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IMPACT OF CLIMATE CHANGE ON HABITAT SUITABILIYT AND DISTRIBUTION OF ADANSONIA DIGITATA, TAMARINDUS INDICA AND SCLEROCAYRA BIRREA IN ZIMBABWE.

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DECLARATION

I, CHANTEL ZIMBIZI hereby declare that the work presented in this Research Project titled 'Impacts of climate change on habitat suitability and distribution of Adansonia digitata, Tamarindus indica and Sclerocarya fruit trees in Zimbabwe' is my own work undertaken in partial fulfillment of the requirements of the Bachelor's Honors Degree in Natural Resources Management under the Faculty of Agriculture and Environmental Science. I confirm that this research project has not been submitted anywhere else for academic credit by myself or any other person. All sources of information, data or ideas drawn from other works have been properly acknowledged and cited according to academic standards. I understand what plagiarism implies and declare that this Research contains my own ideas, words and results except where reference is explicitly made to another's work. I further understand that any unethical academic behavior which includes plagiarism is seen as an offense by BINDURA UNIVERSITY OF SCIENCE EDUCATION and is a punishable offense.

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DEDICATION

I dedicate this Research project to my family for all their support and love.

LIST OF ACRONYMS AND ABBREVIATIONS

AGRITEX	Department of Agriculture, Technical and Extension **Services**
CSV	Command Separated Values
GBIF	Global Biodiversity Information Facility
FAO	Food Agricultural Organization
MaxEnt	Maximum Entropy
NBAZ	National Biotechnology Authority of Zimbabwe
NGO	Non-Governmental Organization
IUCN	International Union of Conservation for Nature
SDM	Species Distribution Modelling
USD	United States Dollar

ABSTRACT

This study explores the impact of climate change on the distribution and habitat suitability of three key indigenous fruit tree species found in the low veld of Zimbabwe which are *Adansonia digitata* (baobab*)*, *Sclerocarya birrea* (marula), and *Tamarindus indica* (tamarind) as climate change has become an escalating environmental concern that significantly influences species distribution. The target species are ecologically, culturally, and economically significant to rural communities, yet their survival is increasingly threatened by shifting climatic conditions, land-use changes, and unsustainable harvesting methods. These tree species are currently classified as 'Least Concern' according to the International Union for Conservation of Nature (IUCN) Red List of Endangered Species, as they are not significantly threatened by habitat degradation or population decline, among others, however, the potential impacts of changing climate on this species remain unaccounted for and require further study. Acquiring knowledge on and understanding how species inhabit their current locations and predicting their future location under various climatic scenarios is a very important part of biodiversity conservation Using Species Distribution Modelling (SDM) techniques in MaxEnt and environmental variables under current and projected climate scenarios (RCP 8.5 for 2050-2070 and 20.80), this research assesses both current habitat suitability and potential future shifts in distribution. Occurrence data were sourced from the Global Biodiversity Information Facility (GBIF), filtered for spatial relevance and processed alongside bioclimatic variables. Results show species-specific responses to climate change. *S. birrea* and *T. indica* are projected to expand their suitable ranges, suggesting high ecological plasticity and potential resilience to warming climates. Conversely, *A. digitata* is expected to lose suitability in its traditional low-veld habitats and shift toward central watershed areas, indicating potential vulnerability to extreme temperature and moisture stress. These findings align with existing literature identifying *A. digitata* as susceptible to regeneration failures under prolonged drought conditions. The study further reveals that natural regeneration of these species is constrained by climatic stress, habitat degradation, limited seed dispersal, and overharvesting driven by commercialization. While the indigenous fruit value chain is expanding, particularly for baobab, marula, and *masawu* the lack of structured cultivation, domestication strategies, and policy frameworks exacerbates species decline. The research concludes that climate change will not affect

all species uniformly. Adaptation strategies are urgently required for effective conservation of indigenous fruit trees.

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CHAPTER 1

INTRODUCTION

1.1 Background to the Study

Climate change has disrupted the phenology of tree species, affecting flowering and fruiting patterns, which in turn impact seed production and germination success. Prolonged droughts, erratic rainfall, and rising temperatures have been observed to reduce fruiting frequency and alter flowering calendars, thereby hindering natural regeneration processes (Matarira et al., 2021; Zhou et al., 2022). It has become one of the most pressing global challenges, threatening ecosystems, biodiversity, and human livelihoods through rising temperatures, shift in rainfall patterns, and an increase in extreme weather events (IPCC, 2021). Forest ecosystems, such as indigenous fruit forests, play an important role in carbon sequestration, water cycling, and supporting livelihoods, yet they still face growing pressure under changing climate (FAO, 2020). Across the African continent, the impacts are extreme as a result of over dependence on rain-fed agriculture and natural resources, with changes in climate causing increased aridity, land degradation, and biodiversity loss (Niang et al., 2014). Indigenous fruit trees such as *Adansonia digitata* (baobab), *Sclerocarya birrea* (*mapfura*), and *Tamarindus indica* (tamarind) are important for improved rural nutrition, cultural practices, and local economies, although their survival is at risk (Shackleton et al., 2017). Despite their significance, these species remain largely undomesticated, and there is a lack of structured harvesting practices or propagation knowledge among local communities (Chivandi et al., 2021). This reliance on natural regeneration, which has become increasingly unreliable under current climatic change and socio-economic conditions, emphasizes the need for integrated conservation initiatives. Such initiatives should highlight climate-resilient agroforestry practices, community education, and institutional support for the domestication and propagation `of key indigenous fruit tree species.

In Zimbabwe, rising temperatures, change in rainfall patterns, and reoccurring of extreme weather events like droughts have aggravated these threats, with target indigenous fruit tree species showing signs of altered regeneration, distribution, and habitat suitability (Mudzengi et al., 2019). In the low veld, specifically the Zambezi Valley the local community heavily depends on indigenous fruit trees for food supply, household income, and ecological services, but climate induced stressors such as erratic rainfall and prolonged dry seasons are threatening their sustainability (Matose et al., 2020). Additionally, overharvesting driven by commercial demand leads to the collection of fruits before seeds fully mature, leaving few to regenerate naturally (Matongorere, 2020). Despite their importance, these species remain largely undomesticated, and there is a lack of structured cultivation practices or propagation knowledge among local communities (Chivandi et al., 2021). Understanding the impacts of climate change on these tree species 'distribution and their habitat suitability is essential for developing local conservation strategies and strengthening community resilience (Maron et al., 2022).

1.2 Problem Statement

Natural regeneration of indigenous fruit tree forests in Zimbabwe is facing noticeable threat due to changes in climatic conditions. Rising temperatures, shift in rainfall patterns and increased frequency of extreme weather events are altering the balance of these ecosystems, making it almost impossible for indigenous fruit trees to thrive. The sustainability of Zimbabwe's indigenous fruit trees is under severe threat due to the increased commercial pressure and the adverse impacts of climate change. On the other hand, the swift expansion of markets for indigenous fruit products has led to heighted harvesting practices that prioritize short-term economic gain over long-term ecological health (Mujuru & Moyo, 2021). On one hand, climate change is initiating new variables into the equation, such as unpredictable weather patterns and reduced growing seasons, which further jeopardize the regenerative capabilities of these indigenous fruits (Gwaze et al., 2017).

