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DEPARTMENT OF NATURAL RESOURCES

THE IMPACT OF CLIMATECHANGE ON THE NATURAL RANGE OF *FAIDHERBIA ALBIDA*

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MAY 223

DECLARATION

The undersigned attest that they have reviewed and approved this research project for marking in accordance with the department's standards and regulations.

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Date……………………

Supervisor

Signature…………………………..

Date……………………………

DEDICATION

This study project is centered on myself and my family.

ACKNOWLEDGEMENTS

I greatly appreciate the help and guidance provided by Prof. L. Jimu, who served as my supervisor for the entirety of my studies.

I also want to express my gratitude to my family and friends for their unflagging love and support during the research. I am most thankful to God Almighty for giving me knowledge, understanding, and revelation throughout my studies.

ABSTRACT

In Africa, trees both inside and outside of forests help to ensure food security and rocketing soil richness in the face of climatic change and fluctuations. As a part of farming livelihoods, they additionally offer social and environmental benefits. In various regions of Africa, distinct ecological and socioeconomic circumstances have given rise to particular types of agroforestry. The effectiveness of global programs on addressing climate change adaptation and mitigation can be increased by explicitly include agroforestry and integrating agriculture and forestry objectives. For the contributions to this special issue, we highlight the significance of *F. albida* in curbing food insecurity and soil infertility through agroforestry. Climate change is now a major environmental concern at a global level, impacting the distribution and composition of species. By anticipating the spread of various species, climate change models have evolved into a crucial tool for guiding biodiversity protection. Finding out how climate change is affecting *F. albida* in Southern Africa was the aim of this study. The maximum Entropy (MaxEnt) method of the R programming language was used to predict how widely spread will *F. albida* be in Southern Africa. 19 bioclimatic variables and 278 occurrence reports were used to simulate the species' range. Two Representative Concentration Pathways (RCPs), namelyRCP_8.5 and RCP_2.6, were used to forecast distributions for the years 25 and 27. The current protrusion shown a reduction in the range of *F. albida* and the potential for occurrence outside the area of current existence was above .2. Under two climatic scenarios, the future ecological niche models for *F. albida* predicted considerable changes in the current suitability. All of the scenarios showed a significant range reduction, demonstrating that climate change has a significant effect on the survival of *F. albida*, with the eventual loss of biodiversity as a result. *F. albida* is one of the well-known species whose extinction is foreseen by hard climatic circumstances in accordance with our findings, particularly under the intense scenario (RCP_8.5). Continuous monitoring in this area is necessary to ascertain the size of *F. albida's* range since the predicted suitability regions in this study can help in assessing the conservation status of tree species at a regional level.

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LIST OF ACRONYMS AND ABBREVIATIONS

AUC	Area Under the Curve
BIO	Bioclimatic variable
CA	Conservation Agriculture
BIODIVERSITY	Biological Diversity
CO_2	Carbon dioxide
CH_4	Methane
FAO	Food and Agriculture Organization
GBIF	Global Biodiversity Information Facility
IPCC	Intergovernmental Panel on Climate Change
MaxEnt	Maximum Entropy
N_2O	Nitrous Oxide
RCP	Representative Concentration Pathway
SO_2	Sulfur dioxide
SOM	Soil Organic Matter
%	Percent
°C	Degrees Celsius

CHAPTER 1

INTRODUCTION

1.1 Background to the Study

In Sub-Saharan Africa (SSA), soil nutrient mining is viewed as a significant threat to food security and the preservation of natural resources in Southern Africa (Bationo et al., 2006) and the consequent downward spiral of soil fertility has contributed to corresponding decline in crop yields, an increase in food insecurity, food aid and environmental degradation (Mafongoya et al., 2006). Small-scale farmers have been depleting their soils of nutrients for decades without using enough manure or fertilizer to restore the soil. In 37 African countries over the past 3 years, farmed land has a very high average yearly depletion rate of 22 kg of nitrogen (N), 2.5 kg of phosphorous (P), and15 kg of potassium (K), which is equivalent to a loss of $4 billion in fertilizer per year (Lynamet al., 1998). Southern Africa is also experiencing higher temperatures, which is leading to a higher evaporative demand, especially in dry circumstances and if the soil is sufficiently moist, as it is in irrigated areas, poor farm or land water management, irrigation planning, or drainage practices could result in salinization of the soil (Bowman and Strain, 1987). Food security is becoming more and more problematic over time as a result of soil infertility, shifting supply and demand, a growing population, a changing climate, and other environmental issues (Misselhorn et al., 2012). For a country, community, or individual to have food security, they must always have access to enough nutritive food to keep up with an active and healthy lifestyle (FAO, 2009). Without fertile soil, nutritive food will be much harder to produce into the near future, thus, food insecurity (Cordell, 2009).

However, in order to reduce soil infertility and food insecurity, Agroforestry, also known as fertilizer tree systems, is a dynamic, ecologically based natural resources management system that integrates trees into farmland and rangeland to diversify and sustain production for greater social, economic, and environmental benefits for land users at all levels. It has been proposed as a solution to reduce nutrient mining in soils (Leakey, 1996). It is influenced by a variety of management objectives, motivators, and environmental conditions.

