SPATIAL DISTRIBUTION OF ELEPHANTS (*LOXODONTA AFRICANA*) IN HWANGE MINING CONCESSION AREA

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Abstract

In this study we tested whether and how environmental factors such as distance from water points inside mine dumps, distance from water points outside mine dumps, distance away from settlements, distance away from agricultural fields, distance from mine dumps and NDVI (vegetation cover) significantly predict the spatial distribution of elephants in the mining area of Hwange, Zimbabwe. To achieve this, we digitized different land cover strata in the study area which included mine dumps, agricultural fields, settlements and water points from satellite remotely sensed data made available in Google Earth. Elephant data was collected as presence and absence based on presence indicators such as dung piles. Logistic regression was used to relate elephant data and environmental variables. Results show that distance away from mine dumps, distance away from settlements, distance away from water points outside mine dumps and NDVI are significantly ($p<0.05$) related with elephant distribution. Distance away from water points inside the mine dumps and distance from agricultural fields are however not significantly ($p>0.05$) related with elephant presence. The results imply that if elephants are to exist sustainably in areas dominated by mining activities, wildlife conservation strategies should be adopted. The conservation strategies should involve reclamation of the mine dumps through reforestation since elephants rely on forests for food and habitat.

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Dedication

To my sons, Tavonga and Tatenda

Acknowledgements

I would like to thank Professor A. Murwira for his guidance and support throughout the study. I also thank Dr L. Zanamwe for his support and guidance during the study. My gratitude is also extended to Mr. O.J. Maponga, the Business Development Manager at Hwange Colliery for granting me permission me to carry out the study within the Concession Area. I also appreciate the financial support that was rendered to me by my husband, Mr. W.V. Madzimure.

CHAPTER 1: INRODUCTION

General background

Wildlife habitat loss and fragmentation are one of the topical issues in ecology (Sibanda and Murwira 2012). In several studies done, vegetation cover has been identified as one of the key factors which explain the spatial distribution of elephants (Osbourne 2002). The reason behind this is that elephants are browsers and associate with woodlands (Smith 2006).

Much is known about the effects of agricultural fields on the spatial distribution of elephants (Leingruber 2003). Crop fields have been regarded as the most common predictor of elephant presence (Barnes 2008). The fields result in habitat loss, fragmentation and compression since it involves conversion of large forests. In Asia, the decline in elephant population is linked to habitat fragmentation and loss due to agriculture (Leingruber 2003). The habitat for the African elephant (*loxodonta Africana*) is also being compressed as a result of agricultural fields' expansion (Parker 1989).

Crop fields' expansion was found to be the major driver of elephant distribution in the Zambezi Valley (Sibanda and Murwira 2012). This indicates that humans and elephant compete for space (Leingruber 2003; Smith 2006). Rangeland compression often leads to human- elephant conflicts which result in human injuries, deaths and crop destruction. Hence environmental planners with an ecological vision are concerned with linking up the remaining islands of elephant habitats with corridors to address the problem of fragmentation (Osbourne and Parker 2003).

The effects of surface water availability are well understood. The availability of surface water is the best predictor of elephant presence (Chamaille- Jammes 2007). Elephants move around but do not go further away from water sources (Chamaille- Jammes 2007). For example, it has been observed that in water scarce areas, elephants are found closer to human settlements (Ngene 2009). However, the effects of mining on the spatial distribution of elephants remains largely unexplored, yet such studies are essential in Hwange Concession Area since mining should also take elephant conservation as a priority.

1.2 Statement of the problem

Much is known about the effects of crop field expansion on the spatial distribution of elephants. As crop field expansion increases, elephant distribution is affected as a result of increased fragmentation (Sibanda and Murwira 2012). However, much has not been done to explore the effects of mining activities on the spatial distribution of elephants. Hence this study intended to test whether open cast coal mining, in addition to other factors significantly affects elephant distribution especially in cases where the mining activities are located closer to a conservation area.

1.3 Objectives and hypothesis

The main objective of this study was to test the hypothesis that distance from mine dumps, distance from agricultural fields, distance from water points inside mine dumps, distance from water points outside mine dumps, distance from settlement and vegetation cover (NDVI) significantly predict the spatial distribution of elephants.

1.4 Justification of the study

It is important to understand how human land use activities can co-exist sustainably with elephant conservation. The research provides a framework in which development can take place in the context of elephant conservation. This is particularly important in Hwange since land use planners should have a balanced vision in environmental planning.