1.3 Justification

This research is important as it will address the urgent environmental and economic issues affecting Zimbabwe's natural fruit tree resources. The findings to this study will be helpful to multiple stakeholders, especially policymakers, conservationists, and local communities by providing data on the impacts of climate change on the distribution and habitat suitability of indigenous fruit trees in Zimbabwe, this research will help policymakers to come up with regulations that promote sustainable indigenous forest management. Additionally, conservation organizations and advocates can use the findings to design community-based initiatives that encourage sustainable harvesting methods, such as agroforestry and replanting programs.

1.4 Aim of the Study

The main aim of this study is to assess the impacts of climate change on the distribution and habitat suitability of indigenous fruit forests in the low-veld of Zimbabwe amidst the increasing demand for indigenous fruit products and to give recommended initiative and practical strategies to promote the sustainable use of indigenous fruit forests while supporting local livelihoods.

1.5 Research Objectives

. Specifically, this study aims to:

1. Assess the current habitat suitability of *Sclerocarya birrea*, *Tamarindus indica* and *Adansonia digitata* in Zimbabwe.
2. Predict the impact of climate change on future distribution and habitat suitability of *Sclerocarya birrea*, *Tamarindus indica* and *Adansonia digitata*.

1.6 Research Questions

1. What is the current suitability of *Sclerocarya birrea*, *Tamarindus indica* and *Adansonia digitata* in Zimbabwe?
2. What is the likely impact of climate change on future distribution and habitat suitability of *Sclerocarya birrea*, *Tamarindus indica* and *Adansonia digitata?*

CHAPTER 2
LITERATURE REVIEW

Efforts to add value to indigenous fruits in Zimbabwe has caused an increase in the market for indigenous fruit products. However, climate change has altered the ecological fabric of indigenous fruit forests, threatening the long term sustainability of these vital ecosystems. As the national demand for indigenous fruit products continue to escalate, the pressure on indigenous fruit forests intensifies compromising their natural regeneration process. This chapter documents previous research and practices regarding problems associated with excess consumption of the indigenous fruits, impacts of climate change on indigenous fruits forests, factors affecting the distribution of indigenous fruit forests and the natural regeneration of indigenous fruit trees in Zimbabwe.

2.1 Importance of Indigenous Fruits Trees

Indigenous fruit trees play a significant role globally by contributing to biodiversity conservation, and climate resilience while in African communities, natural fruits contribute to food security, nutrition, economic livelihoods, cultural identity, and environmental sustainability especially in Zimbabwean communities. Despite their importance, these fruits often receive less attention than commercially cultivated exotic species such as *Eucalyptus spp., Pinus spp.* (pine), *Tectona grandis* (teak) and *Swietenia macrophylia* (mahogany). (FAO, 2020)

Indigenous fruits such as *Uapaca kirkiana* (mazhanje), *Strychnos cocculoides* (matamba), *Parinari cutratellifolia* (mupundu/hacha/chakata), and *Adansonia digitata* (baobab) are rich in essential nutrients, like vitamins, iron calcium and antioxidants, which are important for combating malnutrition and micronutrient deficiencies in rural communities (Chinomona et al, 2024). They are increasingly being recognized for their potential to fight food and nutrition insecurity in rural and semi-arid regions of Zimbabwe. Among these, *A. digitata, S. birrea* and *T. indica* are widely grown and harvested in dry regions of Zimbabwe, where the sour sweet fruit pulp is consumed in its fresh form or processed into sauces, pastes or drinks. Nutritional assessment from Mwewa et al. (2021) highlighted tamarind's richness in organic acids which gives it its sour flavored acid in digestion. Tamarind is also a good source of magnesium and calcium, both crucial for muscle function and oxygen transportation. Tamarind pulp contains medium amounts of vitamin B, which supports metabolism and energy (Mugabe et al., 2021).

Indigenous fruits like *A. digitata, S. birrea*, *Z. mauritiana and T. indica* have attracted national and international interests because of their nutritional significance. Baobab powder for instance, is marked as a super food in Europe and North America, with prices ranging from $20 to $40 per kilogram (Gruenwald and Galizia 2005, Mabhaudhi et al, 2019). This global demand presents opportunities for Zimbabwean producers to tap into lucrative export markets (News Day, 2023). Bindura University of Science Education established a processing plant in Muzarabani that produces 2000 bottles of *Masawu* juice per hour (All Africa, 2024). This therefore improves the country's economy. Marula is one of the most valued indigenous fruit in southern Africa, producing yellowish juicy fruits used for food consumption, fermentation and oil extraction. Recent nutritional evaluations confirm that marula pulp has high concentrations of vitamin C (200-300mg/g) making it a significant antioxidant rich fruit, (Mwewa et al., 2021) of particular interest is marula seed oil, which has gained significant international prominence due to its moisturizing and anti-aging properties. It contains high levels of monounsaturated fatty acids and tocopherols fatty acids (vitamin E) providing both nutritional and cosmetic benefits (Mugabe et al., 2021). The global marula oil market was valued at 58.3 million USD in 2024 and is projected to reach 106 million USD in 2034 driven by consumer preference for natural and organic products (FACT.MR February, 2024). The combination of both edible pulp and valuable seed oil positions marula as a multifunctional indigenous resource with both dietary and commercial benefits.

Besides their importance on food security and income generation, indigenous fruit trees have a social and cultural value attached to them. For example, in the Shona culture the Ficus species are associated with water and it is believed that where they located there is presence of ground water. Therefore it is used to identify area with potential for drilling wells in rural areas. The *muchakata* tree (*Parinari curatellifolia*) plays a significant role in the Shona culture, particularly in spiritual rituals and ancestral adoration. It is often considered as a sacred site for bira ceremonies also known as rainmaking ceremonies and they are believed to provide a direct link to the vadzimu (ancestral spirits) (Makuvaza & Mavhunga, 2020). Cutting down or damaging these indigenous trees is considered a taboo, as it is thought to disturb spiritual harmony communication line and bring misfortune to the community (Zvarevashe, 2021). In addition to its spiritual role, the muchakata tree also has medicinal benefits. Its bark, leaves, and roots are used to treat infections and wounds (Mhlanga et al., 2021). The fruits are also consumed and processed into flour that boosts the nutritional quality of traditional foods (Taruvinga & Mawere, 2021).

