The WILD Foundation — Save the Elephants
The Environment and Development Group

Initial Measures for Conservation of the Gourma Elephants, Mali

Interim Summary Progress Report 2004

THE WILD FOUNDATION
SAVE THE ELEPHANTS
The Environment & Development Group

Preliminary assemblage and analysis of GIS data

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Save the Elephants

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Acronyms and abbreviations

STE	Save the Elephants
EDG	Environment and Development Group
AGEFORE	Amenagement et Gestion des Forets et de l'Environnement-GIE
GEF	Global Environment Facility
SSE	*Programme de Recherche Sahel-Soudan-Ethiopie (SSE) Mali-Norvege 'Environnement et Developpement' au Mali.*
USGS	United States Geological Survey

1. Introduction

A full account of the movements of three elephants radiotracked using GIS technology between March 2000 and July 2001 is reported in the report entitled *The Last Sahelian Elephants* by Blake et al (2002). This report gives the detailed seasonal movements and speeds and provides the most up to date record of the range and utilization of the Gourma by elephants. However the sample size of three animals is too small and the tracking period too short to describe the entire range, and those elephants living in the Gossi area to the east were not successfully radio-tracked at all. With our current project a high emphasis has been given on acquiring other GIS layers and further information on the full range of these elephants. Additional analysis of the radio-tracking data has been made against human settlement, administrative boundaries, and human population densities. Here we report on the additional data acquired in 2004 and how it relates to what we know so far about the elephants movements and range.

This report begins by addressing progress in compiling and organising GIS data. This work has enabled an assessment of data quality and availability. Subsequent sections document the additional information produced using the data acquired in 2004 followed by tentative conclusions, and the follow-up work required.

2. Compilation of GIS data

2.1 Data collection and generation

The data gathered is summarized in Table 1 together with its source and current availability. Data sources included:

- Save the Elephants (STE) - in addition to generating the GPS collar data, STE had already digitised some map information and collected additional information during the 2002 field excursion to collect the GPS collars.
- Environment and Development Group - Reports and maps collected by the preliminary missions to Mali in 2003.
- Data collected by the *Programme de Recherche Sahel-Soudan-Ethiopie (SSE) Mali-Norvege 'Environnement et Developpement' au Mali, (*a major study supported by Norwegian Aid to provide baseline data for its three sub-projects: rational natural resource use; the role of wild plants in nutrition, health and handcrafts, household nutrition).

SSE data are the digital GIS data collected by the Norwegian project for the northern part of the elephant range over a period of five years. Two copies of these were left in the University of Oslo and with the Malian government. The former appear to have been lost during a fusion of the Geology and Geography Departments, while the latter exist on a 'corrupted' hard disk at DNCN in Bamako, and may be retrievable. This project was terminated prematurely and only the soil map was published. There is a dwindling supply of A3 black and white hard copies of some of the other data layers, however are no hard copies of others such as settlements and roads.

These data are of good quality and represent extensive ground-truthing effort which would enormously enhance any GIS analyses performed by this project. Some of the simpler 'point'

data have been re-digitized by the STE team in Nairobi. The more complex data such as the vegetation and soil maps would take extra effort or could be re-digitised in a simpler form, if the SSE data cannot be obtained from the computer in Bamako.

It is worth noting that a consultancy called AGEFORE have apparently had access to the SSE data to produce a report in 2001 to document the maps available on the different aspects of biodiversity in the Gourma for the *Projet de Conservation et de Valorisation de la Biodiversite et des Elephants du Gourma*. This was of extremely poor quality and dubious accuracy, especially regarding the elephants, and highlights the urgency for much better information to be disseminated before the GEF project gets underway. All attempts to contact this organisation by email and phone failed.

Elephant needs	GIS layers	Source	Availability/comment
Range	Historic range	Douglas-Hamilton files, Nairobi	Available
Presence/ absence	GPS collar data	Save the Elephants, Nairobi	Available
	Dung	2005 Field data	Available
	Local knowledge		
	Satellite imagery		
Water	Temporary waterholes	Landsat image (mosaic of Oct 1999&2000 images) /SSE data	Available
	Permanent waterholes	Landsat image/SSE data	Available
Forage	Seasonal quantity	1km resolution NDVI using USGS MODIS and AVHRR	Available from USGS needs downloading, and processing.
	'Snapshot'	30m resolution NDVI Oct 99/00 image	Available already created by SC from the existing Landsat image
	Vegetation	SSE data	Redigitizing required if not obtained in Bamako plus satellite image classification to extend the map to areas in the south.
	Soil	SSE data	Redigitizing required if not obtained in Bamako. Not an immediate priority.
	Watercourses	SSE data/maps/Landsat image	Bamako/digitise/image classification
Disturbance	Human population	Census data	Incomplete (see text)
	Settlement location	Maps, reports data, ground truth, SSE data	Some available – to be updated in Bamako and by ground-truthing
	Nomad density	Report: transhumance routes through the year by fraction and village.	Available but needs labour-intensive work. Not yet convinced that this is a priority
	Wells	SSE data (includes puisards) & boreholes	Available mostly
	Cultivation	Landsat image, aerial photography or other data	Bamako (see text)
	Livestock populations	Census data	Bamako (see text)
		Aerial data (STE 2002 / Mike Fay 2004)	Point locations collected during overflights
	Incidence of conflict	Reports, other?	Bamako (see text)
Salt	Cures salees	SSE data.	Available

Misc	Various UN, USAID, CF, GEF etc. data on vegetation and agriculture		Bamako
Basic GIS datalayers	Administrative boundaries	Maps, SSE data	These have changed over the years and there are several versions: clarification required in Bamako
	Roads	Maps, satellite image, SSE data	Some available – need completing by on-screen digitising/Bamako
	Route of new road		Bamako

Table 1: The data gathered, together with their source and current availability

Priorities
The main unknown is the degree to which human cultivation can be mapped and to what resolution, and yet this is a crucial dataset. Dialogue with Gray Tappan of the USGS about the use of satellite imagery for this shows some promise, particularly if used in conjunction with information gained from other sources such as bilateral and NGO aid projects, and the aerial photographs taken by Mike Fay of the elephant migration route.