CHAPTER 2: MATERIALS AND METHODS

2.1 Study area

The study was conducted in Hwange concession mining area which is located in the western part of Zimbabwe in latitude 18^o S and longitude 26^o E. The area of study is about 4km from Hwange National Park. The local geology constitutes shallow sandy soils of the Karoo origin (Chamaille- Jammes 2007). The main rock types in the area include coal, sandstones, sedimentary, mudstone and fire clay. The main vegetation type in the study area is colophospermum mopane woodlands and baikiaea plurijuga (Mukwashi 2012). The study area is characterized by a semi-arid climate. The rain season is from October to April. Annual rainfall is below 600mm (Chamaille- Jammes 2007). Day temperatures can exceed 40^o during the hottest months of the year (Chamaille- Jammes 2007). The area is closer to Hwange National Park which has an estimated 44 492 elephants (Chamaille- Jammes 2007).

The study area constitutes open cast mining activities. This mining activity involves the extraction of large pits which reach the permanent water table. The water is pumped out during the mining process (Mosuwe 2010). When the coal is exhausted, huge heaps of excavated soils (mine dumps) and pits remain behind. Water also accumulates within these huge pits since pumping ceases as soon as mining stops (Mosuwe 2010). Within the study area, there are dams that have been constructed to store water that is pumped out from the underground and the open cast mines during the mining process. These dams are situated outside the mine dumps and are 5km away from Hwange National Park.

