CLIMATE CHANGE, ANTHROPOGENIC PRESSURE AND HABITAT SUITABILITY FOR AFRICAN ELEPHANT (*Loxodonta africana*) IN KEFTA HUMERA, TIGRAY, ETHIOPIA

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Climate change, habitat destruction and environmental degradation pose a threat to elephant (*Loxodonta africana*). Therefore, this study aimed to: i) characterize future climate variables, ii) predict the distribution and habitat suitability for elephant and iii) identify anthropogenic pressures that threaten elephant and its habitats. Climate data from 1980-2009 was used as a baseline for generating a future climate scenario. The climate modeling RCPs (RCP4.5 and RCP 8.5) were used with three general circulation model (GCMs). Anthropogenic pressure was assessed with questionnaires administered to 420 randomly selected households. The projection of maximum and minimum temperature from 2010-2099 indicates an increase in future. Higher rainfall will be expected in End Term RCP 8.5. Maxent distribution modeling showed, habitat types and climatic variables had higher contribution for the distribution of *Loxodonta africana*. Encroachment, over grazing, gold mining, cutting of tree and burning of charcoal were the major anthropogenic pressures threaten elephant and its habitats.

**Key Words:** Climate variable, Downscale, *Loxodonta Africana*, Maxent and Projection

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INTRODUCTION

East Africa has diverse and high populations of wildlife. A total of 288 species of mammals (29 endemics), 201 reptiles (10 endemics), 63 amphibians (25 endemics) and 188 fishes (37 endemics) were recorded in Ethiopia (Sewnet 2012). The African elephant (*Loxodonta africana*) is being conserved in Ethiopia’s protected areas. But, African elephants in Ethiopia are threatened by extinction (Yrimed et al 2006). Due to threats, Ethiopia has lost about 90% of African elephant population (Yrimed et al 2006).

In the past, the number of elephants in Ethiopia was decimated to an endangered level. As estimated by Yrimed and Afework (2000), the total number of elephants all over the country is approximate to 1,000. Now-a-days, nine isolated elephant populations conservation areas are established in Ethiopia (Yrimed 2004). Kefta Humera National Park (KHN) is one of the elephant’s conservation areas of Ethiopia.

Habitat destruction and other sources of environmental degradation including climate change, poses a serious and increasing threat to African elephant distribution (Walther et al 2002). The future climate change is fundamentally important for effective management and conservation of elephant (Hannah et al 2002). Elephants are dependent on habitat structure as well as climatic requirements for their persistence. The future climate change and change of habitat structure particularly in savannas altered the distribution of elephants. In view of the fact that, if dominated trees or grasses in savannas destructed, the presence of elephant in this habitat is faced in danger of extinction (Bond et al 2003).

Anthropogenic pressure on elephants increased from time to time due to human interest of using natural resources from National Parks which is elephant’s habitats (Malcolm et al 2002). The

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resettlement program around Kefta Humera National Park, illegal hunting and exhaustive exploitation of resources devastate the park and finally elephants (Yirmeth 2008). The anthropogenic pressure have impact on the species ability to thrive by limiting access to critical food and water sources made scarce by seasonal climate changes (Lee and Graham 2006).

As a result, forest and wildlife managers are facing with incorporating the conceptual connection between future climate change, impact of anthropogenic pressure and elephant distribution for conservation and their decision making process. In addition, there is no clear evidence of climate change impacts on elephant distribution.

For this reason, this study aimed to: i) characterize future climate variables (Maximum temperature, minimum temperature and rainfall), ii) predict the distribution and habitat suitability of *Loxodonta africana* at the study area and iii) identify anthropogenic pressure that threaten *Loxodonta africana* and its habitats.

**MATERIALS AND METHODS**

**Study area Description**

Kefta Humera National Park is located in Kefta Humera wereda, northwest of Ethiopia between 13° 04’-14° 01’ N and 37° 01’-38° 04’ 5”E. It is one of the largest conservation areas in Ethiopia. It is bordered by Eritrea in the north, Sheraro in the east, Wolkait in the south and Humera in the west. While the main river is the Tekeze, it is fed by a number of rivers that originate in the Semen Mountains and highlands of Wolkait. The elevation ranges from 550 m on the edge of Tekeze River to 1800 m on the highlands of Kefta (Fig.1).