Maps of human and livestock populations are also crucial datalayers. Contacts in Bamako suggest that the raw data are available at least by commune in Bamako, although it may be that data at smaller administrative levels may be held by local administrations. There has also been the suggestion that conflict data exist although the nature of these data is not clear from a distance.

Geo-referenced data collected during field-work is relatively painless and cost-effective to collect and yet creates significant 'added value' by completing, verifying and extending existing data-sets it can allow analysis that might not otherwise have been possible.

2.2 Assessment of data quality and organisation

The varied sources of data mean that the data are disparate in terms of resolution, accuracy, area covered, and projection which means that a certain amount of harmonisation is required before they can be used together. Some of this work has been done already by SC during the Samburu visit (see below). Needs in this area will be continually reviewed during the process of analysis in the light of the budget and time available, and performed by SC and the STE team in Kenya. Hard copy maps were produced during SC's visit to STE-Kenya in November 2004.

Projection
The GIS datalayers are in many combinations of projection, spheroid and datum[1]. Some appear to have been digitised without recording this information. Files with different projections cannot be overlain (except in Erdas-Imagine). The source maps are also in different projections.

It is suggested that for the moment the standard projection for the datalayers is Universal Transverse Mercator Zone 30; Spheroid and Datum WGS84 as this is the projection that the

1 Variations in projection-spheroid-datum specifications can result in 100s of metres or even over a kilometre misalignments, which is important for some of the analyses.

satellite image came in, and it is more accurate to reproject vector files (shapefiles and Arc coverages) than raster files such as images. However, the error will need to be monitored and if it becomes too significant, some data may need to be re-digitised by the STE team in Kenya

GIS database structure and metadatabase
GIS files have a tendency to replicate themselves with slight variation each time and no record. A start has been made to ascertain their origin, weed them out, and organise the remaining data into a logically structured set of folders that enable anyone new to the system to find their way around[2]. This needs to be completed and a system of metadata constructed that contains information about each dataset.

Future Activities
- Data collection in Bamako to:
  - Locate and attempt to retrieve the SSE digital data
  - Complete collection of human census data
  - Collect livestock census data
  - Determine accurate digital administrative boundaries
  - Collect other data (see table) including background data and information on conflict and trends.
- Ongoing organisation of database and error monitoring
- Generation of extra data-layers through analysis as described in the following sections.

3. Elephant numbers and their significance

Elephants once occupied a nearly continuous range across the West African Sahel, but their populations have collapsed due to poaching, human encroachment and neglect. Most remnant populations are small, highly fragmented and geographically isolated, with over half now containing fewer than 100 individuals (Blake et al., 2003).

Recent field work by Save the Elephants through the techniques of individual photo – identification, carried out by Emmanual Hema during 2004 indicates that the Gourma elephants of Mali and extreme north of Burkina Faso number between 400 and 500 making them one of the most important populations in West Africa and the only significant remaining Sahelian elephants. It is therefore accorded a high priority in IUCN's regional strategy.

4. Analysis of Elephant GPS tracking data

The analyses described in the following sections use the location data gathered by STE's GPS collars over the period 2000/2001. Positions for the full 18 months are used where the concern is for areas of elephant presence/absence; and 12 months where it is important to look at elephant behaviour through the year.

2 This is particularly important when using ArcView as 'projects' or collections of datalayers record the location of those datalayers by their path structure. ArcView projects are unusable if the datalayers are moved to different folders.

Data come from 3 elephants:

Elephant	Sex	Number of observations		Notes
		18 months	12 months	
Ahni	F	4,274	3,676	
El Mehdi	M	4,778	3,554	
Doppit Gromoppit	F	405	338	Intermittent therefore omitted from the analyses that require complete data.
TOTAL		9,457	7,568	

Where 12 months of data are shown this has come from Ahni and El Mehdi from 1 April 2000 to 31 March 2001.

5. Elephant range

5.1 Elephant range since the 1970s

Documenting change in elephant numbers, range and movement over time and comparing this with environmental change helps us to understand the factors that determine elephant needs.

Information on elephant range collected by Bruno la Marche, Jachmann and Iain Douglas-Hamilton over the past 35 years gives a preliminary basis from which to understand the factors influencing elephant movement in the Gourma[3] and is summarised in Figure 1. Also shown are the lines of movement documented by La Marche which can be evaluated by comparison with the 2000/1 GPS collaring study.

[3] La Marche made a special study of the elephants through the 1970s. His estimate is based on local knowledge, observations and aerial reconnaissance. Jachmann's 1991 estimate is based on local knowledge plus a short-term dung count. STE's 2000/2001 estimate is based on GPS tracking, aerial reconnaissance and ground observations.

