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HABITAT SUITABILITY MODELING OF AFRICAN FOREST ELEPHANT (*Loxodonta Cyclotis)* IN OMO FOREST RESERVE, OGUN STATE, NIGERIA

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ABSTRACT

Maximum entropy (MAXENT) algorithm was used to explore how environmental variables influence habitat of African forest elephant in Omo Forest Reserve. The occurrence data and the predictor variables were processed using Geographic Information system software. The survey was conducted for both wet and dry season. Result shows that distance to river, mean diurnal range, distance to farmland, distance to road, and NDVI contributed mostly to predicting the habitat suitability for both dry and rainy seasons. There were several streams that flows within the forest reserve which reflects in elephant movement pattern towards riverine areas. Suitable habitat within the study area were found to be areas with dense vegetation. Elephant frequent movement around agricultural and cultivated areas within the reserve resulted in crop raiding and destruction. The model combined result for the study area suitability shows a suitable area of 332.90km^2, moderate area of 434.47km^2 and unsuitable area of 529.65km^2. The performance ratings of AUC values (area under receiver operating curves) were 0.779 and 0.781 for dry and rainy seasons respectively. Due to increasing anthropogenic activities, elephants' activities were greater in the northwestern part of the forest reserve which provides suitable habitat that meets food, water and vegetation cover requirement for the species.

Keywords: African forest elephant, Habitat suitability, forest reserve, Environmental variables

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INTRODUCTION

Global decline in wildlife species abundance and distribution is a function of various threat to biodiversity (Grooten and Almond, 2018; IPBES, 2019). Role of biodiversity in structuring the ecosystem is gaining importance and more understanding with the need to accurately measure biodiversity and provide means for its conservation (Birkhofer *et al*., 2015). Biodiversity contributes greatly to the global economy, human survival and welfare (Dai *et al*., 2019). In the recent years, there has been growing pressure of human activities on the natural habitats which leads to the loss of biodiversity (Terrado *et al*., 2016). Moreover, the decline in biodiversity is higher than in the time past and it is expected to increase in the future [6, 7]. (Wu *et al*., 2019; Mashizi and Escobedo, 2020).

African elephant (*Loxodonta africana)* have suffered decline since early 2000s, in less than a decade, the Savanna elephant has a decline of 32% and 62% decline for forest elephant (Chase *et al*., 2016; Maisels *et al*., 2013). African elephant (*Loxodonta africana*) is one of the largest terrestrial mammals, they are keystone species that plays a vital role in structuring both plant and animal communities (Thouless *et al*, 2016; Amusa *et al*., 2017). African forest elephant (*Loxodonta cyclotis)* population have declined greatly over the years owing to a number of factors including habitat loss through the conversion of land to agriculture, ivory poaching and trade across their range, and increasing resource competition due to growing human populations populations (Maisels *et al*., 2013). Now listed as critically endangered on the International Union for Conservation of Nature Red List of Threatened Species (IUCN, 2021). There has been decrease in in forest elephant population in Nigeria while they have become extinct in many areas. They inhabit areas that are under anthropogenic activities such as agriculture, logging, pastoralism, roads, and degradation of pristine areas which compress elephants into protected areas (Amusa *et al*., 2017).

Elephant require large ranges for their survival but their home ranges vary across different sites and the expansion of road networks in forest areas alongside the settlement of farmers along their range have led to fragmentation of elephant habitat and an increase in incidences of human-elephant conflict (Ananda *et al.*, 2014). Their home range is influenced by various factors but mainly food and water availability, surrounding land use, herd size, forest type and intensity of human disturbance. Elephant occurrence are high in secondary forest than in dense primary forest due to the abundance of food resources. Factors that influence elephant home range poses difficulties in selecting critical areas as habitat. Regardless of a forest size, elephant may utilize only some certain areas which indicates that the identification of habitat characteristics has an advantage in making predictions of elephant habitat in a large area (Kumar *et al.*, 2010; Alfred *et al.*, 2012, Bahar *et al.*, 2018).

