

Effects of anthropogenic factors on the population structure of *Pterocarpus angolensis* DC in a communal area of Khalavha Village in Vhembe Biosphere

By

Student Name: Tshihumbudzo Ndou

Student no. 17012694

Effects of anthropogenic factors on the population structure of *Pterocarpus angolensis* DC in a communal area of Khalavha Village in Vhembe Biosphere

By

Student Name: Tshihumbudzo Ndou (Student no. 17012694)

Dissertation submitted in fulfilment of the requirements of

Master of Science Degree in Botany

In the

Faculty of Science, Engineering and Agriculture

University of Venda

Thohoyandou, Limpopo Province

South Africa

Student: Ms Tshihumbudzo Ndou

Supervisor: Prof MP Tshisikhawe

Co-Supervisor: Dr SP Mashile

ABSTRACT

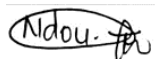
Pterocarpus angolensis DC. is an indigenous species of value across Africa. The species have been identified as having a high utilization rate for different purposes. The purpose of the study was to analyze the population structure of *P. angolensis*, a species in high demand. Ethnobotanical information was collected with an aid of a questionnaire from fifty-three informants. The informants identified two plant parts preferred by the community. The only preferred parts are stem (67%) and bark (33%). The study identified a lack of indigenous knowledge of the species amongst the youth. Some of the uses reported on *P. angolensis* were firewood (n=33), medicine (n=43), craftwork (n=35), protection (n=16), and timber (n=4). The transect sampling technique was used to document ecological data on the species to analyze its population structure. Fifty-three transects of 100m x 10m were constructed within the population. Ecological parameters recorded included stem diameter, height, and crown health status. Basal stem diameter data recorded on *P. angolensis* sampling were grouped into seven size classes and displayed an inverse J-shaped curve when analysed. The study showed that the population had more individuals (n=60) within the seedlings size class (0-5cm) when compared to the bigger size classes (20.1-25cm, 25.1-30cm, and >30.1cm). The majority (37%) of *P. angolensis* individuals had light crown damage which depicts on average an aspect of healthy crowns. Only 1% of sampled individuals had dead crowns. Monitoring of the *P. angolensis* population will assist in making sure that it stays healthy and viable.

Keywords: *Pterocarpus angolensis* DC; Anthropogenic factors; Population structure; Khalavha Village; Vhembe Biosphere.

DECLARATION

I, Tshihumbudzo Ndou (Student no. 17012694), declare that this Dissertation is my original work and has not been submitted for any degree at any other university or institution. The dissertation does not contain other persons' writing unless specifically acknowledged and referenced accordingly.

Signed (Student):



Date: 15 February 2024

DEDICATION

I am dedicating this dissertation to both my late mother and late grandmother. At this moment in my life, I am considered as an adult. As am growing up and achieving great things in my life, I realize how much you did for me. For that, I truly appreciate having you as my parents, even though it was for a short period.

Heavenly love for both of you.

ACKNOWLEDGEMENTS

I would like to express my special thanks of gratitude to Prof. M.P Tshisikhawe and Dr. SP Mashile for providing me with an opportunity to do my dissertation under their supervision and guidance. I sincerely appreciate your willingness to assist in the supervision of my research.

Completion of this dissertation could not have been accomplished without all the contributions and participation of the Khalavha community. I thank the community for embracing my research. Finally, to my supportive sisters and caring aunt, your encouragement during rough times is appreciated.

CONTENTS

ABSTRACT	i
DECLARATION	ii
DEDICATION	iii
ACKNOWLEDGEMENTS	iv

CHAPTER ONE

INTRODUCTION

1.1 Background to the study	1
1.2 Description of <i>Pterocarpus angolensis</i> DC	Error! Bookmark not defined.
1.3 Problem statement	6
1.4 Aim and research objectives	7
1.5 Hypotheses	7
1.6 Justification of the study	8
1.7 Structure of dissertation	8
References	10

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction	15
2.2. Description of <i>Pterocarpus angolensis</i> DC	16
2.4. Factors threatening <i>Pterocarpus angolensis</i> DC.	21
2.5 Management of <i>Pterocarpus angolensis</i> DC. in various countries.	22
2.6. Conclusion	24
References	25

CHAPTER THREE

ETHNOBOTANICAL STUDY OF *Pterocarpus angolensis* DC. AT KHALAVHA VILLAGE IN THE VHEMBE BIOSPHERE

3.1 Introduction	300
3.2 Study area, materials, and methods	333
3.2.1 Study area description	33
3.2.2 Methodology	34
3.3 Results and Discussion	355
3.3.1 Informants profile	35
3.3.2 Use categories	39
3.3.3 Methods of collection and plant parts used	41
3.3.4 Ethnobotanical profiling of <i>Pterocarpus angolensis</i> DC	42

3.4. Conclusion	46
References	48

CHAPTER FOUR

ECOLOGICAL ANALYSIS OF THE STRUCTURE AND DISTRIBUTION OF *Pterocarpus angolensis* DC. IN A COMMUNAL AREA OF KHALAVHA VILLAGE IN VHEMBE BIOSPHERE

4.1 Introduction	53
4.2 Study area, materials, and methods	55
4.2.1 Study area description	55
4.2.2 Methodology	57
4.3 Results and Discussion	60
4.3.1 Basal stem diameter	60
4.3.2 Plant height	622
4.3.3 Crown health.....	633
4.3.4 Anthropogenic factors affecting <i>Pterocarpus angolensis</i> population of Khalavha Village.	666
4.4 Conclusion	733
References	755

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary	822
5.2 Conclusion	844
5.3 Recommendations	855
References	877
Appendix A.....	888
Ethnobotanical data questionnaire	888
Appendix B	900
Ecology data sampling form	900

LIST OF FIGURES

Figure 3.1: Area where the study was conducted, Khalavha Village.....	34
Figure 3.2: Gender profile of all the informants interviewed in the study.....	37
Figure 3.3: Age categories of all the informants interviewed in the study.....	38
Figure 3.4: Education background of all the informants who participated.....	39
Figure 3.5: Different use categories of <i>Pterocarpus angolensis</i>	40
Figure 3.6: Plant parts that are preferred on <i>Pterocarpus angolensis</i>	41
Figure 4.1. The area where the study was conducted, Khalavha Village.....	56
Figure 4.2: A research assistant recording basal stem diameter with a diameter tape.....	58
Figure 4.3: A research assistant releasing a measuring pole to record the height of <i>Pterocarpus angolensis</i> at Khalavha Village.....	59
Figure 4.4: Basal stem diameters of <i>Pterocarpus angolensis</i> individuals recorded in Khalavha Village.....	61
Figure 4.5: Heights of <i>Pterocarpus angolensis</i> individuals recorded in Khalavha Village.....	62
Figure 4.6: Crown health of <i>Pterocarpus angolensis</i> individuals recorded in Khalavha Village.....	64
Figure 4.7: A picture showing an infected branch of <i>Pterocarpus angolensis</i>	66

Figure 4.8: A picture showing the burnt stump of *Pterocarpus angolensis*.....67

Figure 4.9: A picture showing the area that was affected by human-made fire before the current study took place.....68

Figure 4.10: Pictures showing fresh (a) removal and regeneration (b) of stem bark....70

Figure 4.11: A picture showing a resprouting *Pterocarpus angolensis* stump.....72

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Pterocarpus angolensis dc is a dry woody plant from the Fabaceae family that may be found throughout tropical southern Africa, especially in the Miombo woodlands. The tree is widely harvested for its attractive hardwood and is regarded as the most significant timber species in much of its range (Pedro et al., 1955). It is commonly referred to as Kiaat or Blood wood, is Namibia's most valuable timber species. In Namibia, this deciduous tree grows in mixed populations of open forest and can reach a height of 10 to 18 metres. The wood is popular for making furniture and decking due to its attractive grain, colour, and resilience. Its density ranges from 440 to 680 kg/m³ when air dried (Vermeulen, 1990). The species is only commercially viable when the bole is large enough to saw planks from the black heartwood. Although the species is economically significant, there are no national estimates for its population growth (FAO, 2010).

Biodiversity refers to a variety of life across all levels of biological organization. Wilson (1988) described biological diversity as a global resource of great importance that must be protected and used sustainably. Gowdy (1997), also emphasized that plant biodiversity has a highly rated significance to the health of both humans and animals. Furthermore, biodiversity has a critical importance on the economy worldwide, as it can be transformed into many things such as furniture, medicines, and crafts that have

market value. They provide humankind with four groups of ecosystem goods and services which are supporting, cultural, regulating, and provisioning services (MEA, 2003). They provide humans with direct provisioning services such as medicines, food, timber, fodder, grazing, and fuelwood. The other benefits that animals get from plants are regulating services in the form of water quality, erosion control, and air moderation (Khan *et al.*, 2013). Supporting services such as nutrients, soil formation, water cycling and cultural services such as traditional human knowledge systems are the precious benefits that plants provide in our daily lives (Khan *et al.*, 2013). Therefore, plants are important as they are required to fulfil our different day-by-day needs.

The utilization of plants for herbal medicines in our daily lives has a long history and still has great importance in indigenous cultures, and they are still being used as a primary healthcare system (Gurib-Fakim, 1994). They provide primary healthcare to more than 75% of the world's population. International markets are being fed by these plants for botanical medicines, and they are the origins of many pharmaceutical drugs. Plants are being critically utilized across the whole world because they are the most affordable and easily accessible source of treatment, food, and construction in resource-poor communities (Hosseinzadeh *et al.*, 2015).

In Kenya, several farmers such as those who reside in Maasai, Luo, and Kuria ethnic groups already depend on indigenous plants for treatment of livestock diseases (De Lange-Jacobs *et al.*, 2020). Therefore, the utilization rate is high because antimicrobials are said to be expensive and not accessible in many regions of Kenya. A study of plant-based medicines in South Africa which was conducted by Nadi (2017),

reported that plant materials are still largely utilized for their medicinal importance, and they will continue to be used for the longest time to come. In Limpopo Province, several communities still depend on plants as a source of traditional medicine and have a develop more knowledge of their identification (Rankoana, 2001).

Anthropogenic activities are usually accompanied by negative impacts on the environment. Anthropogenic therefore refers to environmental changes caused by human activities (Kennish, 2021). Worldwide, ecosystems are being transformed and reduced at an increasing rate of anthropogenic factors (Porter *et al.*, 1997). These factors have a great influence on the structure and abundance of the ecosystems. Prasad *et al.* (2008), reported that the size, depth, and distribution of the ecosystem in India and other countries in the world are negatively affected by some of these factors. Anthropogenic factors such as species translocations, deforestation, land development, pollution, and overexploitation are the primary factors that lead to genetic and ecological effects that cause species declination, extinction, and endangerment (Bogan *et al.*, 2015). For example, land development leads to intensification of metapopulation dynamics, habitat fragmentation, and separation of small populations that end up finding it difficult to mate (Lande, 1998).

According to Petchey *et al.*, (2015), predicting the effects of environmental change seemed to be the biggest ecological challenge of the twenty-first century. Key understanding in ecology, natural resource management, environmental change, and conservation of biodiversity are largely dependent on long-term ecological studies (Lindenmayer *et al.*, 2012). In many tropical forests across the world, long-term plant

population monitoring has been done (Tredennick *et al.*, 2017). To ascertain their natural dynamics, research is required on variables like recruitment rates and annual mortality in regions shielded from human influence (Clark *et al.* 2001).

Plant population dynamics is noteworthy because it provides an understanding of how the existing populations are functioning (Moore, 2020). For that reason, population ecologists have been, and still conducting further studies trying to understand how plant environments are being affected by human activities through studying their population size, structure, density, and geographical distribution (Cousins *et al.*, 2014).

In conservation biology, population viability analysis (PVA) is a species-specific risk assessment technique that is commonly used to determine the likelihood that a population will become extinct in a specific number of years (Boyce, 1992). PVA has more recently been defined as the marriage of ecology and statistics that forecasts population health and extinction risk by combining species characteristics and environmental variability (Hokit *et al.*, 2001). When performing a PVA, the ultimate objective is to guarantee the long-term self-sufficiency of the species population (Lopez and Pfister, 2001). This method is also used to evaluate current recovery initiatives, compare suggested management options, and pinpoint the variables influencing population dynamics. It is widely used in the management of endangered species to create action plans, weigh the advantages and disadvantages of various management options, and evaluate the possible effects of habitat loss (Akçakaya, 2000).

Pterocarpus angolensis DC or Mutondo as it is known by Vhavenda, was described as a medium to large angiosperm deciduous tree that belongs to the family Fabaceae, subfamily Faboideae. It is estimated to grow up to 19m tall in height (Sadiki *et al.*, 2018). It is characterized by compound leaves, grey-like young twigs, smooth and covered with hairs, whereas else the older branches and stems are dark grey and rough to break (Van der Riet *et al.*, 1998; Orwa *et al.*, 2009). In South Africa, it is mostly found in savanna woodlands, rocky hillsides, wooded grasslands, or deep sandy soil (Sadiki *et al.*, 2018). *P. angolensis* is categorized as one of the protected species in South Africa, but nowadays people no longer care to use the species sustainably (Shackleton *et al.*, 2002).

Pterocarpus angolensis DC has been identified as having a high utilization rate as firewood, timber, and medicine (Zininga *et al.*, 2017). Its preference for timber is based on its moderately dense heartwood, which is easily worked, very attractive, and widely used for high-quality furniture and ornaments (Orwa *et al.*, 2009). It is natively distributed throughout Mozambique, Namibia, Botswana, the Democratic Republic of Congo, South Africa, Swaziland, Zimbabwe, Tanzania, and Zambia (Orwa *et al.*, 2009). In South Africa's rural communities, wood is the most valuable source of fuel (Zininga *et al.*, 2017). Shackleton *et al.* (2007), reported that back then *Pterocarpus Angolensis* was the only species used by furniture makers and firewood carvers in the central Lowveld region of Southern Africa. Firewood from this species is said to be more flammable. Therefore, overexploitation of this species has been a major concern because the community's annual need exceeds the natural supply (Mokgolodi *et al.*, 2011) and its populations would seem to be natively unstable (Desmet *et al.*, 1996).

1.2 Problem statement

According to most studies, *Pterocarpus angolensis* is one of the tree species that is harvested for a variety of uses, thus there's a chance that this species will be subjected to harvesting practices that are not sustainable (Corrigan et al., 2011). There is global demand for ethnobotanical use of plant materials, particularly that of *P. angolensis* DC. The species is continuously used for its bark in the treatment of different ailments. Its high-quality wood is preferred as timber (Sadiki *et al.* 2018). The high demand resulted in a perceived marked decline in the density of this species around South Africa (Graz, 2004; Vermeulen, 1990; Mushove, 1996).

It appears from observations at the designated research area (Khalavha village) that *P. angolensis* is still being harvested. Therefore, the future existence of its population in this area may be threatened due to its high utilisation rate of people with a good knowledge about its benefits, growth rate and also the anthropogenetic activities occurring in that area. Anthropogenetic activities are one of the most factors that is affecting the plant populations in general. Thus, the unprecedented exponential increase of human population has also become one of global concern in biodiversity loss which is negatively affecting several plant species including *P. angolensis*. Since the population of the world is getting bigger every day, it means there will be addition of more services and increase in anthropogenetic activities around the communities. For example, there has been lot of vegetation removal due to settlement expansions, human made fires and pollutions due to irresponsible activities which leads to loss and destruction of vegetation.

Nevertheless, population ecology and ethnobotanical research should be continuously conducted as a way of monitoring utilization of species important to communities. The IUCN red list listed it as a species of least concern since there is little evidence on the species (Kennish, 2021). Thus, ethnobotanical profiling of this species' utilisation, and its harvesting practices is vital. Additionally, it is more important to determine whether harvesting has influence on the demographic composition. This has the potential to make a major contribution to the creation of strategies for this species conservation and sustainable management.

1.3 Aim and research objectives

This study aimed to analyze the effects of anthropogenic factors on the population structure of *Pterocarpus angolensis* in a communal area of Khalavha Village in the Vhembe Biosphere. The following objectives will be investigated to achieve the aim:

- i. Ethnobotanical analysis about the categories of uses of *P. angolensis* in a communal area of Khalavha Village in Vhembe Biosphere.
- ii. Ecological analysis of the structure and distribution of *P. angolensis* in a communal area of Khalavha Village in Vhembe Biosphere.

1.4 Hypothesis

The utilization profile of *Pterocarpus angolensis* species in Khalavha Village will display a high level of utilization of its parts with the population structure not displaying

an inverse-J-shaped curve thereby indicating a population that is under stress from anthropogenic activities.