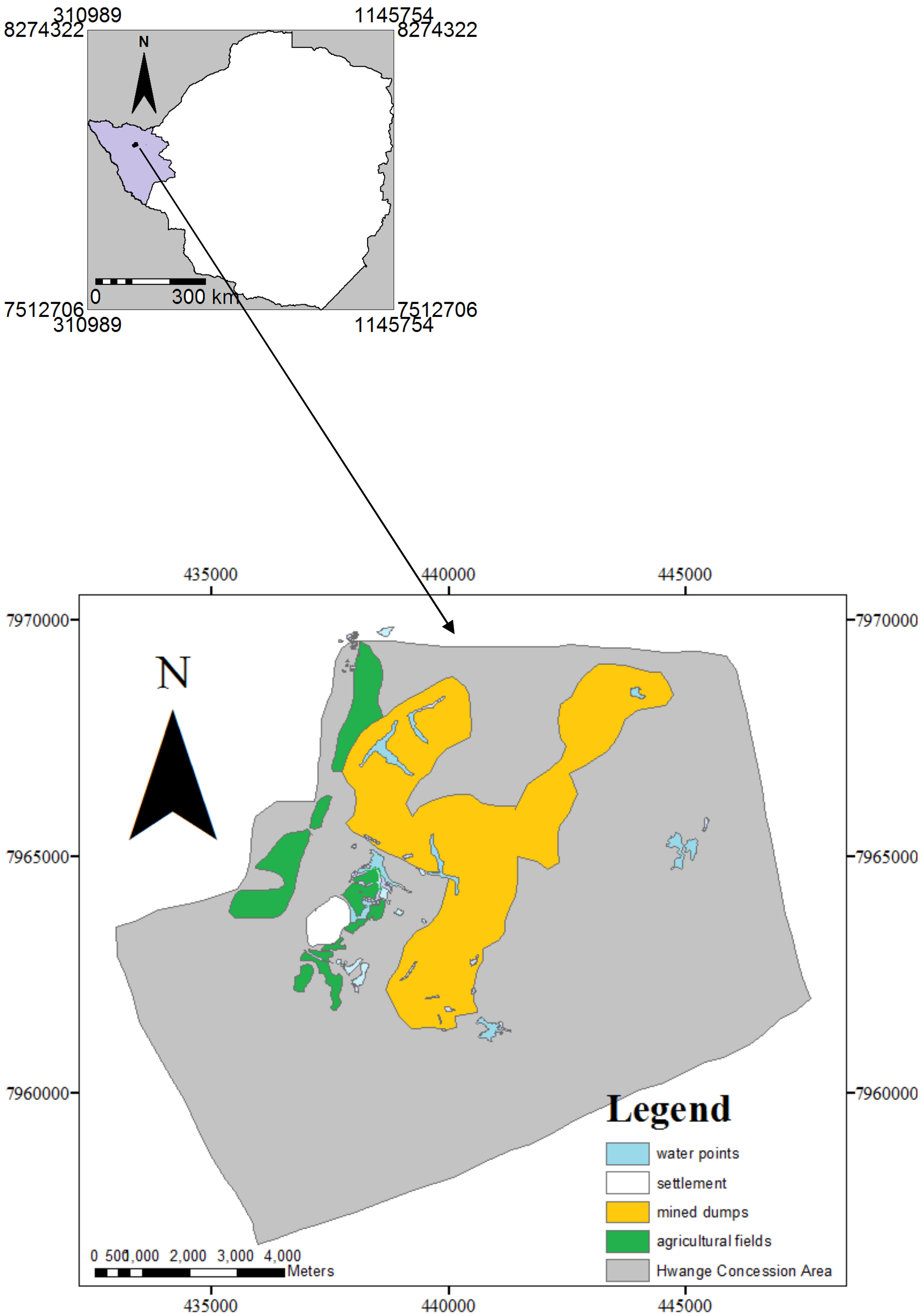

Figure 1: Location of the study area in Hwange Mining Town, Zimbabwe

2.2 Data collection

2.2.1 Environmental variables

Vegetation cover Normalized Difference Vegetation Index (NDVI) figure 6c) was calculated from the Landsat image of 31 May 2011. The image was radio metrically corrected. We georeferenced the Landsat image to Universal Transverse Mercator (UTM) Zone 35K. The Landsat image was chosen since it has a finer spatial resolution. We used the following the formula to calculate NDVI:

NDVI=Near Infrared- Red/ Near Infrared +Red

The data for land covers such as mine dumps, settlement, agricultural fields, and water points was obtained through digitizing satellite images made available in from Google Earth (www.Googleearth.com). The Key hole markup language files (kml files) of the different land cover strata digitized from Google earth were all georeferenced to UTM zone 35K (figure 1). The raster maps of the land cover strata were used to calculate distance maps in ILWIS GIS (ITC, 2003) (figure 5 and figure 6). We then used an overlay GIS function to extract distances of elephant presence from each of the predictor variables.

2.2.2 Elephant data collection

Elephant data was collected as presence (**1**) or absence (**0**). We used the base line elephant data collected in 2008 by the Business Development Unit of Hwange Colliery Company during the Environmental Impact Assessment (EIA) process. The baseline data was in the form of coordinates (table 2). The baseline data was used as it revealed the extent to which the mining activities had affected elephant distribution. We navigated to the points (coordinates) using a GPS. After navigating to a point, we would measure a radius of 100m around the point. We would look out for elephant presence indicators (dung piles or spoors) within this radius (figure 2). Each time we spotted dung piles or spoors, we would record the coordinates as (**1**) on the data sheet. Where there was no evidence of elephant presence, we recorded absence (**0**) and the coordinates on the data sheet (Buckland 1993). The index method was used for data collection (Buckland 1993). It provides a good figure for the distribution of animal populations (Barnes 1996). Dung piles and spoors (figure 2) were used to detect the presence of elephants (Beer 2008).

Figure 2: Dung piles as elephant presence indicators

2.2.3 Data analysis

The binary logistic regression function was used to test whether each of the predictor variables significantly predict the spatial distribution of elephants. Binary Logistic Regression is used for predicting the outcome of a categorical or dichotomous dependent variable (Pampel 2000). It measures the relationship between a categorical dependent variable and one or more independent variables (Menard 2002). We used binary logistic regression since the data was collected as presence or absence meaning it was dichotomous or categorical. In this case we used logistic regression to test the relationship a categorical variable (elephant presence or absence) and the independent variables (NDVI, distance from settlements, distance from mine dumps, distance from water points and distance from agricultural fields. The data was analyzed in SPSS.

CHAPTER 3: RESULTS, DISCUSSION AND CONCLUSIONS

3.1 Results

Table 1 illustrates that NDVI (vegetation cover), distance from water points outside the mine dumps, mine dumps, and distance from settlements significantly ($p<0.05$) predict the spatial distribution of elephants in the study area. Distance from water points inside the mine dumps and distance from agricultural fields are not significant ($p>0.05$).

Table 1: Logistic regression model results

Factor	Slope	Intercept	P value
Water points inside the mine dumps	0.0001	1.297	0.614
Distance from agric fields	0.0002	1.002	0.416
Distance from water points outside the mine dumps	**0.001**	**-1.849**	**0.0001**
Distance from settlement	**-0.001**	**2.814**	**0.009**
Distance from mine dumps	**0.001**	**0.444**	**0.047**
NDVI	**5.215**	**0.925**	**0.010**

Figure 3 illustrates a significant ($p<0.05$) positive relationship between probability of elephant presence and NDVI. At low NDVI (0.02), probability of elephant presence is low (0.935). As NDVI values increases (0.5), the probability of elephant presence also increases (0.9985).

