https://doi.org/10.4314/rjeste.v3i1.7S

Spatial Modelling of Common Chimpanzees' (*Pan troglodytes schweinifurthii*) Ecological Niche in the Western Part of Rwanda

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Abstract

The Western Part of Rwanda is a mountainous region that hosts two important forest parks namely the Nyungwe National Park (NNP) and Gishwati-Mukura National Park (GMNP). The two parks which are located in the Albertine Rift region are known for their high endemism and harbour several endangered plant and animal species, including particularly the Common Chimpanzees *(Pan troglodytes schweinifurthii)*. However, these forests are facing threats including mainly habitat loss, aggravated by climate change both of which are continuously having direct and indirect effects to the Chimpanzees. While conservation of chimpanzees appears critical, there is a need to deeply understand the dynamics of their habitat. This study aimed at modelling the ecological niche of common chimpanzee by integrating species distribution data and environmental layers. Species location data collected in both NNP and GMNP were integrated with environmental variables (temperature, precipitation, altitude, and land cover) through Maximum Entropy (MaxEnt), and Generic Algorithm for Rule-based Prediction (GARP) Models. The results of both models showed that chimpanzees prefer the Southern and the Northern parts of the study area ($0.5 < p < 0.87$), which is characterised by high altitude, low temperature, and intensive rainfall. It was also noted that MaxEnt predictions were more accurate compared to the GARP's. MaxEnt predictions showed that 35% (2058.61 ha) of the Western Province are suitable for chimpanzees, while GARP predicted that only 24% (1411.62 ha) are suitable. Furthermore, the study found that the high precipitation, annual and maximum precipitations, and food availability are the most determinants of chimpanzees' habitat. The land use in the Western Province has made the central part less suitable to chimpanzees and therefore, this study recommends that special efforts for the conservation of Common chimpanzees in Rwanda should be concentrated in the Southern Part (around NNP) Nyungwe National Park (main forest and Cyamudongo fragment) and the northern Part (around GMNP)

Keywords: Spatial Modelling, Common Chimpanzee, Ecological Niche, Nyungwe National Park, Gishwati-Mukura National Park, Rwanda.

1. Introduction

In the past decades, many animal populations have declined drastically and thousand animal species are close to extinction worldwide owing to anthropogenic impacts (Gross-Camp & Kaplin, 2005). The effects of this environmental crisis have been particularly severe in tropical regions, which host about 50% of global animal species, including the common Chimpanzees (*Pan troglodytes shweinfuthii*) (Gross-Camp & Kaplin, 2005; Plumptre et al., 2002; Plumptre et al., 2007; Wilson et al., 2009).

In tropical mountain forests of Africa, Chimpanzees, as frugivorous primates, are among seeds dispersers (Plumptre, Cox, & Mugume, 2003; Plumptre et al., 2010). Their humanlike face, fingers, and behaviour have made them tourist-attracting animals and they have become flagship animals of Nyungwe National Park (NNP) and Gishwati-Mukura National Park (GMNP) (Gross-Camp & Kaplin, 2005; Plumptre et al., 2002; Plumptre et al., 2010). However, these animal species are continuously facing serious threats mainly human-induced such as habitat destruction and climate change which have led to the loss of their habitat and, subsequently, the decrease of their population (Wilson et al., 2009).

While these threats require effective conservation, there is a prior necessity to deeply understand chimpanzee's distribution pattern and dynamics of their habitats to guide conservation decision making at a different level to evaluate the effectiveness of chimpanzees' conservation worldwide (Caldecott & Miles, 2005). Additionally, this conservation will require a better understanding of the source and drivers of which mainly results from large-scale infrastructure development and resource exploitation projects, as well as increasing poaching pressure and climate change impacts (REMA, 2009b).

Currently, in Rwanda, there is an apparent research gap in species habitat assessment using more accurate and advanced methods such as spatial models that combines both remote sensing and global environmental data to predict suitable locations of a particular species. Therefore, the main objective of this paper is to make spatial modeling of the ecological niche of Common Chimpanzees (*Pan troglodytes schweinifurthii*) in the Western Part of Rwanda by using Maximum Entropy (MaxEnt), and Generic Algorithm for Rule-based Prediction (GARP) Models.