1.5 Justification of the study

Documentation of ethnobotanical and ecological data will provide enough evidence on what is happening within the population of *Pterocarpus angolensis* in the communal area of Khalavha Village. Ethnobotanical study will reveal the level of utilization of the species by flagging out all the utilization and plant parts preferences. Ecological study will provide information related to the structure of the population. This study is important and justified because without the current ecology and ethnobotanical knowledge it will be difficult to pronounce on the development of such a population. Results of the study will assist in development of management and monitoring plans of the species by the local and scientific communities.

1.6 Structure of dissertation

The dissertation has been presented in publication format. It has two specific objectives that have been presented as free-standing chapters. Repetition of certain aspects is unavoidable when using the publication format. The first chapter introduces the research topic using background information, rationale, aim, and objectives of the study as well as the hypotheses. The second chapter presents the work on the ethnobotanical importance of *Pterocarpus angolensis* DC. Chapter 3 deals with the

population ecology of the species. The final chapter summarizes the findings of the objectives, concluding remarks, and recommendations.

References

- Akçakaya, H.R., (2000). Population viability analyses with demographically and spatially structured models. *Ecological Bulletins*, pp.23-38.
- Bogan, E., Doina, S.T.A.N. and Vărvăruc, D., (2015). The impact of anthropogenic activities on components of the natural environment of the Titu Plain. *GEOREVIEW: Scientific Annals of Stefan cel Mare University of Suceava. Geography Series*, 24(1), pp.54-64.
- Boyce, M.S., (1992). Population viability analysis. *Annual Review of Ecology and Systematics*, 23(1), pp.481-497.
- Clark, D.A., Brown, S., Kicklighter, D.W., Chambers, J.Q., Thomlinson, J.R., Ni, J. and Holland, E.A., (2001). Net primary production in tropical forests: an evaluation and synthesis of existing field data. *Ecological Applications*, 11(2), pp.371-384.
- Cousins, S.R., Witkowski, E.T.F. and Pfab, M.F., (2014). Elucidating patterns in the population size structure and density of *Aloe plicatilis*, a tree aloe endemic to the Cape Fynbos, South Africa. *South African Journal of Botany*, 90, pp.20-36.
- De Lange-Jacobs, P., Shaikh-Kader, A., Thomas, B. and Nyakudya, T. (2020). An overview of the potential use of ethnomedicinal plants targeting the Renin–Angiotensin System in the treatment of hypertension. *Molecules*, 25(9), p.2114.
- Desmet, P.G., (1996). The vegetation and restoration potential of the arid coastal belt between Port Nolloth and Alexander Bay, Namaqualand, South Africa. MSc dissertation, University of Cape Town, Cape Town, South Africa.

- Gowdy, J.M., (1997). The value of biodiversity: markets, society, and ecosystems. *Land Economics*, pp.25-41.
- Graz, F.P., (2004). Description and ecology of *Pterocarpus angolensis* in Namibia. *Dinteria*, 29, pp.27-39.
- Gurib-Fakim, A. (1994). Constituents of the essential oils from *Piper sylvestre* growing in Mauritius. *Planta Medica*, 60(04), pp.376-377.
- Hokit, D.G., Stith, B.M., and Branch, L.C., (2001). Comparison of two types of metapopulation models in real and artificial landscapes. *Conservation Biology*, 15(4), pp.1102-1113.
- Hosseinzadeh, N., Samadi, S., Jafari, Javid M., and Takzare, A., (2015). Impending complete airway obstruction from a reinforced orotracheal tube: A case report. *Acta Medica Iran*, 53 (9), pp.590-592. PMID: 26553090.
- Kennish, M.J., (2021). Drivers of change in estuarine and coastal marine environments: An overview. *Open Journal of Ecology*, 11(3), pp.224-239.
- Khan, S.M., Page, S.E., Ahmad, H. and Harper, D.M., (2013). Sustainable utilization and conservation of plant biodiversity in montane ecosystems: the western Himalayas as a case study. *Annals of Botany*, 112(3), pp.479-501.
- Lande, R., (1998). Anthropogenic, ecological, and genetic factors in extinction and conservation. *Population Ecology*, 40(3), pp.259-269.
- Lindenmayer, D.B., Likens, G.E., Andersen, A., Bowman, D., Bull, C.M., Burns, E., Dickman, C.R., Hoffmann, A.A., Keith, D.A., Liddell, M.J. and Lowe, A.J., (2012). Value of long-term ecological studies. *Australian Ecology*, 37(7), pp.745-757.

- Lopez, J.E. and Pfister, C.A., (2001). Local population dynamics in metapopulation models: implications for conservation. *Conservation Biology*, 15(6), pp.1700-1709.
- MEA (Millennium Ecosystem Assessment), (2003): Ecosystems and human well-being: a framework for assessment. Island Press, Washington DC, United States of America.
- Mokgolodi, N.C., Ding, Y.F., Setshogo, M.P., Ma, C. and Liu, Y.J., (2011). The importance of an indigenous tree to southern African communities with specific relevance to its domestication and commercialization: a case of the marula tree. *Forestry Studies in China*, 13(1), pp.36-44.
- Moore, S., (2020). Effect of Human Activity on Plant Biodiversity. AZoLifeSciences, Accessed 24 May 2022, <https://www.azolifesciences.com/article/Effect-of-Human-Activity-on-Plant-Biodiversity>.
- Mushove, P.T., (1996). Population dynamics in *Pterocarpus angolensis* DC. stands growing on Kalahari sands. In sustainable management of indigenous forests in the dry tropics: proceedings of an international conference, Kadoma, Zimbabwe, 28 may-1 June 1996, pp. 155-167. Forestry Commission, Zimbabwe.
- Nadi, A., (2017). Diversity of medicinal plants used in the treatment of skin diseases in Tabuk region, Saudi Arabia. *Journal of Medicinal Plants Research*, 11(35), pp.549-555.
- Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Simons, A., (2009). Agroforestry Database: a tree reference and selection guide. Version 4. Agroforestry Database: a tree reference and selection guide. Version 4.

- Petchey, O.L., Pontarp, M., Massie, T.M., Kéfi, S., Ozgul, A., Weilenmann, M., Palamara, G.M., Altermatt, F., Matthews, B., Levine, J.M., Childs, D.Z., McGill, B.J., Schaepman, M.E., Schmid, B., Spaak, P., Beckerman, A.P., Pennekamp, F. and Pearse, I.S., (2015). The ecological forecast horizon, and examples of its uses and determinants. *Ecology Letters*, 18, pp.597-611.
- Porter, D.E., Edwards, D., Scott, G., Jones, B. and Street, W.S., (1997). Assessing the impacts of anthropogenic and physiographic influences on grass shrimp in localized salt-marsh estuaries. *Aquatic Botany*, 58(3-4), pp.289-306.
- Prasad, V.K., Badarinath, K.V.S. and Eaturu, A., (2008). Biophysical and anthropogenic controls of forest fires in the Deccan Plateau, India. *Journal of Environmental Management*, 86(1), pp.1-13.
- Rankoana, S.A. (2001). Plant-based medicines of the Dikgale of the Northern Province. *South African Journal of Ethnology*, 24, pp.99-104.
- Sadiki, A. and Ncube, B., (2020). Challenges of accessing water for agricultural use in the Breede-Gouritz Catchment Management Agency, South Africa. *Water Alternatives*, 13(2), pp.324-346.
- Shackleton, C.M., Timmermans, H.G., Nongwe, N., Hamer, N. and Palmer, R.C.G., (2007). The direct use value of non-timber forest products from two areas on the Transkei wild coast. *Agrekon*, 46, pp.135–55.
- Shackleton, C.M., (2002). Growth patterns of *Pterocarpus angolensis* in savannas of the South African lowveld. *Forest Ecology and Management*, 166(1-3), pp.85-97.

- Shackleton, S.E., Shackleton, C.M., Netshiluvhi, T.R., Geach, B.S., Ballance, A. and Fairbanks, D.H.K., (2002). Use patterns and value of savanna resources in three rural villages in South Africa. *Economic Botany*, 56(2), pp.130-146.
- Tredennick, A.T., Hooten, M.B. and Adler, P.B., (2017). Do we need demographic data to forecast plant population dynamics? *Methods in Ecology and Evolution*, 8(5), pp.541-551.
- Van der Riet, K., Van Rensburg, L., De Sousa Correia, R.I., Mienie, L.J. and Kruger, G., (1998). Germination of *Pterocarpus angolensis* DC. and evaluation of the possible antimicrobial action of the phloem sap. *South African Journal of Plant and Soil*, 15(4), pp.141-146.
- Vermeulen, W.J., (1990). A Monograph on *Pterocarpus angolensis*. SARCCUS Standing Committee for Forestry. Pretoria, South Africa.
- Wilson, E.O., (1988). Biodiversity. National Academy Press, New York, United States of America.
- Zininga, T., Anokwuru, C.P., Sigidi, M.T., Tshisikhawe, M.P., Ramaite, I.I., Traoré, A.N., Hoppe, H., Shonhai, A. and Potgieter, N., (2017). Extracts obtained from *Pterocarpus angolensis* DC and *Ziziphus mucronata* exhibit antiplasmodial activity and inhibit heat shock protein 70 (Hsp70) function. *Molecules*, 22(8), p.1224.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Pterocarpus angolensis DC belongs to the family Leguminosae: Fabaceae (Therrell *et al.*, 2007). The genus *Pterocarpus* comprises approximately 30 species distributed across tropical regions, excluding Australia and Madagascar. In Africa, four species, including *angolensis*, are present (Von Breitenbach, 1973). *P. angolensis* thrives in the miombo woodlands of East and Southern Africa, as well as in dry evergreen and dry deciduous forests (Storrs, 1995). Miombo woodlands cover an extensive area, ranging from 2.7 to 3.6 million km² across 11 African countries, including Angola, Botswana, Democratic Republic of Congo, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe (Brummitt *et al.*, 2007).

Additionally, *P. angolensis* has been planted on a small scale in Kenya (Takawira-Nyenya, 2005) and Mozambique (Orwa *et al.*, 2009). It thrives in woodland and wooded grasslands within an elevation range of 300 to 1550 meters above sea level (Loots, 2005). This species is commonly found in various woodland types, including Kalahari sands and savanna woodland on alluvial transition soils (Fanshawe, 1972). Within miombo woodlands, *P. angolensis* stands out as a prominent tree species and is often found in association with other tree species such as *Brachystegia speciformis*, *Julbernardia paniculata*, *Julbernardia globiflora*, *Parinari curatellifolia*, *Syzygium guineense*, *Uapaca* species, and *Isoberlinia angolensis* (Chisha-Kasumu *et al.*, 2007).

Regarding soil preferences, *P. angolensis* thrives best in well-drained, medium soils, typically deep sandy or light soils with low to moderate fertility and a pH range of 5.5 to 7 (Van Wyk *et al.*, 1993). Miombo woodland soils are characterized by low organic matter, nitrogen, and phosphorus content (Mehl *et al.*, 2010). However, *P. angolensis* has developed adaptations such as vesicular-arbuscular mycorrhizae and functional nitrogen-fixing root nodules, enabling efficient utilization of available nutrients (Mehl *et al.*, 2010).

Pterocarpus angolensis is well-suited to withstand harsh environmental conditions, including fire and drought (Mehl *et al.*, 2010). It thrives in regions characterized by distinct wet and dry seasons, tolerating rainfall as low as 500 mm/year and as high as 1500 mm/year (Takawira-Nyenyanya, 2005). Furthermore, it exhibits resilience to low temperatures, enduring levels as low as 4°C (Loots, 2005).

2.2 Description of *Pterocarpus angolensis* DC

Pterocarpus angolensis DC., known for its deciduous nature, features a straight trunk and a broad, flat, or rounded crown, as reported by Palgrave (2007). Typically, a medium to large tree, it can reach heights of up to 16 meters, with optimal conditions allowing for heights of up to 28 meters, with exceptional instances noted in Mozambique, where some trees have grown up to 36 meters (Palgrave, 2007). The base of its stems occasionally swells, and at breast height, they can have diameters ranging from 50 to 60 centimetres, with reports of up to 122 centimetres under favourable circumstances (Takawira-Nyenyanya, 2005).

Sadly, there is currently a scarcity of younger stems, exacerbating the species' vulnerability to extinction, largely due to logging practices targeting immature trees to meet the growing demand for timber (Stahle *et al.*, 1999). The bark, described as grey to brown or black, exhibits a rough texture with deep cracks forming rectangular patterns, reminiscent of crocodile skin (Palgrave, 2007). Its thick bark is highly resistant to fire and emits a blood-red sap containing colorants and organic compounds like tannin and muningin when damaged (Fichtler *et al.*, 2004).

The leaves, drooping and alternate, grow up to 38 centimetres in length and are arranged in pairs of 5-9, with a central leaflet up to 7 centimetres long (Takawira-Nyenya, 2005). Leaflets range from elliptic-lanceolate to oval, initially hairy when young but becoming smooth with maturity. They fall between May and June, making way for new growth emerging between September and October (Fichtler *et al.*, 2004).

Flowers, characterized by their sweet scent and orange-yellow hue, appear in large, branched sprays, measuring 10-20 centimetres long (Palgrave, 2002). They are bisexual and typically bloom between August and December, just before the emergence of new leaves (Takawira-Nyenya, 2005).

Palgrave (2007) describes the flowers of *P. angolensis* as sweetly scented, followed by distinctive round bristly pods encased in a stiff papery wing. These fruit pods are round with a notable papery wing and typically contain a single seed (Mulofwa *et al.*, 1994). Hanging in clusters, they can reach diameters of up to 10 cm (Van Wyk *et al.*, 1993), appearing between January and June (Palgrave, 2007). The papery wings aid

in dispersal by wind, allowing them and the enclosed seeds to be carried away from the parent tree, a mechanism that can distribute pods over several kilometres (Vermeulen, 1990). These pods typically do not split open on their own but rely on external forces such as physical abrasion or fire for seed release (Boaler, 1966). Fire, in particular, helps break down the woody pod, facilitating germination in natural environments (Banda *et al.*, 2006).

Trees typically begin flowering and seeding between 15 and 20 years of age (Oldfield *et al.*, 1998) and continue producing seeds throughout their lifespan. The wood of *P. angolensis* exhibits a grey or creamy-white sapwood and heartwood, ranging from pale golden brown to darker reddish or purplish brown (Storrs, 1995). With a density of 640 kg/m³ at 12% moisture content (Goldsmith and Carter, 1981), it is renowned for its durability and resistance to various forms of degradation, including fire, decay, wood rotting fungi, termite attack, as well as terrestrial and marine borers (Takawira-Nyenyanya, 2005). The wood's grain is typically straight to interlocked with a medium to coarse texture (Takawira-Nyenyanya, 2005), making it easily workable with both hand and machine tools (Bolza and Keating, 1972).

2.3 Uses of *Pterocarpus angolensis* DC.

Pterocarpus angolensis DC., is renowned for producing some of the finest timber in Southern Africa, as noted by Palgrave (2007), contributing to its high demand owing to its exceptional quality (Aubrey, 2003). This timber finds extensive use in various

applications, including furniture making, veneer production, carving, and as a versatile building material (Takawira-Nyeny, 2005).

Artists often utilize *P. angolensis* wood to craft intricate sculptures of wildlife, catering to the curio industry (Van Wyk et al., 1993). Its flexibility, resistance to marine borers, and lightweight nature make it particularly suitable for constructing boats, doors, and window frames (Takawira-Nyeny, 2005). Additionally, its minimal shrinkage during the drying process, combined with its high durability, renders it ideal for boat and canoe building (Palgrave, 2007). The wood also serves in the creation of various items such as dishes, drums, and mortars (Palgrave, 2007), constituting a significant portion of the wood carvings found in curio shops across Southern Africa (Shackleton, 2002).

The wood of *P. angolensis* is prized for its ability to produce a rich, resonant sound, making it a preferred material for crafting various musical instruments (Palgrave, 2007). Additionally, different parts of the tree, including the bark, roots, flowers, sap, and seeds, hold significance in traditional medicine (Mulofwa *et al.*, 1994), offering remedies for a variety of ailments.

The sap, for instance, is utilized to halt nosebleeds (Palgrave, 2007) and has been known to combat ringworms and treat ulcers (Van der Reit *et al.*, 1998). Various studies have documented its use in addressing conditions such as eye cataracts, malaria, blackwater fever, skin inflammation, and urinary schistosomiasis (Watt and Breyer-Brandwijk, 1962). Furthermore, the bark, when heated in water and combined with figs, is applied as a breast massage to stimulate milk production (Palgrave, 2007).

