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An application of geographic information systems to model the habitat suitability of *Pan troglodytes ellioti* in Mount Cameroon National Park in the context of a changing global climate

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Abstract: As scientists continue to discover convincing evidence that the earth's climate is adversely changing, and that these changes could impact the habitat suitability of some wildlife species; wildlife conservationists are increasingly worried of what may become the fate of most species on earth. In the light of such uncertainty, geographic information systems (GIS) can be used as a tool to model for the habitat suitability of a species. Such modeling provides reliable information upon which decision making could be based for planning conservation management aimed at protecting areas that are currently suitable as well as those that may become suitable in future if the global climate changes according to the scenarios as described; and the changes impact the species' habitat suitability. GIS in combination to Maximum Entropy (MaxEnt) distribution model were used to model the habitat suitability for *Pan troglodytes ellioti* on Mount Fako (Cameroon) as a case study area. The results show that the predicted habitat suitability may shift from lower altitudes to higher altitudes as the global climate may change from the current climatic conditions to warmer climatic conditions in the future as proposed in the climate scenario that assumes the concentration of carbon dioxide and other greenhouse gases may double by 2050. The accuracy assessment measured in terms of the Area Under the Curve (AUC) was 0.699.

Key words: GIS, MaxEnt, habitat suitability modeling, climate change, Pan troglodytes ellioti, *Mount Fako.*

Introduction

Reports by the Intergovernmental Panel on Climate Change (IPCC, 1990; IPCC, 1992; IPCC, 2007) have put forward convincing evidence purporting that the global climate is changing and these changes may have negative effects on nature. Besides, such negative consequences may increase due to increases in greenhouse gases as the carbon footprint resulting from human civilization and life style continue to increase. Literature by the IPCC reports of increment in the mean global temperature by as much as 0.5°C over the last century (IPCC, 1990); and forecasts a possible rise of as much as 6.4°C by the close of the century (IPCC, 2007). Changes in the earth's climate could likely impact the environment; and could further impact the suitability of the habitats of some wildlife. Africa is foreseen to be among the places that may likely become vulnerable to some of the environmental consequence of climate change (Busby *et al*., 2010). The survival of many wildlife species are being threatened by anthropogenic disturbances including climate change (Chapman, 2006). Unlike before, the phenomenon of a changing global climate is increasingly gaining wide acceptance nowadays and it is becoming a factor for consideration when making decisions aimed at sustainable management of natural resources. With this growing acceptance of the phenomenon as a challenging reality, wildlife conservationists are increasingly worried of what may become the fate of most wildlife species on earth because of the uncertainties about the future. Therefore, modeling the presence / absence of a species in a biome is increasingly becoming important in conservation ecology. In other words, habitat suitability modeling has become useful in biodiversity conservation most especially as the contemporary global climate is changing at an unprecedentedly fast pace.

A majority of species distribution models have been developed based on the concept of a species' niche. That is, all the environmental factors including the habitat necessary for a species to exist in a location. Models generate a representation of the relationship between the presence of a species and a set of environmental factors. As such, the relationship is extrapolated to other locations to generate maps of a species' habitat suitability. Since climate is a constituent component of the environmental factors that determine a species niche -and thus, the habitat suitability. In this light, the changing global climate may impact the habitat suitability of *Pan troglodytes ellioti* on Mount Fako. That is, following Purves *et al*., (2000) who demonstrated that geographical range size is significantly associated with high extinction risk in declining population of species; also by considering the rarity of species (Gaston, 1994); the survival of *Pan troglodytes ellioti* is severely being threatened by the numerous anthropogenic activities on Mount Fako. However, indirect threat that could emanate as an impact of the changing global climates cannot be completely ignored.

Among the various chimpanzee sub-species that are spatially distributed across

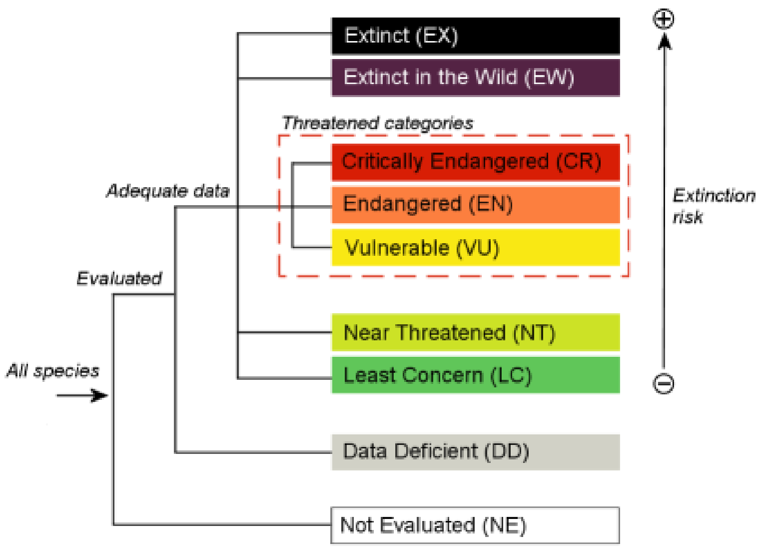

Figure 1- Classification for biodiversity conservation status (IUCN 2001).

Africa (Oates, 2006); *Pan troglodytes ellioti* (Matschie 1914; Matschie 1919; Oates *et al.*, 2009) is an endangered primate species (Figure 1). The species' taxonomic hierarchy is presented in Table 1. The survival of the species continues to be threatened by natural phenomena that are being aggravated by anthropogenic activities including land-use (Mwambo, 2010). Furthermore, because of the relatively negligible population of the species (Oates *et al.*, 2007 in IUCN 2008; Oates *et al.*, 2008 in IUCN, 2009); and small geographic distribution which is limited to the Cameroon-Nigeria trans-boarder area, and although the global population of this sub-species has been estimated to be only about 3500 – 9000 individuals (Morgan *et al.*, 2011); the sub-species is vulnerable to the increasing anthropogenic disturbances (Greenpeace, 2013) in the area (Figure 2).