2.2 Recent Efforts to Add Value to Indigenous Fruits

Recently, there has been a drive to add value and to commercialize indigenous fruits in Zimbabwe. For instance, through farmer field schools and community workshops initiatives, the Department of Agricultural Extension (AGRITEX) and the Forestry Commission have organized and conducted training in fruit drying, seed oil extraction, and hygienic packaging (Forestry Commission of Zimbabwe, 2022). Rural women in Mazvihwa, in the Midlands Province have formed a cooperative called Mazvihwa Baobab Oil Cooperative that produces baobab oil. This oil can be used in cosmetic and skincare products Supported by Environment Africa and local NGOs, this initiative has created alternative income sources while promoting sustainable harvesting (Chikuni and Mutenje, 2022). Other women's groups in Mutoko and Chipinge areas in Mashonaland East Province are processing *Tamarindus indica* into syrups, fruit pastes, and spiced concentrates used in beverages, sauces and flavour enhancements for stews. These products are now being sold in local supermarkets and open markets, with packaging supported by ZimTrade (ZimTrade, 2022), although its value chain is still less developed compared to baobab and masawu but it has gained significant recognition in Zimbabwe (Matongo et al., 2023). Small-scale processors have developed masawu based alcoholic drinks, like wine and liquors, which are popular in local bars and are beginning to reach urban markets through vendor networks (Musara et al., 2022). Masawu wine is commonly being processed in Masvingo at the moment. The National Biotechnology Authority of Zimbabwe (NBAZ) commissioned the marula processing plant in Rutenga growth point under Masvingo Province. The facility processes marula into various products including marula wine, cosmetic oils, edible oils and juices. B'Ayoba is one of Zimbabwe's most prominent baobab processing companies, established to produce certified organic baobab powder and baobab seed oil for export and local markets (B'Ayoba 2022). Marula Zimbabwe is a growing enterprise in Zimbabwe, with amazing focus of adding value to marula fruits. Supports the production of marula fruit pulp products like jams, juices and fermented beverages.

2.3 Factors Affecting the Distribution of Indigenous Fruit Trees

The distribution of indigenous trees is influenced by a combination of climatic, edaphic, biological and anthropogenic factors, all of which are increasingly affected climate change. Variations in temperature and rainfall directly impact tree growth, reproduction and geographical range, with droughts and heat stress reducing seedling survival and altering habitat suitability (Mujari et al., 2020, Mapurazi et al., 2023). Soil properties such as fertility, texture and ph further determine the viability of indigenous fruit tress species, while biological processes like seed dispersal and pollination are essential for regeneration but are increasingly disrupted by habitat fragmentation and pollinator decline (Nyamadzawo et al., 2017). Human activities, including deforestation, land conversion and the harvesting of fruits ad tree parts continue to degrade habitats and reduce native populations (Gondo et al., 2017, Chibememe and Ndebele 2022). Moreover, climate change is accelerating shifts in species distribution, with some traditional areas becoming unsuitable for its traditional species due to increased aridity and erratic rainfall (Chivenge et al., 2015; Mataruse et al., 2024). As a result, the sustainability and ecological balance of indigenous fruit forests are increasingly at risk across Zimbabwe.

2.4 Current Distribution of Target Fruit Trees in Zimbabwe

The distribution of indigenous fruit trees in Zimbabwe is closely linked to ecological regions, particularly the drier agro-ecological zones (Natural Regions IV and V), which are better suited for drought-tolerant species such as *Tamarindus indica*, *Adansonia digitata*, and *Sclerocarya birrea (*Matarira et al., 2021; Chidumayo & Gumbo, 2010).

Tamarind is naturally distributed in the northern, eastern and southern parts of Zimbabwe. It is found in wooded grasslands often associated with termite mounds, and it thrives at elevations of up to 1000 meters above sea level. (Hyde 2024). Tamarind's distribution is concentrated in semi-arid to sub humid areas. It grows well in well drained sandy soils and is also a drought resistant tree which makes it well suited for low rainfall regions of Zimbabwe particularly region V and IV (Makarau and Mataruse 2023).

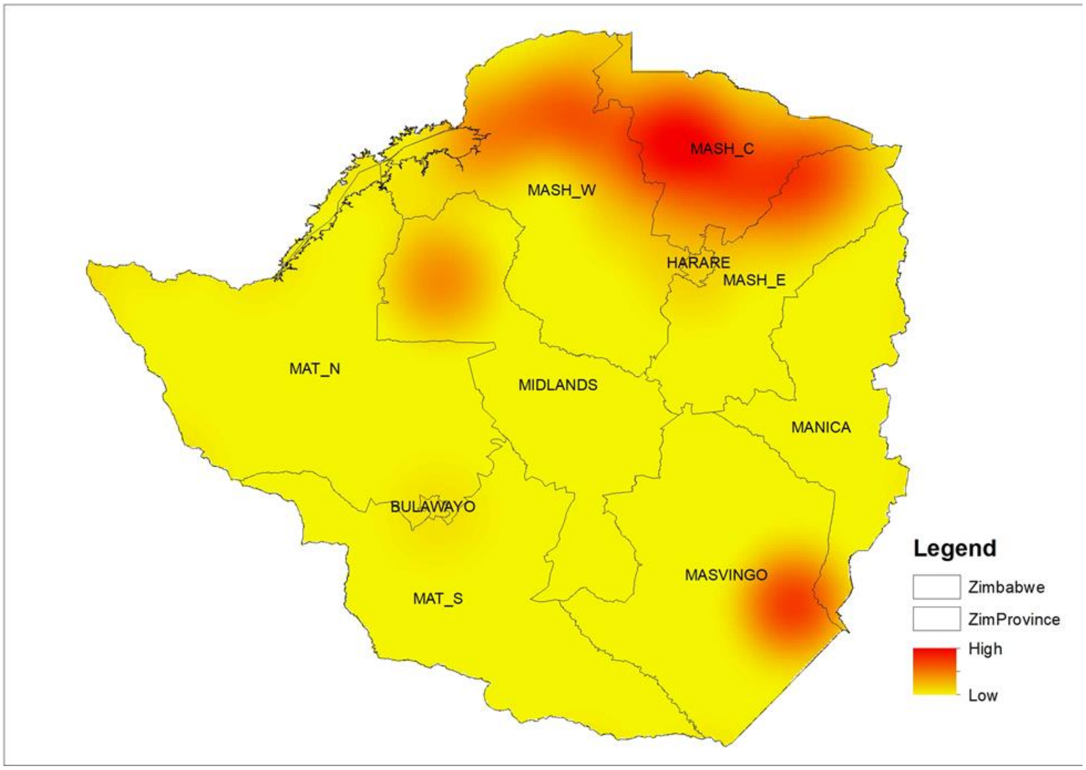

Figure 2.1. Current distribution of T. indica. (Surveyor General of Zimbabwe. 2020)

Mawuyu, or baobab, is widely distributed across the southern and western regions of Zimbabwe (savanna and woodland regions), including Beitbridge, Gwanda, and parts of Matabeleland North. The tree thrives in hot, low-rainfall areas with well-drained soils and is often found in communal grazing lands and near homesteads (Gumbo et al., 2020). Baobab fruits are collected for their pulp, which is rich in vitamin C and increasingly used in health products and beverages. A national survey estimated around 4.2 million baobab trees in Zimbabwe, with a destiny of approximately 61 trees/km^2 in some regions (Gumbie, Masvuungwa and Mashingaidze, 2023).