2. Materials and Methods

2.1. Study Area Description

Firstly, data were collected in NNP in 2010 and 2017; Rwanda's largest remaining natural forest and one of the most biologically important rain forests in Africa (Rwanyiziri, 2013). It covers about 1,000 km^2, in the Southwest of Rwanda and it is home to 13 species of primates, 260 species of birds, and more than 260 species of trees and shrubs (Plumptre et al., 2002). Nyungwe represents a key area for rainforest conservation in Central and Eastern Africa and supports an abundance of plant and animal life. The thirteen species of primates known to inhabit the forest include mainly chimpanzees (*Pan troglodytes schweinfurthii*), owl-faced monkeys (*Cercopithecus hamlyni*), blue monkeys (*Cercopithecus mitis kandti*) and white colobus monkeys (*Colobus angolensis ruwenzorii*) (Gross-Camp & Kaplin, 2005; Plumptre et al., 2002). Our observations on chimpanzee's daily travel distance were made on the semi-habituated *Mayebe* group of chimpanzees located approximately two kilometres east of the *Uwinka* Visitor Center in the main forest of the park. Observations were also done in a small patch forest, called Cyamudongo that covers approximately 4.5 km² (Figure 1). Lastly, in 2018, data were collected in Gishwati Forest which is one of the fragments of Gishwati-Mukura National Park (GMNP) located in the north-western part of Rwanda. Created in 1933, this forest constitutes the relic of the *ombrophyllous* montane forests (REMA, 2009a). Its rich natural flora varying from big trees to shrubs and grass has made Gishwati a habitat for different primates such as chimpanzee (*Pan troglodytes schwenfurthii*), mountain monkey (*Cercopithecus l'hoesti*) and golden monkey (*Cercopithecus mitis kandti*)(Barakabuye, 2005).