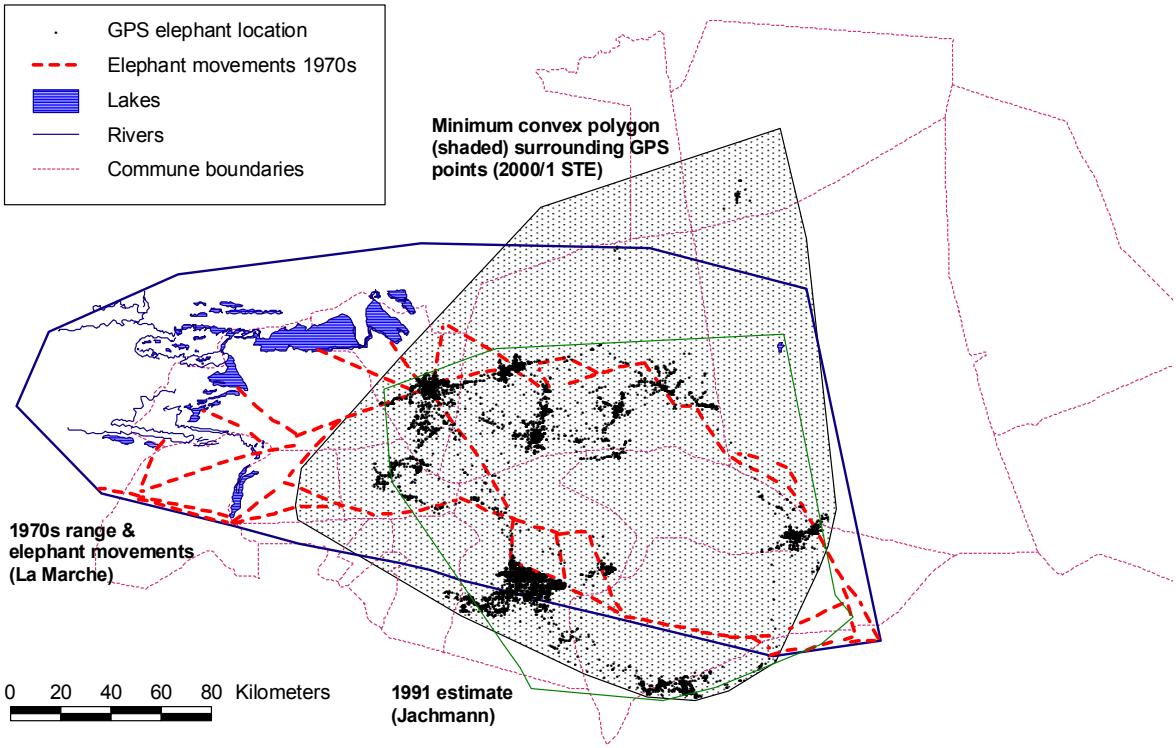


Figure 1: Change in elephant range Gourma, Mali, 1970s – 2001 overlain on administrative boundaries, riverine lakes of the Niger & 2000/1 GPS collar positions

The major change is that elephant range has shrunk. In the 1970s elephants were found as far west as the lakes bordering the river Niger but by 1991 the western part of their range had been lost, possibly due to changes in climate and land use.

There are also indications that other changes may have occurred although the patchiness of the data makes this difficult to determine with certainty. It appears, for example, that by 1991 elephants were travelling further south than previously; while it is only the radio-tracking studies that have detected a northward movement. Is this a remnant of northward migrations to the river Niger, or a result of displacement from other parts of the range?

Both Jachmann and La Marche suggested that elephant range extended further to the south west and south-east, but we have not yet ascertained if they actually visited all these parts of the migration route to the South. In any case it is possible that elephants vary their route from year to year. More information will be sought to answer these questions, including clarification from La Marche and Jachmann about the areas they actually visited.

5.2 Current elephant range

Current elephant range as indicated by the 2000/1 GPS collar locations is shown in Figure 2. It confirms the belief that the Gourma elephants make a large (450km), annual, circular migration, and suggests that certain areas are important at certain times of the year, and that the movement pattern is an adaptation to life in an arid zone.

Two features become apparent. The first is that elephants avoid the centre of their range, possibly due to human settlement (see section X); and the second is that the elephants visit encompasses many different administrative areas or communes during the course of a year. It follows that if an As a result any elephant conservation strategy is to succeed it will need commitment from several different regional authorities in the Gourma.

Future Activities
Achieve the best possible map showing the extent of current and historical elephant range by combining different methods of estimating elephant range - remote sensing, dung surveys and local information networks.

- GPS radio-tracking data is the best method for determining range and has already defined the main concentration areas, with the exception of areas to the East around Gossi and up as far as Adjora. Ideally 10 more GPS radio-collars should be deployed of a superior design to the previous models, lighter, tougher and more long lasting. This would depend on funds being found to pay for the cost and permission from the DNCN.
- In the meanwhile dung searches and local information networks can supplement and extend our present knowledge of the elephants. Elephant dung indisputably indicates the presence of elephants and asking local people can often improve the range map with information of the presence or absence of elephants.