The use of geographic information system (GIS) has been prominent as an important tool in conservation management as a means of planning strategies and decision support in protection and management of biodiversity (McNulty, 2013). Habitat suitability models has become an essential tool for estimating the likely impact of environmental and climatic change on species distribution in the last decades (Lavergne *et al*., 2010). To conserve and protect an endangered species it is essential to identify the needs of the species and the habitat it prefers, these valuations will help in managing the species (Halvorsen *et al*., 2016). Maximum entropy (MAXENT) is one of the method most widely used to model the distribution of various species.

Maximum entropy (MAXENT) is a species distribution model that combines presence only data with selected environmental variables to predict species distribution. Studies have shown that MAXENT in comparison with other methods performed better and has been widely used for ecological niche modeling of many species (Elith *et al*., 2006, Brito *et al*., 2011). Incorporating GIS technology and ecological modelling therefore will aid in African forest elephant management in terms of habitat selection, anthropogenic threats and their protection (Reza *et al*., 2013; McNulty, 2013; Sanare *et al.*, 2015). This study used MAXENT model to assess the habitat suitability of African forest elephant habitat use in Omo forest reserve for both dry and rainy season.

MATERIALS AND METHODS

Study Area

Omo Forest Reserve (OFR) gazetted in 1925 as part of the old Shasha forest reserve of southwestern Nigeria. It is located between latitude $6^0$35'- 7^0 05'N and longitudes $4^0$19'- 4^0 40'E in Ijebu East and North Local Government Areas of Ogun State, South-western Nigeria. The reserve covers an area of about 1,305km^2 and has common boundaries with Oluwa Forest Reserve in Ondo State and Ago-Owu, Osun and Shasha forest reserves in Osun State, all of which have some natural endowment in common (Amusa, 2015).

The reserve has a tropical climate which is characterized by both rainy and dry season. The temperature ranges between 21 and 34°C and the rainy season usually start in March with mean annual rainfall which ranges between 1500mm to 3000mm with two annual peaks in June and September with dry season ranging from November to February (Larinde *et al*., 2011; Adedeji *et al*., 2015).

The forest reserve is inhabited by various ethnic group with the Yoruba of the Ijebu extraction dominating the area. The reserve harbor the remaining population of elephant, chimpanzee and white throated monkeys (Amusa *et al.*, 2017).

