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

Farai Madzimure nee Nyakupanda[*]

Abstract

In this study we tested whether environmental factors such as distance from water points outside mine dumps, 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 to environmental variables. For this small study area, results show that distance away from mine dumps, distance away from water points outside mine dumps and NDVI are significantly ($p<0.05$) related with elephant distribution. Distance away from agricultural fields are however not significantly ($p>0.05$) related with the probability of elephant presence. The significant positive relationship between the probability of elephant presence and distance away from mine dumps imply is that mining activities repel elephants. However, the results are not conclusive since they are based upon a study area which is smaller than an elephant home range. Future studies should extent the study area so as to come up with results which can be generalized.

[*] **Lecturer: Zimbabwe Open University**

Introduction

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 1991). The fields result in habitat loss, fragmentation and compression since it involves conversion of large areas of woodlands. 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 (Osbourne 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). (Ngene 2009) also observed that in water scarce areas, elephants are found closer to human settlements. 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

Study area

The study was conducted in Hwange concession mining area which is located in the western part of Zimbabwe at latitude 18^{o} S and longitude 26^{o} E. 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 dominant 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 (Tiwary 2000). When the coal is exhausted, heaps of excavated soils (mine dumps) and pits remain and water also accumulates within these huge pits since pumping ceases as soon as mining stops (Geller 1998). Within the study area, there are 17 dams that have been constructed to store water that is pumped out from underground and the open cast mines during the mining process.

