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EFFICACY OF PROTECTED AREAS IN CONSERVING THE PRESENT AND FUTURE OF THE CORDIA AFRICANA (LAM.) IN DRY LANDS OF ETHIOPIA

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Abstract

Climate change will cause species range shift. However, conservation implications of species range shift are limited. Therefore, this study aimed at assessing the efficacy of Protected Areas (PAs) in the conservation of Cordia Africana (Lam.) species under present and future climatic conditions in Tigray region, northern Ethiopia. Maximum Entropy (MaxEnt) model, a species predictive modelling software was used to model both the present and future distributions of Cordia Africana species within the Protected Areas of Tigray region. An ensemble of three General Circulation Models ('CCSM4', 'HadGEM2-ES' and 'MIROC5') along with two Representative Concentration Pathways; RCP4.5 and RCP8.5 scenarios over two time periods (2050 and 2070) were used for modelling the future species distribution. Results indicate that suitable habitats for Cordia Africana species under current climatic conditions covers only 17% of the total area in PAs. However, the total area of suitable habitats for Cordia Africana within the PAs will increase up to 32% under future climate scenarios. The results suggest that PAs show low efficacy to protect Cordia Africana species. Therefore, conservation planning should integrate in situ and forest management strategies while taking into consideration climate change scenarios.

***Keywords**: Species distribution; Cordia Africana; Protected Areas; Climate change; Predictive modelling; Conservation planning; Northern Ethiopia*

Introduction

Cordia Africana (Lam.), is a deciduous forest tree species which belongs to the Boraginaceae family [1, 2]. *Cordia Africana* (*C. Africana*), a multipurpose tree, is widespread in almost 17 African countries, mainly in primary or secondary forests and woodlands in West Africa, and it is restricted to montane and submontane habitats [1]. *C. Africana* have been found to be in those regions with warm climate and high rainfall, but it can also grow in areas with drier climatic conditions through adaptation mechanisms such as leaves shading or closing the stomata in order to minimize its water consumption [2].

The tree is valued for its numerous socio-economic, nutritional, medicinal, ecological, environmental benefits and it is considered to be essential in agro-silvopastoral systems and act as a source of shade to other crops [3]. In Ethiopia, *C. Africana* (locally known as the 'Wanza or Awhi') is a native tree species, widely distributed all over the country. The species is managed through agroforestry schemes and used by the community in several ways to get

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several socio-economic, nutritional, medicinal and ecological benefits [4, 5]. The species had showed an added potential for climate change adaptation and mitigation when integrated into the farming systems [3]. The species has the potential for carbon sequestration and the capability to improve soil fertility that is linked to an increase in crop yield [3-5]. In addition to its promise for climate change adaptation and mitigation, it minimizes food insecurity and alleviates poverty [5]. However, overharvesting, land use activities and climate variability are linked to the increased decline in the distribution and population status of forest tree species such as *C. Africana* [6-8]. Climate change is occurring at an alarming rate globally. Predictions shows that if the temperature continues to increase at the current rate, it will reach up to 1.5°C between 2030 and 2052 [9]. In Ethiopia, the temperature has been predicted to increase up to 2.1°C and 3.4°C by 2050 and 2080, respectively, when compared to the 1961 – 1990 normal [10]. Climate has had a significant impact on the reproduction and growth of plant species and has become an important factor in determining the spatial distribution of the forest tree species [11, 12]. Increasing temperatures together with lack of protection of some forest tree species have been linked to the contraction of important forest tree species' geographical distribution, shifting of these species to unprotected areas and sometimes they even experienced extinction [13-15].

Ecological Niche Models (ENMs) or species habitat models, also known as Species Distribution Models (SDMs) are the main instruments for assessing both the current and future spatial distribution of a target forest tree species [16]. ENMs rely mainly on the statistical association between the species occurrence data and the corresponding ecological predictors [17, 18]. Among the ENMs, the Maximum Entropy (MaxEnt) model for species' distribution modelling has been commonly used in modelling the current and future species distribution [17-21] where conservation measures are needed for sustainable development [19]. MaxEnt model represents an estimate of species' realized niche considering the abiotic dimensions [22]. The model has gained attention in species distribution modelling as a common approach for presence-only data sets [23, 24]. This model has been observed to outperform other modelling methods such as the Genetic Algorithm for Rule-Set Prediction (GARP), Envelope Score (ES) and Mahalanobis Distance [22, 24]. This is so because the model can tolerate very small sample size and its prediction accuracy is high [22, 25]. The model has gained more attention on its application in the management and conservation of threatened and important plant species [14, 16-21].

