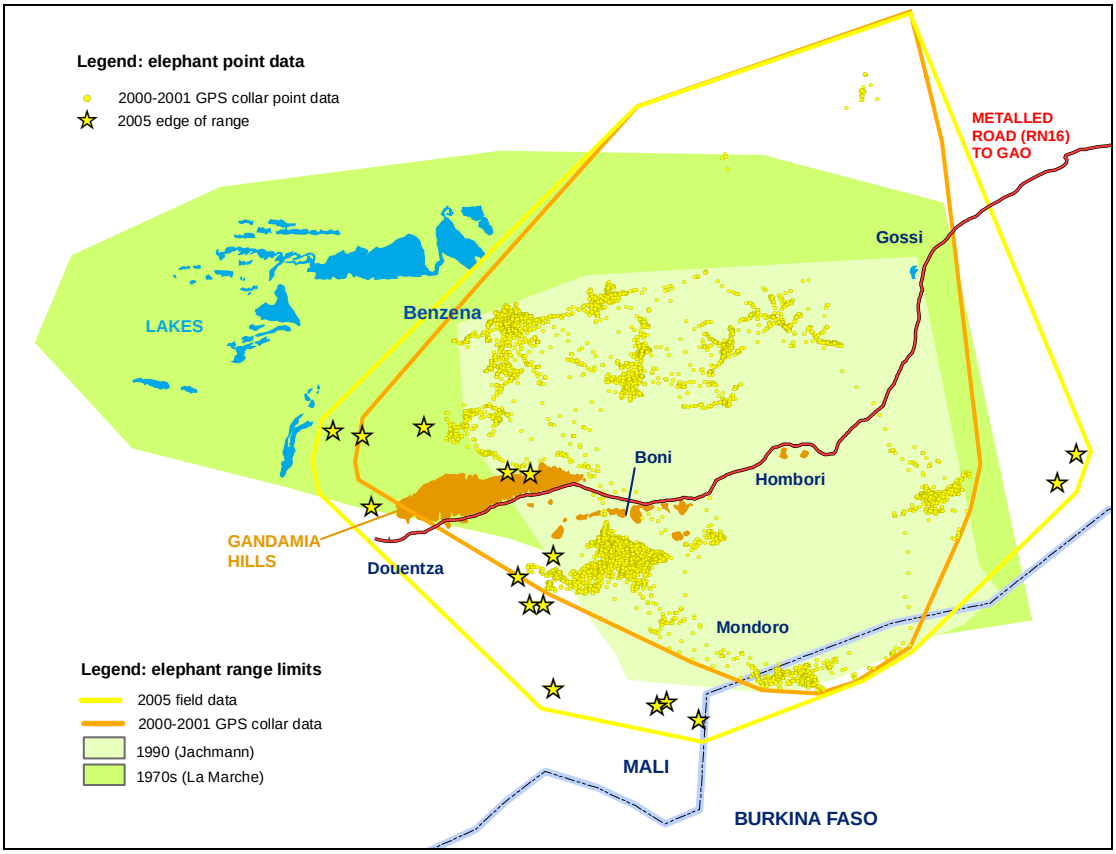


Figure 3.1 Map summarizing elephant range estimates from La Marche (1970s), Jachmannn (1991), GPS collar data and the 2005 field work

The key points are listed below together with references to sections of this report that discuss them in more detail:

Elephant range has shrunk since the 1970s

Loss of the western part of the range around the lakes since La Marche in the 1970s that is possibly due to the drying of the lakes and the increase in population density and settlement.

Elephants are found further to the south than recorded in the 1970s

By 1990 the elephants have lengthened their route further to the south-east and west. The importance of the south-east corner is confirmed by the 2005 field-work.

Elephants are moving further north than previously recorded?

The GPS collar data show elephants moving further north than previously recorded, however the extent and number of elephants using the area north of Gossi is not yet firmly established. Neither is the importance of the Gossi corridor.

Elephant movements since the 1970s

La Marche and Jachmannn also recorded the trajectories of elephant movements and these are shown in the figure below, together with the GPS collar data.

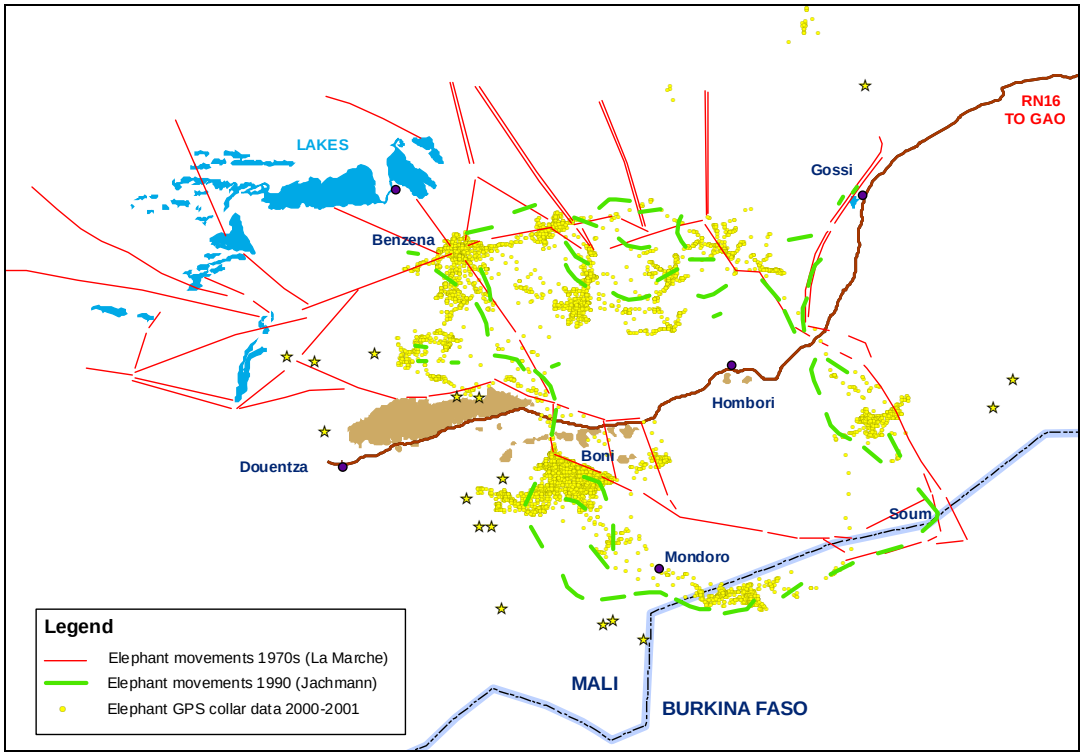


Figure 3.2 Map summarizing elephant movements from La Marche (1970s), Jachmannn (1991), GPS collar data and the 2005 field work.

Several features are apparent:

Elephants tend to avoid the centre of the range

All three sources record little elephant use of the centre of the range.

Since the end of the 1980s Benzena is the only permanent water source available for the herds at the end of the dry season

Females used to visit Gossi until the end of the 1980s, but since then the rapid growth of the town along the east bank and gardens along the west bank has meant that the lake can only be accessed along a small portion of the southern end, and a few bulls still use Gossi.

The Porte des Elephants represents a 'choke-point' in the migration where elephant movement has become increasingly constrained and are in danger of becoming blocked

La Marche records elephants moving through 3 passes through the hills in the 1970s; however by Jachmannn's time in 1990 they were using one of these - the 'Porte des Elephants'. This is confirmed by the collar data and 2005 ground data, and appears to be due to increased settlement in the other two corridors.

There are indications that males behave differently to females in trying more risky strategies

The outer limits of the range are defined by records of bulls. Bulls also stay longer than the herds in the south-east and are most commonly associated with the raiding of grain-stores. A group of around 7 bulls remain in the vicinity of Gossi between October and June (Doumbia personal communication; Ganame, 1999).

The GPS data showed that the two females followed the circular route, and while the male stayed in the same general range, he did not continue to the south-east in 2000-2001. Instead, he stayed in the Burkina border area between mid August and mid October in 2000 before returning to the Boni-Serma area, only returning to the water-holes of the north in January 2001. Eye witness accounts state that the male elephants tend to stay in the south-west area longer than the herds and that some elephants may remain in Burkina Faso until after the beginning of January (Barnes, 2006) although the sex of these elephants was not noted.

The GPS data show that the elephant range is divided into concentration areas and corridors.

The GPS collar data indicate – and the 2005 ground observations confirm - that there are some areas where elephants congregate for periods of time and other 'corridor' areas where they move rapidly between these 'concentration areas'.

3.4 Corridors and concentration areas

Concentration areas are likely to possess resources of interest to elephants while corridors represent areas where elephants do not want to linger, either because there is nothing of interest or because they feel harassed or threatened. By examining and comparing concentration and corridor areas, we can understand what these important resources are, and at what time of year they are important.

The figure below shows the GPS collar data from all three elephants and approximate limits of the corridors and concentration areas according to these data. Our knowledge of elephant movements in the most northerly part of the range is incomplete, not least because the collar on one of the female elephants recorded intermittently, and this was the individual which frequented this area. [In addition, the field team found only bulls when they visited this area in March – April 2004 and 2005.] It appears however that elephant movement is less constrained in the North than the south.

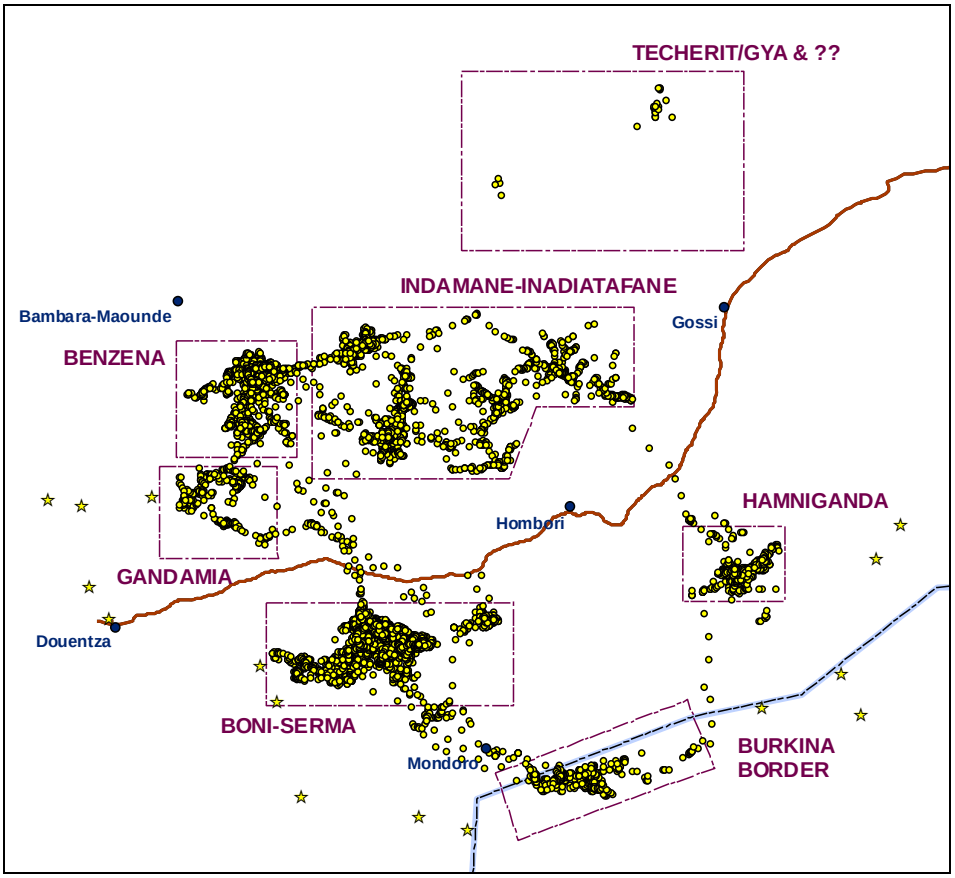


Figure 3.3 Map of the collar data (yellow circles) and 2004-5 limits of range data (yellow stars) showing the concentration areas

The elephants spend different amounts of time in different concentration areas. The figure below shows the proportion of time spent in the different concentration areas by the male (left) and the female (right), with dark stipple representing areas in the south of the range and dark stipple representing areas in the north of the range. There are marked differences between them, with the bull spending two-thirds of its time in the south - particularly in the Boni-Serma area but also in the Burkina border area – while the cow spends a third of her time in the Boni-Serma area and far more time in the north in the Indamane – Inadiatafane area. Unfortunately we do not have a complete dataset for the female who went to the extreme north of the range.

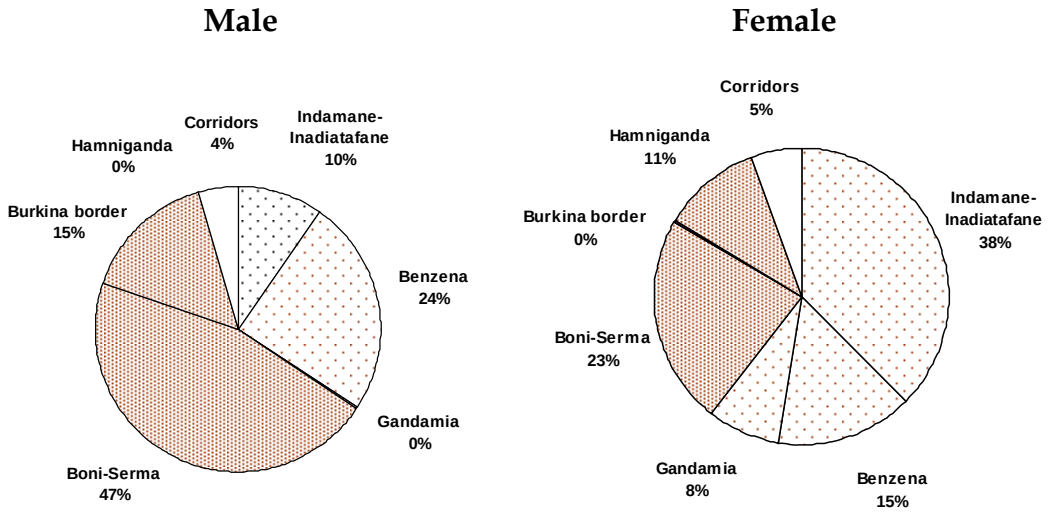


Figure 3.4 Percentage of year spent in each concentration area by the male (left) and the female (right). Dark stipple indicates areas in the south of the range and light stipple represents areas in the north.