Assets associated to ecosystem services and food security are typically the primary driving forces behind the adoption of agroforestry (DeSouza and DeGoede, 2012). Agroforestry also perform supportive roles, such as enhancing soil fertility or recycling water especially when management strategies like mulching or conservation agriculture are used (Simelton, 2013). As a result, agroforestry is frequently thought of as a way to use socially and economically advantageous management techniques to sustainably intensify farming activities for increased food security (Sharma, 2016). Numerous agroforestry techniques do this by requiring less external input, reutilizing rates that are high, and crop-livestock synergy. (Altieri 2012). An agroforestry production system based on the acacia species *F. albida* has shown significant promise to supply an energy input by adding nitrogen to various agricultural systems (Haskett, 2019).

A *Faidherbia albida* agroforestry production system effectively absorbs solar energy and transforms it into a nitrogen fertilization input, through symbiotic nitrogen fixation in root nodules (Kessler and Breman, 1991). The proponents of conservation agriculture (CA) assert that incorporating *F. albida* trees into CA systems based on the three principles of minimal tillage, diversified crop rotations, and permanent soil surface cover enhances the benefits of CA for improving the soil because *F. albida* not only fixes nitrogen but also returns other nutrients tithe soil and boosts the amount of soil organic matter (SOM) through the decomposition of its leached nutrient-rich leaves (Andersson and D'Souza, 2014). The enhanced SOM reduces excessive evapo-transpiration and soil temperatures while enhancing soil micro-fauna populations and improving soil structure (Mokgolodi et al., 2011).

Faidherbia albida is a riverine tree native to northern, eastern, and southern Africa that was introduced through pastoralism and agriculture into western Africa, where it was only found on cultivated or previously cultivated land (Figure 2.1). It is thought to have originated in the Sahara before desertification. (Setshogo, 2011). Due to its distinctive "reverse phenology," which is a phenomenon in which the tree enters a physiological dormancy and sheds its nitrogen-rich leaves in the early rainy season when seeds are being planted and need the nutrient, and then regrows them when the dry season starts and the crops are dormant (Ibrahim and Tibin, 23), *F. albida* has been promoted in agroforestry due to the fact that it does not compete with food crops for nutrients or light, it is very compatible with them (Dury, 1991). As soon as the raining season begins, the leaves are lost, drastically reducing the amount of shade the trees provide and the competition for water, light, and nutrients with other crops grown at this time. As a result, crop yields are frequently low. When the rainy season starts, the leaves fall off the trees, significantly reducing the amount of shade they cast and the competition they face for water, light, and nutrients with other crops that are cultivated during this time. Crop yields are usually raised as a result, which adds to the species' appeal to farmers (Wahl and Bland, 2013). In fact, a large body of research has linked F. albida to appreciable yield gains in a variety of crops, including maize, millet, sorghum, and peanuts (Barnes and Fagg, 2003). The effects of *F. albida* were observed to increase barley yields in Tigray, Ethiopia (Hadgu et al. 2009). When these trees were present, maize yields in Malawi increased by 28% (Saka et al., 1994). When cultivated with *F. albida*, maize, soybean, and groundnut yields all showed consistent increases, but cotton yields showed a concomitant decline (Shitumbanuma, 2012). The tree supplies a lot of pods and leaves for animal feed all year long because of its phenology. Animals are said to eat the dried pods and leaves, which contain an average of 12%–4% crude protein and 42%–65% nitrogen free extract (Wilson, 1990). But because climate change is a complicated phenomenon with unpredictable effects on plant species, including temperature, rainfall patterns, and extreme weather events, *F. albida* is probably going to be impacted (Brandt and Romankiewicz, 2014). Millions of people's livelihoods, agricultural productivity, food security, and other aspects of life are already significantly impacted by climate change in Africa and according to the Intergovernmental Panel on Climate Change (IPCC), the continent is expected to experience further increases in temperature, changes in precipitation patterns, and more frequent and intense extreme weather events in the coming decades (McCarthy and Canziani, 2001) and these changes will have significant impacts on *F. albida*. Temperatures a critical factor that influences the growth and distribution of plant species (Zhao, 2018). *F. albida* is a heat-tolerant species, and it can grow in areas with mean annual temperatures of up to 3°C but as temperatures continue to rise due to climate change, the species may face challenges in areas where temperatures exceed its tolerance levels and this may reduce the germination rate of *F. albid*a seeds, which can reduce the species' ability to regenerate in some areas (Georgis, 2001). Rainfall is another vital factor that determines the distribution of plant species, and changes in precipitation patterns can have significant impacts on plant growth and survival. *F. albida* is a drought-tolerant species that can survive in areas with low rainfall (Vandenbeldt, 1992). However, as climate change causes shifts in rainfall patterns, the species may face challenges in areas where rainfall is decreasing or becoming more erratic, for example, in areas where droughts become more frequent, the species may experience reduced growth rates, reduced seed production, and increased mortality (Beier, 2012). Extreme weather events such as floods, storms, and wildfires can have significant impacts on plant species. *Faidherbia albida* is vulnerable to these events, especially when they occur during the seedling and juvenile stages, for example, in the event of a flood, water can wash away seeds and seedlings, reducing the species' ability to regenerate increase its ability to regenerate somewhere (Diez, 2012). Storms and wildfires can also damage mature trees, reducing their ability to fix nitrogen and provide other ecosystem services (D'Antonio, 2012).