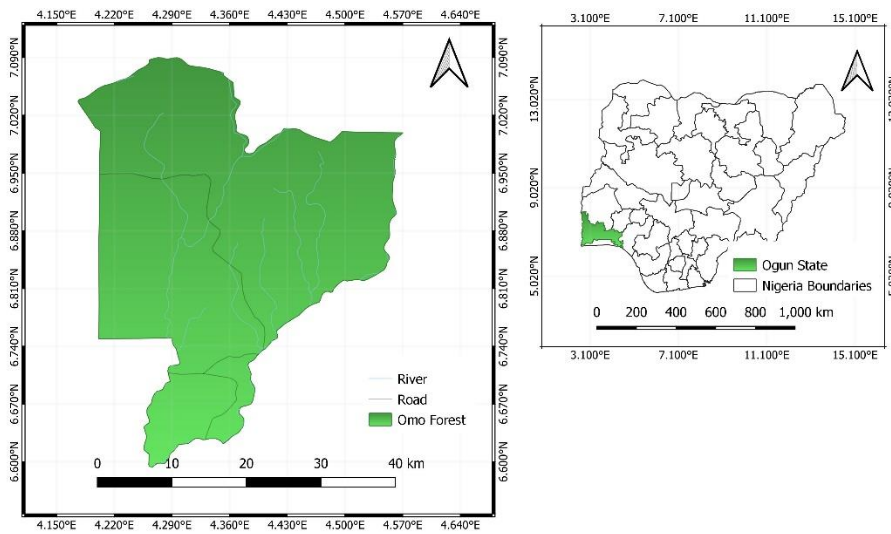


Figure 1: Map of Omo forest reserve, Ogun State, South West, Nigeria

Data Collection

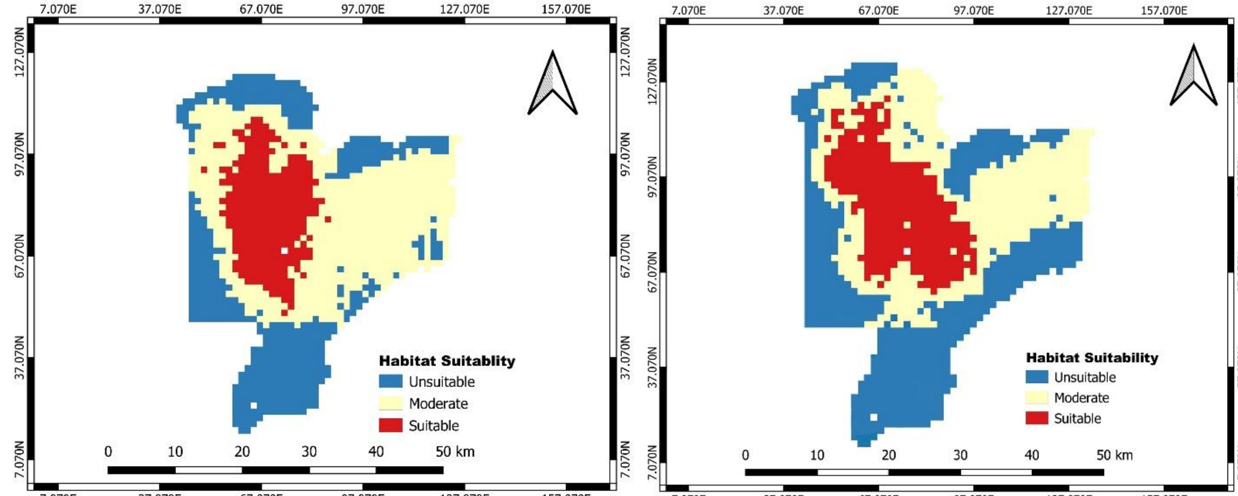
The field survey on determining the occurrence point forest elephant was carried out using line transect foot survey (Jachmann, 2008; Amusa *et al*., 2017). The survey was carried out for both wet and dry season between January and August, 2022. Indirect observations (foot print and dung piles) of forest elephant presence occurrence data were recorded with a GPS. Coordinate points of the species footprints and dungs were recorded. Observation of habitat related information such as threats, vegetation types, land use and land cover information were recorded. The survey was carried out by 7:00 and 10:00 in the morning and between 16:00 and 19:00 in the afternoon when there was much activity of wildlife species. Ground survey was carried out to obtain information on the observations of various threat identified including logging, farmlands, and human settlements. The occurrence point of each observation were recorded with the use of GPS. A total of 65 occurrence points for the dry season and 68 occurrence points for the rainy season were used for the modeling using the maximum entropy (MAXENT) algorithm (Phillips *et al*., 2006).

Environmental Variables Selection

Topography data was obtained from a digital elevation model (DEM) from the United States Geological Survey (USGS) (https://earthexplorer.usgs.gov/). The DEM was used to generate the slope and aspect and the images were resampled to a 30m pixel resolution using the Spatial Analyst tool of ArcGIS 10.7.1. Bioclimatic variables were obtained from the WorldClim historical database). The 19 bioclimatic variables were resampled to 100m using ArcGIS software. Landsat 8 data obtained from USGS Earth Explorer was used to analyze the NDVI (Normalized Difference Vegetation Index). Other variables such as distance to river and distance to road and distance to farmland were prepared using Euclidean distance from the ArcGIS 10.7.1 software. The predictor variables were adjusted using QGIS analyst tool to have similar resolution, projection and extent as required by the MAXENT software (Phillip *et al*., 2006). There are certain environmental factors that influence the spatial and temporal distribution of species. Selecting high priority habitats for the species depends on climate-related parameters and the landscape composition (Pr'eau *et al*., 2020). In Omo Forest Reserve, African elephant habitat use and distribution is affected by anthropogenic activities such as human settlement, logging and agricultural activities (Amusa *et al.*, 2017).