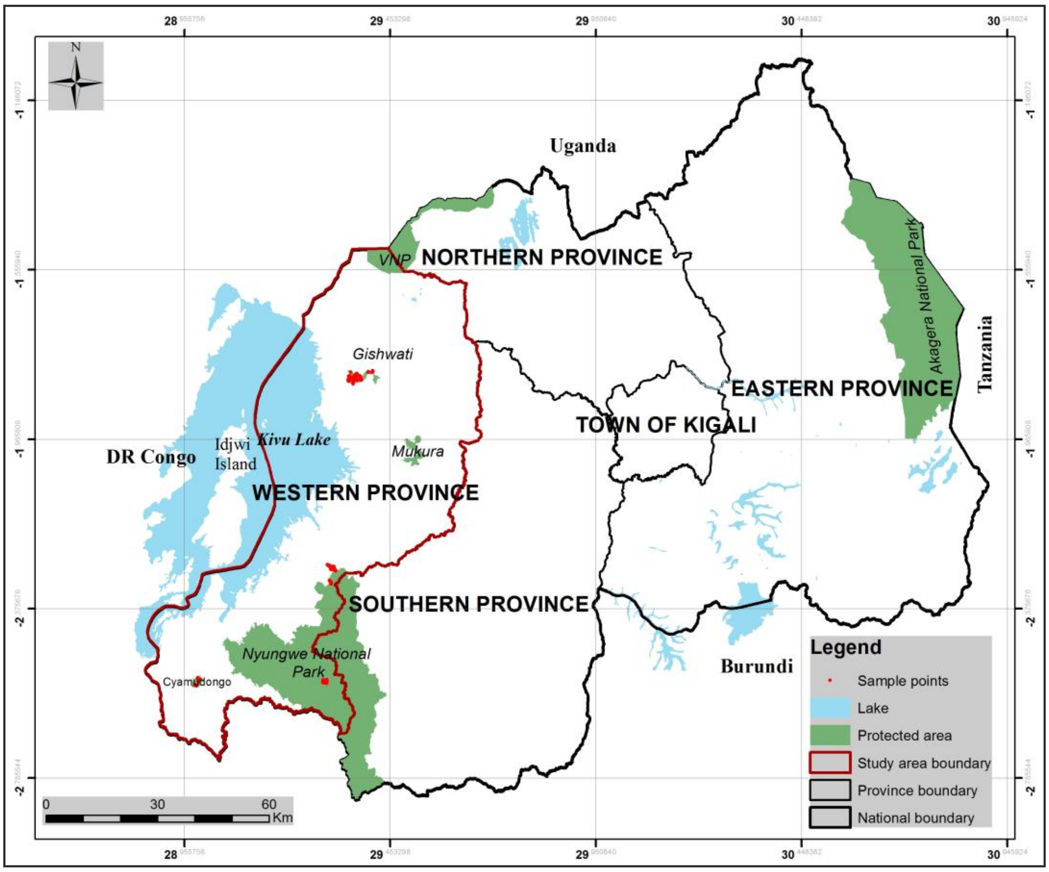

Figure 1: Study area in the Western Part of Rwanda. Data were collected in three forests: Nyungwe National Park (main forest), Cyamudongo Forest Fragment and Gishwati Forest Reserve

2.2. Data Collection Techniques

Chimpanzee presence data

Data Collection used an opportunistic sampling. Focal samplings were carried out on individuals that were easy to recognize by their shape, color, size, sex, and other physical characteristics (Bates & Byrne, 2009). During each focal sampling, the target individual was followed continuously through the forest as long as possible, optimally until the night nest site. The groups were localized before they left their night nest. If the target group was lost during a focal sample, every attempt was made to regain contact. This technique was preferred given its success in previous similar studies (Romero-Calcerrada & Luque, 2006; Secretariat of the Convention on Biological Diversity, 2010; Tsiaras & Domakinis, 2013; Twinomugisha & Chapman, 2007). During a focal sample, we recorded the location of the subject every 15 minutes during travel periods, using a hand-held Garmin XL GPS device with an Estimated Positional Error (EPE) of less than 10 m.

Food availability

The Distribution of animal species is highly influenced by food availability. At each observation point, all plants that chimpanzees were feeding on, were recorded and identified onsite. In case of doubt, a picture was taken using a digital camera, and later on, taxonomically identified using plant identification keys (Piel et al., 2017).

Environmental data

Environmental variables consisting of precipitation and temperature were downloaded from World Bioclim (**Error! Reference source not found.**). The altitude was derived from a Shuttle Radar Topography Mission (SRTM) 30 meters resolution Digital Elevation Model (DEM) of the study area. The Land cover of the study area was produced from sentinel-2 imagery of June 2016 with an overall accuracy of 89%. Table 1 elaborated in the inputs environmental variables used for the spatial modeling purpose, the assigned code in the model, and which variables have been retained for final modeling after collinearity analysis.

Table 1. Input Environmental variables that have been retrieved using the data

Variable	**Code in the Model**	**Retained after Collinearity Analysis**
BIO1 = Annual Mean Temperature	temp_mean	Yes
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))	temp_mdr	No
BIO3 = Isothermality (BIO2/BIO7)	temp_iso	No
BIO4 = Temperature Seasonality (standard deviation)	temp_seas	No
BIO5 = Max Temperature of Warmest Month	temp_max	Yes
BIO6 = Min Temperature of Coldest Month	temp_min	Yes
BIO7 = Temperature Annual Range (BIO5-BIO6)	temp_rang	No
BIO8 = Mean Temperature of Wettest Quarter	temp_wetq	No
BIO9 = Mean Temperature of Driest Quarter	tem_drq	No
BIO10 = Mean Temperature of Warmest Quarter	temp_waq	No
BIO11 = Mean Temperature of Coldest Quarter	temp _coq	No
BIO12 = Annual Precipitation	prec_ann	Yes
BIO13 = Precipitation of Wettest Month	prec_max	Yes
BIO14 = Precipitation of Driest Month	prec_min	Yes
BIO15 = Precipitation Seasonality (Coefficient of Variation)	prec_seas	No
BIO16 = Precipitation of Wettest Quarter	prec_ wetq	No
BIO17 = Precipitation of Driest Quarter	prec_ drq	No
BIO18 = Precipitation of Warmest Quarter	prec_ waq	No
BIO19 = Precipitation of Coldest Quarter	prec_coq	No
Altitude	alt	Yes
Land cover	l_cover	Yes