For the male and the female for which we had continuous data, it was found that they spent only 4-5% of their time in corridor areas (as measured by number of GPS points), often at night when temperatures are lower and there is less human activity. The speed of elephants was also greater in the corridor areas, where they were more likely to 'streak' at speeds of over 10km/hour.

Understanding corridors is of particular importance to ensure that any development does not inadvertently block elephant movement and create further problems for elephants and people. The Porte des Elephants was identified in the last section as being of particular importance. The GPS data record nine passes through this area, eight of which are through the Porte des Elephants. The other pass (by the male) is shown in the figure below. The male begins his move north-eastwards at around 07.00 but spends a day wandering in the vicinity (possibly avoiding human activity) before dashing through a pass in the hills in the early hours of the morning.

Figure 3.5 also shows the location of reported elephant damage, which suggests that elephants might, on occasion, be attempting routes other than the Porte des Elephants. The cultivation of millet fields here since at least 2004 is a sign of encroaching settlement (Amis des Elephants, personal communication). Increasing impediment to elephant movement in the vicinity of this pass is likely to result in a sudden escalation of problems once a critical threshold is reached. In Zimbabwe, for example, Hoare and du Toit (1999) found that vicinity of this pass is likely to result in a sudden escalation of problems once a critical threshold is reached. In Zimbabwe, for example, Hoare and du Toit (1999) found that

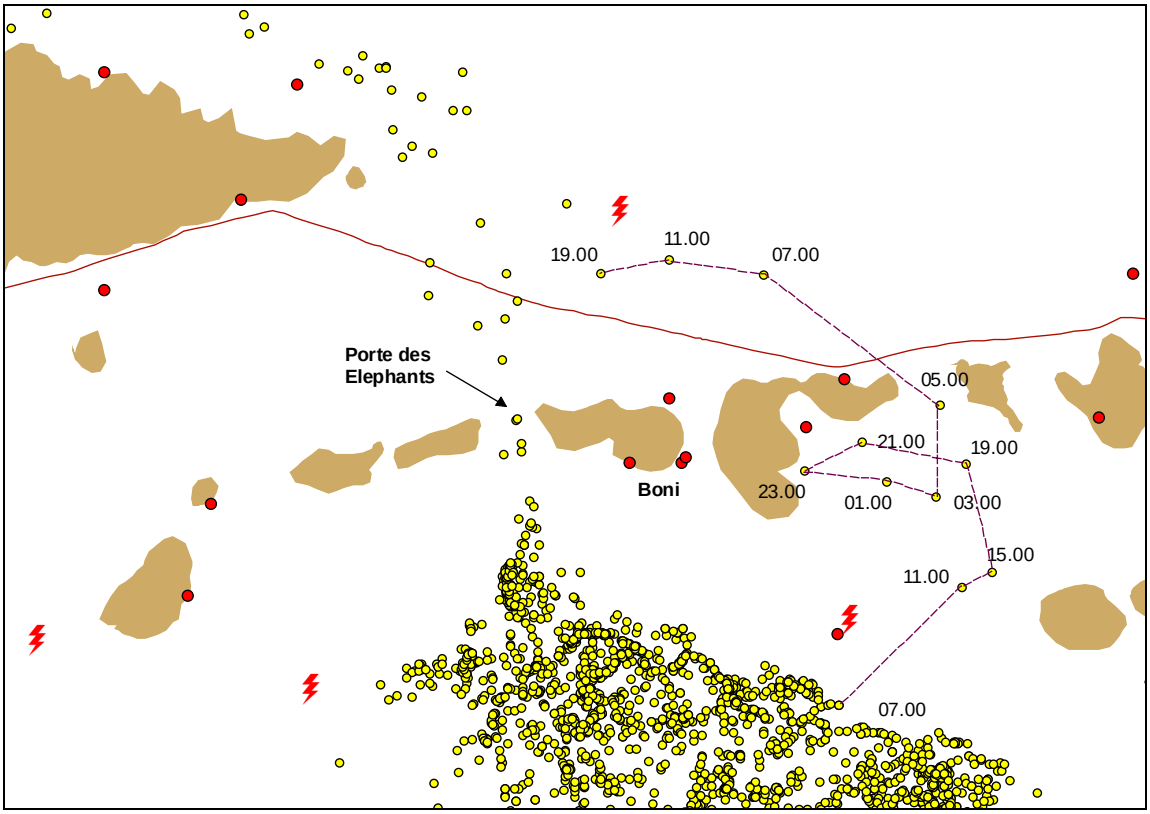


Figure 3.5 The trajectory northwards of the one out of nine passes that did not use the Porte des Elephants. Locations of conflict are shown as red lightning bolts.

elephant density was unrelated to human density until it reached a threshold that corresponded to a transformation of land use to about 40-50% human activities, when elephants moved away. The problems come if elephants have nowhere to move to.

3.5 Understanding the migration pattern

This population of elephants has adapted to the harsh environment by evolving a long annual migration. Like any life-form, elephants have a suite of needs which vary in relative importance throughout the year according to a complex interplay between their own internal state and the surrounding environmental conditions. To gain insight into the factors influencing this migration, the pattern of elephant movement in time and space was analyzed in relation to the distribution of resources deemed important for elephant survival: water, food, shade, cover, ease of movement, salt.

To understand the migration it is necessary to refer to the geographical distribution of the various landscape-vegetation formations that play a key role in shaping the migration. These include the drainage lines, dunes, laterite plains, inselbergs (or hills), the Seno (a large fossilized sand-dune), the Finta. Figure 3.6 shows a Landsat image labeled with the location of these elements together with the elephant locations in yellow, the international border with Burkina Faso and the Route Nationale (RN16) as reference points.

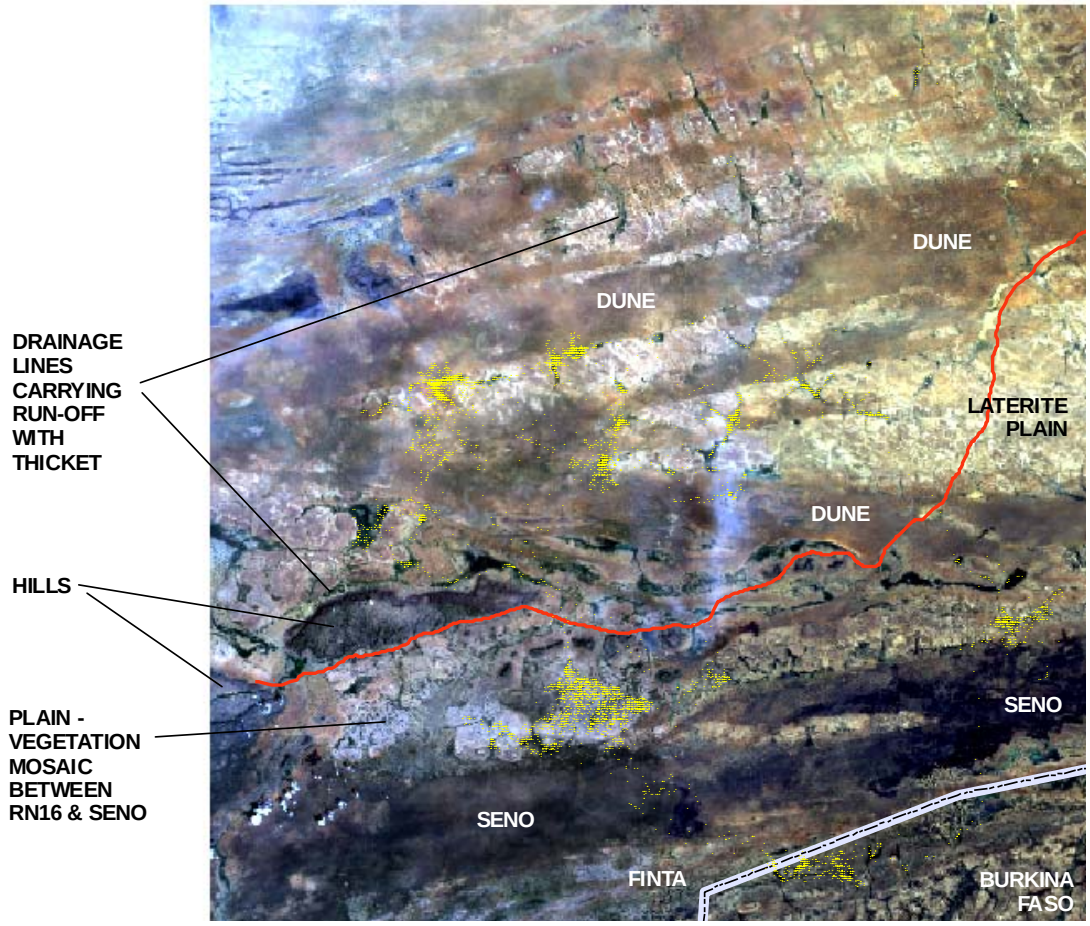


Figure3.6 The location of key landscape-vegetation formations that shape the migration. The Seno is a large, stabilized sand-dune that burns each year (hence the black coloration). The Finta is a flat, low-lying, markedly agricultural area with large well-organized fields.

3.5.1 Water

During the dry season the elephants occupy the northern half of their range, north of the Sevare-Gao road, where they depend on a series of small lakes, fed by surface water run-off from local rainfall that collects in depressions in drainage ways or 'bottomlands',
The elephants move from lake to lake which dry out as the dry season progresses, forcing the elephants to converge on permanent water towards the end of the dry season. There are two permanent lakes - Benzena and Gossi - but human development and infrastructure have restricted access to Gossi, and that apart from the 7 bulls at Gossi, the elephants rely on Benzena. Figure 3.7 shows that all three of the collared elephants reached their furthest distance from Benzena in September and October as the rainfall decreased.

Water sources in the southern half of the region tend to be ephemeral, being heavily used by humans and livestock and the elephants return to the water resources of the north at the beginning of the dry season.

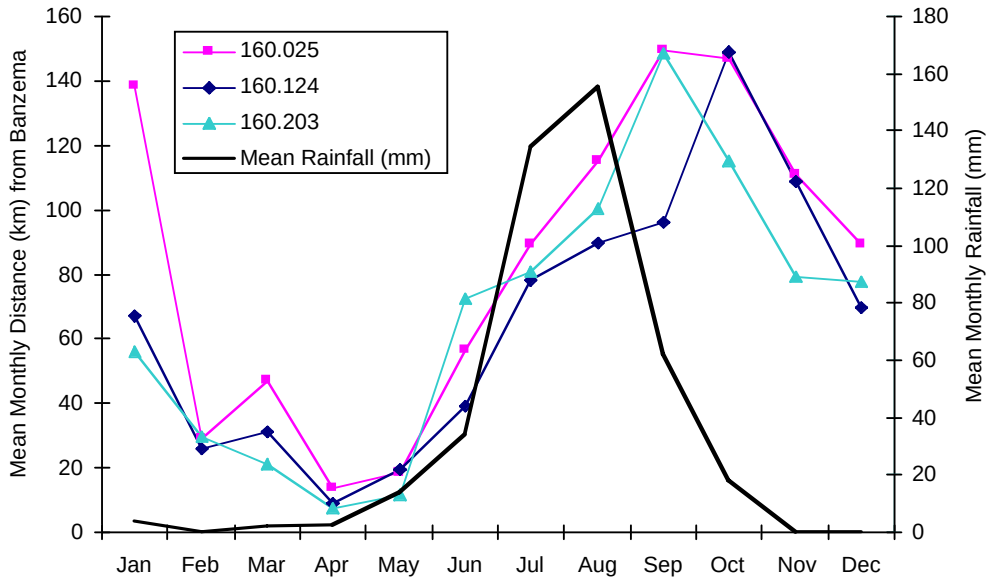


Figure 3.7 Mean monthly distance from Benzena by the three elephants, shown together with the mean monthly rainfall (from Blake *et al*., 2003)

3.5.2 Food

Elephants' large body size and their lack of a rumen mean that they require a high intake and throughput of food (Spinage, 1994), and so the quantity of vegetative biomass was used as a proxy to create a map of the distribution of elephant food across the zone.

The close coupling between Sahelian rainfall and the growth of vegetation has made it possible to use satellite derived vegetation indices as a proxy for the land surface response to rainfall variability (e.g. Justice, 1985). In this analysis twenty-seven MODIS[1] images at a resolution of 250m were used to map the quantity of green vegetation (or biomass) - as measured by the Normalized Difference Vegetation Index (NDVI) - throughout the period that GPS collar data were collected. Some images were corrupt or unavailable and so the elephant information for these time periods was not used.

The importance of migrating south – the overview

The maps below show the changing distribution of green biomass over the period of the 2000 wet season and into the early dry season, covering the period from 27 July to 30

[1] Moderate Resolution Imaging Spectroradiometer carried on the *Terra* satellite.

October, and scaled from red (low) to green (high). It is shown superimposed with the 1970s and GPS collar ranges as well as with the collar locations at the time of the image to show how elephant use of the zone is related to patterns of biomass.