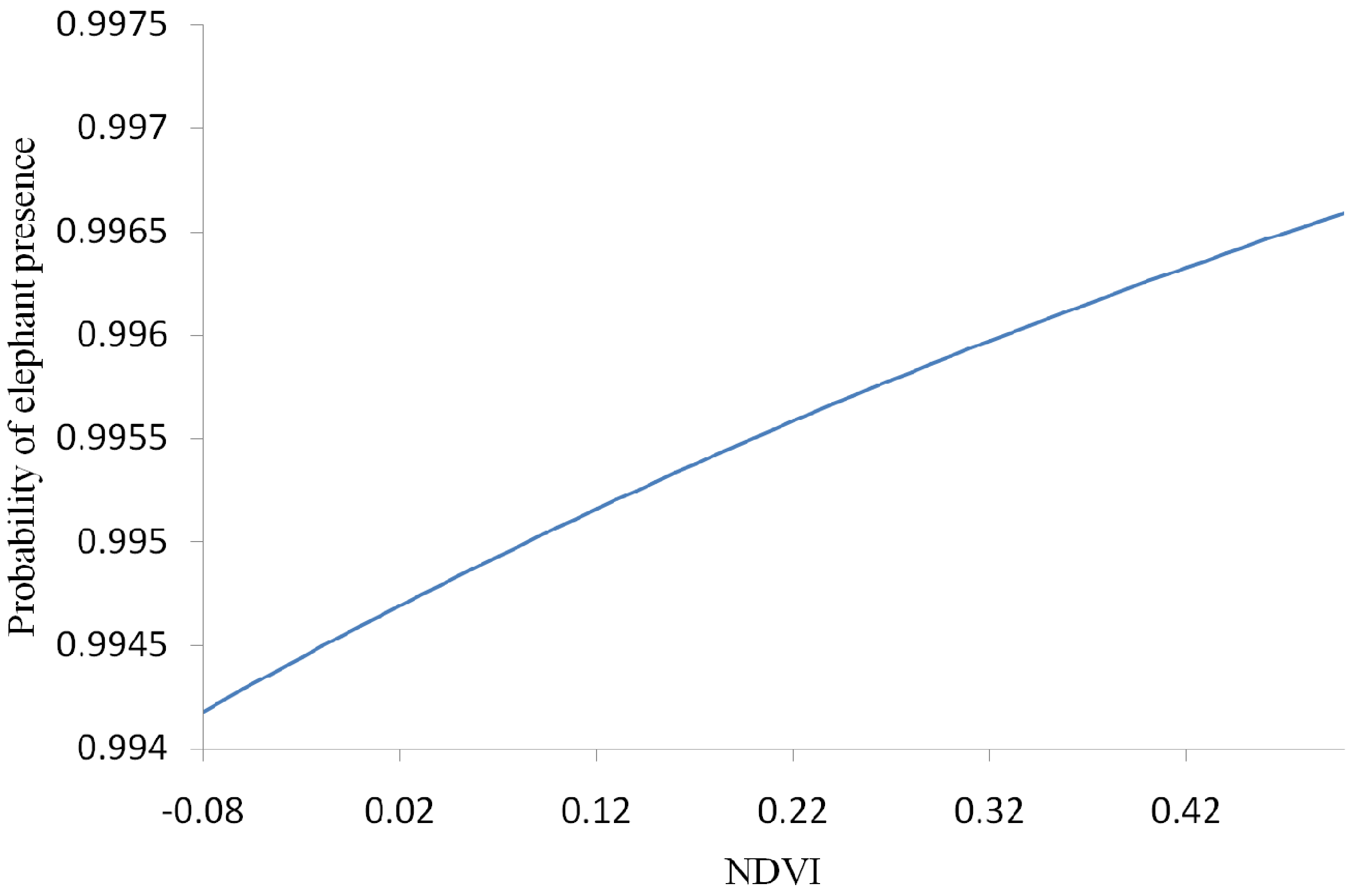

Figure 3. Probability of elephant presence ($y=e^{(5.215+(0.925*x))}/(1+e^{(5.215+(0.925*x))}$ as a function of NDVI.

Figure 4 illustrates the probability of elephant presence as a function of distance from mine dumps, distance from agricultural fields, and distance from water points inside mine dumps, distance from water points outside mine dumps, and distance from settlement.

It can be observed from figure 4e) that there is a significant ($p<0.05$) negative relationship between water outside the mine dumps and elephant presence. At shorter distances for instance 2km, probability of elephant presence is high (0.6). Probability of elephant presence is low (0) at longer distances (12km) away from water points outside the mine dumps.

A non-significant ($p>0.05$) positive relationship is observed between elephant presence and water sources inside the mine dumps (figure 4b). The probability of elephant presence increases with increasing distance away from water sources inside the mine dumps. For instance, at 7km away, probability is 0.9. At shorter distances away from water points inside the mine dumps (1km), probability is as low as 0.3.

Probability of elephant presence is significantly ($p<0.05$) and positively related to distance away from mine dumps (figure 4d). At shorter distances (1km) away from the mine a dump, the probability of elephant presence is very low (0.4). Probability of elephant presence is higher (0.9) at longer distances (8km) away from the mine dumps.