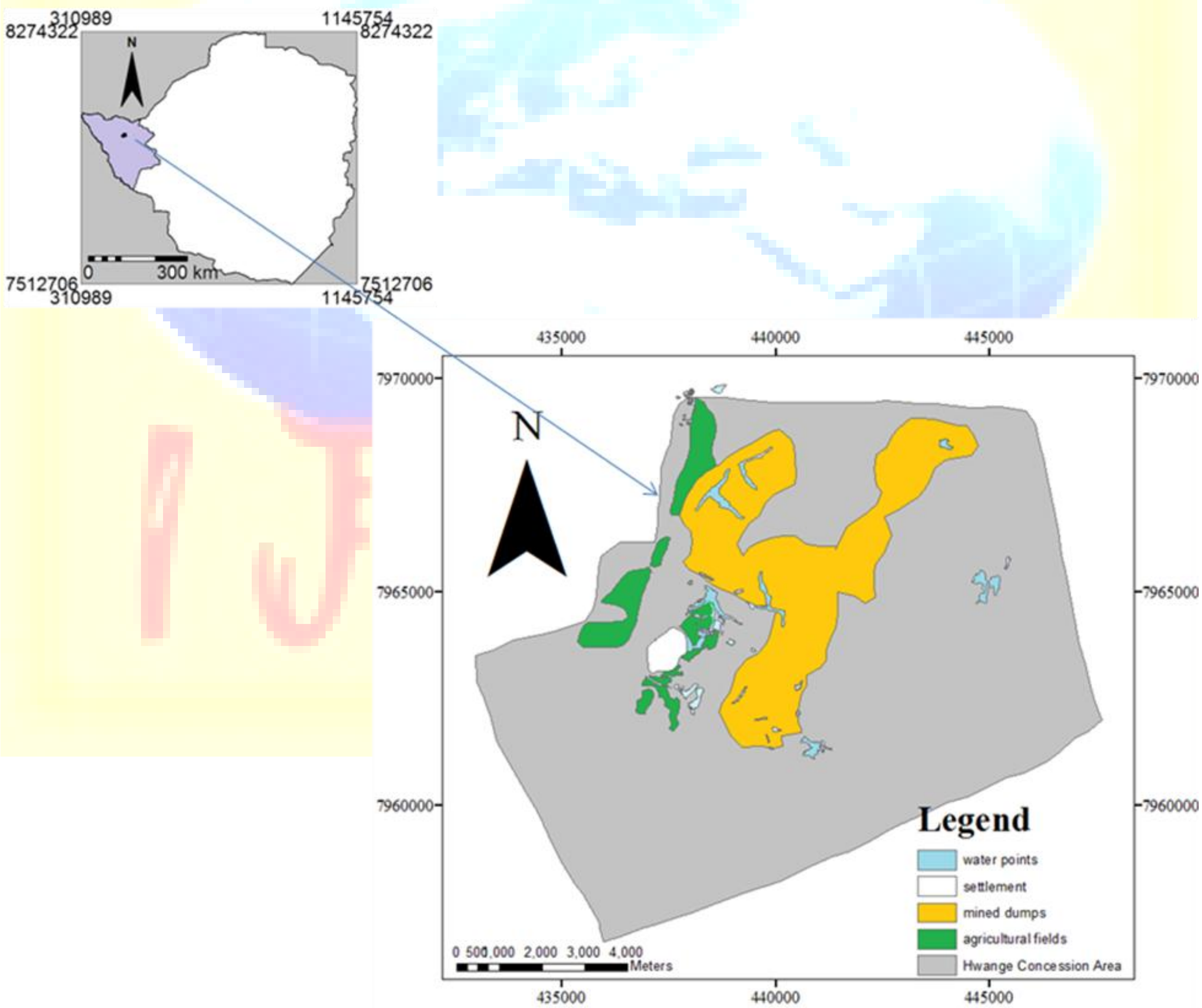

Figure 1: Location of the study area in Hwange Mining Town, Zimbabwe

Materials

The following materials were used to collect data: compass, meter tape, data sheets, and pens, hand held GPS. The following softwares were used : SPSS, ILWIS, Arc GIS, and Arc View 3.3.

Methods

Data collection

Environmental variables

The data for land covers such as mine dumps, settlement, agricultural fields, and water points was obtained through digitizing satellite images made available in Google Earth (www.Googleearth.com). The coordinate system of the shape files was changed from geographic to UTM zone 35K (figure 1). The ILWIS GIS was used to create distance surfaces for all the predictor variables (ITC, 2003) .The distance surfaces (figure 5 and 6 in appendix) show the change of distance from the data layers such as settlements, mined out areas, water points inside the mine dumps, water points outside the mine dumps, agricultural fields.

Mapping vegetation cover (NDVI)

Vegetation cover was estimated from a remotely sensed Normalized Difference Vegetation Index (NDVI) based on Landsat Thematic Mapper Satellite Imagery (Barnes, 1995). NDVI is a combination of the reflectance of the earth objects in the RED and Near Infrared (NIR) spectrum. NDVI is a strong estimate of vegetation productivity and standing plant biomass (Chamaille-Jammes, 2007). The following formula was used to calculate NDVI= (NIR-RED) / (NIR+RED). The NDVI calculations were done in ILWIS.

Elephant data collection

Figure 2 shows elephant dung piles which were used as surrogates of elephant presence during data collection

Figure 2: Dung piles as elephant presence indicators

Elephant data was collected as presence (**1**) or absence (**0**). Dung piles and spoors (figure 2) were used as surrogates of the presence of elephants (Beer 2008). Elephant data was obtained using the index method. The index method is an indirect measurement of the status of animal population in an area (World Wide Fund for Nature, 2000). Examples of index methods include dung counts and spoors. Dung counts were used as surrogates of elephant presence for this research. The method is easy to apply and it is cheap and affordable. The line transect dung count method was used to determine relative abundance and distribution of elephants within the study area (Barnes, 1996). Elephant data was collected based on transects randomly selected from land cover strata in a GIS. One hundred transects were selected proportional to the area of the strata. The transect width was 45m as this width is compatible with remotely sensed data from a Landsat TM image (Sibanda, 2012). The length of the transect line was 500m which Skidmore and Murwira (2005) observed to be the minimum patch dimension suitable for elephant habitat. Elephant data was collected as presence only along the transects. The GPS

Garmin Etrex 10 was used to navigate to the sampling points. A minimum of two observers walked each transect. One observer l followed the compass bearing of the transect to walk the centre line while the other observer walked behind looking for dung on either side of the centerline. When a dung pile was spotted, the UTM Coordinates were recorded using a GPS.

1.7 Data analysis

The extracted distances for all the explanatory variables were imported into SPSS and tested for normality using the Kolmogorov- Smirnov test. Pearson`s rank correlation was used for correlation analysis since the data was normally distributed. A correlation matrix was used to identify predictor variables which were strongly correlated. If two factors were found to have a correlation >0.7, the factor that was correlated to other factors was dropped from the analysis (Ngene 2013). This is because if X variables are highly correlated, they convey the same information (Fowler 1998). Predictor variables such as distance from water points inside the mine dumps and distance from settlement were dropped since they were strongly correlated. So distance from water points outside the mine dumps, distance from mine dumps, distances from agricultural fields and NDVI are the only factors which were used for further analysis. The logistic regression function was used to test whether the predictor variables significantly predict the spatial distribution of elephants. The graph showing the relationship between the probabilities of elephant presence as a function of distance from predictor variables was computed using statistica 7.