Study Area

The study area (Figure 2) is 58,178 hectares in extent. Created in 2009 by the government of Cameroon; the Mount Cameroon National Park is located on Mount Fako; which is geographically positioned between 3° 57' - 4° 27' N and 8° 58' - 9°24'E (WWF, 2010). With a base of about 50 km long x 35 km wide, the massif has two peaks: Etinde towering 1715m, and Fako summiting at 4095m respectively. Mount Fako is the only strato-volcano that is still active among the volcanic peaks that chain up along the Cameroon Volcanic Line (Njome *et al.*, 2010). The summit at 4095 m asl is the highest elevation in both Central and West Africa. In terms of climate; the

Table 1- Taxonomic ranking of the chimpanzee subspecies in the study area.

Taxonomic rank	Taxonomic name	Reference
Domain	*Eukaryota*	Whittaker & Margulis,1978
Kingdom	*Animalia*	Linnaeus, 1758
Subkingdom	*Balateria*	Hatschek, 1888) Cavalier-Smith, 1983
Branch	*Deuterostomia*	Grobben, 1908
Infrakingdom	*Chordonia*	Haeckel, 1874; Cavalier-Smith, 1998
Phylum	*Chordata*	Bateson, 1885
Subphylum	*Vertebrata*	Cuvier, 1812
Infraphylum	*Gnathostomata*	Auct. - Jawed Vertebrates
Superclass	*Tetrapoda*	Goodrich, 1930
Class	*Mammalia*	Linnaeus, 1758 - Mammals
Subclass	*Theriiformes*	Rowe, 1988; Mckenna & Bell, 1997
Infraclass	*Holotheria*	Wible *et al.*,1995; Mckenna & Bell, 1997
Superlegion	*Trechnotheria*	Mckenna, 1975
Legion	*Cladotheria*	Mckenna, 1975
Sublegion	*Zatheria*	Mckenna, 1975
Infralegion	*Tribosphenida*	Mckenna, 1975; Mckenna & Bell, 1997
Supercohort	*Theria*	Parker & Haswell, 1897; Mckenna & Bell, 1997
Cohort	*Placentalia*	Owen, 1837; Mckenna & Bell, 1997
Magnorder	*Epitheria*	Mckenna, 1975; Mckenna & Bell, 1997
Superorder	*Preptotheria*	Mckenna, 1975; Mckenna, in Stucky & Mckenna, in Benton (Ed.) 1993
Grandorder	*Archonta*	Gregory, 1910; Mckenna, 1975
Order	*Primates*	Linnaeus, 1758
Suborder	*Haplorrhini*	Pocock, 1918
Infraorder	*Simiiformes*	Haeckel, 1866
Parvorder	*Catarrhini*	Geoffroy Saint-Hilaire, 1812
Superfamily	*Hominoidea*	Gray, 1825; Gregory & Hellman, 1923
Family	*Hominidae*	Gray, 1825
Genus	*Pan*	Oken, 1816
Specific name	*troglodytes*	Blumenbach, 1775
Subspecies	*ellioti*	Matschie, 1914
Scientific name	*Pan troglodytes ellioti*	Matschie, 1914

Source: http://zipcodezoo.com/Animals/P/Pan_troglodytes/

mountain's altitude and proximity to the Atlantic Ocean makes the area humid. Debundscha in the West Coast receives about 10000mm of annual rainfall making it one of the wettest places on the globe while some places on the leeward side receive comparatively less rainfall. The temperature varies between 4°C at the summit to about 32°C at places close to the coastline in Limbe (Molua and Lambi, 2006). In terms of biological diversity and ecological significance; Mount Fako area is a biodiversity hotspot and one of the globally important areas of both floral and faunal endemism (Scholes *et al.,* 2006; Cheek *et al.*, 1996; Olsen *et al.*, 2001). It is the only area in the Guinea-Congolian region of Africa where there is still an intact continuous