Cultivation has been reported to be one of the effective strategies for restoring and conserving important plant species in order to mitigate the impacts of climate change [26]. However, studies showed that artificial cultivation of those plants which have high quality normally depends on suitable ecological conditions together with resources of good germplasm [15, 27]. The main and important strategy in biodiversity conservation is the establishment of protected areas. However, climate change is likely to affect the future species' representativeness in protected areas [28]. Therefore, there is a great need to plan protected areas networks taking into consideration both the current species' distribution and its response to climate change. This assists in minimizing the climate change impacts on our biodiversity [14, 20]. Similarly, modelling climate change impacts on our biodiversity can help in re-assessing the present set of protected areas. Here, taking into consideration how their geographic locations, design, size and general layout will assist in conserving our biodiversity as the climate changes [14, 17]. Identifying some suitable environmental habitats, especially in protected areas, for the specific forest tree species as affected by climate change is of great socio-economic value, medicinal, nutritional, ecological benefits in addition to the general conservation of the tree species. The implications of Protected Areas (PAs) for the conservation of *Cordia Africana* species under current and future climatic conditions in Ethiopia still remains unknown. This study predicted the current and future climate conditions suitable for these species within the Protected Areas of Tigray region, northern Ethiopia. The study made a hypothesis that a changing climate will affect the future distribution of *Cordia Africana* species within the existing PAs in Tigray region, Ethiopia.

Tigray region is located in the northern part of Ethiopia and lies between 12.5°N and 15°N latitude, and 36°E and 40°E longitude (Fig. 1). It has variable temperature and rainfall with average annual rainfall ranging between 500 and 1000mm [29]. The topography of the region contains three main agroecological zones, being the Lowlands, Mid Highlands and Highlands [29]. The soil types within the region include Vertisols, Lithosols, Cambisols, Leptosols, Regosols, Luvisols and Fluvisols etc. [30, 31]. The region has a total number of fourteen PAs [33].

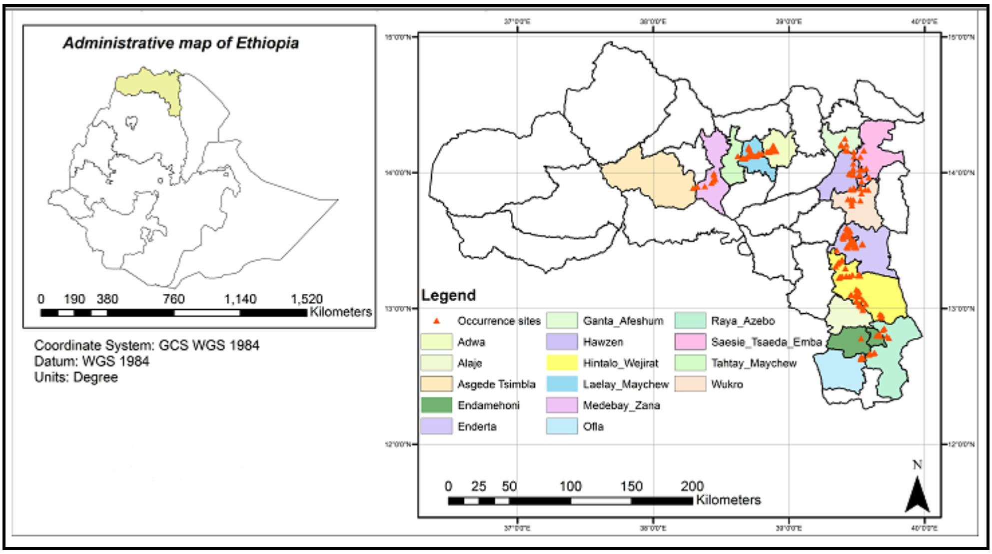

Fig. 1. Map of the species occurrence sampling sites

Materials for data collection and methods for data analysis

Sources for collection of Cordia Africana species data

A total of 164 species presence-only data for *Cordia Africana* species was collected within Tigray region including in seven purposefully sampled Protected Areas, covering fifteen districts where these species were reported to be found in both mid and highlands of Tigray region, in the northern part of Ethiopia [32]. The presence-only data for *Cordia Africana* were collected using a handheld GPS (Garmin 72H) and recorded as coordinate pairs using the decimal latitude/longitude format. These 164 coordinates collected for *Cordia Africana* species were used to run the MaxEnt model. In order to increase the sampling size for the species presence-only data from protected areas, the sampling exercise was done both within the protected areas and outside the protected areas. This was because the species occurrence inside protected areas were relatively lower and some of the locations inside the protected areas were inaccessible.

Protected areas data

Spatial data in the form of shapefiles, for the protected areas of Tigray region, were obtained from the Ministry of Agriculture, Ethiopia [33].

Climate and environmental data

Nineteen current bioclimatic variables with a spatial resolution of 30 arc seconds were downloaded according to R.J. Hijmans and C.H. Graham [34] from the WorldClim dataset, version 1.4 (for the period 1950-2000) (www.worldclim.org). Furthermore, a detailed soil layer

(Harmonized World Soil Database version 1.2) and land use were downloaded from Food and Agriculture Organization of the United State website. Altitude, slope and aspect were derived from the Digital Elevation Model which was downloaded from the National Aeronautics and Space Administration website. All these environmental layers were resampled to 30 arc seconds spatial resolution and to the same extent (Tigray region) using the resampling tool in ArcGIS 10.4 software. The nineteen bioclimatic variables together with the environmental variables (Table 1) were used for predicting the current distribution of *C. Africana* in Tigray region. According to R.J. Hijmans and C.H. Graham [34], the nineteen bioclimatic variables have a strong relationship with plant species distribution. They also summarize the seasonal and mean annual conditions, extreme values in addition to the intra-year variation [35]. Moreover, these environmental variables have been observed to influence the distribution of *C. Africana* in Africa [2, 32, 36].