Its cold infusion serves as a remedy for nettle rash and is employed to alleviate stomach disorders, headaches, and mouth ulcers (Palgrave, 2007).

Moreover, the bark is peeled off along with its red sap and used to address various issues such as Diarrhea, heavy menstruation, nosebleeds, headaches, stomach aches, schistosomiasis, sores, and skin problems (Takawira-Nyenyanya, 2005). Interestingly, it has also been employed in fishing as a method of poisoning fish. Boiling the bark or roots with fresh meat serves as an initial step in treating gonorrhoea (Orwa *et al.*, 2009). Furthermore, cleaned roots soaked in clean water produce an eye wash and aid in cleansing corneal ulcers (Palgrave, 2007). Additionally, the powder derived from crushed seeds is applied as a wound dressing to expedite the healing process (Takawira-Nyenyanya, 2005).

Furthermore, the heartwood extracted from roots is pounded to create a reddish-brown dye, traditionally used in Namibia and Zimbabwe's cottage industry to dye palm-leaf fibres utilized in basket weaving (Takawira-Nyenyanya, 2005). *P. angolensis* also plays a role in soil conservation projects by fixing atmospheric nitrogen, which enriches the soil (Mulofwa *et al.*, 1994; Takawira-Nyenyanya, 2005), and has been utilized in stabilizing sand dunes (Takawira-Nyenyanya, 2005) and as an ornamental tree.

Additionally, the leaves and shoots of the tree are browsed by various wildlife, particularly elephants, who exhibit a preference for them. There is evidence suggesting that elephants have toppled numerous trees in Botswana and Zimbabwe to access the leaves more easily (Roodt, 1998). Unfortunately, this behaviour exposes

the trees to fire damage and mukwa disease (Mmolotsi *et al.*, 2012). Moreover, the flowers serve as a valuable source of forage for bees (Takawira-Nyenyanya, 2005).

2.4 Factors threatening *Pterocarpus angolensis* DC.

The uncontrolled exploitation of *Pterocarpus angolensis* DC., dates back to the 1950s or even earlier in regions like the Democratic Republic of Congo, Tanzania, Zambia, and Mozambique (De Cauwer *et al.*, 2014). Both legal and illegal harvesting has been conducted to meet the growing demand for its timber, resulting in a significant decline in populations (Schwartz *et al.*, 2002). This exploitation, targeting primarily large trees, has skewed the size class profile of the species, with loggers increasingly turning to immature, small-diameter trees due to the scarcity of larger specimens (Stahle *et al.*, 1999). Unfortunately, this practice prevents these trees from reaching reproductive maturity, further exacerbating the decline in population density observed across Southern Africa (Shackleton, 2002). Additionally, land clearance for agriculture, urbanization, infrastructure development, population growth, and heavy browsing by wildlife contribute to the species' decline. Forest fires and elephant damage also play significant roles in reducing population density (Mmolotsi *et al.*, 2012).

In 1998, the World Conservation Monitoring Centre assessed the status of *P. angolensis*, resulting in its classification as "near threatened" on the IUCN Red List (IUCN., 1998). Moreover, a disease known as mukwa disease has been extensively documented in Botswana, South Africa, Zambia, and Zimbabwe, posing a significant threat to *P. angolensis* (Mehl *et al.*, 2010). Symptoms vary but commonly include wilt,

dieback, bark discoloration, vascular and phloem streaking, and the emergence of epicormic shoots (Mmolotsi *et al.*, 2012). *Fusarium oxysporum*, a fungus isolated from discoloured wood, has been identified as the causal agent of this disease (Mehl *et al.*, 2010). The disease is often intensified during the rainy season, and infected trees tend to occur in patches, typically dying 2-3 years after infection (Mehl *et al.*, 2010). Rainfall patterns, particularly prolonged droughts, have been correlated with outbreaks of the disease, suggesting a complex interplay between environmental factors and pathogen activity (Mehl *et al.*, 2010).

2.5 Management of *Pterocarpus angolensis* DC. in various countries

The natural regeneration of *Pterocarpus angolensis* DC., in the wild faces significant challenges, leading to poor and sparse regrowth (Caro *et al.*, 2005). One major obstacle is the low survival rate of seedlings during establishment, attributed to various factors such as forest fires, unfavourable climate conditions, animal browsing, and competition from other plants for light and resources (Caro *et al.*, 2005). Studies have suggested that only a small percentage of seeds produced in the wild, estimated at around 2%, actually germinate (Boaler, 1966). Even in disturbed miombo woodlands, where seedlings were observed, their numbers remain low.

Forest fires play a crucial role in the germination of *P. angolensis* seeds, as they burn and suppress existing vegetation, reducing competition for nutrients, moisture, sunlight, and growing space (Boaler, 1966). Additionally, forest fires remove wings and

bristles from the pods, crack the seeds, and facilitate better soil contact (Oldeman, 1994). Although forest fires slow down seedling development, they accelerate the growth of saplings (Boaler, 1996).

Efforts to establish commercial plantations or raise seedlings in nurseries have often been unsuccessful due to various factors such as delayed seed production, pod damage during opening, low seed germination rates, slow tree growth, and competition from dense grass and other vegetation (Caro *et al.*, 2005). However, small-scale plantings have shown success in warm areas of Mozambique where proper management practices like clear-cutting, fire control, and weeding were implemented (Orwa *et al.*, 2009).

Individual seedlings of *P. angolensis* often remain in a shrublet stage for several years, experiencing diebacks during dry seasons until their root systems develop enough to extract sufficient moisture and nutrients to support above-ground growth (Vermeulen, 1990). This shrublet stage can last for about 14 years, but many seedlings fail to survive this phase due to various factors such as drought, forest fires, nutrient deficiency, and browsing (Boaler, 1966). Factors like above-average rainfall, fire or browsing protection, and reduced competition can stimulate seedlings to transition into stages of rapid above-ground growth (Vermeulen, 1990).

Propagation of *P. angolensis* can be done through seeds and stem cuttings, although stem cuttings often have low survival rates in nurseries (Magingo and Dick, 2001). Seed collection is challenging as the pods are difficult to open without damaging the

seeds, and their hard, spiny centres do not split open naturally (Boaler, 1966). Fire, physical, mechanical, or chemical scarification treatments are often necessary to stimulate seed germination (Chisha-Kasumu *et al.*, 2007), as germination rates are irregular without such treatments (Magingo and Dick, 2001).

2.6 Conclusion

Pterocarpus angolensis DC., serves as a valuable multipurpose tree in East and Southern Africa, but it faces significant threats due to excessive exploitation for its prized timber and changes in land use. The unsustainable harvesting of this species jeopardizes its natural populations within their habitats. Additionally, factors such as forest fires, damage caused by elephants, and challenges in seedling survival during establishment contribute to the decline in mukwa populations.

Efforts to cultivate *P. angolensis* in commercial plantations have been largely unsuccessful. To address these challenges and conserve this valuable resource, a comprehensive, large-scale collaborative research effort is necessary. This research should focus on improving seed germination rates, reducing the duration of the shrublet stage in seedlings, and accelerating the growth of saplings. By implementing these measures, we can work towards saving *P. angolensis* from the threat of extinction and ensure its continued presence in the region's ecosystems.

References

- Aubrey, R. and Tang, C., 2003. The pathogenesis of disease due to type b Haemophilus influenzae. Haemophilus influenzae protocols, pp.29-50.
- Banda, T., Schwartz, M.W. and Caro, T., 2006. Woody vegetation structure and composition along a protection gradient in a miombo ecosystem of western Tanzania. Forest ecology and management, 230(1-3), pp.179-185.
- Boaler, S.B. and Sciwale, K.C., 1966. Ecology of a miombo site, Lupa North Forest Reserve, Tanzania: III. Effects on the vegetation of local cultivation practices. *The Journal of Ecology*, pp.577-587.
- Bolza, E. and Keating, W.G., 1972. African timbers-the properties, uses and characteristics of 700 species.
- Breitenbach, F.V., 1973. *Pterocarpus angolensis*.
- Brummitt, C.D., Gomez-Lievano, A., Goudemand, N. and Haslam, G., 2007. Hunting for keys to innovation: The diversity and mixing of occupations do not explain a city's patent and economic productivity. PNAS, 104, p.17.
- Caro, T.I.M., Eadie, J. and Sih, A., 2005. Use of substitute species in conservation biology. Conservation Biology, 19(6), pp.1821-1826.
- Chisha-Kasumu, E., Woodward, S. and Price, A., 2007. Comparison of the effects of mechanical scarification and gibberellic acid treatments on seed germination in *Pterocarpus angolensis*. Southern Hemisphere Forestry Journal, 69(1), pp.63-70.

- De Cauwer, V., Muys, B., Revermann, R. and Trabucco, A., 2014. Potential, realised, future distribution and environmental suitability for *Pterocarpus angolensis* DC in southern Africa. *Forest Ecology and Management*, 315, pp.211-226.
- Fanshawe, D.B., 1972. The bamboo, *Oxytenanthera abyssinica*—Its ecology, silviculture and utilization. *Kirkia*, 8(2), pp.157-166.
- Fichtler, E., Trouet, V., Beeckman, H., Coppin, P. and Worbes, M., 2004. Climatic signals in tree rings of *Burkea africana* and *Pterocarpus angolensis* from semiarid forests in Namibia. *Trees*, 18, pp.442-451.
- Goldsmith, B. and Carter, D.T., 1981. The indigenous timbers of Zimbabwe (No. 9, pp. x+406).
- Heywood, V.H., Brummitt, R.K., Culham, A. and Seberg, O., 2007. Flowering plant families of the world (Vol. 88). Ontario: Firefly books.
- Loots, S., 2005. Red data book of Namibian plants (Vol. 38). Pretoria and Windhoek: Sabonet.
- Magingo, F.S.S. and McP Dick, J., 2001. Propagation of two miombo woodland trees by leafy stem cuttings obtained from seedlings. *Agroforestry systems*, 51, pp.49-55.
- Mehl, J.W., Geldenhuys, C.J., Roux, J. and Wingfield, M.J., 2010. Die-back of kиаat (*Pterocarpus angolensis*) in southern Africa: a cause for concern? *Southern Forests: a Journal of Forest Science*, 72(3-4), pp.121-132.
- Mehl, J.W., Slippers, B., Roux, J. and Wingfield, M.J., 2011. Botryosphaeriaceae associated with *Pterocarpus angolensis* (kиаat) in South Africa. *Mycologia*, 103(3), pp.534-553.

- Mmolotsi, R.M., Obopile, M., Kwerepe, B.C., Sebolai, B., Rampart, M.P., Segwagwe, A.T., Ramolemana, G., Maphane, T.M., Lekorwe, L., Kopong, I. and Kelatlhilwe, M., 2012. Studies on Mukwa (*Pterocarpus angolensis*, DC) Dieback in Chobe Forest Reserves in Botswana.
- Mmolotsi, R.M., Obopile, M., Kwerepe, B.C., Sebolai, B., Rampart, M.P., Segwagwe, A.T., Ramolemana, G., Maphane, T.M., Lekorwe, L., Kopong, I. and Kelatlhilwe, M., 2012. Studies on Mukwa (*Pterocarpus angolensis*, DC) Dieback in Chobe Forest Reserves in Botswana.
- Mulofwa, J., S. Simute and B. Tengnas, 1994. Agroforestry Manual for Extension Workers in Southern Province, Zambia. Ministry of Agriculture, Food and Fisheries, 41-43.
- Oldeman, L.R., 1994. An international methodology for an assessment of soil degradation, land georeferenced soils and terrain database.
- Oldfield, S., Lusty, C. and MacKinven, A. eds., 1998. The world list of threatened trees (pp. ii+-650).
- Orwa, C., Muta, A., Kindt, R., Jamnadass R., & Anthony, S. (2009). Agroforestry Database: A Tree Reference and Selection Guide Version 4.0, World Agroforestry Kenya, 1-5.
- Palgrave, M.C., Van Wyk, A.E., Jordaan, M., White, J.A. and Sweet, P., 2007. A reconnaissance survey of the woody flora and vegetation of the Catapú logging concession, Cheringoma District, Mozambique. *Bothalia*, 37(1), pp.57-73.
- Roodt, V., 1998. Trees and shrubs of the Okavango delta: medicinal uses and nutritional value. S Mmolotsi, R.M., Obopile, M., Kwerepe, B.C., Sebolai, B.,

- Rampart, M.P., Segwagwe, A.T., Ramolemana, G., Maphane, T.M., Lekorwe, L., Kopong, I. and Kelatlhilwe, M., 2012. Studies on Mukwa (*Pterocarpus angolensis*, DC) Dieback in Chobe Forest Reserves in Botswana. Oil Botswana (Pty) Ltd.
- Schwartz, M.W., Caro, T.M. and Banda-Sakala, T., 2002. Assessing the sustainability of harvest of *Pterocarpus angolensis* in Rukwa Region, Tanzania. *Forest Ecology and Management*, 170(1-3), pp.259-269.
- Shackleton, C.M., 2002. Growth patterns of *Pterocarpus angolensis* in savannas of the South African lowveld. *Forest ecology and management*, 166(1-3), pp.85-97.
- Stahle, D.W., Mushove, P.T., Cleaveland, M.K., Roig, F. and Haynes, G.A., 1999. Management implications of annual growth rings in *Pterocarpus angolensis* from Zimbabwe. *Forest Ecology and Management*, 124(2-3), pp.217-229.
- Stahle, D.W., Mushove, P.T., Cleaveland, M.K., Roig, F. and Haynes, G.A., 1999. Management implications of annual growth rings in *Pterocarpus angolensis* from Zimbabwe. *Forest Ecology and Management*, 124(2-3), pp.217-229.
- Storrs, R.W., Tropper, F.D., Li, H.Y., Song, C.K., Kuniyoshi, J.K., Sipkins, D.A., Li, K.C. and Bednarski, M.D., 1995. Paramagnetic polymerized liposomes: synthesis, characterization, and applications for magnetic resonance imaging. *Journal of the American Chemical Society*, 117(28), pp.7301-7306.
- Takawira-Nyenyanya, R., Jansen, P.C.M. and Cardon, D., 2005. *Pterocarpus angolensis* DC. *Plant Resources of Tropical Africa 3: Dyes and Tannins*, pp.126-130.

- Therrell, M.D., Stahle, D.W., Mukelabai, M.M. and Shugart, H.H., 2007. Age, and radial growth dynamics of *Pterocarpus angolensis* in southern Africa. *Forest ecology and management*, 244(1-3), pp.24-31.
- Van der Riet, K., Van Rensburg, L., De Sousa Correia, R.I., Mienie, L.J. and Kruger, G., 1998. Germination of *Pterocarpus angolensis* DC. and evaluation of the possible antimicrobial action of the phloem sap. *South African Journal of Plant and Soil*, 15(4), pp.141-146.
- Van Wyk, J.B., Konstantinov, K.V. and Erasmus, G.J., 1993. Variance component and heritability estimates of early growth traits in the Elsenburg Dormer sheep stud. *South African Journal of Animal Science*, 23(3-4), pp.72-76.
- Vermeulen, M. and Van Gijn, J., 1990. The diagnosis of subarachnoid haemorrhage. *Journal of neurology, neurosurgery, and psychiatry*, 53(5), p.365.
- Walter, K.S. and Gillett, H.J. eds., 1998. 1997 IUCN red list of threatened plants. IUCN.
- Watt, J.M. and Breyer-Brandwijk, M.G., 1962. *The Medicinal and Poisonous Plants of Southern and Eastern Africa being an Account of their Medicinal and other Uses, Chemical Composition, Pharmacological Effects and Toxicology in Man and Animal.*

CHAPTER THREE

ETHNOBOTANICAL STUDY OF *Pterocarpus angolensis* DC. AT KHALAVHA VILLAGE IN THE VHEMBE BIOSPHERE

The specific objective of this chapter was to investigate the ethnobotanical profile of the categories of uses of *Pterocarpus angolensis* in a communal area of Khalavha Village in Vhembe Biosphere.

3.1 Introduction

According to Selin (2013), the phrase Ethnobotany was introduced by John Harschberger in 1895. It was specifically used in relation to how Native Americans used plants. Ethnobotany considers the full spectrum of interactions between humans and plants as well as the purposes of plants. However, the term is currently used to refer to the study of traditional or indigenous plant knowledge (Iwu, 2002). It includes the traditional understanding of how to classify, grow, and use plants for food, medicine, timber, fuels, and others. The name ethnobotany does not always refer to the study of how "other" people utilize plants, even while most of the early ethnobotanists examined how plants were used in cultures other than their own. Additionally, it is not restricted to indigenous cultures research on medicinal plants. Documenting the interaction between plants and indigenous communities is crucial to the application of ethnobotany in plant selection.