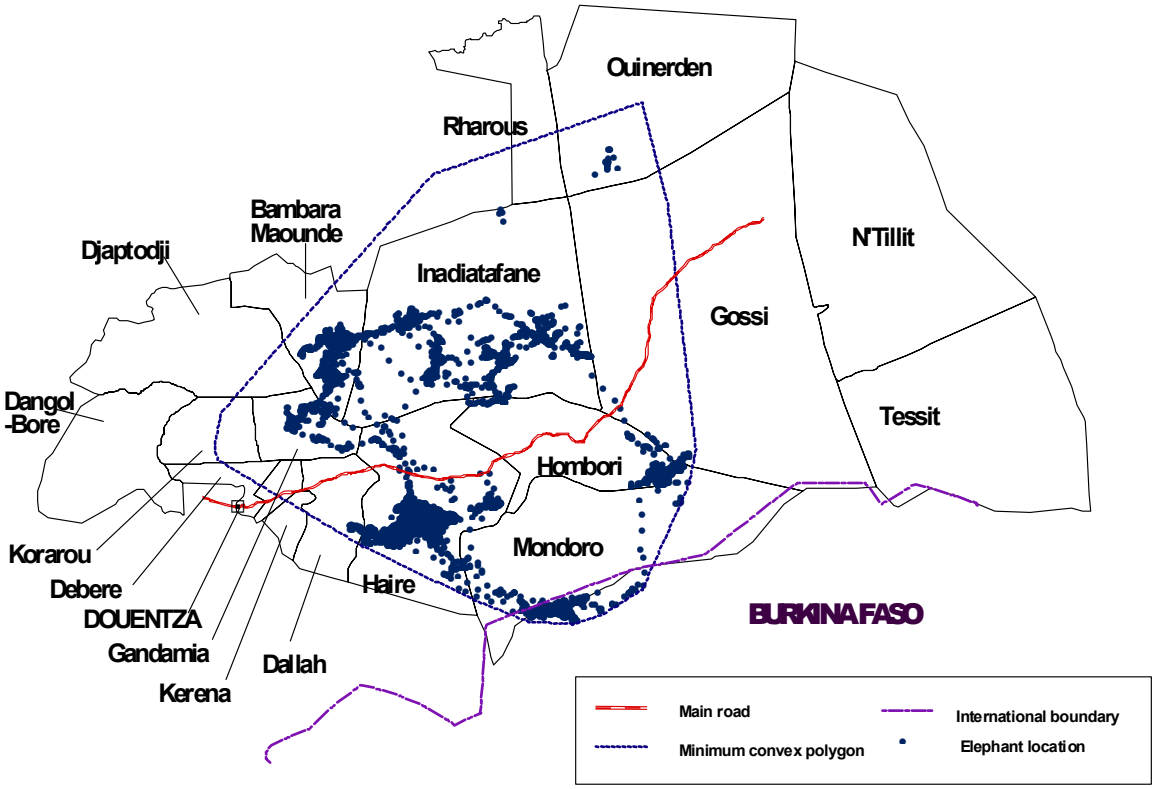


Figure 2 The location of the three elephants in 2002/1, minimum convex polygon enclosing them, main road, boundary with Burkina Faso and the administrative regions

6. Elephant range: concentration areas and corridors

The 2000/1 GPS location data indicate that there are some areas where elephants congregate for periods of time, and other 'corridor' areas where they move rapidly between 'concentration areas', often at night. These are shown in Figure 3.

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 to them there or because they feel harassed or threatened. For the two elephants for which we have relatively continuous data, only 7% of their time was spent in areas defined as corridors, as shown in Table 2.

Corridor	Ahni (F)	El Mehdi (M)	Total
Benzena-Porte des Elephants	1%	4%	3%
Benzena-Indamane	1%	1%	1%
Gossi	1%	0%	0%
Haire-Mondoro	2%	1%	1%
Mondoro Tin Senane	1%	0%	1%
North	1%	1%	1%
Other	**93%**	**93%**	**93%**

Table 2: Percentage time spent in corridors

They also spent very different amounts of time in different concentration areas with marked differences between the bull and the cow, as shown in Figures 4 and 5. Benzena was not as important as originally thought. The concentration area in Haire proved to be exceptionally important to the male, while the female spent more of her time in the more northerly areas around Indamane and Inadiatafane.