1.8 Results

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

Table 1: Relationship between elephant distribution and elephant presence/absence and environmental variables.

Factor	Slope	Intercept	P value
Distance from agricultural fields	0.0002	1.002	0.416
Distance from water points outside the mine dumps	**0.001**	**-1.849**	**0.0001**
Distance from mine dumps	**0.001**	**0.444**	**0.047**
NDVI	**0.338**	**3.152**	**0.043**

Figure 3 depicts a significant ($p<0.05$) positive relationship between probability of elephant presence and NDVI. At low NDVI (-1 to -0.2), probability of elephant presence is low (0.2). As NDVI values increases (0.6), the probability of elephant presence also increases (0.8).

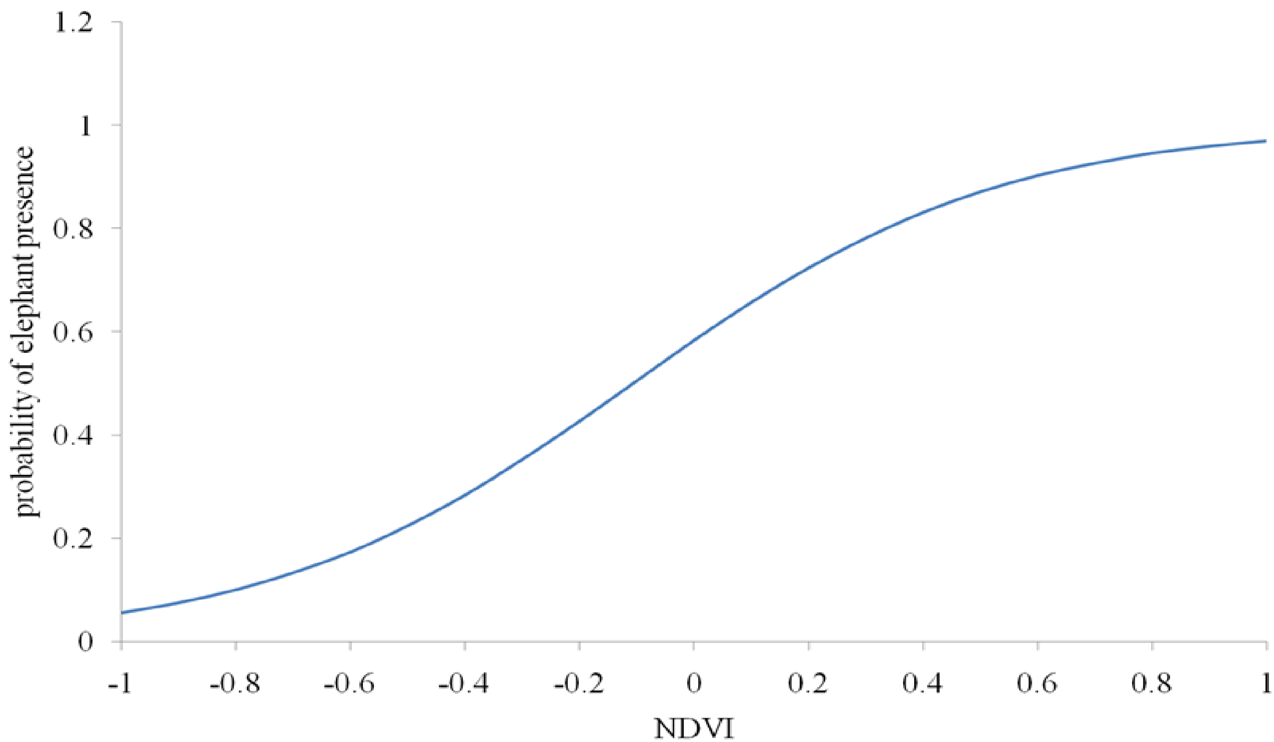

Figure 3: Probability of elephant presence (y=e $^{(0.338+ (3.152*x))}$/ (1+e $^{(0.338+ (3.152*x))}$ as a function of NDVI.