Figure 4a) illustrates a significant ($p<0.05$) positive relationship between elephant presence and settlements. As distance away from settled areas increases (8km), the probability of elephant presence is higher (0.7). At shorter distances (1km) away from the mine dumps, probability of elephant presence is low (0.2).

Figure c) illustrates a non significant ($p>0.05$) relationship between distance from agricultural fields and the probability of elephant presence. At shorter distances away from agricultural fields, probability of elephant presence is low. The probability of elephant presence is high at longer distances away from the agricultural fields.

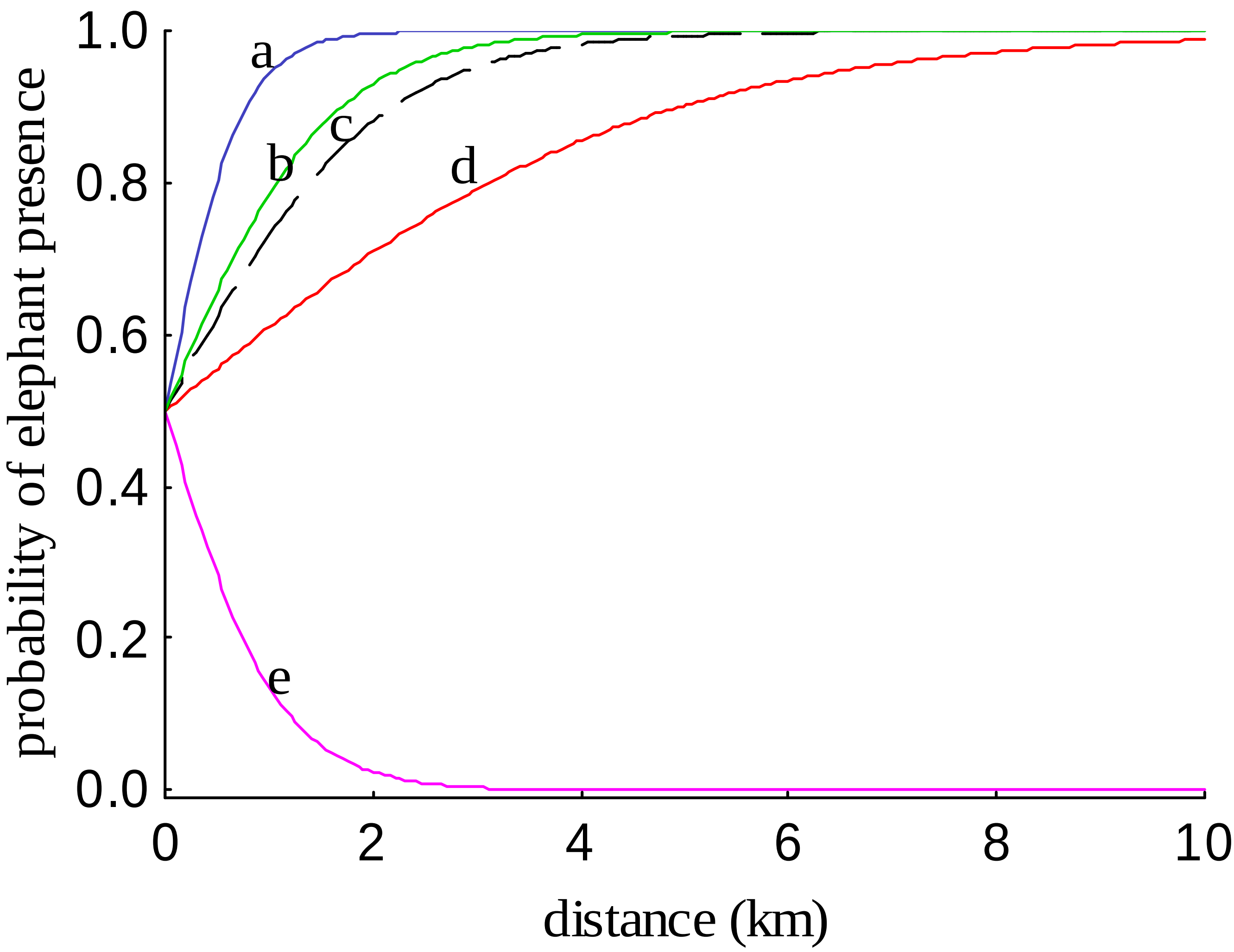

Figure 4: Probability of elephant presence as a function of distance from a) settlement ($y=e^{(-0.001+(2.814*x))}/(1+e^{(-0.001+(2.814*x))}$, b) water inside the mine dumps ($y=e^{(0.0001+(1.297*x))}/(1+e^{(0.0001+(1.297*x))}$, c) agricultural fields ($y=e^{(0.0002+(1.002*x))}/(1+e^{(0.0002+(1.002*x))}$, d) mining ($y=e^{(0.001+(0.444*x))}/(1+e^{(0.001+(0.444*x))}$, e) water outside the mine dumps ($y=e^{(0.001+(-1.814*x))}/(1+e^{(0.001+(-1.814*x))}$