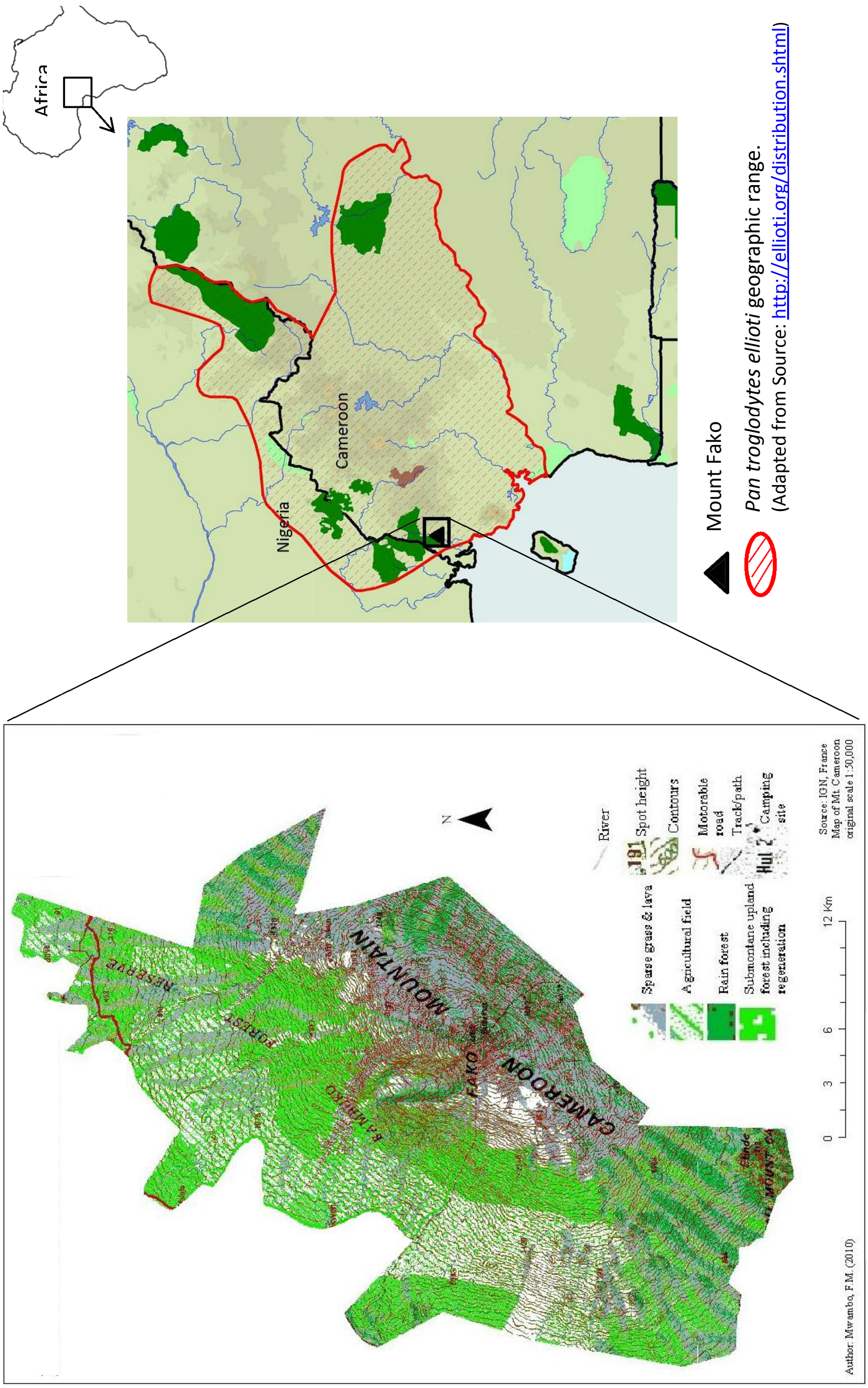

Figure 2 - Study area.

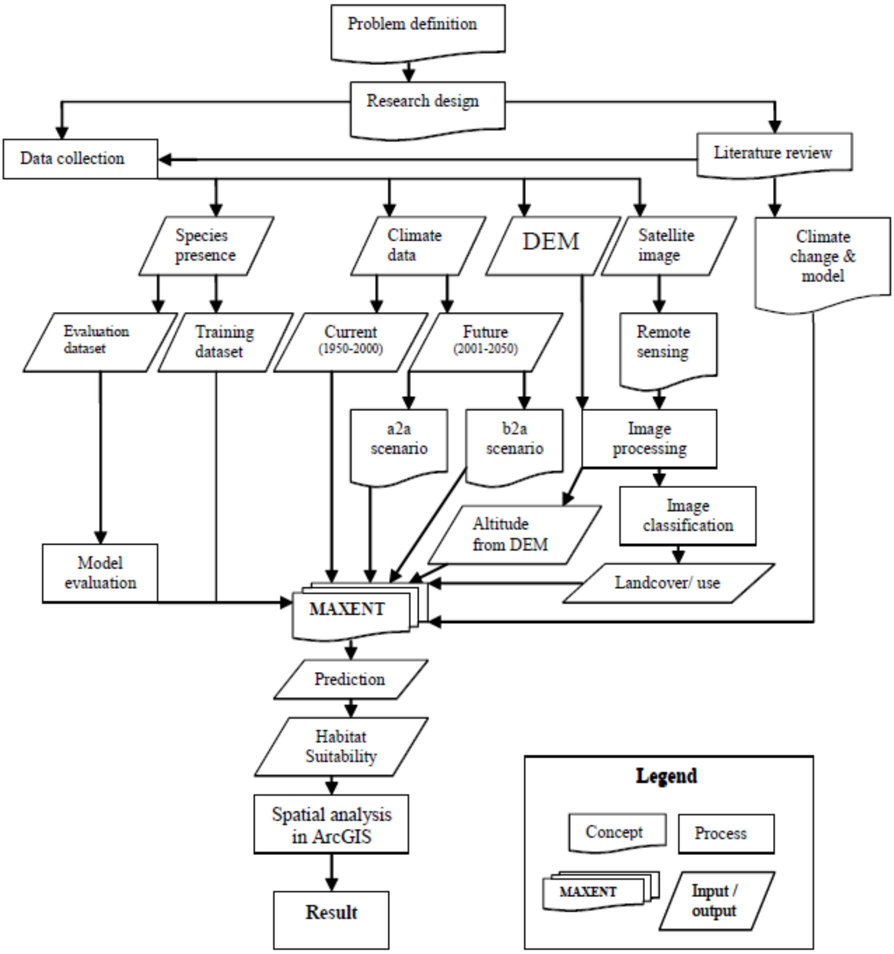

Figure 3 - Flow chart showing the methodology.

chain of vegetation strata that transition from mangrove forest that stretches along the intertidal zone at the coast, through rain forest followed by savannahs that pass onto sub-alpine grassland towards the summit (Cheek *et al.*, 1996). These vegetation strata form habitats for several faunal species including *Pan troglodytes elliotí*. Following the creation of the park; the use of tools to support spatial decision making on conservation issues is fundamental for the sustainable management of the park; as well as for achieving the sustainable development that the park is intended to contribute to the region. Thus, the objective of this paper is to demonstrate the use of GIS as a tool that can be used to model the habitat suitability of biological species in the area; of which *Pan troglodytes elliotí* has been highlighted as a flagship species.