Plants have been also used traditionally by people for the treatment of various diseases since time immemorial (Devi, 2012). In the traditional medicinal system, plant extracts in various forms such as decoction, infusion, maceration, and others are used to treat a wide variety of diseases. Jadhavar *et al.* (2022), reported that some whole plants and some plant parts are useful for the treatment of different diseases and disorders. Dönmez (2006) reported the medicinal values of species that belong to the Fabaceae family.

Pterocarpus angolensis DC. is known as a species that has antimicrobial properties (Orwa *et al.*, 2009). When the bark is cut, it exudes a blood-red sap that contains colourants and other organic compounds such as tannin (Watt and Breyer-Brandwijk, 1962). The ethnobotanical study which was conducted by Anokwuru *et al.* (2017), revealed that this species contains phenolic compounds such as gallic acid, rutin, taxifolin, caffeic acid, epicatechin, catechin, and protocatechuic acid. Other compounds with antimicrobial properties that are reported to be contained within the heartwood of this species are isoflavonoids, hydro dihydrochalcones, and alpha-methyldeoxybenzoins.

Infusion is the process in which active compounds of plants are extracted by soaking their parts in water to make a remedy (Orwa *et al.*, 2009). The bark of *P. angolensis* is soaked in cold water to prepare a remedy for nettle rash, and it can also be taken orally for the treatment of different ailments such as blood in the urine, headaches, stomach disorders, and mouth ulcers. This can also be used to neutralize the pain of an aching ear, by making a few drops inside. Infusion can also be made by soaking

the roots of this species in cold water to make a remedy that is used for treatment that is taken orally for the treatment of bilharzia, abdominal pains, and diarrhoea (Venter and Venter, 1996). Remedy for treatment of tuberculosis and asthma is made by burning roots to make ashes that are mixed with water, and it is taken orally. Bark infusion is also used to solve infertility problems among women. Roots are cleaned and soaked in cold water for about 6 hours (minimum) to make a remedy that is used to bath as a treatment for corneal ulcers (Nyazema *et al.*, 1994).

Mutondo is very well-known for its popular use in the treatment of ailments such as eye infections, wounds, and psoriasis (Venter and Venter, 1996). When the bark of *P. angolensis* is boiled in water it results in red fluid that is used remedy which is taken orally for piles, menorrhagia, blackwater fever, malaria, ringworms, and skin lesions, furthermore, this decoction can also be taken topically for treatment of skin lesions by bathing with that remedy (Venter and Venter, 1996). The decoction can also made by boiling flowers of *P. angolensis* to make a remedy for eye disorders, and it is applied by steaming wherein the patients have to cover themselves using a blanket with their eyes open to allow the steam to enter the eyes (Watt and Breyer-Brandwijk, 1962).

Bleeding gums and inflamed areas of the skin are said to be treated by applying ashes of burned ripe seeds of this species directly on that affected area. The sap of this species is believed to heal sores If a person is stabbed and has other skin-related ailments, you just extract the sap from the bark or stem and apply it on the sores, and it is reputed to be the treatment of cataracts (Venter and Venter, 1996).

3.2 Study area, materials, and methods

3.2.1 Study area description

A. Topography and geology

The current study was conducted in a communal area of Khalavha Village in Vhembe Biosphere Reserve, in the Limpopo Province, South Africa (Figure 2.1). The geographical coordinates of Khalavha Village are 22° 55' 24" South and 30° 17' 48" East, (www.mapcarta.com).

The study area is located in the far west part of Thohoyandou town which is under Thulamela municipality which falls under Vhembe district in Limpopo Province, South Africa. Khalavha village is situated just after Thathe holy forest when you are on your way coming from Thohoyandou going to Siloam hospital, just 15 km away from Phiphidi Waterfalls. Its elevation is approximately 1 032 meters and 3 386 feet (www.mapcarta.com). Its surface area is approximately 5.97 km², with an estimated population size of about 3 237 people in 2011, of which 100% of them were black African, and the majority (97%) of them speak the Tshivenda language as their native language (Census, 2011).

B. Vegetation and climate

The village is composed of a forest and savannah biome, dominated by trees in hilly areas and shrubs with grasses in gentle areas. The soil is mainly stony in hilly areas and loam with sandy soil in some flat areas.

At Khalavha, they experience hot summers, which are more humid with rainfalls, and moderate cold winters, which are less humid with dry air. During summer, temperature ranges from 28°C to 33°C and winter ranges from 13°C to 29°C (www.mapcarta.com).

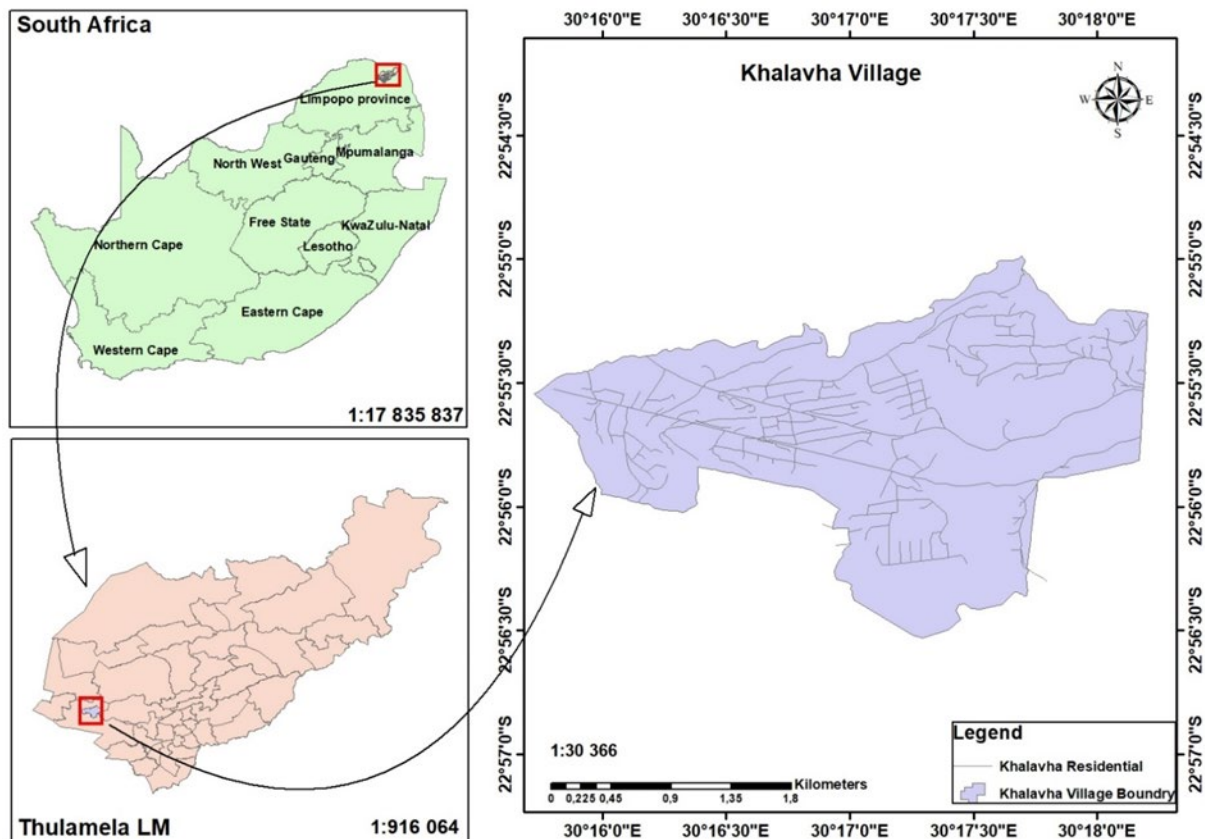


Figure 3.1: Area in Thulamela municipality, where the study was conducted, Khalavha Village.

3.2.2 Methodology

Consent to conduct the study at Khalavha Village was granted by the local headman of the area before data collection amongst the community. The purpose of the study was clearly explained to informants before they agreed to participate in the study.

There were no targeted informants, a random sampling technique was used to collect data. The interviews were completed through door-to-door visits and by approaching any villagers across the village. To diagnose if informants were suitable to be part of the study, they were prior asked if they knew *Pterocarpus angolensis* and its uses. However, the informant's profile for those who indicated that they knew the species was recorded. This was noted to help during the evaluation of indigenous knowledge that is being transmitted amongst different age groups.

Ethnobotanical data was collected from participating informants with an aid of semi-structured questionnaire (Annexure A). All the interviews were facilitated in Tshivenda so that informants could understand what the questionnaire required. Information was captured in the questionnaires using both Tshivenda and English languages. Information captured in Tshivenda was later transliterated into English language and Microsoft Office Excel was used to capture all the data from questionnaires. Descriptive statistics was used to analyse the frequency patterns.

3.3 Results and Discussion

3.3.1 Informants profile

A. Gender

Fifty-three informants were interviewed, of which 35 of them were females, while 18 of them were males (Figure 2.2). A higher percentage of informant's participation being

females can be attributed linked with the findings from the survey which was conducted by the Census in 2011 (STATSSA). An ethnoecological investigation conducted in Ha-Matsa village (Phalanndwa, 2022) on the utilization of *Spirostachys africana* also recorded high participation of women informants as was also observed in this study.

The higher participation of women informants is associated with the consideration that *Pterocarpus angolensis* is mostly known for treating ailments that are associated with women, thus fertility-related disorders. The study which was conducted by Santos *et al.* (2020), also reported that *P. angolensis* is one of the most preferred species for the treatment of different ailments including fertility problems. Compared to their male counterparts, females are more likely to be dependent on forest resources because of their ongoing interactions with the environment (Heltberg *et al.*, 2000). Generally speaking, women's knowledge of local plants used for various purposes can be said to be greater than that of men, and it can be explained by the roles that women play in every household when comparing roles that are based on masculine hormones. The certainty that women showed more knowledge of this species in this study can also be associated with the fact that they are the ones who are responsible for taking care of food preparations because it is known for being the best source of the most flammable firewood.

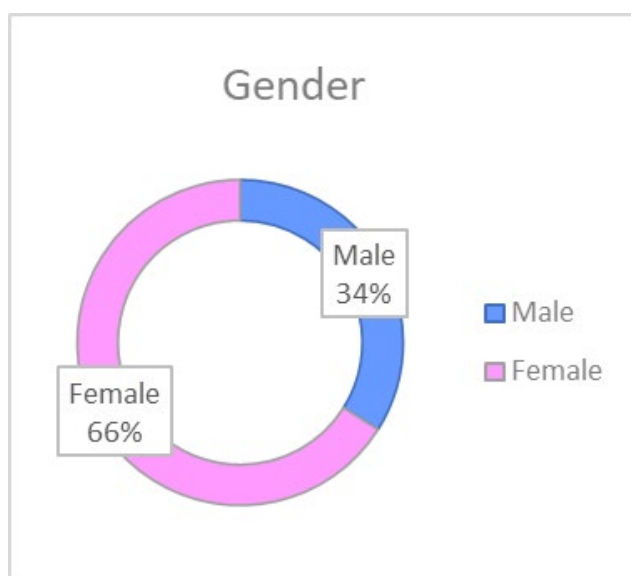


Figure 3.2: Gender profile of all the informants interviewed in the study.

B. Age groups

Overall, 10 youth (15 - 35), 15 adults (36 – 55), and 28 elders (56 and above) were interviewed as shown in Figure 2.3. A similar trend was also observed, where the majority of informants that participated were 60 years old and above at Lwamondo village, Limpopo Province of Southern Africa (Mahwasane *et al.*, 2013). The age profile of participants plays a major role in sustaining the utilization and application of local knowledge associated with their natural resources (Chepkosgei and Jerotich, 2016).

In this study, 3 age groups of informants were only considered, starting with youth, then adults, and elders. Adults and elders were more knowledgeable about this species because they contributed more to this study with each group contributing 53% (n=15) and 28% (n=28) respectively. Significantly low participation of 19% shown by the youth age group was recorded. Comparable to this study, Cheikhoussef *et al.*

(2011) also reported a similar trend, where elders had substantive indigenous knowledge compared to youth and adults.

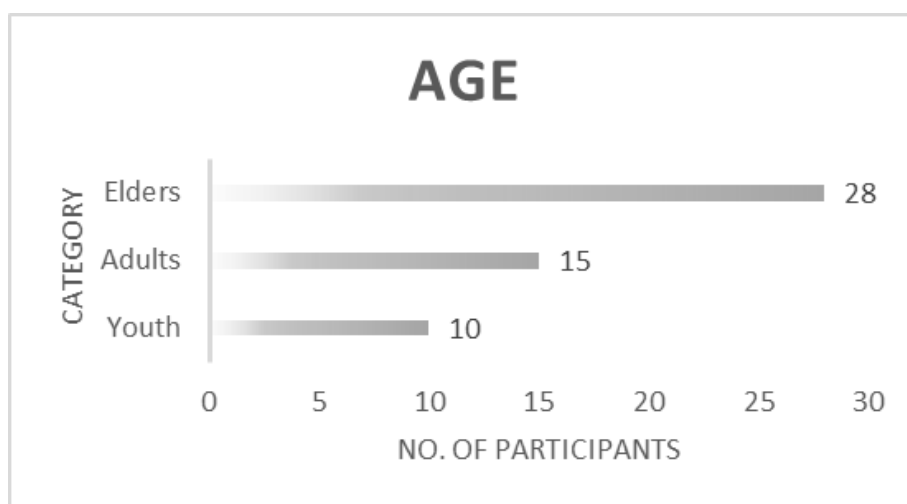


Figure 3.3: Age categories of all the informants interviewed in the study.

C. Education background

Educational background information for informants who participated in interview was also recorded to establish if there was some correlation between educational level and the distribution of indigenous knowledge. Out of 53 informants that participated, nine of them attended school up to the primary level, while the majority (n=22) of them ended at the secondary level, and only 7 of the informants pursued education up to the tertiary level. Fifteen of the informants never went to school (Figure 2.4). Comparable to this finding, Nefhere (2019) also reported a similar trend, where most informants had secondary education in a study on perceptions of traditional healers with regard to ethnobotanical importance and conservation status of indigenous medicinal plants of Thulamela. However, the same study reported a lower percentage of informants who had tertiary education and a higher percentage of informants who

had primary education. Other studies reported that female informants were less educated than males (Yesil and Inal, 2021).

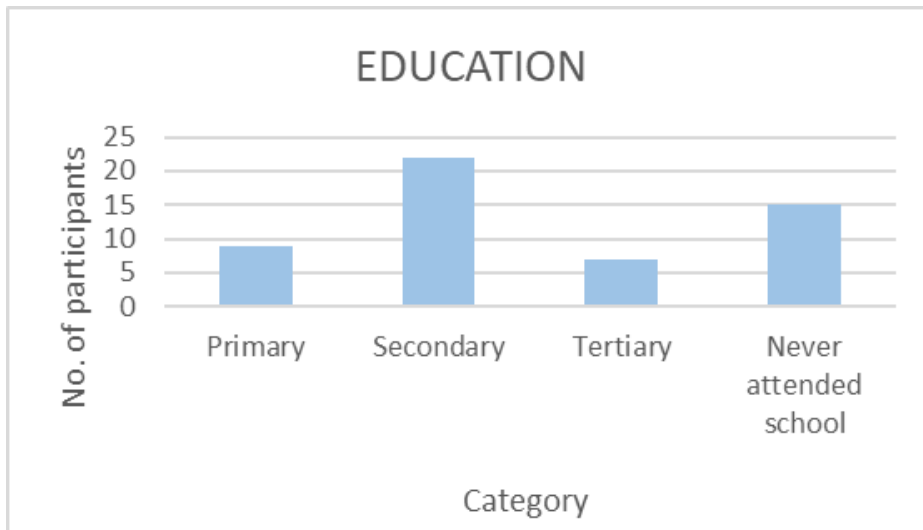


Figure 3.4: Education background of all the informants who participated in the study.

3.3.2 Use categories

Some of the anthropogenic factors affecting population of *Pterocarpus angolensis* at Khalavha Village were recorded and grouped into five categories namely, firewood, medicine, craftwork, protection, and construction. It was noteworthy that, in Khalavha Village they mostly use this plant species as medicine, craftwork, and firewood compared to other uses, as shown in Figure 2.5.