1.2 Problem statement

The majority of studies have highlighted the value of *F. albida* as an agroforestry because it contributes to the social and environmental well-being of farmers, but research on the tree species conducted in Sub-Saharan Africa has not yet provided sufficient insight into how climate change will affect *F. albida's* future distribution in Africa. There is currently little to no information on how climate change will alter its environmental requirements and distribution.

1.3 Justification of study

Faidherbia albida's use in agroforestry sub Saharan African countries has motivated the need to generate knowledge on the connection of the species' ecological niche and climate change so as to conserve the species. The species is a solution to soil nutrient mining which reduces food insecurity worldwide, so the knowledge of the effects of climate change on *F.albida* is important in the conservation of the species and to support future management decisions.

1.4 Aim of the study

The aim of the study is to project the impacts of climate change on *F. albida* in its natural range of sub-Saharan African.

1.5 Objectives of the Study

To determine the current suitability of *F. albida.*

To determine the impacts of climate change on of *F. albida.*

To determine the factors that affect the distribution of *F. albida*.

1.6 Research questions

What is the current suitability of *F. albida?*

What are the impacts of climate change on *F. albida?*

What are the factors that affect the distribution of *F. albida?*

CHAPTER 2

LITERATURE REVIEW

2.1 Importance of *F. albida* as a Native Agroforestry species

In order to raise agricultural yields and improve soil fertility, farmers in various parts of Africa are increasingly caring for naturally occurring *F. albida* trees on and around their farmland. This particular kind of tree has a unique phenology in that it loses its leaves in the wet season and retains them in the dry. During the crop's growing season, it seldom faces competition for light and water. When a tree's leaves are integrated into the soil, it also fixes nitrogen and supplies other nutrients to a crop (Rao et al. 1998).Through symbiotic nitrogen fixation in root nodules, an *F. albida* agroforestry production system turns solar energy into a nitrogen fertilization input.

In Malawi, the advantages of farming beneath *F. albida* trees are well acknowledged and esteemed (Sake et al. 1990). Crop yields are better understood in the shade of the trees. The trees serve as a fence, a source of fuel, and a supply of food for the cattle. According to Costanza et al. (1997), Daily (1997), and MEA (2003), the presence of *F. albida* within the conventional smallholder farming system provides ecosystem services like food production, climatic management, nutrient cycling, soil conservation, and supports services like biodiversity conservation. Ethiopian farmers often use the manure of animals fed *F. albida* leaves as fertilizer, according to Tekalign et al. (1991).

Faidherbia albida is adapted to dry regions like those in the Sahel, therefore employing this plant in agroforestry considerably increases maize yields, creating a clear connection between this tree-based energy input and increased food security (Haskett et al., 2019). It was also found that *F. albida* tree canopies could promote food security and lower the risk of crop failure on the fields of resource-poor smallholder farmers, particularly during drought years, in Zambia, where maize is grown (Yengwe et al., 2018a). Similar results have been achieved using the plant material from *F. albida* as a fertilizer for maize in Nigeria (Chinke et al., 2022).

2.2 Threats to *F.albida*

Due to its many advantages, such as its ability to withstand harsh environmental conditions, store carbon, improve soil, and conserve biodiversity, *F.albida* is a highly valued tree species in Africa but, however, the tree also faces numerous threats that could have an effect on its development and survival (Sharma and Bohra, 2016). One of the biggest risks to *F. albida* is land use change and some examples that have led to deforestation, the degradation of forests and woodlands, and the loss of habitat for tree species include agricultural expansion, urbanization, urban expansion, and industrialization (Gupta and Daga, 2002). Large-scale commercial agricultural and mining operations have occasionally resulted in the total eradication of *F. albida* stands (Seely and Henderson, 2003).

Another serious threat to *F. albida* is livestock overgrazing. The tree is a useful source of fodder for animals, and in regions with heavy grazing pressure, its growth can be drastically decreased, which can cause *albida* stands to deteriorate and eventually disappear (Wickens, 1995) Another major hazard to the species is the unsustainable harvesting *of F. albida* for use as fuel wood, lumber, and other purposes (Fagg and Stewart, 1994). The population of the tree has decreased as a result of overharvesting, and in some places, it is in danger of going extinct (Hegazy and Hosni, 2002). The health and regeneration of *F. albida* may be negatively impacted for a long time by the use of unsustainable harvesting techniques, such as the removal of bark or the chopping of entire trees (Noulekoun, 2017).

Faidherbia albida is susceptible to various pests and diseases that could impact its growth and survival, for example, stem borers, leaf-eating caterpillars, and termites are known to cause significant damage to the tree and in some cases, the infestation can be severe enough to lead to the death of the tree (National Research Council, 22). Despite the numerous benefits of *F. albida*, the species often receives little attention from policymakers and stakeholders. The lack of awareness and support for the tree could limit its conservation efforts, leading to a decline in its population. While *F. albida* has shown resilience to harsh environmental conditions, climate change could still pose a threat to the species. Changes in temperature and rainfall patterns could alter the tree's growth and distribution, leading to a decline in its population. Additionally, climate change could also increase the incidence forests and diseases, which could negatively impact *F. albida's* growth and survival.