Material and Methods

The software used for the modelling were ArcGIS 9.3, and the machine algorithm: Maximum Entropy (MaxEnt) distribution model[1]. The datasets used for the study included: data on species presence –which was obtained by recording the geographic coordinates of undecomposed nests within the study area during the period between September 2006 and January 2007. A total of 59 nests were counted. The dataset was split in the ratio of 3:1 for the training and testing respectively. Data on the land-cover/ land-use (LCLU) was gotten by performing a supervised classification of LANDSAT 7 Enhanced Thematic Mapper (ETM+), and LANDSAT 5 Multi Spectral Scanner (MSS) images of the study area. The images were acquired in 2000 and 1986 respectively. The LANDSAT 7 image being relatively recent was the main image upon which the classification was based; while the LANDSAT 5 image was useful in areas where the LANDSAT 7 image was cloudy for a reasonable classification. The altitude, slope, and aspect were derived from the Digital Elevation Model (DEM) of the study which is a product from the Shuttle Radar Topographic Mission (SRTM). Because of the paucity of meteorological stations located in and around the study area, as well as the non-consistency of the data provided by the few existing stations; climate data provided by the Canadian Centre for Climate Modeling and Analysis (CCCMA)[2] was used. In this study, the climate data for the periods 1950-2000 has been considered as the current climate; while modelled climate for 2001-2050 has been considered to be the future climate. Furthermore, two scenarios were considered under the future climate; that is; a medium-high emission rate of greenhouse gasses; denoted as "*a2a*". The scenario assumes that the concentration of greenhouse gases (GHGs) particularly carbon dioxide (CO_2) will double by 2050 unlike in a low emission rate denoted as "*b2a*"; which assumes that the concentration of GHGs particularly CO_2 will in the future remain the same as current emission rates.

Using the boundary shapefile of the study area as the mask; the above data layers were clipped to fit the limits of the study area. The clipped data layers were imported into MaxEnt followed by the running of the model to obtain predictions of the habitat suitability. The accuracy of the predicted habitat suitability were evaluated using the model's Receiver Operating Characteristics Area Under Curve (ROC AUC) (Hanley and McNeil, 1982). The predicted habitat suitability were imported into ArcGIS. Spatial analyses were conducted on the imported habitat suitability predictions. These were further finalised into output maps to aid decision making.

[1]Maxent software for species habitat modeling. (Version3.3.2) Available from http://www.cs.princeton.edu/~schapire/maxent/ Accessed [January 2010]
[2]WorldClim: Global Climate Data. Available from http://www.worldclim.org/ Accessed [January 2010]

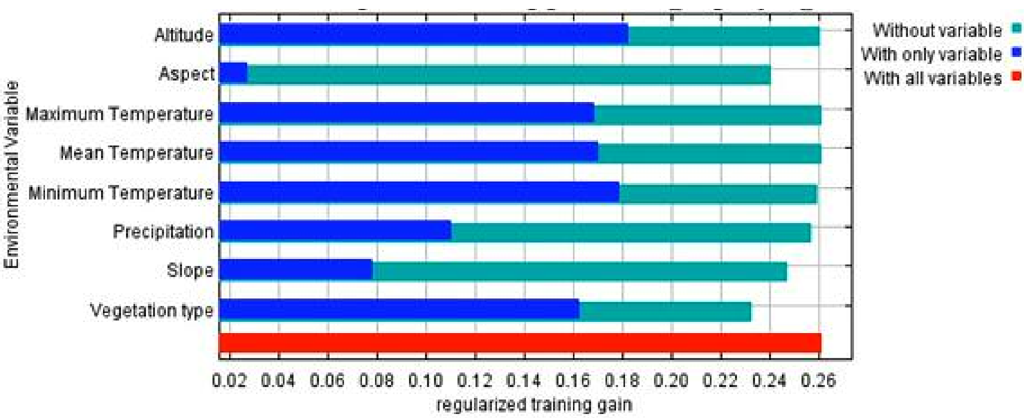

Figure 4 - Jackknife of regularised training gain using all variables.

Results and discussion

Initially, all the variables; namely: maximum temperature, minimum temperature, mean temperature, precipitation, vegetation, aspect, slope, and altitude were imported into MaxEnt model which was run. Based on the relative gain (Figure 4) for each variable; the variables that were less important in predicting the habitat suitability were eliminated while the following; namely: maximum temperature, minimum temperature, precipitation, vegetation, slope, and altitude; which were found to be more important in predicting the habitat suitability for *Pan troglodytes ellioti* in the study area were retained. The altitude had the highest gain when used in isolation meaning it had the most useful information by itself. Simultaneously, the land cover decreased the gain most when omitted; implying the land cover contained the information which the other variables did not have. In relative term, these would mean the habitat suitability was much sensitive to both the altitude and the land cover type besides the other variable. The reason for such high sensitivity is that slight changes in altitude could likely bring about significant changes in the micro-climatic conditions and in turn a change in suitability that may eventually result to a change in the spatial distribution of *Pan troglodytes ellioti* in the study area (Mwambo, 2010). In nature, habitat suitability is rather continuous and fuzzy than discrete. That is, classes transitionally pass from one class to another and such transitions are not often sharp. In this light, habitat suitability is often qualitative and descriptive in analysis. In this study; the habitat suitability for *Pan troglodytes ellioti* under the current climate shows four classes of suitability; which have been denoted as: most suitable, suitable, less suitable, and least suitable. The accuracy assessment of the predictions for the current, *a2a,* and *b2a* scenarios were: 0.650 AUC, 0.699 AUC, and 0.609 AUC respectively (Table 2).