RESULTS

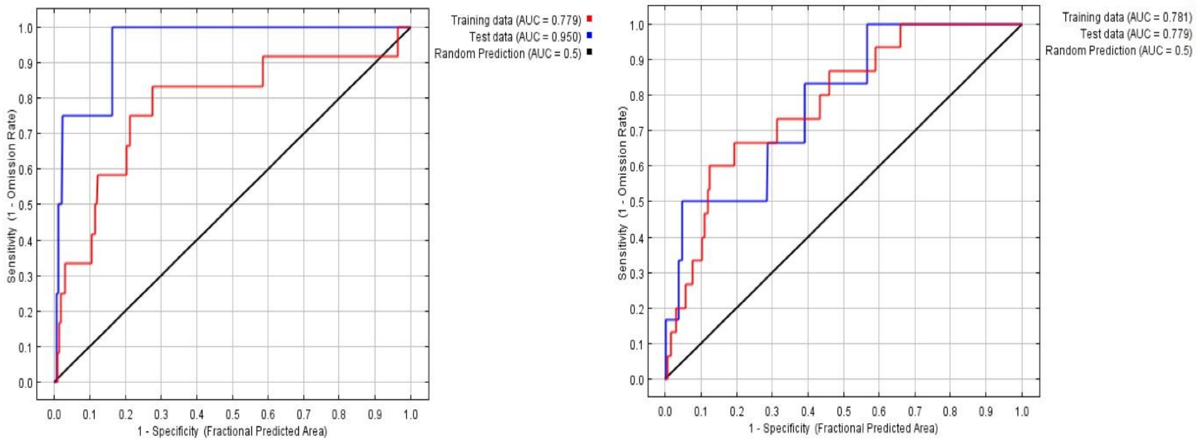
The MaxEnt 3.4.4 software was used to predict the habitat suitability of African forest elephant in Omo Forest Reserve. MaxEnt is a machine learning program which uses presence-only occurrence points and environmental variables to generate habitat suitability of a given species thereby, avoiding data absence and assumptions. MaxEnt was used to build and calibrate the spatial models based on 10 fold cross-validation with a regularization multiplier β=1 with the linear and quadratic features to have smooth models (Dudík, 2008; Elith *et al*., 2010; Anderson & Gonzalez, 2011; Anderson & Raza, 2010). 70% of the occurrence data were used for training and 30% for testing the model performance and the MaxEnt default settings were used for the remaining parameters (Phillips *et al*., 2006). The model combined result for the study area suitability shows a suitable area of 332.90km^2, moderate area of 434.47km^2 and unsuitable area of 529.65km^2.



Dry Season Rainy Season

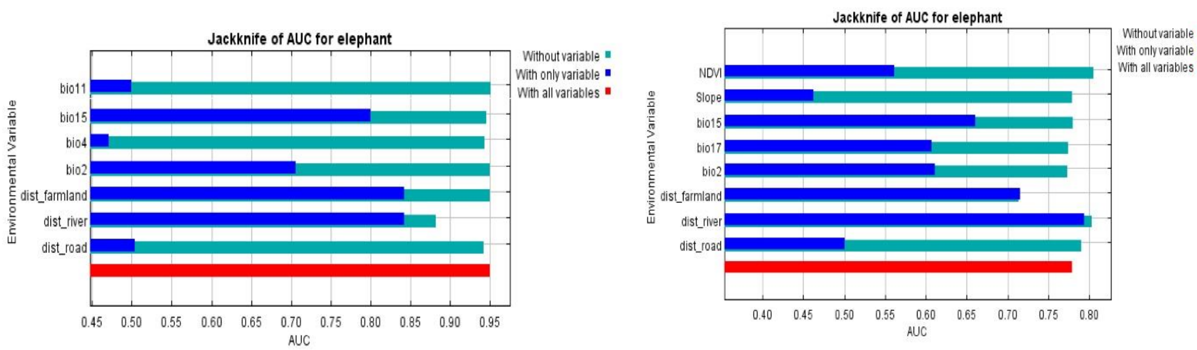
Figure 2: MAXENT model result of African forest elephant habitat use

The ROC provide a summary statistics called area under the ROC curve or AUC. AUC value ranges from 0 to 1. AUC less than or equal to 0.5 means that the model is random while the AUC greater than 0.5 means that the prediction is more than random. The receiving operating characteristic (ROC) curve (figure 3) provided AUC values of 0.779 with a standard deviation of 0.033 and 0.781 with a standard deviation of 0.086 for both dry and rainy season respectively. Both the training data and the test data are greater than the random prediction line (0.5.) in both seasons which indicates a good predictive ability in determining elephant habitat suitability in the study area.