Table 1. Input bioclimatic and environmental predictors for MaxEnt model (*): Predictors selected after running the model three times and were included in the final modelling

Environmental predictor	**Units**
Bio 1: Annual Average Temperature	°C
Bio 2: Average Diurnal Range [Mean of monthly (max temp - min temp)]	°C
Bio 3: Isothermality (BIO2/BIO7)	Dimensionless
Bio 4*: Temperature Seasonality (Standard Deviation)	°C
Bio 5: Maximum Temperature of Warmest Month	°C
Bio 6: Minimum Temperature of Coldest Month	°C
Bio 7: Temperature Annual Range (BIO5-BIO6)	°C
Bio 8: Average Temperature of Wettest Quarter	°C
Bio 9: Average Temperature of Driest Quarter	°C
Bio 10: Average Temperature of Warmest Quarter	°C
Bio 11: Average Temperature of Coldest Quarter	°C
Bio 12*: Annual Rainfall	mm
Bio 13: Rainfall of Wettest Month	mm
Bio 14*: Rainfall of Driest Month	mm
Bio 15: Rainfall Seasonality (Coefficient of Variation)	Fraction
Bio 16*: Rainfall of Wettest Quarter	mm
Bio 17: Rainfall of Driest Quarter	mm
Bio 18: Rainfall of Warmest Quarter	mm
Bio 19*: Rainfall of Coldest Quarter	mm
Aspect	°
Elevation*	m
Slope*	%
LULC: Land use/cover type	No unit
Soil type*	No unit

Simulated data from the nineteen bioclimatic predictors for 2050 and 2070 was obtained from the WorldClim database (http://www.worldclim.org/cmip5_30s). The basis of these bioclimatic predictors was on the Representative Concentration Pathways (RCPs) 4.5 and 8.5 scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) [9] of the United Nations (UN). An average layer of three General Circulation Models (GCMs) was used for this study in order to minimize the degree of uncertainties while projecting the likely impacts of future climate [37]. The GCMs used are the Community Climate System Model 4 (CCSM4), Hadley Global Environment Model 2 – Earth System (HadGEM2-ES) and Model for Interdisciplinary Research on Climate 5 (MIROC5) [9]. These GCMs have been commonly applied in biodiversity and climate change impacts studies due to their ability to produce consistent results [14, 27, 37, 38]. Moreover, the RCPs were chosen because of the recent report made by IPCC [9] that there is a great increase in fossil fuel (CO_2) emissions rate than the past decades.

Model validation

From the 164 records collected, eighty percent were used for training the model and twenty percent for testing. 80% and 20% was used for this study instead of the 70% and 30% which is widely used for training and testing the model respectively, because of the view that a model is well trained in order not to make inaccurate projections when using a relatively higher percentage from the records collected [39]. For validating the accuracy of the model, 5000 iterations together with fifteen replicates were set in the MaxEnt software settings as reported by S.J. Phillips *et al* [23]. The accuracy of the model in predicting the distribution of the species within the study area was evaluated through the aid of a random test percentage setting in MaxEnt software [22, 23]. The area under the receiver operating characteristic (AUC) was also used for testing the accuracy of the model. The model performance based on its specificity and sensitivity is shown by the AUC through providing its threshold-independent measure [23, 40]. The AUC of 0.5 shows that the model did not perform well than random while a value of 1.0 shows ideal prediction [14, 23]. AUC for the models can be interpreted as: Invalid if it lies between 0.5 and 0.6; Bad if it lies between 0.6 and 0.7; Acceptable if it ranges between 0.7 and 0.8; Good if it is between 0.8 and 0.9; and Excellent if it greater than 0.9 [40].

Climatic and environmental predictors' contribution to the model

The percent contribution table was used for measuring the contribution of the individual climatic and environmental predictors for species suitability. This measure shows the performance of each variable in the model in terms of its importance on explaining the species distribution, when it is trained and the extent of its uniqueness [23, 40]. MaxEnt model uses a 'gain' method for testing the performance of each environmental variable. Important predictors to the model show a relatively high gain when modelled independently. These predictors also show a decrease in gain and AUC when excluded from the model [22, 23]. Therefore, important predictors for this study showed relatively high percent contribution and high permutation importance during the test. This means that the mlodel relied heavily on those predictors.

Current predicted distribution of C. Africana

The 164 coordinate pair collected and recorded as decimal latitude/longitude were saved in Comma separated values (.csv) format for the species together with the nineteen bioclimatic and five environmental predictors (Table 1). These predictors were also converted to ASCII raster file format required for the MaxEnt 3.3.3k model and the model was run to produce results (in ASCII raster file format) for the suitable habitats for *Cordia Africana* species. The binary presence (1) and absence (0) map (suitable/unsuitable habitat) was obtained by applying to the current predicted map, the ten-percentile training presence threshold generated by the model. The ten-percentile training presence threshold is on the assumption that areas with a likelihood above the threshold have environmental and climatic conditions suitable for the distribution of the species, while the species would not grow in areas below the threshold [23, 40]. The binary presence and absence map was then imported into the DIVA-GIS 7.5 software for visualization and further analysis.