This National Park is important for the conservation of elephants. Currently, the site seasonally holds about 100-150 individual elephants; these elephants spend the rest of the year in Eritrea. Besides elephants, it conserves 42 mammals, 167 birds, and 9 reptile species (Wossenseged et al 2014, Atakilt et al 2016).
Modeling elephant distribution using Maximum entropy modeling (Maxent)

Bioclim current data (30 arc-seconds resolution) that are expected to have an impact on the distribution of species and its main habitats were downscaled from the worldclim database according to Hijmans et al (2005).

The Bioclim current data were clipped down on Arc MAP to the Kefta Humera wereda map extension. 550 ground point data were collected in terms of coordinate pair as decimal latitude/longitude using a hand-held ground positioning system (GPS). These points were collected from dropping spots of the species at the study area. The habitat type samples were collected from forestland (110 Records), shrubland (110 records), grassland (110), irrigation site (around irrigation land 110 Records) and arable land (110 Records).

The maximum entropy modeling or Maxent model was mainly used for predict the distribution of L. africana in the study area. Individual sampling location to current environmental geo-datasets was used to estimate the probability of species (Philips et al 2006). Habitat types (forest, shrubland and grassland) data were organized to ASCII format for environmental layer and used as inputs for the modeling approach. It was assumed that African elephant distribution is not only determined by Bioclim variables. Then species occurrence and habitat type samples (Latitude and Longitude) were arranged to CSV (comma delimited) format for the samples file.

The modeling was used Area Under Curve (AUC) to verify model performance. The curves plot sensitivity (a measure of the rate of correct prediction of known locations) and against 1–specificity (a measure of the rate of correct prediction of absences) were used to verify model performance. The area under curve (AUC) is then used to verify index of model accuracy. A value of AUC was range between 0.5 and 1.0. With values above 0.9 indicating very well fit and model performance is good (Young et al 2011). The relative percent contribution value of each variable (downscaled bioclim variables and Habitat type’s variables) was done (Baldwin and Bender 2008). These values, in combination with the AUC values, were used to select the subset of variables determining the distribution elephants.

From the output of Maxent, Map representing the model of species current and future distribution was done using HadGEM2-ES GCM in near term (2010-2039), midterm (2040-2069) and end term (2070-2099). Maps for distribution of elephants were prepared and used later to be reclassified into high distribution area to low distribution area at the study area using Arc Map.

Model validation

Out of the total records (550 sample points), 75% were used for model training and 25 % for testing to evaluate the model accuracy (Philips et al 2006). AUC > 0.5 higher predictive power, AUC ≤ 0.5 random chance, and AUC < 0.5 worse than random (Philips et al 2006). In addition to jackknife results, environmental variables response curves are displayed by maxent. Logistic output was selected because it is the easiest to conceptualize the environmental variables (Pearson et al 2007)

Data collection from Local Community

The primary source of data was used to identify major anthropogenic pressure on the elephant and its habitat at the study area. At initial stage of the survey, informal meetings were undertaken with the staff of the park and the scouts in order to get hold of the general socio-economic situation of the population of the study area. Formal meetings also take place with key
A random sampling technique was used to select 420 households out of 16,340 households living near the study area. Questionnaire was properly distributed and subsequently, interviews were conducted by the researcher. Focus group discussions were also used to reinforce questionnaire data (Mesele 2006). Focus group discussions in each Tabia and with the workers of the study area were conducted. Local community was invited to discuss issues according to their convenience. Finally, direct observation and field walks in the National Park also provided good information.

**Data analysis**

R statistical software was used to generate climate scenarios from CMIP5 using 30-year baseline climate data. Maximum entropy modeling software (Maxent), ArcGIS and Arc MAP were used to predict the distribution of the elephant in the study area. Statistical Package for Social Science (SPSS) software was used to analyze questionnaire data collected from community at the study area.