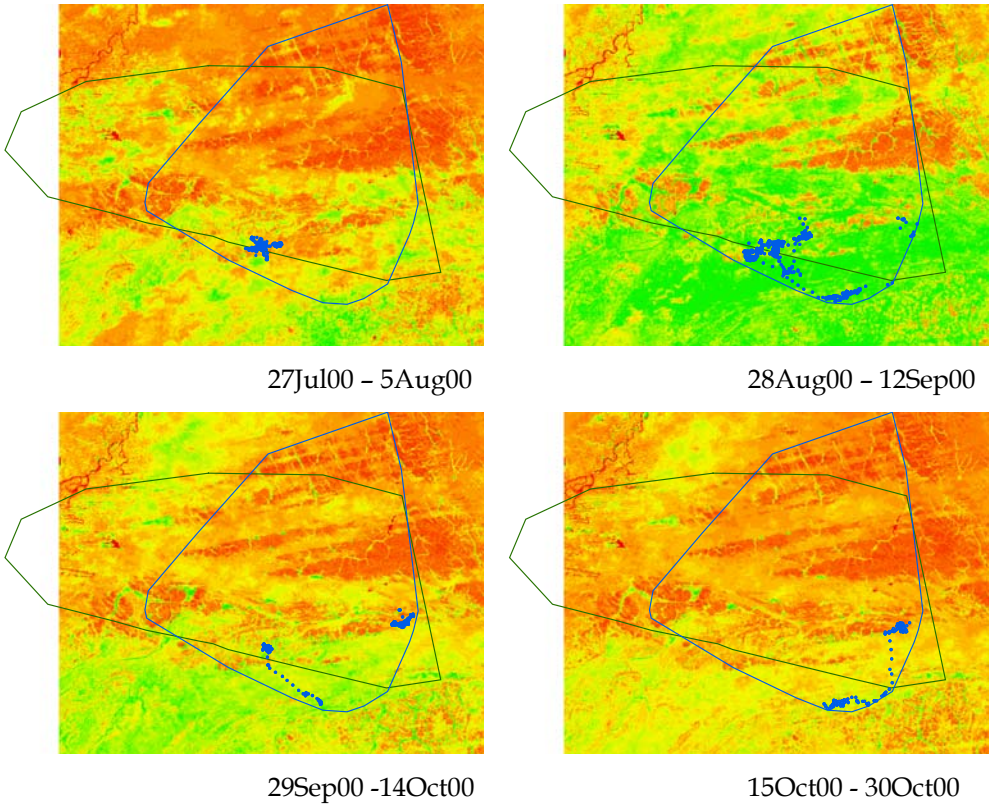


Figure 3.8 Four images showing the distribution of biomass during the wet season scaled from red (low) to green (high). Elephant locations at the time of the image are shown as blue dots and the polygons show the elephant range in the 1970s (darker green) and as shown by the GPS collar data (blue).

Points to note include:

- There is a clear north-south gradient in biomass across the Gourma that reflects the gradient in rainfall, with greater vegetation availability in the south

- The south greens first and stays green for longer than the north. Elephants therefore migrate south as soon as it rains to obtain food as soon as possible in the wet season, and stay there until the need for water causes them to return to the northern part of their range.

- In the north high biomass during the wet season is restricted to the dunes and the thickets of the bottomlands but the flush of herbaceous dune vegetation soon dries, leaving the woody browse vegetation of the thickets as the last remaining source of green biomass by the onset of the dry season.

- The laterite plains of the north support little green vegetation even in the wet season.

Selection of green biomass through the year

To gain some insight into the degree to which the elephants were constrained by food availability through the year, and the degree to which they selected particular vegetation types, the images were used to provide a measure of green vegetation quantity (using NDVI) at each elephant location. This was then compared with the average quantity for the area within a 10km radius of the elephant range to give an indication of the degree to which elephants were selecting areas with high amounts of green vegetation, The results are shown in the figure below.

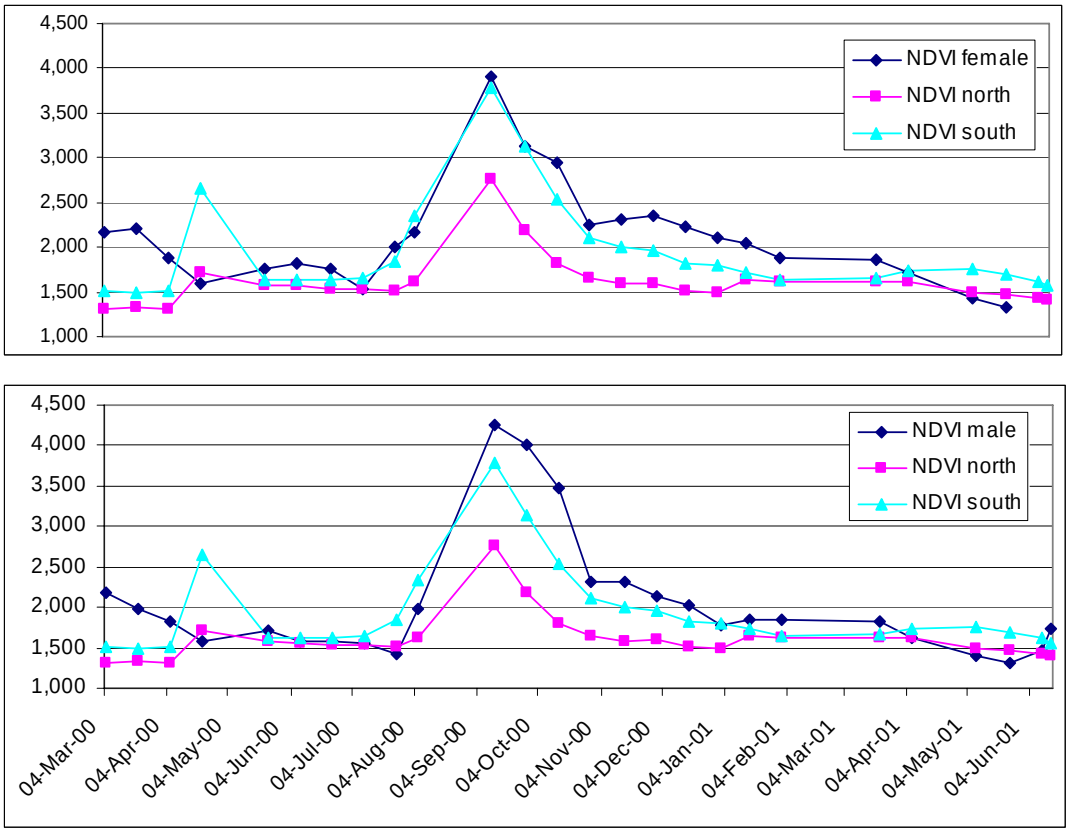


Figure 3.9 The amount of green vegetation (as measured by NDVI) in the area selected by elephants throughout the year is shown in dark blue. This can be compared with the average amount of green vegetation in the north (pink line) and the south (turquoise line). The time period between the dotted lines marks when the elephants are in the south of the migration route.

There are several features of interest:

- There is a much greater amount of biomass in the south compared to the northern part of the elephant range, particularly during the wet season.

- The elephants are selecting areas of higher green biomass than average when in the north of their range; however this margin diminishes substantially once they reach Benzena, and then dips below average by April reflecting the depletion of forage as livestock and elephants converge round the last permanent water. This is especially marked in 2001 and probably reflects the poor rains of 2000. In 2000, by contrast, their selected NDVI only dips briefly below average at one point in April. During the period February – April 2000 both elephants were selecting significantly above average NDVI in the north which possibly reflects the good rains of 1999 which filled waterholes and enabled more habitat choice for the elephants.

- In both years there was some rain during May, which possibly accounts for the small rise in May-June.

- In the south the male frequents areas of higher NDVI than average whereas the female frequents areas of average NDVI. This may be because the movement of herds is constrained by the presence of calves.

- These graphs appear very similar in shape to that of Breman and de Wit (1983) who measured the protein levels in the grass eaten by migratory cattle in the Sahel throughout the year and whose results are shown in the graph below. In this case the cattle migrated north in the wet season as this was the region with no dry season water but good quality pasture. The minimum protein requirement is shown by the dotted line. Throughout the dry season the grass eaten by the cattle contained less than the minimum protein requirement but soared above this level during the few months of the wet season, when the cattle gained weight and reproduced.

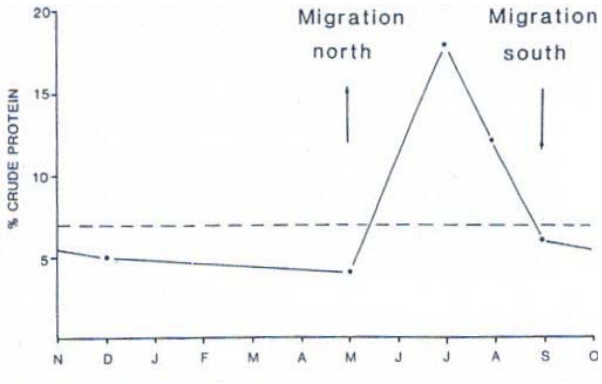


Figure 3.10 Protein levels in the grass eaten by cattle in the Sahel who migrated north for the high-protein grasses in June and July, then returned south. The broken line represents the minimum protein requirements of cattle. Data from Breman and de Wit as cited in Sinclair and Fryxell (1985)

Elephants, however, have a large body side and lack a rumen and so may seek food that is more abundant rather than higher in quality (Bell, 1972). Figure 3.10 shows that the quantity of vegetation increases towards the south and that it stays green for longer, suggesting that this may their chief motivation for migrating south. It also means that the south is likely to be their preferred habitat but they have to spend most of the year in the sub-optimal north because the water-holes are larger and hold water through the dry season.

Selection of vegetation type: the importance of thicket in the north and the Seno-Mondoro in the south

NDVI on its own measures green vegetation biomass, however a time series of NDVI images can be used to distinguish between different vegetation types, as these vary in the timing of their response to rainfall (Karnieli et al, 2002 cited in Olssen, 2005). Constraints of time and ground-truth data prevented the production of a detailed vegetation map, but to assess the degree to which the elephants were selecting different habitat types, the 27-band image was classified into 100 classes using an unsupervised classification algorithm.

This image was used to determine the vegetation class associated with each elephant point and the proportion of time spent by the elephants in each vegetation type was calculated. The elephant preference for a particular vegetation type was measured by comparing it to the frequency expected if the elephants distributed themselves at random and calculated for the north and the south of the elephant range separately so that behaviour in the two areas could be compared.

The results are summarized in the table below and show very high selectivity in the north during the dry season but virtually none in the south during the wet season.

In the north 40 of the available 95 vegetation types were selected at some point by the elephants, but a very few were very highly selected, with the highest preference being 75 times that expected at random. By contrast, in the south, a smaller number - 22 - of the available 98 habitat types were selected but none of these were particularly highly selected with the highest preference being 6 times that expected at random.

	Level of preference (Number of times an elephant was found in a particular vegetation type compared to expected					
	< 1	1.1 - 10	10.1 - 20	20.1 - 30	30.1 - 40	75
No. veg. classes North	55	30	2	3	4	1
No. veg. classes South	76	22				

The North

All the highly selected vegetation types in the north were associated with the drainage-ways and bottomlands that support thicket, dry forest and water-holes, providing further evidence of the importance of these areas. This is supported by the abundance of dung found by the field team in these areas (Barnes et al., 2005). A closer look at the collar data overlain on the satellite image in the north of the range (see figure 3.11) also shows that elephants spend more time in the bottomlands and their associated lines of thicket, where they can find water, food, shade and cover. They appear to spend little time on the open laterite plains or dunes, however while in the dunes, will prefer to move along lines of vegetation in the troughs between dune crests rather than cross the dunes directly.

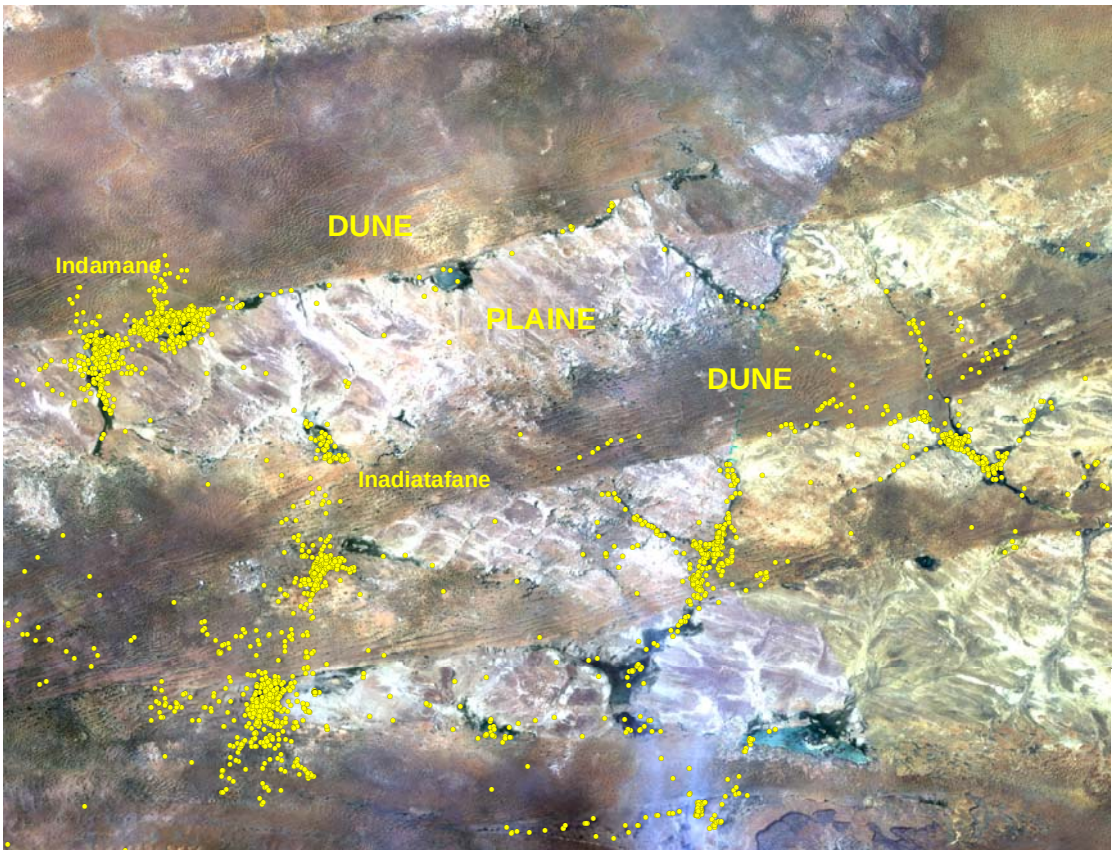


Figure 3.11 A Landsat satellite image (30m pixels) of a typical area in the North, with GPS collar data showing elephant preference for the thicketed drainage lines and bottomlands (darker colours) and the avoidance of lateritic plains (bright) and sandy dunes (parallel crests of relatively bare sand interspersed with vegetated troughs). There is some light haze in the lower-central part of the image.

It may also be that elephants find it tiring to climb the dunes (Elmehdi personal communication). Energetic calculations suggest that even minor hills might represent considerable barriers for animals that are heavy as the reduced muscle efficiency when climbing means heavy animals expend large amounts of energy to shift their body mass

upwards (Wall, 2006). This is especially important for herbivores whose energy replenishment is much more time consuming that for carnivores.

