Chapter 4
Tsetse eradication, arable fields and the elephant (*Loxodonta africana*) distribution in Zimbabwe: How strong is the link?[3]

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Abstract

We investigated whether the proportion of arable fields increased in relation to the tsetse eradication regime in the Sebungwe region. We also investigated whether and to what extent this increase in arable fields may have affected the distribution of the African elephant (*Loxodonta africana*) between the 1980s and 1990s. Results showed a relatively higher increase in the proportion of the habitat under arable fields in the zone cleared of tsetse by 1986 compared to the zone that was still tsetse infested by the same date. Results also showed a change in the relationship between the proportion of the habitat under arable fields and elephant distribution between the two periods. In the 1980s, when arable field cover was between 0 % and 11 %, there was a weak positive relationship between elephant presence and the proportion of the habitat under arable fields. In contrast, a negative relationship emerged in the 1990s, when arable field cover ranged between 0 % and 88 %. Furthermore, the results demonstrated that the change in the probability of elephant presence between the early 1980s and the early 1990s was significantly related to the change in the proportion arable fields. In conclusion, this study demonstrated that the expansion of arable fields in the Sebungwe was greater in areas where tsetse had been eradicated compared with areas that were still tsetse infested. Overall, the results suggest that tsetse eradication led to new ecological patterns, manifested in the redistribution of elephants in response to arable field expansion.

[3] In review: African Journal of Ecology

4.1 Introduction

The shortage of land that resulted from population pressure in parts of the country, forced the authorities in Zimbabwe to initiate a programme to eradicate tsetse fly *(Glossina* spp.) in the Zambezi valley since the 1960s, particularly in the Sebungwe region (Lovemore 1994, Cumming and Lynam 1997, Nobanda*, et al.* 1998). However, this action would unleash new landscape conditions for wildlife species. The tsetse fly transmits sleeping sickness to humans and Trypanosomiasis to livestock. Hence, areas that are tsetse-infested are normally not supporting a large agricultural population and livestock but instead support thriving wildlife populations that are not affected by tsetse (du Toit 1985, du Toit 1995). As a consequence of tsetse eradication, farmers began to increasingly occupy the valley since the 1960s (Cumming and Lynam 1997). By the mid-1980s agricultural expansion accelerated thereby threatening the persistence of wildlife in the area (Cumming and Lynam 1997).

Despite efforts to preserve wildlife species through a network of national parks in the 1960s, poaching in wildlife reserves, as well as expanding agriculture in wildlife habitats continued to negatively affect wildlife species persistence in the Sebungwe (Hulme and Murphree 2001). Therefore, from the early 1980s, the approach to wildlife management shifted to encompass conservation in agricultural areas, this time by involving local communities (Cumming 1981). This approach was formalized through the communal areas management programme for indigenous resources (CAMPFIRE) in 1989. In this programme, local communities would treat wildlife as an economic asset rather than an impediment to agricultural production (Logan and Moseley 2002). In other words, the programme envisions the of agriculture-wildlife coexistence outside the protected wildlife reserves. Naturally, the success of CAMPFIRE can only be ensured by the persistence of wildlife in these agricultural landscapes. Consequently, the need to understand the spread of arable agriculture following tsetse eradication as well as how this may have affected wildlife distribution is critical.

The first critical question is whether, in the first place, we can quantitatively attribute the increase in arable fields to the tsetse eradication regime. In addition, if there was an increase in arable fields, how did the proportion of the habitat under arable fields impact on the spatial distribution of wildlife species in the area? To date, only a few attempts have been made to quantitatively investigate a link between the expansion of arable fields and the tsetse eradication process (Pender and Rosenburg 1995). Furthermore, few attempts have also been made to quantitatively establish how and to what extent the proportion of the habitat under arable fields in areas where tsetse had been eradicated may have affected the spatial distribution of wildlife (Cumming and Lynam 1997). Existing work has mainly focused on how human population density and settlement in the Sebungwe is related to the distribution of wildlife, particularly that of the elephant (Hoare and Du Toit 1999) without a temporal investigation in the context of the tsetse eradication regime. Therefore, it is important to understand how wildlife responded to varying amounts of agricultural incursions in their habitat over time as this may lead to solutions that lead to the possibility of wildlife-human coexistence.

In the Sebungwe, understanding the extent to which arable fields expanded following tsetse eradication, as well as understanding the extent to which this has affected the spatial distribution of wildlife is critical for aiding CAMPFIRE. Previous studies have suggested a negative relationship between agriculture and wildlife distribution (Ottichilo 2000). However, for the management of programmes such as CAMPFIRE, it is not only important to know that there may be a negative relationship between wildlife presence and agriculture but it is also important to know the conditions under which this negative relationship might set in as this may lead to the establishment of possible thresholds favourable for wildlife-human coexistence. Therefore, analysing the expansion of arable fields and their possible effect on wildlife in a spatial and temporal context is critical.