**RESULTS AND DISCUSSION**

**Future trends of climate variables**

**Maximum temperature**

The maximum temperature (Tmax) at the study area varied according to scenarios and GCMs. The projection of maximum temperature by HadGEM2-ES GCM (Fig. 2(a)), showed there will be an increase of maximum temperature by 1.2°C in near term (2010-2039) for RCP 8.5, by 2.2°C in mid-term (2040-2069) for RCP 4.5, by 3°C in mid-term (2040-2069) for RCP8.5, by 3°C in end term (2070-2099) for RCP4.5 and by 5.3°C in end term (2070-2099) for RCP8.5 compared to the baseline. The Tmax of the study area will be reached 41.82°C in end term RCP8.5 from the average Tmax of the baseline which is 36.52°C.

Similar projection of maximum temperature indicated that, according to MIROC5 GCM projection (Fig. 2 (b)), the maximum temperature will be increased by 0.7°C in near term (2010-2039) for RCP 4.5, by 0.7°C in near term (2010-2039) for RCP 8.5, by 1.5°C in mid-term (2040-2069) for RCP 4.5, by 1.7°C in mid-term (2040-2069) for RCP8.5, by 1.8°C in end term (2040-2069) for RCP4.5 and by 3°C in end term (2070-2099) for RCP8.5 compared to the baseline. The Tmax of the study area will reach 39.52°C in end term RCP8.5 from the average Tmax of the baseline which is 36.52°C.

The other projection of maximum temperature by CCSM4 GCM (Fig. 2 (c)) confirmed that, the maximum temperature will be increased by 0.88°C in near term (2010-2039) for RCP 4.5, by 1°C in near term (2010-2039) for RCP 8.5, by 1.63°C in mid-term (2040-2069) for RCP 4.5, by 2.08°C in mid-term (2040-2069) for RCP8.5, by 1.71°C in end term (2070-2099) for RCP4.5 and by 3.62°C in end term (2070-2099) for RCP8.5 compared to the baseline. The Tmax of the study area will reach 40.14°C in end term RCP8.5 from the average Tmax of the baseline which is 36.52°C.

Therefore, the maximum temperature will be increased from the base line which is 36.52°C to 41.82 by HadGEM2-ES GCM for RCP 8.5 in end term, 40.14°C by CCSM4 GCM for RCP8.5 in end term and 39.52°C by MIROC5 GCM for RCP8.5 in end term. Generally, the projections of Tmax prove that, there will be an increased of Tmax by 3.97°C in future up to 2099.
**Figure 2:** Projected annual maximum temperature from Annual base line data of 1980-2009 and change trends using (a) HadGEM2-ES, (b) MIROC5 and (c) CSSM4 GCMs

**Minimum temperature**

The projection of minimum temperature (Tmin) by HadGEM2-ES GCM (Fig. 3 (a)), the minimum temperature will be increased by 1.4°C in near term (2010-2039) for RCP 4.5, by 1.7°C in near term (2010-2039) for RCP 8.5, by 3.5°C in midterm (2040-2069) for RCP 4.5, by 4.5°C in midterm (2040-2069) for RCP8.5, by 4.4°C in end term (2070-2099) for RCP4.5 and by 7.3°C in end term(2070-2099) for RCP8.5 compared to the baseline. The Tmin of the study area will reach 29.89°C in end term RCP8.5 from the average Tmin of the baseline which is 22.59°C.

Besides, projection of minimum temperature by MIROC5 GCM (Fig. 3 (b)), the minimum temperature will be increased by 0.8°C in near term (2010-2039) for RCP 4.5, by 0.9°C in near term (2010-2039) for RCP 8.5, by 1.6°C in midterm (2040-2069) for RCP 4.5, by 2.1°C in mid-term (2040-2069) for RCP8.5, by 2°C in end term (2070-2099) for RCP4.5 and by 3.8°C in end-term(2070-2099) for RCP8.5 compared to the baseline. The Tmin of the study area will reach 26.19°C in end term RCP8.5 from the average Tmin of the baseline which is 22.59°C.