2.3 Impact of climate change on *F. albida*

Climate change's effects on various plant species depend on a number of factors, including temperature, rainfall patterns, and the frequency of extreme weather events. Millions of people's livelihoods, agricultural output, and food security are already being negatively impacted by climate change in Africa. According to the Intergovernmental Panel on Climate Change (IPCC), the continent is expected to continue warming, experience changes in precipitation patterns, and experience more frequent and severe extreme weather events in the next decades.

Temperature has a significant impact on the growth and spread of different plant species. *F. albida* may thrive in regions with mean annual temperatures as high as 3°C because it is a heat-tolerant species (Tirado, 2001). Climate change may make it difficult for the species to repopulate in some areas when temperatures are over its tolerance thresholds, which may result in fewer *F. albida* seeds germinating on a regular basis (Teketay, 1996). The growth and survival of plants can be significantly impacted by changes in precipitation patterns. The distribution of many plant species is significantly influenced by rainfall (Hulme, 2009). However, as a result of changes in rainfall patterns brought on by climate change, the species may have difficulties in regions where rainfall is declining or becoming more irregular (Woodall, 2016). For instance, the species may face slower growth rates, less seed output, and more mortality in regions where droughts are more common (Clark, 2016).

Extreme weather events such as floods, storms, and wildfires can have significant impacts on plant species. *F. albida* is vulnerable to these events, especially when they occur during the seedling and juvenile stages (Hughes, 1994). Floods, for example, can wash away seeds and seedlings, reducing the species' ability to regenerate. Storms and wildfires can also damage mature trees, reducing their ability to fix nitrogen and provide other ecosystem services.

2.4 Factors that affect the distribution of *F. albida*

Faidherbia albida frequently grows close to water sources, including along rivers and lakes as well as in gullies and ravines (Wood, 1992). All of these situations have alluvial or hydromorphic soils as a rule. It can also be found on dunes of stabilized sand. In western Africa, it grows on darker, deeper sand or silt soils, however lateritic soils with a shallow pan are also infrequently encountered. It can grow in soils with high levels of acidity and is adaptable to low fertility soils (Wickens, 1998).

F. albida can grow at different altitudes, but is most suited to low to medium altitudes (Frederick, 2019). Human activities such as deforestation, land-use changes, and overgrazing can affect the distribution of *F. albida* (Ibrahim, 2018). The tree is often cut down for timber, firewood, and charcoal, which reduces its population (Balzter, 2018). *F. albida* distribution is also often limited by the availability of water. It is commonly found along riverbanks and other areas with access to water (Roupsard, 1999). It does not store moisture but is effective at acquiring water for transpiration, as plainly evidenced by the strength of its vegetative growth during the dry season, when there hasn't been a drop of rain, when temperatures are high, humidity is low, and evapotranspiration is at its highest (Wood, 1992). To achieve this, its root system has a taproot that grows very rapidly and will reach the water table if it is within range; depths of about 4 m have been recorded (Lemaitre 1954). *F. albida* relies on animals such as elephants and baboons for seed dispersal. The distribution of the tree is affected by the availability and movements of these animals.

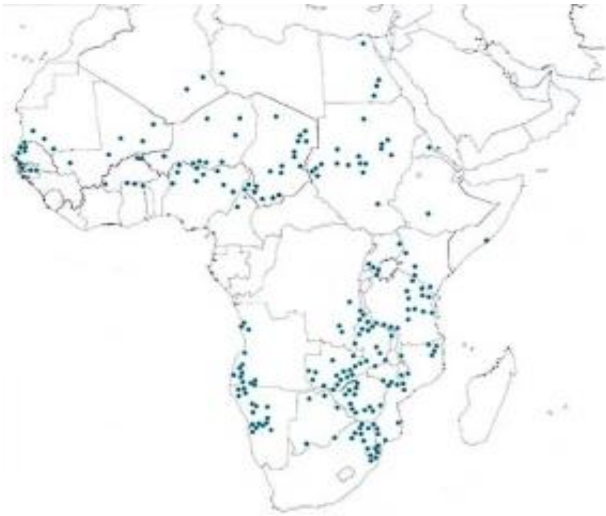

Figure 2.1: Showing distribution of *F.albida* in Africa.

CHAPTER 3

MATERIALS AND METHODS

3.1 Occurrence Data Acquisition

The Global Biodiversity Information Facility (GBIF) database provided the data on where F. albida has been found. The information on the prevalence of the studied species that was used in the Ecological Niche Modeling was gathered from 55 published datasets with 1,265 records that were accessible in the Global Biodiversity Information Facility (GBIF, http://gbif.org). Continent, location, and specie filters in GBIF were used. Three columns species, latitude, and longitude were added after the data removing excess information, which had originally been an Excel sheet, was received by email. To facilitate entry into R, the file was saved as a.csv.

3.2 Climate Change Models and Environmental Data

Bioclimatic variables were used to identify environmental factors affecting the distribution of *F. albida* across its whole range. The projected carbon dioxide concentrations for the years 25 (average estimates for 2041-2060) and 2070 (average estimates for 261-28) were calculated using the minimum and highest emission representative concentration scenarios (RCP_2.6 and RCP_8.5). We downloaded 2.5 arc-minute-resolution bioclimatic data from WorldClim for the recent and upcoming years.