In this study, we investigated whether the proportion of the habitat under arable fields increased in the Sebungwe region in Zimbabwe in relation to the tsetse eradication process. We also investigated whether and to what extent arable fields could have affected the distribution of the African elephant (*Loxodonta africana*), i.e., a keystone species (Hoare and Du Toit 1999), between the early 1980s and the early 1990s. Therefore, based on the Sebungwe region, we specifically made three predictions. Firstly, we predicted a statistically significant difference in the proportion of the habitat under arable fields between the zones in which tsetse had been eradicated by 1986 and the ones still tsetse infested by the same date. Secondly, we predicted a statistically significant relationship between the proportion of the habitat under arable fields and the probability of elephant presence in sampling units defined by an intersection of administrative ward and vegetation class boundaries in 1983 and 1995. Finally, we predicted a statistically significant relationship between changes in the probability of elephant presence and the changes proportion of arable fields in sampling units defined by an intersection of administrative ward and vegetation class boundaries between the early 1980s and the early 1990s

4.2 Material and methods

Study area

The study was based on the Sebungwe region in Zimbabwe (fig. 4.1). The Sebungwe has undulating topography with the average elevation of 700 – 800 m above sea level. The region is characterised by a single wet season (November to March) with a mean annual rainfall of 680 – 700 mm, as well as a long dry season (April to October). Savanna woodlands and grasslands characterise the main natural land cover. The natural cover types include, Miombo woodland dominated by *Brachystegia spp.* and *Julbernardia globiflora,* Mopane dominated by *Colophospermum mopane,* Faidherbia woodland dominated by *Faidherbia albida,* Miombo-Mopane with co-dominance of *Brachystegia spp.* and *Julbernardia globiflora* and *Colophospermum mopane,* as well as Setaria grasslands dominated by *Setaria incrassata, Ischaemum afrum* and *Dicathium papillosum* (Timberlake*, et al.* 1993) (fig. 4.1b). The floristic-physiognomic vegetation units are constant over time, representing the vegetation classes that would be there in an undisturbed environment (Timberlake*, et al.* 1993). Therefore, the boundaries do not change within a matter of decades.

The Sebungwe consists of five wildlife reserves, interspersed with communal lands. The communal lands have varying degrees of agriculture within the natural vegetation units and varying degrees of elephant presence. Communal lands are a land category that are