Similarly, the projection of minimum temperature by CCSM4 GCM (Fig. 3(c)), the minimum temperature will be increased by 0.81°C in near term (2010-2039) for RCP 4.5, by 1.01°C in near term (2010-2039) for RCP 8.5, by 1.59°C in midterm (2040-2069) for RCP 4.5, by 2.12°C in Mid Term (2040-2069) for RCP8.5, by 1.64°C in end term (2070-2099) for RCP4.5 and by 3.62 °C in end term(2070-2099) for RCP8.5 compared to the baseline. The Tmin of the study area will reach 26.21°C in end term RCP8.5 from the average Tmin of the baseline which is 22.59°C.

Therefore, the minimum temperature will be increased from the base line 22.59°C to 29.89°C by HadGEM2-ES GCM for RCP 8.5 in end term, 26.21°C by CCSM4 GCM for RCP8.5 in end term and 26.19°C by MIROC5 GCM for RCP8.5 in end term. Generally, the projection of Tmin showed that, there will be an increased of Tmin by 4.9°C in future up to 2099.

**Figure 3:** Projection of annual minimum temperature from annual base line data of 1980-2009 and change trend using (a) HadGEM2- ES, (b) MIROC5 and (c) CSSM4 GCMs

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Rainfall

The HadGEM2-ES GCM projection Fig. 4(a) of rainfall indicated that, there will be an increase of 6.2 mm in near term (2010-2039) for RCP 4.5, 0.7 mm in near term (2010-2039) for RCP 8.5 of 8.5 mm in midterm (2040-2069) for RCP 4.5, 31.1 mm in midterm (2040-2069) for RCP8.5, 15 mm in end term (2070-2099) for RCP 4.5 and 12.4 mm in end term (2070-2099) for RCP 8.5 compared to the baseline. The highest rainfall amount of the study area will be reached 576.28 mm in midterm RCP 8.5 compared to baseline which is 545.18 mm.

Alike projection by of rainfall by MIROC5 GCM (Fig. 4 (b)), the rainfall will be increased by 76.5 mm in near term (2010-2039) for RCP 4.5, by 85 mm in near term (2010-2039) for RCP 8.5 by 60 mm in midterm (2040-2069) for RCP 4.5, by 156.9 mm in midterm (2040-2069) for RCP 8.5, by 81.9 mm in end term (2070-2099) for RCP 4.5 and by 207.3 mm in end term (2070-2099) for RCP 8.5 compared to the baseline. The study area will receive higher rainfall amount (752.48 mm) in end term RCP 8.5 compare to the total rainfall of the baseline which is 545.18 mm.

In addition, the projection of the rainfall by CCSM4 GCM (Fig. 4 (c)) be evidence that, the rainfall will be increased by 8.69 mm in near term (2010-2039) for RCP 4.5, by 5.78 mm in near term (2010-2039) for RCP 8.5, by 6.54 mm in mid term (2040-2069) for RCP 8.5, and by 8.18 mm in end term (2070-2099) for RCP 8.5 compared to the baseline. The higher rainfall amount of the study area will be reached 553.87 mm in near term RCP 4.5 compare to the baseline which is 545.18 mm.

ES, (b) MIROC5 and (c) CSSM4 GCMs

Figure 4: Projection of annual rainfall from annual base line data of 1980-2009 and change trend using (a) HadGEM2-ES, (b) MIROC5 and (c) CSSM4 GCMs

Impacts on elephant distribution
Therefore, higher rainfall will be expected in end term RCP 8.5 by MIROC5 GCM which is 752.48 mm, in midterm RCP 8.5 by HadGEM2-ES GCM which is 576.28 mm and in near term RCP 4.5 by CCSM4 GCM which is 553.87 mm at the study area.

Associated with temperature change and rainfall, there was an intermittent draught and flood events at the study area especially in 2015/2016 due to El Niño. Therefore, there was observation of dry up of water points in some parts of the Tabias with the general trend of the temperature and rainfall pattern of the Kefta Sheraro. Poor people, specifically agriculture dependent communities and Agro- pastoral at some parts of Kefta Humera were affected by the drought and flood events happened in 2015/2016 as observed from focus group discussions held with selected community members and direct observations during the study period.