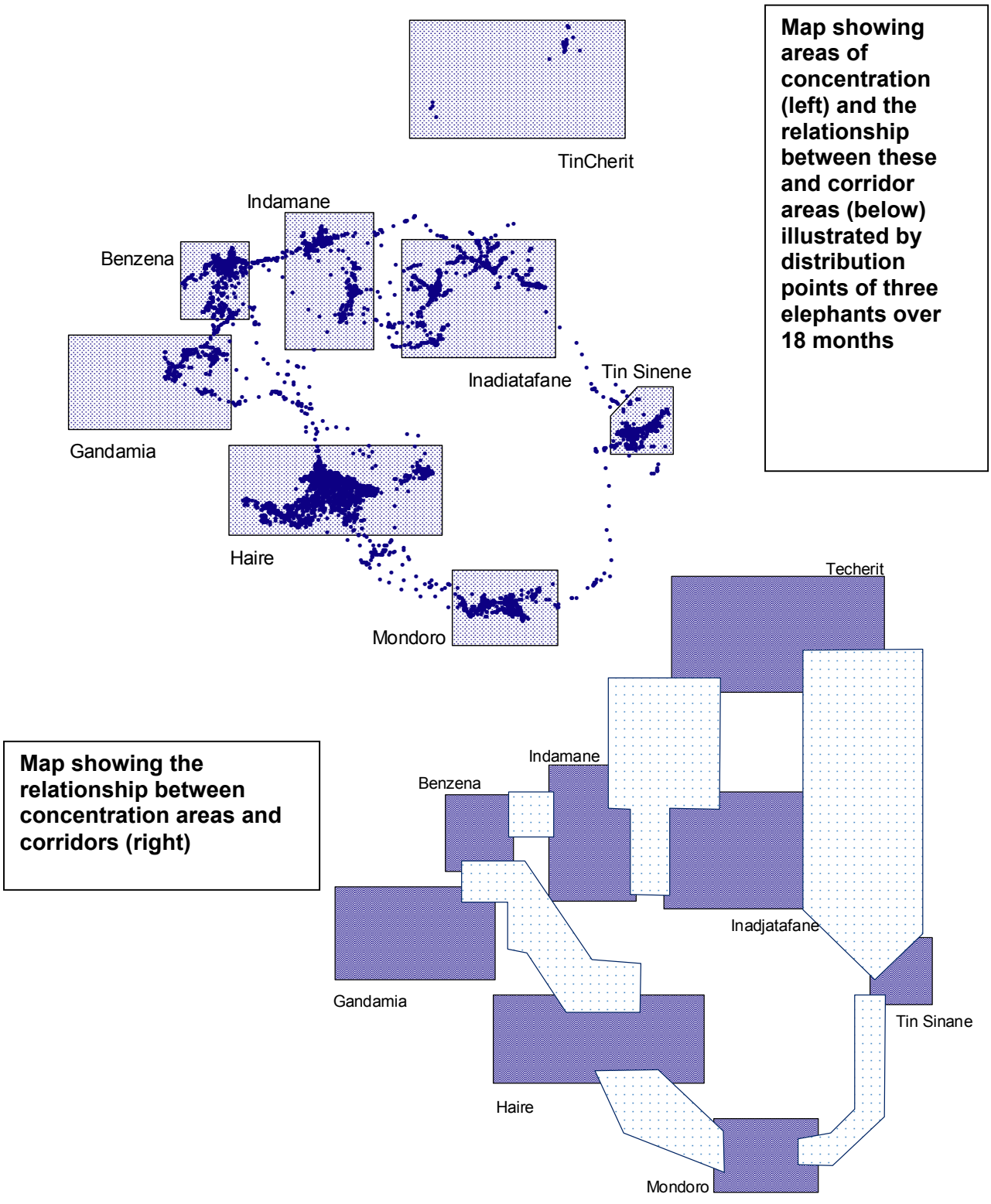


Figure 3: Elephant Concentration Areas and Corridors

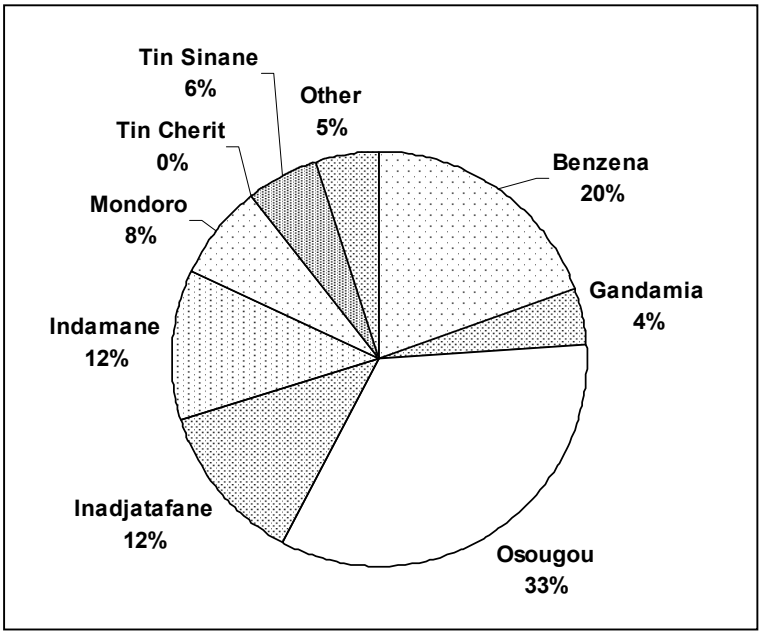


Figure 4: Percentage GPS positions in each concentration area over 1 year

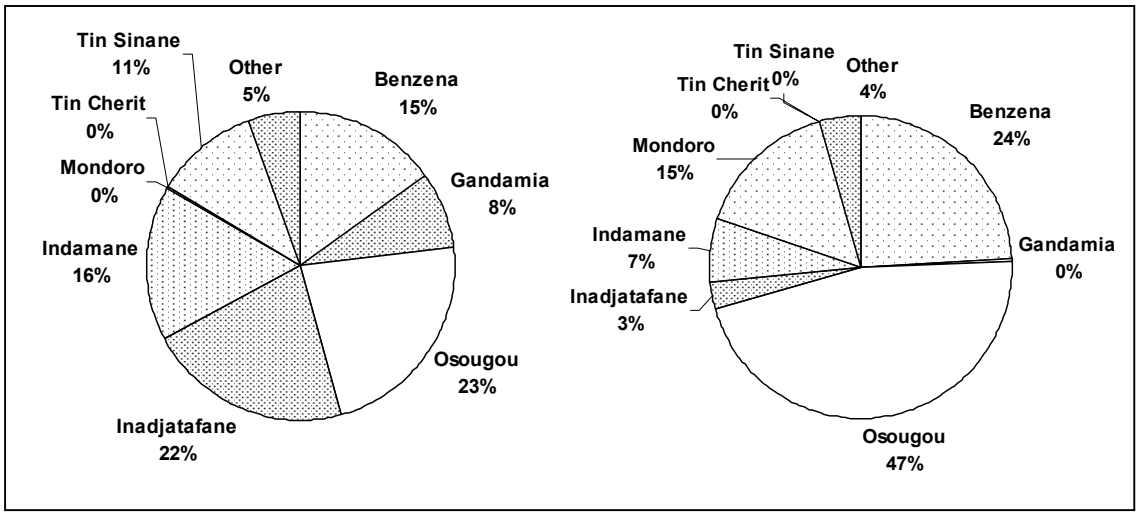


Figure 5: Percentage GPS positions in each concentration area: Ahni (F) on the left and El Mehdi (M) on the right

By examining and comparing concentration and corridor areas, we can understand what these important resources and threats are, and at what time of year they are important. 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. La Marche, for example, identified three key corridors through the high ground to the south, shown in Figure 1. Today one of these, known as 'La Porte des Elephants', is heavily used by the vast majority of elephants. Of the other two, one is virtually unused and the other infrequently used possibly due to human settlement (see sections 7 and 8 for further discussion). If this is the case any further settlement near these corridor areas would cause a great deal of hardship for the elephants and escalate conflict with humans.