3.2 Discussion

Results of this study indicate that NDVI (vegetation cover), distance from water points outside the mine dumps, distance from mine dumps, and distance from settlements significantly predict the spatial distribution of elephants in the study area. Distance from water points inside the mine dumps and agriculture are not significantly related with elephant presence.

Mine dumps were significantly and positively related with the probability of elephant presence. This is for the first time that elephant distribution has been related with mining activities. Previous studies have explored the effects of elephant habitat loss as a result of crop fields expansion (Murwira, Skidmore et al. 2010). Hence investigating the effects of forest clearance by mining activities on the spatial distribution of elephants have been done for the first time. For instance, (Priyadarshi 2013) has indicated that mining involves vegetation clearance which causes severe damage to the land resources. This is because elephants are mainly herbivores ((Hoare 1999). However, (Priyadarshi 2013) did not map the spatial distribution of elephants in relation to mining activities.

The probability of elephant presence was high near woodland and vegetated areas. As vegetation cover (NDVI) increased, the probability of elephant presence also increased. The results are consistent with (Hoare 1999) who observed that elephants tend to associate with vegetation since they are herbivores which feed on leaves and bark of bushes and trees. The association of elephants with vegetation has been observed by (Young 2009). This explains why vegetation cover (NDVI) is positively related to the probability of elephant presence. Vegetation tends to provide important forage and shade for elephants (Smith 2006).

Results also indicated a significant negative relationship between water points outside the mine dumps. The findings are similar to those of (Ngene 2009) who noted that in semi arid environment elephants tend to aggregate around water points. (Mukwashi 2012) also observed that surface water plays a crucial role in elephant distribution in areas with a semi-arid climate. The results are also supported with (Chamaille- Jammes 2007) who observed that availability of drinking water is the main predictor of elephant presence. The results are also consistent with (Van Aarde 2006) who noted that surface water availability is the common predictor of elephant presence.

Water points inside the mine dumps portray an unusual relationship as they are positively related to the probability of elephant presence. This indicates that water points inside mine dumps are shunned by elephants. Such a finding is contrary to the usual scenario where the probability of elephant presence is significantly and negatively associated with water points (Ngene 2009). These results imply that elephants are repelled by mining activities. This also means that although water normally attracts elephants, they shun water in mine dumps. This is because the water points are inaccessible since they are situated in deep pits. The depth of the can be seen from the satellite image.

A significant positive relationship between probability of elephant presence and distance from settlements was observed. These results are supported by (Sibanda and Murwira 2012) who observed that settlements encroach into elephant habitats leading to conflicts. (Ngene 2009) also noted that elephants tend to be near settlements in situations where water sources are found closer to settled areas. (Rood 2000) also suggested that opening up forest areas to pave way for settlements significantly affects the spatial distribution of elephants.

A non-significant positive relationship between elephant distribution and agricultural fields was observed. These results are consistent with (Hoare 1999) who noted that agricultural fields overlap with elephant ranges in areas closer to conservation areas. (Rood 2000) also discovered that agricultural fields encroach into elephant ranges. Agricultural fields also fragment elephant habitat (Sibanda and Murwira 2012).

3.3 Conclusion

The main objective of this study was to test whether distance from mining activities in addition to other factors such as distance from water points, distance from settlements, distance from agricultural fields, and NDVI (vegetation cover) significantly predict the presence of elephants. We conclude that distance away from mine dumps also significantly predict elephant presence in addition to other factors such distance from water points, distance from settlement and NDVI . The results imply that the mining activities repel elephants. This implies that if elephants are to exist sustainably in areas dominated by mining activities, wildlife conservation strategies should be adopted. The conservation strategies should involve reclamation of the mine dumps through reforestation since elephants rely on forests for food and habitat. Vegetation might attract the elephants since they are browsers and associate with woodlands. Environmental Planners with an ecological vision may also consider constructing a canal which links the dams outside the mine dumps with water points in Hwange National Park as the mining activities are only 4km away from the park. This is because the dams are perennial and yet most water points around the park dry up during the dry season.