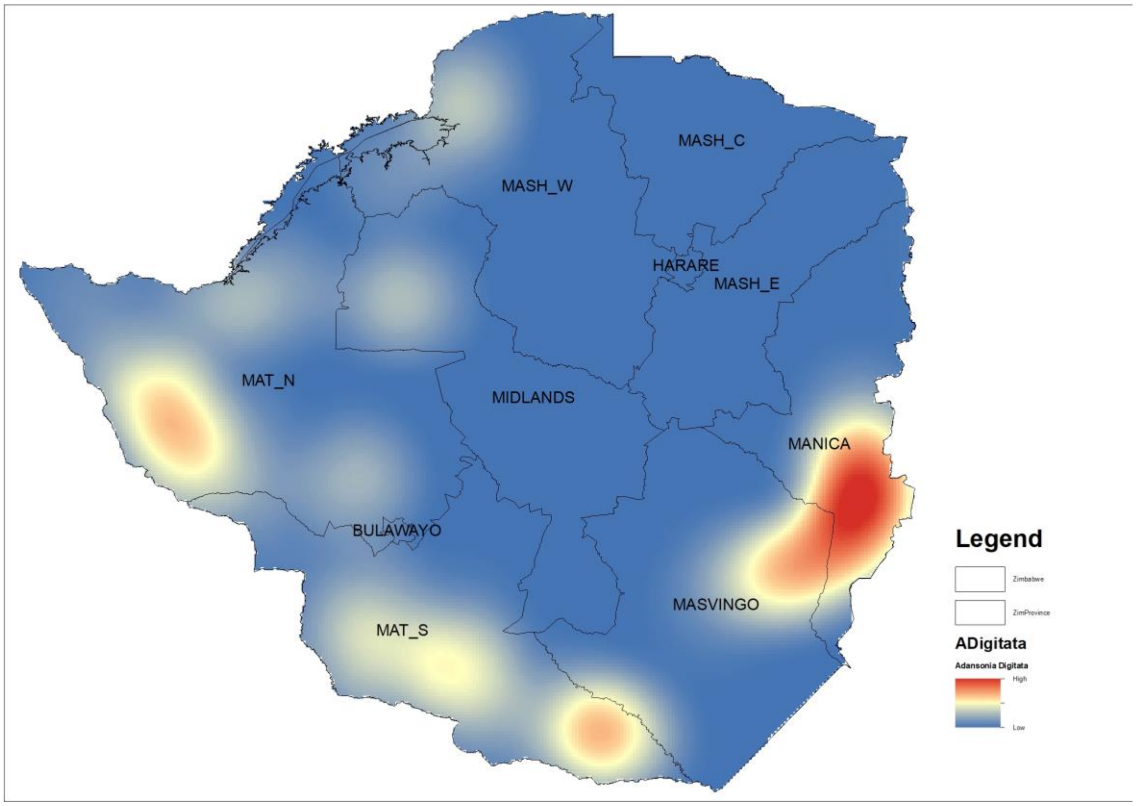

Figure 2***.2. Current distribution of A. digitata***. (Surveyor General of Zimbabwe, 2020)

Mapfura is most commonly found in southern Zimbabwe, particularly in mopane and miombo woodland zones in places like Mwenezi, Chiredzi, and parts of Matabeleland South. These regions fall under agro-ecological Region V and are characterized by low rainfall and high temperatures, conditions under which the marula tree (*Sclerocarya birrea*) flourishes (Madzara, 2019). Mapfura is harvested between January and March, and its fruits are fermented into traditional alcoholic beverages.

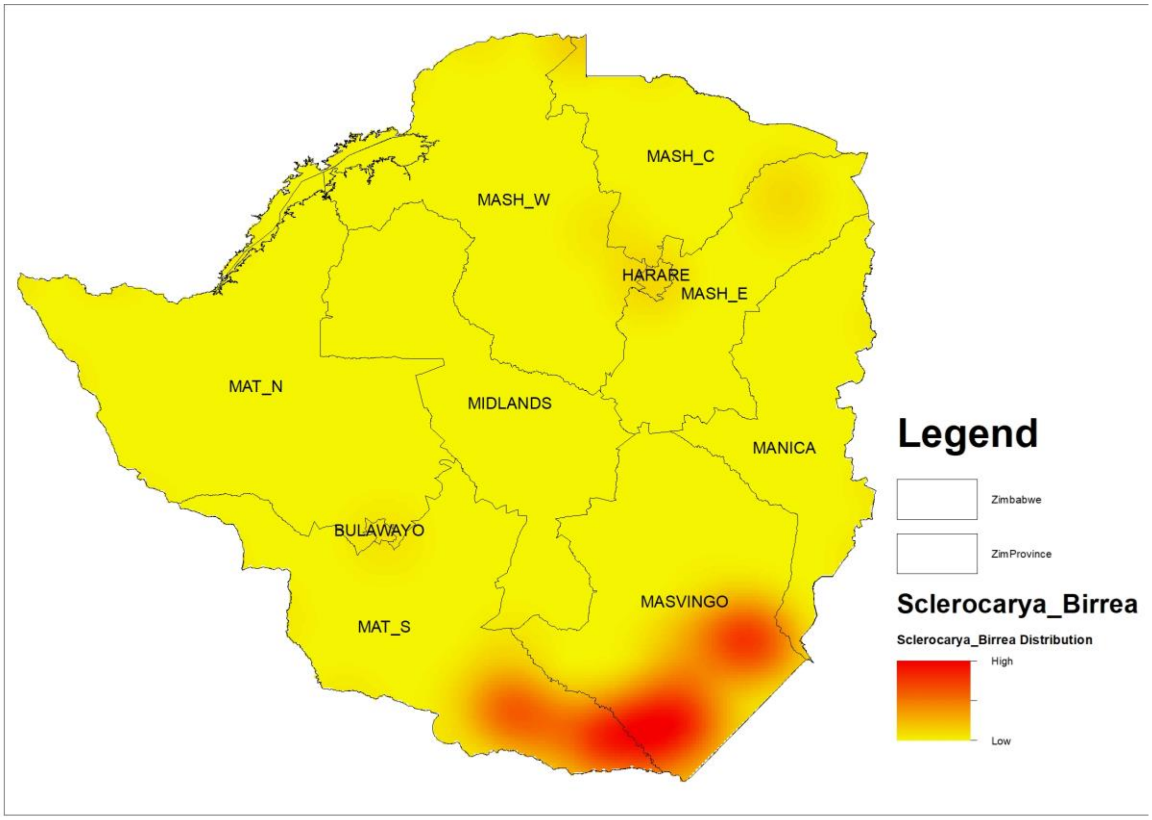

Figure2.3. Current distribution of S, birrea. (Surveyor General of Zimbabwe, 2020)

2.5 Climate Change and Its Impact on Indigenous Fruit Forests.

Zimbabwe is experiencing rising temperatures and erratic rainfall patterns, leading to prolonged droughts that adversely affect forest ecosystems. These climatic changes derange seed germination, reduce seedling survival rates, and alter Phenological patterns, thereby impeding natural regeneration processes (Chinomona et al., 2024) resulting in a shift in habitat suitability. Indigenous fruits typically rely on animals such as rodents and birds for seed dispersal. Climate change has altered animal migration patterns and feeding patterns, disrupting the dispersal networks necessary for forests regeneration (Shackleton et al., 2017). Moreover, the increased frequency of droughts has led communities to rely more heavily on indigenous fruit trees as alternative food sources, intensifying pressure on these species (Kupika et al., 2019).