Source: World Bioclim (2015)

2.3. Data Analysis

Choice of Models

In nature, animal and plant species are not evenly distributed. This uneven distribution is mostly determined by environmental factors consisting of climatic, topographic, anthropogenic, and geologic factors (Stevens & Pfeiffer, 2011). The basis of biodiversity modelling is to integrate different contributing variables in a computer-based model to map the probability of occurrence of a given species at a local or global scale (Eklund, Arponen, Visconti, & Cabeza, 2011; Stevens & Pfeiffer, 2011).

For this study, Generic Algorithm for Rule-based Prediction (GARP) and Maximum Entropy (MaxEnt) which are presence-only modeling methods were used. Indeed, the two models were chosen because they could better fit our dataset compared to Boosted Regression Trees (BRT) and Logistic Regression that require presence-absence data. GARP and MaxEnt modeling approaches do not need species absence data which can be biased especially for animals that are always moving (Stevens & Pfeiffer, 2011). Some of the studies showed that both models perform almost the same way and could be successively used for Species Distribution Modelling (Fourcade et al., 2014; Jane et al., 2011; Kayijamahe, 2008). Therefore, the outputs could be easily compared.

Choice of variables

Collinearity test was performed to avoid the use of variables that reflect almost the same attributes. After performing a collinearity test, correlated variables ($r > 0.5$ or $VIF > 5$) were removed from the model. The remaining ones were later converted into ASCII grid format, and chimpanzee's GPS location data in a table format, for the data integration in both GARP and MaxEnt as summarized in Figure 2, following the commonly applied flow by similar studies (Kayijamahe, 2008; Phillips et al., 2006; Stevens & Pfeiffer, 2011).