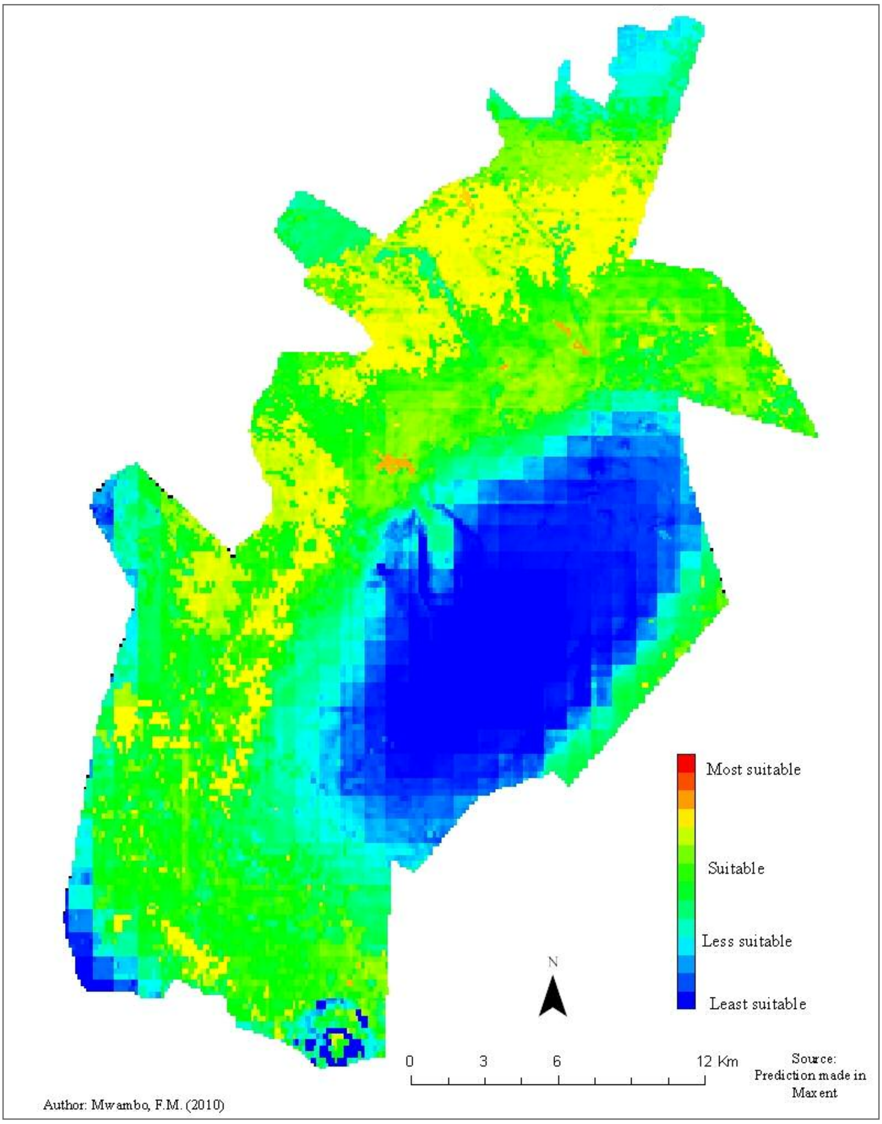

Figure 5 - The habitat suitability under the current climate.

Table 2 - The accuracy assessment measured in terms of Area Under the Curve (AUC).

AUC	CURRENT	MAX. POSSIBLE VALUE	B2A	MAX. POSSIBLE VALUE	A2A	MAX. POSSIBLE VALUE
Training	0.726	/	0.728	/	0.720	/
Testing	0.650	0.694	0.609	0.687	0.623	0.699