Future Work

- Determine the range limits to each core and corridor zone using a combination of GPS-tracking data, dung locations and local information networking (see section 5)
- Determine the distribution of the radio tracking GPS points by concentration area and polygon: (a) by day and night, and (b) by time of year
- Compare data for Banzena with Richard Barnes dung transects (the GPS location of these is in hard copy at Douentza).
- Obtain data on human-elephant conflict, and compare with elephant distribution (male/female; time of day; time of year) and location in terms of concentration areas/corridors.
- Assess the level of human harassment, and represent this spatially, using the results of analyses described in the following sections.
- Obtaining additional GPS-tracking data by collaring more elephants:
  - Analyse how much extra range each additional elephant adds to the elephant range
  - Assess the degree of variability in the route taken by elephants between years

7. Elephants & Human Population Density

It is possible that elephants try to avoid areas of high human population density and so using data from the 1997 census we calculated the human population density for each commune and overlaid the GPS elephant distribution data. The result is shown in figure 5 and suggests that elephants are avoiding areas of higher population density. Of particular interest are the high densities in the former western elephant range.

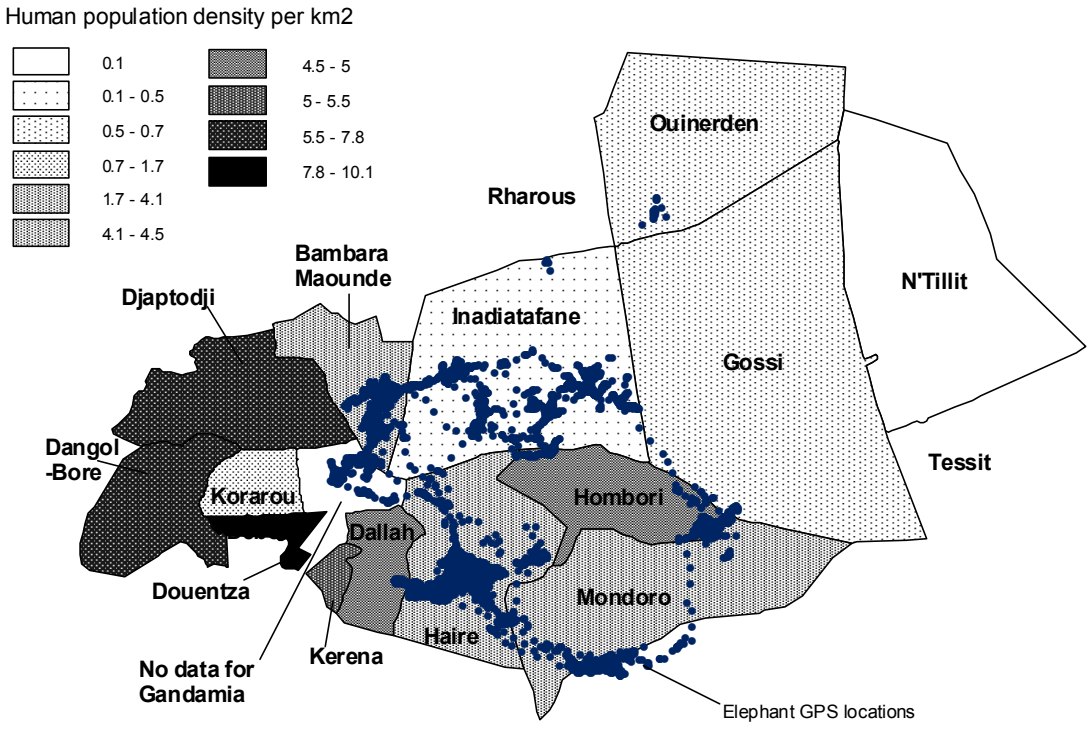


Figure 6: Map showing the relationship between one year of elephant positions & population density from the 1997 census. Dark shading indicates higher density.

Human population census data were collected in 1997, 1986 and 1974/5 and are potentially available to us through contacts in Bamako. We have located some of these but the dataset is incomplete, and administrative boundaries have changed since 1974. Preliminary indications are that the population has increased in some areas and decreased in others. A more general trend appears to be a reduction in nomads and an increase in settlement.

Future Work

- Collect missing census data to gain an idea of the rate and extent of changing demography and its distribution over the Gourma, compared with elephant distribution.
- Repeat using the data by village and by nomadic fraction to determine whether the elephants respond differently (if at all).
- Locate settlement growth areas to see whether parts of the elephant range are at risk.
- Collect census data for smaller administrative units if possible to allow a finer grained map of population density
- Repeat the analyses for livestock data

8. Elephants and settlement

Figure 7 shows the location of settlements taken from a 1961 map together with a 10km 'buffer' zone around them. It suggests that elephants are tending to avoid settlements, particularly in the south.