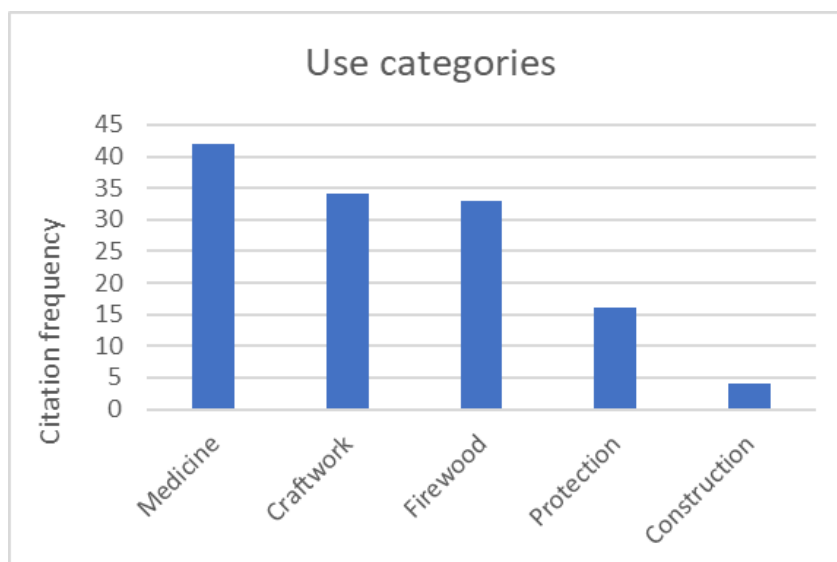


Figure 3.5: Different use categories of *Pterocarpus angolensis*.

Van der Riet *et al.* (1998), also reported a similar trend where the majority of informants disclosed that this species is mostly used as medicine for various ailments, firewood, and also as craft. Gurib-Fakim (1994) reported that the use of herbal medicines in our daily lives has a long history and still has great importance in indigenous cultures, and they are still being used as primary healthcare systems. Comparable to this finding by Sigidi *et al.* (2017), reported that about 80% of the world's population depends on traditional medicines from indigenous plants for their primary healthcare. The high dependency of Vhavenda people in Khalavha Village on medicinal plants may be due to the existence of many elders because they still hold the indigenous knowledge, and the shortness of the distance that they must travel to have access / harvest the medicinal plant materials.

3.3.3 Methods of collection and plant parts used

Methods and procedures for the collection of plant materials differ according to the preferred part of the plant and types of use categories. Ethnobotanical data collected during this survey indicated that different parts of *Pterocarpus angolensis* have been and still are the plant species preferred by the people of Khalavha Village. However, all the informants disclosed that only two parts of this plant are preferred: stem (67%) and bark (33%). The stem was the most frequently used part as shown in Figure 2.6.

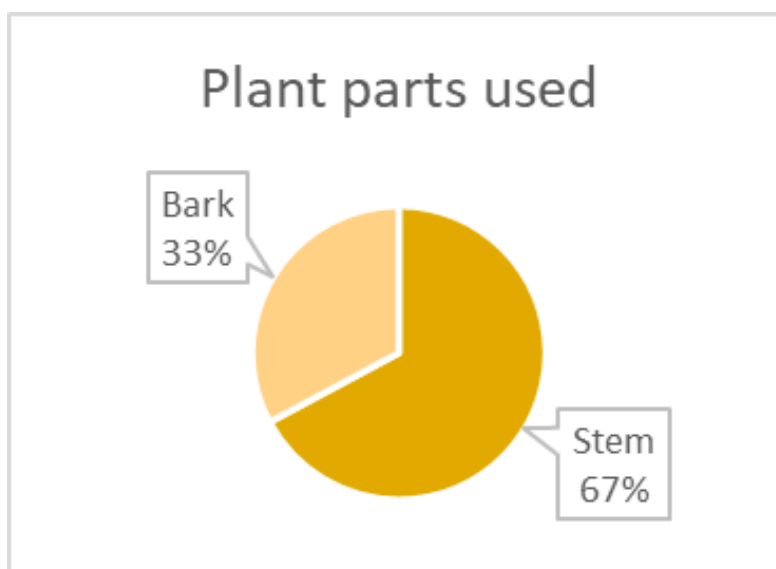


Figure 3.6: Plant parts that are preferred on *Pterocarpus angolensis*.

Zininga *et al.*, (2017) reported that *P. angolensis* has been identified as having a high utilization rate as timber, firewood, and medicine. The same study reported that, extracts obtained from *Pterocarpus angolensis* DC and *Ziziphus mucronata* exhibit antiplasmodial activity and inhibit heat shock protein 70 function. Therefore, the high percentage of stem cutting from this study can be associated with findings that were

reported by Orwa *et al.* (2009). They indicated that the preference of this species for timber is based on its moderately dense, easily worked, very attractive, and widely used for high-quality furniture and ornaments. People of Khalavha Village revealed that they use that blood-like sap to cure any blood-related ailments, such as high blood pressure, menstrual overflow, bringing back menstruation, blood cleansing, and cleansing of the womb. Watt and Breyer-Brandwijk (1962) reported that the bark of *P. angolensis* exudes a blood-red sap that people use as medicine.

Mokgolodi *et al.* (2011), indicated that the overexploitation of *P. angolensis* has been a major concern mostly in rural areas, which may be due to speculations that this species produces flammable firewood, strong and long-lasting construction materials. People of Khalavha Village said that sticks made from *P. angolensis* adult branches or juvenile stems are cut and put at the gate for yard/home stand protection against evil spirits that can be brought by evil people, and menstruating girls entering the Kraal and garden protection against women that are menstruating.

3.3.4 Ethnobotanical profiling of *Pterocarpus angolensis* DC.

A. Medicinal uses

In the findings of this study, a total of 43 (27 females and 16 males) informants representing 81% of people that participated in this study indicated that *Pterocarpus angolensis* DC. is mostly used for traditional medicine to treat various ailments in humans and livestock. The remaining 19% showed null knowledge about this tree being used as medicine. Most females were found to be more knowledgeable about

the medicinal uses of this species compared to males. Thus, 51% of female participants stated that *P. angolensis* is well known to be used as medicine to cure different ailments such as eye problems, menstruation-related diseases, bilharzia, and wounds. They also disclosed that decoction made from the inner bark of this species does help to increase the milk of breast-feeding women.

Thirty percent of male participants stated that it is used as medicine to cure ailments such as eye problems, men's urinary system, and men's sexual problems. *P. angolensis* is also used as a mixture with other plants to treat some ailments. Thus, its barks are mixed with the barks of *Albizia adianthifolia*, *Sclerocarya birrea*, and Muene-ene for blood cleansing. The bark of this species are also mixed with the barks of *Elaeodendron transvaalense* to make a decoction for men's reproduction system cleansing. They also postulated that the sap of *Albizia adianthifolia* is extracted and makes a stick-like shape, and its tip is deepened inside red blood-like sap for the extraction of that grey-like cover in the eye (Cataract). Schwartz *et al.*, (2002), reported that the sap has a long history of usage in South Africa to cure skin problems, ulcers, and cataracts in the eyes.

Comparable to this study, Cheikhoussef *et al.* (2011) and Phalanndwa (2022), reported that women normally consider using herbal medicines for their sexual or infertility-related problems. The research which was conducted by Whaley (2011), showed that women (especially those who reside or grew up in rural areas) have a lot of knowledge when it comes to traditional medicines, this is due to the responsibility that they carry of making sure that their family's health or wellbeing is taken care of.

Medicinal barks of *P. angolensis* are mostly used to treat skin illnesses, respiratory issues, gastrointestinal and urine-genital disorders, and fertility problems (Santos *et al.*, 2020).

B. Firewood

Most informants who participated in this study disclosed that *Pterocarpus angolensis* is one of the most preferred trees that makes the best firewood because it produces Mopane-like woods that are very flammable. In this study, female informants (51%) showed more knowledge about this particular use compared to males (13%), this may be because women are the ones who cook or prepare food at home. Other participants stated that it is not easy to harvest this kind of tree for firewood purposes, because it is said to be a protected or restricted species. Other participants bad-mouthed it, saying that its firewood produces a lot of black-like smoke that extremely darkens the pots, and they lack charcoals. Rahman *et al.* (2011) and Zininga *et al.* (2017) reported that in the rural areas of South Africa, wood from *Pterocarpus angolensis* is one of the most preferable sources of fuel.

C. Craftwork and timber

Orwa *et al.* (2009), reported that *Pterocarpus angolensis* is one of the most preferred trees for materials such as timber and crafts because its heartwood is moderately dense, very attractive, and easily worked and the materials made from this species have quality in such a way that they are strong, and they last long.

Sixty-six percent (both females and males) of villagers who participated in this study, attested that thick branches and stems of matured trees of this species (young adults and adults) were and are still preferred for designing crafts that are used as household utensils such as wooden spoons, dishes, mutuli and many more. They also disclosed that they are used to make attractive and quality furniture such as cupboards, couches, chairs, and other ornaments that people use to decorate their houses. *Pterocarpus angolensis* is a very admired species because of its strength, acoustic qualities, durability, and beauty in flooring, ornaments, and crafts such as musical instruments, and furniture (Antwi-Boasiako *et al.*, 2019). The study which was compiled by Shackleton and Shackleton (2004), reported that the wooden domestic goods (spoons, bowls, mortars, pestles, and agricultural implements) and ceremonial and cultural artifacts (sticks, drums, and headrests) have long been made using the raw materials harvested from *Pterocarpus angolensis*.

Only 8% of participants said that this species was also being used to make timber such as roofing materials that are used during house-building projects. This particular use had the lower percentage because participants showed that they are no longer using this species for roofing since it is now a protected species, so they are not allowed to harvest it. *Pterocarpus angolensis* is one kind of timber tree that naturally regenerates in Namibia's dry forest (Kayofa, 2015).

D. Garden yard and kraal protection

Several participants disclosed that *Pterocarpus angolensis* is mostly used by people who are practicing cattle farming. Once the kraal is constructed, they cut two sticks of

this species and cross them over to make a gate (Mapango), or this species can also be planted in the middle of the kraal. All that is done to protect cattle from getting sick if ever the women who are menstruating enter the kraal. It is also believed that if women who are menstruating enter a garden that has vegetables such as Thanga (pumpkin leaves), vegetables will no longer produce edible pumpkins. Once they reach the mature stage, they will all be spoiled (u moda in Tshivenda). In Tshivenda they call those processes “u elula” (to prevent). Every human believes that they are distinct individuals with their own set of beliefs, routines, tastes, and peculiarities (Peregrine and Ember, 2003). Most people in the society share many of these beliefs and practices. *Pterocarpus angolensis* was one of the trees that was being used for protection against evil spirits such as bad luck and witchcraft (Sapkota, 2013).

3.4 Conclusion

The current ethnobotanical study on *Pterocarpus angolensis* DC. Khalavha Village revealed that some of the villagers who reside in this area harvest and use this species. They also showed that the stem was the most preferred plant part for various uses ranging from firewood, crafting, protection, and others compared to the bark. The use of *P. angolensis* for traditional medicinal purposes was found to be the most common among different age groups and genders with adult and elderly females contributing more information on its uses. Data further revealed that *P. angolensis* is also popular in this village for its firewood which is said to be more flammable and also its heartwood which is mostly preferred for making precious and attractive furniture.

This study also identified the lack of indigenous knowledge about this species by youth age group. In this case, it is a great thing that youth lack knowledge about this species. Because it simply means that this species will be more sustainable in the future without being brutally harvested. In this study, we hypothesized that the bark and stem of this species in Khalavha Village will have a high level of utilization. The collected data showed that the stem is the most utilized part of this species, and their utilization rate was not that high since it was only mature adult trees that were debarked.

References

- Anokwuru, C.P., Sigidi, M.T., Zininga, T., Tshisikhawe, M.P., Shonhai, A., Ramaite, I.D.I., Traoré, A.N. and Potgieter, N., (2017). Phenolic contents, antioxidant activity and spectroscopic characteristics of *Pterocarpus angolensis* DC. stem bark fractions. *Indian Journal of Traditional Knowledge*, 16(3), pp.400-406.
- Antwi-Boasiako, C., Anthonio, F.A. and Frimpong-Mensah, K., 2019. Mechanical properties of coppiced and non-coppiced *Pterocarpus Erinaceus* boles and their industrial application. *Journal of Forestry Research*, 30, pp.1973-1980.
- Cheikhoussef A., Shapi M., Matengu K., and Ashekele H.M., (2011). Ethnobotanical study of indigenous knowledge on medicinal plant use by traditional healers in Oshikoto region, Namibia. *Journal of Ethnobiology and Ethnomedicine* 7:10-21.
- Chepkosgei, M.P. and Jerotich, C.G., (2016). Trends for application of indigenous knowledge in natural resource management among Nandi people, Kenya. *Journal of Environmental Science, Computer Science, and Engineering and Technology* 5 (3): 513-527.
- Devi, S., Gupta, A.K. and Singh, M., (2012). Ethno-Medicinal use of plants belonging to families Fabaceae and Solanaceae, Hamirpur district (HP). *International Journal of Scientific and Research Publications*, 2(11), pp.1-4.
- Dönmez, E.O., (2006). Prehistoric and Medieval plant remains from two sites on the Euphrates, south-eastern Turkey. *Turkish Journal of Botany*, 30(1), pp.11-38.

Dwivedi, S.A., Gharde, S.K. and Kumar, V., (2019). Effect of environmental factors on population incidence *Helicoverpa armigera* (Hubner) in Bengal gram. *Think India Journal*, 22(34), pp.1307-1316.

Heltberg, R., Arndt, T.C. and Sekhar, N.U., (2000). Fuelwood consumption and forest degradation: A household model for domestic energy substitution in rural India. *Land Economics*, pp.213-232.

[Http://www.maplandia.com/south-africa/northern-province/thohoyandou/khalavha/](http://www.maplandia.com/south-africa/northern-province/thohoyandou/khalavha/).

Accessed on 01/05/2022.

[Http://www.statssa.gov.za/census/census_2011/census_products/LP Municipal Report.pdf](http://www.statssa.gov.za/census/census_2011/census_products/LP_Municipal_Report.pdf). Accessed on 01/05/2022.

[Https://mapcarta.com/](https://mapcarta.com/). Accessed on 01/05/2022.

Iwu, M.M., (2002). Introduction: Therapeutic agents from ethnomedicine. *Advances in Phytomedicine*, 1, pp. 1-22. Elsevier.

Jadhavar, P. and Deshpande, D.S., (2022). Recent updates on the medicinal potentiality of the Fabaceae family: Critical. *International Journal of Pharmacological Sciences*, 13(3), pp.32-41.

Kayofa, F., (2015). Natural regeneration potential of *Pterocarpus angolensis* (Kiaat Tree) in the dry forests of northern Namibia. MSc dissertation, Stellenbosch: Stellenbosch University, Western Cape, South Africa.

Mahwasane, S.T., Middleton, I. and Boaduo, N., (2013). An ethnobotanical survey of indigenous knowledge on medicinal plants used by the traditional healers of the Lwamondo area, Limpopo province, South Africa. *South African Journal of Botany*, 88, pp.69-75.

- Mokgolodi, N.C., Ding, Y.F., Setshogo, M.P., Ma, C. and Liu, Y.J., (2011). The importance of an indigenous tree to southern African communities with specific relevance to its domestication and commercialization: a case of the marula tree. *Forestry Studies in China*, 13(1), pp.36-44.
- Nefhere, K.V., (2019). Perceptions of traditional healers regarding ethnobotanical importance and conservation status of indigenous medicinal plants of Thulamela, Limpopo. University of Limpopo, Polokwane, South Africa.
- Nyazema, N.Z., Ndamba, J., Anderson, c., Makaza, N. and Kaondera, K.C., (1994). The doctrine of signatures or similitudes: a comparison of the efficacy of praziquantel and traditional herbal remedies used for the treatment of urinary schistosomiasis in Zimbabwe. *International Journal of Pharmacognosy*, 32(2), pp.142-148.
- Peregrine, P.N. and Ember, M. eds., (2003). Encyclopaedia of Prehistory: Volume 8: South and Southwest Asia (Vol. 8). Springer Science and Business Media.
- Phalanndwa, M.V., (2022). Ethnoecological investigation of *Spirostachys africana* Sond. population at ha-Matsa village, Limpopo Province, South Africa. MSc dissertation, University of Venda, Thohoyandou, South Africa.
- Rahman, M.H., Khan, A.S.A., Roy, B. and Fardusi, M.J., (2011). Assessment of natural regeneration status and diversity of tree species in the biodiversity conservation areas of North-eastern Bangladesh. *Journal of Forestry Research*, 22, pp.551-559.
- Sapkota, P.P., (2013). Religious culture and medicinal plants: an anthropological study. *Dhaulagiri Journal of Sociology and Anthropology*, 7, pp.197-224.