Using total radioactive forcing values of 2.6, 4.5, 6and 8.5 watt/m2, the IPCC created four representative concentration scenarios (RCPs) (Mudereri et al., 2002). We used the most severe climate change scenario (RCP_8.5), which predicts that greenhouse gas emissions will increase until the year 21, along with RCP_2.6, which is a "very stringent" approach and suggests that CO_2 emissions will decline. RCP 8.5 accurately predicts where we will be in the future if current patterns are merely continued; it matches historical emissions to within 1%. The 21st century will see an increase in emissions. The worst-case climate change scenario model RCP_8.5 was built on an overestimation of expected coal emissions. The IPCC (2007) forecasted that CO_2 emissions would start to decline by 2020 and will be completely eliminated by 21. Additionally, it asks for a reduction in SO2 emissions to around 1% of what they were between 198 and 199 and a reduction in CH4 emissions to almost half of what they were in 22 (Parry and Canziani, 2007).

3.3 Ecological Niche Modelling

Ecological niche modeling was carried out in R v3.6. where library packages including the raster, rgdal, maps, mapdata, dismo, rJava, maptools, and jsonlite were installed. R was used to perform data de-duplication. The getData () function was used to import the bioclimatic variables (bio1, bio2, bio3, bio4, bio5,bi6, bio7,bio8, bio9, bio1, bio11, bio 12, bio13,bio14, bio15, bio16, bio18, bio19) directly into R (McIntosh et al.,2022).

Table 3.1: Environmental variables used to foresee *F. albida* distribution in Africa

Bioclimatic variable	Code Description
BIO1	Annual Mean Temperature
BIO2	Mean Diurnal Range(Mean of monthly (max temp-min temp)
BIO3	Isothermality(BIO2/BIO7) (×1)
BIO4	Temperature Seasonality
BIO5	Max Temperature of Warmest Month
BIO6	Min Temperature of Coldest Month
BIO7	Temperature Annual Range (BIO5-BIO6)
BIO8	Mean Temperature fittest Quarter
BIO9	Mean Temperature of Driest Quarter
BIO1	Mean Temperature of Warmest Quarter
BIO11	Mean Temperature of Coldest Quarter
BIO12	Annual Precipitation
BIO13	Precipitation of Wettest Month
BIO14	Precipitation of Driest Month
BIO15	Precipitation Seasonality(Coefficient of Variation)
BIO16	Precipitation of Wettest Quarter
BIO17	Precipitation of Driest Quarter
BIO18	Precipitation of Warmest Quarter
BIO19	Precipitation of Coldest Quarter

CHAPTER 4

RESULTS

4.1 Predicted Suitability of *F. albida*

The predicted suitability model for *F. albida* shows that habitats for the tree species are compatible and the species occurrence are confined to areas within the range above .2 which shows that the conditions in those areas can accommodate the species' environmental tolerance

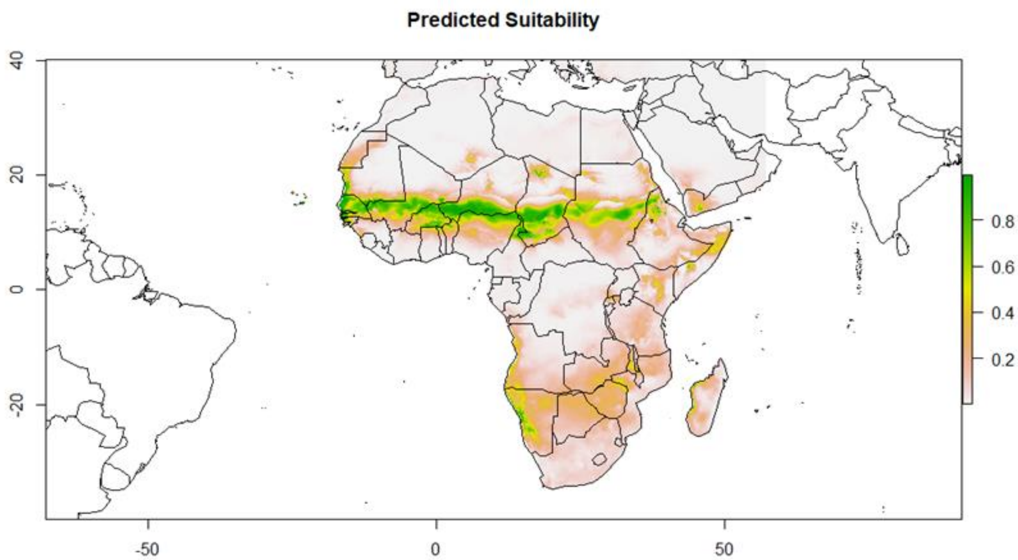

Figure 4.1: Predicted Suitability of *F. albida*

4.2 Future Suitability of *F. Albida*

The future ecological niche models for *Fra albida* of the 2 climatic scenarios, predicted significant changes in the current suitability. The models (RCP_2.6and RCP_8.5) when projected to 2050 and 2070, all presented a restrictive and contraction of the area suitable for *F. albida* (Figs 4.2 & 4.3).