Climate change impacts on C. Africana distribution

In predicting the impacts of climate change on the distribution of *Cordia Africana*, only those bioclimatic (five) and environmental (three) predictors which were used for running the final model (Table 1) for the current distribution of the species were used. The mean raster layer for each of the simulated five bioclimatic predictors was computed in ArcGIS 10.4 software and used for the future projection. The climate projection data sets were used as input into the MaxEnt model in addition to the three environmental predictors in order to obtain the predicted species distribution maps for 2050 and 2070 based on RCP 4.5 and 8.5. The ten-percentile training presence threshold level was also applied to the model to obtain binary presence and absence projected maps.

Measuring the effectiveness of Tigray protected areas in conserving C. Africana

In evaluating the effectiveness of Tigray protected areas in the conserving the *C. Africana* species, ArcGIS 10.4 software was used for overlaying the current and future species distribution range with the Tigray protected areas map. The results were analyzed through calculating the area of the current and future potential predicted species distribution (from MaxEnt model) within some protected areas of Tigray region. This was done using the 'spatial analyst' tool in ArcGIS with the aim of revealing information on the total area (%) within the protected areas which represent the current and future predicted suitability area for the conservation of *C. Africana* species. This method was used for this study because it has been commonly applied in studies assessing the effectiveness of some protected areas network for species conservation under a changing climate [14, 19, 20]. This method has been shown to produce consistent results and assist a lot in conservation planning under current and future climate scenarios [14].

Results and discussion

Model predictive ability

The model performance was high with mean AUC value of 0.87. This means that there was 87% likelihood that a presence point selected at random, is found in a raster cell with a relatively high likelihood value for the *C. Africana* existence than a randomly created point. Therefore, the MaxEnt model did perform much well than a random model, with a good performance [14, 40].

Climatic and environmental predictors controlling the predicted habitats of C. Africana

According to the results obtained from the model (Table 2), about 91% of the current distribution of the species was explained by 3 variables: (i) Precipitation of Wettest Quarter (57.5%); (ii) slope (21%); and (iii) soil type (12.4%). Moreover, precipitation of driest month showed from the significance on permutation that it is the strongest predictor for the species distribution (Table 2).

Table 2. Comparative contribution of the environmental predictors used in MaxEnt modelling

Predictor	Percent influence	Significance on Permutation
Bio 16	57.5	14
Slope	21	5.2
Soil type	12.4	1.3
Bio 19	4.6	0.9
Elevation	2	0.8
Bio 14	1.7	58.9
Bio 12	0.5	11.4
Bio 4	0.3	7.5

Current predicted distribution of C. Africana in protected areas

The protected areas of Tigray region have an area of approximately 508374.78 hectares (Table 3). These protected areas include: Agefet Gheralta state Forest, Assimba state Forest, Waldba state Forest, Hirmi state Forest, Kafta welkait state forest, Kafta mesil state forest, Mugulat REDD+ Forest, Higumbrda Grat Kahsu state Forest, Seloda state Forest, Wujig Mahgo Waren state forest, Ghere Giba state Forest, GeASeGo state Forest, Desa state forest and Mechare Hawelti Tsehafti state Forest.

Table 3. Area for the predicted current distribution of *C. Africana* species in protected areas

Category	Area (ha)	%
Unsuitable areas	422651.56	83.1
Suitable areas	85723.22	16.9
Total	508374.78	100.0

The results obtained from the MaxEnt model and GIS analysis (Fig. 2) show that the efficacy of Tigray protected areas in conserving *C. Africana* species under current climate conditions is only 16.9% (Table 3). Generally, the efficacy of Tigray protected areas in conserving *C. Africana* species under current climatic conditions is very negligible (Fig. 2). This is so because the area (%) of suitable habitats for the species covered by these protected areas is very small (Table 3 and Fig. 2).