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

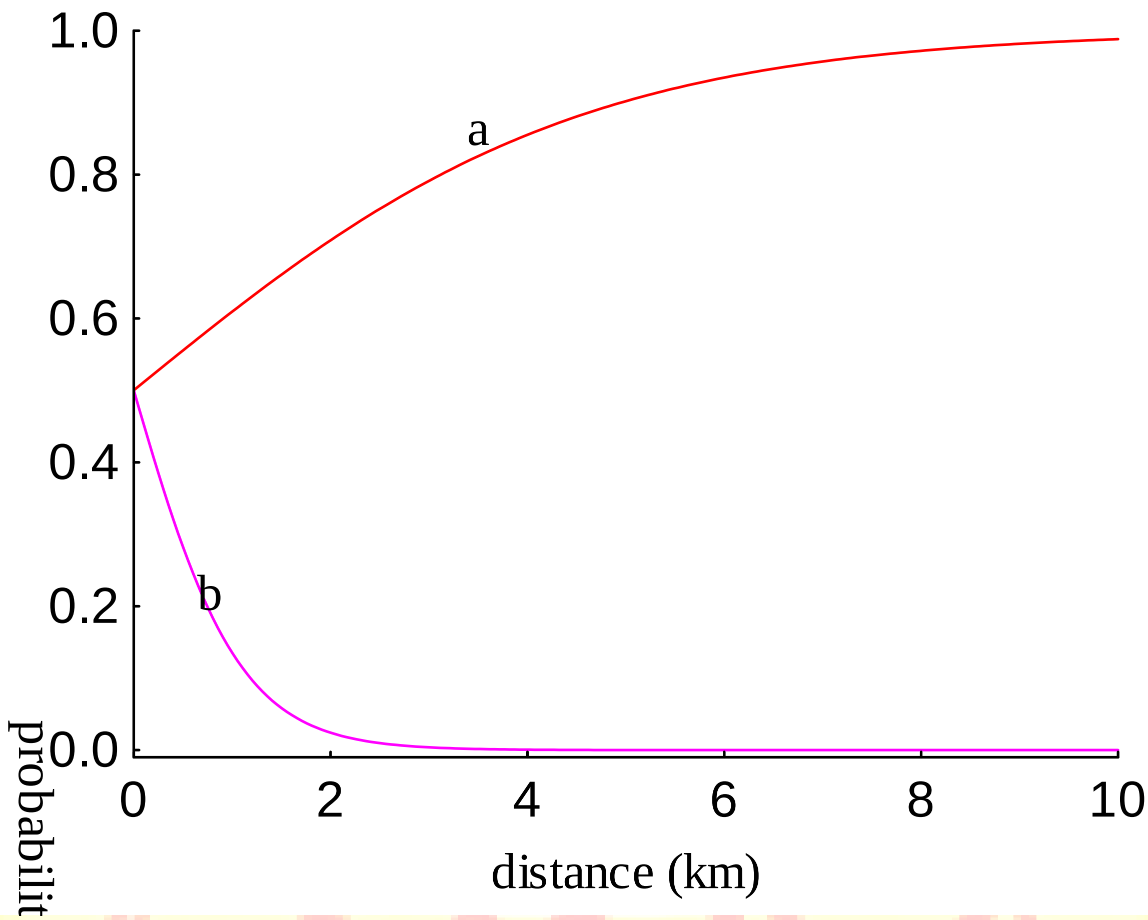

Figure 4: Probability of elephant presence as a function of distance away from a) mine dumps $(y=e^{(0.001+(0.444*x))}/(1+e^{(0.001+(0.444*x))})$ and b) water outside the mine dumps $(y=e^{(0.001+(-1.814*x))}/(1+e^{(0.001+(-1.814*x))})$

It can be observed from figure 4b) that there is a significant ($p<0.05$) negative relationship between water outside the mine dumps and elephant presence. At shorter distances for instance 1km, probability of elephant presence is high (0.5). Probability of elephant presence is low (0) at longer distances (10km) away from water points outside the mine dumps.

Probability of elephant presence is significantly ($p<0.05$) and positively related to distance away from mine dumps (figure 4a). At shorter distances (1km) away from the mine dump, the probability of elephant presence is very low (0.2). Probability of elephant presence is higher (0.8) at longer distances (8km) away from the mine dumps.

1.9 Discussion

Results of this study indicated that NDVI (vegetation cover), distance from water points outside the mine dumps, and distance from mine dumps significantly predict the spatial distribution of elephants in the study area. Distance from agricultural fields was not significantly related with the probability of elephant presence.

The current study established that the probability of finding an elephant near mine dumps was low. Investigating the effects of forest clearance by mining activities on the spatial distribution of elephants has been done for the first time. Previous studies have largely explored the effects of crop field expansion on the distribution of elephants (Sibanda and Murwira 2012).