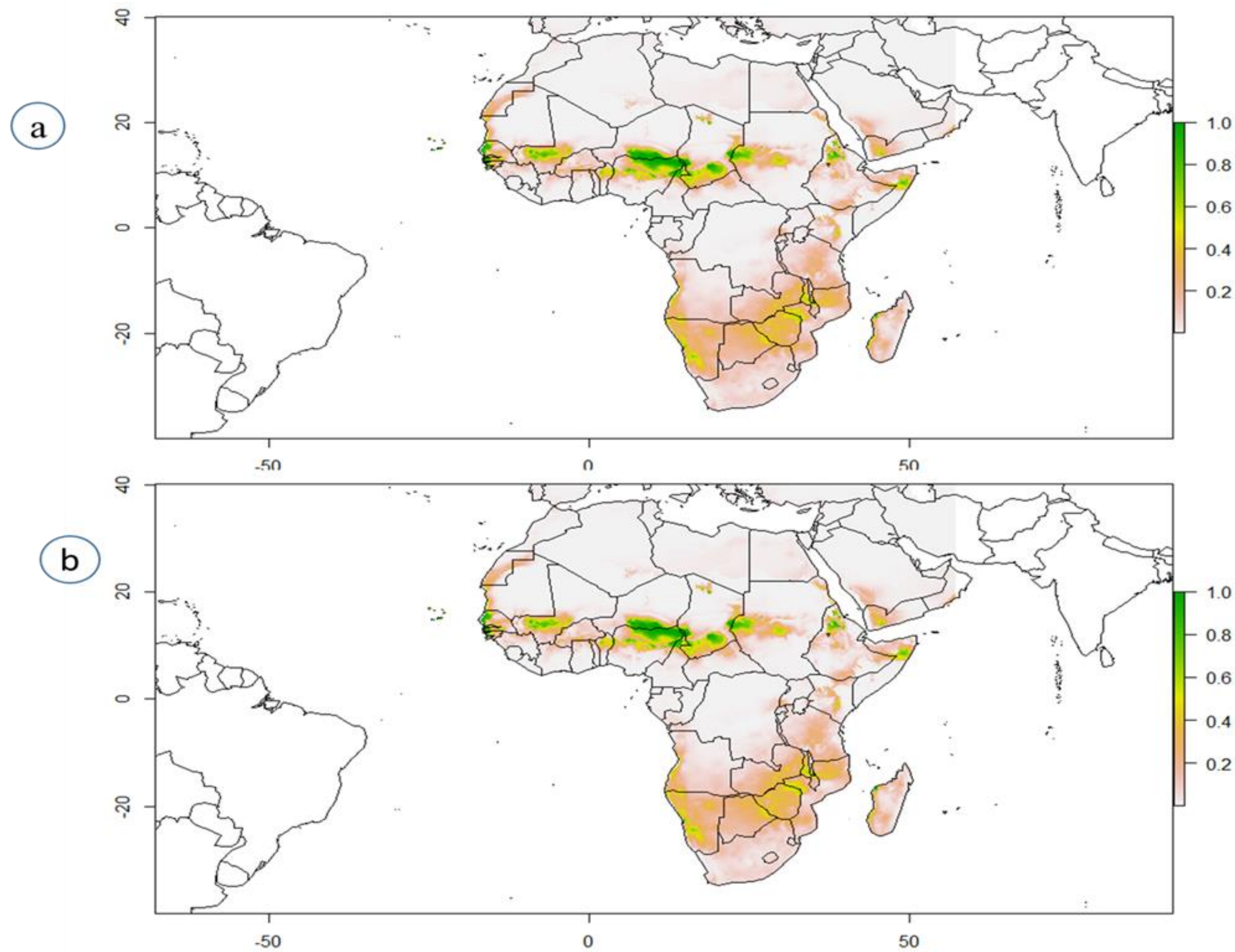

Figure 4. 2: Future suitability *F. albida* under RCP2.6 2050(a) and RCP 8.5 2050 (b)

In a comparison to the predicted distribution with projected future distribution, there is decline in niche suitability in territories like Sudan, Ethiopia, Namibia and Senegal for both 2050 and 2070 under RCP_2.6. A shrink in the ecological niche of F. albida was observed for both RCP_2.6 2050 and RCP_2.6 2070. Both scenarios under RCP_2.6 have showed same results in the changes of the ecological niche compared to the predicted suitability of *F. albida*. RCP 2.6 2050 and 2070 showed that the suitability area will slightly expand towards Zimbabwe and Mozambique where it was not suitable before where its suitability range was slightly above .4.