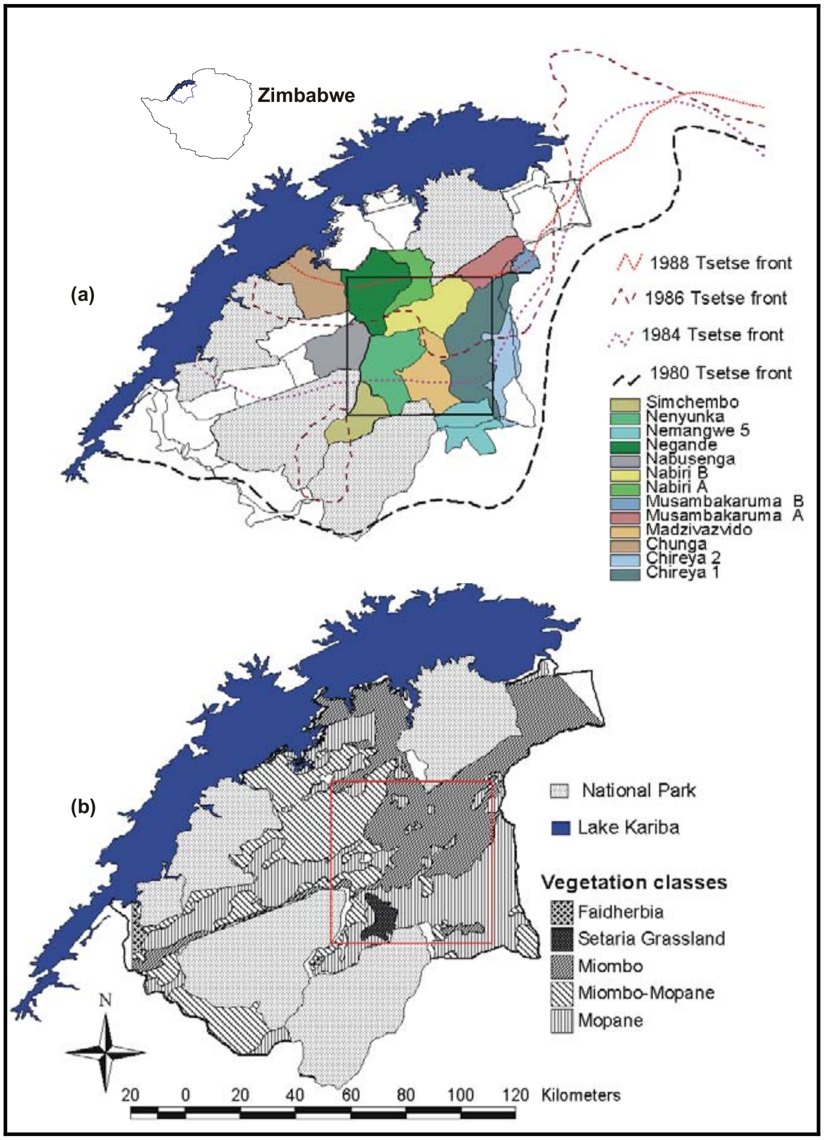

Figure 4.1: The location of the Sebungwe region in Zimbabwe and (a) the wards, national parks and the history of the progression of tsetse eradication (source: Tsetse and Trypanosomiasis control branch, Harare) and (b) the physiognomic-floristic vegetation classes in the communal lands based on Timberlake and Nobanda (1993). The square box is a 61 km x 61 km area selected for this study.

characterised by collective or community land ownership and they are subdivided into administrative or management units called wards (fig. 4.1a). In the communal lands elephant presence is affected by ecological conditions, and also poaching and human disturbance rather than by conservation measures or laws like those enforced in wildlife reserves, i.e., in communal lands elephants are present provided there are necessities such as enough cover and water available for both elephants and humans. Elephants have to cross the communal lands when moving between the wildlife reserves, thereby making communal lands an important wildlife corridor that links the national parks.

The Sebungwe landscape evolved from a complex of different historical forces linked to the eradication of tsetse fly (*Glossina* sp.) (fig. 4.1a). Historically, the Sebungwe region was home to both tsetse fly and a wide range of wildlife species until the 1960s when the tsetse belt began to continually dwindle as a consequence of the tsetse eradication programme that was meant to enable livestock ranging and arable agriculture, thereby relieving population pressure from elsewhere in the country.

Agricultural fields from remote sensing

In order to fulfil the objectives of the study, agricultural field distribution was extracted from land cover for 1984 and 1992 and the land cover maps were derived from an image classification of Landsat Thematic Mapper (TM). In this case, the 1984 map was produced from a supervised image classification of a 19th October image performed by the authors while the 1992 map was sourced from the Forestry Commission of Zimbabwe based on a 16th April image. Dry season imagery was used because elephant counts by aerial surveys were conducted in the dry season. In addition, it is easier to distinguish between fallow agricultural fields and natural vegetation from dry season imagery. Aerial photographs were used for both image classification and accuracy assessment of the 1984 image and for accuracy assessment of the 1992 map. Overall accuracies of 90% and 80% were obtained for the 1984 and 1992 maps respectively.

Elephant distribution data

The data on the spatial distribution of elephants in the 1980s and 1990s were determined using respectively a GIS based combination of 1981-1983 point data sets, and 1993-1995 point data sets. These data were obtained from point location data from the analyses of Sebungwe aerial surveys by Cumming and Lynam (1997) and made available by the World Wildlife Fund (WWF) in Harare. The recordings of the elephant sightings were made within 0.5 minute segments (≤ 1 km) along the flight path with an aircraft travelling at approximately 120 km per hour and the sightings could be up to 250 m on either side of the aircraft (Cumming and Lynam 1997), suggesting that the worst case of locational error in these surveys would be closer to 500 m. The aerial surveys were carried out in the dry season, i.e., between August and October of the relevant years. This was considered an appropriate period for studying the effect of spatial heterogeneity on elephant distribution because the crop fields are fallow during the dry season. Crop fields tend to attract the elephants outside their normal natural range, thus making wet season (October to March) data less reliable for assessing the effect of spatial heterogeneity. In other words, an area that can be suitable for the elephant in the dry season can safely be assumed to be suitable in the wet season.

We considered the elephant distribution map of our study area R as a spatial point pattern (Diggle 1983). Each point where elephants were observed is called an event. We calculated the first-order intensity function $\lambda(x)$ for the elephant point map to give an expected number of events per unit area (Fotheringham, *et al.* 2000):

$$\lambda(x) = \lim_{r=0} \frac{E(N(C(x,r),X))}{\pi r^2} \tag{4.1}$$

where *E(N)* is the expected number of events in the study area considered and *C*(*x,r*) a circular sub-region of R located at *x* with a radius *r*. A kernel function was used in this study with the radius *r* equal to 3000 m based on an exploratory analysis in S-PLUS software (Lam 2001). This kernel radius was also large enough to overcome any locational errors in elephant sightings. We then normalised $\lambda(x)$ by dividing it by the expected number of events in R to produce a normalised or probability function $\lambda n(x)$ (Fotheringham, *et al.* 2000):

$$\lambda n(x) = \frac{\lambda(x)}{E(N(R,X))} \qquad (4.2)$$

We used the λn(x) to estimate the spatial distribution of elephants in the study area during the 1981-83 and 1993-95 periods. This spatial point pattern analysis was carried out in the S-PLUS software (Lam 2001) and the map data were transferred to ILWIS GIS software (ITC 2002) where it was converted to a raster map format. This method was used because it is spatially explicit and gives weight to elephant location rather than absolute numbers: the aim was to determine whether spatial heterogeneity affects the presence of at least a single elephant and since the elephant survey data sets were combined, adding the total number of observed elephants of the years would give a false impression.