- Santos, E.S., Luís, Â., Gonçalves, J., Rosado, T., Pereira, L., Gallardo, E. and Duarte, A.P., (2020). *Julbernardia paniculata* and *Pterocarpus angolensis*: From ethnobotanical surveys to phytochemical characterization and bioactivities evaluation. *Molecules*, 25(8), pp.1828.
- Schwartz, M.W., Caro, T.M. and Banda-Sakala, T., (2002). Assessing the sustainability of harvest of *Pterocarpus angolensis* in Rukwa Region, Tanzania. *Forest Ecology and Management*, 170(1-3), pp.259-269.
- Selin, H., (2013). Encyclopaedia of the history of science, technology, and medicine in non-western cultures. *Springer Science and Business Media*.
- Shackleton, S.E. and Shackleton, C.M., (2004). The *Pterocarpus angolensis* DC. based woodcraft industry in the Bushbuckridge district, South Africa. In: T. Sunderland and O. Ndoye, Forest products, livelihoods, and conservation: Case studies of non-timber forest product systems, 2, pp.203-228.
- Sigidi M.T., Traoré A.N., Boukandou M.M., Tshisikhawe M.P., Ntuli S.S. and Potgieter N., (2017). Anti-HIV, pro-inflammatory, and cytotoxicity properties of selected Venda plants. *Indian Journal of Traditional Knowledge*, 16(4), pp.545-552.
- Van der Riet, K., Van Rensburg, L., De Sousa Correia, R.I., Mienie, L.J. and Kruger, G., (1998). Germination of *Pterocarpus angolensis* DC. and evaluation of the possible antimicrobial action of the phloem sap. *South African Journal of Plant and Soil*, 15(4), pp.141-146.
- Venter, F. and Venter, J.A., (1996). Making the most of indigenous trees. Briza Publications, Pretoria, South Africa.

Watt, J.M. and Breyer-Brandwijk, M.G., (1962). The medicinal and poisonous plants of Southern and Eastern Africa are an account of their medicinal and other uses, chemical composition, pharmacological effects, and toxicology in man and animals. (Ed. 2).

Whaley, I., (2011). Women and the practice of medical care in early modern Europe, 1400-1800. Springer. New York City, United States.

Yeşil, Y. and Inal, I., (2021). Ethnomedicinal plants of Hasankeyf (batman-turkey). *Frontiers in Pharmacology*, 11, p.624710.

CHAPTER FOUR

ECOLOGICAL ANALYSIS OF THE STRUCTURE AND DISTRIBUTION OF *Pterocarpus angolensis* DC. IN A COMMUNAL AREA OF KHALAVHA VILLAGE IN VHEMBE BIOSPHERE

The specific objective of this chapter was to conduct ecological analysis of the structure and distribution of *Pterocarpus angolensis* in a communal area of Khalavha Village in Vhembe Biosphere.

4.1 Introduction

Monitoring plant and animal populations is one of the core activities of conservation biology. The objectives of the method are to monitor and map the distribution of vegetation at selected sites, together with changes in population levels in terms of its mortality and reproductive success (Vancanneyt *et al.*, 1990). Marsh and Trenham (2008) reported that this is one of the best methods that population ecologists use to identify whether the species are declining or at risk of extinction. To evaluate if the specific management strategies are working, track the pest species and also the spread of invasive species, finally and most importantly to establish sustainable levels of harvest or utilization.

The forest ecosystem and its functioning are mostly composed of different vegetation structures (Rahman *et al.*, 2011). Species population structure and distribution have a great influence on the plant diversity of any ecosystem. Population structure is mostly

described in terms of several individuals present in each of the precise girth class distributions of tree species. Saxena and Singh (1984) reported regeneration behaviour of plant species in a forest can be predicted from the population structure. A successful regeneration can be predicted by the overall individual of their populations, more especially the presence of enough seedlings, juveniles, or young trees in a given population (Pokhriyal *et al.*, 2010), and the seedlings of any species can be regarded as the regeneration potential of that species (Negi and Nautiyal, 2005). Natural regeneration is a central component of all the forest ecosystem dynamics across the world (Getachew *et al.*, 2010) and is essential for the preservation and maintenance of biodiversity (Rahman *et al.*, 2011). It is more important to understand the population structure of a species in the ecosystem and it is one of the foremost parameters used to predict ecosystem stability (Deb and Sundriyal, 2011).

Besides species regeneration and being able to predict population stability, a healthy age-structured population prevents population declination and extinction. Species need to have a healthy and stable population structure because it will be easy for them to survive disturbances such as utilization, manmade fires, deforestation, and others (Rahman *et al.*, 2011). Thus, if the population is composed of both seedlings and juveniles, in most cases they can resprout or shoot again after being cut or burnt by fire. *Pterocarpus angolensis* is reported as a most recommended species by people and animals. Orwa *et al.* (2009), reported that *P. angolensis* plays a vital role in the world's ecosystems' food web because Kudu and Elephant browse its leaves for nutrients purposes. He also emphasized that it is important in the plant community because it is capable of fixing atmospheric nitrogen and it is also superior when it

comes to dune fixation and soil conservation. *P. angolensis* has been reported to be utilized as firewood, timber, and medicine (Zininga *et al.*, 2017). Therefore, it is a priority to have a healthy and stable population structure of plants such as *P. angolensis* because it provides plant community and animals with vital benefits.

4.2 Study area, materials, and methods

4.2.1 Study area description

A. Topography and geology

The current study was conducted in a communal area of Khalavha Village in Vhembe Biosphere Reserve, in the Limpopo Province, South Africa (Figure 3.1). The geographical coordinates of Khalavha Village are 22° 55' 24" South and 30° 17' 48" East (www.mapcarta.com).

The study area is located in the far west part of Thohoyandou town which is under Thulamela municipality which falls under Vhembe district in Limpopo Province, South Africa. Khalavha village is situated just after Thathe holy forest when you are on your way coming from Thohoyandou going to Siloam hospital, just 15km away from Phiphidi waterfalls. Its elevation is approximately 1 032 meters and 3 386 feet (www.mapcarta.com). Its surface area is approximately 5.97 km², with an estimated population size of about 3 237 people in 2011, of which 100% of them were black African, and the majority (97%) of them speak the Tshivenda language as their native language (Census, 2011).

A. Vegetation and climate

The village is composed of a forest and savannah biome, dominated by trees in hilly areas and shrubs with grasses in gentle areas. The soil is mainly stony in hilly areas and loam with sandy soil in some flat areas (Mucina *et al.*, 2006)

At Khalavha, they experience hot summers, which are more humid with rainfalls, and moderate cold winters, which are less humid with dry air. During summer, temperature ranges from 28°C to 33°C and winter ranges from 13°C to 29°C (www.mapcarta.com).

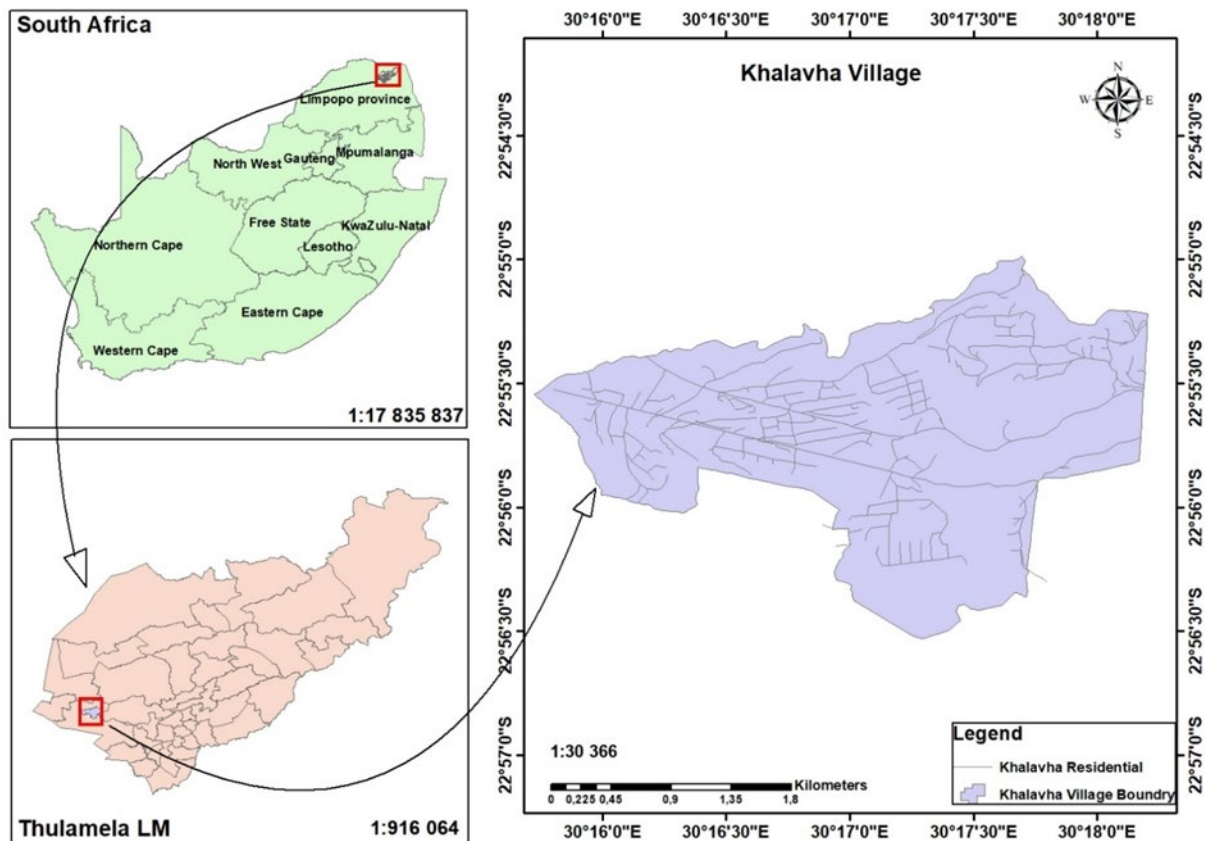


Figure 4.1. The area where the study was conducted, was Khalavha Village.

4.2.2 Methodology

The transect sampling technique was used to record ecological data on the species to analyze its population structure. Several (9) 100m x 10m transects were constructed within the population. All individuals of *Pterocarpus angolensis* located within the transects were identified and several ecological parameters were recorded using tape measures and height rods. Parameters recorded include basal stem diameter (measured with a diameter tape), the height of plants (measured with a height rod), and crown health status (recorded through an ocular sliding scale of 0-5). The sliding scale technique was used to assess visible human disturbances (Tshisikhawe *et al.*, 2012). The population structure of *P. angolensis* was therefore evaluated if it was in a good viable state or not.

One of the most popular metrics used to evaluate the benefits that woody vegetation offers to the environment and industry is stem diameter. A crucial parameter in plant physiology is the diameter of the plant stem (Paul *et al.*, 2017). Numerous research on irrigation scheduling have made use of high-resolution stem diameter variations (SDV), which are universally acknowledged as a valuable indication of drought stress (De Swaef *et al.*, 2015). More recently, basic principles underlying whole-plant development and functioning have been studied using SDV in conjunction with other plant data and biophysical models (De Swaef *et al.*, 2015). In this study, the stem diameter of *Pterocarpus angolensis* was measured to see if their population would live to survive during the rush time such as drought and other roles situations that may affect its healthy state, as shown in Figure 3.2.



Figure 4.2: A research assistant recording basal stem diameter with a diameter tape.

According to Moles *et al.* (2009), the ecological strategy of a plant species heavily relies on its height. Height plays a major role in a plant's capacity to compete for light, and there are correlations between plant height and characteristics like leaf mass fraction, leaf area ratio, leaf nitrogen per area, leaf mass per area, and canopy area, which make it essential to a species' carbon gain strategy (Falster and Westoby, 2003). In this study, the height of *Pterocarpus angolensis* was measured to see if their population would live to survive during times of competition and other roles that are believed to be associated with plant height, as shown in Figure 3.3.



Figure 4.3: A research assistant releasing a measuring pole to record the height of *Pterocarpus angolensis* at Khalavha Village.

Data collected using a questionnaire was analysed in terms of age groups, gender, religious belief, and preferred parts of the plant. Data was interpreted using Microsoft Excel, wherein descriptive graphs were used to show the population structure and distribution of *Pterocarpus angolensis*. Microsoft Excel was also used to show the relationship among variables by determining the correlation between the data sets. Descriptive statistical analysis was used to analyze the frequency trends of *P. angolensis* population.

4.3 Results and Discussion

4.3.1 Basal stem diameter

According to Paul *et al.* (2017), stem diameter is one of the most popular metrics used to evaluate the growth of woody vegetation and the advantages it offers for the environment and economy. It is a biometric that is used by foresters to forecast other biometrics that are difficult to measure directly, quantify ecosystem services, and estimate amounts of timber (Magarik *et al.*, 2020).

In this study, the size-class distribution curve of the *Pterocarpus angolensis* population found in Khalavha Village was contracted by grouping them into seven intervals based on their basal stem diameter (Figure 3.4), and they showed an inverse J-shaped curve. The studied population consisted of enough seedlings compared to other size classes. Therefore, *Pterocarpus angolensis* of Khalavha Village portrayed a healthy and stable plant population that will be able to maintain its future existence.

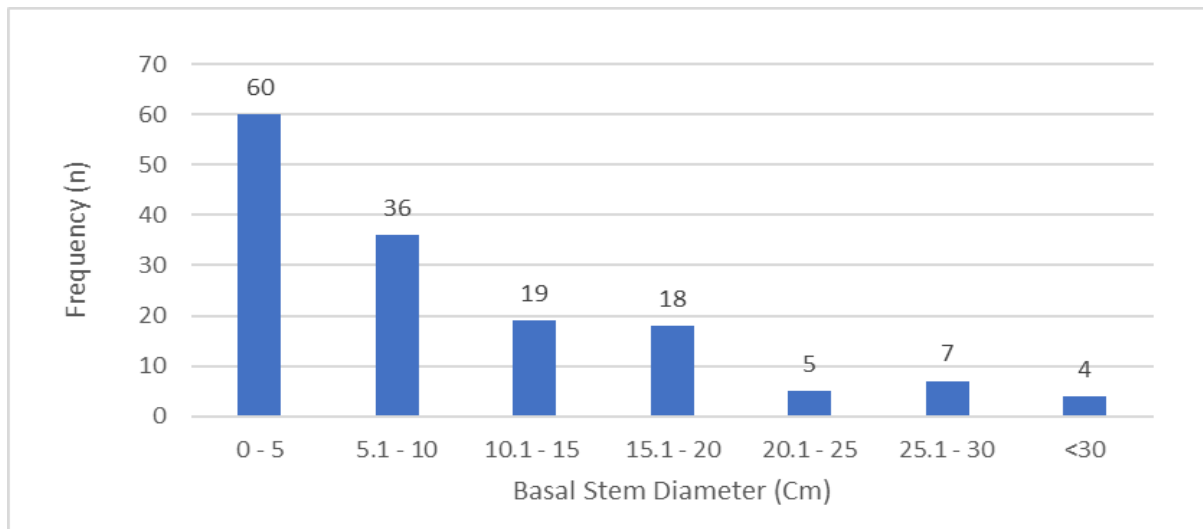


Figure 4.4: Basal stem diameters of *Pterocarpus angolensis* individuals recorded in Khalavha Village.

Tshisikhawe and Van Rooyen (2013), postulated that three absolute types of size-class distribution curves can be acknowledged in ecological studies about tree population structure: thus, the Bell-shaped curve, the typical reverse J-shaped curve, and the straight horizontal line. Normally, the Bell-shaped curve reveals that the population has few seedlings and juveniles, and it is mostly represented by young adults and adult individuals (Tshisikhawe and Van Rooyen, 2013). The straight horizontal line portrays that the plant population has relatively low seedlings and juveniles. Nevertheless, the inverse J-shaped curve depicts the healthy and stable plant populations containing continuous establishment of seedlings (Cousins *et al.*, 2014; Tshisikhawe and Van Rooyen, 2013).