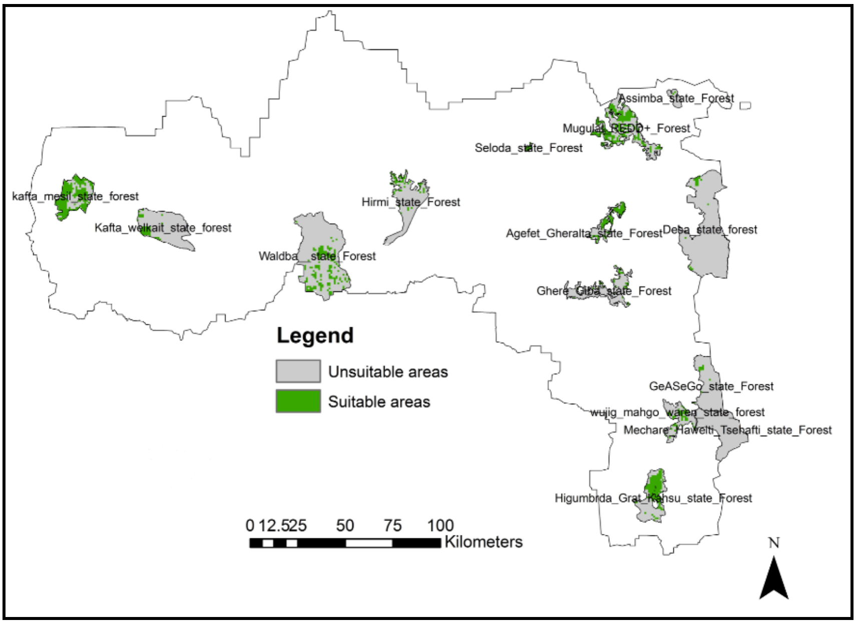

Fig. 2. Potential predicted current distribution of *C. Africana* in protected areas of Tigray region

Even though the general efficacy of Tigray protected areas in conserving *C. Africana* species under current climate conditions is very minimal, there are some of the protected areas which have relatively better effectiveness for the conservation of this species (Fig. 2 and Table 4).

Climate change impacts on C. Africana distribution within the PAs of Tigray region

The mean layer of an ensemble of three General Circulation Models (‘CCSM4’, ‘MIROC5’ and ‘HadGEM2-ES’) used for climate projection for Tigray region predicted that rainfall and temperature will increase by the year 2050 (mid-century) and 2070 (end-century) for all the scenarios. For instance, the average annual temperature will increase by a range of 1.5 and 2.2°C by the mid-century. The results showed that the efficacy of Tigray protected areas in conserving *C. Africana* species under future climate conditions will increase across all scenarios as compared to the 16.9% for the current climate conditions (Fig. 3). The MaxEnt model predicted the efficacy of these protected areas in conserving *C. Africana* species under future climate conditions for the mid-century RCP 4.5 and end-century RCP 4.5 to be 29.6 and

29.5% respectively (Fig. 3). Their effectiveness for the conservation of this species will increase from the current climatic conditions to mid-century RCP 4.5 and end-century RCP 4.5 by 12.7 and 12.6% respectively. Similarly, their effectiveness for the conservation of this species will increase from the current climatic conditions to mid-century RCP 8.5 and end-century RCP 8.5 by 9.2 and 15.4% respectively. The results of this study are in agreement with observations made by I.K. Dawson *et al* [41] who reported that predicted climate change will cause significant shifts in vegetation boundaries of the protected areas in East Africa.

Table 4. Effectiveness of each protected area in conserving *C. Africana* species in Tigray

Forest Name	**Area (ha)**	**Current predicted distribution**		
		Unsuitable (ha)	Suitable (ha)	% effectiveness
Kafta_mesil_state_forest	32692.7	13699	18993.7	58.1
Agefet_Gheralta_state_Forest	13614.93	8068.11	5546.82	40.7
Mugulat_REDD+_Forest	43282	26557.5	16724.5	38.6
Higumbrda_Grat_Kahsu_state_Forest	30171.3	19329.8	10841.5	35.9
Seloda_state_Forest	1260.63	840.42	420.21	33.3
Wujig_Mahgo_Waren_state_forest	17733.05	14287.3	3445.75	19.4
Waldba__state_Forest	92194.9	78748.1	13446.8	14.6
Hirmi_state_Forest	35382.03	32188.4	3193.63	9.0
Kafta_welkait_state_forest	43198.03	39416.1	3781.93	8.8
Ghere_Giba_state_Forest	25212.81	23027.7	2185.11	8.7
Assimba_state_Forest	5210.66	5042.57	168.09	3.2
GeASeGo_state_Forest	35129.93	34289.5	840.43	2.4
Desa_state_forest	93371.51	91774.7	1596.81	1.7
Mechare_Hawelti_Tsehafti_state_Forest	39920.3	39920.3	0	0
Total	508374.78			

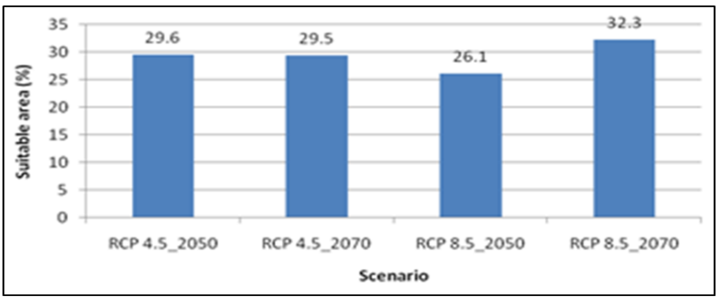

Fig. 3. Area for the future distribution of *C. Africana* species in protected areas

The efficacy of Tigray protected areas in conserving *C. Africana* species in the face of a changing climate is a loss-gain scenario. Those protected areas that were predicted by the MaxEnt model to be having a relatively better effectiveness under current climatic conditions will lose their efficacy under future climatic conditions (Fig. 4).