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Appendix

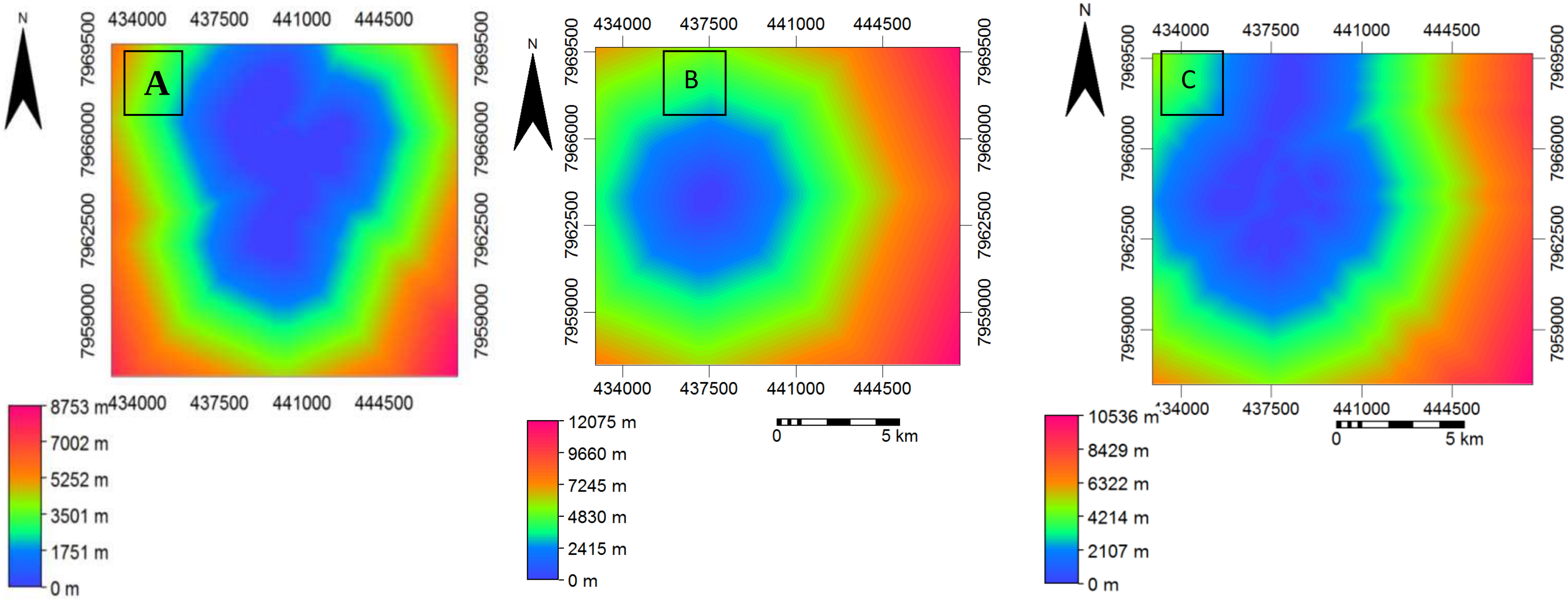

Figure 5 a) mine dumps distances 5b) settlement distances 5c) Agricultural distances