4.3.2 Plant height

According to Therrell *et al.* (2007), height growth is very essential for the tree because it dictates its position in the competition for resources such as light and is the lively way for the tree to create new branches and enlarge the size of its crown. In this study, plant heights were sorted into five different class sizes, each with a class interval of 2 as shown in Figure 3.5. The majority (43%) of *Pterocarpus angolensis* individuals recorded in this study were popular to result in a foremost height category of 0 – 2m, followed by 21% of individuals that are within the size class of 2.1m - 4m tall. Trees that are in the height size class of 4.1 - 6m and 6.1 - 8m were found to have almost similar percentages (18% and 16% respectively). Only 4% of *P. angolensis* which was recorded in this study were found to have grown past 8m. Similar to the findings of this study, Therrell *et al.* (2007) also reported that this species can grow up to a height that averages between 10 to 20m. *Pterocarpus angolensis* is an angiosperm plant that is a medium to large size deciduous tree that can grow up to 19m tall (Sadiki *et al.*, 2018).

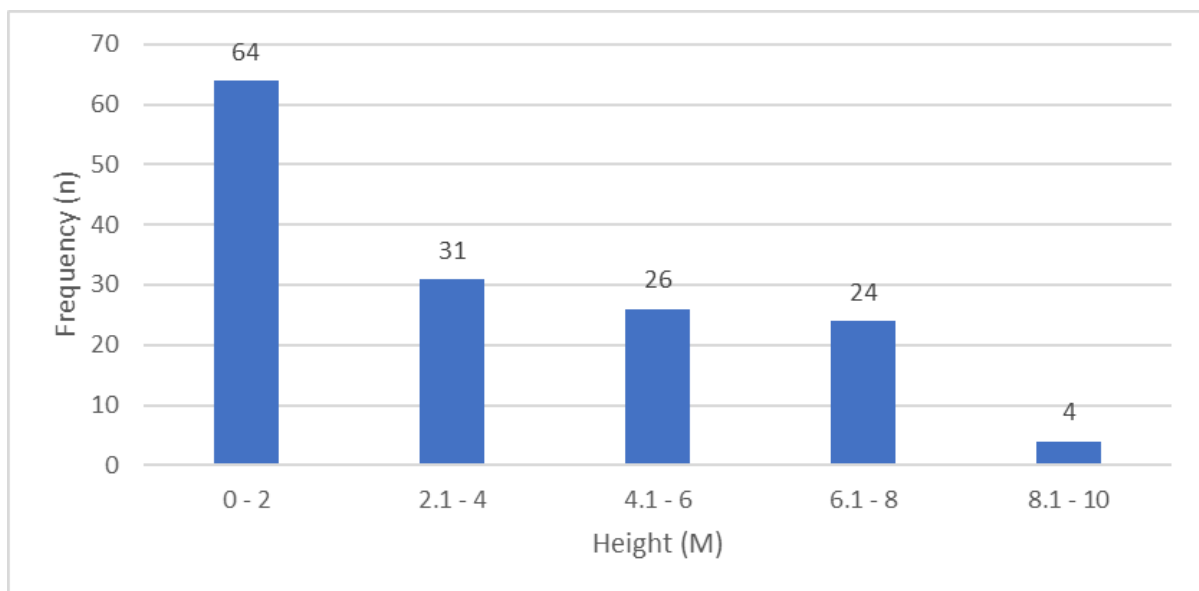


Figure 4.5: Heights of *Pterocarpus angolensis* individuals recorded in Khalavha Village.

Phalanndwa *et al.* (2022), emphasized that height measurements can also be used to detect if the population is recruiting new seedlings that will mature and form a stable population that will survive and maintain its future existence.

4.3.3 Crown health

The crown health data collected in this study revealed that the crown health of the *P. angolensis* population in Khalavha Village depicted the crowns that are bearably damaged. This damage could be due to anthropogenic factors such as fire and plant parts harvesting, that occur from time to time in some of the areas in Khalavha Village.

In this study, 37% of trees were established to have light-damaged crowns, whereas 22% of them showed little traces of crown damage, and 15% were severely damaged. Eleven percent (11%) of studied trees had healthy crowns, and only 1% of them showed 100% mortality of their crowns, as shown in Figure 3.6. However, most of the trees with healthy crowns were seedlings and juveniles. Most young adults and adults had yellowish leaves, which may be due to improper watering since they are located in mountainous areas.

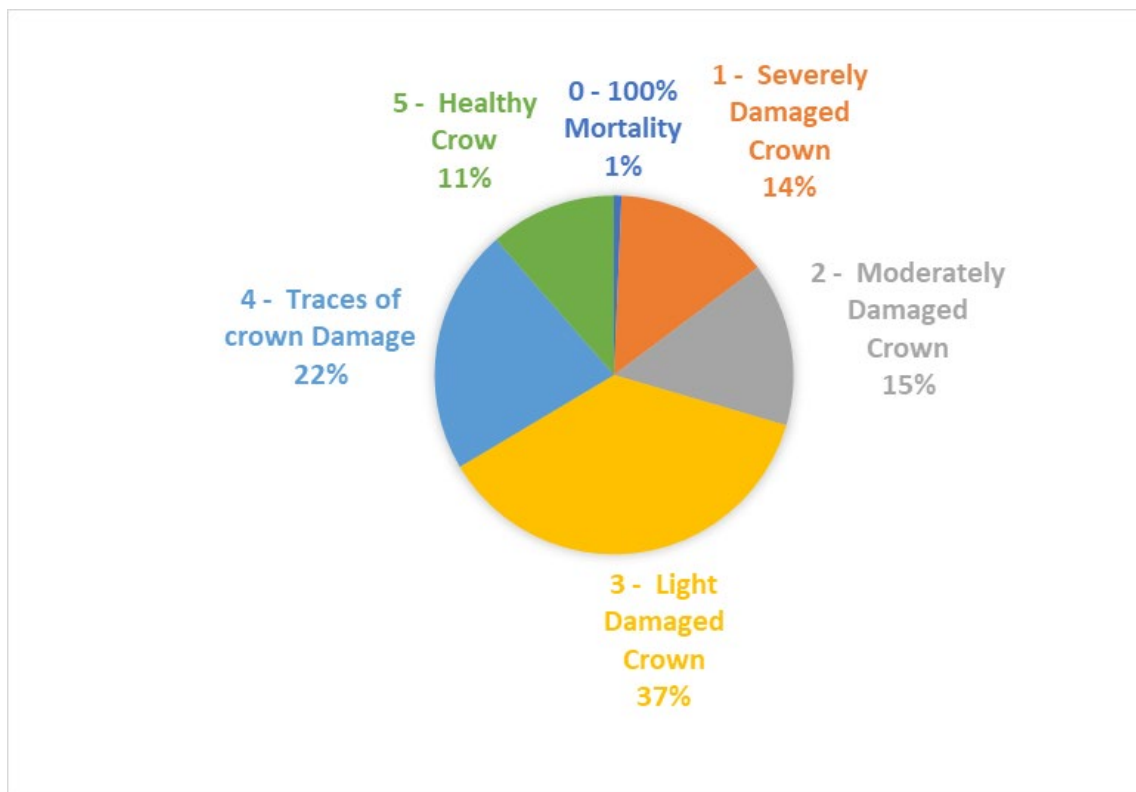


Figure 4.6: Crown health of *Pterocarpus angolensis* individuals recorded in Khalavha Village.

The tree canopy is more important because it contains leaves that play a vital role during the process of photosynthesis. They also provide shade for understory species; and soil and they also provide shelter for some animals such as birds. According to Morin *et al.* (2015), the condition of plant crowns is an important measure of a healthy tree. In addition, changes in tree canopy density influence light regimes and microclimatic changes such as soil humidity and temperature (Wagner *et al.*, 2011; Phalanndwa *et al.*, 2022).

Furthermore, the crown plays a vital role in providing both a habitat and nutrients for fauna, its state can have an impact on the overall population of living organisms (Scott

et al., 2013). The amount of nutrients in the soil is influenced by the crown condition, with healthy crowning producing more litter than unhealthy ones. The study conducted by Zarnoch *et al.* (2004), reported that when it comes to its decomposition, this litter turns into humus, which helps the soil absorb more water and hold on to organic matter, a crucial component of plant growth. The surrounding forest's environmental elements, such as the availability of nutrients, sunlight, water, and space for tree crown growth, have an impact on the condition of the crown (Zarnoch *et al.*, 2004).

Plant diseases have been shown to have the potential to lower the quality of crops. Diseases are disruptions to a plant's normal state that alter or stop its ability to carry out essential processes such as photosynthesis, transpiration, pollination, fertilization, and germination. Plant diseases can strike a leaf at any stage during the growing season, drastically reducing crop yield and market value (Annabel *et al.*, 2019). Pathogens, such as bacteria, viruses, and fungi, as well as unfavourable environmental factors, are the causes of many diseases (Gavhale and Gawande 2014).

In the current study, some *Pterocarpus angolensis* trees showed other factors that are affecting their crown health. As shown in Figures 3.7a and 3.7b, the majority of trees of that population are being affected by a certain infection and others are being overgrazed by insects.



Figure 4.7: Pictures showing infected branch (a) and browsed leaves (b) of *Pterocarpus angolensis*.

4.3.4 Anthropogenic factors affecting *Pterocarpus angolensis* population of Khalavha Village.

A. Fire.

Bowman *et al.*, (2020) described vegetation fire as an essential component of the earth system. Burning of biomass and subsequent fire regimes are major models of vegetation changes, and they also affect plant population dynamics (Conedera *et al.*, 2009). In the study that was done in north-western US forests, the fire was and still is believed to be an important part of the disturbance regimes (Whitlock, 2003). Palaeoecological records of that region also recorded that fires are responsible for maintaining and altering forest vegetation (Whitlock, 2003; Gedye *et al.*, 2000). Montenegro *et al.* (2004) reported that wildfires caused by thunderstorms that occur

in Mediterranean-climate regions, like southern California play an important role in the evolution and ecology of the flora. In the current study, it was found that human-made fires are among the anthropogenic factors that are affecting plant populations of Khalavha Village including that of *Pterocarpus angolensis*, as shown in Figure 3.8 and Figure 3.9.



Figure 4.8: A picture showing the burnt stump of *Pterocarpus angolensis*.



Figure 4.9: A picture showing the area that was affected by human-made fire before the current study took place.

Plant traits other than bark thickness that reduce the impacts of fire on the physiology and structure of tree trunks may exert important influences on fire-induced tree mortality (Michaletz and Johnson, 2007). Trees wounded during surface fires, for instance, are susceptible to wood decay that can be slight or fatal depending on the capacity of the tree to compartmentalize the damage, which generally increases with wood density (Romero and Bolker, 2008). As trees grow larger, they also become less susceptible to indirect fire damage caused by falling trees and branches that were killed by the burns. Similarly, larger-diameter trees are less likely to have their entire circumference heated during a fire (Gutsell and Johnson, 1996), and taller trees may disproportionately survive fires because their crowns are less likely to be damaged. Thus, large individuals may be more likely to survive surface fires than smaller trees even if bark thickness is the same.

B. Debarking

According to Delvaux *et al.* (2010), the outer barks play a major role in the protection of plants against the outside world because they help prevent them from losing moisture during the dry air seasons. The barks are the most important plant parts because they prevent fungal and insects attack, minimize water loss from the stems, and are also said to be an effective protector against fire damage (Stobbe *et al.*, 2002). They are also known as a plant's insulator against cold and heat. The outer barks are also known as waterproof, which helps the inner barks from drying out (Stobbe *et al.*, 2002).

The inner barks are composed of living tissues, which is helpful in the translocation of sugars that are created in the leaves to other parts of the plant that are needed. The translocation process takes place in the secondary phloem (Delvaux *et al.*, 2010). Once the secondary phloem dies off due to debarking, layers that are responsible for the protection of the plant begin to fail, leading to the disturbance of all the responsibilities that are associated with the inner barks.

In this study, most participating informants disclosed that the inner barks of Mutondo or *Pterocarpus angolensis* are preferred for the treatment of various ailments. They also said that only young adults and adults are used because seedlings and most juveniles do not have that red-like blood sap that they use for treatments. Figures 3.10a and 3.10b, show the picture of debarked *P. angolensis* taken during this study in Khalavha Village. It simply shows that young adults and adults' future existence in that village is nearly threatened, because the majority of them are getting intensively

debarked, and that can lead to an unhealthy population because those trees will undergo stress since some parts that play vital roles are removed.



Figure 4.10: A picture showing the removal of stem bark, with one (a) freshly removed while the other one (b) has old bark removal scars.

C. Deforestation

Chakravarty *et al.* (2012), reported that the world is losing most of its natural resources, and one of the major concerns is anthropogenic factors leading to deforestation. Forests are being cut down to meet human needs, such as agricultural (food), residential, industrial commercial, and other activities that lead to land expansion

(Allen and Barnes, 1985). Deforestation disrupts the ecological balance. Moreover, it also obstructs the lives of human beings and wildlife as well. Removal of some trees may have a huge negative impact on the ecosystem. Thus, when there are few trees left, the water cycle will get disturbed because there won't be enough trees available to absorb water during rainy seasons. Therefore, it will cause floods and an increase in soil erosion (Abere and Opara, 2012). Furthermore, the removal of forests also causes an increase in carbon dioxide and oxygen levels. Deforestation does contribute to climate change and global warming.

Houghton (1990) reported that in some cases, overpopulation may be the main cause of deforestation. Once the population increases, more land will be required, leading to Agricultural expansion, an increase in wood extraction, and infrastructural expansion. As it is indicated in the study area part, Khalavha Village is comprised of gentle areas (that are suitable for residential needs), and mountainous areas made of hills that consist of forests. However, due to overpopulation, there is now residential expansion to the point where gentle areas have run out of space, and people are starting to climb the mountains (hills), cutting down the trees so that they can build their houses. However, the base of the *P. angolensis* stump that had been examined showed evidence of resprouting as shown in Figure 3.11.



Figure 4.11: A picture showing a resprouting *Pterocarpus angolensis* stump.

The ability of certain plants to produce new shoots following the disruption and destruction of living tissues is known as resprouting. It is widespread in many plants across the world and is assumed to be widespread in prehistoric floras (Pausas and Keeley, 2014).

According to Pausas (2004), resprouting is frequently regarded as a binary trait that is species-specific, with certain species having the capacity to resprout. This resprouting pattern was linked to stumps that were cut at a height greater than 50 cm from the

tree's base. According to Pausas *et al.* (2016), it is speculated that the height of the cut stump affects the sources of buds needed for resprouting.

4.4 Conclusion

The basal stem diameter measured in this current study showed that the *Pterocarpus angolensis* population in Khalavha Village is healthy and viable. That was concluded due to more seedlings that are existing compared to other age categories. Amongst measured trees, only a few of them reached a matured stage in which they can produce seeds that will help in the germination of new species. The majority (43%) of *P. angolensis* individuals recorded in this study were short (0 – 2cm). Data about crown health revealed that the population in Khalavha Village depicted crowns that are bearably damaged.

In this study, it was hypothesized that the population structure of *P. angolensis* in Khalavha Village will not display an inverse-J-shaped curve, and it will also display a population curve that is under stress from anthropogenic activities. Due to the data recorded and analysed in this study, the Null hypothesis is therefore rejected. Because the basal stem diameter measurements displayed an inverse-j-shaped curve, and the displayed curve did not show the population that is under stress.

The major anthropogenic factors that seemed to be affecting that population were human-made fires, collecting for firewood, collection for craftworks such as wooden

spoons, and deforestation for settlement which is due to overpopulation. Therefore, these shows that *Pterocarpus angolensis* is continually being used on a daily basis by people staying in khalavha villagers.

References

- Abere, S.A. and Opara, J.A., (2012). Deforestation and Sustainable Development in the Tropics: Causes and Effects. *Journal of Educational and Social Research*, 2(4), pp.104-109.
- Allen, J.C. and Barnes, D.F., (1985). The causes of deforestation in developing countries. *Annals of the Association of American Geographers*, 75(2), pp.163-184.
- Annabel, L.S.P., Annapoorani, T. and Deepalakshmi, P., (2019). Machine learning for plant leaf disease detection and classification—a review. *INTERNATIONAL CONFERENCE ON COMMUNICATION AND SIGNAL PROCESSING (ICCSP)* (pp. 0538-0542). IEEE.
- Bowman, D.M., Kolden, C.A., Abatzoglou, J.T., Johnston, F.H., van der Werf, G.R. and Flannigan, M., (2020). Vegetation fires in the Anthropocene. *Nature Reviews Earth and Environment*, 1(10), pp.500-515.
- Chakravarty, S., Ghosh, S.K., Suresh, C.P., Dey, A.N. and Shukla, G., (2012). Deforestation: causes, effects and control strategies. *Global Perspectives on Sustainable Forest Management*, 1, pp.1-26.
- Conedera, M., Tinner, W., Neff, C., Meurer, M., Dickens, A.F. and Krebs, P., (2009). Reconstructing past fire regimes: methods, applications, and relevance to fire management and conservation. *Quaternary Science Reviews*, 28(5-6), pp.555-576.