Analysis of agricultural field expansion

We started the analysis by using GIS overlay to explore changes in the spatial patterns of arable fields (fields) between 1984 and 1992 relative to the tsetse status in 1986, i.e., by subdividing the study area into two zones (with tsetse and where tsetse had been eradicated) while specifically focussing on the communal lands. The operation produced a map of fields in each tsetse status zone in 1984 and 1992. Consequently, we calculated the proportion of fields in 1984 and 1992 in the two zones. Finally, we statistically compared the amount of arable fields in each zone at different times (1984 and 1992), as well as between the two zones at each time based on proportions.

Analysis of agricultural fields and the probability of elephant presence

We investigated whether there was a significant relationship between the proportion of fields and the probability of elephant presence by focusing on a 61 km by 61 km subset of the study area, specifically covering communal lands in the zone that had become largely free of tsetse by 1988 (fig. 4.1a). This was to facilitate the study of the effects of tsetse eradication on wildlife distribution. This study area was considered large enough for studying the spatial distribution of elephants. Specifically, elephants in the Sebungwe region have an estimated range of between 83 km^2 to 263 km^2, approximating a horizontal (east-west) length scale (horizontal (east-west) dimension) of 9.1 km and 16.2 km, respectively (Guy 1976a, Dunham 1986). This makes the extent of the study area, i.e., 3721 km^2, which is at least 14 times the estimated range of the elephant in the Sebungwe large enough to study elephant distribution.

We based our analysis on 22 different land units (sampling units) that were defined by an intersection of ward and the physiognomic-floristic vegetation class boundaries. The intersection was accomplished in a GIS. The sampling units were appropriate from a management and ecological point of view, i.e., the ward boundaries cater for the fact that arable and wildlife management decisions are made at ward level whereas the vegetation classes cater for ecological differences between sampling units. Fig. 4.2 illustrates the sampling units used in this study.

Next, the probability of elephant presence in each of the sampling units, which was used to measure elephant distribution, was obtained by crossing the probability of elephant distribution map with the sampling unit map (i.e., intersection of wards and vegetation classes) in a GIS and then calculating the mean probability of elephant presence in each sampling unit. Also, the proportion of arable fields in each sampling unit was obtained by crossing a map of arable fields with the sampling unit map in a GIS and then calculating the proportion of arable fields by dividing the amount of arable fields with the total area of the sampling unit.

The next procedure involved using the 1980s and 1990s data to analyse the relationship between the proportion of fields and the mean probability of elephant presence, through regression. The differences in date between the elephant data and arable field data was expected to have negligible effects on the results because the dates were close enough. In a situation whereby a sampling unit is close to a National park, there is likely to be a high level of elephant persistence despite the amount of arable fields. Therefore, the distance from National Parks was calculated in a GIS for use in aiding the proportion of the habitat under arable fields to explain elephant distribution. Finally, we used regression to investigate whether changes in the proportion of arable fields (plus distance from the National parks) in each sampling unit significantly explained changes in the probability of elephant presence in the study area. In order to accomplish this, the proportion of arable fields in the 1980s was subtracted from the proportion of arable fields in the 1990s for each sampling unit. In this way, positive values would represent an increase while negative values