2.6 Current Habitat Suitability of Target Species.

The current habitat suitability for *Tamarindus indica* in Zimbabwe is being affected by recent climatic changes, peculiarly rising of temperatures, decline in rainfall and longer dry seasons. Traditionally tamarind is well suited to the semi-arid and sub humid regions like agro regions IV and V due to its drought tolerance (Makarau and Mataruse, 2023), tamarind now experiences minimal seedling survival and reduced growth rates in areas where it is traditionally suited (Chikodzi, 2022). However, areas in the northern and eastern highlands may/ have become more suitable due to relatively higher and stable rainfall patterns (Mataruse, Dube and Gwitira, 2022). The species' resilience to erratic weather and deep-rooting system may allow it to persist, but active conservation and agroforestry integration are crucial for its survival under changing climatic conditions (FAO, 2022; Hyde et al., 2024).

The African baobab is a keystone species in the dry savanna ecosystems of Zimbabwe. It is predominantly found in the southern and northern low veld, where it provides critical ecological and socio-economic functions. The baobab is well adapted to high temperatures and seasonal droughts due to its water-storing trunk and deep roots. However, climate change projections for Zimbabwe indicate increasing temperatures and decreasing rainfall in many parts of the country. These changes could potentially expand the suitable habitats for A. digitata, as its resilience to arid conditions may allow it to colonize areas where other species cannot survive. However, its adaptability also raises concerns about its potential invasiveness, which could disrupt native ecosystems (Chagonda et al., 2023). On the other hand, there are studies indicating that climate change may reduce the extent of suitable habitats for A. digitata in Zimbabwe, especially if rainfall becomes more erratic and temperatures rise beyond the species' thermal tolerance threshold. Predictive modelling shows a potential contraction in its distribution range in the coming decades if global warming persists (Gebauer et al., 2016; Munzara et al., 2023). Conservation strategies are increasingly needed to preserve its genetic diversity in the face of these climatic threats.

Mapfura, or marula, is widely distributed in Zimbabwe's dry deciduous woodlands, particularly in mopane and miombo ecotones. It is favoured in areas receiving between 300 and 1,000 mm of rainfall annually and is known for its high drought resilience. Research has shown that marula is likely to remain suitable and may even expand its range under moderate climate change scenarios due to its broad ecological tolerance and deep root system (Shackleton et al., 2021). However, increasing incidences of fire, overharvesting, and land conversion pose greater threats than climate itself. Importantly, marula is culturally significant and economically valuable, contributing to rural livelihoods through the production of oils, drinks, and crafts, thereby making its conservation an economic as well as ecological priority (Gandiwa et al., 2021).

2.7 Predicted Impacts of Climate Change on Distribution and Habitat Suitability

Climate change is predicted to significantly alter the distribution and habitat suitability of indigenous fruit trees in Zimbabwe by shifting climate zones, modifying key ecological conditions and increasing environmental stressors. Rising temperatures and declining rainfall, especially in semi-arid and arid regions are expected to reduce the range and productivity of indigenous fruit tress like *A. digitata*, *T. indica* and *S. birrea* (Mataruse et al., 2024, Mugari et al., 2020). These species, which are highly sensitive to moisture available and temperature extremes, may face habitat contractions in low lying areas, with suitable zones shifting to higher elevations or regions with more stable rainfall (Mapurazi et al, 2023). Additionally, climate induced changes in soil moisture regimes and increased frequency of drought events could limit seed germination, sapling survival, and fruiting, thus reducing the natural regeneration capacity of these tress (Nyamadzawo et al., 2017). Alterations in seasonal patterns may also lead to mismatches between flowering times and pollinator availability, further affecting reproductive success (Chibememe and Ndebele, 2022). Furthermore, as climate change intensifies, areas currently suitable for these species may become ecologically marginal, threatening both biodiversity and the socio economic benefits derived from indigenous fruit trees across rural communities (Chivenge et al., 2015). Chagonda et al., (2023) suggests that A. digitata is likely to expand its range into regions that are currently marginal or unsuitable, particularly in the central and north parts of Zimbabwe, by the year 2050-2080. This projected range expansion is largely attributed to the exceptional physiological adaptations of baobab trees which make them highly resilient to drought.

2.8 Natural Regeneration Challenges

Natural regeneration of indigenous fruit forests in Zimbabwe, particularly species such as, *Adansonia digitata* and *Sclerocarya birrea* and *Tamarindus indica* are increasingly constrained by the pressures of climate change and heightened commercial demand of indigenous fruit products. Rising temperatures, change in rainfall patterns and prolonged drought seasons disrupt flowering and fruiting phenology, leading to reduced seed production and lower germination success in dry land environments (Zhou et al., 2022; Matarira et al., 2021). Simultaneously, overharvesting of fruit often collected before seeds fully mature for processing or sale means few viable seeds are returned to the soil seed bank, further undermining natural recruitment (Matongorere, 2020). Land use change for agriculture, settlement expansion and livestock overgrazing degrades and fragments woodland habitats, destroying the microhabitats under parent trees that are critical for seedling establishment (Gumbo et al., 2020). In addition, inherent biological constraints such as the hard seed coat of *Ziziphus mauritiana*, which limits water uptake, the dormancy requirements of *S. birrea* result in low germination rates, a situation exacerbated by declining animal dispersers like elephants and baboons due to habitat fragmentation (Mungate et al., 2018). Finally, despite their economic and ecological value, these species remain largely undomesticated, and local communities often lack the technical skills, nurseries or seed - bank infrastructures necessary for propagation, relying instead on increasingly unreliable natural regeneration (Chivandi et al., 2021).