For example, 58.1% of the total area for the Kafta mesil and 33.3% of Seloda state forest will reduce their effectiveness by almost 57.1 and 33.3% respectively, by 2070, RCP 8.5. On the other hand, Desa, Higumbrda Grat Kahsu, Mugulat REDD+ and Mechare Hawelti Tsehafti state Forest will increase their effectiveness by almost 62.5, 23.7, 35.8 and 26.6% respectively, by 2070, RCP 8.5 (Table 5).

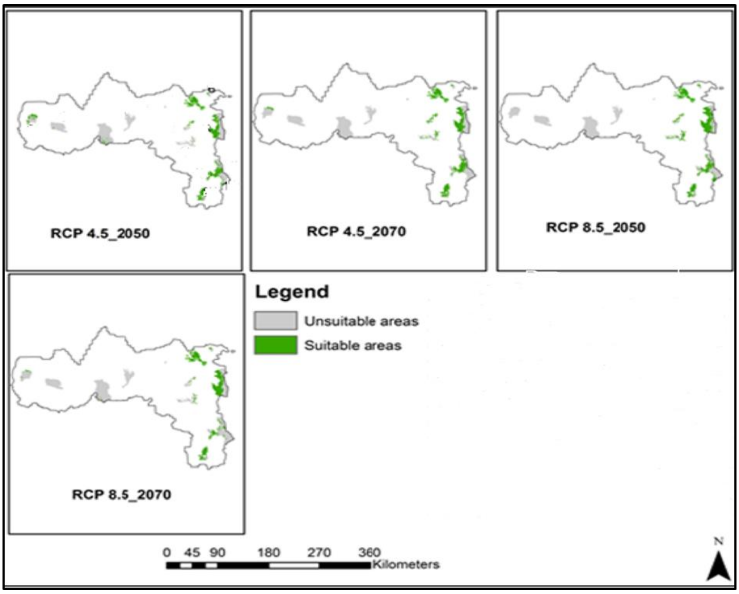

Fig. 4. Potential predicted future distribution of *C. Africana* in protected areas of Tigray region

Table 5. The efficacy of Tigray protected areas in conserving *C. Africana* species under future climate scenarios

Forest name	Effectiveness (Suitable Area_ha)			
	2050_RCP 4.5 (%)	2070_RCP 4.5 (%)	2050_RCP 8.5 (%)	2070_RCP 8.5 (%)
Agefet_Gheralta_state_Forest	23.5	46.9	14.2	40.1
Assimba_state_Forest	21.0	21.0	25.8	29.0
Desa_state_forest	43.1	48.6	57.0	64.2
GeASeGo_state_Forest	43.8	48.5	15.7	40.8
Ghere_Giba_state_Forest	4.0	24.4	13.0	38.8
Higumbrda_Grat_Kahsu_state_Forest	61.3	64.6	56.3	59.6
Hirmi_state_Forest	0.7	0.5	0.2	0.0
kafta_mesil_state_forest	31.6	11.8	8.0	1.0
Kafta_welkait_state_forest	1.2	0.0	0.0	0.2
Mechare_Hawelti_Tsehafti_state_Forest	25.1	17.2	5.2	26.6
Mugulat_REDD+_Forest	75.0	74.4	73.8	74.4
Seloda_state_Forest	13.3	13.3	6.7	0.0
Waldba__state_Forest	3.5	0.0	0.8	0.0
Wujig_Mahgo_Waren_state_forest	49.5	32.4	41.0	33.3

The results of this study are in contrary with previous findings from some researchers elsewhere, who found out that the species distribution in protected areas will remain largely much stable under future climate scenarios [14, 19].

Conclusion

The effectiveness of protected areas of Tigray in conserving *C. Africana* species is very low for both current and future climatic conditions. Only 17% of the total area of the PAs in Tigray region has been predicted by the MaxEnt model to be suitable for the species under current climatic conditions. The model showed that less than 33% of the total area of the PAs in Tigray region will be suitable for the species under future climatic conditions across all the scenarios. The model has predicted a low efficacy for most of the PAs located in the western part of the region in conserving the species under future climatic conditions. The PAs located in the eastern part will on the other hand, increase their effectiveness in conserving the species as the earth warms. Therefore, there is a need for implementing climate change-conservation and management strategies within the PAs. These strategies should be based on and implemented in specific PAs which showed suitability for the species. Future studies on the cultivation of *C. Africana* species in PAs located in the western parts of Tigray region such as the lowlands of Kafta Humera district are highly recommended. This is so because the MaxEnt model predicted those areas to be suitable for this species yet previous studies reported absence of this species in those lowlands.