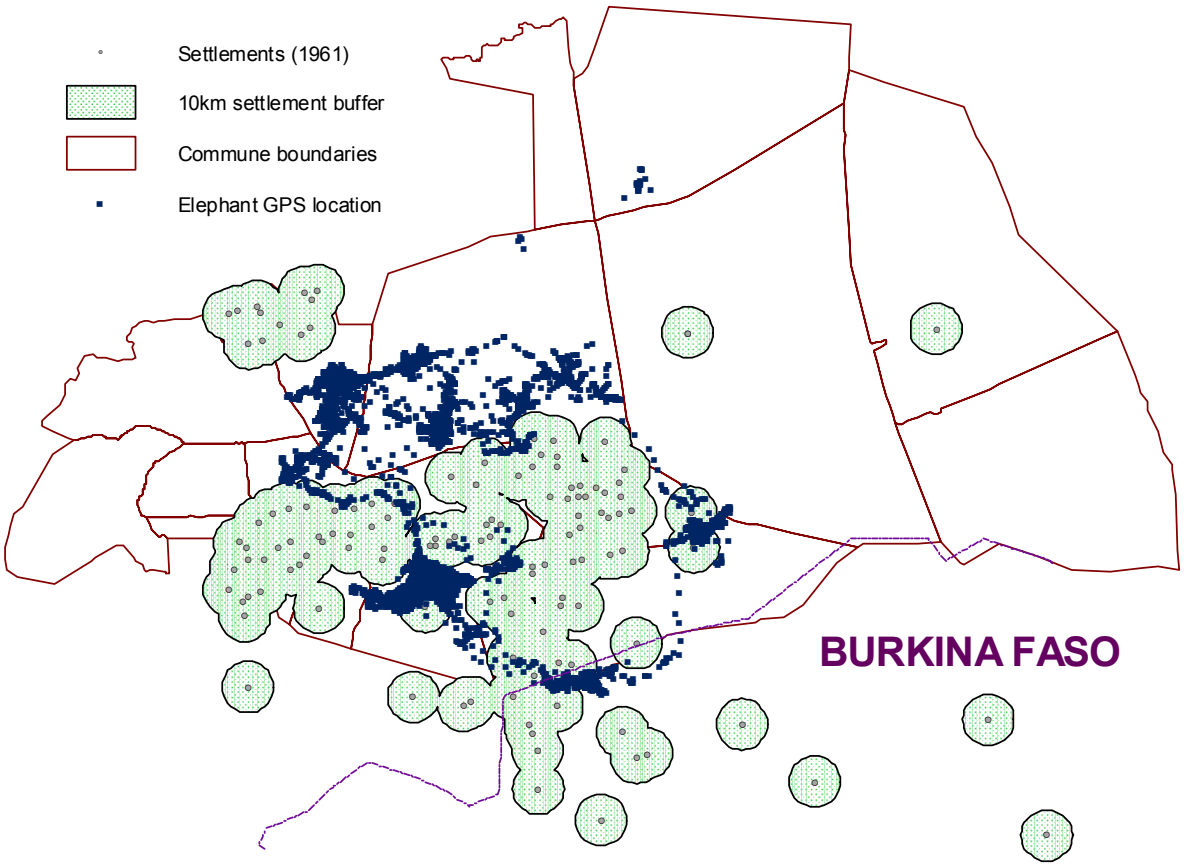
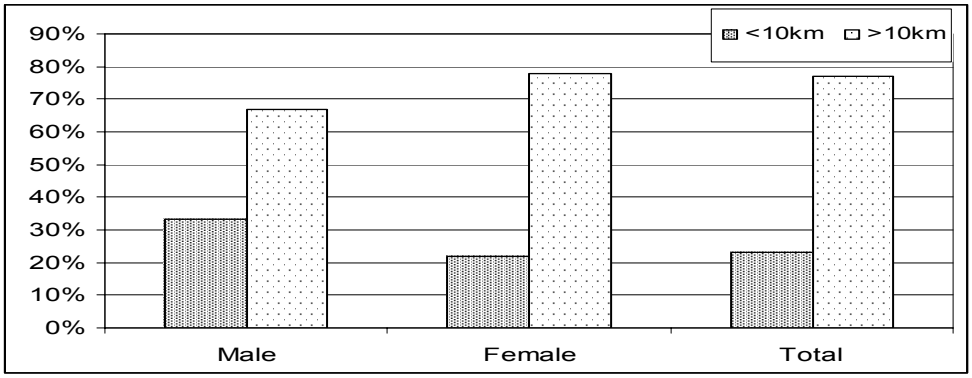


Figure 7: Map showing elephant positions over 18 months in relation to a 10km buffer around settlements (as digitised from the 1961 map)

The charts below compare the amount of time (as measured by number of GPS locations) spent by the male and female elephants closer and further than a 10km distance from settlement, and show that the male spends 67% and the female 77% of their time further than 10km from a settlement, indicating that the male may be more willing to approach.

Animal	<10km	>10km	Grand Total
El Mehdi (male)	33%	67%	100%
Ahni (female)	22%	78%	100%
Grand Total	**23%**	**77%**	**100%**



One problem with these data is that the settlement locations are as determined on the 1961 map. We know that the droughts and conflict of the 1970s and 1980s have encouraged settlement in the northern part of the range, for example around Gossi and Inadiatafane. If elephants are avoiding settlements we would expect the result to be even stronger if repeated with updated information on settlement location.

When the elephant locations are examined against the satellite image, it can be seen that elephants approach closer to settlement where there are corridors of dense vegetation in an otherwise open area (e.g. Gandamia). This may be because they are choosing thicket for cover and/or vegetation for food.

Preliminary analyses indicate a change in behaviour between day and night. The figure below shows speeds by day (left) and night (right) for Ahni, the female (blue represents areas of slow movement and red shows areas of high speed). Most of the high-speed 'streaks' occur at night in the south of the range.