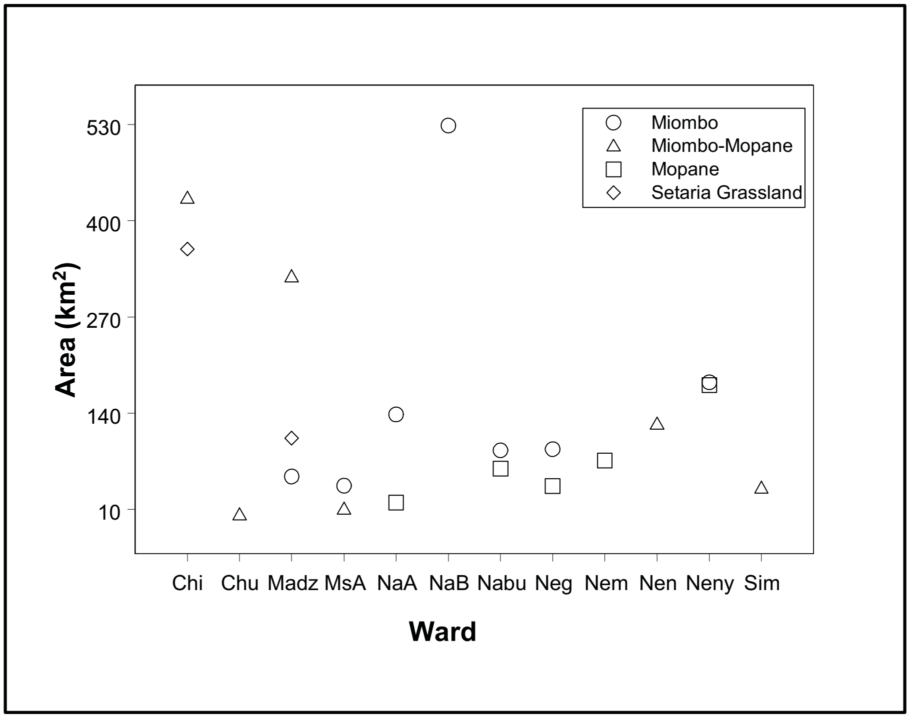

Figure 4.2: Sampling units (intersection of wards and vegetation classes) used in the regression of the probability of elephant presence on the dominant scale and intensity of spatial heterogeneity based on the early 1980s and the early 1990s data (Chi = Chireya 1, Chu = Chunga, Madz = Madzivazvido, MsA = Musambakaruma A, NaA = Nabiri A, NaB = Nabiri B, Nabu = Nabusenga, Nem = Nemangwe 5, Neg = Negande, Neny = Nenyunka and Sim = Simchembo).

would represent a decrease in each factor between the two dates. The same was done to obtain changes in the probability of elephant presence between the early 1980s and the early 1990s.

4.3 Results

Fig. 4.3 shows the distribution of arable fields in 1984 and 1992. It can be observed that the amount of arable fields increased in the study area

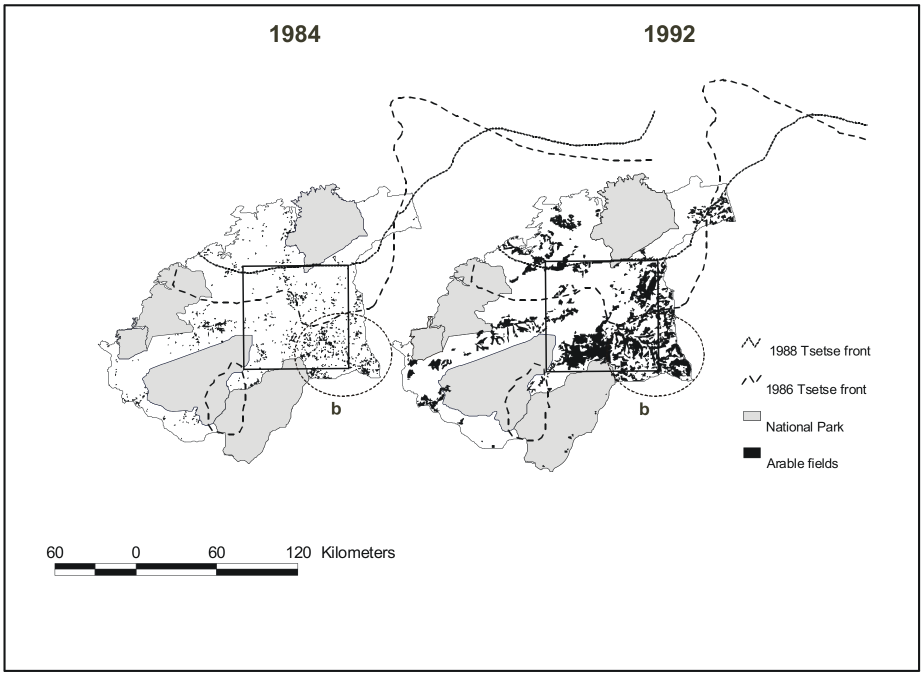

Figure 4.3: Maps showing the distribution of fields in relation to tsetse eradication status in 1984 and 1992 and the 61 km by 61 km square box selected for detailed spatial analysis. The total area of the tsetse zone by 1986 equals to 482 100 hectares while the total area of the eradicated zone is equals to 514 825 hectares (these figures exclude the nature parks). The ellipse (b) illustrates an area where there was a high increase in arable fields between 1984 and 1992**.**

between 1984 and 1992. The highest increase in the area under arable fields between 1984 and 1992 can be observed in the southeastern corner of the study area marked by an ellipse (b).

In addition, fig. 4.4 shows the proportions of arable fields in both tsetse-eradicated and tsetse zones in 1984 and 1992. It can be observed that the proportion of the habitat under arable fields in the tsetse-eradicated zone was higher than the proportion of the habitat under arable fields the tsetse zone in both 1984 and 1992. There were more new fields in the tsetse-eradicated zone than in the tsetse zone. A comparison of the proportions of arable fields within each zone between 1984 and 1992, as well as between the zones in both 1984 and 1992, showed that the proportions were significantly different ($p < 0.05$)