Dry Season Rainy Season

Figure 3: The Area Under the Receiver Operation Characteristic Curve (AUC)



(a) Dry Season (b) Rainy Season

Figure 4: The Jacknife of AUC of important variables for elephant distribution model

For the evaluation of the relative contributions of the predictor variables to the model, jackknife test and the variable response curve were used (Phillips *et al*., 2006; Elith *et al*., 2011; Martins *et al.*, 2021). The jackknife (figure 4) shows the relative importance of each environmental variables used in the model prediction of the elephant habitat suitability.

Table 1: Relative contribution and importance of predictor variables to the MaxEnt model in both dry and rainy season

Predictor Variables	Percent contribution	Permutation importance	Percent contribution	Permutation importance
	Dry season		Rainy season	
Distance to river	53.3	68.4	24.9	11.5
Distance to road	16.4	4.1	0.2	0
Mean diurnal range	13.6	18.5	15.1	21.8
Bio 15	5.2	1.9	0.1	0
Distance to farmland	4.6	0.3	48.2	33.4
NDVI	0	0	11.2	32.2
Bio 11	3.3	1.4	0	0
Bio 4	2.6	3	0	0

Table 1 showed the percentage contribution of each predictor variables. There was a higher percentage for distance to river (53.3%), distance to road (16.4%), and mean diurnal range (13.6%) during the dry season. The environmental variable with the highest gain when used in isolation during the dry season is the distance to river which appears to have the most useful information by itself (figure 4a). During the rainy season, the model showed a higher percentage for distance to farmland (48.2%), followed by distance to river (24.9%), mean diurnal range (15.1%), and NDVI (11.2%). Other variables include precipitation of driest quarter, distance to road, precipitation seasonality and slope.

The response curve shows the effect of each environmental variables on MAXENT prediction for both dry and rainy seasons.