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References

[1] J. Gindaba, A. Rozanov, L. Negash, *Response of seedlings of two Eucalyptus and three deciduous tree Species from Ethiopia to severe water stress*, **Forest Ecology and Management, 201,** 2004, pp. 119-129.
[2] C. Orwa, A. Mutua, R. Kindt, R. Jamnadass, S. Anthony, *Agroforestree Database: a tree reference and selection guide version 4.0*, (2009), (http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp).
[3] T. Teklay, **Organic Inputs from Agroforestry Trees on-Farms for Improving Soil Quality and Crop Productivity in Ethiopia**, Swedish University of Agricultural Sciences. Umea, 2005, p.147.
[4] K. Markos, S. Simon, *Floristic Composition, Vegetation Structure, and Regeneration Status of Woody Plant Species of Oda Forest of Humbo Carbon Project, Wolaita, Ethiopia*, **Journal of Botany, 1,** 2015, pp. 1-9.
[5] M.K, Robi, E.M. Edris, E.M, *Distribution, Abundance and Population Status of Four Indigenous Threatened Tree Species in the Arba Minch Natural Forest, Southern Ethiopia*, **International Journal of Natural Resource Ecology and Management, 2**(1), 2017, pp. 1-8.
[6] B. Etana, **Ethnobotanical Study of Traditional Medicinal Plants of Goma Wereda Jima Zone of Oromia Region, Ethiopia**, Addis Ababa University., Addis Ababa, 2010, p. 67.
[7] D.A. Amente, *Ethnobotanical Survey of Wild Edible Plants and Their Contribution for Food Security used by Gumuz People in Kamash Woreda ; Benishangul Gumuz Regional State,* **Journal of Food and Nutrition Sciences, 5**(6), 2017, pp. 217-224.
[8] G. Zenebe, M. Zerihun, Z. Solomon, *An Ethnobotanical Study of Medicinal Plants in Asgede Tsimbila District, Northwestern Tigray, Northern Ethiopia*, **Ethnobotany Research and Applications, 10,** 2012, pp. 305-320.
[9] * * *, **Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty; Summary for Policymakers**, UNEP and WMO, Geneva, 2018, p. 323.

[10] * * *, **Initial National Communication of Ethiopia to the UNFCCC**, National Meteorological Services Agency (NMSA), Addis Ababa, 2001, p. 130.

[11] S.T. Jackson, D.F. Sax, *Balancing biodiversity in a changing environment : extinction debt, immigration credit and species turnover*, **Trends in Ecology and Evolution, 25**(3), 2009, pp. 153-160.

[12] I.C. Chen, J.K. Hill, R. Ohlemuller, D.B. Roy, C.D. Thomas, *Rapid range shifts of species associated with high levels of climate warming*, **Science, 333,** 2011, pp. 1024-1026.

[13] * * *, **Climate Change 2007: Climate Impacts, Adaptation and Vulnerability, Working Group II to the Intergovernmental Panel on Climate Change Fourth Assessment Report**, Intergovernmental Panel on Climate Change, Geneva, 2007, p. 231.

[14] M.L.G. Guidigan, F. Azihou, A.A. Okhimamhe, B. Sinsin, B.S. Usman, L. Adet, *Examining the Effectiveness of a Protected Areas Network in the Conservation of Kigelia Africana under Climate Change by 2050 in Benin*, **Open Access Library Journal, 5,** 2018, pp. 1-15.

[15] P.J. Gullan, P.S. Cranston, **The Insects; An outline of Entomology (5th Edition),** Wiley Blackwell., West Sussex, 2014, p. 455.

[16] P. Sourabh, *Modeling potential invasion range of alien species, Verbesina encelioides (Cav.) Benth. and Hook. Fil ex Gray in India*, **NeBIO, 8**(2), 2018, pp. 124-129.

[17] V. De Cauwer, B. Muys, R. Revermann, A. Trabucco, *Potential, realised, future distribution and environmental suitability for Pterocarpus angolensis DC in southern Africa*. Forest **Ecology and Management, 315,** 2014, pp. 211–226.

[18] A. Marcer, L. Saez, R. Molowny-Horas, X. Pons, J. Pino, *Using species distribution modelling to disentangle realised versus potential distributions for rare species conservation*, **Biological Conservation, 166,** 2013, pp. 221-230.

[19] R. Idohou, A.E. Assogbadjo, R.G. Kakaï, A.T. Peterson, *Spatio-temporal dynamic of suitable areas for species conservation in West Africa: eight economically important wild palms under present and future climates*, **Agroforestry Systems, 90**(3), 2016, pp. 1-13.

[20] C.A. Marchioro, K.L. Santos, A. Siminski, *Present and future of the critically endangered Araucaria angustifolia due to climate change and habitat loss*, **Forestry, 00,** 2019, pp. 1-10.

[21] H. Abrha, E. Birhane, H. Hagos, A. Manaye, *Predicting suitable habitats of endangered Juniperus procera tree under climate change in Northern Ethiopia*, **Journal of Sustainable Forestry, 37**(8), 2018, pp. 842-853.

[22] J. Elith, C.H. Graham, R.P. Anderson, M. Dudik, S. Ferrier, A. Guisan, R.J. Hijmans, F. Huettmann, J.R. Leathwick, A. Lehmann, J. Li, L.G. Lohmann, B.A. Loiselle, G. Manion, C. Moritz, M. Nakamura, Y. Nakazawa, J.M.M. Overton, A.T. Peterson, S.J. Phillips, K. Richardson, R. Scachetti-Pereira, R.E. Schapire, J. Soberon, S. Williams, M.S. Wisz, N.E. Zimmermann, *Novel methods improve prediction of species' distributions from occurrence data*, **Ecography, 29**(2), 2006, pp. 129-151.