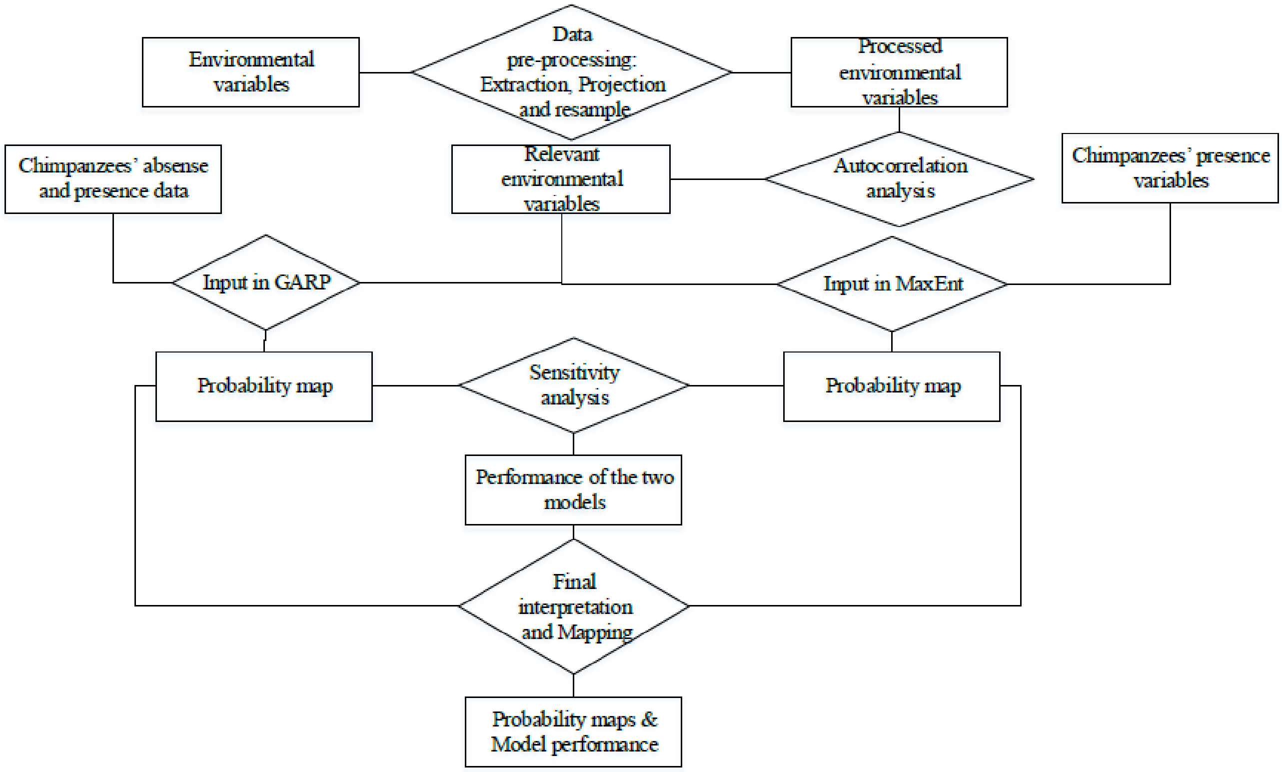

Figure 2. Summarized Steps for Species Distribution Modelling using MaxEnt and GARP Models (adapted from Stevens & Pfeiffer, 2011).

Model Comparison and validation

For training the model, 75% of the observation records were used, while the other 25% of observation records were for the model performance testing. The models were evaluated using the receiver operating characteristic curve (ROC), which is a graphical plot of the true positive rate (sensitivity or 1- Omission rate) versus the fraction of the total study area predicted present (1-specificity) (Kayijamahe, 2008; Phillips et al., 2006; Stevens & Pfeiffer, 2011).

3. Results

3.1. Chimpanzee Distribution Probability Map

The probability maps produced using both Maxent and GARP (Figures 3) indicated that MaxEnt predictions showed that 35% (2058.61 ha) of the Western Province are suitable to chimpanzees, while GARP predicted that only 24% (1411.62 ha) are suitable. The area of high suitability for chimpanzee was observed in the southern, while some parts of the northwest were either moderately suitable or suitable for chimpanzees. The central part of the study area was either less suitable or unsuitable for chimpanzees and is therefore characterised by a very low probability of chimpanzees' occurrence (Figure 3).