The South

This preference diminishes during the wet season when, although they can be seen to be following thicket lines part of the time, they are also spending much of their time in a range of vegetation types. This is consistent with the nature of their digestive system which means that they must select a wide variety of food types with a mixture of plant types and species (Barnes, 1983).

At the onset of the rains, the elephants move south through the Porte des elephants to the Boni-Serma concentration area. This area, lying between the inselbergs south of the RN16 and the Seno is fed by runoff from the adjacent inselbergs during the rains and supports a mosaic of habitats including forest, bush and grass, temporary pools and drainage lines and salt pans, thus providing a rich variety of grazing, browsing, cover and salt. The two female elephants spent the majority of the wet season here, while the male split his time during the wet season between this area and the Burkina border, but he also spent most of the time between the end of the wet season and January in this area.

The elephants then move south. Local accounts describe their rapid movement across the Seno and through the cultivated areas of the Finta in Mali into the more tranquil areas of northern Burkina Faso in around August, although locals report that there are males that pass in October or November and may stay until January if water remains (Hema, personal communication; Barnes, 2006), as did the collared male.

This part of Burkina Faso is covered by the Aire de Protection de Faune de Nassaoumbou. There is little cultivation and a chain of temporary water-holes, between which the elephants move until they dry (see figure3.12 below). The Toussougou and Soum water-holes on the frontier are the largest, and hold water for longest. From Soum, the elephants used to travel eastwards to the waterholes at Sebangou and Loukodo (Spinage, 1985), and although these areas no longer retain surface water for as long as before, a few elephants still visit these areas (Barnes, 2006).

One elephant was reported to have reached So, 9km north of Djibo, in September 2005 (see figure 3.12). He arrived in the morning but left for the north in the evening and represents the most southerly movement of these elephants in recent years (Barnes, 2006).

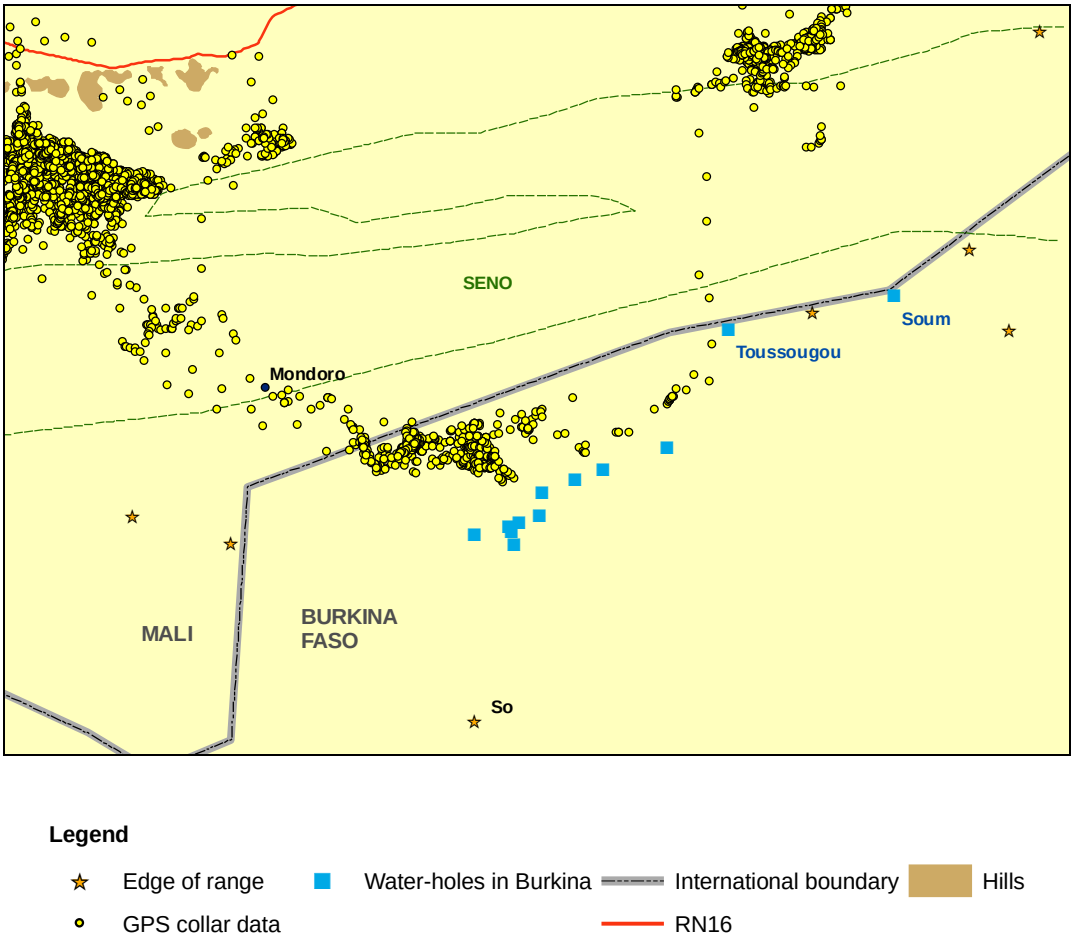


Figure 3.12 Movements of the elephants in the southern-most extent of their range according to Barnes (2006) and shown in relation to the collar data

Those elephants returning north by the eastern route (the females in this case) spent some time in the thickets around the salt pan at Hamniganda and near to the waterhole at N'daki before streaking across a dune and laterite plains to reach the thicketed drainage lines and water-points of the north.

The abundant food obtained while in the south of the elephant range is of particular importance for the females as they need to put on weight until their fat reserves reach the level where they enter oestrus and can conceive. After a two-year pregnancy, they will give birth during the same season when the protein content of grass is greatest and most readily available for lactation (Barnes, 1983).

Elephant diet – the evidence from carbon isotope analysis of elephant tail hairs

Stable carbon isotope ratios in hair record the diet of mammals, and are particularly useful in distinguishing diets of browse versus grass in tropical regions (Cerling et al. 2006)[2]. Hair

[2] This is because of the large difference in the 13C/12C ratios between plants using the C3 and C4 photosynthetic pathways, respectively. In tropical regions, the C3 pathway is used primarily by trees and shrubs, whereas plants using the C4 pathway are principally grasses.

is a particularly useful indicator of diet change because it grows quickly, and so tail hairs from the collared elephants were collected during immobilization operations when the collars were being removed.

Figure 3.13 shows the ratio over the period 18th July 2001 to 16th April 2002. For most of the year – throughout the dry season – the elephants are eating browse only, while the peaks that indicate more grass in the diet, coincide with the wet season months of July, August and September. This supports the findings from the NDVI analysis described in the previous sections.

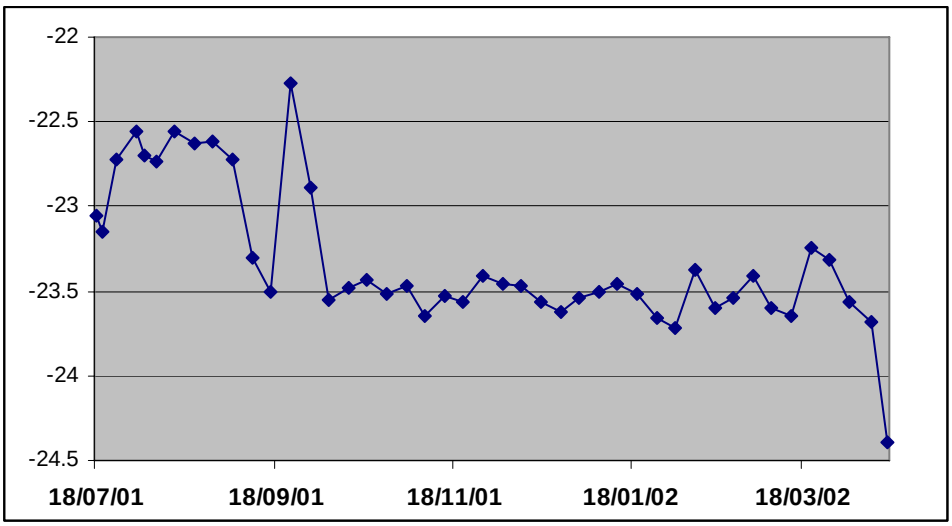


Figure 3.13 The relative amounts of grass compared to browse in the elephant diet through the year (as measured by carbon isotope analysis)

The use of habitat around Benzena – a key resource and its relevance to nutrition

Degradation of the food resource around waterholes - In the Gourma large numbers of elephants and livestock concentrate around water-holes during the dry season and particularly around the Benzena water-hole at the end of the dry season.

To make a preliminary assessment of elephant and livestock use of Benzena and the impact such a concentration of animals and humans might be having on the vegetation, Barnes et al. (2005) measured 40 transects at the end of the 2004 dry season. The transects showed a strong positive relationship between the elephant dung and the abundance of favoured tree species such as *Balanites aegyptiaca* and *Acacia radiana*, as well as with the total number of woody species, and concluded that if over-browsing (by goats or elephants) reduced the abundance of these trees, Benzena would be able to support fewer elephants.

Blake et al. (2003) had also found that browsing pressure was heavy on certain species such as *Balanites aegyptiaca* and *Acacia radiana*, although it was difficult to distinguish between elephant and camel browsing. Barnes et al. (2005) found that some trees were so heavily

browsed that they were unlikely to recover during the next wet season and they thought that regeneration seemed inadequate to replace these heavily-browsed adult trees, however species such as *Boscia senegalensis* were hardly touched because of their toxins. They also noticed a marked reduction in the shrub canopy over the month of April 2004.

These findings raise the question of the trend in the woody vegetation around the lakes, and particularly Benzena, and the degree to which elephants, droughts, and human activities are contributing to its decline (Barnes et al., 2005).

Barnes et al. (2005) also found that most elephants browse within a short radius – 6km - of the lake, much smaller than previously supposed. Since elephants are very mobile, it is something of a mystery as to why the elephants did not forage further afield, particularly as Blake et al. (2003) found that the mean height of woody vegetation increased with distance from the lake. 2004 was an atypical year in that there had been abundant rains in the 2003 wet season, which meant that the elephants had been well nourished and that many water sources had filled up and lasted longer. It might therefore be expected that their movements were less restricted by water availability in the dry season, and they could feed for longer in places that they would normally have to abandon in the dry season. However the suggestion that elephants use a much smaller proportion of the landscape than previously thought is also supported by examination of the GPS collar data which also shows a tendency to spend most of their time within 6km of Benzena at the end of the dry seasons in 2000 and 2001, and while 2000 was preceded by the good rains of the 1999 wet season, the 2000 wet season was bad.

The importance of adequate food in arid environments was highlighted by the 1970-1971 dry period in Tsavo-East National Park, Kenya[3], when a considerable proportion of the elephant population died.

The high mortality was not found to be due to lack of water - it occurred in the most arid areas near permanent water - but was found to be due to starvation precipitated by low rainfall and long dry seasons of 1970 and 1971. Increasing elephant numbers in the 1950s and 1960s had led to decreased food in the vicinity of permanent water holes. A period of below average rainfall then reduced primary productivity leaving elephants with inadequate food supplies to last them through the following prolonged dry season[4]. Females experienced higher mortality probably because they were limited by calves in their search for food, and the high juvenile mortality typical of the <1 year age group was extended to the 5-10 year age group.

In this instance food supplies around the permanent water-holes had been degraded by the increasing elephant population, however it flags the importance the depletion and degradation of the vegetation in these areas - whether from elephants, droughts, or human activities –in making it more difficult for them to survive dry years.

[3] Although this area experiences two wet seasons, compared to just one in the Sahel, there is sparse permanent water and rainfall can be below 250mm in some years.
[4] This was also observed in Uganda where elephants died in large numbers around Lugard Falls. It is as yet unexplained why they left partially exploited food largely untouched some 15km upstream.

3.5.3 Salt

The Gourma is valued by herders for its salt pans and it is for this that many of the seasonal herders visit from as far afield as Niger and Burkina Faso. Analysis of elephant movement in relation to location of salt pans showed no relationship which suggests that salt is sufficiently distributed to provide elephants with what they need, at least in the north, as we only had data for this part of the migration route. However elephants do appear to spend a significant amount of time in the region of Hamniganda, an important salt source in the south, at the end of the wet season which may be to obtain salt after several months of water-rich food, before returning to the tranquil areas of the north (Elmehdi, personal communication).

3.5.4 Summary - the need to move

Rangeland production in the Sahel is highly seasonal and migrations are a strategy for coping with variation in abundance and quality of food (Sinclair and Fryxell, 1988). In this harsh and variable environment, the ability to migrate and move is critical to elephant survival.

An analysis of the pattern of elephant movements has shown that they spend 95% of their time in concentration areas where they find the key resources for their survival. Analyses of these areas and patterns suggest that the south is likely to be their preferred habitat for its food resource, but the water-holes are small and ephemeral. The elephants are obliged to return to the sub-optimal north where the water-holes are larger and where water can be found through the dry season. Adequate food is also required to survive the long dry periods and the elephants rely heavily on the woody vegetation of the thicketed drainage ways and bottomlands, and mostly avoiding the dunes and plains. Fortunately all their needs of water, food, shade and cover are provided by this habitat. At the onset of the rains the elephants migrate to replenish their fat reserves with the abundant forage of the south. This allows them to survive the meagre food of the long dry season and achieve the condition required for reproduction and lactation.

Although the elephants only spend 5% of their time in corridors between concentration areas, these are of crucial importance in allowing them to migrate. A number of studies have shown that migration by ungulates allows higher populations to exist than if the same animals are sedentary (Barnes, 1978, 1979; Sinclair, 1979, Fryxell et al., 1988), and this applies for both wild and domestic species (Sinclair and Fryxell, 1985). Where such migrations have been impeded, animal numbers have declined drastically REFS, and the concern is that they decline to a threshold below which the population is no longer viable and dwindles to zero.

Anything that prevents or impedes their free movement, or restricts access to forage or water resources will, adversely influence their survival probabilities. It is the infants that

are the first to suffer when elephants are obliged to travel long distances in search of food and water or forage (see for example Barnes 1983), leading to a higher rate of infant mortality and a population with a high proportion of adults that is more vulnerable to prolonged stress such as drying climate or increased human pressure.