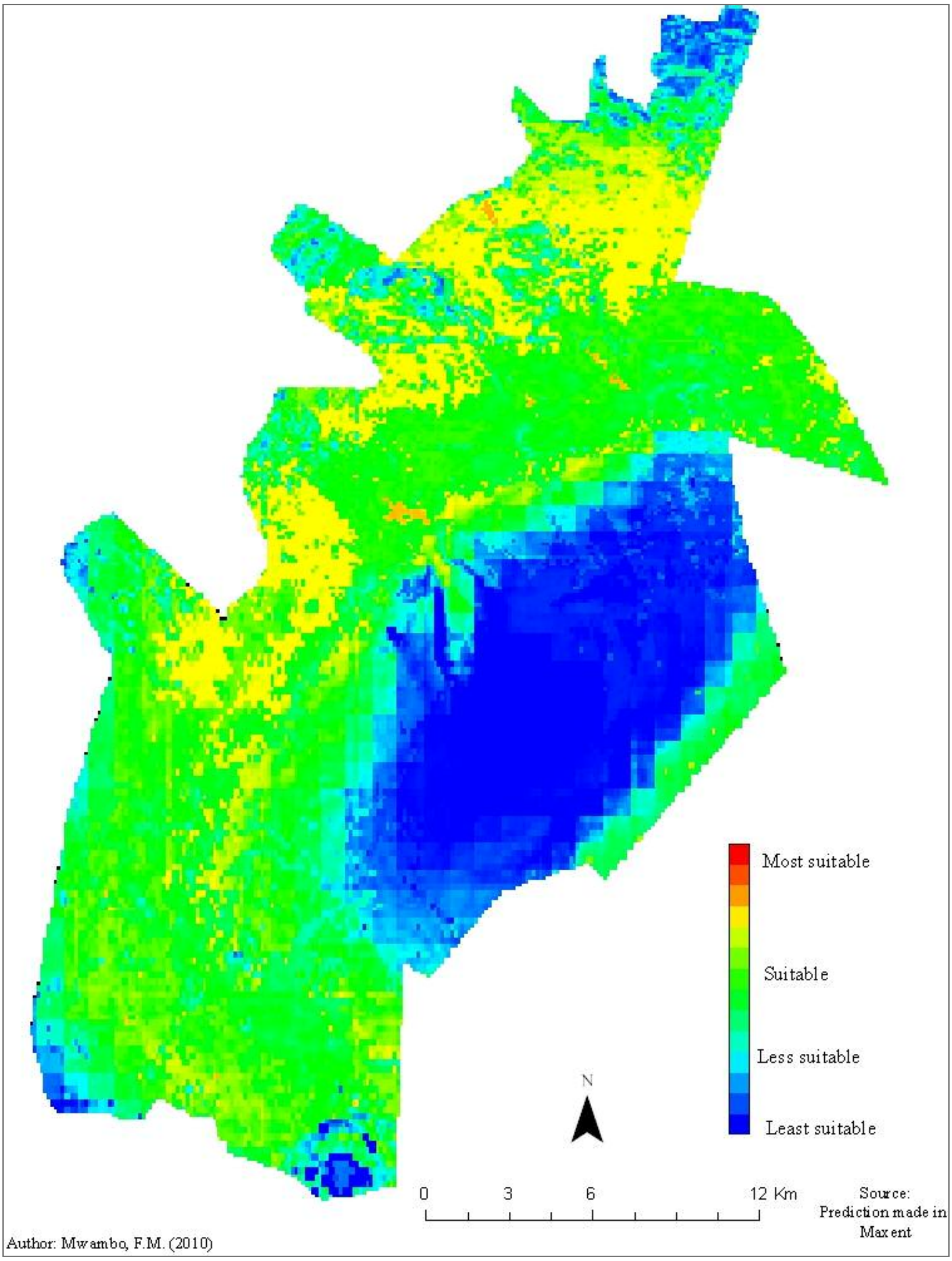

Figure 6 - The habitat suitability under the a2a climate scenario.

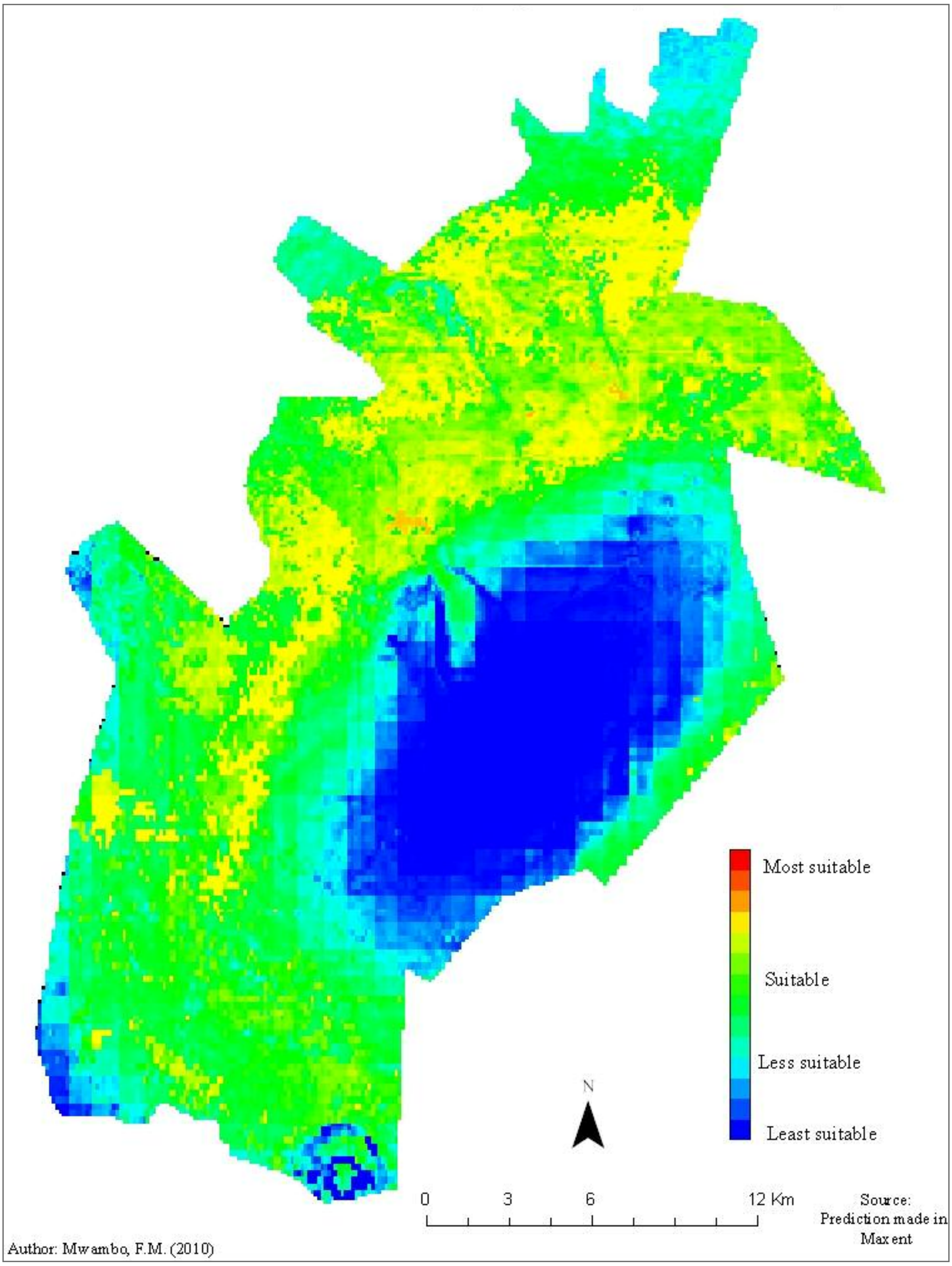

Figure 7 - The habitat suitability under the b2a climate scenario.