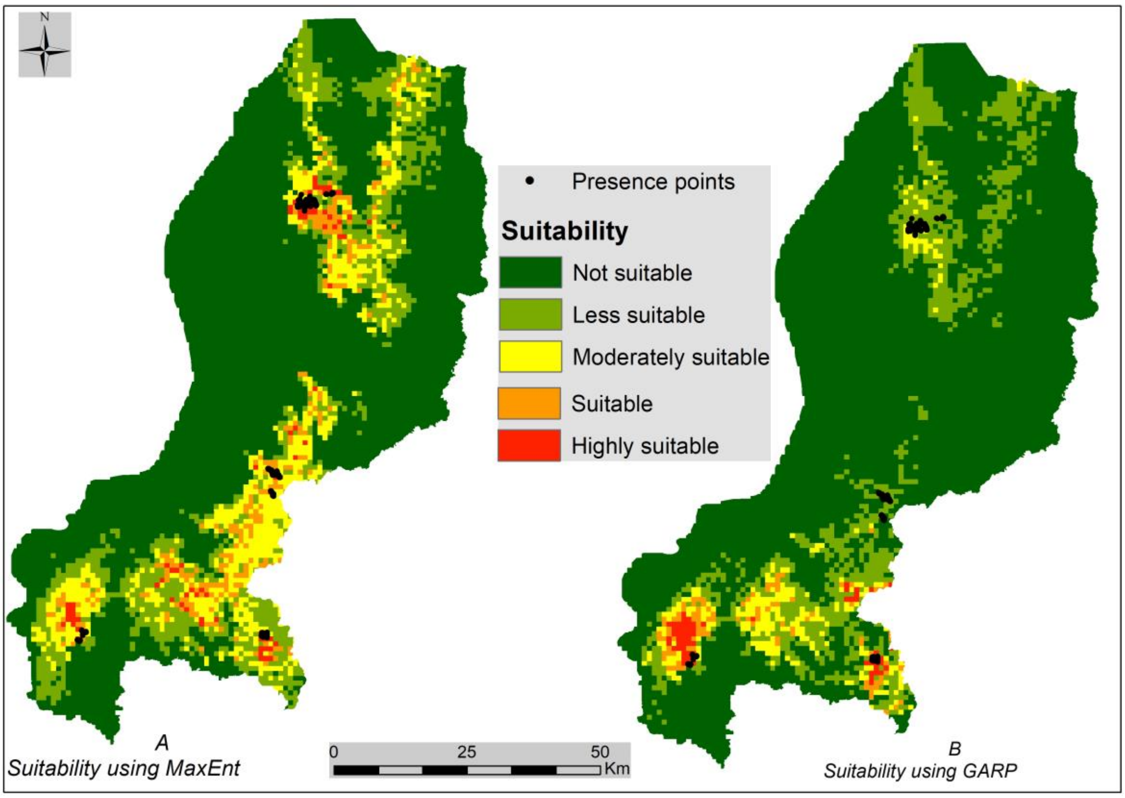

Figure 3: Probability Map of Chimpanzees Distribution: (A) Using Maxent Model, the Suitable Areas are mostly in the South and the North of the Study Area; (B) GARP Model Shows the Southern Part as more suitable

Performance of MaxEnt and GARP models

The Receiver Operating Characteristic (ROC) integrating the two models for both training and test data, showed that Maxent (Sensitivity=0.87) performed better than GARP (Sensitivity=0.83), although the two models could be successfully used for chimpanzee habitat distribution modelling (Figure 4).

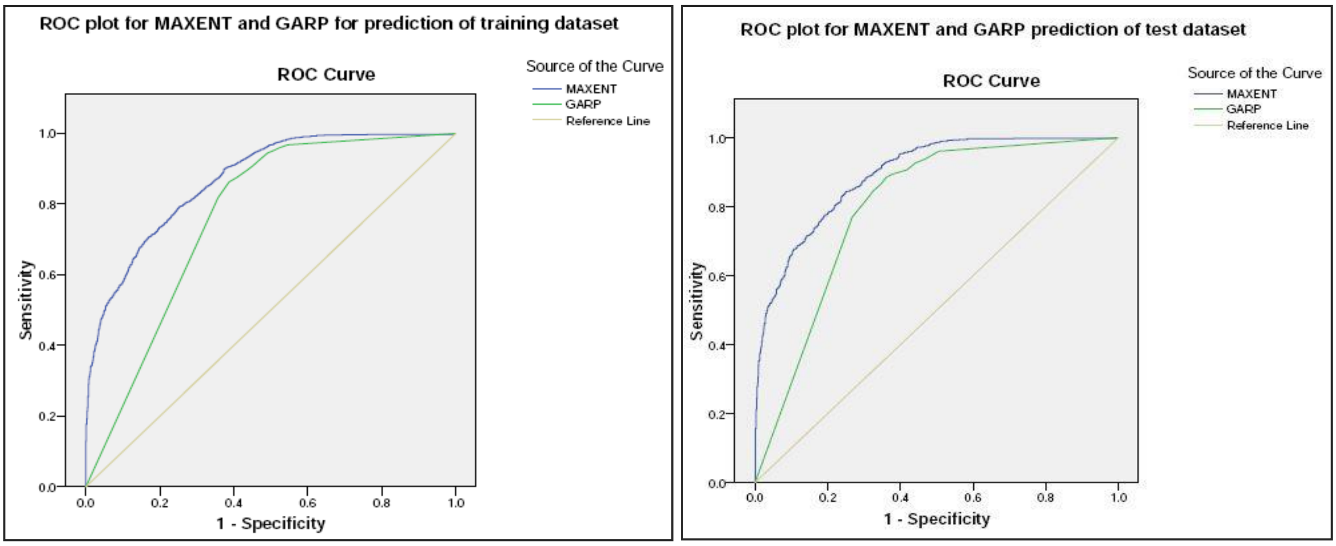

Figure 4: The ROC for GARP and MaxEnt Models Performance.