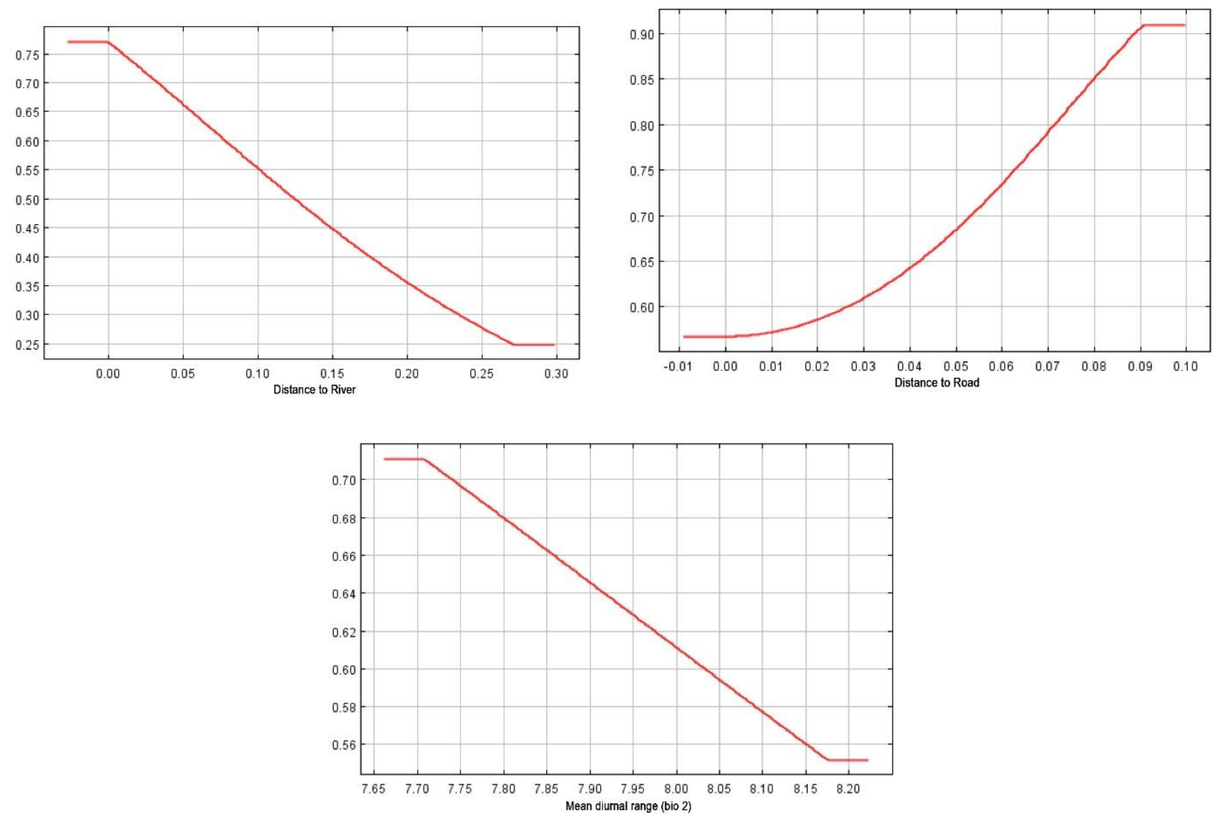
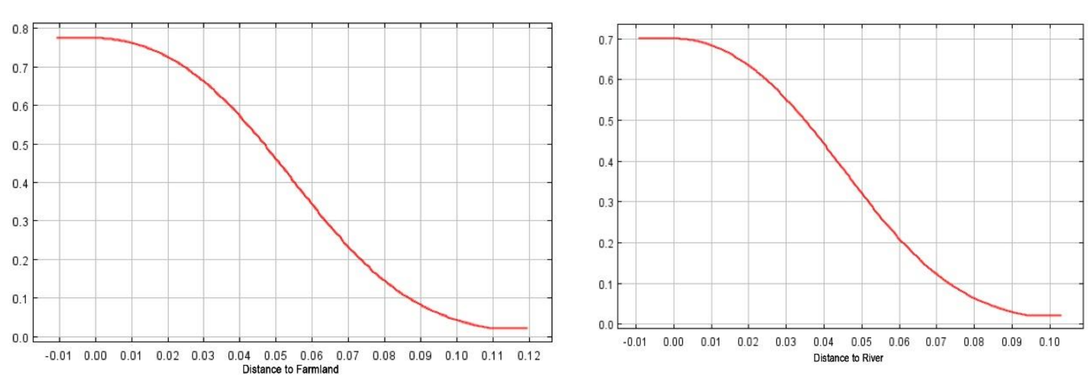


Figure 5: The response curve of the most important predictor variables showing forest elephant habitat suitability during the dry season



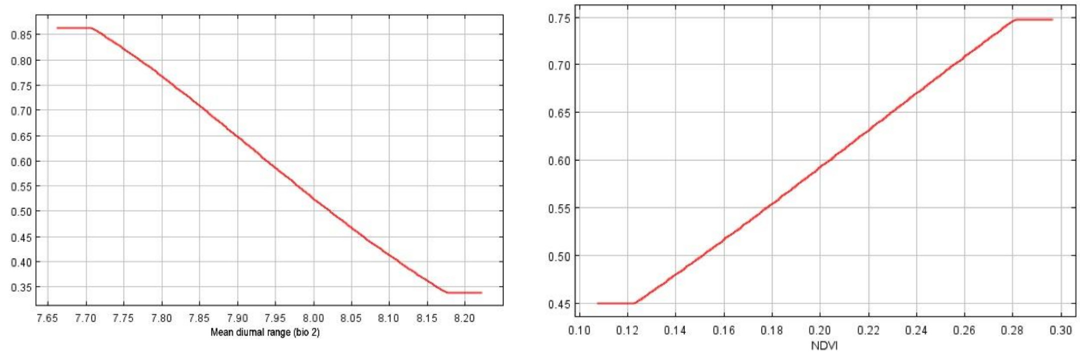


Figure 6: The response curve of the most important predictor variables showing forest elephant habitat suitability during the rainy season

During the rainy season, the environmental variable with the highest gain when used in isolation is the distance to farmland which therefore appears to have the most useful information by itself. The environmental variable when used in isolation is the distance to river which appears to have the most useful information in itself (figure 4b). The relative contribution of the environmental variables to the MaxEnt model showed that distance to river, distance to road, distance to farmland, mean diurnal range and NDVI were the most important predictor variables having the contribution > 10%.