CHAPTER 3
MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted in selected semi-arid and arid regions of Zimbabwe, focusing on the traditional habitats of three key indigenous fruit tree species, *Adansonia digitata*, *Sclerocarya birrea*, and *Tamarindus indica* (Figure 3.1). These species are prevalent in districts such as Mbire and Muzarabani (Mashonaland Central), Beitbridge and Gwanda (Matabeleland South), and Mwenezi and Chiredzi (Masvingo), which fall within Agro-ecological Regions IV and V. These regions experience low rainfall annually (typically below 650 mm), high temperatures (15–30°C), and frequent droughts. The vegetation is dominated by *mopane* and miombo woodlands, open savannahs', and bushveld, with soils that are mostly sandy or loamy and of moderate to low fertility. These ecosystems support low-input subsistence agriculture and are rich in wild fruit tree biodiversity. *Tamarindus indica* thrives particularly in the Zambezi Valley and Middle-Lower Zambezi Basin—areas characterized by sandy or alluvial soils, high temperatures, and semi-arid conditions. *A. digitata* is widespread in southern and south-western Zimbabwe, often found in communal lands and along riverbanks and seasonal watercourses due to its exceptional drought tolerance. *S. birrea* is most dominant in the hot and dry lowveld regions of Natural Regions IV and V. These species contribute significantly to local food systems, nutrition, and livelihoods. However, their habitats are increasingly threatened by deforestation, land degradation, agricultural expansion, and unsustainable harvesting practices.

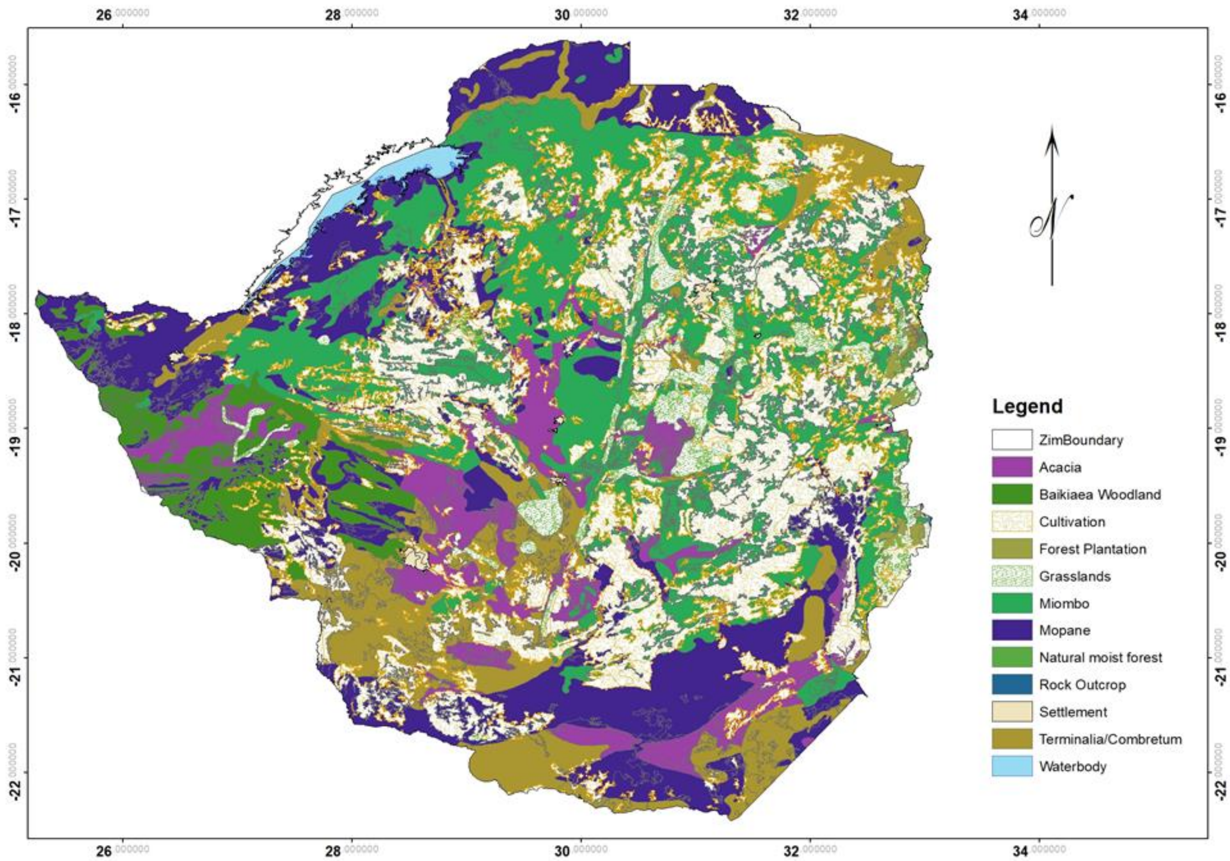

Figure. 3.1. Study area for the target species. (CIA, 2023)

3.2 Data Acquisition and Processing.

Habitat suitability for the periods 2050-2070 and 2080 was projected using the Representative Concentration Pathway (RCP) 8.5 scenario. This scenario represents a high emission trajectory characterised by continuously increasing greenhouse gas concentrations throughout the 21st century. The use of RCP 8.5 was intended to stimulate extreme climate change conditions, thereby illustrating the potential worst case impacts on species distribution, habitat fragmentation and potential loss of suitable environments for target species under warming conditions

To perform ecological niche modelling, several specialised R packages were employed to support data handling, spatial analysis, and modelling. These included raster (for handling spatial raster data), rgdal (for reading and transforming spatial datasets), maps and mapdata (for geographic visualisation), dismo (for species distribution modelling), rJava (for Java integration required by MaxEnt), map tools (for spatial data manipulation), and jsonlite (for handling data in

JSON format). These tools collectively enabled efficient data pre-processing, model building, and visualisation of spatial predictions.

Bioclimatic variables representing current and future climatic conditions were downloaded directly into studio. These variables were derived from the WorldClim climate datasets at a special resolution suitable for ecological modelling. The future climate layers corresponding to 2050-2070 and 2080 were extracted based on projections from Global Climate Models aligned with the RCP 8.5 pathway.

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Species occurrence data were combined with environmental predictors to construct species Distribution Models using Maximum Entropy algorithm. MaxEnt estimates the probability distribution of species occurrence by identifying the most uniform distribution constrained by the environmental variables at known presence locations. This method is particularly effective for presence only data and has been widely used for predicting potential distributions under current and future climate scenarios.

The resulting models provided spatially explicit predictions of suitable habitats for each target species under both current and projected climate conditions. These outputs were subsequently used to access potential shifts in species ranges, loss of suitable areas and emergence of new habitats under high emission climate scenario.

CHAPTER 4
RESULTS

4.1 Distribution Modelling of *A. digitata*

Currently, *A. digitata* habitat suitability in Zimbabwe is largely dense in the country's low-lying, hot, and semi-arid regions, specifically where annual rainfall is low and soils are well-drained (Figure 4.1a). These areas include the south-eastern low veld (Chiredzi, Mwenezi, Beitbridge) and the Zambezi Valley (Binga, Kariba, and Hurungwe), where average annual temperatures range between 20°C and 35°C and annual rainfall range between 300–800. Moderate suitability exists in some transitional zones like Gokwe and parts of Matabeleland. In contrast, the Eastern Highlands (e.g., Mutare, Chimanimani) and central Highveld (e.g., Harare, Marondera) are largely unsuitable.