3.2. Food Availability and Chimpanzees Distribution

The occurrence of chimpanzees was associated with their preferred food plant species. *Bambus spp (*especially in GMNP), *Cassipaurea ruwenzoriensis, Ficus sp., Galiniera saxifrage, Macaranga kilimandcharica and Musanga leo-errerrae* are the most important plants species that chimpanzees feed on. Other plant species are used for nesting and therefore, are also important factors of their distribution (Figure 5).

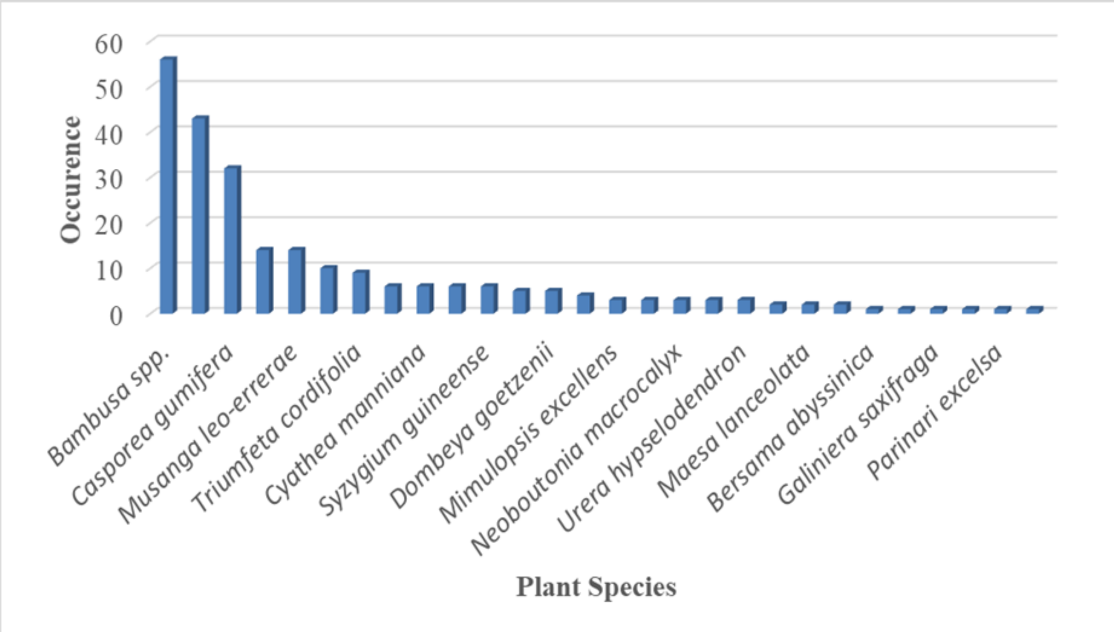

Figure 5: Food Preference for Chimpanzee in Each Sample Area

4. Discussion

4.1. Chimpanzee Distribution Probability Map

In general, approximately 35% (2058.61 ha) of the Western Province are suitable for chimpanzees. The Southern and the northern parts of the study area are suitable for chimpanzees while the central part is either less suitable or unsuitable to chimpanzees (Figures 3). The South-Western part of the study area hosts the Main Forest of NNP and Cyamudongo forest fragment which are the main habitats for chimpanzees in the country. The central part hosts Gishwati-Mukura National Park that is also a habitat of a small group of chimpanzees in the country. The whole areas that are suitable for chimpanzees share in common climatic and topographic conditions that have an influence on both the health and food availability of high altitude and mostly frugivorous animals like chimpanzees (Gross-Camp & Kaplin, 2005; Plumptre et al., 2002; Chancellor et al.,2012). The unsuitability of the central part of the study area to chimpanzees is associated with land use. The area is characterized by mosaics of agricultural fields and artificial forests that the diet and shelter sites have become scarce to chimpanzees.