DISCUSSION

Elephants were seen to be restricted to certain areas of the forest complex which could be attributed to the availability of water, food, settlements and human disturbance (figure 2). There are several rivers and streams that flow within the reserve. Elephant presence data (dung, footprint, and playing ground) were found around the areas where they have access to water and quality forage during the dry season (Amusa *et al*. 2017). Elephants are water dependent species which reflects in their movement pattern in relation to surface water. The high rate of evaporative and respiratory water loss in elephants makes them drink more often and reduce their distance to the closest water source (Dunkin *et al*., 2013; Xu *et al*., 2020).

Wildlife species are more often widely dispersed during the rainy season when there is abundance of water and food availability (Kebede *et al*., 2012). During the dry season, the MAXENT model map out an area of 421.67km^2 as unsuitable, moderate area of 564.22km^2 and 332.90km^2 as a suitable habitat use. During the rainy season, an area of 447.28km^2 (unsuitable), moderate area of 495.08km^2 and a suitable area of 376.43km^2. The suitability map (figure 2) showed that the species were found in areas with less disturbance and anthropogenic threat within the forest reserve (Amusa *et al*. 2017).

Elephant occurrence during the rainy season shows high percentage for distance to farmland (table 1) which resulted in crop destruction and plantation raiding. Illegal farming activities and illegal settlements within the reserve interferes with elephant home range (Mills *et al*., 2018; Tucker *et al*., 2018). Studies have also shown that elephants may have an attraction for secondary habitats cleared for agriculture which support their activities around farmlands (Poulsen *et al*., 2011).

The model indicates NDVI as a variable for elephant habitat suitability during the rainy season which shows quality and quantity of vegetation and the availability of food and cover. Elephant utilizes shrub, open grassland and the herbaceous areas within the forest reserve. The NDVI of the forest reserve showed that the areas occupied by elephants are areas with sparse vegetation. The habitat suitability was found with areas with NDVI between 0 and 0.3 (figure 6). This is supported by the findings of Matawa *et al*. (2012) who observed that elephants do not prefer areas with very dense vegetation as an intermediate vegetation provides food and cover requirement by elephants.

Mean diurnal range was determined as the key bioclimatic variable for both wet and dry season with the temperature between 7.70 – 7.75^{0}C (figure 5, 6). This influence the distribution and range behavior of elephants. Studies have shown that bioclimatic conditions such as seasonal rainfall and temperature affect physiology, behavior and interaction of species (Ashiagbor and Danquah, 2017; Mole *et al*., 2016).

Elephant confinement to certain areas within the study site is linked to anthropogenic activities which include farming activities, logging and illegal settlements. An effort towards mitigating threat to biodiversity in Omo forest reserve involved the establishment of a wildlife sanctuary which include an area of 30,000ha ≈ 23% of the total reserve area designated for the conservation of forest elephants. This intervention by government agencies and the Nigerian Conservation Foundation (NCF) makes the area designated as erin camp the most suitable habitat for elephants both in dry and rainy season (Amusa *et al*., 2017).

CONCLUSION

This study provided information on the habitat suitability of African forest elephants under the current environmental conditions in Omo forest reserve. The result of this study indicates that suitable habitats for elephants are areas with availability of water, and area of intermediate vegetation cover for both dry and rainy seasons. Elephants were seeing around farmlands where they feed on crops which brings elephant in contact with human. Elephants uses forest areas for their primary habitat where they get adequate resting and hiding areas while they forage and move around within their home range. Elephants were restricted to certain areas of the reserve with most of their activities found in the northwestern part which has been designated as Erin camp with reduced anthropogenic activities. Erin Camp is the area conserved and maintained by the Nigerian Conservation Foundation (NCF) to preserve the remnant of elephant species. With increasing human population, logging and clearing of land for agriculture, suitable habitat for elephants within the reserve is being encroached into. There is need for increased management practices and surveillance activities to halt agricultural practices in the core elephant habitat within the reserve.

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