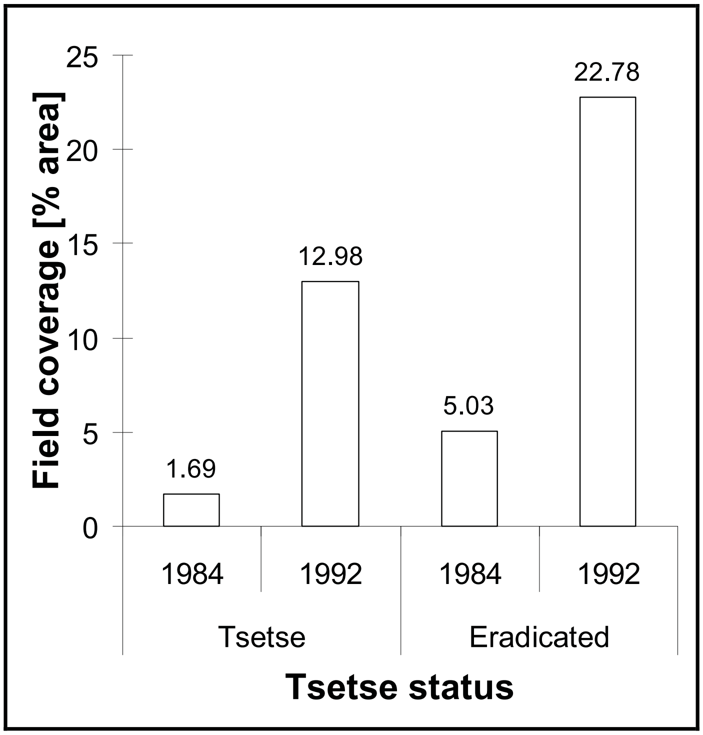

Figure 4.4: The proportion of the habitat under arable fields in the tsetse and tsetse-eradicated zones in 1984 and 1992.

Fig. 4.5 shows the probability of elephant presence between 1981-83 and 1993-95. It can be observed that the probability of elephant presence decreased noticeably between 1981-83 and 1993-95 in areas that had a higher increase in the amount of arable fields (fig. 4.3), particularly in the southeastern corner of the study area marked by the ellipse (b). It can also be observed that areas close to the National parks can have relatively high probabilities of elephant presence despite high proportions of arable fields (fig. 4.3).

Fig. 4.6 shows that the relationship between the probability of elephant presence and the proportion of arable fields in 1984 and in 1992 revealed contrasting patterns. In the 1980s, a non-significant ($p > 0.05$)

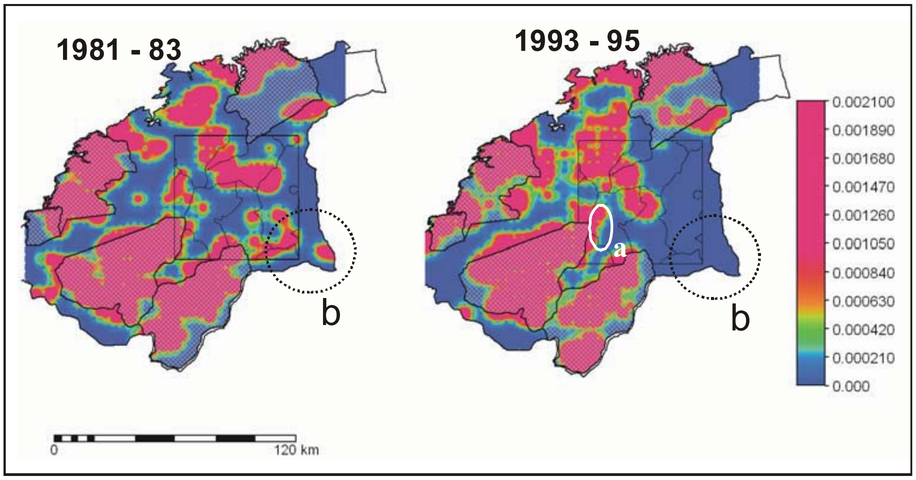

Figure 4.5: Maps probability of elephant presence within a 3 km radius in the study area in 1981-83 and 1993-95 and the 61 km by 61 km square box selected for detailed spatial analysis. The ellipse (b) illustrates an area where there was a major noticeable decrease in the probability of elephant presence between 1981-83 and 1993-95 and ellipse (a) shows an area close to the park where the probability of elephant presence is high.

and weak positive relationship appeared between elephant presence and the proportion of fields in different sampling units. It can be observed that in 1984 all sampling units had less than 11 % of their area covered by arable fields. In contrast, there was a significant ($p < 0.05$) quadratic relationship between the probability of elephant presence and the proportion of the habitat under arable fields in the 1990s. The relationship is largely negative. It can also be observed that during this period the proportions of arable fields in different land units ranged between 0 % and 88 %.