Examining the changes in elephant range since the 1970s suggested that increasing human impact plays a role in influencing elephant movement. In the next chapter we look more closely at how measures of human activity relate to elephant movement.

4. Elephant movement in relation to human presence and activity

A better understanding of elephant needs did not explain all features of the elephant movements. The project also wanted to determine whether human presence and activity exerted a significant influence on elephant movement, and to identify potential threats, given that the Gourma had recently undergone a series of upheavals due to the droughts and the conflict of the early 1990s.

4.1 The people of the Gourma and their livelihoods

Faure-Osei and Diakite (2002) recognize three categories of people using the Gourma's resources: sedentary permanent residents; regular transhumant and nomadic herders; temporary residents from other areas forced to migrate through hardship and waiting for better times before returning to their home areas. It is difficult to obtain accurate numbers of these nomadic and transhumant populations. Ag Mahmoud (1992) published figures for 1975 and 1987 but felt that official figures should be treated with caution. In particular he thought that the figures for 1987 were probably 10% too low, and suggested that an extra 30% be added to account for the influx of seasonal inhabitants coming from neighbouring regions – particularly the Inner Delta - and from as far away as Niger and Burkina Faso. He also noted that the activities of the NGO "*Aide de l'Eglise Norvegienne*" had attracted many people from outside the region into the Gourma.

Numbers of livestock are even more difficult. Changes in these numbers have been even larger than those of human populations but are not so well documented, or are difficult to interpret because of the effects of herds moving in and out of the Gourma between seasons (Hiernaux, 1996). Faoure-Osei and Diakite (2002) estimated that there are around a million cattle and a million-and-a-half shoats in the Gourma of which around 10-20% are sedentary and around 10-20% come from Niger and Burkina Faso. 40% of the livestock in the region of Mopti stay for some time during the year in the Gourma, 45% of the livestock from in the region of Timbouctou and 30% of the livestock from the region of Gao.

While the north of the elephant range is predominantly a pastoral area (apart form the gardens described below), the south – between the RN16 to the frontier with Burkina Faso – is an agricultural and agro-pastoral area comprising the Ferro de Boni, the Seno-Mondoro and the Finta. Maiga (1996) and Ganame (1999) described the following socio-economic systems:

- The pastoral system of the Tuareg.

- The agropastoral system of the Peulh, Sonrhai, Bellah and Dogon, in which animals are kept around the villages during the dry season. In the wet season the animals are moved away from the villages and/or northwards us the pasture of the dunes of the

non-cultivated regions, and return to their villages at the end of the harvest and the beginning of the dry season. Fields are also cultivated in small parcels around villages and from cleared bush often situated in bottomlands.

- The Dogons, Sonrhai and Peulhs rimaibes for whom agriculture is their principal activity and cultivate large fields of grain and store their harvest in stores in the fields or close to villages, and sell their cereals in the markets of Boni, Hombori and Djibo in Burkina Faso.

- Gardening is practiced by sedentary populations (chiefly Bellah and Sonrhai) around perennial water-holes such as Gossi, Dimamou, Adiora and Inadiatafane. Millet, sorghum, maize and water melons are cultivated in the wet season and vegetables and spices for the rest of the year. The influx of the people from the North fleeing drought and the insecurity associated with the conflict of the early 90s, means that most of the perennial water-holes are exploited. This is a recent activity in the Gourma and only became significant since the mid 1980s.

In addition the Peulh of the Delta use this area as wet season pasture and there can be conflict between herders and agriculturalists when fields are cleared on the paths of the herds and the animals enter into the fields.

4.1.1 Recent changes and their impact on human-elephant interactions

In general the people of the Gourma are traditionally well-disposed towards elephants, and conflict was not an issue before the late 1980s (Maiga, 1996; PCVBG, 2002). Elephants were able to fulfill their needs at the same time as avoiding human activity. The drying climate[5] and reduction in resources, together with increased demographic and livestock pressure and the conflict of the early 1990s, have led to increased human settlement and cultivation, sometimes aided by international aid agencies (Maiga, 1996). The result is that humans and elephants have come increasingly into conflict (PCVBG, 2001). The trends include:

The development of settlement and gardening around water-holes in their dry-season range since the late 1980s.

Gardens around water sources[6] in the north of the elephant range impede elephant access to water and are therefore vulnerable to trampling. In addition, any crops are a temptation for hungry elephants on their way to water. Development at Gossi has almost completely surrounded this permanent lake and it is now avoided by the herds. Not only does this increase the potential for crop destruction but also represents an additional pressure on the water resource.

[5] The ecological changes that have resulted from the droughts of the 70s and 80s include the reduction of water resources, death of large trees, change in species composition from broad-leaved species to an increased frequency of spiny species associated with drier zones, degradation of pasture.
[6] For example Gossi, Dimamou, Inadiatafane, Adiora

Increasing rain-fed agriculture on the path of the elephants in their wet-season range.

These fields are vulnerable towards the end of the wet season as crops achieve growth, and grain-stores are filled. This takes two general forms (Ganame, 1999)

- Multiplication of fields[7] related to the population growth of agricultural peoples such as the Dogons, Sonrhai, mostly in the south of the elephant range, who often keep grain in stores made of thatch and left unattended in fields.

- The adoption of agro-pastoralism by traditional herders who tend to clear bushland and thicket to cultivate in small parcels around dwellings as a secondary activity. The creation of artificial water-points has allowed a greater number of people and animals to exploit this otherwise waterless area.

Increasing conflict around water-holes

Generally elephants and livestock coexist peacefully around water-holes, as elephants drink in the evening and at night while people and livestock use the water during the day (Blake et al., 2003; Barnes et al., 2006). In addition, livestock such as goats can benefit from branches and pods pulled down by the elephants while foraging. Historically herders and livestock have only been a problem for elephants at the very end of the dry season when high concentrations of people and animals increase the probability of accidents. However, where there are large concentrations of livestock, and in dry years when the concentration of elephants and livestock around the remaining water increases, there are incidences of elephant aggression towards livestock and occasionally humans (PCVBG, 2001).

Observations at the water-hole at Techerit in April 2004 indicated that elephants leave a water-hole before it dries completely. Perhaps this is because competition with livestock for access to water as the circumference of the water-hole shrinks, or perhaps the concentration of pollution by livestock reaches a level that the elephants find intolerable (Barnes, 2006).

Elephants can also cause the collapse of *puisards* – shallow and un-reinforced 'well holes' dug in the bottom of water-courses – in their search for water.

4.2 Measuring human impact

The number of people in a given area is frequently cited as a primary cause of declines in species and ecosystems (Cincotta and Engelman, 2000), with higher human densities leading to higher levels of influence on nature. Simple mathematics suggests that the greater the number of people, the more resources will be required from the land (Wackernagel and Rees, 1996) but beyond this general understanding, the way in which human influence scales with human population density is not clear, and inevitably will be context specific. Numbers on their own take no account of the nature of human activities and their impact on elephant livelihoods.

[7] Growing millet, sorghum, beans and peanuts

Perhaps the best proxy for mapping the impacts of pastoralism is the distribution of livestock through year. High numbers of livestock impact on elephant livelihoods by making it more difficult and stressful for them to access water, at the same time as causing water-points to dry earlier in the dry season (Mohamed Agbilal cited in Blake, 2003) and thus increasing the dependence of elephants, humans and livestock on Benzena for longer. The destruction of forage by cutting thicket vegetation for browse may also have an impact in localized areas at particular times of the year.

Settlement and agriculture impact on elephants by blocking their routes and inducing stress through human disturbance and conflict. To measure this we looked at the trends and distribution of settlement and associated agricultural activities over the study area in three ways:

- Measuring human impact in terms of population density of the land surface, and trends over time.

- Measuring human impact in terms of activity through mapping the distribution of settlement and associated infrastructure.

- Indicators of the impact of human activity on elephant well-being: conflict and priorities for conservation intervention.

4.3 Measures of human impact: population density

4.3.1 Human population density 1997 by commune

To assess the general distribution of human population in the Gourma, the GPS elephant collar data were overlain on map of human population density by commune (figure 4.1). This suggests that elephants are avoiding areas of the highest population density, and this may have been a contributing factor in the elephants abandoning the western part of their range since the 1970s.

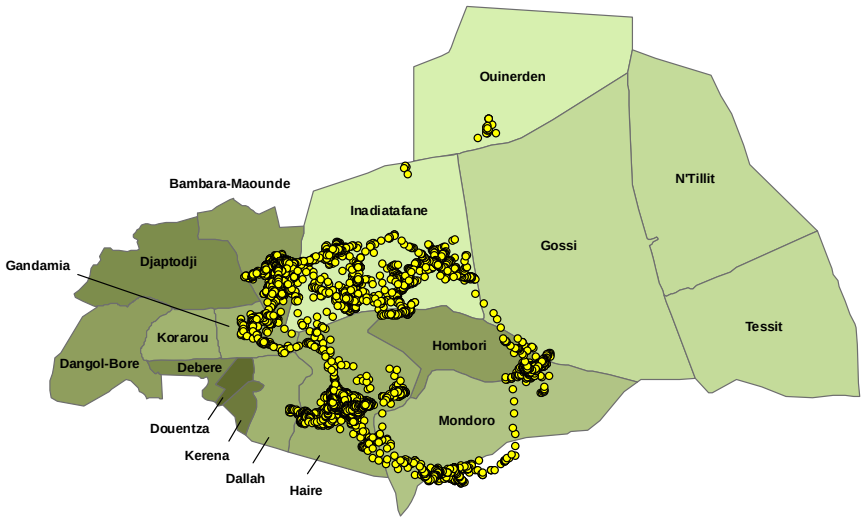


Figure 4.1 Elephant collar data in relation to human population density by commune. Darker colours indicate greater population densities.

4.3.2 Human population density 1997 by village/campement in the north of the elephant range

A more detailed map of population distribution was made possible through Action Contre le Faim's work in collecting census data for each settlement and campement. These point data were extrapolated to create a map using the spatial analysis functions within ArcGIS (figure 4.2). This indicates that the herds are avoiding the relatively high population concentration around Gossi and for the most part appear to be frequenting areas of lesser population density.

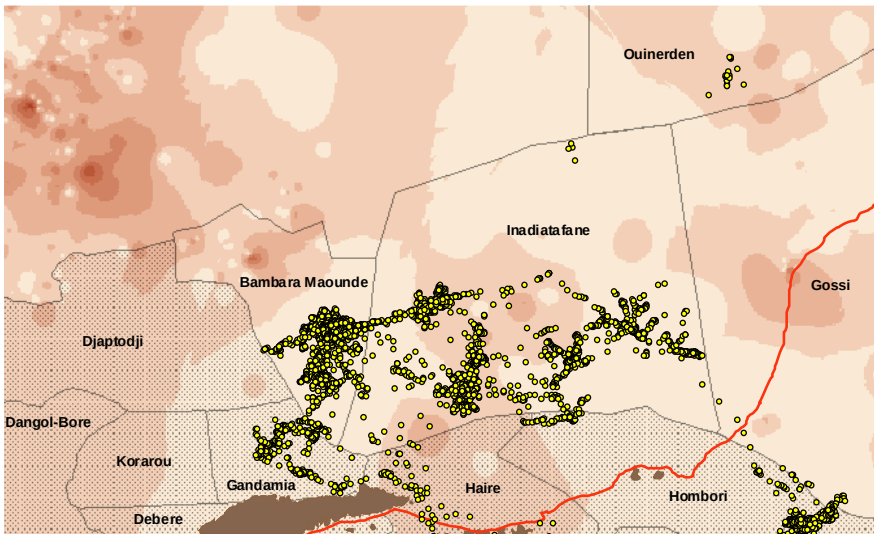


Figure 4.2 1997 human population densities in the north of the migration route together with the elephant GPS data and the commune boundaries. The hatched area represents areas where the data were incomplete. Darker colours indicate greater population densities.

4.3.3 Changes in human population 1975 – 1987 – 1997

In the north of the migration route

It was difficult to use census data to look at population change as administrative boundaries had changed between 1987 and 1997, when arrondissements were replaced by communes, however we mapped Action Contre le Faim's census data for 1976, 1986 and 1997 for each settlement and campement to highlight areas of increase and decrease in human population density over two time periods 1976-1987 and 1987-1997 (figure 4.3).

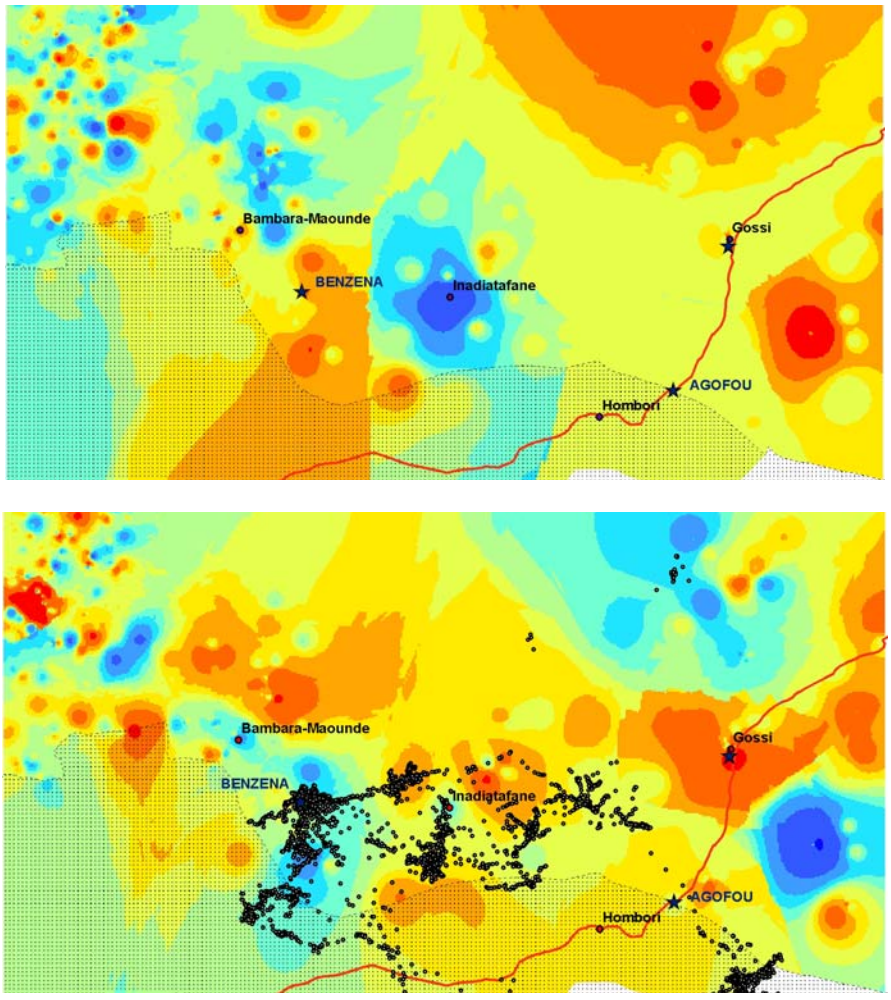


Figure 4.3 Changes in human population density 1976-1987 (top) and 1987-1997 (bottom) with blue and green colours representing a decrease in population and yellows, oranges and reds representing an increase. The shaded area represents no data.