4.2. Performance of MaxEnt and GARP Models

Both algorithms performed significantly better than random, and MaxEnt achieved better results than GARP. ROC analysis, the threshold independent method used to evaluate both models, showed significantly better than random performance for both algorithms (Figure 4). The area under the ROC curve (AUC) was higher for MaxEnt. The values of AUC (0.80 – 0.87) obtained were very good given the fact that this is modelling with presence-only data (Phillips et al., 2006). The same two models have been successfully (AUC>0.80) used by Kayijamahe (2008) for modelling mountain gorillas (*Gorilla beringei beringei*) in Volcanoes Massif bordering Rwanda, Uganda and the Democratic Republic of Congo. The higher AUC obtained for MaxEnt could be due to over-fitting (Jane et al., 2011). In fact, MaxEnt was shown to be prone to over-fitting, resulting in an inadequate prediction of large unsampled regions at high probability levels (Peterson, 2006).

4.3. Environmental Factors and Food Availability

The high probability of chimpanzees' occurrence in the southern and northern parts of the study area is justified by climatic conditions such as high rainfall, high humidity and low temperature that characterize the western region which is mainly made of mountains of the Congo-Nile Divide (Bizuru et al., 2014; Dusenge et al., 2015). The same microclimate has favoured the proliferation of plant species especially Bambusa spp., Ficus spp. and Musanga leo-errerae (Figure 5) which are the main sources of diet for chimpanzees (Gross-Camp & Kaplin, 2005; Plumptre et al., 2002; Chancellor et al., 2012). In addition to the provision of fruits, giant trees in natural forests located at Congo Nile Divide serve as shelter for different primates species especially chimpanzees (Gross-Camp & Kaplin, 2005; Chancellor et al.,2012).

The Central part of the study area is almost unsuitable to chimpanzees. The low probability of chimpanzees' occurrence in this part could be attributed to land use characterized by mosaic fields and high population density which contributed to the rarefaction if not the extinction of plants that serve as either source of diet or nesting sites for chimpanzees (Barakabuye, 2005). This part is made of fertile soils which are mostly exploited for agriculture (Mukashema, 2007; REMA, 2009).

The demonstrated Chimpanzee spatial distribution is in line with findings by previous studies such as Eklund et al. (2011) and Kayijamahe (2008) who indicated that the distribution of great apes are not only influenced by climatic variables, but also by food availability. The climatic conditions in the south western part of the study area (characterised by high humidity, high rainfall and moderate temperature) justifies the high probability of occurrence of chimpanzees in these areas in accordance with findings by other previous studies (Eklund et al., 2011; Fourcade, Engler, Rödder, & Secondi, 2014; Jane et al., 2011; Kayijamahe, 2008; Phillips et al., 2006; Plumptre et al., 2003; Purvis, Gittleman, Cowlishaw, & Mace, 2000). In addition, the protection status of the mountain forest such as Nyungwe Forest National Park (Nyungwe, Cyamudongo) and Gishwati as a part of Gishwati-Mukura National Park, have favoured the welfare of flora and fauna biodiversity especially the Common Chimpanzees (Gross-Camp & Kaplin, 2005; Chancellor et al.,2012).

5. Conclusion and Recommendations

The output of MaxEnt and GARP models showed that the southern and northern parts of the study area are suitable while the central part is almost unsuitable. This unequal suitability is defined by climatic conditions especially rainfall and temperature and man-induced phenomena such as land use change which have a direct influence on chimpanzees' food and nesting sites availability. This study recommends that efforts for chimpanzee's conservation should be focused on land use management around NNP in the southern part and around GMNP the northern part rather than the highly degraded central. The study further recommends MaxEnt and GARP as potential tools to be used for chimpanzees' home range modelling the West of Rwanda. However, even if MaxEnt showed a higher performance (AUC=0.87), the fact the two models use only presence data, may influence the results of the study, and lead to over or under-prediction.

Acknowledgment

Authors convey great gratitude to the Rwanda Development Board (RDB) and Wildlife Conservation Society/*Projet pour la Conservation de Nyungwe* (WCS/*PCFN*) for facilitating the data collection; Mrs Jeannette Batamuliza for providing a part of the dataset, and our field assistant Mr. Thomas Kanyempura

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