Fig. 4.7 shows the results of the investigation on whether the probability of elephant presence could be significantly explained by the interaction between the proportion of the habitat under arable fields and the distance to the national parks in both the 1980s and the 1990s, as well as whether the changes in the probability of elephant presence were also explained by changes in the proportion of arable fields modified by the distance from the national parks (fig. 4.7). Fig. 4.7a shows that there was a non-significant ($p > 0.05$) relationship between the probability of elephant

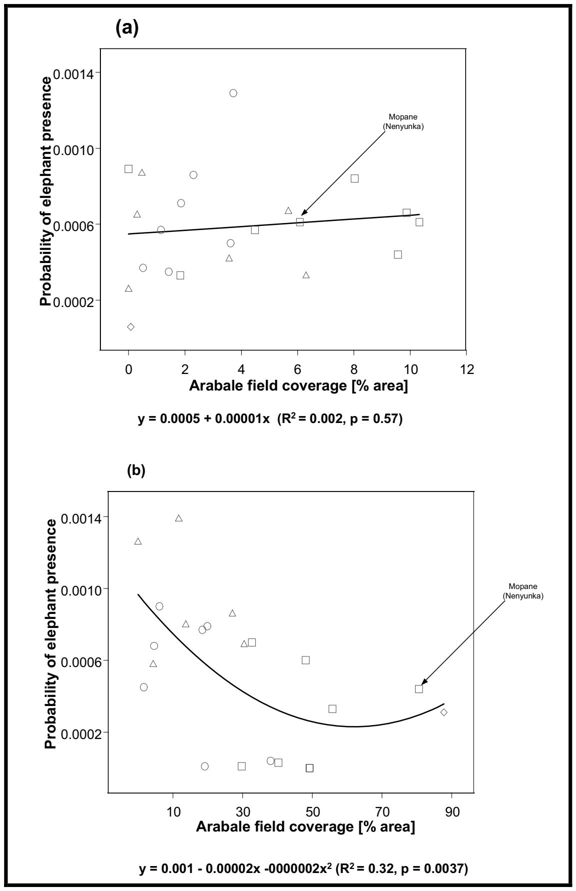

Figure 4.6: Non-significant ($p > 0.05$) relationship between probability of elephant presence on the proportion of the habitat under arable fields in the (a) 1980s and significant ($p < 0.05$) relationship in the (b) 1990s in (○) Miombo, (□) Mopane, (◇) Setaria Grassland and (△) Miombo-Mopane floristic-physiognomic vegetation classes. The marked point is close to National parks.

presence in the 1980s and the interaction between the proportion of the habitat under arable fields and the distance to the national parks while fig. 4.7b shows a significant ($p < 0.05$) largely negative relationship in the 1990s.

During both periods, the proportion of arable fields, modified by the influence of the distance to the national park explained < 1 % and 59 %

of the variance in the probability of elephant presence respectively. Fig. 4.7c shows that the changes in the probability of elephant presence between the early 1980s and the early 1990s were significantly ($p < 0.05$) explained by the increase in the proportion of arable fields between the two dates. In fact, elephants decreased most where arable fields increased most. This model predicted 47 % of the variance of the change in the probability of elephant presence. For example, the Mopane vegetation class in Nenyunka clearly illustrates that increases in the levels of arable fields negatively affected the probability of elephant presence (fig. 4.6 and fig. 4.7). In addition, the same sampling unit illustrates the positive influence of shorter distance to the national park to the probability of elephant presence.

4.4 Discussion

This study revealed a link between tsetse eradication and the expansion of arable fields in the Sebungwe, between 1984 and 1992. This confirms reports from related work, suggesting an increasing number of farmers settling in the area as tsetse was being progressively eradicated in the Sebungwe (Cumming and Lynam 1997). The results also support the widely held hypothesis that tsetse eradication drives changes in land use and therefore, land cover patterns (De Vos 1978, Rogers and Randolph 1988, Jordan 1992, Reid*, et al.* 1997).

An interesting finding of this study was that elephants showed a variation in their reaction to the transformation of habitat by arable agriculture in the Sebungwe following tsetse eradication (fig. 4.6 and fig. 4.7). The results suggested that in the early 1980s when the proportion of arable fields was between 0 % and 11 % there was no significant relationship between elephants and the proportion of the habitat under arable fields. In contrast, the results indicated that in the early 1990s when the proportion of the habitat under arable fields rose up beyond 11 %, the relationship between elephant presence and the proportion of the habitat under arable fields became significantly negative. Since the elephant data were collected in the dry season when arable fields are fallow, the