[23] S.J. Phillips, R.P. Anderson, R.E. Schapire, *Maximum Entropy modeling of species geographic distributions*, **Ecological Modelling, 190,** 2006, pp. 231-259.

[24] D.P. Junior, C.C. Nobrega, *Evaluating collinearity effects on species distribution models: An approach based on virtual species simulation*, **PLoS ONE, 13**(9), 2018, Article Number: e0202403.

[25] R.A. Baldwin, *Use of Maximum Entropy modeling in wildlife research*, **Entropy, 11,** 2009, pp. 854-866.

[26] A.C. Sanchez, P.E. Osborne, N. Haq, *Identifying the Global Potential for Baobab Tree Cultivation using Ecological Niche Modelling*, **Agroforestry Systems, 80,** 2010, pp. 191-201.

[27] F. Noulekoun, S. Chude, A. Zenebe, E. Birhane, *Climate Change Impacts on Faidherbia albida (Delile) A. Chev. Distribution in Dry Lands of Ethiopia*, **African Journal of Ecology, 55,** 2016, pp. 233-243.

[28] M.M. Vale, T.V. Souza, M.A.S. Alves, R. Crouzeilles, *Planning protected areas network that are relevant today and under future climate change is possible: the case of Atlantic Forest endemic birds*, **PeerJ, 6,** 2018, pp. 1-20.

[29] G.A. Nigus**, *The impact of climate change on rural livelihood and their adaptation methods: the case of Alamata Woreda, Southern Tigray***, **Master Thesis** of Arts, Addis Ababa University., Addis Ababa, 2011, p.91

[30] F. Tonini, G. Jona, H.H. Hochmair, *Mapping return levels of absolute NDVI variations for the assessment of drought risk in Ethiopia*. **International Journal of Applied Earth Observations and Geoinformation, 18,** 2012, pp. 564-572.

[31] A. Yirgu, B. Manjur, A. Haile, T. Girmay, D. Getnet, A. Gezahgne, E. Guilbert, *Leaf Defoliators associated with Cordia Africana Lam. in Ethiopia*, **African Entomology, 25**(1), 2017, pp. 108-112.

[32] S.T. Gebreegziabher, ***Cordia Africana* (Lam.) Fruit and its Uses**, Doctoral thesis, Norwegian University of Life Sciences., Norway, 2014, p.138.

[33] * * *, **Woody Biomass Inventory and Strategic Planning Project Phase 2, Final Report**, Ministry of Agriculture, Federal Democratic Republic of Ethiopia, MA., Addis Ababa, 2004, p.185

[34] R.J. Hijmans, C.H. Graham, *The ability of climate envelope models to predict the effect of climate change on species distributions*, **Global Change Biology, 12,** 2006, pp. 1-10.

[35] J. Watling, S.S. Romanach, D.N. Bucklin, C. Speroterra, L.A. Brandt, L.G. Pearlstine, F.G. Mazzotti, *Do bioclimate variables improve performance of climate envelope models?* **Ecological Modeling, 246,** 2012, pp. 79-85.

[36] M. Kebede, E. Yirdaw, O. Luukkanen, M. Lemenih, *Plant community analysis and effect of environmental factors on the diversity of woody species in the moist Afromontane forest of Wondo Genet, South Central Ethiopia*, **Biodiversity Research and Conservation, 29**(1), 2013, pp. 63-80.

[37] Y. Tang, J.A. Liu, Y. Zhang, A. Wina, J.A. Winkler, X. Zhang, X. Li, F. Wang, J. Zhang, Z. Zhao, *Uncertainty of future projections of species distributions in mountainous regions*, **PLoS ONE 13**(1), 2018, Article Number: e0189496.

[38] H. Shiferaw, A. Gebremedhin, T. Gebretsadkan, A. Zenebe, *Modelling hydrological response under climate change scenarios using SWAT model: the case of Ilala watershed*, **Northern Ethiopia, Modeling Earth Systems and Environment, 4,** 2018, pp. 1-13.

[39] X. Xu, H. Zhang, J. Yue, T. Xie, Y. Xu, Y. Tian, *Predicting Shifts in the Suitable Climatic Distribution of Walnut (Juglans regia L.) in China : Maximum Entropy Model Paves the Way to Forest Management*, **Forests, 9**(3), 2018, Article Number: 103.

[40] M.B. Araujo, D. Alagador, M. Cabeza, D. Nogues-Bravo, W. Thuiller, *Climate change threatens European conservation areas*, **Ecology Letters, 14**(5), 2011, pp. 484-492.

[41] I.K. Dawson, S. Carsan, S. Franzel, R. Kindt, L. Graudal, C. Orwa, R. Jamnadass, *Agroforestry, livestock, fodder production and climate change adaptation and mitigation in East Africa: Issues and options*, **ICRAF Working,** Paper No. 178, Nairobi, World Agroforestry Centre, 2014, p.178.

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