The current study noted a high probability of elephant presence with increased vegetation cover (NDVI). 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 high probability of elephant presence around water points outside the mine dumps. The findings are similar to those of (Ngene 2009) who noted that in semi arid environment like Kenya, 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.

However, the results presented here are not conclusive as the study area of $4km^2$ is less than the average elephant home range. Hence, future studies should focus on extending the area of study to suit the average size of elephant home range.

Conclusion and Recommendations

The main objective of this study was to test whether distance from mine dumps in addition to other factors such as distance from water points, distance from agricultural fields, and NDVI (vegetation cover) significantly predict the probability of elephant presence. Within this small study area, distances away from mine dumps also significantly predict elephant presence in addition to other factors such distance from water points, and NDVI. The results imply that the mining activities repel elephants. However, the results are not conclusive since the study area is smaller than the average size of a home range for an elephant. Hence future studies should focus on extending the area of study to suit the size of an elephant home range.

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Appendix

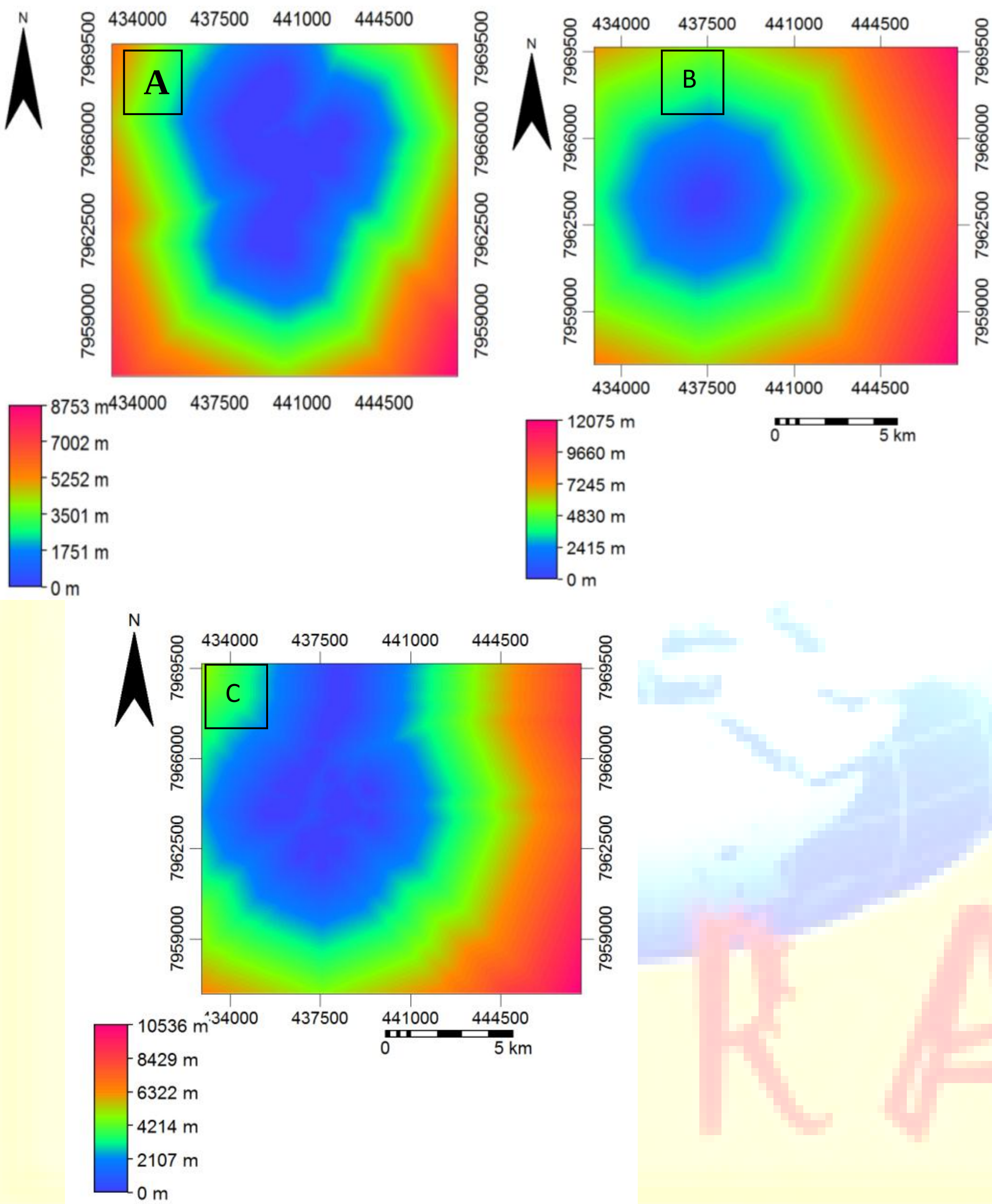

Figure 5 a) mine dumps distances 5b) settlement distances 5c) Agricultural distances