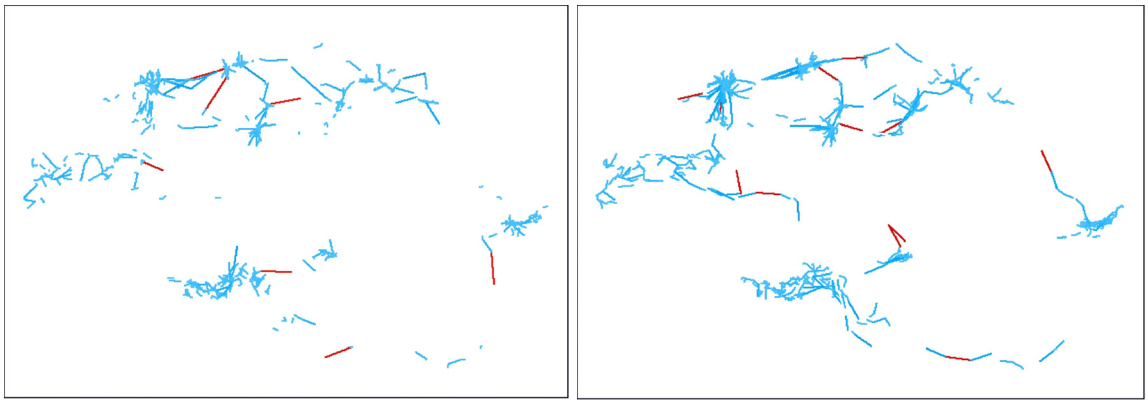


Figure 8 : Speeds by day (left) and night (right) by Ahni, the female elephant

Future Work

- Update settlement map and repeat.
- Examine areas where elephants approach within 10km to see what may be interesting the elephants.
- See whether the distance to settlement varies with area indicating that some areas seem to be 'safer' than others; and whether it varies throughout the year to see if the elephants are bolder at certain seasons.
- Compare with any data on human-elephant conflict
- Analyse distance from settlements by day and night/male and female.

9. Elephants and vegetation/soil

No quantitative analysis has been done using vegetation but an examination of the satellite image overlain with elephant locations indicates that particular vegetation types appear to be important to elephants as they often appear to follow corridors of a particular type of vegetation.

It is likely that different vegetation types may be important at different times of the year, for example at the beginning of the rains when elephants are no longer limited by water availability; and in different places, for example to provide corridors of cover in more densely populated areas. A study in Samburu comparing elephant distribution with a satellite derived index of green biomass has demonstrated shifts in preference throughout the annual cycle indicating times when forage becomes a priority.

Vegetation analysis is likely to help answer questions such as:

- Why do the elephants have to move on such a long north/south route?
- What are the most vital parts of their range that must be safe-guarded at all costs?
- What are the implications for the elephants' survival if they lose particular parts of their range?

Correlations between particular soil types and elephant location may also be interesting, possibly from the point of view of salt content, because elephant movements do not appear to be influenced by the location of salt licks.

Future Work

- Acquire digital data on vegetation data layers, particularly on vegetation structure.
- Use these, together with ground data and informed by further discussions with Gray Tappan to extend the vegetation map south using the Landsat image together with ground-truth, aerial photographs and report data. This should enable the identification of some key vegetation types such as thicket, and agriculture. Grass and thicket are difficult to distinguish by eye from the image but digital analysis should be able to do this.
- A soil map would greatly help the creation of a vegetation map from the satellite image.
- AVHRR and/or MODIS NDVI data (free) can be used to characterise the area into zones reflecting seasonal change in green biomass throughout the year, and is often able to identify agriculture.
- NDVI analyses to see whether, when, and to what degree elephants are selecting areas of high green biomass (i.e. actively growing vegetation)

10. Synthesis

Significant progress has been made in establishing the basis for GIS analyses to understand why the elephants make this migration and which factors are important in which places at which times of year. Data requirements and sources have been identified, and their quality assessed. Gaps in the data have been identified plus ways of completing datasets determined within the time and budget allocated. The preliminary analyses summarised in this report have enabled a plan for future GIS work to be drawn up and work planned for 2005 (as set out in the 'Future work sections of this report). They have also pin-pointed the essential data to be collected by the field team during 2005 to add information about elephant range and enable data layers such as the vegetation map to be extended to the southern part of the elephant range; and the essential data to be gathered in Bamako. The GIS-based information can then be combined with the field observations to better understand the limits of the elephants' range, their needs through the year and the degree of stress they are experiencing.

Annexe: Terms of Reference for S. Canney's visit to STE-Kenya

Data Gathering and Organization:
1. Review the GIS data layers already acquired for the Gourma (please bring any you think we may not have out here).
2. Assess the needs of the project for fresh data layers,
3. Make a list of GIS data needed and make a plan for acquiring it.

Training:
1. Train and assess Emmanual Hema in GIS programming, using ESRI software to be made available by STE. I am very keen to get him thinking on all he wider issues that become apparent with the GIS approach, and he is a good and meticulous worker, so I think he can be entrusted with fairly massive amounts of data entry.

Analysis:
1. Assess the relevance of GIS techniques and analysis used by Save the Elephants in the semi-arid habitats of Northern Kenya to the project needs in Mali.
2. Participate in a preliminary analysis of the Gourma radio-tracking data, with respect to defining corridors and concentration areas.
3. Help define the areas of prime concern for elephants and define quantitative criteria for each subzone, in terms of area covered and time spent.
4. Help analyse the speeds of elephants in and out of corridors.
5. Define criteria to classify land use in the Gourma, with a view to analysing the elephant data against different land uses.
6. Brainstorming and perhaps partial analysis of radio-tracking data in relation to water sources, habitats, roads, villages or other data layers.

Outputs:
1. Preliminary definition of areas of prime concern for elephants.
2. Quantitative definition of these areas in relation to administrative areas or other data layers in Mali.
3. Preliminary definition of critical corridors.
4. A new digital working map, or series of maps of the Gourma, utilizing the satellite images already supplied by USAID and overlaying, or creating overlays of other data layers, such as villages, roads, water-points, protected area boundaries, administrative boundaries.
5. Hard copy high quality prints of these maps for use by the field team in Mali and for planning purposes for STE, EDG and WILD
6. A full progress report for STE on your mission, listing achievements, and making recommendations for future GIS and research activities within the WILD led consortium.
7. A summary report on all research progress made by the project in the year 2004.
8. Inclusion of any other spatial analysis in the above two reports that can be completed by the end of your field visit.

STE will provide GIS staff to help with the data analysis and map making, and we will help set up the deal with the printing company in Nairobi to make the hard copy maps.