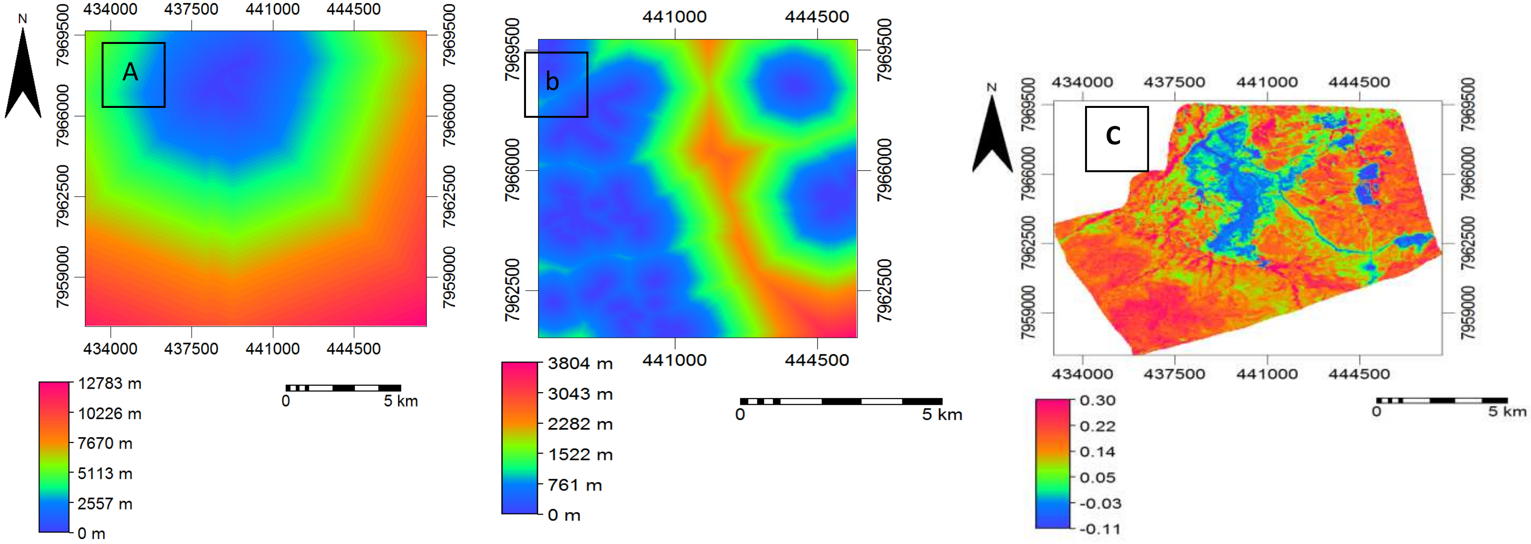

Figure 6: a) Water points inside mine dumps distances 6 b) water points outside the mine dump distances 6 c) NDVI

Table 2: Baseline elephant presence data: Source: Hwange Colliery Environmental Department

x	y		x	y		x	y	
432722	7963831	1	438026	7962138	1	440911	7961541	1
435313	7963875	1	438028	7962130	1	440916	7961516	1
435436	7963874	1	438031	7962133	1	440919	7961509	1
435498	7963886	1	438039	7967310	1	440922	7961490	1
435504	7963885	1	438055	7964320	1	440935	7961463	1
435554	7963931	1	438060	7966493	1	440936	7961387	1
435652	7963972	1	438116	7967655	1	440938	7961405	1
435683	7963793	1	438146	7965482	1	440939	7961381	1
435690	7963766	1	438164	7962403	1	440939	7961420	1
435692	7963729	1	438166	7962218	1	440943	7961372	1
435710	7963680	1	438173	7962248	1	440943	7961444	1
435876	7963592	1	438178	7962285	1	440945	7961365	1
436473	7965014	1	438182	7962487	1	440961	7961353	1
436584	7962259	1	438184	7962454	1	440987	7961137	1

436999	7965592	1	438196	7962391	1	440992	7961356	1
437024	7963695	1	438297	7967612	1	441005	7961351	1
437024	7963695	1	438388	7962466	1	441007	7965439	1
437030	7963660	1	438576	7965289	1	441011	7961347	1
437045	7963686	1	438627	7967296	1	441021	7961344	1
437045	7963686	1	438641	7966601	1	441025	7961342	1
437086	7963775	1	438663	7965289	1	441030	7961338	1
437086	7963775	1	438684	7967676	1	441046	7961338	1
437113	7963813	1	438770	7967827	1	441201	7965353	1
437261	7963855	1	438878	7964772	1	441781	7965074	1
437326	7963864	1	438879	7966947	1	441975	7967224	1
437363	7966141	1	439028	7965439	1	442039	7965203	1
437391	7963855	1	439093	7967934	1	442125	7966192	1
437431	7966124	1	439114	7967956	1	442233	7965891	1
437485	7963852	1	439200	7965450	1	442319	7966235	1
437515	7966107	1	439250	7962719	1	442408	7967962	1

437586	7963864	1	439372	7968096	1	442448	7967784	1
437630	7963816	1	439372	7964342	1	442470	7967805	1
437633	7966158	1	439438	7969056	1	442509	7966400	1
437683	7965199	1	439480	7965482	1	442534	7968278	1
437775	7963813	1	439616	7965312	1	442577	7966213	1
437781	7966644	1	439814	7961143	1	442620	7968472	1
437784	7963810	1	439845	7961136	1	442642	7968407	1
437831	7663808	1	439924	7961120	1	442792	7967676	1
437845	7966923	1	439933	7961116	1	443007	7968579	1
437852	7966124	1	440026	7961096	1	443201	7968300	1
437903	7964202	1	440034	7961094	1	443437	7969053	1
437915	7963835	1	440077	7961034	1	443523	7969074	1
437920	7964629	1	440078	7961071	1	443900	7967827	1
437951	7967741	1	440085	7961030	1	440909	7961548	1
437952	7968442	1	440088	7968163	1			
437953	7965654	1	440090	7961029	1			

437953	7966751	1	440254	7966579	1
438011	7962149	1	440259	7968329	1
438015	7962160	1	440345	7961356	1
438018	7962173	1	440603	7961449	1