Noticeable features are:

1976 – 1987

- The increase in population in the north-east and to the south of Gossi in 1987 after the drought, due to the migration of pastoralists from the more arid zones north of the Niger river
- The decrease in some areas accompanied by the increase in adjacent areas representing the increase in concentrations of people associated with settlements.

1987 – 1997

- The continued increase in settlement around Gossi, and in the Lakes region
- The emptying of the north-east and the filling of the central Gourma.
- For the most part elephants are avoiding the most densely occupied areas.

In the south of the migration route 1975 – 1987 – 1997

We do not have comparable data for the south of the migration route, apart from the commune of Haire, where the elephants spend a large proportion of the wet season. The figures are shown in the table below.

Year	Population
1976	13,784
1987	16,455
1996	21,440

From (Ganame, 1999)

This is consistent with the general impression that the south of the Gourma has experienced an increase in people, nomad camps, and a multiplication of fields as the offspring of agricultural families each cultivate their own individual land parcels (Ganame, 1999). These figures represent a 1.8% increase between 1976 and 1987 and a 3% increase between 1987 and 1997, rates that are consistent with a wider trend in Mali and throughout the Sahel and can be compared with Mali's national population growth rate of 3% during the 1980s and 1990s (Olssen et al., 2005).

4.4 Measures of human impact: settlement

4.4.1 Location of settlements in relation to elephant movement

Blake *et al*. (2003) performed a rapid aerial survey of the migration route that suggested an inverse relationship between elephant concentrations and villages. They also found that the distribution of land under cultivation closely followed that of permanent villages. To test this, the elephant GPS positions were plotted on the 1961 map of settlements with each settlement surrounded by a buffer zone of 10km. The result is shown in figure 4.4 and suggests that these elephants appear to be avoiding settlements, and probably have been

using this circular route since the 1960s. It also suggests that the density of settlement is a reason the elephants are avoiding the central part of the range. Where the elephants approach within 10km such as along the north edge of the Gandamia escarpment, in the Hamniganda concentration area, and the Dimamou mare in the north, inspection of the satellite image shows that the elephants are following dense cover along drainage lines, and presumably feel relatively secure.

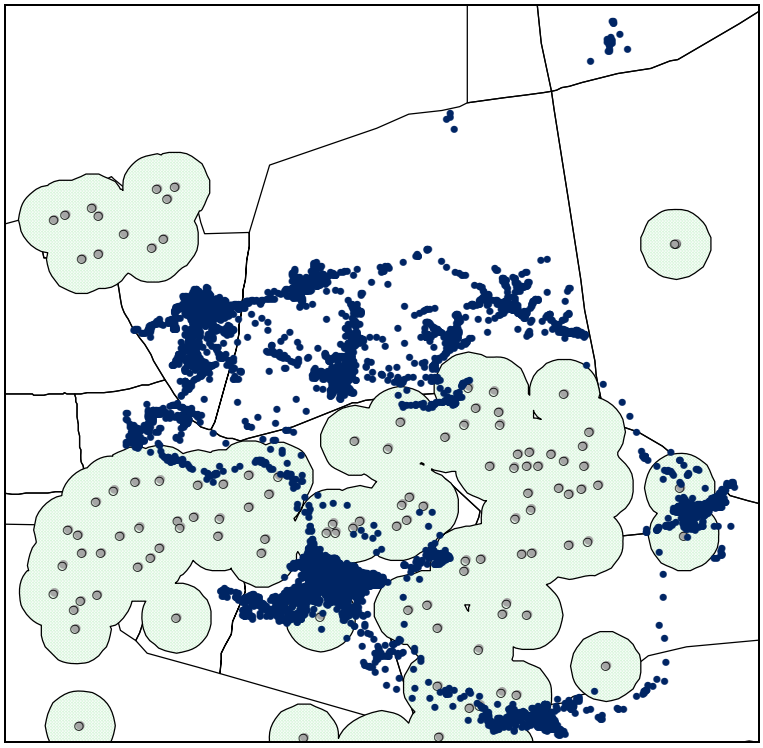


Figure 4.4 Elephant positions in relation to a 10km buffer around settlement locations throughout the migration route

When the number of GPS locations are plotted against distance from settlement (figure 4.5) it can be seen that elephants rarely approach within 5km, while a comparison between the male and female elephant shows that the male spends 67% of his time and the female 77% of her time further than 10km from settlements (as measured by number of GPS locations). Although these are data from only two elephants, this is consistent with observations from other populations that male elephants tend to be bolder than female elephants.

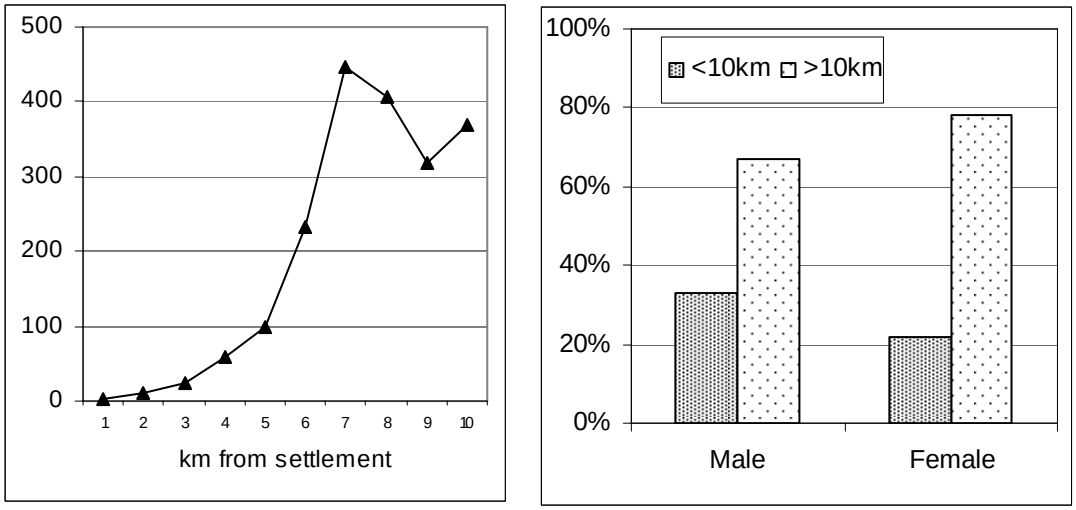


Figure 4.5 The number of elephant GPS positions found with distance from settlement (left) and the proportion of points found less than 10km from a settlement compared with more than 10km for the male and female elephants (right)

4.4.2 Changes in numbers of people in villages compared to nomads in the north of the migration route 1975 – 1986

To test for trends in settlement, we compared census data for 1976 and 1987. The result in figure 4.6 shows that there was an increase in settlement and a reduction in nomads between 1976 and 1987 in three out of the four communes for which we have data covering the northern part of the migration zone. This was even before the reported larger trend towards settlement at the end of the 1980s.

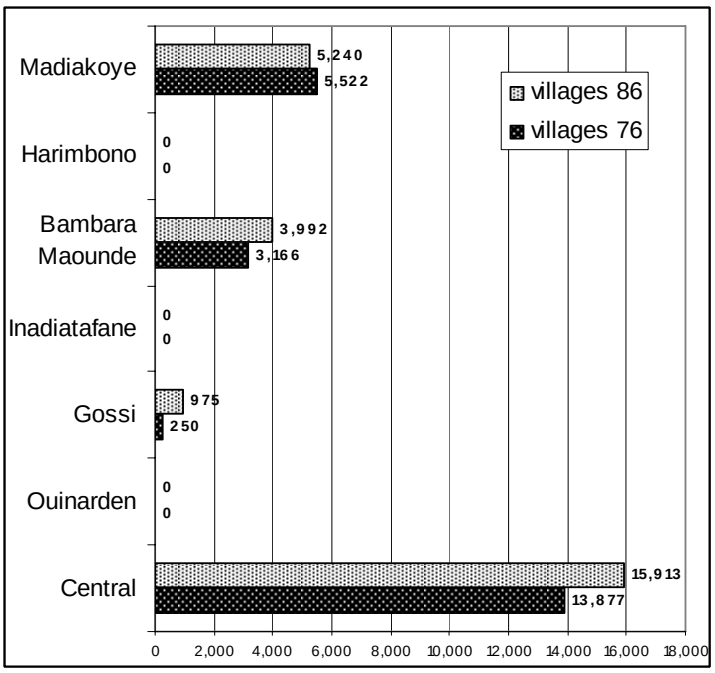


Figure 4.6 The size of the population settled in villages has increased in the communes covering the northern part of the migration route (data source Ag Mahmoud, 1992)

These figures are equivalent to growth rates of 2% in Central/Rharous, 6.7% in Bambara-Maounde and an astonishing 26.4% in Gossi, and be compared with FAO's estimate of urban growth for Mali during the 1990s of 5% over the same period (Olssen et al., 2005).

4.4.3 Modelling the impact of human settlement and associated developments

To portray the distribution of relative levels of human impact associated with settled livelihoods, we assembled datapoints[8] that recorded aspects of human activity. We combined these in an Arc Map model constructed with ESRI's ArcGIS software to produce a map showing the relative intensity of human activities. Data were collected on the location of:

- **Settlement** as a source of agents to transform land use (the 1961 map, 2005 field data[9]).
- **Fields** as a measure of land transformation, often thought of as the single biggest threat to biodiversity (2005 field data).
- **Roads**, not because the elephants avoid them per se but because they are a measure of human activity and accessibility for cultivation, markets and development and therefore are associated with areas of land transformation (2005 field data).
- **Waterpoints** that could be used by people and livestock – permanent lakes, semi-permanent lakes/water-holes, wells, puisards and traditional watering points (SSE data).

The resulting map is shown in figure 4.7 together with the elephant collar data and the parts of their migration where they were moving rapidly at greater than 10km/hour, known as 'streaking'.

Overlaying the GPS collar data shows that:

- These three elephants were avoiding the hotspots of most intense activity completely, coloured red and orange, and choosing areas of relatively low activity, coloured blue. On the occasions that they are found in the yellow areas they tend to be moving quickly or hiding in thicket lines.

- In the south-west part of their range, the elephants are picking their way between the 'hotspots' of human activity to gain access to the next concentration area. There are few tranquil areas left for them. Most of their time was spent in the Boni-Serma concentration area which is reserved as grazing land by the villages of Boni and Serma and remains free of cultivation (Hema and Doumbia, personal communication).

[8] These data would consist of a geographical XY co-ordinate accompanied by the activity occurring at that point e.g. village, cultivation, market gardening etc.

[9] The field team spent a disproportionate amount of time in the elephant concentration areas which meant that these areas, and so, if anything, the difference in human activity between the concentration areas and areas where there are no elephants is likely to be greater than shown by this model.

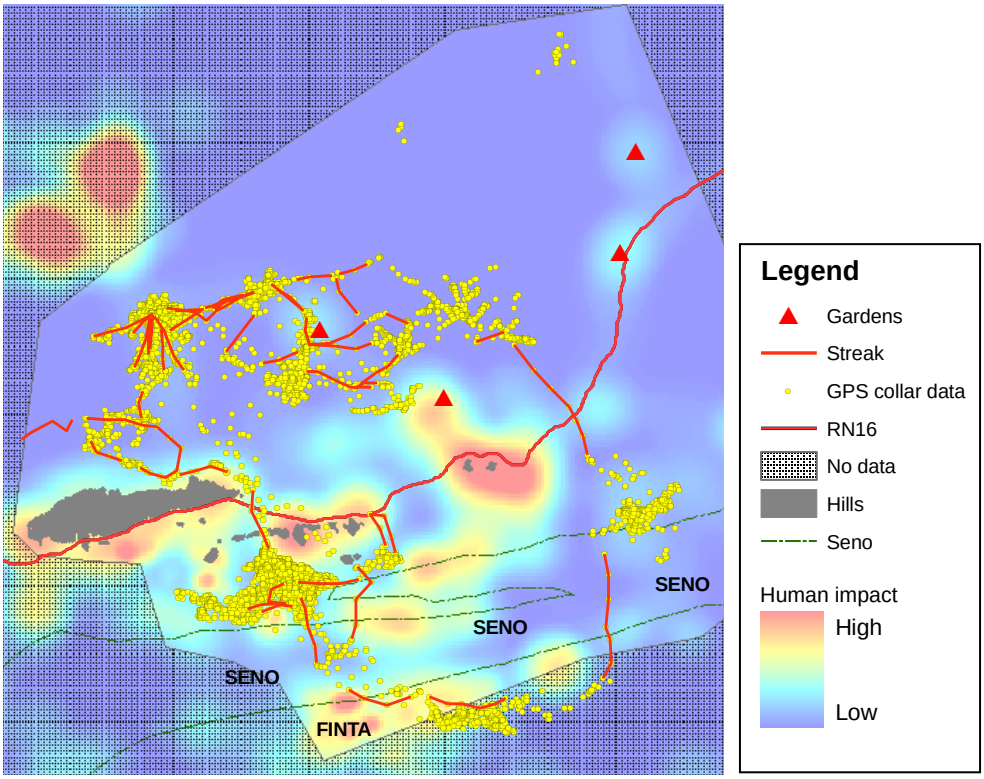


Figure 4.7 The relative intensity of human activity as measured by a combination of settlement, cultivation, roads and water-point density. The location of gardens is shown by red triangles. The red lines show the part of the migration route where elephants were 'streaking' while the green dashed line indicates the edge of the Seno Mondoro a large fossil sand-dune. The shaded areas represent areas outside the range of the ground data.