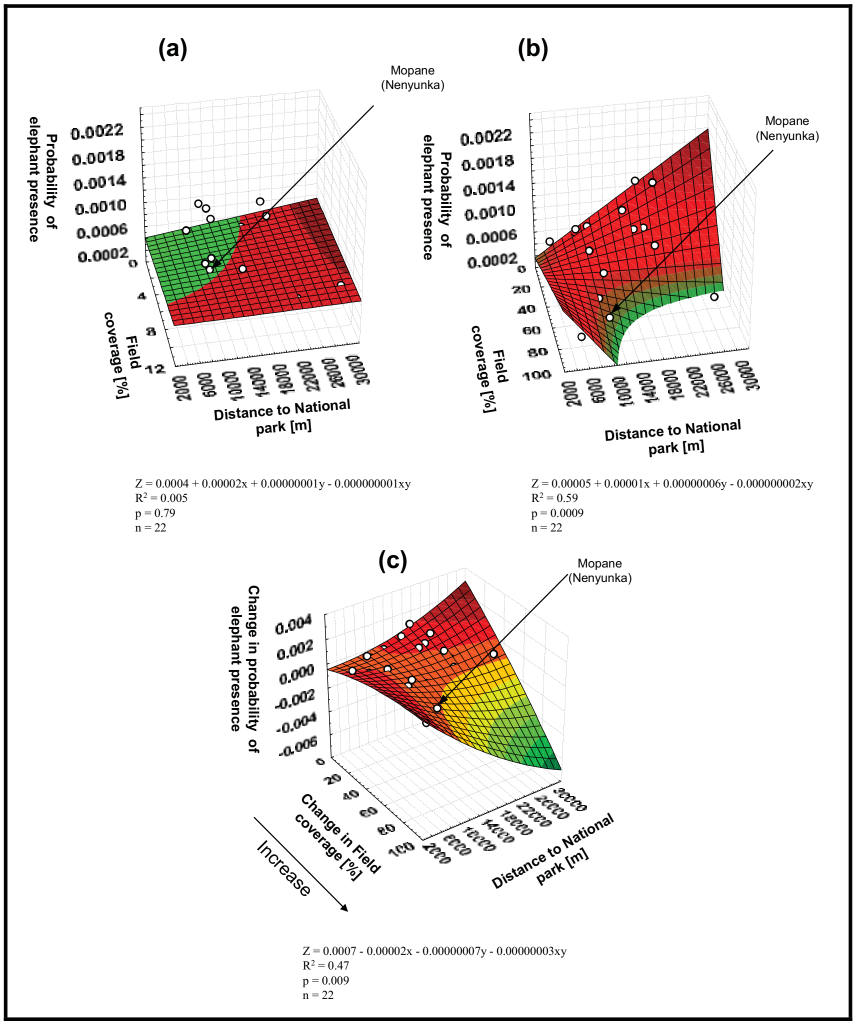

Figure 4.7: A non-significant ($p > 0.05$) relationship between probability of elephant presence on the proportion arable fields plus distance to National parks in the (a) 1980s, a significant ($p < 0.05$) relationship in the (b) 1990s, as well as a significant ($p < 0.05$) relationship between the change in the probability of elephant presence between the 1980s and the 1990s and the increase in arable fields plus a modification by the distance to the National the park during the same period. The labelled sampling unit illustrates the decrease in the probability of elephant presence with the increase in the proportion of arable fields. The graph surfaces represent relatively low probability of elephant presence in green and the highest probability of elephant presence in deep red.

relationship between elephant presence and the proportion of the habitat under arable fields can be explained from a cover (or shelter) perspective. In this regard, at low proportions of arable fields within a land unit, elephants still have sufficient cover to hide from humans. However, when the proportion of the habitat under arable fields increases, the landscape is opened up and there are less hiding opportunities for the elephants. These observations are supported by the findings of (Hoare and Du Toit 1999) that elephants are expected to persist in areas where human settlement occurs within a matrix of untransformed habitat. From the results, we can deduce that the relationship between agricultural encroachment and elephant presence is not necessarily a negative one, but instead, it depends on the proportion the habitat transformed into arable fields. The distance from the national park modifies the relationship, as places that are close to national parks tend to have high levels of elephant presence, even though the proportion of habitat under arable fields is high (figs. 4.6 and 4.7).

We also observed that elephants decreased most where arable fields increased most, suggesting that the increase in the proportion of habitat under arable fields had a negative impact on elephant persistence in the Sebungwe. This result confirms the findings of Cumming and Lynam (1997) who reported that although there was an increase in the Sebungwe elephant population between the 1980s and 1990s, the dry season range shrunk by 15 %. The decline in the elephant range has negative implications for CAMPFIRE, since the survival of this programme hinges upon wildlife species persistence in the agricultural areas. However, the increase in the proportion of arable fields explained only less that half of the variance of the decrease in the probability of elephant presence, suggesting the influence of other factors that need to be investigated in future studies.

4.5 Conclusions

Three main conclusions could be drawn from this study. Firstly, the expansion of arable fields was greater in areas where tsetse had been eradicated earlier compared with areas that were still tsetse infested in the Sebungwe, suggesting that tsetse eradication gave way to accelerated arable field expansion. Secondly, the increase in the proportion of the habitat under arable fields was negatively related to elephant presence in the Sebungwe but only when the proportion of the habitat under arable fields ranged beyond 11 % among the sampling units. Finally, the results suggest that tsetse eradication lead to new ecological patterns, manifested in the redistribution of elephants in response to arable field expansion.