- Cousins, S.R., Witkowski, E.T.F. and Pfab M.F., (2014). Elucidating patterns in the population size structure and density of *Aloe plicatilis*, a tree aloe endemic to the Cape Fynbos, South Africa. *South African Journal of Botany*, 90, pp.20-36.
- De Swaef, T., De Schepper, V., Vandegheuchte, M.W. and Steppe, K., (2015). Stem diameter variations as a versatile research tool in ecophysiology. *Tree Physiology*, 35(10), pp.1047-1061.
- Deb, P. and Sundriyal, R.C., (2011). Vegetation dynamics of an old-growth lowland tropical rainforest in North-east India: species composition and stand heterogeneity. *International Journal of Biodiversity and Conservation*, 3, pp.405-430.
- Delvaux, C., Sinsin, B. and Van Damme, P., (2010). Impact of season, stem diameter and intensity of debarking on survival and bark re-growth pattern of medicinal tree species, Benin, West Africa. *Biological Conservation*, 143(11), pp.2664-2671.
- Falster, D.S. and Westoby, M., (2003). Plant height and evolutionary games. *Trends in Ecology and Evolution*, 18(7), pp.337-343.
- Gavhale, K.R. and Gawande, U., (2014). An overview of the research on plant leaves disease detection using image processing techniques. *Iosr Journal of Computer Engineering (iosr-jce)*, 16(1), pp.10-16.
- Gedye, K.R., Morris, C.F. and Bettge, A.D., (2004). Determination and evaluation of the sequence and textural effects of the puroindoline a and puroindoline b genes in a population of synthetic hexaploid wheat. *Theoretical and Applied Genetics*, 109, pp.1597-1603.

- Getachew, T., Demel, T., Masresha, F. and Erwin, B., (2010). Regeneration of seven indigenous tree species in a dry Afromontane Forest, Southern Ethiopia. *Flora*, 205, pp.135-143.
- Gutsell, S.L. and Johnson, E.A., (1996). How fire scars are formed: coupling a disturbance process to its ecological effect. *Canadian Journal of Forest Research*, 26(2), pp.166-174.
- Houghton, R.A., (1990). The global effects of tropical deforestation. *Environmental Science and Technology*, 24(4), pp.414-422.
- Magarik, Y.A., Roman, L.A. and Henning, J.G., (2020). How should we measure the DBH of multi-stemmed urban trees? *Urban Forestry and Urban Greening*, 47, p.126481.
- Marsh, D.M. and Trenham, P.C., (2008). Current trends in plant and animal population monitoring. *Conservation Biology*, 22(3), pp.647-655.
- Michaletz, S.T. and Johnson, E.A., (2007). How forest fires kill trees: a review of the fundamental biophysical processes. *Scandinavian Journal of Forest Research*, 22(6), pp.500-515.
- Moles, A.T., Warton, D.I., Warman, L., Swenson, N.G., Laffan, S.W., Zanne, A.E., Pitman, A., Hemmings, F.A. and Leishman, M.R., (2009). Global patterns in plant height. *Journal of Ecology*, 97(5), pp.923-932.
- Montenegro, G., Ginocchio, R., Segura, A., Keely, J.E. and Gomez, M., (2004). Fire regimes and vegetation responses in two Mediterranean-climate regions. *Revista Chilena de Historia Natural*, 77(3), pp.455-464.

- Morin, R.S., Randolph, K.C. and Steinman, J., (2015). Mortality rates associated with crown health for eastern forest tree species. *Environmental Monitoring Assessment*, 187, p.87.
- Mucina, L., Jürgens, N., Le Roux, A., Rutherford, M.C., Schiedel, U., Esler, K.J., Powrie, L.W., Desmet, P.G., Milton, S.J., Boucher, C. and Ellis, F., (2006). Succulent karoo biome. The vegetation of South Africa, Lesotho, and Swaziland. *Strelitzia*, 19, pp.221-299.
- Negi, C.S. and Nautiyal, S., (2005). Phytosociological studies of a traditional reserve forest- Thal Ke Dhar, Pithoragarh, Central Himalayas (India). *Indian Forester*, 131, pp.519–534.
- Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Simons, A., (2009). Agroforestry Database: a tree reference and selection guide. Version 4. Agroforestry Database: a tree reference and selection guide. Version 4.
- Paul, K.I., Larmour, J.S., Roxburgh, S.H., England, J.R., Davies, M.J. and Luck, H.D., (2017). Measurements of stem diameter: implications for individual-and stand-level errors. *Environmental Monitoring and Assessment*, 189, pp.1-14.
- Pausas, J.G. and Keeley, J.E., (2014). Evolutionary ecology of resprouting and seeding in fire-prone ecosystems. *New Phytologist*, 204(1), pp.55-65.
- Pausas, J.G., (2004). Changes in fire and climate in the eastern Iberian Peninsula (Mediterranean basin). *Climatic Change*, 63(3), pp.337-350.
- Pausas, J.G., Pratt, R.B., Keeley, J.E., Jacobsen, A.L., Ramirez, A.R., Vilagrosa, A., Paula, S., Kaneakua-Pia, I.N. and Davis, S.D., (2016). Towards understanding resprouting at the global scale. *New Phytologist*, 209(3), pp.945-954.

- Phalanndwa, M.V., (2022). Ethnoecological investigation of *Spirostachys africana* Sond. Population at ha-Matsa village, Limpopo Province, South Africa. MSc dissertation, University of Venda, Thohoyandou, South Africa.
- Pokhriyal, P., Uniyal, P., Chauhan, D.S. and Todaria, N.P., (2010). Regeneration status of tree species in forest of Phakot and Pathri Rao watersheds in Garhwal Himalaya. *Current Science*, 98, pp.171–174.
- Rahman, M.H., Khan, A.S.A., Roy, B. and Fardusi, M.J., (2011). Assessment of natural regeneration status and diversity of tree species in the biodiversity conservation areas of North-eastern Bangladesh. *Journal of Forestry Research*, 22, pp.551-559.
- Romero, C. and Bolker, B.M., (2008). Effects of stem anatomical and structural traits on responses to stem damage: an experimental study in the Bolivian Amazon. *Canadian Journal of Forest Research*, 38(3), pp.611-618.
- Sadiki, T.S., Tshisikhawe, M.P. and Potgieter, M.J., (2018). The Dynamics on the Ecology of *Pterocarpus angolensis* DC. *Research and Reviews: Journal of Agriculture and Allied Sciences* 7(1), pp.31-35.
- Saxena, A.K. and Singh, J.S., (1984). Tree population structure of certain Himalayan Forest associations and implications concerning their future composition. *Vegetation*, 58, pp.61-69.
- Scott, P.M., Shearer, B.L., Barber, P.A. and Hardy, G.S.J., (2013). Relationships between the crown health, fine root, and ectomycorrhizae density of declining *Eucalyptus gomphocephala*. *Australasian Plant Pathology*, 42, pp.121-131.
- Statistics South Africa. <https://www.statssa.gov.za/>

- Stobbe, H., Schmitt, U., Eckstein, D. and Dujesiefken, D., (2002). Developmental stages and fine structure of surface callus formed after debarking of living lime trees (*Tilia* sp.). *Annals of Botany*, 89(6), pp.773-782.
- Therrell, M.D., Stahle, D.W., Mukelabai, M.M. and Shugart, H.H., (2007). Age, and radial growth dynamics of *Pterocarpus angolensis* in southern Africa. *Forest Ecology and Management*, 244(1-3), pp.24-31.
- Tshisikhawe, M.P., Baloyi, O., Ligavha-Mbelengwa, M.H. and Bhat, R.B., (2012). The population ecology of *Securidaca longepedunculata* Fresen. in the Nylsvley Nature Reserve, Limpopo Province, South Africa. *International Journal of Experimental Botany*, 81, pp.107-112.
- Tshisikhawe, M.P. and Van Rooyen, M.W., (2013). Population biology of *Elaeodendron transvaalense* Jacq. in the presence of harvesting. *International Journal of Experimental Botany*, 82, pp.303-311.
- Vancanneyt, G., Schmidt, R., O'Connor-Sanchez, A., Willmitzer, L. and Rocha-Sosa, M., (1990). Construction of an intron-containing marker gene: splicing of the intron in transgenic plants and its use in monitoring early events in *Agrobacterium*-mediated plant transformation. *Molecular and General Genetics*, 220(2), pp.245-250.
- Wagner, S., Fischer, H. and Huth, F., (2011). Canopy effects on vegetation caused by harvesting and regeneration treatments. *European Journal of Forest Restoration*, 130, pp.17-40.
- Whitlock, C., Shafer, S.L. and Marlon, J., 2003. The role of climate and vegetation change in shaping past and future fire regimes in the northwestern US and the

implications for ecosystem management. *Forest Ecology and Management*, 178(1-2), pp.5-21.

Zarnoch, S.J., Bechtold, W.A. and Stolte, K.W., (2004). Using crown condition variables as indicators of forest health. *Canadian Journal of Forest Research*, 34(5), pp.1057-1070.

Zininga, T., Anokwuru, C.P., Sigidi, M.T., Tshisikhawe, M.P., Ramaite, I.I., Traoré, A.N., Hoppe, H., Shonhai, A. and Potgieter, N., (2017). Extracts obtained from *Pterocarpus angolensis* DC and *Ziziphus mucronata* exhibit antiplasmodial activity and inhibit heat shock protein 70 (Hsp70) function. *Molecules*, 22(8), p.1224.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

There are typically adverse effects on the environment linked to anthropogenic activity. Thus, the term "anthropogenic" describes changes in the environment brought about by human activity (Kennish, 2021). The current study was conducted in a communal area of Khalavha Village in Vhembe Biosphere Reserve, in the Limpopo Province, South Africa, with an estimated population size of about 3 237 people, of which 100% were black African, and the majority (97%) of them speaks the Tshivenda language as their native language. The village is composed of a forest and savannah biome, dominated by trees in hilly areas and shrubs with grasses in gentle areas. The study was conducted to analyze the effects of anthropogenic factors on the population structure of *Pterocarpus angolensis* in Khalavha Village.

Information on ethnobotany was gathered from each informant using a semi-structured questionnaire. To enable informants to comprehend the requirements of the questionnaire, all interviews were done in Tshivenda. Fifty-three informants were interviewed, of which 35 of them were females, while 18 of them were males. In total, 28 elderly people, 15 adults, and 10 youth were interviewed. At Lwamondo village in the Limpopo Province of Southern Africa, a similar trend was also noted, with the majority of participating informants being 60 years of age or older (Mahwasane et al., 2013). To look for a relationship between the distribution of indigenous knowledge and

educational attainment, background information on education for each informant interviewed was also documented. Of the fifty-three informants who took part in the study, nine went to primary school, the majority ($n = 22$) finished at the secondary level, and only seven went on to tertiary education. Of the informants, fifteen did not complete their education.

Informants disclosed that stem (67%) and bark (33%) are the most preferred parts of this species. The stem was the most frequently used part. The residents of Khalavha Village disclosed that they use blood-like sap to treat blood-related illnesses, including high blood pressure, menstrual overflow, menstrual restoration, blood cleansing, and womb cleansing. According to Watt and Breyer-Brandwijk (1962), *P. angolensis* bark secretes a blood-red sap that is used medicinally. *Pterocarpus angolensis* is one of the most popular trees for producing firewood because it yields highly flammable wood that resembles mopane. Sixty-six percent of villagers who participated in this study attested that thick branches and stems of matured trees of this species were and are still preferred for designing crafts that are used as household utensils such as wooden spoons, dishes, and others.

To analyze the population structure of the species, ecological data were collected using the transect sampling technique. Several transects measuring 100 m x 10 m were built inside the population. Descriptive statistical analysis was used to analyze the population structure of *P. angolensis* in the presence of anthropogenic factors. In this study, 37% of trees were established to have light-damaged crowns, followed by 22% of them showing little traces of crown damage, and 15% of them were severely

damaged. Eleven percent (11%) of studied trees had healthy crowns, and only 1% of them showed 100% mortality of their crowns. The studied population consisted of enough seedlings compared to other size classes.

Therefore, *Pterocarpus angolensis* of Khalavha Village portrayed a healthy and stable plant population that will be able to maintain its future existence. The majority (43%) of *P. angolensis* individuals in this study fell into the top height category (0–2 m), with 21% of those admitted being between 2.1 and 4 m tall. The percentages of trees with heights between 4.1–6 m and 6.1–8 m was found to be nearly identical (18% and 16%). In this study, only 4% of the *P. angolensis* trees were found to have grown larger than 8 m. Human-made fires, debarking and deforestation were found to be the major anthropogenic factors affecting the *P. angolensis* population of Khalavha Village.

5.2 Conclusion

The deficiency in indigenous knowledge regarding this species among the youth age group was noted to be poor in this study. Dwivedi (2019) and Phalanndwa (2022) also reported a similar trend. That young people are ignorant of this species is a good thing in this instance. All it signifies is that this species won't be cruelly hunted in the future, making it more sustainable. The present study posted that there would be significant utilization of the species' parts in Khalavha Village. Given that only fully grown adult trees were debarked, the data gathered indicated that the barks are the most used part of this species, but at a relatively low utilization rate.

According to the study's hypothesis, the *P. angolensis* population structure in Khalavha Village will not display an inverse-J curve but rather a population curve that is stressed by human activity. The null hypothesis is thus rejected in light of the data collected and examined in this investigation. because the measurements of basal stem diameter showed an inverse-j-shaped curve that did not depict the population that is under stress.

5.3 Recommendations

Educating the villagers about the value of *Pterocarpus angolensis* can be rendered more beneficial by the fact that it is a protected species and is preferred for a variety of applications. They should also be told about the advantages that using plant resources sustainably will bring them in terms of environmental benefits. Monitoring the use of protected species regularly is also advised. Protected species should always be made known to the community. To maintain and safeguard the current population, ecologists must collaborate with the landlords of Khalavha Village and the neighbouring villages to ensure that any anthropogenic factors are eliminated. Additionally, it is advised that scientists carry out ongoing global surveys to identify all protected species and ensure that they remain widely recognized and are well protected.

The fact that *Pterocarpus angolensis* is a protected species and is preferred for many different uses, it becomes more helpful to educate the villagers about its importance. They should also be informed on how they will enjoy benefits from the environment if

they sustainably use plant resources. It is also recommended that the utilization of protected species be continuously monitored. Communities should always be made aware of protected species.

The fact that *Pterocarpus angolensis* is a protected species and the studied species postulated a healthy population, there for it will be more helpful to educate the villagers about the importance of this species. The ecologists must also work together with the landlord of Khalavha Village and its leaders to make sure that they come up with a way to maintain and protect the present population by making sure that the detected anthropogenic factors are eliminated. They should be advised on how they will happily benefit from the environment if they use resources such as plants, in a sustainable manner. It is also recommended that scientists continuously conduct surveys worldwide to locate all the protected species, and make sure that they are very well known and still protected.

References

- Dwivedi, S.A., Gharde, S.K. and Kumar, V., (2019). Effect of Environmental factors on population incidence *Helicoverpa armigera* (Hubner) in Bengal gram. *Think India Journal*, 22(34), pp.1307-1316.
- Kennish, M.J., 2021. Drivers of Change in Estuarine and Coastal Marine Environments: An Overview. *Open Journal of Ecology*, 11(3), pp.224-239.
- Mahwasane, S.T., Middleton, I. and Boaduo, N., (2013). An ethnobotanical survey of indigenous knowledge on medicinal plants used by the traditional healers of the Lwamondo area, Limpopo province, South Africa. *South African Journal of Botany*, 88, pp.69-75.
- Phalanndwa, M.V., (2022). Ethnoecological investigation of *Spirostachys africana* Sond. Population at ha-Matsa village, Limpopo province, south Africa (doctoral dissertation).
- Watt, J.M. and Breyer-Brandwijk, M.G., (1962). The medicinal and poisonous plants of southern and eastern Africa are an account of their medicinal and other uses, chemical composition, pharmacological effects, and toxicology in man and animals. (Ed. 2).

APPENDIX A

Ethnobotanical data questionnaire

Research