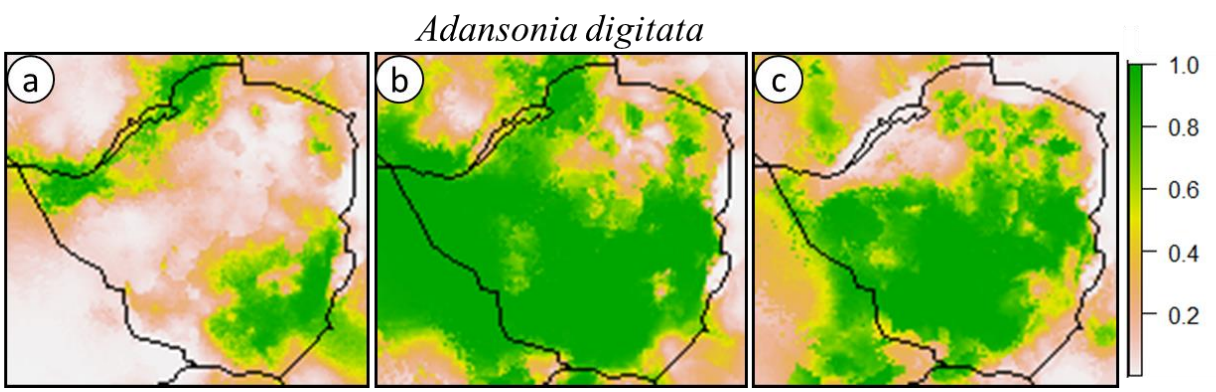

Figure 4.1. Distribution modelling of A. digitata a) current suitability, b) predicted impacts of climate change on habitat suitability by 2050 and 2070, c) predicted impacts of climate change on habitat suitability by 2080.

(Figure 4.1b), the habitat for *A. digitata* is projected to have significantly expanded into mostly the central water-shed of Zimbabwe, areas not covered by the current suitability of the species depicted in Figure 4.1a. By 2070 (Figure 4.1c), the distribution of *A. digitata* is projected to be concentrated in the central-watershed of the country, with areas where the species currently occur having mostly lost its suitability due to climate change. For both 2050 and 2070, the dark green colour code shows high probability (0.6-1.0) for the projected scenarios.

4.2 Distribution Modelling of *S. birrea*

As depicted in Figure 4.2a, the zone currently suitable for *S. birrea* is northern Zimbabwe, along the Zambezi Valley, with high probability ranging from 0.6 to 1. However, the central watershed of the country is relatively suitable, with a probability range of 0.4 to 0.6.

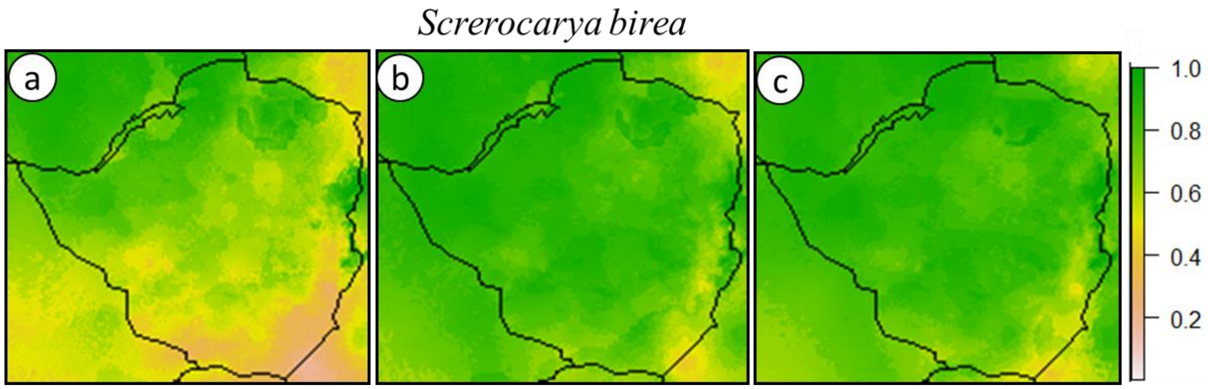

Figure 4.2. Distribution modelling of S. birrea a) current suitability, b) predicted impacts of climate change on habitat suitability by 2050 and 2070 c) predicted impacts of climate change on habitat suitability by 2080.

Projections for 2050 show that the whole country will be suitable for S. birrea, with a probability of 0.4-1 (Figure 4.2b). The same trend was observed for projections for the year 2070 (Figure 4.2c).

4.3 Distribution Modelling of *T. indica*

For *T. indica*, the area currently suitable for the natural occurrence of the species is along the semi -arid and dry savanna regions of the Zambezi Valley (Figure 4.3a).

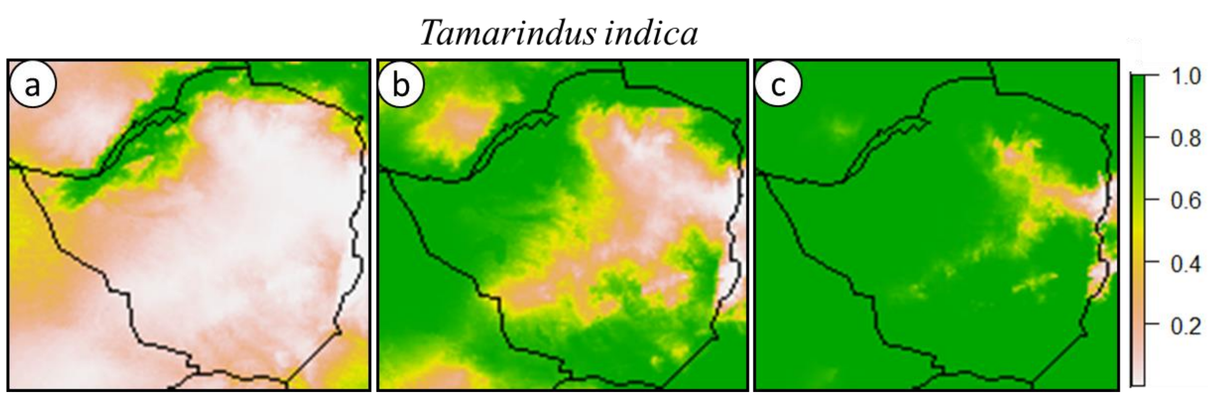

Figure. 4.3. Distribution modelling of T. indica a) current distribution, b) predicted impacts of climate change on habitat suitability by 2050 and 2070, c) predicted impacts of climate change on habitat suitability by 2080.

Due to climate change, the distribution of the species is projected to widely expand by 2050 (Figure 4.3b) to cover all semi-arid parts of the country i.e. the Save Valley, Limpopo Valley and the Zambezi Valley where the species is currently suitable. The only area that will not be suitable for the species is the wetter central watershed. By 2070 (Figure 4.3c), the whole country will be suitable for the natural occurrence of the species except for the wet Eastern Highlands, an area belonging to agro-ecological region 1 with very high rainfall.