Model performance and potential contribution of selected variables for distribution of elephant

The training data Area under Curve (AUC) for the replicate was 0.98 and test data was 0.97 for elephant distribution at the study area. Accordingly, these values indicate that, the Area under Curve (AUC) values was closer to 1. Therefore, Sensitivity vs 1–Specificity showed higher predictive power and the model performed distribution of elephant in high-quality way.

The percent contribution and permutation importance of variables were used in the model for predicting distribution of elephant at the study area. The higher the percent contribution, the more impact that particular variable has on predicting the distribution elephant. Accordingly, Bio_12 (annual precipitation) (0.72), Bio_18 (precipitation of warmest quarter) (0.55), and Bio_13 (precipitation of wettest month) (0.35) were identified as the most important percent contribution of climatic variables determining the distribution of elephant at the study area (table 1).

In comparable ways, the permutation importance of predicting model indicated, the distribution of elephant at the study area heavily depends on variables with higher percentage. Bio_18 (precipitation of warmest quarter) (55.15), Bio_8 (mean temperature of wettest quarter) (1.16), and Bio_12 (annual precipitation) (0.06) were identified as the most important climatic variables contributing for distribution of elephant at the study area. In addition, the presence of forest (86.8), shrubland (6.6) and grassland (4.38) were identified as the most essential habitats variables contributing for distribution of elephant (table 1).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Percent Contribution</th>
<th>Permutation importance</th>
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</thead>
<tbody>
<tr>
<td>Forest</td>
<td>86.8006</td>
<td>40.20</td>
</tr>
<tr>
<td>Grassland</td>
<td>4.3832</td>
<td>0.64</td>
</tr>
<tr>
<td>Shrub land</td>
<td>6.6025</td>
<td>2.15</td>
</tr>
<tr>
<td>Bio_12</td>
<td>0.7276</td>
<td>0.06</td>
</tr>
<tr>
<td>Bio_13</td>
<td>0.3561</td>
<td>0</td>
</tr>
<tr>
<td>Bio_15</td>
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<td>0</td>
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<td>Bio_18</td>
<td>0.5595</td>
<td>55.15</td>
</tr>
<tr>
<td>Bio_6</td>
<td>0.2095</td>
<td>0</td>
</tr>
<tr>
<td>Bio_8</td>
<td>0.2878</td>
<td>1.16</td>
</tr>
</tbody>
</table>

Table 1: Contribution and permutation importance of different variables for distribution of African elephant

Impacts on elephant distribution
However, according to this study, habitat types (forest, shrubland and grassland) had higher contribution than climatic variables (precipitation of warmest quarter, mean temperature of wettest quarter and annual Precipitation) for distribution of elephant. Similarly, jackknife test graphs of relative importance of each variables with respect to the AUC, test gain and regularized training gain confirmed, habitat type (forest, shrubland and grassland) and climatic variables (Bio_18, Bio_8 and Bio_12) were most indispensable variables contributing for distribution of elephant at study area (Fig. 5).
Figure 5: Results of jackknife test of relative importance of each variables with respect to the AUC, test gain and regularized training gain for distribution of elephant

Impacts on elephant distribution
According to this study, forest (at threshold of 0.9), shrubsland (at threshold of 0.66 to 0.84) and grassland (at threshold of 0.8 to 0.9) were identified as area of where high distribution of elephant. In addition, the response curves also indicated the most important variables for prediction of elephant distribution at the study area. Accordingly, the most suitable Bioclim variables for distribution of elephant were annual precipitation (Bio_12) between 600mm to 745 mm.

The green indicates very high distribution, the yellow indicates high distribution, lime indicates medium distribution, red indicates very low distribution and the blue one indicates no distribution of elephant for current (During study period 2015), near term (2015-2039), midterm (2040-2069) and end term (2070-2099) at the study area (Fig. 6). Therefore, the Maxent current distribution of elephant illustrated that, very high distribution of the species is mainly found at the shoreline of Tekeze River. This area is where easily elephant obtains enough water for drink and bath. In addition, elephant concentrated and depend on mainly forest for survival. But, there were anthropogenic threats which are restricted elephant movements at riverside.