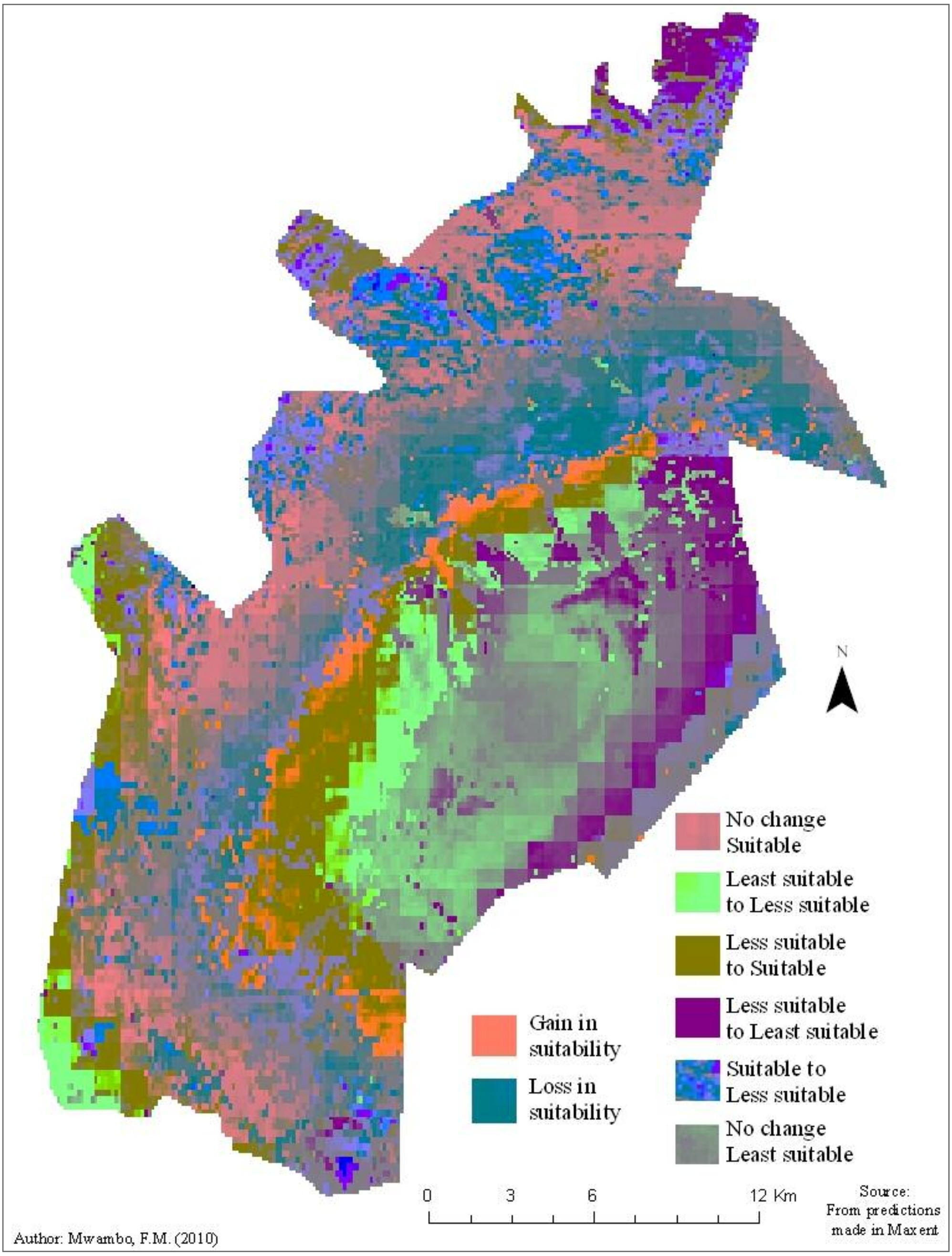

Figure 8 - Possible changes in habitat suitability caused by a change in climate from current condition to a2a climate scenario.