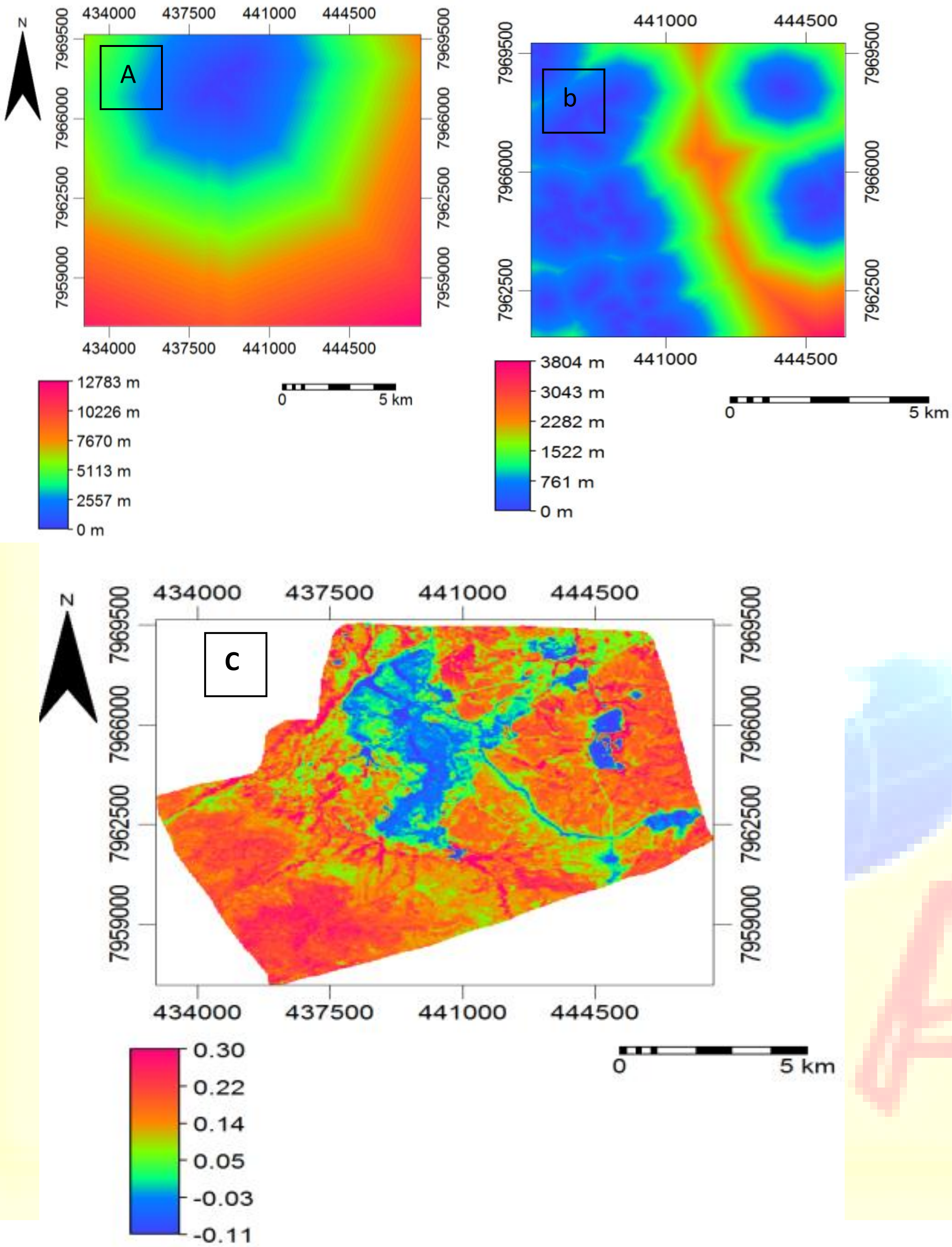

Figure 6: a) Water points inside mine dumps distances 6 b) water points outside the mine dump distances 6 c)NDVI