CHAPTER 5
DISCUSSION

The modelling results for *A. digitata*, *S. birrea* and *T. indica* provide significant insights into how climate change will affect their future distribution and habitat suitability in Zimbabwe. The current distribution of *A. digitata* is concentrated in Zimbabwe's hot, dry and semi-arid areas like the Zambezi valley and eastern lowveld. However, under future climate scenarios, the species' habitat suitability shifts drastically to the central water shed, an area that was previously considered unsuitable for *A. digitata* to thrive. These projected shifts suggest that the traditional baobab zones may become too hot and dry, pushing the species towards regions with slightly more moderate conditions. The loss of suitability in these areas indicates that climatic thresholds such as maximum heat and drought tolerance could be crossed therefore stressing existing populations. This causes challenges for conservation, as mature baobab trees have long lifespans but limited natural regeneration under stressful conditions. These results are closely similar with findings by Makarau and Mataruse (2023), who observes that baobab populations across Africa are increasingly vulnerable to rising temperatures and declining soil moisture, especially at dry margins of their ranges. Also Gebauer et al. (2016) emphasized that while baobab is drought tolerant there are physiological limits beyond which survival and regeneration drop significantly, particularly during prolonged drought periods, which are predicted to intensify with changes in climate. Munzimi et al (2017) further explained that regeneration failures will occur even when mature trees persist, can lead to long term population decline of *A. digitata*, matching observation from this study that traditional baobab zones may face future unsuitability. This study reinforces the argument that conservation strategies must shift from only protecting current populations to anticipating future refugia, especially in the central watershed zones where baobab may thrive under changing climatic conditions (Munzara et al., 2023)

Presently *S. birrea* is concentrated in the Zambezi valley and moderately suitable in parts of the central watershed, the predictions for 2050-2070 show that almost the whole country will become climatically suitable for S. birrea (85%). This suggests that the species has high degree of climatic plasticity and resilience to projected temperatures and rainfall changes. The findings to this research strongly align with the growing consensus that marula may be a ‘climate change winner’ meaning it is capable of thriving across a broader range of environments (Helm et al., 2011). Shackleton et.al (2019) report that marula is one of the most climate resilient indigenous fruit tree in Zimbabwe that tolerates a wide range of environmental conditions.

T. indica’s current suitable zones are limited to semi-arid and dry savanna regions such as the Zambezi Valley. The RCP 8.5 climatic model predict that a broad expansion of suitable habitat by 2050, covering the Save valley, Limpopo valley and much of the semi-arid arid areas of the country through the wetter Eastern highlands will likely remain unsuitable due to their high rainfall. This clearly indicates that tamarind is well adapted to warm and dry conditions meaning it will adapt well and benefit from the warming climate especially areas that are too cold and wet. From a conservation point of view, this provides a chance to promote tamarind planting and restoration in degraded semi-arid landscapes, potentially improving food security and livelihoods. These results closely align with existing literature from Orwa et al., (2009), Mugido et al., (2014)) where they are agreeing that they characterize tamarind as a drought adapted specie. Tamarind’s physiological traits such as deep root system and a long juvenile period, make it especially suited to withstand prolonged dry spells. Findings in this research that the Eastern highlands remains unsuitable are consistent with tamarind’s well documented intolerance to excessively wet or cold conditions. This confirms that even under climate change, local microclimatic barriers (e.g. rainfall, elevation) will continue to shape species distribution.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions.

This study was set out to assess the influence of climate change on the distribution and habitat suitability of three ecologically and economically important indigenous fruit species in Zimbabwe *A. digitata, S. birrea and T. indica*. Using predicting modelling techniques under future and current climatic scenarios (2050-2070 and 2080), the research has produced vital insights of how these species are likely to respond to changing climatic conditions. The results indicate that climate change will not have a uniform across the three target species. *T. indica* and *S. birrea* are projected to expand their suitable ranges under climate change while *A. digitata* may experience a contraction or shift away from its traditional strongholds which are Zimbabwe's semi-arid regions. *A. digitata* future refugia are most likely to emerge into the central watershed while S. birrea seemingly shows expansion nearly across the country. *T. indica* similarly shows expansion across all semi-arid regions but remains repressed by wetter eastern highlands regions. The results show that impacts of climate change on biodiversity are complex and species specific. They are shaped by the relationship between climatic, ecological and physiological factors as per specie.

When compared with existing regional and international literature, these results align with existing scientific literature which highlight climate change will act as both a threat and an opportunity with some species being labelled as climate change 'winners', depending on the species ecological tolerance and adaptive capacities. Importantly, the projected changes in habitat suitability do not only carry ecological implications, but also substantial socio-economic consequences for local communities that depend on indigenous fruits for food security, medicinal purposes, cultural identity and income generation. Therefore, changes in the distribution and availability of these species will directly affect the resilience of rural households and communities, specifically in semi-arid and marginal regions where alternative resources are scarce.

6.2 Recommendations.

Based on the findings of this study and comparative insights from existing literature, several detailed recommendations are proposed to guide conservation action, further research, policy development and local communities.

Currently there is a gap in policies and explicitly focus on indigenous fruit trees, although Zimbabwe has developed various national policies on forestry, biodiversity and climate change adaptation. Most national framework prioritizes commercial timber species, agricultural cash crops and exotic plantations often overlooking the ecological, cultural and economic significance of indigenous fruits tree species. It is recommended that national and subnational government develop dedicated policies and regulatory frameworks that specifically address the conservation, management and sustainable use of indigenous tress tailored to their unique ecological roles, cultural importance and climatic vulnerabilities.

Natural regeneration plays a significant role in maintaining populations of indigenous tree species, it is often constrained by factors such as seed dispersal limitations, land degradation, competition with agriculture and human disturbances therefor the need for establishment of plantations in already suitable places, projected areas to remain suitable and projected areas to become suitable in the country. Plantations will serve as genetic reservoirs, generate direct economic benefits for rural households and also plantations can support ecosystem restoration goals.

Existing indigenous fruit forests need to be protected and regulate access to ensure ecologically sustainable harvesting practices. In many parts of Zimbabwe indigenous fruit forests are open access as they grew naturally and are on state land, harvesting is often unregulated. While they offer a lot of benefits to the local communities, open access systems usually lead to overharvesting, resource depletion and degradation of the ecosystem. Without effective management, rising demand for indigenous fruit products especially now under added pressure of climate change and growing markets may accelerate unsustainable extraction, threating long term economic opportunities. Furthermore, alongside regulatory measures, capacity building initiatives should be introduced to train local harvesters on sustainable techniques, resources monitoring and ecological stewardship. This will help in understanding why access restrictions are important, enhancing compliance and reducing conflict.

To translate research findings into meaningful action it is important that climate change models and habitat suitability projections need to be systematically integrated into Zimbabwe’s forestry, land use and biodiversity strategies to ensure that management plans anticipate future conditions, rather than focusing solely on current species distributions. This will enable more effective and also evidence based policies. There is also need for policy makers to promote cross sectorial collaboration, bringing together environmental agencies, agricultural departments NGOs, rural communities and local governments to co-design strategies that balance ecological conservation with socio economic development.

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