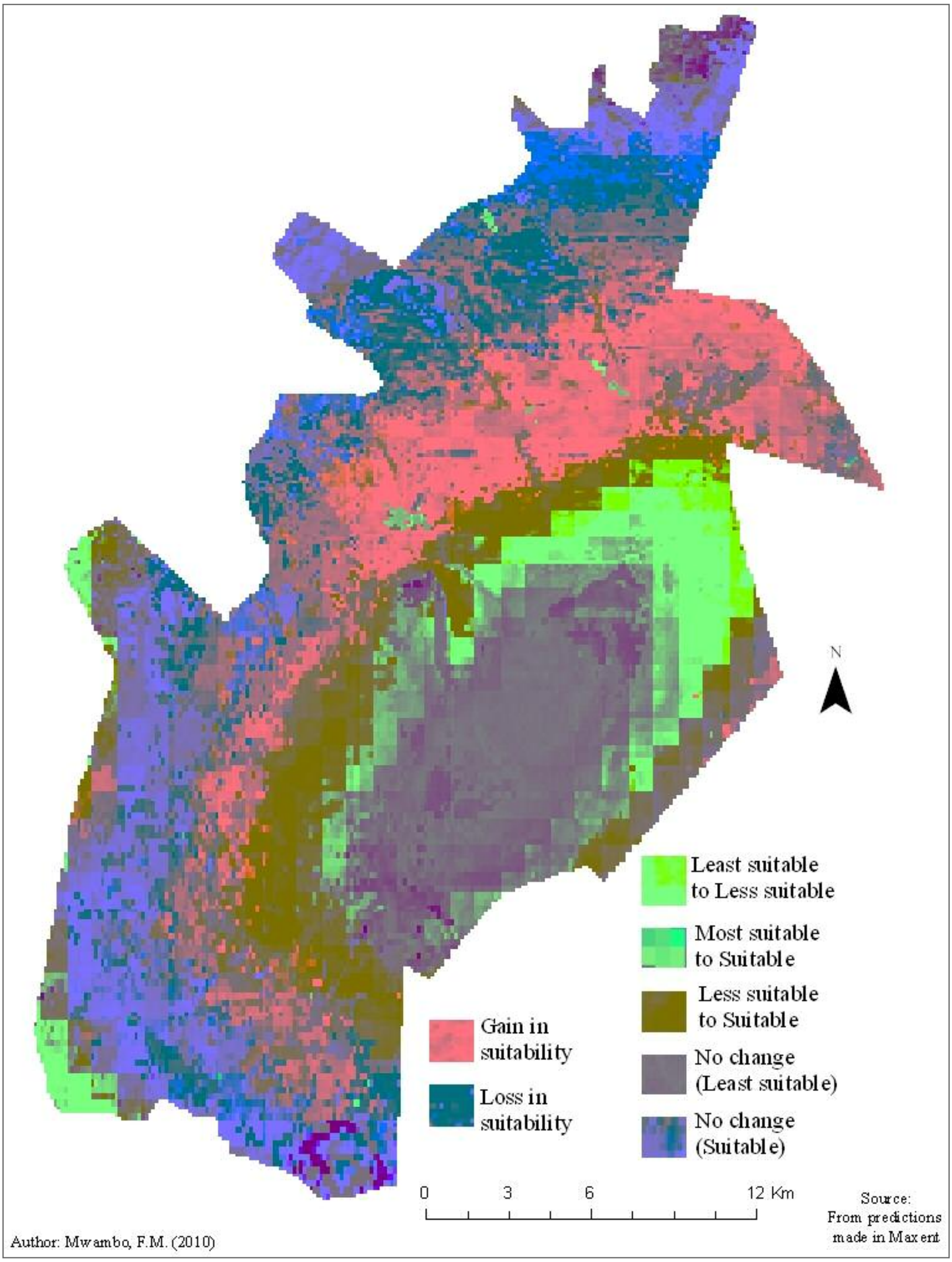

Figure 9 - Possible changes in habitat suitability caused by a change in climate from current condition to b2a climate scenario.

Table 3 - An estimate of the superficial distribution of suitability classes in percent.

	Current Climate Scenario	B2A Scenario	A2A Scenario
Suitability classes	Estimated superficial distribution (%)	Estimated superficial distribution (%)	Estimated superficial distribution (%)
Most suitable	0.29	0.25	0.18
Suitable	67.41	67.11	67.06
Less suitable	6.06	6.34	6.37
Least suitable	26.24	26.30	26.39

Assuming the change in global climate is driven by the rate of emission of CO_2 and including other greenhouse gasses; and assuming the global climate changes according to either of the scenarios defined above. An increase in the rate of emission as defined in the *a2a* scenario implies the concentration of greenhouse gases in the atmosphere will also increase rapidly. Thus, contributing to a climate condition that will in the future be warmer compared to the current climate condition. The prediction under the *a2a* scenario (Figure 6) shows that the habitat suitability may ascend from low altitude areas to high altitude areas as the climate changes from current to warmer conditions in the future. That is, according to the predicted suitability; more suitable habitats for *Pan troglodytes ellioti* may in the future be found in areas located at high altitude. Implying higher altitude areas that are currently cooler and unsuitable for the species will gain sufficient warmth that will transform these areas to become suitable to the species. MacArthur (1972) suggests that species may response to such impact by migrating from lower altitude to higher altitude areas. An application of such response in conservation planning will be to protect areas located at high altitudes from unsustainable human activities including: agriculture, hunting, logging, and other extractive activities. If the changes in the global climate lead to climatic conditions are defined in *b2a* scenario; the predicted habitat suitability (Figure 7) averages between the two extremes. The global climate change may unfavourably impact the species' habitat suitability. The suitability in habitat decreases as climate may change from current conditions through *b2a* scenario to *a2a* scenario (Table 3).

To visualise the changes in suitability and the spatial locations where the changes in suitability may occur; the difference between the current habitat suitability and the predicted habitat suitability for the *a2a* and *b2a* scenarios were analysed respectively. More changes in the suitability classes were observed for a transformation "from current habitat suitability to the predicted habitat suitability in the *a2a* scenario"

(Figure 8) compared to the case of a transformation "from current habitat suitability to the predicted habitat suitability in the *b2a* scenario" (Figure 9). The magnitude of change is higher in the former because a change from current climate to a future climate according to the *a2a* scenario assumes that emission rate of CO_2 and other greenhouse gasses may double unlike the change in climate from the current condition to a future climate as in the *b2a scenario* that assumes the rate of emission of CO_2 and other greenhouse gasses may be equal to current emission rates; which is mild compared to the former change in climate conditions.

Conclusions

The complexity in climate change makes it difficult to predict the impacts with absolute certainty. However, possible impacts that are based on reasonable assumptions are preferable to a complete absence of knowledge. GIS is a useful tool for deriving information that could be used by decision makers to plan conservation strategy aimed at mitigating some of the negative consequences of climate change on vulnerable wildlife. GIS reduces the uncertainty by providing invaluable answers to fundamental questions on spatiality. Modeling a species' habitat suitability in relation to possible changes in the global climate; increases our knowledge on the possible consequences such changes in climate could have on wildlife. Conservationists can use the knowledge to plan wildlife conservation on Mount Fako. For instance the predicted ascend in habitat suitability observed under *a2a* scenario; could meaningfully caution for a conservation action such as protecting the areas at higher altitude from disturbances caused by human. GIS can reliably be used as a tool to model for species' habitat suitability; that can facilitate decision making on wildlife conservation issues in the newly created park.

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