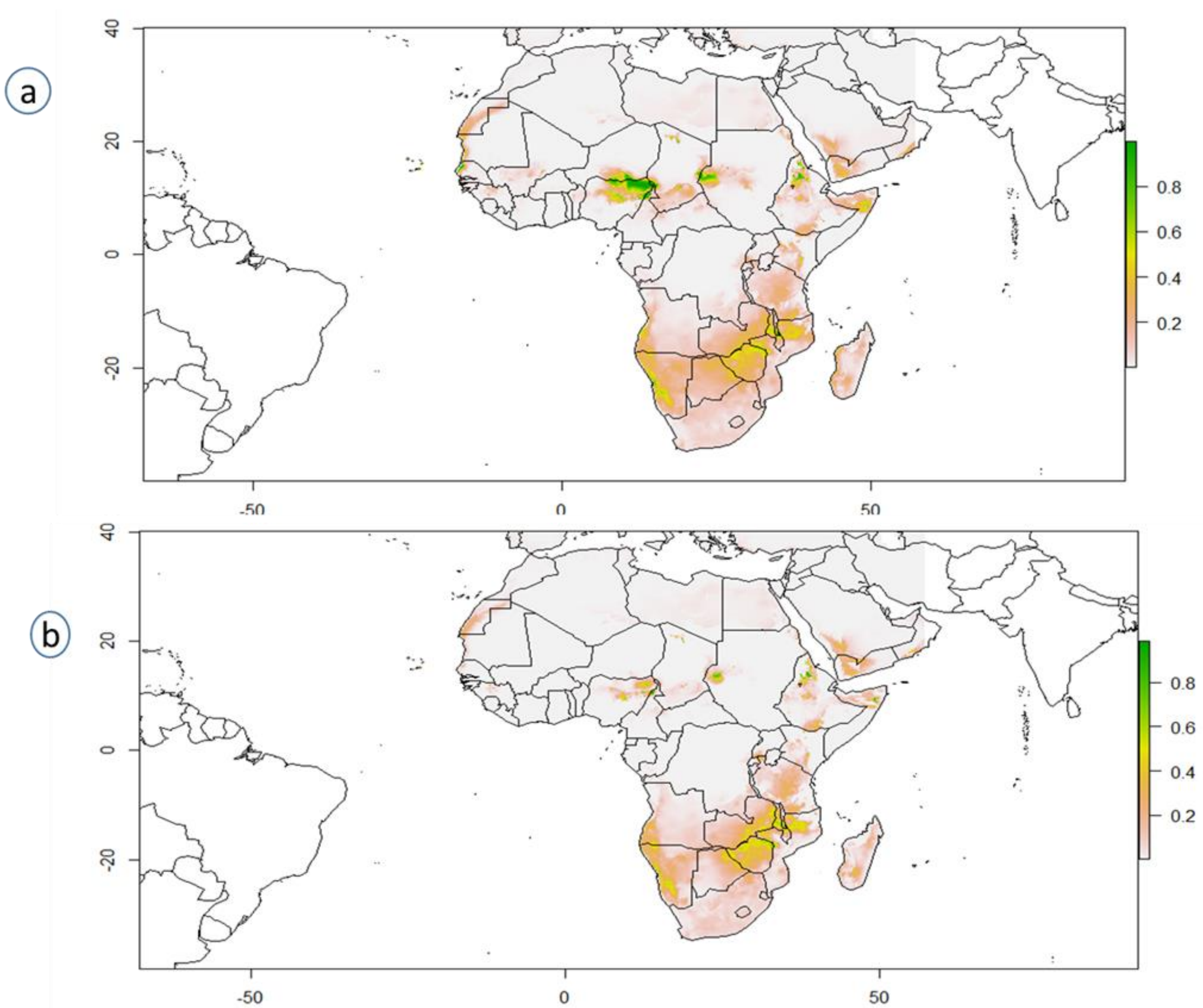

Figure 4.3: Future suitability of *F. albida* under RCP 8.5 2050 (a) and 2070 (b).

The niche suitability for *F. albida* was observed to have further shrank in the years 2050 and 2070 under RCP 8.5with the species covering an extensive range in 2050 than in 2070. The suitability zones contracted or shrank across central Africa, all the way to West Africa, covering partial territories like Northern Ethiopia and West Sudan that had been inhabited before. The two models revealed that by 2050 and 2070 the suitability of *F. albida* for Northern Zimbabwe, Northern Nigeria and Southern Namibia will remain at a suitability range between .2 and .6 by 2050 and 2070..