- There is much less human activity in the south-east but much of this is covered by the Seno, and it is waterless in the dry season.

The above model focused on the area of the elephant migration route. To obtain an idea of how the migration related to the wider context of human activity we superimposed the elephant collar data on a section of the global human footprint model (Sanderson et al., 2002) and the result is shown in figure 4.8. It shows how elephants are avoiding the areas of greater human footprint in the west and the south. Although the north and east has a low footprint, much of this area is dune and plain, and resources used by elephants are confined to the drainage ways.

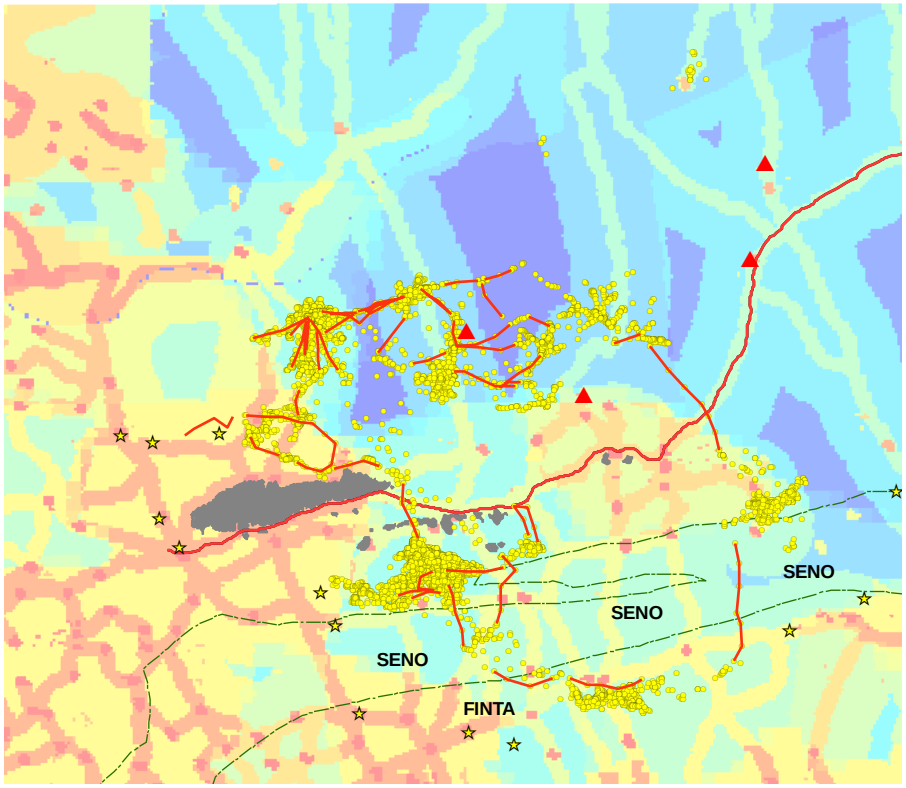


Figure 4.8 The intensity of human activity as measured by Sanderson et al.'s global footprint model (Sanderson et al., 2002)[10]. The location of gardens is shown by red triangles. The red lines show the part of the migration route where elephants were 'streaking' while the green dashed line indicates the edge of the Seno Mondoro a large fossil sand-dune.

4.5 Indicators of the impact of human activity on elephant well-being

Locations of elephant damage to humans and infrastructure were compiled from studies by the PCVBG project (PCVBG, 2001; Maiga, 1996; Ganame, 1999), supplemented by that of the field team. All these authors noted the difficulty in obtaining accurate data as there was often a tendency to exaggerate the destruction in the hope of compensation, and so it was therefore difficult to evaluate the severity and comparability of reports.

The location of conflict was overlain on the map of human impact due to settlement and cultivation. The result is shown in figure 4.9 below.

It is clear that conflict is occurring on the edge of the most intense areas of human activity (areas of high activity being avoided completely), although in some areas, such as Gandamia, it occurs where cultivation in drainage-ways is a relatively recent occupation (Hema and Doumbia, personal communication).

[10] Areas coloured red and orange will have high levels of one or more of the following: human population density; land transformation; accessibility; and electrical power infrastructure.

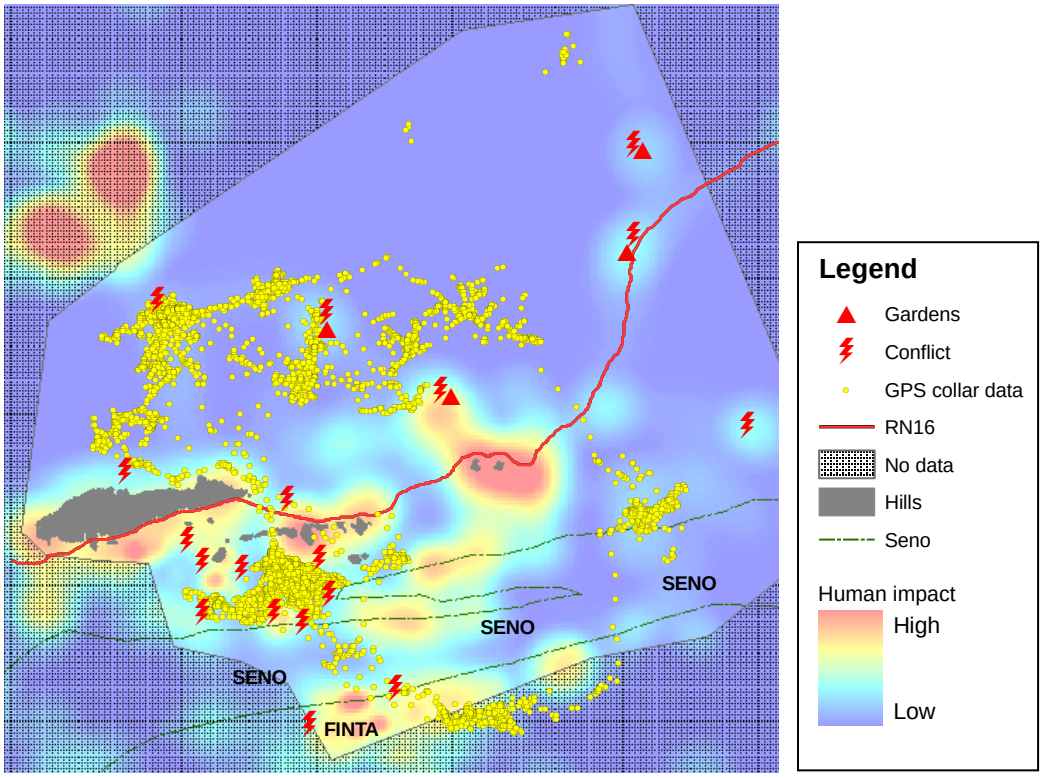


Figure 4.9 The location of incidents of conflict (red bolts) in relation to the intensity of human impact. The green dashed line indicates the edge of the Seno Mondoro a large fossil sand-dune. The shaded areas represent areas outside the range of the ground data.

4.6 Discussion

The evidence suggests that the trends of increased human presence, settlement and cultivation in the elephant range have had a significant impact on the elephants in:

- Shaping the migration route by:
  - Preventing the use of the centre of the range
  - Possibly contributing to the displacement of the elephants – particularly the herds - from the region of the Lakes
- Impeding their access to water where market gardens and settled infrastructure have been established around water-points in their dry-season range. This can be seen in extreme form at Gossi which the herds have stopped using since the late 1980s and is now frequented for 8-9 months of the year by 6 or 7 bulls.
- Confining the elephants to small patches of critical habitat during the wet season.

The south-west is under the greatest pressure and any further spread in cultivation in this area threatens to exacerbate conflict at a time when the elephants need access to the abundant and varied food that will enable them to survive the privations of the dry season, reproduce and lactate.

The Boni-Serma concentration area is virtually the only remaining area of their preferred habitat between the RN16 and the Seno that is relatively free of human activity. If this area is closed to them, there is very little other place for them to use and conflict will increase dramatically. The quieter border area with Burkina Faso is also favoured but requires passing through areas of relatively high human activity.

- Reducing the options for passage through the Gandamia hills to the food resources of the south.

  Any settlement or increase in cultivation threatens to block their route through the Porte des Elephants, and impede their route through Gandamia. This is suggested by one foray of the female elephant who tries to move north around one of the hills to the east of the Porte des Elephants through an area of high human impact but turns back. On another occasion, the male tries an alternative route north but turns back and in the end waits until the middle of the night to dash through.

We were not able to assess quantitatively the impact of pastoralism and livestock on the elephants, and the nearest approximation is the map of human population density for the north of the elephant range. Here the conflict is about access to water and accidents that occur when humans, livestock and elephants are concentrated around water. This is exacerbated by large numbers of livestock causing the semi-permanent lakes to dry earlier in the dry season thus increasing the dependence of the elephants on fewer water-points for longer, and on Benzena in particular.

The pressure is increasing in all parts of their range. There is a danger that the incremental expansion of human activity induces sudden threshold increases in impact. This phenomenon was documented by Hoare and du Toit (1999) who looked at the effect of human density on elephant numbers in Zimbabwe. They discovered that where the transformation of land use to human activities reached around 40-50%, a threshold was reached at which point elephants moved away. In the Gourma, it is not clear that the elephants would have anywhere to move to that could provide all their requirements within the reach of an annual migration. As the options for the elephants are reduced sudden threshold increases in conflict will occur. Once this happens the options for reducing it are limited, and solutions much more difficult to implement.

5. Key findings, discussion and recommendations

5.1 The population

The population size is around 550-700 animals, a number that appears to have remained more or less stable since the 1970s. It was possible to obtain an estimate of the population age structure, and through its examination, an indication of survivorship. Compared to other populations throughout Africa, it is an old population with over 50% of the population composed of adults, with a fairly high fertility rate but very high rates of mortality in newborns and young animals. A simple population model produced a provisional estimate of rate of increase of about 1.4% per annum. This is very low, and given the uncertainty of age estimates and the assumptions of the model used, it is likely that the population can be considered, at best, stable, neither increasing nor decreasing significantly at present. The high calf mortality is probably due to the harsh environment and long migration, and means that the population is vulnerable to any increase in disturbance of its dry season foraging resources, and very dependent on adequate nutrition during wet season migrations.

Small, incremental stress factors are expected to reduce the inherent capacity for population recovery from a more acute stress such as a succession of drought years or the blockage of a key elephant corridor. There is therefore an increased likelihood of a sudden, dramatic fall in animal numbers. Examples of such incremental stress factors include:

- Having to search farther afield for water as water-points become settled or used up through increasing pressure of livestock
- A reduction in forage available in the thickets of the north
- A reduction of forage in the wet season concentration areas through increased livestock and land conversion to agriculture
- The increased energy and stress required in avoiding human activity.

5.2 The importance of the current migration route

This study has shown that the elephants have survived through an ability to find resources in areas of low human activity, and that they avoid contact with humans wherever possible.

The way the elephants use the space is critical to their survival and allows them to eke out a living in this marginal environment. Their migration involves moving relatively rapidly along migration corridors between concentration areas where they spend the majority (95%) of their time. These concentration areas contain key resources required at particular times of the year such perennial water, dry season water, sufficient quantities of food, and

refuge from areas of high human activity. The elephant use of these areas demonstrates a fine balance of trade-offs that ensures their year-round survival[11].

5.3 Finding resources

- Of this large area the elephants predominantly use only specific habitats. In the north the elephants are almost completely restricted to thicket areas near mares and drainage ways which represent a very small proportion of the total area but are the crucial key habitat providing water, browse (the only green vegetation), shade and cover.

- The elephants avoid the barren laterite plains in the north, and the dunes in both the north and south.

- In the south they exhibit a strong preference for the diverse habitat mosaic of the Boni- Serma concentration area, and the Nassaoumbou protected area in Burkina Faso. These areas are vital forage sources for them to gain body condition, reproduce and put on the weight required to last the long dry season.

5.4 Avoiding human activity - dry season

> "The bad feeling of some pastoralists towards elephants came from the fact that in recent years the human population and the number of cattle increased in the region and led to the creation of settlements around the lakes. The competition between elephants and humans and their cattle for drinking water and for food has led to conflict between them."
>
> Mohamed Agbilal, head of a tribe at Tinabou,
> cited in Blake et al., 2003

- Elephants are reported to avoid contact with humans by waiting until night fall before visiting waterholes (Barnes 2005), although they are also seen drinking during the day together with small livestock (Blake et al., 2003). Competition and accidents are more likely where large numbers of humans, livestock and elephants are concentrated in the same place, for example at Benzena at the end of the dry season. Therefore anything that increases the reliance of livestock and elephants on Benzena - such as increasing numbers of livestock drinking water-holes dry sooner in the season (Mohamed Agbilal ibid); and impeded access to water-points such as Gossi - will increase the probability of accidents. It will also increase the exploitation

[11] It appears from the GPS collar data plus accounts of local people that the family herds (females and juveniles) tend to follow the circular migration route, while the males may only follow part of it. In addition, it is the males that are more frequently involved in conflict and who are sighted on the edge of the range, scouting for new territory. The key movement is, therefore, the north-south movement between water in the dry season (including a perennial water-source) and areas of accessible high-quality food.

of food resources around Benzena, giving the vegetation less time to regenerate and increasing the vulnerability of elephants to prolonged dry spells.

- In their dry season range, settlement and gardens around particular water-points[12] generate conflict as the elephants trample or raid gardens on their way to water.

5.5 Avoiding human activity - wet season

- The elephants strongly avoid areas of high human activity associated with settlement and agriculture in their wet season range. It is difficult to know how stressful human presence and conflict is for the elephants - that they strongly avoid these areas suggest that it is.

- The spread of agricultural and agro-pastoral livelihoods on the elephant migration route is threatening to block their path. The corridors under the most threat are:

  - The Porte des Elephants
  - The bottom lands of Gandamia through increasing clearance of thicket and cultivation.
  - Through the Finta on the way to the Nassaoumbou protected area in Burkina Faso.

This study has suggested that there are limited options for these elephants should their movement be further impeded and a threshold increase in conflict can be expected. Once conflict escalates, the options for its amelioration are much reduced, while cutting any one of these corridors completely could ultimately bring about the end of a population that has no other options.