Figure 6: Predicted potential distribution of elephant (a) Current, (b) Near Term (2010-2039), (c) Mid Term (2040-2069) and (d) End Term (2070-2099)
Major Anthropogenic Pressure on Elephant and Its Habitats

Views about the anthropogenic pressure threat on elephant and its habitats were collected from the respondents. Eight major anthropogenic pressures distressing elephant and its habitat at the study area were identified. In view of respondents, (encroachment) (89%), over grazing in the National Park (88%), gold mining (85%), fire (85%) and cutting of tree (for fire wood, burning of charcoal) (76%) were the major anthropogenic pressures. In addition, respondents mentioned that, settlement (36%), charcoal burning (34%) and poaching (29%) were also imposing pressure on elephant and its habitat.

Root Causes of the Problems

The root causes of those anthropogenic pressures were unemployment (33.75%) followed by poverty (economic weakness of the community) and lack of awareness about conservation of elephant with natural resources (15%) as presented by pie chart. In addition to these, exclusion against indigenous people during decision making (11.25%), climate change (11.25%), population growth, lack of farmland (absence of land owners license) and lack of Ethiopian Wildlife Conservation Authority (EWCA) policy implementation were the revealed root causes for the anthropogenic pressure on elephant according to respondents at the study area.

As a result, the park area was reduced from 5000km² to 2176.43km²(from EWCA of the study area) which is by 56.47% mainly due to encroachment (18.8%), habitat loss mainly due to fire 23.8%, habitat fragmentation mainly due to irrigation outside the park (18.8%) and the extreme anxiety of thus three consequences on the national park be a route to the mass migration of the elephant (37.5%) out of the park crossing Tekeze river to Eritrea.

DISCUSSION

The study of World Bank (2007) provides, under RCP 8.5 scenario, mean warming in Ethiopia is likely to be in the range 1.46 - 2 °C by 2030s and 2.68 - 3.80°C by 2080s relative to the historical period. But, According to this study, the Tmax will be an increased by 3.9°C in future up to 2099 and the Tmin will be an increased by 4.9 °C in future up to 2099. In addition, according to World Bank (2007), most projections indicated that an increase in rainfall for eastern Africa. This is similar with this study, which showed the higher rainfall will be expected in end term RCP 8.5 by MIROC5 GCM which is 752.48 mm, in midterm RCP 8.5 by HadGEM2-ES GCM which is 576.28 mm and in near term RCP 4.5 by CCSM4 GCM which is 553.87 mm at the study area.

L.africana can travel long distance to search for favorable environment. But, according to this study, irrigation, encroachment, gold mining and other anthropogenic pressures restrict species in one area. They are mainly focused on selected habitats such as riverside which provide all necessary resources particularly water, forages and shades (Shoshani et al 2004). Therefore, according to this study the maxent model prediction showed high concentration of elephant found around Tekeze River. Lahm (1994) also suggested that human elephant conflict and continuous cultivation of elephant’s habitat has impact on elephant which supported for this study.

In addition to this, Teshale (2007) found that, lack of awareness about natural resource conservation as the root causes of anthropogenic pressure which is supported this study. According to Nelson et al (2003), changes in land-use (i.e., fragmentation of habitats, conversion of forest land to crop cultivation land, settlement, and livestock grazing) have increased human impact on elephant.

CONCLUSIONS

Temperature and rainfall will increase under future scenarios, but the best model to predict climate influence on L.africana was a habitat types. Habitat types had higher contribution than climatic variables for distribution of L. africana. Climate variables (variables from bioclim) and anthropogenic pressure (human activities) have impacts on L.africana. The most suitable Bioclim variables for distribution of L.africana were annual precipitation. Therefore, according to this study the maxent model prediction showed high concentration of elephant found around Tekeze River. On the other hand, Encroachment, over grazing, gold mining, cutting of tree and burning of charcoal were the major anthropogenic pressures distressing elephant and its habitat at the study area. The root causes for thus anthropogenic pressures were unemployment, economic weakness the community and lack of awareness about conservation at the study area.

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