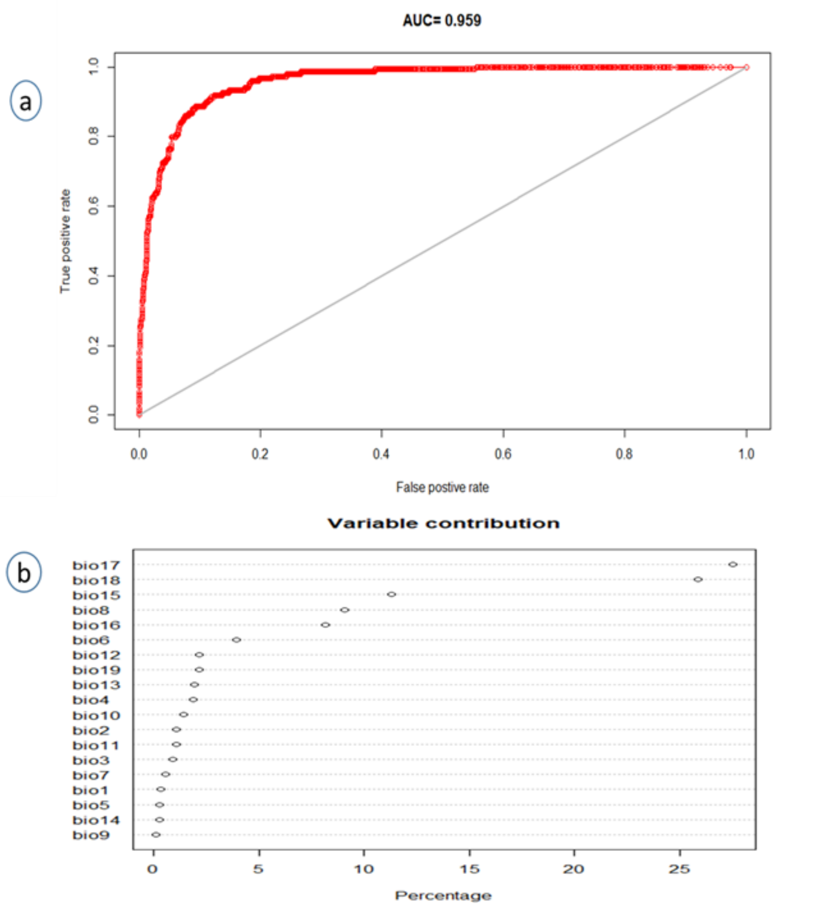

Figure 4.4: Confidence level to future projections of *F. albida* (a) and percentage contribution of bioclimatic variables to future projections of *F. albida.* (b).

The results portrayed a strong correlation between bioclimatic variables and future distribution of *F. albida*, the results displayed an Area Under the Curve (AUC) value of 0.959 (Fig 4.4 a). It was observed that the dominant variable was annual precipitation (bio 17) which had 28% influence on the four scenarios (RCP_2.6 2050 &2070 and RCP_8.5 2050 & 2070), followed by precipitation of warmest quarter (bio 18) with a 25% influence.

CHAPTER 5

DISCUSSION

Ecological niche modelling showed a negative correlation between present suitability results and future suitability of *F. albida* because of limitations linked to environmental conditions. However, the actual occurrence of *F. albida* could be determined by the local environment, the surrounding anthropogenic conditions and the combined effects of land use and climate change (Garcia-Valdés et al., 2015; Wang et al., 2019). Thus, it is anticipated that future climatic and land-use changes will significantly alter the ranges of plant species, increasing the rate of extinction. The availability and suitability of habitat can be restricted by the composition and structure of the landscape (Faring et al., 2003; Zhang et al., 2017; Wang et al., 2019).

The outcome from this study demonstrated a shrink in the region under RCP_2.6 as minimum temperatures and low precipitation currently considered to be limiting factors will be increasing. Temperature is projected to remain at 1.5°C-2°C towards the year 2050 (Pachauri, 2014). Evidence shows that by 2050, using RCP_2.6, threatened species will decrease or remain constant as emissions of CO2, CH4 and N2O are mitigated. The results show no change in habitat expansion but a slight fragmentation under RCP_2.6 2070. A movement toward sparser vegetation has been brought about by the anthropogenic forces connected to changes inland use and land cover (such as fire, wood extraction, the introduction of animals, and agricultural activities) may also decrease the expansion of the species (Romeiras et al., 2016). The habitat for *F. albida* is projected to further decrease under the extreme carbon emission scenario (RCP_8.5). Scholarly evidence suggests that suitable habitats will become scarce in the future as climate change impacts increase in severity and intensity, thereby threatening species population (Jinga and Ashley, 2019). Some species will expand while others contract. *F.albida's* range will shrink as increasing temperature and precipitation will decrease opportunities for its occurrence. Similar results were also found on *Leucaena leucocephala* by Maxwell. C. Obiakara in April 2023. *F.albida* is a heat-tolerant species, and it can grow in areas with mean annual temperatures of up to 30°C but it will face challenges in areas where temperatures will exceed its tolerance levels.

The model proved good at replicating *F. albida* likely future habitat, as shown by the training data's Area Under the Curve (AUC) value, which was more than .9 (Figure 4.4(a)). Therefore, it is safe to rely on the study's main conclusions and results. Our findings demonstrated that identifying the ideal habitat *for F. albida* depended mostly on the variables linked to temperature (Bio2, Bio3 & Bio9) and precipitation (Bio17 and Bio18) (Fig. 4.4(b)). For *F. albida*, which can withstand high temperatures and precipitation (Global & Report, 2006), temperature and precipitation have an impact on range availability and size.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

There is a very high likelihood that climate change will pose a threat to tree species in Africa that are declining at a rapid rate. The results of this research in Africa, which represent changes in the available favorable habitat under various climatic scenarios, show that *F. albida* is one of the species whose distribution is likely tube impacted by climatic changes. One of the species predicted to worsen and be at risk from climate change, under RCP_2.6, and further decline under the extreme scenario (RCP_8.5), according to our analysis, is *F.albida.* According to current and future forecasts (both RCP_2.6 and 8.5) for the years 2050 and 2070, the expected distribution of the species indicates range decline, demonstrating that this species is at significant risk.

6.2 RECOMMENDATIONS

The predicted suitability areas in this research can help in assessing the conservation means of tree species at national and regional level. The results of this study can be utilized to choose the best locations for regeneration experiments. The methodology used in this study can also be applied to identify suitable habitats and develop plans and mechanisms for the conservation of the local tree species. A continuous assessment and monitoring in this field should be practiced to determine the range size of the tree species for natural resources evaluation, especially coming up with inventory list of threatened species.

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