5.6 Conflict mitigation - urgent

This study has shown that incidences of conflict are located in areas where human activity is pushing into elephant territory.

Any further decrease in elephant range is likely to exacerbate conflict and cause a change in elephant behaviour. There some is evidence that this is beginning to happen. At Gossi the explosion of settlement and gardens around the lake since the mid-1980s has meant that the herds no longer visit this water source and have been forced to use more intensively the other semi- permanent water-points of the north instead. Recently a group of around 7-8 bulls has taken to staying in the vicinity of Gossi all through the dry season, leaving for the south and the area of the Burkina border along the part of the migration route normally used by the family herds on their return journey at the end of the wet season (Faure-Osei & Diakite, 2002). A group of 7 bulls stayed close to the water point of Ousougou, between

[12] Inadiatafane, Gossi, Adiora, Dimamou

Boni and Serma, all year (Maiga, 1996; Amis des Elephants, personal communication) when this was excavated to keep water year round.

5.7 Discussion

In trying to assess the implications of these findings for the elephants' future the following issues have emerged as pertinent to their conservation.

5.7.1 The attitude of the population

According to La Marche, the elephants lived in relative harmony with nomadic Touareg pastoralists in the 1970s, a coexistence that continued in the 1980s and 19905 (Douglas-Hamilton and Douglas-Hamilton 1992; Olivier 1983; Jachmannn 1991; Youssef 2001). Many communities in the Gourma consider the elephants as a patrimony that it is necessary to conserve, as a sign of good luck, as a part of their culture, and as a source of useful by-products (PCVBG, 2001; Ganame, 1999; Maiga, 1996). There is also a perception that elephants and humans like the same areas and therefore if the elephants disappear, the area is no longer good for humans (M. Diakite, personal communication).

The attitude of the population often depends on the degree to which their livelihood is compromised by the elephants (PCVBG, 2001). In general, herders do not have a problem in living with the elephants (although see Agbilal above), whereas agriculturalists are more likely to regard them as a problem (Zampaligre et al., 1997).

5.7.2 Conflict mitigation

The people questioned in a series of surveys felt that much of the problem came from cultivators and herders that did not take account of elephant presence in their activities such as locating their fields, storing grain or siting their camps; and that better management of the land and regulation of access to it was key to the resolution of conflicts (PCVBG, 2001; Maiga, 1996; Ganame, 1999).

> "In the Gourma, there is space for everyone: pastoralists, transhumants, nomads, villagers and wildlife on condition that it's known who belongs where."
>
> O.Tall, elder herder,
> cited in Maiga, 1996

The work of the PCVBG-E aims to remedy this through the support to communes and communities in identifying solutions and compatible land use agreements (PCVBG-E, 2004). A related issue is that the elephants are deemed the property of the State and therefore any damage is also the responsibility of the state. This does not encourage

individuals to take responsibility for their actions regarding elephants and make 'elephant-aware' decisions. It also makes it difficult to obtain accurate data on conflict, as there was a tendency to exaggerate losses in the hope of compensation (Maiga, 1996; Ganame, 1999). Again, this is something that will be tackled by the PCVBG-E.

5.7.3 Greater elephant awareness

The population also raised the importance of supporting measures such as the dissemination of information about the elephants and their migration route, as this would help them make decisions about how to avoid contact with elephants, where to cultivate and how to avoid elephants destroying crops and buildings. The Amis des Elephants have already had some success in this (Maiga, 1996). The local people would also welcome information about possible techniques to deter elephants such as chilli deterrents, early warning systems etc.

5.7.4 Tourism

There was also a feeling that a development of ecological tourism that was based in the area and brought tangible benefits to the local people would provide more incentive for people to help protect the elephants, as they would feel their survival was more linked with that of the elephants (Maiga, 1996).

5.7.5 Development: agriculture, roads and water

Clearly, it is a primary goal of any government to provide rural populations with the benefits and services that citizenship brings; however, the manner in which those benefits are introduced may put at risk the environment on which those developments depend and exacerbate the problems, not mitigate them. Given the complex nature of the natural-human ecosystem of the Gourma, and the risks associated with its unpredictability, we raise the following questions to stimulate fur1her debate and discussion.

Agriculture - Given the inherent variability of the Gourma ecosystem and the current dry - conditions, it is worth considering whether an expansion of agricultural production (crops and livestock) can be accomplished at the same time as ecosystem restoration and wildlife conservation, particularly given the past experience of well-meaning, but ecologically damaging, development interventions in the Gourma. Rather than strive for ever-increasing production from marginal habitats, it would seem prudent to encourage the traditional nomadic systems that are best adapted to such variability, guided by limits and community systems of management, while agricultural intensification be pursued in other, more suitable areas such as the Taoussa scheme on the Niger River to the north.

Roads - Development of the road network is generally perceived as an integral support for the development of agricultural production in providing access to markets. In some

contexts this may encourage sustainable agricultural practice (e.g. Tiffen, 1994). However, roads link population centres and market economies to countryside environments, and can rapidly transform subsistence-based resource exploitation into market-based systems, which may rapidly drive local exploitation to unsustainable levels and create conflicts between communities of agro-pastoralists and intensive cultivators (large literature reviews in Wilkie et al., 2000; Gucinski et al. 2001). In the Gourma a concern would be, for example, that an upgraded road between Boni and the markets of Burkina Faso would lead to pressure for an expansion of agriculture in the south of the zone, in the midst of an important livestock grazing area and key component of the elephant migration route.

Water - Access to water is obviously a key issue in the Gourma and there will always be pressure to make more available (particularly in a drying climate). However we question whether more water-points will merely provide for those already present or, rather, will encourage more livestock to be kept: ever-increasing livestock numbers pose a risk, given that the Gourma is experiencing a drying of the climate.

There is also the question of whether additional, artificial waterpoints could contribute to an increased exploitation and degradation of the Gourma's resources. It is well documented that the area around a waterpoint becomes a 'sacrificial zone' where the impact of trampling reduces vegetation cover and can increase soil erosion depending on the substrate REFS… The severity of this phenomenon depends on the substrate, the proximity of waterpoints, and whether there is a sustainable community-based system of maintenance and management in place. The latter point is illustrated by the wide-diameter well constructed at Benzena in 1999 with no system to regulate use, and resulted in the number of sedentary families in the area increasing from 1 to 110 within the space of four years because it was effectively an open access resource (Ganame, personal communication). Much depends on the existence of community-based resource management systems that are respected by all users, a particular challenge in an area with such diverse and fluid human populations.

Constructing water-points as a means of segregating humans and elephants will need to tackle these issues realistically, given that the water in natural water-holes is free and easier to access than from a borehole or well. Any failure in regulation of its use risks lead to further environmental degradation that would be difficult to reverse. Studies are required to understand customary systems of natural resource use and to determine whether better management of the existing mares or natural water-points to retain their water for longer, might be an alternative.

5.7.6 Awareness of the whole system

Although the migration route of the elephants can be thought of as comprising a series of concentration areas and corridors with different emphases on particular elephant needs, the migration is really an integrated system whereby impacts in one place ramify through and influence other parts of the system. Thus a reduction of access to water in one part of the dry season range, for example, will increase reliance – and pressure – on other parts and ultimately Benzena. It is important to bear in mind that the elephant migration is a product

of the landscape, both natural and human, a perspective which helps minimize the risk of unforeseen consequences that sometimes result from piecemeal approaches.

In each of the areas of development intervention mentioned above, environmental and social impact studies would help reduce the risk and uncertainty associated with the potential impacts of such developments on the wider Gourma system, and suggest ways to ensure that they will not ultimately exacerbate the over-exploitation of the Gourma's resources.

Annexe I - Bibliographie

Barnes, R. F. W. (1999). "Is there a future for elephants in West Africa?" Mammal Review **29**: 175-199.

Barnes, R. F. W. (2006). Transfrontier corridors for West African elephants: the Ponasi-Red Volta and Sahelian corridors, IUCN.

Barnes, R. F. W., G. C. Craig, et al. (1998). The African Elephant Database. Occasional Paper, 22., IUCN Species Survival Commission.

Bell, R. H. V. (1971). A grazing system in the Serengeti. Scientific American **225**: 86-93.

Blake, S., P. Bouche, et al. (2003). The Last Sahelian Elephants: ranging behaviour, population status and recent history of the desert elephants of Mali, Save the Elephants.

Bremen, H. and C. T. de Wit (1983). Rangeland productivity and exploitation in the Sahel. Science **221**: 1341-1347.

Canney, S. (2005). Initial Measures for Conservation of the Gourma Elephants, Mali: interim summary progress report, The Mali Elephant Consortium: WILD Foundation - Save the Elephants - Environment and Development Group.

Cincotta, R. P., J. Wisnewski, et al. (2000). Human population in the biodiversity hotspots. Nature: 990–992.

Cobb, S. and S. Lapuyade (1994). Les elephants du Gourma: un programme de développement.

Davenport, M. L. and S. E. Nicholson (1993). On the relation between rainfall and the normalized difference vegetation index for diverse vegetation types in East Africa. International Journal of Remote Sensing **14**(12): 2369-2389.

Douglas-Hamilton, I. (1999). The African elephant action plan, IUCN.

Douglas-Hamilton, I. and S. Canney (2004). The Elephants of the Gourma: preliminary assemblage and analysis of GIS data, Save the Elephants for the Mali Elephant Project.

Douglas-Hamilton, I. and O. Douglas-Hamilton (1992). Battle for the Elephants, Viking Adult.

Faure-Osei, A. and N. Diakité (2002). Etude d'impact environnemental et social.

Fuller, D. O. (1998). Trends in NDVI time series and their relation to rangeland and crop production in Senegal, 1987-1993. International Journal of Remote Sensing **19**(10): 2013-2018.

Ganame, N. (1999). Conservation et valorisation ecotouristique des elephants. Bamako, Association Française des Volontaires du Progrès.

Hiernaux, P. (1996). The crisis of sahelian pastoralism: ecological or economic?, Overseas Development Institute, Pastoral Development Network.

Hoare, R. E. and J. T. du Toit (1999). Coexistence between people and elephants in African savannah. Conservation Biology **13**: 633-639.

Jachmannn, H. (1991). Current status of the Gourma elephants in Mali: a proposal for an integrated resource management project. Gland, Switzerland, IUCN.

Justice, C. O. (1986). Monitoring the Grasslands of Semi-arid Africa using NOAA AVHRR data. International Journal of Remote Sensing **7**(11).

Justice, C. O. and P. Hiernaux (1986). Monitoring the grasslands of the Sahel using NOAA/AVHRR data. International Journal of Remote Sensing **7**: 1475-1497.

Kone, B. (2001). Biodiversity and forests: Mali case study. Integration of biodiversity in national forestry planning programme. CIFOR and GEF. C. I. F. R. C. a. G. G. E. Facility). Bogor, Indonesia.

La Marche, B. (1978). Les éléphants au Mali: le Gourma et l'est. Bamako.

Lee, P. C. and M. D. Graham (2006). "African elephants *Loxodonta africana* and human-elephant interactions: implications for conservation." International Zoology yearbook **40**: 9-19.

Leeuw, P. N., L. Diarra, et al. (1993). An analysis of feed demand and supply for pastoral livestock: the Gourma region of Mali. Range ecology at disequilibrium. C. Kerven. London, Overseas Development Institute.

Mahmoud, A. (1992). Le Haut Gourma Central. Présentation Générale, Coopération norvégienne.

Maiga, M. (1996). Enquête socio-économique sur les interactions homme-elephants dans le Gourma malien.

Olivier, R. C. D. (1984). The Gourma elephants of Mali: a challenge for the integrated development of Sahelian rangeland. Nairobi, UNEP.

Olssen, L., Eklundh, et al. (2005). A recent greening of the Sahel - trends, patterns and potential causes. Journal of Arid Environments **63**: 556-566.

PCVBG, C. (2001). Les conflits hommes/elephants dans le Gourma.

PIRT (1983). Projet Inventaire des Ressources Terrestres au Mali, Gouvernement of Mali/TAMS/US.

Pringle, R. M. and N. Diakité (1992). The last Sahelian elephants. Swara **15**(24-26).

Richard, Y. and I. Poccard (1990). A statistical study of NDVI sensitivity to seasonal and interannual rainfall variations in Southern Africa." International Journal of Remote Sensing **19**(15): 2907-2920.

Roth, H. H. and I. Douglas-Hamilton (1991). Distribution and status of elephants in West Africa. Mammalia **55**: 137-148.

Said, M. Y., R. N. Chunge, et al. (1995). African elephant database 1995. Gland, Switzerland, Cambridge, IUCN/SSC.

Sanderson, E. W., M. Jaiteh, et al. (2002). The Human Footprint and the Last of the Wild. Bioscience **52**: 891-904.

Sinclair, A. R. E. and J. M. Fryxell (1985). "The Sahel of Africa: ecology of a disaster." Canadian Journal of Zoology **63**: 987-994.

Spinage, C. (1994). Elephants. London, Poyser Natural History.

Tiffen, M., M. J. Mortimore, F. Gichuki (1994) More people, less erosion : environmental recovery in Kenya. John Wiley & Sons, Chichester.

Wall, J., F. Vollrath, et al. (2006). Elephants avoid costly mountaineering. Current Biology (in press).

Youssef, A. (2001). Interview in the film *The Lost Elephants of Timbuktu*.

Zampaligre, I., N. Traore, et al. (1997). Les elephants du Gourma Malien et du Sahel Burkinabé: une énigme écologique, Direction Générale des Eaux et Forets, Direction Nationale de l'Aménagement et de l'Equipement Rural.

Annexe II – La liste des acronymes

DNCN	Direction nationale pour la conservation de la nature
EDG	The Environment and Development Group
GPS	Global Positioning System
IUCN	Union mondiale pour la nature
NDVI	Normalized Difference Vegetation Index
PCVBG-E	Projet pour la conservation et valorisation de la biodiversité du Gourma et ses éléphants
PEM	Le Projet Eléphants du Mali
SIG	Système d'Information Géographique
STE	Save the Elephants

Annexe III – articles published about the elephants as a result of project activities:

*Restless Spirits of the Deser*t by Carlton Ward in Africa Geographic, July 2007 (with photographs by Carlton Ward)

Saving Mali's Migratory Elephants by Laura Helmuth (cover story) Smithsonian, July 2005 (with photographs by Carlton Ward)